Alosa alosa and *Alosa fallax* spp. Literature Review and Bibliography

R&D Technical Report W1-014/TR

M. W. Aprahamian
C. D. Aprahamian
J. L. Baglinière
R. Sabatié
P. Alexandrino

Research Contractors
Environment Agency
UMR INRA-ENSA
ENSAR
University of Porto

University of Porto

Publishing Organisation
Environment Agency, Rio House,Waterside Drive, Aztec West, Almondsbury
Bristol BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
Website: www.environment-agency.gov.uk

ISBN 1 84432 109 6

Dissemination Status
Internal: Released to Regions
External: Public Domain

Statement of Use
The aim of this report is to provide fish biologists and fisheries managers with an overview of the biology, status and conservation options for *Alosa alosa* and *Alosa fallax* species.

Research Contractor
This document was produced under R&D Project W1-014 by :
Aprahamian, M. W.(1), Aprahamian, C. D.(1), Baglinière, J. L(2), Sabatié, M. R.(2,3), Alexandrino, P.(4),

(1) The Environment Agency P.O Box 12, Fairclough House, Knutsford Road, Warrington WA 4 1HG, UK.
(2) UMR INRA-ENSA Ecobiologie et Qualité des Hydrosystèmes Continentaux, 65 rue de Saint-Brieuc, 35042 Rennes Cedex, France
(3) Laboratoire d'Halieutique, ENSAR, 65 rue de Saint-Brieuc, 35042 Rennes Cedex, France.
(4) Animal Genetics and Conservation Unit, Faculdade de Ciências, Universidade do Porto, Campus Agràrio de Vairão, R. Monte Castro 4480 Vila do Conde, Portugal.

Environment Agency Project Manager
The Environment Agency's Project Manager for R&D Project W1-014 was
Miran Aprahamian, Noth West Region.

Further copies of this report are available from:
Environment Agency R&D Dissemination Centre
WRc, Frankland Road, Swindon, Wilts. SN5 8YF
Tel: 01793 865000 Fax: 01793 514562 E-mail: publications@wrcplc.co.uk

Keywords

ALOSA ALOSA; *ALOSA FALLAX FALLAX*; *ALOSA FALLAX RHODANENSIS; ALOSA FALLAX NILOTICA*; *ALOSA FALLAX ALGERIENSIS*; *ALOSA FALLAX LACUSTRIS*; *ALOSA FALLAX KILLARNENSIS*; NOMENCLATURE; TAXONOMY; MORPHOLOGY; DISTRIBUTION; HYBRIDIZATION; REPRODUCTION; SPAWNING; ONTOGENY; GROWTH; DIET; DISEASE; PARASITE; INTER- & INTRA-SPECIFIC INTERACTIONS; HOMING; MIGRATION; SEX RATIO; AGE STRUCTURE; RECRUITMENT; MORTALITY; POPULATION DYNAMICS; EXPLOITATION; FISHING EQUIPMENT; FISHING AREA, FISHING SEASONS; CATCHES; HABITAT PROTECTION AND MANAGEMENT; CONSERVATION STATUS; FISH PASS; CULTURE.

PREFACE

This review is for those who have and will work on *Alosa,* to the commercial fisherman and recreational anglers who make their living or obtain pleasure and relaxation from their capture. It is also for the many people we have worked with us over the years, without whose help little would have been achieved and to the many who have freely contributed information and knowledge in the true spirit of collaboration, we hope we have not abused their generosity.

We acknowledge that there still exists mistakes in this draft, especially in the references. We have supplied as much detail as we can but appreciate that in many instances it is incomplete. For this and other errors we apologise, we will, however, endeavour to correct these over time and maintain the review up to date and to help us achieve this we welcome any feedback. In the future we hope the review will be made available on the Internet.

ACKNOWLEDGEMENTS

We thank B. Steinmetz who as a Convenor of EIFAC sub-commission 1 “Biology and Management” first suggested putting together a synopsis of biological data on *Alosa* during a fleeting meeting at a conference in Hull (UK) over ten years ago! We also thank subsequent convenors, C. Moriarty and T. Brenner for the annual request on progress and to whom the many excuses for the lack of any development must have seemed insufferable.

We also thank those who have helped us with obtaining references, translations and with the many aspects of IT, which have made this task considerably easier;

We thank

P. Bianco, P. Bergot, P. Boisneau, G. Boxshall, G. Casternaud, P. Caswell, F. Cassou-Leins, J. J. Cassou-Leins, S. Colclough, M. Collares-Pereira, A. Churchward, P. Economidis, E. Esteves, J. Gregory, P. Gough, B. Hardy, J. Hateley, T. Hatton-Ellis, D. Heaver, P. Henderson, M. Hendricks, J. Hillary, R. Hillman, T. Jacklin, J. King, P. Lambert, M. Le Corre, M. Larinier, S. Lester, A. Lyle, O. McCrimmon, P. Maitland, C. Mennesson-Boisneau, N. Mott, M. Nolan, N. O'Maoileideigh, S. Oesmann, A. Picken, T. Pina, E. Rochard, H. Sari, R. Seaby, M. Skora, L. Syme, C. Taverny, R. Thiel, C. Turan, V. Véron, C. Wallis, A. Walton, A. Wheeler, K. Whittaker. H. Winkler.

For permission to reproduce figures we thank

AULA-Verlag (GmbH Wiesbaden, Verlag für Wissenschaft und Forschung, Luisen Platz No. 2, Wiesbaden, Germany) for Figures 1.2, 1.7, 1.8, 1.11, 3.15, 3.16 and 3.17.
American Society of Ichthyologists and Herpetologists for Figures 1.7, 1.8 and 1.10
Blackwell Publishing for Figures 1.15, 3.26, 3.31, 3.33 and 6.4;
P. Boisneau and C. Mennesson-Boisneau for Figures 3.29 and 5.3;
Bulletin Français de la Pêche et de la Pisciculture for Figures 3.20, 3.22, 3.23, 4.4, 5.12, 5.13 and 6.3;
J. Dartiguelongue for Figure 3.30;
By Courtesy of the Linnean Society of London Figure 1.14;
Conseil Supérieur de la Pêche for Figures 3.1, 3.2, 3.22, 3.23, 4.4, 5.11, 5.12 and 6.3;
FAO for Figure 1.1;
INRA for Figures 3.3, 3.4 and 5.8;
N. O'Maoileideigh for Figure 3.11;
The Zoological Society of London for Figure 1.9.

CONTENTS

page

KEYWORDS **i**

ACKNOWLEDGMENTS **iv**

LIST OF FIGURES **vii**

LIST OF TABLES **xiii**

EXECUTIVE SUMMARY **xix**

1. IDENTITY **1**
- 1.1 Nomenclature 1
- 1.2 Taxonomy 4
- 1.3 Morphology 9

2. DISTRIBUTION **39**
- 2.1 Total Area 39
- 2.2 Determination of Distribution Changes 51
- 2.3 Hybridization 51

3. BIONOMIC AND LIFE HISTORY 52
- 3.1 Reproduction 52
- 3.2 Preadult Phase 86
- 3.3. Adult Phase 92
- 3.4 Nutrition and Growth 105
- 3.5 Behaviour 168

4. POPULATION (SPAWNING STOCK) **179**
- 4.1 Structure 179
- 4.2 Abundance and Density 189
- 4.3 Natality and Recruitment 190
- 4.4 Mortality and Morbidity 193
- 4.5 Dynamics of the Population 193

5. EXPLOITATION **195**
- 5.1 Fishing Equipment 195
- 5.2 Fishing Areas 201
- 5.3 Fishing Seasons 201
- 5.4 Fishing Operations and Results 201
- 5.5 Climatic Influences 206

6. PROTECTION AND MANAGEMANT **208**
- 6.1 Conservation Status 208
- 6.2 Habitat Protection and Management 212
- 6.3 Fish Passes 213
- 6.4 Screens 217
- 6.5 Translocation / Transplantation 218

7. CULTURE **219**
7.1 Collection of Spawn 219
7.2 Incubation of Eggs 220
7.3 Larval and Juvenile Rearing 220

REFERENCES (not cited in bibliography) **222**

BIBLIOGRAPHY **225**

APPENDIX 1 **335**

APPENDIX 2 **342**

LIST OF FIGURES

Figure 1.1 *Alosa alosa* and *Alosa fallax*; reproduced with permission of FAO (www.fishbase.org). Insert, showing the distinct notch into which the symphysis of the lower jaw fits (Whitehead, 1985). 5

Figure 1.2 First gill arch appearance and approximate number of gill rakers for (a) *A. fallax* and (b) *A. alosa.* 9

Figure 1.3 The relationship between number of gill rakers on the first gill arch and total length for *Alosa alosa* (1-10, solid line) and *Alosa alosa* x *Alosa fallax* hybrids (11-14, dotted line). (1 = Rhine (Hoek, 1899); 2 = Aulne (Véron, 1999); 3 = Vilaine (Véron, 1999); 4 & 11 = Loire (Douchement, 1981); 5 = Charente (Véron, 1999); 6 = Garonne (Douchement, 1981); 7 = Adour (Douchement, 1981); 8 & 12 = Aude (Douchement, 1981); 9 & 13 = Rhône (Douchement, 1981); 10 & 14 = Sebou (Sabatié, 1993). 14

Figure 1.4 The relationship between number of gill rakers on the first gill arch and total length for *Alosa fallax*; 15

Anadromous populations: *A. fallax fallax*: 1 = Rhine (Hoek, 1899); 2 = Hass (1965); 3 = Severn (Aprahamian, 1982); 4 = Loire (Douchement, 1981); 5 = Charente (Véron, 1999); 6 = Garonne (Quignard & Kartas, 1977); 7 = Garonne (Douchement, 1981); 8 = Adour (Douchement, 1981); 9 = Loukos (Sabatié, 1993); 10 = Sebou (Sabatié, 1993); *A. fallax rhodanensis*: 11 = Rhône (Quignard & Kartas, 1977); 12 = Rhône (Douchement, 1981); 13 = Rhône (Le Corre, *et al.,* 1997); 14 = Aude (Quignard & Douchement, 1991c); 15 = Aude (Douchement, 1981); 16 = Tirso (Quignard & Douchement, 1991c); *A. fallax algeriensis*: 17 = Miliane (Quignard & Kartas, 1977); 18 = Oubeira (Quignard & Kartas, 1977);
Landlocked populations: *A.fallax nilotica*: 19 = Bacin (Vukovic, 1961a); 20 = Skadar (Vukovic, 1961a); *A. fallax algeriensis*: 21 = Ischkeul (Quignard & Kartas, 1977); *A. fallax*: 22 = Sidi Mohamed Ben Abdullah (Sabatié, 1993).

Figure 1.5 Scale from *Alosa fallax fallax*. 23

Figure 1.6 **Skeletal features of Alosa alosa, axial view. En epineural bone; ep epipleural bone; ha hemal arch; na neural arch; r rib; v vertebra; ec epicentral bone; ea epapophyses. Reproduced from Bertin (1958).** 25

Figure 1.7 The skull of the allis shad *Alosa alosa*. 26

Figure 1.8 The skull of the twaite shad *Alosa fallax fallax* (*a* lateral view; *b* posterior view; *c* dorsal view; *d* ventral view; *e* anterioventral view; *als* alisphenoid; *boc* basioccipital; *bs* basisphenoid; *eoc* exoccipital (lateral occipital); *epo* epiotic; *eth. 1* lateral ethmoidal; *f* frontal; *meth* mesethmoid; *opo* opisthotic; *orb* orbitosphenoid; *p* parietal; *pro* prootic; *ps* parasphenoid; *pto* pterotic; *soc* supraoccipital; *spho* sphenotic; *v* vomer.) Reproduced from Svetovidov (1964). 26

Figure 1.9 Head of *Alosa fallax*; *an* angular; *ar* articular; *cor* circumorbital bones; *d* dentary; *ecp* ectopterygoid; *enp* entopterygoid; *hm* hyomandibular; *iop* interopercular; *mpt* metapterygoid; *mx* maxilla; *n* nasal; *opc* opercular; *pl* palatine; *pm* premaxilla; I 27 preopercular; *pt* post-temporal; *sar* sesamoidarticular; *sm* surmaxilla; *sop* subopercular; *st* supratemporal; *sy* symplectic; *tf* temporal foramen; from Ridewood (1904).

Figure 1.10 The lateral view of the left dentary of *Alosa fallax*, redrawn from Svetovidov (1964). 28

Figure 1.11 Otolith (Sagitta) of a) *Alosa alosa* and b) *Alosa fallax*. *A* area; *ada* anterodorsal angle; *ar* antirostrum; *B* back; *c* cauda; *de* dorsal edge; *es* excisura; *F* front; *ic* inferior crest; *O* ostium; *pa* posterior angle; *pcg* postcaudal groove; *pda* posteroventral angle; *r* rostrum; *sc* superior crest; *ve* ventral edge; *vg* ventral groove. Reproduced from Quignard & Douchement (1991 a & b). 28

Figure 1.12 Stomach of a typical alosoid. 29

Figure 1.13 The pituitary gland of *Alosa alosa*; Pars distalis rostralae (PDR), Pars distalis proximalae (PDP), Pars intermedia (PI), Neurophyophysis (N), PAS+ (O), Melanostimulating (●), somatic (▬), gonadotrophic (≡), prolactin (✻), adrenocorticotropic (★) and thyrotropic (☆) cells. Reproduced from Eiras (1981b). 30

Figure 1.14 General shape of the swimbladder of *Alosa fallax* (Whitehead & Blaxter, 1989). 31

Figure 1.15 Restriction site maps of the mtDNAs of *Alosa alosa* and *Alosa fallax*. The map for each species corresponds to the most common genotype observed for that species. Abbreviated names of restriction sites are as follows: T, *Sst*II; P, *Pst*I; E, *Eco*RI; L, *Sal*I; S, *Sst*I; J, *Cla*I; C, *Eco*RV; X, *Xba*I; H, *Hpa*I; M, *Bst*EII; K, *Kpn*I; V, *Pvu*II; B, *Bgl*I; A, *Sca*I; U, *Stu*I; O, *Bcl*I. One map unit corresponds to approximately 168 base pairs. Reproduced from Bentzen *et al*. (1993). 34

Figure 1.16 Network representing 6 mtDNA haplotypes (360 bp of the 5' –end mtDNA cytochrome b gene) found in 25 *Alosa spp* individuals. Each branch represent a single nucleotide change, solid circles represent missing haplotypes, and size of empty circles reflects the frequency of each haplotype. I, II and III: *Alosa fallax* haplotypes; IV, V and VI: *Alosa alosa* haplotypes (from Alexandrino *et al.,* in preparation). 36

Figure 1.17 Neighbor-Joining tree based on Nei's genetic distances between population samples. Data are based on allelic variance at eihgt allozyme loci screened (data from Alexandrino, 1996a; Le Corre, 1999; Véron *et al.* , 2001; Alexandrino *et al.,* in preparation). Numbers above nodes represent percent bootstrap values (100 replicates). Aguieira and C. Bode *A. alosa* populations are land-locked populations from Mondego and Tejo basins respectively. 37

Figure 2.1 Distribution of *Alosa* spp. In Europe, the Mediterranean and North Africa. 39

Figure 2.2 Distribution of *Alosa* spp. In Northeast Europe. 40

Figure 2.3 The catch of *Alosa alosa* (solid line) between 1880 and 1934, and of *A. fallax* (dotted line) between 1893 and 1950, from the lower Rhine (Data from de Groot, 1989, 1990). Vertical lines show the dates when dams were built. 42

Figure 2.4 Spawning distribution of *A. fallax* in the UK. 1 = Lough Leane. 42

Figure 2.5 Spawning distribution of *Alosa* in France. 1 = Lake Bourget. 43

Figure 2.6 Distribution of *Alosa* in Southwest Europe and Northwest Africa. 1 = Aguieira Reservoir, 2 = Castelo de Bode Reservoir, 3 = El 44

Kansera, 4 = Sidi Mohamed Ben Abdullah.
Figure 2.7 The catch of *Alosa alosa* between 1914-1988 from the River Miño, and the dates when barrages were constructed; 1 = Lugo province, 2 = Orense province (Alexandrino, 1996b). 45
Figure 2.8 The combined marine and river catch of *Alosa alosa* from the Oued Sebou (Morocco) between 1961 and 1993. Numbers refer to when different sugar refineries were constructed (Sabatié, 1993). 45
Figure 2.9 The past and present distribution of *Alosa fallax rhodanensis* in the River Rhône, modified from Pattée (1988). 47
Figure 2.10 Distribution of *Alosa* in Southeast Europe. 1 = Orta, 2 = Maggiori, 3 = Lugano, 4 = Como, 5 = Iseo, 6 = Garda, 7 = Bolsena, 8 = Vico, 9 = Bracciano, 10 = Omodeo, 11 = Flumendosa, 12 = Bacin, 13 = Ichkeul. 48
Figure 2.11 Distribution of *Alosa* in Greece and Southeast Europe. 1 = Scutari, 2 = Ohrid, 3 = Sasko, 4 = Vistonis. 49
Figure 2.12 Catch of *Alosa fallax nilotica* from Lake Skadar (Montenegro), between 1947 and 1987 (Stein *et al.,* 1981; Maric, 1990), the dam on the River Bojana was constructed in 1960, from Bianco (2002). 50
Figure 3.1 The mean age at first spawning for female *Alosa fallax fallax* from the River Severn for the 1973 to 1992 year-classes (Aprahamian & Lester, 2001). 57
Figure 3.2 The relationship between age at maturity for female *Alosa fallax fallax* and an index of biomass for age groups 0-2 and 0-3 inclusive, only those year-classes where more than 10 fish were sampled have been included (Aprahamian & Lester, 2001). 58
Figure 3.3 *Alosa alosa* congregating for spawing (from Baglinière & Elie, 2000). 63
Figure 3.4 The spawning activity (from Baglinière & Elie, 2000). 63
Figure 3.5 Spawning activity of *Alosa alosa* on the Garonne river (France), from Cassou-Leins & Cassou-Leins (1981). Squares represent the mean and dashes the upper and lower limit of the proportion of the spawning activity undertaken each hour between 22:00 and 03:59 (n=8). 64
Figure 3.6 Interovarian egg size in *Alosa alosa* three to four months (solid line) and one month (dashed line) prior to spawning (Reproduced from Lahaye *et al.,* 1963). 68
Figure 3.7 The change in oocyte diameter of *Alosa alosa* from the Garonne (France) in relation to maturation, redrawn from Bengen *et al.* (1991). 68
Figure 3.8a Late vitellogenic female *Alosa fallax* ovary, showing numerous late vitellogenic oocytes (lvit) and early-mid stage vitellogenic oocyte (evit), interspersed with several primary oocytes (po). Nucleus (n), Mayer's Haematoxylin & Eosin x40. 70
Figure 3.8b Transverse section through a secondary oocyte and a primary oocyte to illustrate the formation and development of the "egg shell" or chorion. The primary (balbiani body stage) oocyte (bb) is surrounded by a single layer of follicle cells (fc), whereas the more advanced (secondary) vitellogenic ooctye (2vit) is surrounded by a chorion composed of; zona pellucida (zp), zona radiata (zr), villi (vi), thecal cells (te) and follicle cells (fc), Nucleoli can be clearly seen on the periphery of the nucleus of the primary oocyte, Mayer's Haematoxylin & Eosin x400. 70

Figure 3.8c Transverse sections through the testes of *Alosa fallax*, illustrating normal testicular organisation during the later stages of the reproductive cycle (stage IV-V). Histologically, the testes of shad are of a lobular type, in which the connective tissues divide stroma into a complex network of tightly packed lobules, each comprised of numerous cysts Fully mature shad testes at spermiation showing enlargement of the lobules (lb) and loss of cysts. Spermatozoa (s), Mayer's Haematoxylin & Eosin x100. 70

Figure 3.9 Interovarian egg size in prespawning (A) and postspawning (B) *Alosa fallax fallax* from the R. Severn (England) (Aprahamian, 1982). 71

Figure 3.10 The relationship between egg size (percentage of eggs >1.00 mm in diameter) and length (total) of *Alosa fallax fallax* from the River Severn (Aprahamian, 1982). 74

Figure 3.11 Interovarian egg size for pre-spawning and spent *Alosa fallax killarnensis* from Lough Leane, Ireland; for pre-spawning fish only eggs >0.3mm were counted (Reproduced from O'Maoileidigh, 1990). 75

Figure 3.12 A comparison of the relationship between fecundity and length for a number of populations of *Alosa alosa* (dashed line) and *Alosa fallax fallax* (solid line). 1= Gironde-Garonne-Dordogne (France), Taverny (1991a); 2 = Douro (Portugal), Eiras (1981b); 3 & 7 = Sebou (Morocco), Sabatié (1993); 4 = Severn (England), Aprahamian (1982); 5 = Nyamunas (Lithuania), Manyukas (1989); 6 = Elbe (Germany), Hass (1965); 8 = Mira (Portugal), Pina (2000); 9 = Guadiana (Portugal), Pina (2000). 79

Figure 3.13 Mean density of eggs of *A. fallax* at two sites on the River Wye (Wales); Monmouth (■) and Courtfield (●) from Aprahamian (1981). 82

Figure 3.14 Mean density of eggs of *A. fallax* in relation to water depth in the estuary of the River Elbe (Germany) from Thiel *et al.* (1996a). 83

Figure 3.15 Diagrams of twaite shad redrawn by Quignard and Douchement (1991b) from the figures of Ehrenbaum (1894) and Mohr (1941); (a) pro-larva six days after hatching, (b) and (c) post-larvae, (d) transitional larva, (e) juvenile. 86

Figure 3.16 Immature stages of *Alosa fallax rhodanensis*, redrawn by Quignard & Douchement (1991c) from the figures of Chiappi (1933a). (a) newly hatched larva of 7mm; (b) 7.8mm larva, four to five days after hatching; (c) six days after hatching. 87

Figure 3.17 Juvenile stages of *Alosa fallax lacustris*, according to Chiappi (1933a). (a) just hatched, length 6.5mm; (b) four days after hatching, length 7mm. 88

Figure 3.18 Longevity of various populations of female *Alosa fallax fallax* in relation to latitude; see Table 3.47 for sources of data. 90

Figure 3.19 The relative density of *Mazocraes alosae* found in samples of *Alosa fallax fallax* from the Severn estuary in relation to the number of previous spawnings of individual fish (from Aprahamian, 1985). 102

Figure 3.20 Winberg's (1956) daily ration and mean water temperature of the 1992 year class of *A. fallax* from the Elbe Estuary (Reproduced from Oesmann & Thiel, 2001). 103

Figure 3.21 Diet of juvenile *Alosa alosa* from the River Garonne (France) in 104

relation to time of day (Cassou-Leins & Cassou-Leins, 1981).
Figure 3.22 Daily mean of Ivlev's (1961) electivity index with regard to the main food items in the stomachs of age 0+ *A. fallax* from the Elbe Estuary between July 8th – 9th 1993. Bars: confidence limits; broken lines: levels of significance according to Lazzaro (1987) [Reproduced from Oesmann &Thiel, 2001]. 106
Figure 3.23 Diet (% biomass) of age 0 *A. fallax* shad in the Elbe Estuary during a 24 h period between 8th and 9th July 1993 (Reproduced from Oesmann & Thiel, 2001). 107
Figure 3.24 The diet of juvenile (0+) *Alosa fallax fallax* from the Severn Estuary (England) in relation to tidal height (Aprahamian, 1988). 108
Figure 3.25 The diet of *Alosa fallax fallax* age 0+ (July to August) and 1+ (June to August) from the Severn Estuary, England (Aprahamian, 1988). [Only includes those food items that constituted >1% by volume.] 108
Figure 3.26 The standard length (mean ± 95% confidence intervals) of 0+ *Alosa fallax fallax* from the Severn Estuary (England) between July 1974 and April 1977 (Reproduced from Claridge & Gardner, 1978). 126
Figure 3.27 Relationship between von Bertalanffy coefficient (K) and the asymptotic length (L4). 128
Figure 3.28 Auximetric plot for *Alosa alosa* and *Alosa fallax* spp. 153
Figure 3.29 The abundance of *A. alosa* in the Loire (*c*.150 km from the ocean) and the relationship with tidal state (11 days prior to capture) and temperature (Mennesson-Boisneau *et al.,* 1999). 160
Figure 3.30 The daily count of *Alosa alosa* at Tuilièrs fish pass on the River Dordogne, France, in 1995 (Dartiguelongue, 1996a). 161
Figure 3.31 The daily pattern of movement of *Alosa alosa* at Tuilièrs fish pass on the River Dordogne, France, in 1995 (Reproduced from Travade *et al.,* 1998). 162
Figure 3.32 The diel movement of *Alosa fallax fallax* shoals in the River Wye, Wales (J. Gregory, pers. comm.). 163
Figure 3.33 The weekly 24-h sample size of 0+ *Alosa fallax* from the Severn Estuary (England) between July and November in 1975 and 1976, and the mean water temperature for the week prior to the collection. '0' indicates that no collection was made, from Claridge & Gardner (1978). 166
Figure 4.1 Annual variation in the number of *Alosa alosa* caught in the Gironde per net per day between 1984 to 1999 (Castelnaud *et al*., 2001). 178
Figure 4.2 The CPUE index of female *Alosa fallax fallax* from the Severn Estuary (England) between 1979 and 1998. 179
Figure 4.3 The stock recruitment relationship for *Alosa alosa* in the Gironde-Garopnne-Dordogne (Martin-Vandembulcke, 1999). 180
Figure 4.4 The relationship between year class strength of *Alosa fallax fallax* from the Severn Estuary, England between 1972 and 1996 and mean water temperature between June and August inclusive (Aprahamian & Aprahamian, 2001). 181
Figure 4.5 Size of the adult population between 1989 and 1996 in the Gironde-Garonne-Dordogne system (Martin-Vandembulcke, 1999). 183

Figure 5.1 **A schematic diagram of a stow net being fished (Anon. 1888).** 185
Figure 5.2 Putts 186
Figure 5.3 Putchers 186
Figure 5.4 A schematic diagram of a *filet-barrage* (A) downstream of Tours and (B) upstream of Tours, from Mennesson-Biosneau & Boisneau (1990). 186
Figure 5.5 **Fishing wheel / "baro".** 187
Figure 5.6 **"Le carrelet"** 188
Figure 5.7 Stopping boats in the Severn Estuary. 189
Figure 5.8 Seine netting for *Alosa alosa* in the lower Garonne (from Baglinière & Elie, 2000). 189
Figure 5.9 A fishermen with lave net, from the Severn Estuary. 190
Figure 5.10 Total landings of *Alosa alosa* from 1978 – 1999 and effort data from the Gironde-Garonne-Dordogne system. Solid area indicates catches from the Gironde-Garonne-Dordogne system and clear area represents the combined catches from other river systems and at sea, data from Baglinière *et al.* (2002) and Castelnaud *et al.*, (2001). 192
Figure 5.11 Catch of *Alosa fallax lacustris* from lakes Maggiore (Grimaldi, 1997) and Garda (Novello & Oppi, 1985; Confortini, 1998; pers. comm.), from Bianco (2002). 195
Figure 5.12 The number of juvenile (age 0+) *Alosa fallax* from the Bristol Channel, at Hinkley Point 'B' Power Station and from the Elbe Estuary between 1989 and 1994 (Aprahamian & Aprahamian, 2001). 196
Figure 5.13 The relationship between year-class strength of *Alosa fallax* from the Severn Estuary and the position of the North Wall of the Gulf Stream (First principal component of the position of the North wall of the Gulf Stream), August 1976 and 1989 year-classes marked (Data from A. H. Taylor; http://www.pml.ac.uk/gulfstream/inetdat.htm). 196
Figure 6.1 Location of Special Areas of Conservation (SAC) or Sites of Community Interest (SCI) under the EC Habitats Directive, for *Alosa alosa.* Where a number of sites on a particular river have been designated the whole river has been included for clarity. The individual sites are presented in Appendix 1. 198
Figure 6.2 Location of Special Areas of Conservation (SAC) or Sites of Community Interest (SCI) under the EC Habitats Directive, for *Alosa fallax* spp. Where a number of sites on a particular river have been designated the whole river has been included for clarity. The individual sites are presented in Appendix 2. 199
Figure 6.3 Pool fish passes (a) at Bergerac (R. Dordogne, France) and (b) at Ramier (R. Garonne, France), reproduced from Larinier & Travade (1992a). 203
Figure 6.4 The Golfech fish lift on the River Garonne, France (Travade *et al.,* 1998). 204
Figure 6.5 The count of shad at four fish passes; Golfech and Bazacle on the River Garonne and Tuiliéres and Mauzac on the River Dordogne, France. 205

LIST OF TABLES

Table 1.1 **Standard, common and vernacular names of European alosoids.** 8

Table 1.2 Summary of some morphometric characteristics of *Alosa fallax fallax* (Douchement, 1981; O'Maoileidigh, *et al.,* 1988; Alexandrino, 1996a; Doherty & McCarthy, 2002). 10

Table 1.3 Morphometric characteristics (Mean ± SE) of landlocked *Alosa fallax lacustris* from Lake Skadar, Yugoslavia, n = 27 (Rakaj & Crivelli, 2001). 12

Table 1.4 Morphometric characteristics of *Alosa fallax killarnensis* from Lough Leane, Ireland (O'Maoileidigh, *et al.,* 1988). Relationship with total length is based on mean values. 12

Table 1.5 Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various populations of *Alosa alosa.* 15

Table 1.6 **Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various populations of Alosa fallax fallax.** 16

Table 1.7 Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various anadromous populations of *Alosa fallax rhodanensis, A. fallax nilotica* and *A. fallax algeriensis,* values in italics represent morphometric indices as percentage of fork length (M = male; F = female). 17

Table 1.8 Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various populations of hybrids of *Alosa alosa x Alosa fallax*. 18

Table 1.9 Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various landlocked populations of *Alosa alosa* and *Alosa fallax,* values in italics represent morphometric indices as percentage of fork length. 19

Table 1.10 Coefficients of the least square regression relating the number of gillrakers on the first gill arch of adult *Alosa* (Br) to total length (L_t) in cm; Br = $a.L_t + b$. 21

Table 1.11 Coefficients of the least square regression (Br = $a.L_t + b$) relating the number of gillrakers on the first gill arch of juvenile anadromous *Alosa* (Br) to total length (L_t) in centimetres. 22

Table 1.12 Parameters for the regression of $y = ax + b$, all measurements in mm (LS = least square regression, GM = geometric mean regression). 24

Table 1.13 Parameters for the regression of $y = ax + b$, length is in millimetres and weight in grams (Taverny & Elie, 2001). 25

Table 1.14 Area and diameter of the different cell types and their nucleus in the testis of *Alosa alosa* from the River Douro, Portugal (Eiras, 1981b). 31

Table 1.15 Range in percentage water, protein, lipid and carbohydrate in male and female adult *Alosa alosa* (Eiras, 1981b; Bengen, 1992). 32

Table 1.16 Antioxidant enzyme activity in the liver of *Alosa fallax nilotica* (Kolayli *et al.,* 1997). 32

Table 1.17 Range in concentration (μgg^{-1}) of calcium (Ca), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) in the scales, bone (operculae) liver, muscle and ovary of adult female *Alosa fallax fallax* (n=37) from the Severn Estuary (Aprahamian, unpubl). 33

Table 1.18 Allele frequency for four polymorphic loci; hemaglobin (HBA), adenosine deaminase (ADA), mannosephosphate isomerase (MPI) 35

and alcohol dehydrogenase (ADH) in populations of *Alosa alosa* from the rivers Aulne (A), Charente (C), Mondego (M) and Lima (L) and the landlocked population of Castelo De Bode (CB) and *A.fallax* from the rivers Charente, Lima, Mondego, Tego (T), Guadiana (G) and Rhône ® (Alexandrino, 1996a; Le Corre *et al.*, 1998; Véron *et al.*, 2001)
Table 3.1 The percentage of *Alosa alosa* maturing at different ages in different river systems. 54
Table 3.2 Percentage of *Alosa fallax fallax* maturing at different ages from different river systems. 55
Table 3.3 Percentage of *Alosa fallax rhodanensis* maturing at different ages. 56
Table 3.4 Percentage of *Alosa fallax killarnensis* maturing at different ages (O'Maoileidigh, 1990). 57
Table 3.5 Mean fork length ∀95%CI (mm) at age of four year-classes of female *Alosa fallax fallax* prior to maturation (Aprahamian & Lester, 2001). 58
Table 3.6 Percentage of *Alosa fallax fallax* from a number of populations spawning one or more times. 61
Table 3.7 Percentage of *Alosa alosa* from the Gironde-Garonne-Dordogne (France) spawning one or more times. 59
Table 3.8 Percentage of *Alosa fallax rhodanensis* from the Rhône (France) spawning one or more times. 60
Table 3.9 Percentage of fish with more than one spawning mark on their scales, for three populations of *Alosa fallax nilotica* (Vukovic, 1961a). 60
Table 3.10 Percentage of *Alosa fallax killarnensis* from Lough Leane (Ireland) spawning one or more times (O'Maoileidigh, 1990). 62
Table 3.11 Change in thickness of the zona radiata and granulosa and theca cells associated with oocyte maturation in *Alosa alosa* (Bengen, 1992). 67
Table 3.12 Size of eggs of *Alosa alosa* before and after hydration. 68
Table 3.13a Macroscopic characteristics and histological description of the maturity stages of the ovary of *Alosa fallax fallax* (Pina, 2000). 72
Table 3.13b Macroscopic characteristics and histological description of the maturity stages of the testis of *Alosa fallax fallax* (Pina, 2000). 72
Table 3.14 Size of eggs of *Alosa fallax fallax* before and after hydration. 73
Table 3.15 The relative fecundity (Mean ± 95CI) of populations of *Alosa alosa.* 76
Table 3.16 The relationship between fecundity and fish size for *Alosa alosa.* 76
Table 3.17 The relative fecundity (Mean ± 95CI) of populations of *Alosa fallax fallax.* 77
Table 3.18 The relationship between fecundity and fish size for *Alosa fallax fallax.* 78
Table 3.19 The absolute and relative fecundity of *Alosa fallax nilotica* (Vukovic, 1961a). 80
Table 3.20 The relationship between fecundity (F) and total length (L_t), weight (W_t) and ovary weight (OW_t) for *Alosa fallax algeriensis* (Kartas, 1981). 80
Table 3.21 Incubation time for eggs of *Alosa alosa* in relation to temperature. 84
Table 3.22 Ontogenetic change in certain morphometric characteristcs of *Alosa alosa*, measured as a percentage of standard length (Mean ± SD) [Bergot *et al.*, unpublished]. 84
Table 3.23a Parasites recorded from *Alosa alosa*. 93

Table 3.23b Parasites recorded from *A. fallax fallax.* 95
Table 3.23c Parasites recorded from *A. fallax nilotica.* 97
Table 3.23d Parasites recorded from *A. fallax rhodanensis.* 98
Table 3.23e Parasites recorded from *A. fallax algeriensis.* 98
Table 3.23f Parasites recorded from *A. fallax lacustris.* 98
Table 3.24 Prevalence and relative density of parasites from the branchial chamber and alimentary tract of adult *Alosa fallax fallax* taken in the Severn estuary and fresh water (Aprahamian, 1985). 99
Table 3.25 The prevalence of infection of a) *Hemiurus appendiculateus* and b) *Hysterothylacium aduncum* in *Alosa alosa* and *A. fallax* in relation to life stage and location, sample size in brackets (Taverny, 1991a). 100
Table 3.26 Prevalence and relative density of parasites from adult *A. fallax* from freshwater reaches of the River Barrow (Doherty & McCarthy, 2002) and the River Severn (Aprahamian, 1985). 101
Table 3.27 The relative density and prevalence of *M. alosae* between juvenile (age 0 + & 1+) *A. fallax*, adult *A. fallax* on their first spawning migration, and from repeat spawners (Finlayson, 1981; Aprahamian, 1985). 101
Table 3.28 Stomach contents of *Alosa alosa* (181-538 mm L_t) from the Bay of Biscay, France (Taverny, 1991a). 105
Table 3.29 Diet of 0+ *A. fallax nilotica* from Lake Skadar and 1+ *A. fallax nilotica* from Lake Bačin (Vukovic, 1961a). 109
Table 3.30 Species of fish consumed by *A. fallax nilotica* from the River Neretva and from lakes Bačin and Skadar (Vukovic, 1961a). 112
Table 3.31 The stomach contents of 32 *Alosa fallax killarnensis* from Lough Leane (Ireland) caught during June (O'Maoileidigh, 1990). 113
Table 3.32 Mean total length (± SD) in mm of juvenile (0+) *Alosa alosa* from the Gironde-Garonne-Dordogne system (France), data from Cassou-Leins *et al.* (1988a) and Taverny (1991a). Samples from different years have been combined. 116
Table 3.33 Range in total length (mm) of *A. alosa* from the River Rhine (Hoek, 1899) and Gironde (Cassou-Leins *et al.*, 1988a and Taverny, 1991a). 116
Table 3.34 Total length and standard deviation (mm) of anadromous male *Alosa alosa.* 118
Table 3.35 Mean weight (standard deviation) in relation to age for anadromous male *Alosa alosa.* 119
Table 3.36 Total length and standard deviation (mm) of anadromous female *Alosa alosa.* 120
Table 3.37 Mean weight (standard deviation) in relation to age for anadromous female *Alosa alosa.* 121
Table 3.38 von Bertalanffy growth parameters for male and female anadromous *Alosa alosa*, 95% confidence intervals in brackets. 122
Table 3.39 Maximum length (total) and weight of anadromous *A.alosa* recorded from a number of river systems. 122
Table 3.40 Parameters for the equation weight (g) = aLength^b (mm) for male *Alosa alosa*, (Imm. = immature). 123
Table 3.41 Parameters for the equation weight (g) = aLength^b (mm) for female *Alosa alosa*, (Imm. = immature). 124
Table 3.42 Parameters for the equation weight (g) = aLength^b (mm) for juvenile *Alosa alosa.* 124

Table 3.43 Range in total length (mm) or mean (SD or 95% confidence intervals) of landlocked male and female *Alosa alosa.* 125
Table 3.44 von Bertalanffy growth parameters for male and female landlocked *Alosa alosa*, 95% confidence intervals in brackets. 125
Table 3.45 Mean total length (SD) in mm of *Alosa fallax fallax* from the rivers Elbe (Ehrenbaum, 1894; Möller, 1988; Oesmann, 1994), Severn (Aprahamian, 1988), Gironde estuary (Taverny, 1991a) and Sebou (Sabatié, 1993). 126
Table 3.46 Total length and standard deviation (mm) of anadromous male *Alosa fallax fallax*. 129
Table 3.47 Mean weight (g) and standard deviation (in brackets) in relation to age for anadromous male *Alosa fallax fallax.* 131
Table 3.48 Total length and standard deviation (mm) of anadromous female *Alosa fallax fallax.* 132
Table 3.49 Mean weight (g) and standard deviation (in brackets) in relation to age for anadromous female *Alosa fallax fallax.* 134
Table 3.50 von Bertalanffy growth parameters for male and female anadromous *Alosa fallax fallax*, 95% confidence intervals in brackets. 135
Table 3.51 Maximum length (total) and weight of anadromous *A. fallax fallax* recorded from a number of river systems. 136
Table 3.52 Parameters for the equation weight (g) = aLength^b (mm) for male *Alosa fallax fallax.* 137
Table 3.53 Parameters for the equation weight (g) = aLength^b (mm) for female *Alosa fallax fallax.* 138
Table 3.54 Parameters for the equation weight (g) = aLength^b (mm) for juvenile (age 0+ and 1+) *Alosa fallax fallax.* 139
Table 3.55 Total length and standard deviation (mm) of male *Alosa fallax rhodanensis*. 141
Table 3.56 Mean weight and standard deviation (g) in relation to age for anadromous male *Alosa fallax rhodanensis.* 141
Table 3.57 Total length and standard deviation (mm) of female *Alosa fallax rhodanensis*. 142
Table 3.58 Mean weight and standard deviation (g) in relation to age for anadromous female *Alosa fallax rhodanensis.* 142
Table 3.59 von Bertalanffy growth parameters for male and female anadromous *Alosa fallax rhodanensis*, 95% confidence intervals in brackets. 143
Table 3.60 Parameters for the equation weight (g) = aLength^b (mm) for male *Alosa fallax rhodanensis.* 143
Table 3.61 Parameters for the equation weight (g) = aLength^b (mm) for male *Alosa fallax rhodanensis.* 144
Table 3.62 Total length and standard deviation (mm) of male *Alosa fallax nilotica.* 146
Table 3.63 Mean weight (g) in relation to age for male *Alosa fallax nilotica.* 146
Table 3.64 Total length and standard deviation (mm) of female *Alosa fallax nilotica.* 147
Table 3.65 Mean weight (g) in relation to age for female *Alosa fallax nilotica.* 147
Table 3.66 von Bertalanffy growth parameters for male and female anadromous *Alosa fallax nilotica*, 95% confidence intervals in brackets. 148
Table 3.67 Parameters for the equation weight (g) = aLength^b (mm) for male 148

and female *Alosa fallax nilotica,* based on mean length and weight at age data.
Table 3.68 Mean or range in total length (mm) of male *Alosa fallax algeriensis.* 149
Table 3.69 Mean weight (g) of male *Alosa fallax algeriensis.* 149
Table 3.70 Mean or range in total length (mm) of female *Alosa fallax algeriensis.* 150
Table 3.71 Mean weight (g) of female *Alosa fallax algeriensis.* 150
Table 3.72 von Bertalanffy growth parameters for male and female anadromous *Alosa fallax algeriensis*, 95% confidence intervals in brackets. 151
Table 3.73 Parameters for the equation weight (g) = aLength^b (mm) for male and female *Alosa fallax algeriensis,* based on mean length and weight at age data. 151
Table 3.74 Length (total) of male and female *Alosa fallax lacustris* from the Italian lakes Maggiore (Berg & Grimaldi, 1966a) and Garda (Oppi & Novello, 1989). 152
Table 3.75 von Bertalanffy growth parameters for male and female *Alosa fallax lacustris*, 95% confidence intervals in brackets, calculated from the mean length at age data presented in Table 3.74. 152
Table 3.76 Backcalculated length (total) and standard deviation (mm) of male and female *Alosa fallax killarnensis* from Lough Leane, Ireland (O'Maoileidigh, 1990). [Fork length (L_f) converted to total length (L_t) using $L_t = 1.1325\ L_f + 2.6556$ (Douchement, 1981)]. 152
Table 3.77 von Bertalanffy growth parameters for male and female *Alosa fallax killarnensis* from Lough Leane, Ireland, 95% confidence intervals in brackets. Parameters calculated from data presented in Table 3.76. 153
Table 3.78 Parameters for the equation: weight (g) = aLength^b (cm) for adult pre-spawned male and female *Alosa fallax killarnensis* from Lough Leane, Ireland (O'Maoileidigh, 1990). 153
Table 3.79 The range in mean monthly percentage water, protein, lipid and carbohydrate in the muscle, gonad and liver of *Alosa alosa* from the River Douro, Portugal (Eiras, 1981b), (Est. = estuary; FW = fresh water). 154
Table 3.80 The percentage protein and lipid in the muscle, gonad and liver of *Alosa alosa* obtained from the outer estuary of River Gironde-Garonne-Dordogne (France) in April and from fresh water in July (Bengen, 1992). 155
Table 3.81 The mean (SE) area (μ^2) of the adenohypophyseal cells of *Alosa alosa* during the freshwater phase of their spawning migration (Eiras, 1981b). 155
Table 3.82 The mean (± SE) concentration (μgg^{-1}) of calcium (Ca), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) in the scales, bone (operculae) liver, muscle and ovary of pre- (n=22) and post (n=15) spawned female *Alosa fallax fallax* from the Severn Estuary (Aprahamian, unpubl). 156
Table 3.83 The mean (SE) volumes of the hypophyseal regions (PDR = pars distalis rostralae; PDP = pars distalis proximalae; NIL = neurointermedial lobe) of *Alosa fallax nilotica* during different periods of the sexual cycle in μcm^3 (Pavlović & Pantić, 1975). 157
Table 3.84 The mean (SE) volumes (μm^3) of the adenohypophyseal cells (PLH = prolactin; ACTH = adrenocorticopic; TSH = thyrotropic; STH = 157

somatotropic; GTH = gonadotropic; PAS+ = stain positive with alcian blue-PAS-orange and MSH = melanostimulating cells) and their nuclei of *Alosa fallax nilotica* during different seasons of the sexual cycle (Pavlović & Pantić, 1975).
Table 3.85 Percentage fatty acid composition of liver/muscle/gonad total lipids of *Alosa fallax lacustris* from Lake Como, Italy (Luzzana *et al.,* 1996); SFA = saturated fatty acid; MUFA = monounsaturated fatty acid; PUFA = polyunsatured fatty acid and HUFA = highly unsaturated fatty acid. 158
Table 3.86 Timing of the freshwater phase of the spawning migration of *Alosa alosa.* 160
Table 3.87 Timing of the freshwater phase of the spawning migration of *Alosa fallax fallax.* 163
Table 3.88 Swimming capabilities of shad (0.30 to 0.50 m in length) from Larinier (1996). 168
Table 4.1 Range in the annual sex ratio of *A. alosa* from the Gironde-Garonne-Dordogne (Lambert *et al*., 2001). 169
Table 4.2 Age structure (mean percent and range) of the spawning population of female *Alosa alosa* (N = number of years sampled; n = number of fish aged). 171
Table 4.3 Age structure (mean percent and range) of the spawning population of male *Alosa alosa* (N = number of years sampled; n = number of fish aged). 172
Table 4.4 Age structure (mean percent and range) of the spawning population of female *Alosa fallax fallax* (N = number of years sampled; n = number of fish aged). 173
Table 4.5 Age structure (mean percent and range) of the spawning population of male *Alosa fallax fallax* (N = number of years sampled; n = number of fish aged). 174
Table 4.6 Age structure of the adult population of *Alosa fallax fallax* from four Portuguese rivers (Alexandrino, 1996b). 175
Table 4.7 Age structure (mean percent and range) of the spawning population of female *Alosa fallax rhodanensis* (N = number of years sampled; n = number of fish aged). 176
Table 4.8 Age structure (mean percent and range) of the spawning population of male *Alosa fallax rhodanensis* (N = number of years sampled; n = number of fish aged). 176
Table 4.9 Age structure (mean percent and range) of the spawning population of female and male *Alosa fallax nilotica* (N = number of years sampled; n = number of fish aged). 177
Table 4.10 Age structure (mean percent and range) of the spawning land locked populations (N = number of years sampled; n = number of fish aged). 177
Table 4.11 Range in the annual level of exploitation of *A. alosa* from the Gironde-Garonne-Dordogne by age and sex (Lambert *et al*., 2001). 183
Table 5.1 **Annual catch (tonnes) of Alosa fallax fallax from various river systems.** 194
Table 6.1 Conservation status of *Alosa alosa* and *Alosa fallax* spp., data from P. Maitland (pers.comm.) unless otherwise stated. 200

EXECUTIVE SUMMARY

The review is divided into seven sections:

- Identity: nomenclature, taxonomy and morphology.
- Distribution: European and North African distribution, factors affecting abundance and hybridization
- Bionomic and Life history: reproduction, spawning, ontogeny, growth, diet, disease, parasite, inter- & intra-specific interactions, homing & migration.
- Population (spawning stock): sex ratio, age structure, recruitment, mortality, and population dynamics.
- Exploitation: fishing equipment, area, seasons and catches and the influence of climate on the population.
- Protection and Management: conservation status, protection and management of *Alosa* habitat and fish pass design.
- Enhancement: Culture: collection of spawn and eggs, rearing of larval and juvenile stages.

The review focuses on the European and North African literature with the exception of the section dealing with culture. The section on culture relies on material mainly from North America. Though European alosoids have been cultured the majority of the work was carried out during the second half of the eighteenth and the first half of the nineteenth century. It was therefore considered appropriate to provide a summary of the latest findings in order to take on board some of the more recent advances in culture techniques.

The bibliography contains *c.* 1500 references relating to *Alosa alosa* and *Alosa fallax* spp., it can also be provided in an electronic version. The electronic version (Endnote) incorporates reference abstracts and notes on their contents, together with key words to aid searches.

The shads belong to the subdivision Clupeomorpha. The clupeomorphs are characterised by having ducts running anteriorly from the swim baldder into the skull and sharp boney scutes along their ventral surface. The number of gill rakers on the first gill arch and geographical location have both been used to identify species and sub-species. In the Eastern Atlantic and Mediterranean four species of *Alosa* have been recognised; *Alosa alosa* (Linnaeus, 1758), *Alosa fallax* (Lacépède, 1803), *Alosa macedonica* (Vinciguerra, 1921) and *Alosa caspia* (Eichwald, 1838). No subspecies have been reported for *A. alosa* or for *A. macedonica*, while for *A. fallax* six subspecies have been reported:

Alosa fallax fallax (Lacépède, 1803)
Alosa fallax rhodanensis (Roule, 1924).
Alosa fallax nilotica (Geoffroy Saint-Hilaire, 1808)
Alosa fallax algeriensis (Regan, 1916)
Alosa fallax lacustris (Fatio, 1890)
Alosa fallax killarnensis (Regan, 1916)

It is acknowledged that considerable confusion remains over the systematics of *Alosa fallax* spp. and this ultimately will need to be addressed, especially as there is a move away from subspecies. It has been argued that the following should be reclassified: *Alosa fallax algeriensis* as *Alosa algeriensis*, *Alosa fallax killarnensis* as *Alosa killarnensis* and *Alosa fallax lacustris* as *Alosa agone* (Scopoli, 1786). It has also been suggested that, until explicit data were available the three subspecies *Alosa fallax fallax*, *Alosa fallax nilotica* and *Alosa fallax rhodanensis* should be classified as *Alosa fallax.* This reclassification was on the basis of differences in morphology, habit, life history, and ontogeny. However, for this literature review it is proposed to adopt the classification of Hoestlandt (1991) and Quignard & Douchement (1991e).

Alosa alosa and *Alosa fallax* have been reported from as far North as Iceland at the northern most limit of their range, to Morocco in the south and as far east as Scandinavia and the Baltic Sea. *Alosa alosa* have been reported only from the western part of the Mediterranean, while *Alosa fallax* are encountered through out the Mediterranean. *Alosa fallax rhodanensis* is distributed along the northern coast of the western Mediterranean Sea ranging from Spain to southern Italy while *Alosa fallax nilotica* is distributed around the eastern Mediterranean with its range extending southward down to the River Nile**.** *Alosa fallax algeriensis* is found along the North African coast from the Rif Peninsula to Tunisia. The landlocked, *Alosa fallax lacustris*, is present in Italy, Sardinia and Montenegro. In Southwest Ireland, a landlocked population of *A. fallax*, (*Alosa fallax killarnensis*) exists in Lough Leane its isolation possibly due to local tectonic changes.

There has been a considerable decline in abundance of *Alosa* spp. throughout their geographic range. It is for this reason that the species have been included in Appendix III of the Bern Convention and into Annexes II and V of the EC Habitats Directive. The main reason for this decline has been the construction of dams preventing access to their spawning grounds. In some river systems this has resulted in the extinction of one and / or both species of *Alosa* and in some cases to hybridization. The prevalence of hybridization appears related to the presence of obstructions to the free passage of migrants upstream resulting in the use of communal areas for spawning. The effect of barriers may have been exacerbated by overfishing as fish congregate and become easier to capture below obstructions. Pollution (poor water quality), especially in the lower reaches and estuaries has also been identified as a threat for anadromous populations and also for some of the landlocked population such as *Alosa fallax lacustris* in Lake Maggiore. Habitat destruction has also been implicated for their decline. This can occur as part of a reengineering scheme to improve navigation and for flood defence purposes, or as a consequence of gravel extraction effectively impacting on the species spawning habitat.

Anadromous alosine mature between 2 and 9 years old with females maturing mainly between 4 and 6 years and males a year earlier. The landlocked populations mature on the whole a year earlier than the anadromous forms. Anadromous *Alosa alosa* has a semelparous life history, while the landlocked form are iteroparous. Except for the most southerly populations in the Sebou and Loukos *Alosa fallax* spp. are multiple spawners. A maximum of seven spawnings has been recorded for *Alosa fallax fallax* and *Alosa fallax nilotica*. The oldest anadromous *Alosa alosa* recorded is 8 years for females and 7 years for males, for *Alosa fallax* spp the maximum age reported is 12 for females and 10 for males. For landlocked populations their longevity is lower 5 for *Alosa alosa* and 4 to

5 for *Alosa fallax* spp. For anadromous *Alosa fallax* a latitudinal cline exists with fish at the northern limit of their range living longer, between 7 and 12 years compared to those at the southern limit where longevity of 5 or 6 years appears normal. The fact that the fish live longer further north and that there is little difference in the age at which fish mature would suggest that the proportion of repeat spawners in the population should increase with latitude.

For *Alosa alosa* absolute fecundity ranges from 50,000 to 636,000 eggs and realtive fecundity from 60,000 to 236,000 eggs/kg while for *Alosa fallax* fallax absolute fecundity ranges from 25,942 to 675,000 eggs and relative fecundity from 42,540 to 302,358 eggs/kg. For *Alosa fallax nilotica* the relative fecundity is lower at approximately 80,000 eggs/kg and is less than that of its landlocked conspecific of between 200,000 and 300,000 eggs/kg. The absolute fecundity of the landlocked populations is lower than that of the anadromous forms reflecting in part their smaller size.

The timing of the spawning migration of adults into fresh water occurs along a latitudinal gradient from south to north, and takes place from December to August, mainly during the day. Water temperature, is the most important environmental factor moderating migratory behavior. The freshwater phase of the spawning migration generally take place when temperature ranges from 12 to 20° C, at temperatures below 10-11°C, migration behavior is weak. The tidal cycle also plays a role in migration, mainly in estuaries, but it can act in freshwater bodies up to 150 km from the sea. River discharge also has an influence, notably by halting the migration during strong spates.

Spawning takes place in fresh water during the night. During the day the fish shelter in groups along the shore or on the bed of the river. At dusk the fish move on to the spawning shoals. During the night the fish come up to the surface. The males and females, half submerged and along side each other swim in a circular motion violently thrashing the surface of the water with their caudal fin, releasing sperm and eggs into the water column.

For *Alosa alosa, Alosa fallax fallax, Alosa fallax rhodanensis* and certain populations of *Alosa fallax nilotica* spawning takes place in the main river and major tributaries of the catchment. The fish deposit their eggs onto a substrate which can vary from sand (20µ to 2mm) to pebbles (20 to 200 mm), in water of depth 0.5 to 3.0m and where the current ranges from 0.5 to 2.0ms^{-1}. For *Alosa fallax lacustis* spawning takes place near the shore of the lake. Eggs (1.7 – 4.5mm) successfully develop between 15^{o}C and 25^{o}C. Incubation takes 65 to 240h depending on temperature. Larvae measure between 4 and 12mm at hatching. After hatching the larvae of the anadromous forms migrate transversely into areas of lower current velocity where the juvenile stages can be found from mid-May until mid-September. For *Alosa fallax fallax* temperature preferences for larvae between 7.7 and 15.2 mm were in the range 17.0 to 20.0^{o}C and for larvae from 18.4 to 23.8 mm were between 17.0 and 21.5^{o}C. Juveniles (age 0+) avoid areas of low dissolved oxygen (<4 mgL^{-1}), the majority being caught in water of between 4 and 5 mgO_2L^{-1} . Seaward emigration occurs in shoals in the surface layers of the water column, taking place in the autumn and winter of their first year of life. Their emigration occurring earlier in southern rivers. The juvenile migration is modulated by water temperature and river discharge. Their residence time in the estuary is poorly understood. Most young of the year reach the sea at the beginning of winter at lengths ranging from 45 to over 120 mm TL and weighing 2 to 20 g.

The adults do not feed while on their spawning migration in fresh water. During the freshwater pahse of the spawning migration there was a gradual loss of condition (weight.100/length^3) during the period. The weight loss associated with the migration and spawning has ranged from 30 to 59% being generally higher for females than for males. In the River Douro and in the Gironde-Garonne-Dordogne system the amount of protein and lipid in the muscle decreased as *Alosa alosa* migrate from the estuary into fresh water for spawning. The protein content of female fish declined in the River Douro stock, while in the Gironde-Garonne-Dordogne a slight increase was reported. The decline in lipid and protein content in the muscle and liver relates in part to the energetic costs of migration and to the remobilization of the lipid and protein, associated with maturation of the gonads. The lipid and protein content of the ovary and testis increased as spawning is approached.

Juvenile alosinae consume mainly insect larvae in fresh water and zooplankton in the estuary. At sea Mysidacea and fish dominate the diet of *Alosa fallax* spp., while for *Alosa alosa* euphausids and zooplankton were consumed most frequently. Landlocked populations predominantly consume plankton particularly cladocerans and copepods.

Growth of *Alosa alosa* was fastest in the River Douro followed by those from the rivers Mondego, Loire, Lima and Sebou. On those systems where studies had been carried out over a number of years significant temporal differences were evident, particularly on the Loire, Gironde-Garonne-Dordogne and Adour. For *Alosa fallax fallax* the fastest growing populations were in the Mondego followed by the Nyamunas and Lima rivers. Little difference in growth exists between other populations from the Sebou, at the southern limit of their range to the Severn towards their northern limit. In the Tiber growth of *Alosa fallax rhodanensis* in the first year was faster than in French populations, though not for those which had migrated into the Vaccarès lagoon. However, in older age groups growth was faster in French stocks. French stocks were heavier than those from the Tiber when fish of the same age were compared. For *Alosa fallax nilotica* of a given age the River Po population is smaller at ages one and two compared with populations from the Balkans, though for fish three years and older there is little difference in length at age. The maximum size would appear to be greater in the Balkan populations, with males reaching at least 508 to 543 mm and females 546 to 560 mm, compared with 454 and 477 mm for males and females from the Po river. Females were heavier than males with a maximum weight of 2.4 kg compared to 1.9 kg for males. For the land locked *Alosa fallax* spp. their growth in the first year is faster than in the anadromous forms.

Protein, meristic and morphometric differences indicate separate populations of *Alosa* exist and that in order to maintain these differences homing must take place to their natal river. Protein differences indicated that of the eleven populations of *Alosa fallax* studied three groups are apparent. There is one group comprising *Alosa fallax rhodanensis* from the rivers Rhône, Herault and Aude draining into the Mediterranean and *Alosa fallax fallax* from the Sebou (Morocco) which drains into the Atlantic. The other two groups consist of *Alosa fallax fallax*; the first comprising the rivers Tejo, Mira and Guadiana in Southern Portugal and the second consisting of the Northern

Portuguese rivers Mondego, Lima and Minho and the French river, Charente, all of which drain into the Atlantic Ocean.

At sea *Alosa alosa* and *Alosa fallax* are coastal in their habit and are clumped in aggregations around the major catchments for reproduction. *A. alosa* has been reported from depths ranging from 10 to 150m up to *c*. 300m and *A. fallax* from 10 to 110m with a preference for water of 10 to 20m deep. In the Adriatic, *A. fallax nilotica* could be caught at depths ranging from the surface to 160m, with the fish preferring to be close to the bottom during the winter months. In relation to water temperature, *A. alosa* in Moroccan coastal waters were found to be closely associated with water in the temperature range of 14 to 18^{o}C.

The *Alosa alosa* population in the Gironde-Garonne-Dordogne system is regulated through density dependent processes while *Alosa fallax*, towards the northern limit of their range, is controlled through density independent factors specifically temperature. However, there is little information on their population dynamics.

The most important commercial species in Europe is the allis shad. The fish are generally caught when they migrate from their feeding areas toward their spawning grounds a few catches are recorded in the sea or along the coast. A sport fishery has recently developed in France and in Britain for the twaite shad. Various types of fishing gear are used by the commercial fisheries, the two commonest being the stop net and trammel net. From 1978 to 1998, approximate total landings ranged from 355 to 1,198 tonnes in the current distribution area. About 94% of the total landings are in France and 89% from the Gironde-Garonne-Dordogne system alone. Indeed, catches in this system range from 338 to 1007 tonnes and are very high compared to other rivers. Catches in the River Loire are low, often not exceeding 10 tonnes and declining sharply to about 1 tonne in the years 1995 and 1996. Average catches in the Adour River were approximately 19 tonnes between 1985-1999.

The main conservation options available for the protection and enhancement of *Alosa* populations are reviewed. These include the construction of fish passes to ensure unhindered access to their spawning grounds. Similarly there should not be a water quality barrier preventing access to their spawning areas and no siltation of their spawning grounds. In addition their incorporation into the EC Habitats Directive places an obligation of members of the European Union to assess numbers and exploitation of the populations and to designate Special Areas for Conservation (SAC) / Sites of Community Interest (SCI) to safeguard populations

There have been a number of studies carried out during the second half of the eighteenth – first half of the nineteenth century, which were concerned with the artificial propagation of European alosines. Since then there has been little published information on their culture. In recent years there have been great advances in the techniques used in the artificial culture of *Alosa*, especially in the USA, and this information forms the basis of the summary for alosine culture in this review.

1. IDENTITY

1.1 Nomenclature

1.1.1 Valid name

The valid scientific name for the:

- Allis shad is *Alosa alosa* (Linnaeus, 1758),
- Eastern Atlantic anadromous twaite shad is *Alosa fallax fallax* (Lacépède, 1803),

Western Mediterranean twaite shad is *Alosa fallax rhodanensis* (Roule, 1924) [Roule 1924a],

- Eastern Mediterranean twaite shad is *Alosa fallax nilotica* (Geoffroy Saint-Hilaire, 1808),
- Algerian twaite shad is *Alosa fallax algeriensis* (Regan, 1916),

Agone is *Alosa fallax lacustris* (Fatio, 1890),

- Killarney shad is *Alosa fallax killarnensis* (Regan, 1916),

but see also section 1.2.2 (Taxonomic status)

1.1.2 FAO Code

Alosa alosa (Linnaeus, 1758)	-	1210501104
Alosa fallax fallax (Lacépède, 1803)	-	1210501105
***Alosa fallax rhodanensis* (Roule, 1924)**	**-**	**1210501105**
***Alosa fallax nilotica* (Geoffroy Saint-Hilaire, 1808)**	**-**	**1210501105**
Alosa fallax algeriensis (Regan, 1916)	-	1210501105
***Alosa fallax lacustris* (Fatio, 1890)**	**-**	**1210501105**
Alosa fallax killarnensis (Regan, 1916)	-	1210501105

1.1.3 Synonyms

- Generic (Svetovidov, 1952; Hoestlandt, 1991; Eschmeyer, 1998)

Alosa Linck, 1790: 6(3) 35; Cuvier, 1829:319

Pomolobus Rafinesque, 1820: 2(3), 170
Alausa Valenciennes, 1847: 20, 389
Alausella Gill, 1861: 36, Suppl.54
Clupeonella (non Kessler) Berg, 1913a: 2 (3)
Caspialosa Berg, 1915: 4(6), 4
Paralosa Roule, 1925: 73

Specific (Svetovidov, 1952; Whitehead, 1985; Quignard & Douchement, 1991a; Kartas, 1991; Kottelat, 1997; Eschmeyer, 1998).

Alosa alosa (Linnaeus, 1758)

Alosa alosa (Linnaeus, 1758): Regan, 1916 (8) 18:8; Lozano Rey, 1935, 5:38 fig. 9a, pl. 1.1; Fowler, 1936: 169, fig. 67; Poll, 1947, 138, fig. 91; Berg, 1948: 145; Svetovidov, 1952: 312, pl. 25, fig.1; Albuquerque, 1954-56: 218, fig. 119, 120a; Svetovidov, 1963: 351, pl. 25, fig.1; Wheeler, 1969a: 127, fig.49; Svetovidov, 1973: 105; Wheeler, 1978a: 70, fig.; Whitehead, 1984: 269, fig.; Poll *et al.,* 1984:41; Whitehead, 1985: 194; Wheeler, 1985: 24-25; Whitehead, 1990: 208; Kottelat, 1997: 37.

Clupea alosa Linnaeus, 1758:318;
Alosa communis Yarrell, 1836, 4: 136.
Alausa vulgaris Valenenciennes, 1847, 20: 391 pl.604.
Alosa rusa Mauduyt, 1849: 49.
Alosa cuvieri Malm, 1877**:154 or 654.**
Alosa vulgaris Moreau, 1881, 3:456.
Clupea alosa Day, 1880-4, 2, 234, pl.CXL; Hoek, 1899: 156; Joubin & Le Danois, 1924, 1:15; Kyle & Ehrenbaum, 1927, XII:13; Schnakenbeck, 1931; Andersson, 1942: 254; Soljan, 1948: 248.
Clupea alosa var.B. *alosa* Smitt, 1895:985, fig. 249b.

Alosa fallax fallax (Lacépède, 1803)

Alosa fallax fallax (Lacépède, 1803): Berg, 1948: 144; Svetovidov, 1952: 310, figs 51, pl. 24 fig. 2; Poll *et al.,* 1984: 41; Whitehead, 1985: 199; Whitehead, 1990: 209; Quignard & Douchement, 1991b: 225, fig. 57; Kottelat, 1997: 38.

Alosa ficta Duhamel du Monceau, 1772:320.
Alosa fallax Lacépède, 1803: 5: 424, 452.
Clupea rufa Lacépède, 1803: 452
Clupea finta Cuvier, 1829, 2:320**;** Hoek, 1899: 156; Joubin & le Danois, 1924, 1:17; Kyle & Ehrenbaum, 1927, I:12; Schnakenbeck, 1931:120; Andersson, 1942:254, pl.67.
Alosa finta Moreau, 1881, 3:456; Day, 1880-4,2:236, pl.CXLI; Regan, 1916, (8),18:6.
Clupea alosa var. *A.finta* Smitt, 1895:984, fig248,249a, pl.XLIII(fig.2).
Paralosa fallax Roule, 1925: 78.
Alosa fallax Lozano Rey, 1935, 5:42, fig. 2; Poll, 1947: 141, fig. 92; Albuquerque, 1954-56: 219, fig. 119, 120B; Wheeler, 1969a: 128, fig. 50; Wheeler, 1978a: 68, fig..

Alosa fallax rhodanensis (Roule, 1924).

Alosa fallax rhodanensis (Roule, 1924): Svetovidov, 1973: 108; Quignard & Kartas, 1977, 350:1253; Whitehead & Bauchot, 1985: 36; Whitehead, 1985: 199; Quignard & Douchement, 1991c: 274; Kottelat, 1997:38.

> *Paralosa (nilotica) rhodanensis* Roule, 1925: 80, pl. 16 (fig. 82-88)
> *Alosa finta* Barbieri, 1907a, 9: 127; D'Ancona, 1927a, 38:191.
> *Alosa finta nilotica:* Regan, 1916, 18:10.
> *Alosa* (*Paralosa*) morpha *rhodanensis* De Buen, 1930, 5:182.
> *Alosa fallax* Cottiglia, 1963a, 18:34; Cottiglia, 1968, 7:78.
> *Alosa fallax nilotica* Bini, 1970, II: 53, fig.; Tortonese, 1970: 102, fig. 43; Svetovidov, 1973, I: 107.

Bianco (2002) suggested reclassifying *Alosa fallax rhodanensis* as *Alosa agone* (Scopoli, 1786), see section 1.2.2.

Alosa fallax nilotica (Geoffroy Saint-Hilaire, 1808)

Alosa fallax nilotica (Geoffroy Saint-Hilaire, 1808): Berg, 1932: 91; Berg, 1948: 145; Svetovidov, 1952: 309, fig.51, pl. XXIV, fig. 1; Bini, 1970:, 2:53, fig; Tortonese, 1970, 10: 102, fig. 41-42; Whitehead, 1984, 1:272. Whitehead, 1985: 199; Bianco, 1988: 148; Quignard & Douchement, 1991d: 265; Kottelat, 1997: 38.

> *Clupea nilotica* E. Geoffroy Saint-Hilaire 1808: pl.10.
> *Clupea finta* Boulenger, 1909:154, fig. 123.
> *Alosa finta* Moreau, 1881, 3:456; Soljan, 1948: 247; 1975:631.
> *Alosa finta nilotica* Regan, 1916: 10.

Bianco (2002) suggested that *Alosa agone* (Scopoli, 1786), be recognised as the valid scientific name for *Alosa fallax nilotica*, see section 1.2.2

Alosa fallax algeriensis (Regan, 1916)

Alosa fallax algeriensis (Regan, 1916): Quignard & Kartas, 1977, 501: 1253; Kartas, 1981: 77; Kartas, 1991, 213.

> *Alosa finta algeriensis* Regan 1916, 18: 10.
> *Alosa fallax bolivari* Lozano-Rey, 1929, 15: 660, pl. 30, fig. 3.
> *Alosa fallax* morpha *algeriensis* De Buen, 1930, 5: 182.

It is possible that *Alosa africana* (Regan, 1916) is a simultaneous synonym for *Alosa fallax algeriensis* (Kottelat, 1997), though Furnestin & Vincent (1958) considered *Alosa africana* to be a hybrid between *Alosa alosa* and *Alosa fallax.*

Kottelat (1997) suggested reclassifying *Alosa fallax algeriensis* (Regan, 1916) as a separate species and proposed *Alosa algeriensis* Regan, 1916 as the valid scientific name. However, Bianco (2002) suggested that the subspecies be classified as *Alosa agone* (Scopoli, 1786), see section 1.2.2.

Alosa fallax lacustris (Fatio, 1890)

Alosa fallax lacustris (Fatio, 1890): Ferrero, 1951:24; Dottrens, 1952:23; Bini, 1970, II:48, 53; Tortonese, 1970, X: 105-106.

> *Ciprinus* [sic] *agone* Scopoli, 1786:71
> *Clupea Alosa major* Pollini, 1816:21
> *Clupea Alosa minor* Pollini, 1816:21
> *Clupea Alosa parvula* Pollini, 1816:21
> *Alosa Finta* var. *lacustris* Fatio, 1890: 51
> *Alosa lacustris* forma *ceresio-verbana* Barbieri, 1907a: 140, pl.1, fig.3
> *Alosa lacustris* forma *lariana* Barbieri, 1907a: 140, pl.1, fig.3.
> *Alosa lacustris* forma *benacensis* Barbieri, 1907a: 140, pl.1, fig.3.
> *Alosa finta gracilis* Regan, 1916: 10.

Kottelat (1997) suggested reclassifying *Alosa fallax lacustris* (Fatio, 1890) as a separate species and recommended *Alosa agone* (Scopoli, 1786) as the valid scientific name. Furnestin & Vincent (1958) considered that *A. fallax* var. *lacustri* could be a hybrid between *A.alosa* and *A. fallax.*

Alosa fallax killarnensis (Regan, 1916)

Alosa fallax killarnensis (Regan, 1916): Trewavas, 1938,(150):110-111; Gibson,1956,12:109; Wheeler,1969a:129; Maitland, 1979:241; Whitehead, 1985: 199.

Kottelat (1997) suggested reclassifying *Alosa fallax killarnensis* (Regan, 1916) as a separate species and proposed *Alosa killarnensis* Regan, 1916 as the valid scientific name.

> *Alosa finta killarnensis* Regan 1916, 18(103):9; Went, 1953, 11(1):10.

1.2 Taxonomy

1.2.1 Affinities

The shads belong to the subdivision Clupeomorpha. The clupeomorphs are characterised by having ducts running anteriorly from the swim baldder into the skull (see section 1.3.2.7) and sharp boney scutes along their ventral surface.

1.2.1.1 Suprageneric (Nelson, 1994).

Kingdom:	Animalia
Phylum:	Chordata
Subphylum:	Vertebrata (Craniata)
Superclass:	Gnathostomata
Grade:	Teleostomi
Class:	Actinopterygii
Subclass:	Neopterygii

Division: Teleostei
Subdivision: Clupeomorpha
Order: Clupeiformes
Suborder: Clupeoidei
Family: Clupeidae
Subfamily: Alosinae
Genus: *Alosa* Linck

1.2.1.2 Generic (Eschmeyer, 1998)

Alosa Linck, 1790: 6(3) 35; Cuvier, 1829:319

- **Diagnosis** (Svetovidov, 1952; Hoestlandt, 1991; Whitehead, 1985)

The body is tapered at either end, slightly compressed laterally, with the mature fish reaching a maximum length in the region of 830 mm (L_t). The mouth is terminal and the upper jaw bears a prominent median notch on the premaxillae in which the median symphysis of the lower jaw rests (Figure 1.1). The eyelids are well developed and cover much of the anterior and posterior part of the eye (Figure 1.1). The body is covered by cycloid scales, which form a line of scutes that runs along the entire ventral surface. There are elongated scales (alae) present at the base of the caudal fin (Figure 1.1). One or more black spots are present on the side of the body behind the operculum. The opercular bone bears distinct radial striations: canals with pored sensory organs. The number of gill rakers on the first gill arch ranges from 30 to 180, and the number of vertebrae from 43 to 59. Pelvic fins have one unbranched and eight to nine branched (i 8-9) fin rays. The bifurcating ducts of the swim bladder end in two vesicles within bullae of the prootic and pterotic bones, the prootic bulla being the larger of the two.

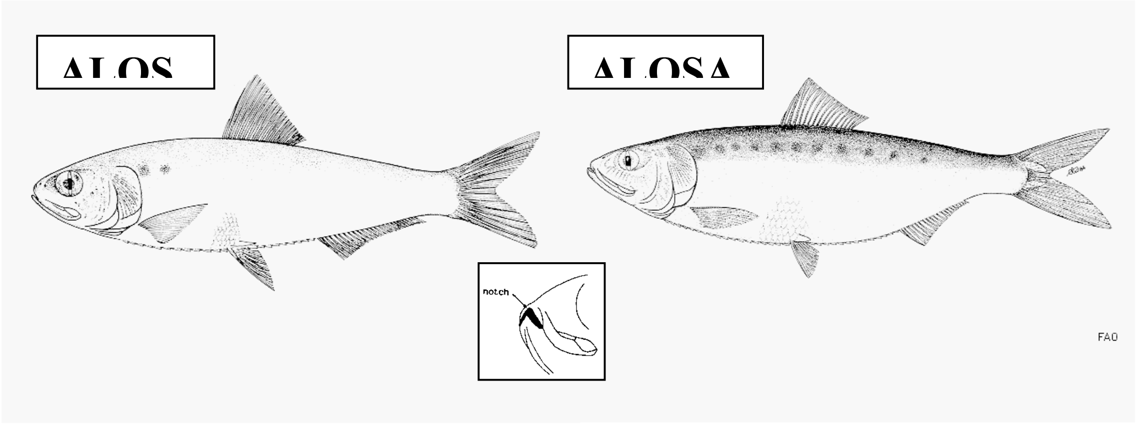


Figure 1.1: *Alosa alosa* and *Alosa fallax*; reproduced with permission of FAO (www.fishbase.org). Insert, showing the distinct notch into which the symphysis of the lower jaw fits (Whitehead, 1985).

1.2.1.3 Specific

The number of gill rakers on the first gill arch and geographical location have both been used to identify species and sub-species (Quignard & Kartas, 1977). In the Eastern Atlantic and Mediterranean four species of *Alosa* have been recognised; *Alosa alosa*

(Linnaeus, 1758), *Alosa fallax* (Lacépède, 1803), *Alosa macedonica* (Vinciguerra, 1921) and *Alosa caspia* (Eichwald, 1838) (Whitehead, 1985; Hoestlandt, 1991). No subspecies have been reported for *A. alosa* or for *A. macedonica*, while for *A. fallax* Quignard & Douchement (1991e) reported six subspecies:

Alosa fallax fallax (Lacépède, 1803)
Alosa fallax rhodanensis (Roule, 1924).
Alosa fallax nilotica (Geoffroy Saint-Hilaire, 1808)
Alosa fallax algeriensis (Regan, 1916)
Alosa fallax lacustris (Fatio, 1890)
Alosa fallax killarnensis (Regan, 1916)

For *A.caspia*, one subspecies, *Alosa caspia vistonica* Economidis & Sinis, 1986 has been reported from Lake Vistonis in Greece.

- Specific diagnosis

Key to adult alosoids from the Eastern Atlantic and Mediterranean (Hoestlandt, 1991).

1. Upper jaw with a median notch; the symphysis of the lower jaw rests in the notch. The last two fin rays on the anal fin are the same length as the others…………………………………………………………………..…...2

2. Teeth present on the palatines. Lakes Volvi or Vistonis, Greece………………...…………………………………………………….....3
   Teeth absent on palatines. Watersheds of the North and Baltic Seas, the Atlantic Ocean and the Mediterranean…..…………………………………………….4

3. Poorly developed teeth on the vomer and palatines. Lake Vistonis, Greece ……………………………… *Alosa caspia vistonica* Economidis & Sinis, 1986.
   Well developed teeth on the vomer and palatines. Lake Volvi, Greece ………… ……………………………..………..*Alosa macedonica* (Vinciguerra, 1921).

4. Not less than 85 gill rakers on the first gill arch, gill rakers longer than branchial filaments………………………………………..... *Alosa alosa* (Linnaeus, 1758)
   Not more than 80 gill rakers on the first gill arch, gill rakers approximately the same length as the branchial filaments………………………………………5

5. Between 40 and 60 gill rakers on first gill arch, North Africa ………… …….…………………..………………*Alosa fallax algeriensis* (Regan, 1916)
   Between 38 and 72 gill rakers on first gill arch, lakes of Italy and Sardinia ………………...……………………….....*Alosa fallax lacustris* (Fatio, 1890)
   Between 43 and 53 gill rakers on first gill arch, Lough Leane, Ireland……..… ………………………….…………..*Alosa fallax killarnensis* (Regan, 1916)
   Between 30 and 49 gill rakers on first gill arch, North West Mediterranean …. ………………………………………..*Alosa fallax rhodanensis* (Roule, 1924)
   Between 28 and 40 gill rakers on first gill arch, Adriatic and Eastern Mediterranean…..………... *Alosa fallax nilotica* (Geoffroy Saint-Hilaire, 1808)
   Between 28 and 60 gill rakers on first gill arch, Atlantic Ocean.………………... ……………………….……… …..*Alosa fallax fallax* (Lacépède, 1803)

1.2.2 Taxonomic status

Kottelat (1997) critically reviewed the systematics of European freshwater fishes and concluded that some of the subspecies identified by Quignard & Douchement (1991e) should be classified as species. This was on the basis of differences in morphology, habit, life history and ontogeny. Kottelat (1997) suggested that the following should be reclassified: *Alosa fallax algeriensis* (Regan, 1916), *Alosa fallax killarnensis* (Regan, 1916), *Alosa fallax lacustris* (Fatio, 1890) and *Alosa caspia vistonica* Economidis & Sinis, 1986 (see section 1.1.3). More recently, Bianco (2002) suggested reclassifying *Alosa fallax algeriensis, Alosa fallax lacustris, Alosa fallax nilotica* and *Alosa fallax rhodanensis* as *Alosa agone* (Scopoli, 1786), effectively only one taxon being recognised in the Mediterranean area.

It is recognised that the status of various alosoids remains uncertain. As such, for the purpose of this synopsis, it is proposed to follow the classification set out by Hoestlandt (1991) and by Quignard & Douchement (1991e), with the exception that the landlocked populations of Sardinia are classified as *Alosa fallax lacustris* as suggested by Cottiglia (1963b, 1968, 1969 (1970)).

The taxonomic status is further complicated by the occurrence of hybrids mainly between *Alosa alosa* and *Alosa fallax fallax*, which appear to be fertile (Alexandrino & Boisneau, 2000). The taxonomic problem of hybrids has been discussed in detail by Sabatié *et al*. (2000), but see also section 2.3.

1.2.3 Subspecies

See sections 1.2.1.3 and 1.2.2.

1.2.3.1 Standard, common names and vernacular names

A list of the standard and more commonly used names is presented in Table 1.1. Details of vernacular names used can be found in Farran (1946) for Ireland, Maitland & Cambell (1992) for Britain, Taverny (1991a) for France, Tortonese (1970) for Italy and at http://www.fishbase.org.

Table 1.1: Standard, common and vernacular names of European alosoids

Country	*Alosa alosa*	*Alosa fallax fallax*	*Alosa fallax rhodanensis*	*Alosa fallax nilotica*	*Alosa fallax algeriensis*	*Alosa fallax lacustris*	*Alosa fallax killarnensis*
Norway	Majfisk	Stamsillen					
Sweden	Majfisken	Staksillen					
Finland	Pilkkusilli	Täpläsilli					
Russia	Aloza, Maiskaya ryba	Atlanticheskaya finta		Sredizemnom-orskaya finta			
Lithuania		Perpele					
Poland	Aloza	Savetha, Parposz					
Germany	Maifisch	Finte					
Denmark	Majsild	Stavsild					
Netherlands	Groote meivisch, Elft.	Meivisch, Fint					
Luxembourg	Péchon de mai	Péchon de mai					
Belgium	Abèye, Alôïe	Abèye, Alôïe					
United Kingdom	Allis shad	Twaite shad					
Ireland	Allis shad	Twaite shad					Goureen
France	Alose vraie	Alose feinte	Alose feinte du Rhône				
Spain	Sábalo común	Saboga	Saboga				
Portugal	Sável	Savelha, Fint					
Morocco	Chebel	Chbouk, Ouarsa					
Algeria					Chbouka		
Tunisia					Chbouka		
Sardinia			Cheppie			Agoni	
Italy			Alosa, Cheppia	Alosa, Cheppia		Agone	
Yugoslavia				Lojka, Kubla, Cepa			
Albania				Lloca, Kubla		Kubla ligenore	
Greece				Sardelomana			
Turkey				Tirsi baligi			
Egypt					Renget El Sabawgha – sardine, Sardeena, Sarboura		

1.3 Morphology

1.3.1 External morphology

Alosa alosa (Linnaeus, 1758) (Wheeler, 1969a; Quignard & Douchement, 1991a; Alexandrino, 1996a).

Gill rakers on first gill arch number 80 to 155, with between 55 and 110 on the lower part of first gill arch (ceratobranchial). Each gill raker is densely covered with lateral spines (Figure 1.2). Total vertebrae number 53 to 58. Number of finrays; anal iii-iv18-24; dorsal iv-vi 13-18; pelvic i 8-9 (10); pectoral i 13-16. The number of pre-pelvic and post pelvic ventral scutes range from 19 to 25 and 13 to 17, respectively, with the total ranging from 33 to 40 scutes. The number of longitudinal scales along the midline varies between 60 and 90 and the number of transverse scale rows between 20 and 26. The length of the head (tip of snout to hind border of gill cover / operculae) as a percentage of total length ranges from 16.27 to 22.31 % (mean values), snout length ranges from 3.73 to 4.57%, and post-orbital distance ranges from 9.55 to 12.89%. The mean pre-dorsal distance varies between 37.21 and 41.63 %, pre-pelvic between 38.56 and 43.79%, and pre-anal from 57.29 to 66.18 % of total length. Maximum size reported 830 mm (L_t), by Sabatié (1993), see also section on growth (3.4.3). The back is deep blue in colour with the flanks golden-silvery (Wheeler, 1978), usually with one dark spot posterior to the gill cover, sometimes absent, occasionally more.

(a) *A. fallax* (less than 60 rakers) (b) *A. alosa* (more than 90 rakers)

Figure 1.2: First gill arch appearance and approximate number of gill rakers for (a) *A. fallax* and (b) *A. alosa;* from Quignard & Douchement (1991a&b).

Alosa fallax fallax (Lacépède, 1803) (Svetovidov, 1952; Wheeler, 1969; Quignard & Douchement, 1991b; O'Maoileidigh, *et al.,* 1988; Alexandrino, 1996a).

The number of gill rakers on the first gill arch range from 35 to 60, with between 24 and 32 on the lower part of the arch. The gill rakers have few lateral spines and are approximately the same length as the gill filaments (Figure 1.2). The total number of vertebrae varies from 49 to 59. Number of finrays; anal iii-iv 16-22; dorsal iv-vi 12-16;

pelvic i 8 and between 15 to 17 finrays (total) in the pectoral fins. The number of pre-pelvic and post pelvic ventral scutes range from 18 to 23 and 12 to 18, respectively, with the total ranging from 32 to 41 scutes. The number of longitudinal scales along the midline varies between 54 and 71 and the number of transverse scale rows between 16 and 20. A summary of morphometric characteristics is presented in Table 1.2.

Table 1.2: Summary of some morphometric characteristics of *Alosa fallax fallax* (Douchement, 1981; O'Maoileidigh, *et al.,* 1988; Alexandrino, 1996a; Doherty & McCarthy, 2002).

Morphometric characteristic	Percent of total length	Morphometric characteristic	Percent of total length
Length of snout	3.20- 4.56[1]	Length of pelvic fin	8.73[1]-8.95[1]
Post-orbital length	9.45-12.03[1]	Standard length	79.95[1]-81.38[1]
Head length	16.61[1]-19.87[1]	Fork Length	86.11[1]
Head width @ eyes	5.43[1]	Height of caudal peduncle	6.46[1]-6.67[1]
Head width @ nostrils	4.41[1]	Width of caudal peduncle	3.34[1]
Gape	7.77[1]	Body depth @ pectoral	19.78[1]
Eye diameter	3.19[1]	Pre-pelvic length	38.04[1]-40.43
Base of dorsal fin	11.27[1]-12.18[1]	Pre-pectoral length	16.86-18.69[1]
Base of anal fin	12.32[1]-13.30[1]	Pre-dorsal length	36.92[1]-39.25[1]
Length of pectoral fin	12.65[1]-13.47[1]	Pre-anal length	57.19[1]-60.85[1]

[1] Relationship with total length based on mean values.

Interorbital distance varies from 18.5 to 24.2%, with a mean of 20.9%, of the head length. The diameter of the eye ranges from 15.2 to 21.2%, with a mean of 18.5%, of head length. Maximum size attained is estimated to be 568 mm ($L_{t,}$), from the Nyamunas river, Lithuania (Manyukas, 1989) [see Section 3.4.3]. The back is deep blue in colour with silvery flanks. There is usually a row of dark blotches posterior to the gill cover, sometimes more than one row, and occasionally just a single blotch behind the operculum.

Alosa fallax rhodanensis (Roule, 1924) (Douchement, 1981; Quignard & Douchement, 1991c; Le Corre *et al.,* 1997).

Gill rakers on the first gill arch number 30 to 49, with between 19 and 31 on the lower part of first gill arch. Total number of vertebrae 54 to 59. Number of finrays; anal iii-iv17-21; dorsal iii-iv 13-16; pelvic i 8-9 and pectoral i 13-15. The number of pre-pelvic and post pelvic ventral scutes range from 15 to 24 and 10 to 17, respectively, with the total ranging from 30 to 40 scutes. The number of longitudinal scales along the midline varies between 54-64 and the number of transverse scale rows between 16 and 20. The length of the head (tip of snout to hind border of gill cover / operculae) as a percentage of total length is 19.46% (mean values). The mean pre-dorsal distance varied between 38.24 and 39.09%, pre-pelvic between 39.83 and 39.87% and pre-anal from 59.38 to 59.66% of total length. The maximum size reported is 676 mm (L_t) [see section 3.4.3].

Alosa fallax nilotica (Geoffroy Saint-Hilaire, 1808) (Vukovic, 1961a; Vitali *et al.,*1983; Serventi, *et al.,* 1990; Quignard & Douchement, 1991d).

The number of gill rakers on first gill arch varies between 28 and 42, with between 17 and 26 on the lower part of the first gill arch. Total number of vertebrae 47 to 60. Number of finrays; anal i-ii 20-22; dorsal ii-iii 16-17; pelvic (total) 9-10 and pectoral (total) 15-18. The number of pre-pelvic and post pelvic ventral scutes range from 19 to 24 and 13 to 20, respectively, with the total ranging from 32 to 39 scutes. The number of longitudinal scales along the midline varied between 55 and 65 and the number of transverse scale rows between 16 and 20. The maximum size reported is 560 mm (L_t) [see section 3.4.3].

[The morphometric and meristic characteristics of the landlocked population of *Alosa* in Lake Skadar have been described by Vukovic (1961a) and Rakaj & Crivelli (2001). It has been assumed, mainly from their size that the that the majority of the sample reported by Vukovic (1961a) consisted of the anadromous *Alosa fallax nilotica.* The sample described by Rakaj & Crivelli (2001) was confined to the non-migatory species, which the authors classified as *Alosa agone* after Kottelat (1997) and which for the purpose of this synopsis has been referred to as *Alosa fallax lacustris*.]

Alosa fallax algeriensis (Regan, 1916) (Kartas, **1981**, 1991)

There are between 40 and 60 gill rakers on the first gill arch with 25 to 38 on the lower portion of the arch. The total number of vertebrae ranges from 53 to 57. Total number of finrays; anal 20 to 25; dorsal 18 to 22 and pelvic 9. The number of pre and post-ventral scutes range from19 to 23 and 13 to 16, respectively, with the total varying from 33 to 39. Head length and pre-dorsal distance as a percentage of **total** length vary between 19.82 and 20.35% and 38.45 and 38.65% (based on mean values), respectively.

Alosa fallax lacustris (Fatio, 1890) (Barbieri, 1907b; **Florin, 1949**; Ferrero, 1951; Cottiglia, 1963b, 1969 (1970); Quignard & Douchement, 1991f).

There are between 38 and 72 gill rakers on the first gill arch with 21 to 59 on the lower portion of the arch. The total number of vertebrae is 59. Total number of finrays; anal i-ii 17-23; dorsal ii-iii 13-18 and pectoral (total) 14 to 18. The number of pre and post-ventral scutes range from 23 to 24 and 13 to 17, respectively, with the total varying from 36 to 41. The number of longitudinal scales along the midline varies between 50 and 70 and the number of transverse scale rows between 17 and 20. Head length and pre-dorsal distance as a percentage of fork length vary between 21.1 and 24.4% and 41.8 and 47.2%, respectively. Maximum size reported is in the region of 500 mm (L_t) [see section 3.4.3].

The morphometric characteristics of landlocked *Alosa fallax lacustris* from Lake Skadar, Yugoslavia are presented in Table 1.3. The maximum size reported is 330 mm and 340 g (Rakaj & Crivelli, 2001).

Table 1.3: Morphometric characteristics (Mean ± SE) of landlocked *Alosa fallax lacustris* from Lake Skadar, Yugoslavia, n = 27 (Rakaj & Crivelli, 2001).

Morphometric characteristic	**Percent of standard length**	**Morphometric characteristic**	**Percent of standard length**
Eye diameter	5.5 ± 0.12	Pre-dorsal length	49.2 ± 0.06
Head length	24.4 ± 0.15	Pre-ventral length	49.0 ± 0.31
Greatest body depth	26.6 ± 0.31	Snout-Anal distance	72.5 ± 0.33
Smallest body depth	8.60 ± 0.12	Eye diam./Head length	22.5 ± 0.44

Alosa fallax killarnensis (Regan, 1916) (Regan, 1916; Trewavas, 1938; O'Maoileidigh, *et al.,* 1988).

There are between 43 and 53 gill rakers on the first gill arch with 29 to 37 on the lower portion of the arch. The total number of vertebrae ranges from 53 to 57. Total number of finrays; anal 19-24; dorsal 17-21; pectoral 15-17 and pelvic 8-9. The number of pre and post-ventral scutes range from 21 to 22 and 15 to 16, respectively. Total number of vertebrae range from 53 to 57 with a mean (±95%CI) of 55.38 ± 0.17. The number of longitudinal scales along the midline varies between 55 and 60 and the number of transverse scale rows between 16 and 20. A summary of morphometric characteristics are presented in Table 1.4.

Table 1.4 Morphometric characteristics of *Alosa fallax killarnensis* from Lough Leane, Ireland (O'Maoileidigh, *et al.,* 1988). Relationship with total length is based on mean values.

Morphometric characteristic	**Percent of total length**	**Morphometric characteristic**	**Percent of total length**
Length of snout	3.8	Standard length	80.3
Post-orbital length	10.3	Fork Length	85.6
Head length	19.7	Width of caudal peduncle	6.9
Base of dorsal fin	12.1	Pre-pelvic length	37.6
Base of anal fin	11.5	Pre-pectoral length	17.6
Length of pectoral fin	13.8	Pre-dorsal length	37.3
Length of pelvic fin	9.5	Pre-anal length	58.7

Maximum length (total) attained is in the region of 240 mm. There is usually at least one row of dark blotches posterior to the gill cover.

1.3.1.1 Meristic and morphometric variation

The number of gill rakers on the first gill arch effectively separates the two species (Sabatié *et al.,* 2000), with fish of intermediate number of gillrakers indicating hybrids. Douchement (1981) and Quignard & Douchement (1991a) report *Alosa alosa* from the rivers Aude and Rhône (France) with mean gill raker counts of *c.* 70. This number is similar to that reported by Boisneau *et al.,* (1992) and Sabatié (1993) for hybrids from the rivers Loire (France) and Sebou (Morocco), respectively (Figures 1.3 & 1.4). This may indicate that these groups of fish are hybrids between *Alosa alosa* and *Alosa fallax rhodanensis*. The discriminatory ability of other meristic (number of anal and dorsal fin rays, pre and post-pelvic scutes and vertebrae) or morphometric (index of head, pre-dorsal, pre-pectoral and pre-anal length) characters to separate *A. alosa* from *A. fallax* is low (Sabatié *et al.,* 2000). However, significant differences between the two species in meristic characters, other than the number of gill rakers, and morphometric characters do exist within certain river systems and these have been summarised by Sabatié *et al.* (2000).

Significant differences have been reported between cohorts and between the sexes (Sabatié *et al*., 2000), details of the latter are presented in section 3.1.1 (sexual differentiation / dimorphism). Differences between year classes were observed for *A. alosa* from the Loire (Boisneau, 1990) and for *A. fallax* from the Sebou (Sabatié, 1993). This was not the case for *A. fallax* from the Loire (Boisneau, 1990) nor for *A. fallax rhodanensis* age 1 from the rivers Aude and Rhône (Douchement, 1981). Sabatié *et al.* (2000) concluded that as the variability was low and not systematic, the combining of samples was justified.

Sabatié (1993) examined the difference between juvenile (L_t = 35-120 mm) and adults from the River Sebou. Juvenile *A. alosa* and *A. fallax* had significantly more dorsal and anal fin rays and post pelvic scutes. Douchement (1981) found no significant difference in the meristic characteristics of immature *A. alosa* and *A. fallax* (L_t = 150-220 mm) and adults from the River Adour.

The variation in certain morphometric indices and meristic characteristics are summarised in Tables 1.5 – 1.9. Where possible the morphometric indices are presented in terms of percentage total length; for the Sardinian populations of *Alosa fallax* (Cottiglia, 1963 a&b; 1969) the indices are in relation to fork length. Significant differences in meristic characteristics and morphometric indices between populations have been reported by Douchement (1981), Sabatié (1993), Alexandrino (1996a) and by Sabatié *et al.* (2000).

Certain of the meristic characteristics vary with size (Sabatié, 1993), most notably the number of gill rakers on the first gill arch (Tables 1.10 & 1.11).

A number of landlocked populations of *Alosa fallax*, in particular those from Italy and Sardinia, have a greater number of gill rakers on the first gill arch compared with their anadromous conspecifics (Tables 1.6 & 1.9). A similar pattern is also evident in the Irish populations of *Alosa fallax*. The number of gill rakers on the lower half of the first gill arch is 32.2 (± 0.14) for the lacustrine population in Lough Leane compared with 25.5 (± 0.12) for the anadromous *A. fallax* from the River Barrow (O'Maoileidigh *et al.,* 1988).

The Mediterranean populations of *A. fallax* from North Africa tend towards the higher end of the range in terms of the number of gill rakers (Table 1.6 & Figure 1.4), while those from the Adriatic are at the lower end, and populations from Southern France intermediate. The Tirso population (Sardinia), though tentatively classified as *Alosa fallax rhodanensis* (Quignard & Douchement, 1991c) would appear to be closer to *Alosa fallax algeriensis* in terms of the number of gill rakers (Figure 1.4).

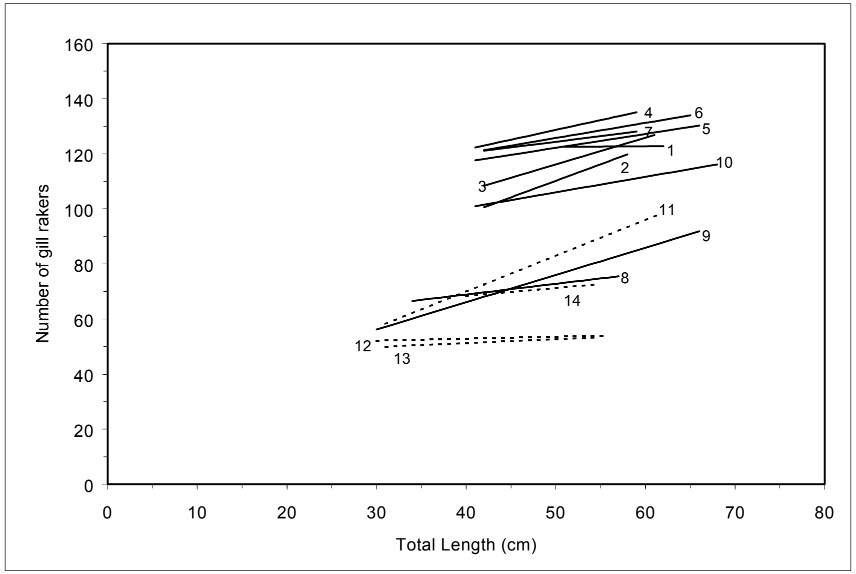


Figure 1.3:

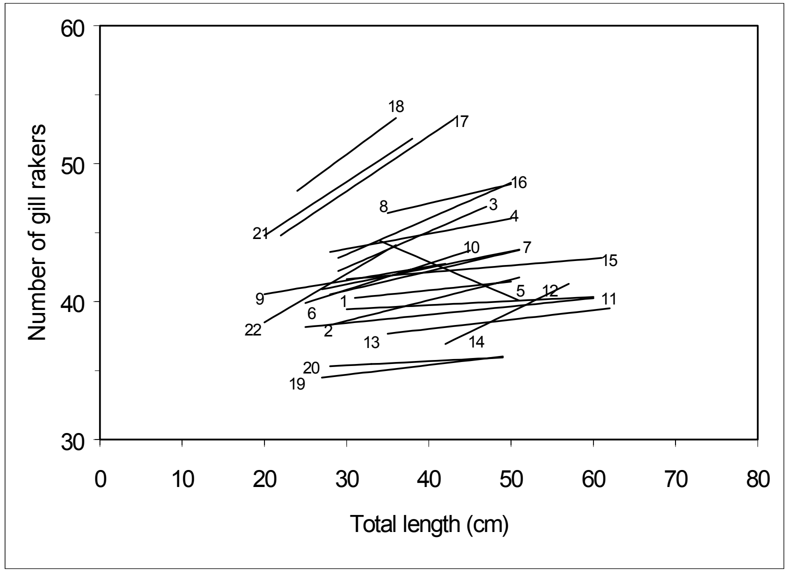


Figure 1.4:

Figure 1.3: The relationship between number of gill rakers on the first gill arch and total length for *Alosa alosa* (1-10, solid line) and *Alosa alosa* x *Alosa fallax* hybrids (11-14, dotted line). 1 = Rhine (Hoek, 1899); 2 = Aulne (Véron, 1999); 3 = Vilaine (Véron, 1999); 4 & 11 = Loire (Douchement, 1981); 5 = Charente (Véron 1999); 6 = Garonne (Douchement, 1981); 7 = Adour (Douchement, 1981); 8 & 12 = Aude (Douchement, 1981); 9 & 13 = Rhône (Douchement, 1981); 10 & 14 = Sebou (Sabatié, 1993).

Figure 1.4 The relationship between number of gill rakers on the first gill arch and total length for *Alosa fallax*;

Anadromous populations: *A. fallax fallax*: 1 = Rhine (Hoek, 1899); 2 = Hass (1965); 3 = Severn (Aprahamian, 1982); 4 = Loire (Douchement, 1981); 5 = Charente (Véron, 1999); 6 = Garonne (Quignard & Kartas, 1977); 7 = Garonne (Douchement, 1981); 8 = Adour (Douchement, 1981); 9 = Loukos (Sabatié, 1993); 10 = Sebou (Sabatié, 1993); *A. fallax rhodanensis*: 11 = Rhône (Quignard & Kartas, 1977); 12 = Rhône (Douchement, 1981); 13 = Rhône (Le Corre, *et al.,* 1997); 14 = Aude (Quignard & Douchement, 1991c); 15 = Aude (Douchement, 1981); 16 = Tirso (Quignard & Douchement, 1991c); *A. fallax algeriensis*: 17 = Miliane (Quignard & Kartas, 1977); 18 = Oubeira (Quignard & Kartas, 1977);

Landlocked populations: *A.fallax nilotica*: 19 = Bacin (Vukovic, 1961a); 20 = Skadar (Vukovic, 1961a); *A. fallax algeriensis*: 21 = Ischkeul (Quignard & Kartas, 1977); *A. fallax*: 22 = Sidi Mohamed Ben Abdullah (Sabatié, 1993).

Table 1.5: Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various populations of *Alosa alosa*.

River (Reference)	Snout length	Post orbital	Head length	Pre dorsal	Pre pectoral	Pre pelvic	Pre anal	Gill rakers	Dorsal finrays	Anal finrays	Prepelvic scutes	Postpelvic scutes	Vertebrae
Rhine, Germany (Hoek, 1899)								122.67 (1.63)	17.33 (0.10)	23.11 (0.15)	20.77 (2.75)	16.54 (0.10)	55.37 (0.11)
Aulne, France (Véron, 1999)								112.00 (3.04)	19.20 (0.13)	24.20 (0.32)	21.10 (0.31)	14.47 (0.22)	
Vilaine, France (Véron, 1999)								119.00 (3.23)	18.60 (0.16)	22.90 (0.35)	20.20 (0.28)	14.80 (0.11)	
Loire, France (Douchement, 1981)			19.42 (0.04)	38.14 (0.06)		38.77 (0.08)	58.05 (0.11)	129.30 (0.62)	19.95 (0.06)	24.40 (0.08)	21.35 (0.06)	14.93 (0.05)	55.84 (0.06)
Loire, France [1] (Mennesson-Boisneau & Boisneau, 1990)			18.97 (0.03)	37.68 (0.06)		38.65 (0.05)	58.59 (0.07)	122.10 (0.39)	17.90 (0.02)	21.60 (0.03)	21.20 (0.02)	14.10 (0.03)	55.7 (0.04)
Charente, France (Veron, 1999)								125.00 (1.32)	18.70 (0.11)	23.50 (0.16)	21.40 (0.11)	14.20 (0.09)	
Garonne, France (Douchement, 1981)			19.37 (0.04)	38.27 (0.09)		38.56 (0.08)	58.17 (0.13)	127.49 (0.52)	19.22 (0.06)	24.34 (0.09)	21.13 (0.05)	14.36 (0.06)	55.90 (0.06)
Adour, France (Douchement, 1981)			19.32 (0.05)	38.52 (0.08)		38.87 (0.08)	58.52 (0.10)	123.85 (0.41)	20.16 (0.05)	24.88 (0.07)	21.77 (0.05)	15.28 (0.04)	56.17 (0.04)
Lima, Portugal (Alexandrino, 1996a)	4.10 (0.09)	10.18 (0.10)	17.15 (0.15)	37.21 (0.22)	17.52 (0.16)	38.98 (0.40)	59.56 (0.33)	126.02 (1.77)	19.14 (0.11)	25.02 (0.17)	22.15 (0.15)	13.92 (0.18)	
Douro, Portugal (Eiras, 1980)								125.66	19.38 (0.06)	23.20 (0.06)	22.61 (0.08)	14.78 (0.05)	
Mondego, Portugal (Alexandrino, 1996a)	3.73 (0.15)	9.55 (0.19)	16.27 (0.30)	37.25 (0.18)	16.32 (0.33)	38.56 (1.10)	57.29 (1.12)	126.07 (2.96)	18.50 (0.34)	24.47 (0.35)	22.80 (0.18)	14.00 (0.29)	
Aude, France (Douchement, 1981)								72.30 (1.19)	20.19 (0.05)	23.74 (0.08)	22.14 (0.05)	15.61 (0.05)	56.71 (0.05)
Rhône, France (Douchement, 1981)								69.85 (2.71)	20.39 (0.11)	23.69 (0.12)	22.10 (0.08)	15.88 (0.07)	57.75 (0.06)
Sebou, Morocco (Sabatié, 1993)			18.00 (0.03)	36.86 (0.05)	17.22 (0.06)	37.02 (0.09)	58.81 (0.12)	109.90 (0.39)	19.25 (0.04)	23.68 (0.06)	21.26 (0.97)	14.54 (0.07)	55.48 (0.16)

1 Fork length (mm) converted to total length using $L_t = 1.1325 L_f + 2.6556$ (Douchement, 1981)

Table 1.6: Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various populations of *Alosa fallax fallax.*

River (Reference)	Snout length	Post orbital	Head length	Pre dorsal	Pre pectoral	Pre pelvic	Pre Anal	Gill rakers	Dorsal finrays	Anal finrays	Prepelvic scutes	Postpelvic scutes	Vertebrae
Rhine, Germany (Hoek, 1899)								40.67 (0.63)	17.11 (0.07)	21.26 (0.11)	20.48 (0.08)	16.30 (0.09)	54.85 (0.08)
Barrow, Ireland (O'Maoileidigh *et al.,* 1988, O'Maoileidigh, 1990)	3.20	10.66	19.20	36.81	17.70	37.43	57.84	40.53 (0.27)	19.25 (0.10)	22.14 (0.12)			55.87 (0.12)
Barrow, Ireland (Doherty& McCarthy,2002)	3.31^2	12.03^2	19.88^2	39.25^2		39.58^2	60.85^2	42.10 (0.20)	17.80 (0.10)	20.60 (0.10)			
Loire, France Douchement, 1981)			19.46 (0.05)	38.46 (0.09)		40.02 (0.10)	59.75 (0.26)	44.96 (0.14)	19.20 (0.06)	21.56 (0.07)	21.45 (0.06)	15.58 (0.05)	56.30 (0.07)
Loire, France ^{1} (Mennesson-Boisneau & Boisneau, 1990)			19.10 (0.13)	38.19 (0.20)		39.25 (0.20)	60.28 (0.29)	48.50 (0.66)	17.6 (0.09)	20.10 (0.13)	20.80 (0.09)	17.30 (0.12)	55.1 (0.18)
Charente, France (Veron, 1999)								42.00 (0.78)	19.10 (0.10)	20.70 (0.21)	20.30 (0.17)	14.80 (0.09)	
Garonne, France (Quignard & Kartas, 1977)									18.65 (0.06)	21.41 (0.10)	20.30 (0.08)	15.04 (0.08)	56.01 (0.13)
Garonne, France (Douchement, 1981)			19.34 (0.06)	38.40 (0.10)		40.43 (0.09)	60.56 (0.12)	42.44 (0.10)	18.82 (0.05)	21.51 (0.07)	20.61 (0.06)	14.98 (0.05)	55.90 (0.09)
Adour, France Douchement, 1981)			19.08 (0.07)	39.15 (0.09)		40.39 (0.14)	60.09 (0.05)	47.51 (0.36)	19.18 (0.08)	22.54 (0.10)	21.28 (0.10)	15.03 (0.10)	56.48 (0.08)
Lima, Portugal (Alexandrino, 1996a)	4.19 (0.12)	9.74 (0.15)	16.95 (0.23)	36.92 (0.41)	17.56 (0.25)	38.04 (0.39)	57.19 (1.09)	52.63 (1.35)	18.16 (0.12)	21.78 (0.22)	21.64 (0.18)	14.67 (0.25)	
Douro, Portugal (Eiras, 1980)								42.17 (0.22)	17.66 (0.06)	20.95 (0.18)	21.35 (0.08)	14.70 (0.12)	54.93 (0.20)
Mondego, Portugal (Alexandrino, 1996a)	4.56 (0.17)	10.68 (0.10)	18.31 (0.24)	38.17 (0.18)	18.69 (0.20)	39.00 (0.14)	59.39 (0.18)	46.41 (0.46)	18.53 (0.10)	21.19 (0.15)	22.12 (0.13)	14.96 (0.10)	
Tejo, Portugal (Alexandrino, 1996a)	4.28 (0.09)	10.22 (0.05)	18.10 (0.12)	38.42 (0.12)	18.03 (0.13)	39.42 (0.11)	60.25 (0.23)	41.32 (0.27)	18.54 (0.07)	22.31 (0.12)	22.45 (0.10)	14.80 (0.12)	
Guadiana, Portugal (Eiras, 1980)								41.66 (0.14)	16.52 (0.08)	20.48 (0.12)	21.42 (0.08)	13.84 (0.15)	54.73 (0.13)
Guadiana, Portugal (Alexandrino, 1996a)	3.47 (0.09)	9.45 (0.15)	16.61 (0.26)	37.53 (0.39)	16.86 (0.26)	38.23 (0.31)	60.19 (0.46)	41.91 (0.20)	18.81 (0.09)	21.42 (0.16)	21.36 (0.13)	14.17 (0.13)	
Loukos, Morocco (Sabatié, 1993)			18.75 (0.08)	36.62 (0.10)	18.14 (0.21)		58.58 (0.19)	41.97 (0.25)	19.18 (0.10)	21.18 (0.14)	20.54 (0.13)		55.61 (0.17)
Sebou, Morocco (Sabatié, 1993)			18.92 (0.04)	34.91 (0.07)	17.57 (0.11)	37.30 (0.11)	57.87 (0.13)	41.77 (0.11)	18.00 (0.05)	21.05 (0.06)	21.23 (0.06)	13.72 (0.13)	53.74 (0.11)

[1] Fork length (mm) converted to total length using $L_t = 1.1264\ L_f + 3.5260$ (Douchement, 1981). [2] Based on mean values.

Table 1.7: Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various anadromous populations of *Alosa fallax rhodanensis, A. fallax nilotica* and *A. fallax algeriensis,* values in italics represent morphometric indices as percentage of fork length (M = male; F = female).

River (Reference)	Snout length	Post orbital	Head length	Pre dorsal	Pre pectoral	Pre pelvic	Pre Anal	Gill rakers	Dorsal finrays	Anal finrays	Prepelvic scutes	Postpelvic scutes	Vertebrae
Alosa fallax rhodanensis													
Aude, France (Quignard & Kartas, 1977)									19.24 (0.11)	22.46 (0.13)	20.73 (0.10)	15.71 (0.11)	57.16 (0.08)
Aude, France Douchement, 1981)			19.46 (0.11)	39.09 (0.11)		39.87 (0.10)	59.38 (0.12)	42.32 (0.15)	19.92 (0.05)	23.23 (0.07)	21.88 (0.06)	15.65 (0.05)	56.79 (0.06)
Rhône, France (Quignard & Kartas, 1977)									19.31 (0.06)	22.30 (0.08)	20.59 (0.07)	15.55 (0.08)	57.20 (0.07)
Rhône, France (Douchement, 1981)			19.46 (0.09)	38.24 (0.09)		39.83 (0.10)	59.66 (0.14)	39.85 (0.12)	19.95 (0.07)	23.06 (0.10)	21.92 (0.06)	15.61 (0.06)	56.82 (0.07)
Rhône, France (Le Corre, *et al.,* 1996)			22.1 (M) 21.4 (F)	42.1	22.6 (M) 21.9 (F)	45.3	68.3						
Rhône, France (Le Corre, *et al.,* 1997)								38.38 (0.12)	18.92 (0.04)	21.91 (0.06)	20.97 (0.05)	15.12 (0.05)	
Coghinas, Sardinia (Cottiglia, 1969 (1970))			*22.33* *(0.33)*	*44.00* *(0.36)*		*44.84* *(0.30)*		44.66 (0.79)	18.50 (0.56)	21.50 (0.22)		14.50 (0.22)	
Tirso, Sardinia (Cottiglia, 1963a)			*22.60* *(0.35)*	*43.96* *(0.89)*		*45.94* *(0.81)*		46.68 (0.81)	18.00 (0.22)	22.00 (0.38)		14.18 (0.24)	
Alosa fallax nilotica													
Po, Italy[1] (Serventi, *et al.,* 1990)									19.00 (15-21)	21.00 (18-25)	22.00 (19-24)	15.00 (13-20)	
Neretva, Yugoslavia (Vukovic, 1961a)								35.17 (0.14)	19.25 (0.07)	22.56 (0.10)			56.91 (0.12)
Nile, Egypt (Boulenger, 1907)									19.14 (0.46)	22.43 (0.43)	20.14 (0.26)	14.14 (0.34)	

Table 1.7: (cont)

River (Reference)	Snout length	Post orbital	Head length	Pre dorsal	Pre pectoral	Pre pelvic	Pre Anal	Gill rakers	Dorsal finrays	Anal finrays	Prepelvic scutes	Postpelvic scutes	Vertebrae
Alosa fallax algeriensis													
Miliane & Medjerdah, Tunisia (Kartas, 1981)			19.82 (0.01)	38.47 (0.02)				48.55 (0.08)	19.18 (0.03)	22.59 (0.04)	21.10 (0.04)	14.50 (0.03)	54.96 (0.03)
Oubeira, Algeria (Kartas, 1991)			20.35 (0.08)	38.45 (0.14)				50.91 (0.56)	19.13 (0.10)	22.60 (0.13)	21.23 (0.13)	14.39 (0.10)	55.38 (0.09)

[1] Mode and range

Table 1.8 Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various populations of hybrids of *Alosa alosa x Alosa fallax.*

River (Reference)	Snout length	Post orbital	Head length	Pre dorsal	Pre pectoral	Pre pelvic	Pre Anal	Gill rakers	Dorsal finrays	Anal finrays	Prepelvic scutes	Postpelvic scutes	Vertebrae
Hybrids of *Alosa alosa x Alosa fallax fallax*													
Loire, France Douchement, 1981)									19.79 (0.10)	23.27 (0.17)	21.29 (0.11)	15.46 (0.13)	56.26 (0.10)
Loire, France [1] (Mennesson-Boisneau & Boisneau, 1990)			19.29 (0.10)	37.78 (0.17)		39.01 (0.17)	59.36 (0.22)	75.90 (0.79)	17.80 (0.07)	21.10 (0.07)	21.10 (0.10)	14.10 (0.08)	55.10 (0.17)
Sebou, Morocco (Sabatié, 1993)			18.92 **(0.08)**	35.54 **(0.15)**				70.68 **(0.70)**	18.95 **(0.10)**	22.74 **(0.12)**	21.96 **(0.14)**	13.75 **(0.34)**	56.04 **(0.15)**
Hybrids of *Alosa alosa x Alosa fallax rhodanensis*													
Aude, France (Douchement, 1981)									19.92 (0.05)	23.23 (0.07)	21.88 (0.06)	15.65 (0.05)	56.79 (0.06)
Rhône, France (Douchement, 1981)									19.95 (0.07)	23.06 (0.10)	21.92 (0.06)	15.61 (0.06)	56.82 (0.07)

[1] Fork length (mm) converted to total length using $L_t = 1.1264 L_f + 3.5260$ (Douchement, 1981)

Table 1.9: Mean (SE) morphometric indices (percentage total length) and meristic characteristics of various landlocked populations of *Alosa alosa* and *Alosa fallax,* values in italics represent morphometric indices as percentage of fork length.

River (Reference)	Snout length	Post orbital	Head length	Pre dorsal	Pre pectoral	Pre pelvic	Pre Anal	Gill rakers	Dorsal finrays	Anal finrays	Prepelvic scutes	Postpelvic scutes	Vertebrae
Alosa alosa													
Castelo de Bode, Portugal (Eiras,1981a)								122.40 (4.45)	19.72 (0.09)	22.22 (0.16)	20.97 (0.13)	13.66 (0.12)	56.40 (0.18)
Castelo de Bode, Portugal (Alexandrino, 1996a)	4.57 (0.09)	12.89 (0.11)	22.31 (0.23)	41.63 (0.42)	21.87 (0.20)	43.79 (0.43)	66.18 (0.54)	142.42 (1.47)	19.75 (0.12)	24.42 (0.17)	22.25 (0.25)	14.50 (0.15)	
El Kansera, Morocco (Sabatié, 1993).			19.81 (0.23)	35.92 (0.34)			58.91 (0.43)	78.89 (2.83)	19.44 (0.40)	22.88 (0.42)	21.66 (0.19)		
Alosa fallax													
L. Sidi Mohamed Ben Abdallah, Morocco (Sabatié, 1993)			19.90 (0.13)	33.90 (2.00)	17.40 (0.16)	36.40 (0.19)	61.90 (0.38)	38.44 (0.73)	17.88 (0.23)	21.83 (0.17)	21.16 (0.19)		54.38 (0.49)
Alosa fallax nilotica													
L. Scutari, Yugoslavia (Vukovic, 1961a)								35.81 (0.19)	18.87 (0.03)	21.38 (0.06)			57.20 (0.05)
L. Scutari, Yugoslavia (Rakaj & Crivelli, 2001)									16.90 (0.17)	20.30 (0.21)			
L. Bacin, Yugoslavia (Vukovic, 1961a)								35.06 (0.14)	18.67 (0.04)	22.12 (0.09)			56.75 (0.11)
Alosa fallax algeriensis													
L. Ichkeul, Tunisia (Kartas, 1981)			20.16 (0.03)	38.65 (0.08)				47.03 (0.01)	19.53 (0.06)	22.73 (0.08)	20.96 (0.07)	14.64 (0.08)	55.28 (0.05)
Alosa fallax killarnensis													
L.Leane, Ireland (O'Maoileidigh *et al.,* 1988)	3.78	10.26	19.67	37.27	17.62	37.58	58.68		19.08 (0.07)	21.60 (0.10)			55.38 (0.08)

Table 1.9: (cont)

River (Reference)	Snout length	Post orbital	Head length	Pre dorsal	Pre pectoral	Pre pelvic	Pre Anal	Gill rakers	Dorsal finrays	Anal finrays	Prepelvic scutes	Postpelvic scutes	Vertebrae
Alosa fallax lacustris													
L. Omodeo, Sardinia (Cottiglia, 1963b)			*22.76* *(0.33)*	*42.76* *(0.44)*		*44.96* *(0.41)*		47.90 (1.08)	17.76 (0.27)	21.64 (0.24)		14.22 (0.29)	
L. Medio-Flumendosa, Sardinia (Cottiglia, 1969 (1970))			*21.97* *(0.10)*	*42.83* *(0.19)*		*43.90* *(0.18)*		43.88 (0.26)	18.45 (0.08)	22.01 (0.10)		14.17 (0.09)	
L.Maggiore, Italy (Barbieri, 1907a)			23.16 (0.11)	45.01 (0.16)				48.83 (0.61)	18.14 (0.26)	21.29 (0.19)		15.86 (0.26)	
L.Maggiore, Italy (Ferrero, 1951)			22.10 **(0.50)**	44.70 **(1.12)**		47.50 **(1.48)**		46.60	16[1]	19-20[1]			
L.Lugano, Italy (Barbieri, 1907a)			22.63 (0.13)	43.90 (0.31)				44.38 (1.18)	18.23 (0.28)	21.08 (0.14)		16.23 (0.12)	
L.Como, Italy (Barbieri, 1907a)			23.50 (0.14)	45.57 (0.29)				52.83 (0.62)	18.65 (0.17)	21.22 (0.22)		15.13 (0.11)	
L.Como, Italy (Ferrero, 1951)			22.00 **(0.85)**	44.50 **(0.56)**		46.30 **(0.99)**		54.10	15-18[1]	17-23[1]			
L.Garda, Italy (Barbieri, 1907a)			22.11 (0.10)	44.45 (0.27)				64.50 (0.83)	18.85 (0.15)	20.90 (0.14)		15.50 (0.20)	
L.Garda, Italy (Ferrero, 1951)			21.90 **(0.65)**	44.70 **(0.82)**		47.00 **(0.95)**		61.70	15-16[1]	19-20[1]			
L.Garda, Italy (Oppi & Novello, 1989)								60.33 (0.25)					
L.Iseo, Italy (Ferrero, 1951)			21.80 **(1.13)**	45.20 **(0.76)**		47.20 **(0.92)**		59.60	15-16[1]	19-20[1]			
L.Bracciano, Italy (Ferrero, 1951)			22.00 **(0.62)**	44.40 **(0.92)**		46.70 **(0.37)**		58.90	15-16[1]	18-23[1]			
L.Bolsena, Italy (Ferrero, 1951)			18.00 **(0.43)**	45.60 **(0.75)**		47.00 **(0.76)**		56.00	15-16[1]	18-23[1]			

[1] Range

Table 1.10: Coefficients of the least square regression relating the number of gillrakers on the first gill arch of adult *Alosa* (Br) to total length (L_t) in cm; $Br = a.L_t + b$.

Species / River, Country	a	b	r^2	n	Reference
***Alosa alosa* - Anadromous**					
Rhine, Germany	0.02	121.69	0.01	12	Hoek (1899)
Aulne, France	1.20	50.09	0.21	20	Veron (1999)
Vilaine, France	0.97	67.77	0.17	10	Veron (1999)
Loire, France	0.71	93.19	0.11	114	Douchement (1981)
Charente, France	0.51	96.92	0.05	60	Veron (1999)
Garonne, France	0.55	98.24	0.18	107	Douchement (1981)
Adour, France	0.41	103.89	0.07	138	Douchement (1981)
Aude, France	0.39	53.30	0.66	12	Douchement (1981)
Rhône, France	0.99	26.50	0.55	20	Douchement (1981)
Sebou, Morocco	0.56	77.82	0.18	303	Sabatié (1993)
***Alosa fallax fallax* – Anadromous**					
Elbe, Germany	0.15	34.10	0.37	67	Hass (1965)[2]
Rhine, Germany	0.06	38.33	0.06	15	Hoek (1899)
Severn, UK	0.26	34.67	0.12	189	Aprahamian (1982)
Loire, France	0.11	40.52	0.12	140	Douchement (1981)
Charente, France	-0.26	53.08	0.04	29	Veron (1999)
Garonne, France	0.14	36.60	0.37	118	Quignard & Kartas (1977)
Garonne, France	0.12	37.65	0.15	231	Douchement (1981)
Adour, France	0.14	41.52	0.64	39	Douchement (1981)
Loukos, Morocco	0.10	38.54	0.10	59	Sabatié (1993)
Sebou, Morocco	0.19	35.15	0.17	318	Sabatié (1993)
***Alosa alosa* x *Alosa fallax* Hybrids – Anadromous**					
Loire, France	1.30	17.91	0.31	48	Douchement (1981)
Aude, France	0.07	50.09	0.02	31	Douchement (1981)
Rhône, France	0.14	45.64	0.07	44	Douchement (1981)
Sebou, Morocco	0.29	56.74	0.06	47	Sabatié (1993)
***Alosa fallax rhodanensis* – Anadromous**					
Rhône, France	0.06	36.65	0.41	147	Quignard & Kartas (1977)
Rhône, France	0.03	38.56	<0.01	380	Douchement (1981)
Rhône, France[1]	0.07	35.30	ca. 0.03	346	Le Corre *et al.* (1997a)
Aude, France	0.29	24.75	0.59	48	Quignard & Douchement (1991c)
Aude, France	0.05	40.15	0.01	388	Douchement (1981)
Tirso, Sardinia	0.26	35.62	0.61	50	Cottiglia (1963a)[3]
***Alosa fallax algeriensis* – Anadromous**					
Miliane, Tunisia	0.40	36.00	0.94	179	Quignard & Kartas (1977)
Oubeira, Tunisia	0.44	37.47	0.72	11	Quignard & Kartas (1977)
***Alosa fallax* – Lacustrine**					
L. Sidi Mohamed Ben Abdullah, Morocco	0.35	31.50	0.74	18	Sabatié (1993)
***Alosa fallax algeriensis* – Lacustrine**					
Ischkeul, Tunisia	0.39	36.98	0.77	95	Quignard & Kartas (1977)
***Alosa fallax lacustris* – Lacustrine**					
Bacin, Yugoslavia	0.07	32.60	0.88		Vukovic (1961a)[4]
Skadar, Yugoslavia	0.03	34.48	0.69		Vukovic (1961a)[4]

[1]Fork length converted to total length using Lt = 1.0315 Lf + 41.76 [(adapted from, Douchement (1981)], [2]Cited by Quignard & Douchement (1991b), [3]Cited by Quignard & Douchement (1991c), 4Cited by Quignard & Douchement (1991d).

Table 1.11: Coefficients of the least square regression (Br = a.L_t + b) relating the number of gillrakers on the first gill arch of juvenile anadromous *Alosa* (Br) to total length (L_t) in centimetres.

Species / River, Country	a	b	r^2	n	Reference
Alosa alosa					
Aulne, France	1.58	45.60	0.34	23	Veron (1999)
Adour, France	2.11	47.73	0.53	68	Douchement (1981)
Aude, France	0.98	36.69	0.32	151	Douchement (1981)
Rhône, France	0.95	37.85	0.14	61	Douchement (1981)
Sebou, Morocco	0.21	32.31	0.42	42	Sabatié (1993)
Alosa fallax fallax					
Elbe, Germany	0.50	26.50	0.90	10	Hass (1965)[2]
Severn, UK[1]	0.90	20.70	*c.* 0.88	72	Claridge & Gardner (1978)
Adour, France	0.39	35.85	0.53	23	Douchement (1981)
Sebou, Morocco	-505.9/L_t	38.70	0.22	335	Sabatié (1993)

1 Adult & juvenile stages combined, standard length converted to total length.
2 Cited by Quignard & Douchement (1991b)

For *Alosa fallax*, a latitudinal cline would appear to exist for anadromous populations along the Atlantic seaboard. Populations north of and including the River Mondego (Portugal) have a greater number of gill rakers (42.00-52.63) compared with more southern populations (41.32-41.97), with the exception of the population from the river Rhine (Germany) and the study by O'Maoileidigh (1990) on the Barrow (Ireland) which have 40.67 and 40.53 gill rakers, respectively (Table 1.6). The gill raker number of adult *A.fallax* from the Severn, England, (Mean∀SE = 43.61 ± 0.35 [Claridge & Gardner, 1978]; 44.51 ± 0.23 [Aprahamian, 1982]) follows the latitudinal pattern. Similarly, though there is only one population of *Alosa alosa* south of the River Mondego, the population in the Sebou (Morocco) has a significantly lower number of gill rakers than more northern populations.

1.3.1.2 Scale

The scales of various members of the genus *Alosa* (Figure 1.5) are similar in structure (Hass, 1965; Berg & Grimaldi, 1967; Cassou-Leins & Cassou-Leins, 1981; Douchement, 1981; Eiras, 1981; Aprahamian, 1982; Baglinière & Le Louarne, 1987; Quignard & Douchement, 1991a&b; Mennesson-Boisneau & Baglinière, 1992; Sabatié, 1993; Le Corre *et al.,* 1997). The scales are cycloid and polygonal in shape. The anterior part of the scale can become modified after spawning by the erosion and/or absorption of scale material. The anterior portion of the scale displays a number of distinctive marks:

Annuli - Lines on the surface of the scale, following the contours of the periphery through both the anterior and posterior portions of the scale. They are usually indicated by attenuation or slight waviness of the transverse grooves and striae.

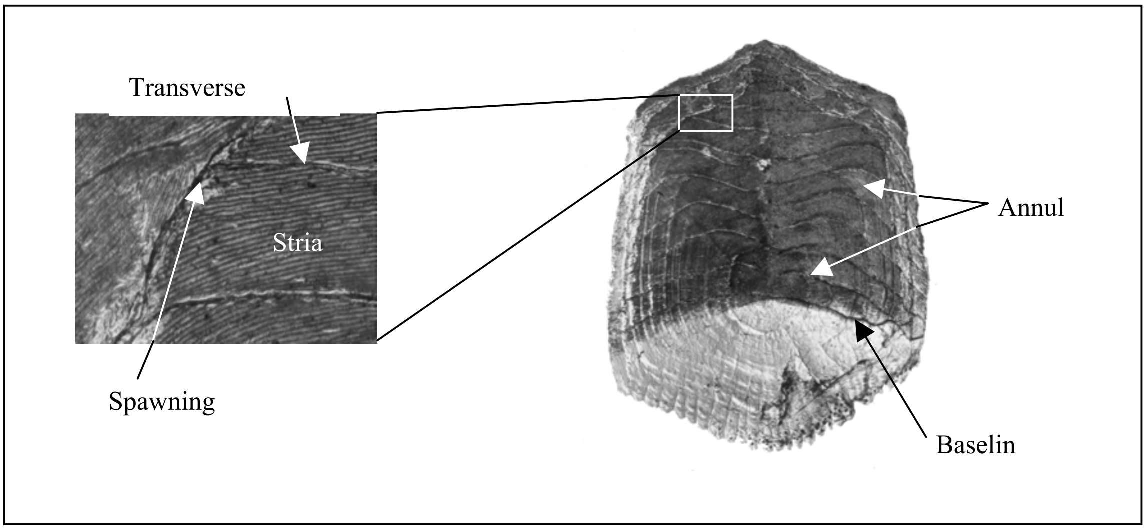


Figure 1.5: Scale from *Alosa fallax fallax*

Spawning mark - Formed during the pre-reproductive period by lateral absorption and/or erosion of the scale followed by rapid regenerative scale growth, leaving a characteristic scar.

Transverse grooves - Characteristic grooves running laterally across the surface of the anterior portion of the scale. The grooves are generally not continuous and may sometimes branch forming two lines.

Stria - Fine ridges covering the anterior portion of the scale; they lie very close together and run laterally across the scale.

Baseline - Taken as that line separating the anterior portion of the scale from the posterior portion.

Supernumary marks / false annuli - They are similar in appearance to true annuli, but are not present on all the scales from an individual. They rarely run around the whole scale and are less accentuated compared to true annuli. In certain populations (e.g. Sebou, Morocco) false annuli form close to the centre and are associated with spates during their first year of life (Baglinière *et al*. 2001; Sabatié & Baglinière, 2001).

For details of the use of scales for age determination see section 4.4.1 and Baglinière *et al*. (2001).

1.3.1.3 Relationship between girth and length

The relationship between girth (mm) and fork length (mm) for *Alosa fallax fallax*, caught in the Severn Estuary at the start of the freshwater phase of their spawning migration, can be described by the least square regression (95% CI in brackets) [Aprahamian, unpubl.]:

Girth = -45.05 (± 33.78) + 0.771 (± 0.093) L_f $\quad$ n = 71; $r^2 = 0.81$.

1.3.1.4 Relationship between various length measurements

To enable comparison with other studies, equations to convert different length measurements are presented in Table 1.12. Throughout this synopsis where there has been a requirement to convert one length measurement to another, the relationships described by Douchement (1981) have been used.

Table 1.12: Parameters for the regression of y = ax + b, all measurements in mm (LS = least square regression, GM = geometric mean regression).

River	Sex	y	x	a	b	n	r^2	Reg.	Reference
Alosa alosa									
Various France	**M & F**	L_f	L_t	**0.8824**	**-2.0989**	**344**	**0.999**	**LS**	**Douchement (1981)**
		L_t	L_f	**1.1325**	**2.6556**	**344**	**0.999**	**LS**	
		L_{st}	L_t	**0.8371**	**-6.0969**	**315**	**0.995**	**LS**	
		L_t	L_{st}	**1.1882**	**9.4799**	**315**	**0.995**	**LS**	
		L_f	L_t	**0.8974**	**-6.6877**	**137**	**0.987**	**LS**	**Véron (1999)**
G-G-D[1] France	**M**	L_t	L_f	**1.0087**	**5.4460**		**0.910**	**LS**	**Martin-Vandembulcke (1999)**
	F	L_t	L_f	**0.9155**	**10.7110**		**0.880**	**LS**	
Adour France	**M**	L_t	L_{st}	**1.1090**	**14.6050**			**LS**	**Prouzet et al. (1994a)**
		L_t	L_f	**1.1000**	**2.2640**			**LS**	
	F	L_t	L_{st}	**1.1290**	**3.9490**			**LS**	
		L_t	L_f	**1.0970**	**2.7500**			**LS**	
Sebou Morocco	**Juv.**	L_{st}	L_t	**0.8025**	**1.4977**	**42**	**0.984**	**LS**	**Sabatié (1993)**
	M	L_{st}	L_t	**0.8581**	**-0.5021**	**280**	**0.964**	**LS**	
	F	L_{st}	L_t	**0.8962**	**-2.6529**	**226**	**0.947**	**LS**	
Alosa fallax fallax									
Severn England	**M & F**	L_t	L_f	1.1446	4.4816	197	0.978	**GM**	**Aprahamian (1982)**
		L_{st}	L_f	0.9702	-9.2629	197	0.842	**GM**	
Various France	**M & F**	L_f	L_t	**0.8907**	**-4.5426**	**34**	**0.992**	**LS**	**Véron (1999)**
Sebou Morocco	**Juv**	L_{st}	L_t	0.8212	-0.1786	345	0.979	**LS**	**Sabatié (1993)**
	M	L_{st}	L_t	0.8511	-0.4854	170	0.956	**LS**	
	F	L_{st}	L_t	0.8752	-1.3544	149	0.949	**LS**	
Alosa fallax rhodanensis									
Rhône France	**Juv**	L_t	L_f	**1.1343**	**-0.0808**	**174**	**0.999**	**LS**	**Crivelli & Poizat (2001)**
Alosa fallax fallax & Alosa fallax rhodanensis									
Various France	**M & F**	L_f	L_t	**0.8849**	**-2.0954**	**791**	**0.997**	**LS**	**Douchement (1981)**
		L_t	L_f	**1.1264**	**3.5260**	**791**	**0.997**	**LS**	
		L_{st}	L_t	**0.8390**	**-4.4002**	**748**	**0.998**	**LS**	
		L_t	L_{st}	**1.1896**	**5.9359**	**748**	**0.998**	**LS**	

1 Gironde-Garonne-Dordogne system

1.3.1.5 Effect of preservation

Taverny & Elie (2001) examined the effect of freezing on length and weight measurements; the following relationships (Table 1.13) were obtained.

Table 1.13: Parameters for the regression of y = ax + b, length is in millimetres and weight in grams (Taverny & Elie, 2001).

Species	Y	X	a	b	n	r^2	Range
Alosa alosa	$L_{t\ fresh}$	$L_{t\ frozen}$	1.007	3.206	16	0.993	214 – 540 mm
	$W_{t\ fresh}$	$W_{t\ frozen}$	1.016	-2.825	16	0.999	87.2 – 1,670.0 g
Alosa fallax	$L_{t\ fresh}$	$L_{t\ frozen}$	0.992	8.944	21	0.997	276 – 445 mm
	$W_{t\ fresh}$	$W_{t\ frozen}$	1.023	-0.978	21	0.999	184.2 – 692.4 g

1.3.2 Internal Morphology

1.3.2.1 Vertebral column

Bertin (1958) described the arrangement of bones around the vertebrae (Figure 1.6). There are three series of bones; the epineural bones associated with the neural arch, the epicentral (adpleural) bones connected with the epapophyses, and the epipleural bones, which are associated with the hemal arch and ribs.

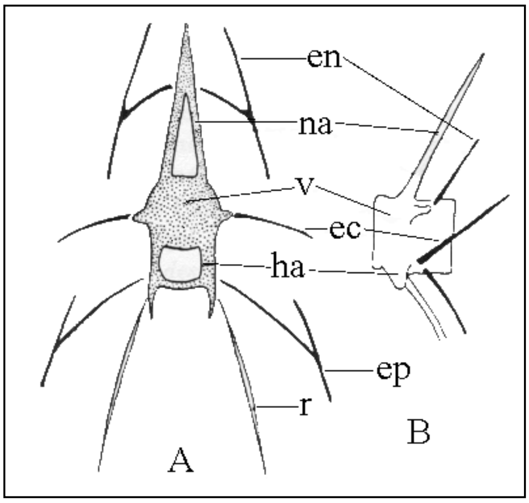
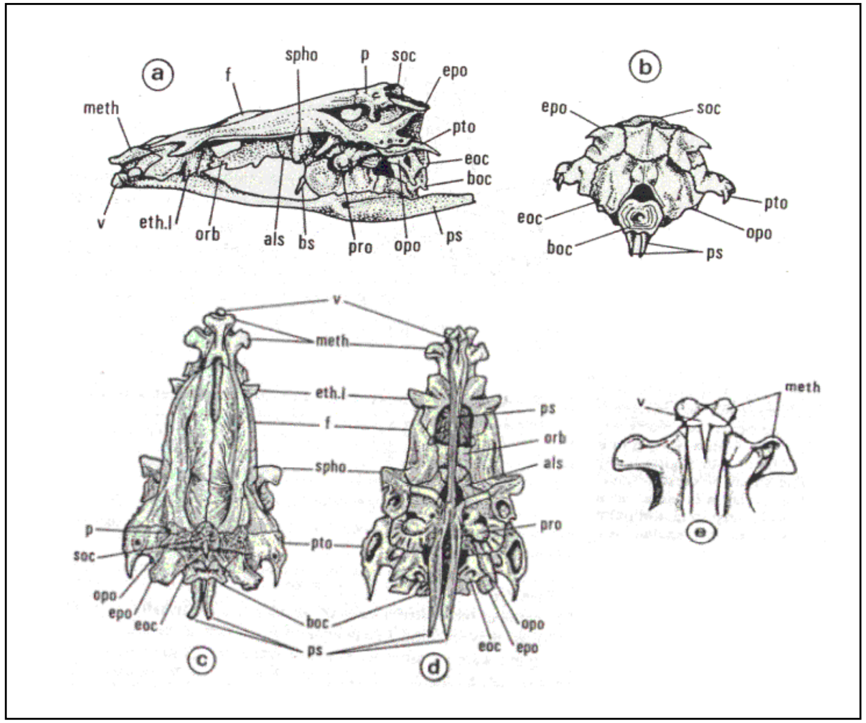


Figure 1.6: Skeletal features of *Alosa alosa*, axial view. *en* epineural bone; *ep* epipleural bone; *ha* hemal arch; *na* neural arch; *r* rib; *v* vertebra; *ec* epicentral bone; *ea* epapophyses. Reproduced from Bertin (1958).

1.3.2.2 Skull

The characteristics of the skull of *Alosa alosa* and *Alosa fallax* (Figure 1.7 & 1.8) have been described by Matthews (1887), Ridewood (1904) and Svetovidov (1964). The description of the skull is taken directly from Svetovidov (1963). *The vomer and the anterior part of the parasphenoid are almost straight. The anterior part of the parasphenoid is rounded in its middle dorsal surface, while the wings of the paraspenoid protrude ventrally underneath the myodome. The ventral edges of the*



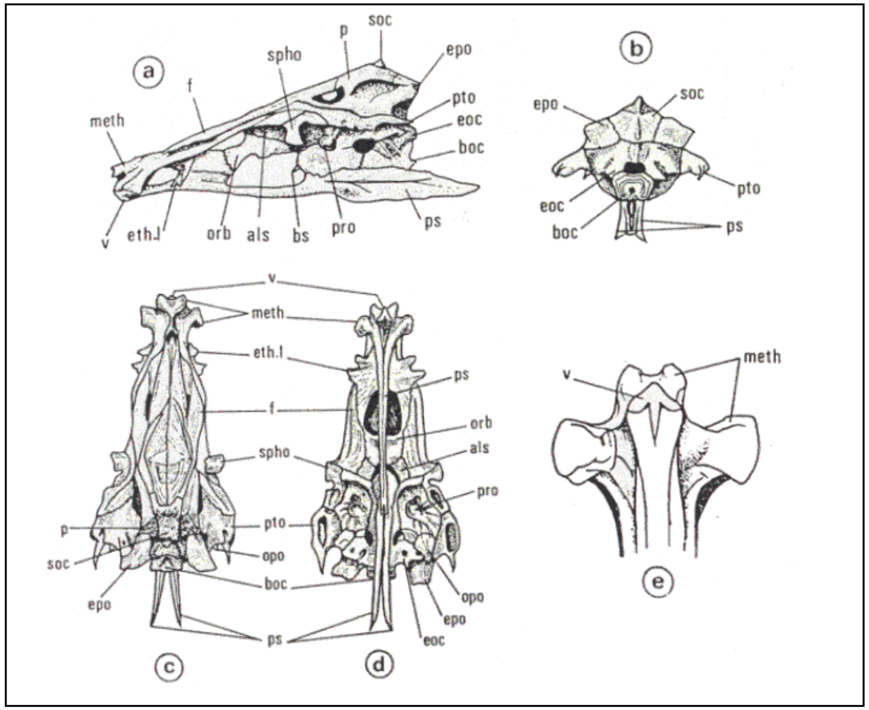


Figure 1.7: The skull of the allis shad *Alosa alosa*

Figure: 1.8 The skull of the twaite shad *Alosa fallax fallax*

a **lateral view;** ***b*** **posterior view;** ***c*** **dorsal view;** ***d*** **ventral view;** ***e*** **anterioventral view.**
als **alisphenoid;** ***boc*** **basioccipital;** ***bs*** **basisphenoid;** ***eoc*** **exoccipital (lateral occipital);** ***epo*** **epiotic;** ***eth. 1*** **lateral ethmoidal;** ***f*** **frontal;** ***meth*** **mesethmoid;** ***opo*** **opisthotic;** ***orb*** **orbitosphenoid;** ***p*** **parietal;** ***pro*** **prootic;** ***ps*** **parasphenoid;** ***pto*** **pterotic;** ***soc*** **supraoccipital;** ***spho*** **sphenotic;** ***v*** **vomer, from Svetovidov (1964).**

wings of the parasphenoid are either straight or slightly bent and are pointed at the tips. The descending process of the basisphenoid is long, frequently almost reaching the parasphenoid. The posterior edges of the supraoccipital and each epiotic on the upper part of the skull extend laterally, forming a right angle. The pterotic terminates posteriorly in a small spine. The anterior end of each sphenotic extends laterally, and may occasionally be directed anteriorly or posteriorly. They are rounded at their tips or bear a small, posteriorly directed hook-like appendage. The transverse extensions of the lateral ethmoids protrude from underneath the anterior end of the frontal bones, varying considerably in form and direction. The anterior extensions of the mesethmoid are directed laterally and somewhat anteriorly. They are straight and somewhat rounded at the tips.

The post temporal region is large and slender with two long limbs attached to the epiotic and opisthotic bones and there is a short limb that carries the sensory canal which touches the back of the supratemporal. The supratemporal is elongated horizontally; its sensory canal divides, with one branch going upward to the parietal and the other going forward into to the squamosal. The orbital ring is incomplete (Figure 1.9). Both the maxilla and premaxilla bear a row of between 20 and 30 minute teeth along the lower edge (Figure 1.10). The highest point of the mandible lies over the back half of the ramus. The hyomandibular articulates with the cranium by two distinct heads. The symplectic is rather small, abruptly terminated and is not enclosed by the quadrate. The palatine is short and has a distinct cartilaginous head for articulation with the prefrontal, not touching the premaxilla (Ridewood, 1904). No teeth are present on the palatine nor on the pterygoid bones. There are seven branchiostegal rays; five attached to the ceratohyal and two to the outer face of the epihyal.

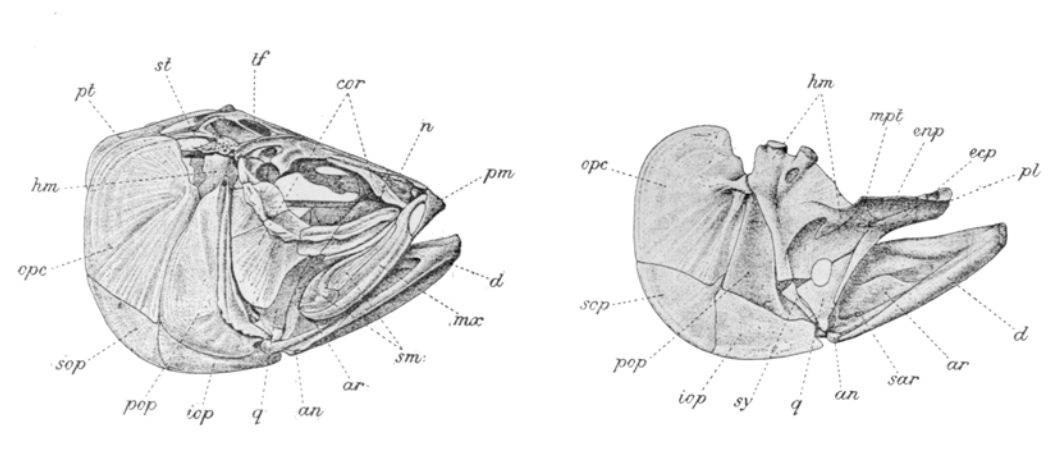
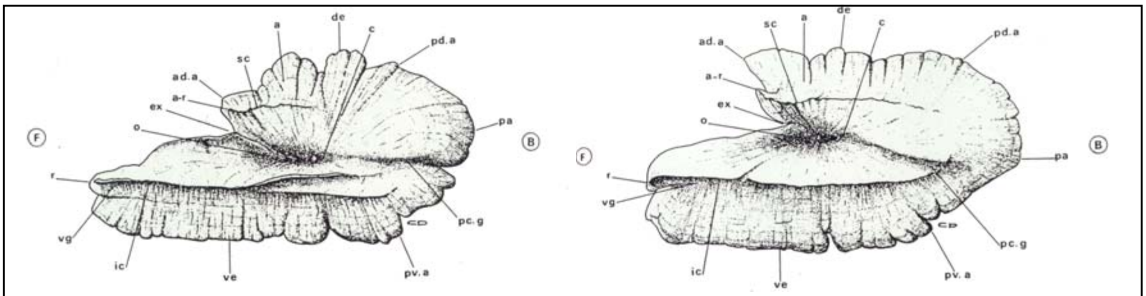


Figure 1.9: Head of *Alosa fallax*; *an* angular; *ar* articular; *cor* circumorbital bones; *d* dentary; *ecp* ectopterygoid; *enp* entopterygoid; *hm* hyomandibular; *iop* interopercular; *mpt* metapterygoid; *mx* maxilla; *n* nasal; *opc* opercular; *pl* palatine; *pm* premaxilla; i preopercular; *pt* post-temporal; *sar* sesamoidarticular; *sm* surmaxilla; *sop* subopercular; *st* supratemporal; *sy* symplectic; *tf* temporal foramen; from Ridewood (1904).

Figure 1.10: The lateral view of the left dentary of *Alosa fallax*, redrawn from Svetovidov (1964).

1.3.2.3 Otolith sagitta

The otolith of *Alosa alosa* has been described by Chaine (1938), and that of *Alosa fallax* by Jenkins (1902), Frost (1925), Chaine (1938) and Bauzá Rullán (1958). The otoliths of *A.alosa* and *A.fallax* (Figure 1.11 a&b) are similar except that, in *A.fallax*, the superior crest is more developed, the anti-rostrum protrudes further, the inferior crest is lower and not as sharp, the post caudal groove runs at an angle from the cauda to the posterior edge of the otolith, and the ventral groove is not as well defined.



a) Otolith of *Alosa alosa*. b) Otolith of *Alosa fallax*.

Figure 1.11: Otolith (Sagitta) of a) *Alosa alosa* and b) *Alosa fallax*. *a* area; *ada* anterodorsal angle; *ar* antirostrum; *B* back; *c* cauda; *de* dorsal edge; *es* excisura; *F* front; *ic* inferior crest; *O* ostium; *pa* posterior angle; *pcg* postcaudal groove; *pda* posteroventral angle; *r* rostrum; *sc* superior crest; *ve* ventral edge; *vg* ventral groove; from Quignard & Douchement (1991a&b).

1.3.2.4 Stomach

The anatomy of the stomach of alosoids has been described by Harder (1975). It is a Y shaped organ (Figure 1.12) consisting of two parts; a terminal blind sac or gastric caecum which is thin walled and used for storage, and a pyloric region where the muscle wall is much thicker, enabling food items to be crushed. In most cases, the food items found in the terminal blind sac have been used to describe the diet as the contents could be more accurately identified and quantified, little digestion having taken place.

The number of pyloric caeca has been reported for one specimen of *Alosa alosa* as 88 (Svetovidov, 1963) and for two specimens of *A. fallax fallax* as 74 (Svetovidov, 1963) and 96 (Fatio, 1890).

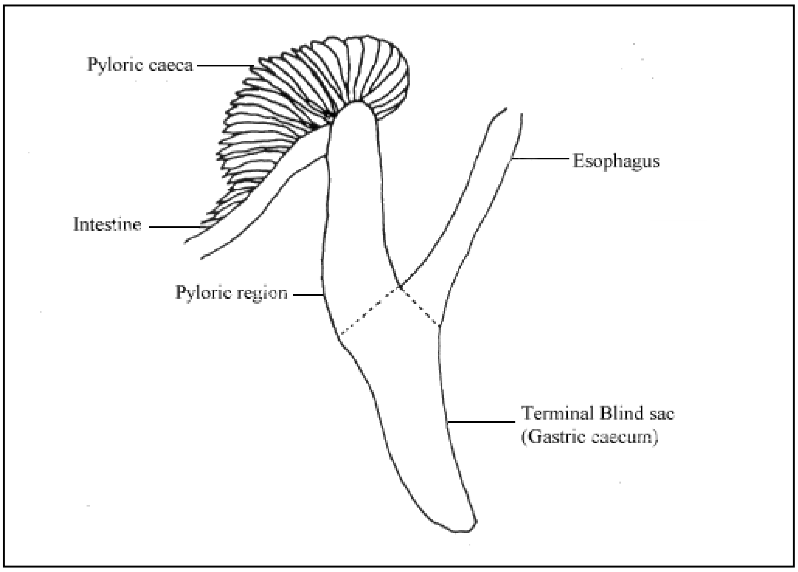


Figure 1.12: Stomach of a typical alosoid.

1.3.2.5 Endocrine system

- Pituitary gland

The pituitary gland has been described by Eiras (1981) for *Alosa alosa* and by Pavlović & Pantić (1975) for *A.fallax nilotica*. The pituitary gland (Figure 1.13) consists of four regions; the pars distalis rostralae (PDR), the pars distalis proximalae (PDP), the pars intermedia (PI) and the neurointermedial lobe (NIL).

The pars distalis rostralae contains both prolactin (PLH) and adrenocorticotropic (ACTH) cells. The prolactin cells are tall and columnar and form the outer layer of the cavity wall. The ACTH cells are situated in the caudal part of the PDR closely associated with the projections of the neurophyophysis. The gonadotropic (GTH), somatotropic (STH) and thyrotropic (TSH) cells are situated in the pars distalis proximalae. The GTH cells are present mainly in the ventral part of the PDP while the STH occupy the dorscranial part. The latter cells are tall and colummnar in shape and situated in the form of a palisade. The TSH cells are present mainly in the dorsal region of the PDP and also in the pars intermedia during spawning. The pars intermedia contains two types of cell, those which stain positively with alcian blue-PAS-orange G(PAS+), and melanostimulting (MSH) cells. The latter cells are distributed mainly around the periphery of the PI.

The volume of the various regions changes during the sexual cycle, with a significant (*P*<0.01) increase in the size of all three regions as the fish commence the freshwater phase of their spawning migration in April (see Section 3.4.4).

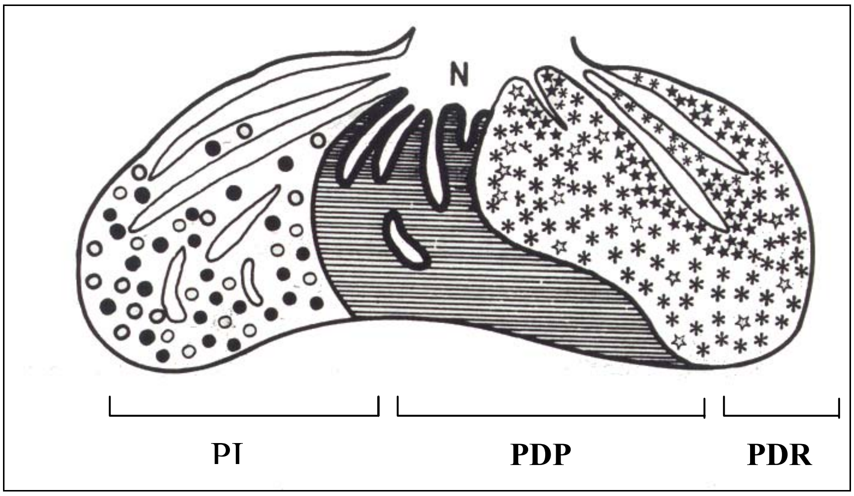


Figure 1.13: The pituitary gland of *Alosa alosa*; Pars distalis rostralae (PDR), Pars distalis proximalae (PDP), Pars intermedia (PI), Neurophyophysis (N), PAS+ (O), Melanostimulating (●), somatic (▬), gonadotrophic (≡), prolactin (✱), adrenocorticotropic (★) and thyrotropic (☆) cells. Reproduced from Eiras (1981b).

1.3.2.6 Thyroid

The thyroid consists of a series of follicle cells situated along the floor of the pharynx between the first and second gill arch (Lahaye, 1959).

1.3.2.7 Muscle

Greer-Walker & Pull (1975) reported that the muscle of a single specimen of *Alosa fallax* measuring 65cm in length (and thus more likely to be *Alosa alosa*) consisted of 21.5% red muscle and 78.5 % white muscle. The section was taken one third of the fish length from the tail and at the position along the fish where there is maximal flexure. The mean diameter of the red and white muscle was 15.9 µm and 39.1 µm, respectively.

1.3.2.8 Swimbladder

The swimbladder of *Alosa fallax* (Figure 1.14) lies at an angle of 9^0 to the axis of the body (Whitehead & Blaxter, 1989). The anterior end of the swimbladder leads straight into the bifurcating ducts (pre-coelomic ducts), no anterior duct being present. The ducts penetrate the skull and open up inside "bullae" (bony capsules) in the prootic and pterotic bones. The pneumatic duct runs from the posterior end of the blind sac of the stomach to the swimbladder, where it joins it approximately two thirds along its length. The swimbladder ends in a blind sac; no anal pore is present. The lack of an anal pore has also been reported for *Alosa alosa* (De Beaufort, 1909).

The gas-filled bullae are used for sound reception. Gregory (1999) reported that *A. fallax* were sensitive to sound transmitted at 200 K Hz but not at 420 K Hz.

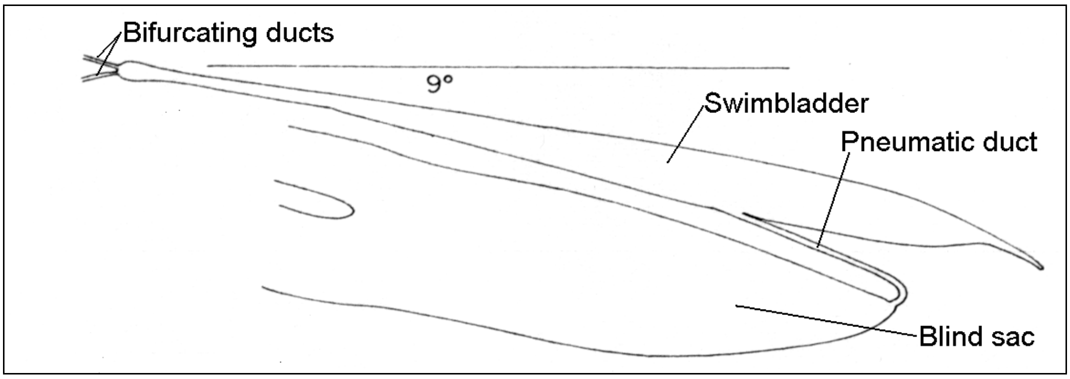


Figure 1.14: General shape of the swimbladder of *Alosa fallax* (Whitehead & Blaxter, 1989).

1.3.2.9 Gonads

The gonads are paired structures in the dorsal lining of the body cavity. In *Alosa* the eggs are released into the external environment via the oviducts, which are continuous with the ovary, forming a closed system. *Alosa* have a lobular testis covered by a membrane, which for *Alosa alosa* varies in thickness from 10.3μ to 21.1μ (Eiras, 1981b). The dimensions of the different cell types and their nucleus are shown in Table 1.14.

Table 1.14: Area and diameter of the different cell types and their nucleus in the testis of *Alosa alosa* from the River Douro, Portugal (Eiras, 1981b).

Cell Type	Cell		Nucleus	
	Area (μ^2)	Diameter (μ)	Area (μ^2)	Diameter (μ)
Spermatogonia	39.25±1.65		18.45±0.99	
Primary spermatocytes	17.55±0.76	4.70±0.11	9.01±0.41	3.36±0.09
Secondary spermatocytes	11.46±1.05	3.87±0.17	5.16±0.49	2.51±0.12
Spermatids			2.44±0.05	1.80±0.09
Spermatozoa			1.05±0.04	1.17±0.03

The histology and maturation of the ovaries is described in the section dealing with the development of the gonads and spawn (Section 3.1.6).

Taverny (1991a) reported that for mature *Alosa alosa* the left-hand ovary was significantly ($P<0.05$) heavier than the right-hand ovary, for *A. fallax* there was no significant difference in weight between the two ovaries.

1.3.2.10 Liver

The weight of the liver of *Alosa alosa* in relation to that of the soma (mean ± 95%CI) ranged from 3.25 ± 1.24 % to 2.19 ± 1.11 % for females and 2.34 ± 2.48 % to 1.50 ± 0.39 % for males (Sabatié, 1993). For *Alosa fallax fallax* the index varied from 1.86% (± 1.75) to 2.67 (± 1.07) (Sabatié, 1993). For both species the difference was not significant ($P>0.05$).

1.3.3 Cytomorphology

The lipid, protein, carbohydrate and water content of adult *Alosa alosa* (Table 1.15) have been described from the River Douro (Portugal) and the Gironde-Garonne-Dordogne system (France) (Eiras, 1981b; Bengen, 1992). The concentration of the various constituents changes during the freshwater phase of their spawning migration (see Section 4.9.2).

Table 1.15: Range in percentage water, protein, lipid and carbohydrate in male and female adult *Alosa alosa* (Eiras, 1981b; Bengen, 1992).

Organ	Sex	Water	Protein	Lipid	Carbohydrate
Muscle	M	67.2-76.6	10.1-18.2	0.8-10.3	1.53-1.83
	F	66.9-76.1	10.5-21.5	0.8-11.3	1.35-1.59
Gonad	M	74.7-78.9	11.0-17.6	3.2-5.8	1.62-2.22
	F	72.2-75.3	14.2-22.1	3.9-6.7	1.59-1.79
Liver	M	61.3-75.9	5.8-11.2	5.1-19.2	1.19-1.47
	F	62.3-76.4	4.3-16.9	3.4-18.5	1.19-1.35

The nucleic content of larvae *Alosa fallax fallax* (4.65 – 18.10 mm L_{st}) from the Mira estuary (Portugal) can be described by the equations (Esteves, pers. comm.):

$$\text{DNA } (\mu\text{g larvae}^{-1}) = -11.79\ e^{(1.62+0.17\ L_{st})} \qquad n = 402;\ r^2 = 0.63$$

$$\text{RNA } (\mu\text{g larvae}^{-1}) = -34.03\ e^{(2.63+0.15\ L_{st})} \qquad n = 402;\ r^2 = 0.47$$

With L_{st} = standard length in mm.

The concentration of the antioxidant enzymes catalase (E.C.1.11.1.6), glutathion peroxidase (E.C.1.11.1.19) and glutathion S-transferase (E.C.2.5.1.18) in the liver of *Alosa fallax nilotica* caught at sea have been reported by Kolayli *et al.* (1997) (Table 1.16).

Table 1.16: Antioxidant enzyme activity in the liver of *Alosa fallax nilotica* (Kolayli *et al.*, 1997).

Enzyme	Enzyme activity		
	B.U[1]/g w.t.w	U/g w.t.w	U/mg.prot
Catalase	0.53 (0.08)		177.20 (26.77)
Glutathion peroxidase		133.9 (23.6)	1.53 (0.27)
Glutathion S-transferase		60.2 (4.1)	0.69 (0.05)

[1] Bergmeyer unit (one B.U. unit is the amount of catalase which decomposes 1.0 g H_2O_2 in one minute).

- Trace metals

The range in concentration of certain trace elements (Table 1.17) has been determined for pre and post-spawned female *Alosa fallax fallax* from the Severn Estuary, England (Aprahamian, unpubl.), see also section 3.4.4 (metabolism).

Table 1.17: Range in concentration (μgg^{-1}) of calcium (Ca), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) in the scales, bone (operculae) liver, muscle and ovary of adult female *Alosa fallax fallax* (n=37) from the Severn Estuary (Aprahamian, unpubl).

Trace Element	Scale		Operculae		Liver		Muscle		Ovary	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Ca	94.4	127.6	125.4	185.1	158.8	2384.0	157.0	2680.0	104.0	3664.0
Cu	3.8	14.1	5.6	27.8	7.0	45.1	1.80	19.7	2.7	19.1
Fe	19.2	425.0	18.4	387.0	803.0	6857.0	24.2	198.7	49.6	793.0
Mn	3.9	40.2	14.4	93.6	4.6	11.1	0.0	3.5	1.0	10.0
Zn	53.8	354.0	70.9	128.5	85.7	224.0	8.3	41.5	66.0	6030.0

The mean (± 95% CI) concentrations of iron, copper, zinc and manganese in the muscle of A. fallax lacustris from Lake Omodeo (Sardinia) was 8.9 (±1.7), 2.1 (±0.5), 10.4 (±2.3) and 1.6 (±0.5) mg kg^{-1}, respectively (Cottiglia et al., 1982).

Berg (1972) reported the calcium and strontium concentrations in *Alosa fallax lacustris* from Lake Maggiore were 6.58 mgCag^{-1} and 4.99 μgSrg^{-1} (wet weight), respectively. In the scale and bone the calcium concentrations were similar 377 and 376 mgCag^{-1} (ash). The dry weight and ash content were 235 and 25 mgg^{-1}, respectively. The proportion of dry weight and ash made up by the scales was 3.4 and 12.3% and by bone 11.5 and 51.3% respectively.

- Heavy metals

The mean (± 95% CI) amounts of mercury in the liver, kidney and muscle of *Alosa fallax fallax* were 0.67 ± 0.08 mg kg^{-1}, 0.50 ± 0.05 mg kg^{-1} and 0.22 ± 0.02 mg kg^{-1}, respectively (Aprahamian *et al.,* unpubl.). Samples were from mature fish collected from the Severn Estuary (England) at the start of the freshwater phase of their spawning migration.

- DNA Adducts

The mean (± 95% SE) concentration of DNA adducts in *Alosa fallax nilotica* from the south-eastern Black Sea was 4.0 ± 0.5 and 4.5 ± 0.5 adduct per 108 nucleotides in the liver and muscle, respectively (KarakoÇ *et al.* 1998). This suggests a relatively unpolluted environment.

1.3.4 Protein and genetic variability

Morel (1974) found real differences in muscle proteins between *Alosa alosa* and *Alosa fallax*. However, Boisneau *et al.* (1992) reported a lack of genetic variation between anadromous *A.alosa* and *A.fallax* in the River Loire (France) at the 22 loci investigated. A high degree of genetic similarity was also revealed for anadromous and landlocked populations of *Alosa fallax* in Ireland (O'Maoileidigh *et al.,* 1988) and Italy (Rizzotti & Gioppato, 1997). Though Rizzotti & Gioppato (1997) reported no evidence of polymorphism, nor any difference according to sex or season, they did report an ontogenetic change in the acidic and basic components of haemoglobin.

Analysis of mitochondrial DNA by Bentzen *et al.* (1993) did indicate a low level of differenciation between *Alosa alosa* and *Alosa fallax* (Figure 1.15). Alexandrino (1996a) found that 4 out of the 15 protein loci examined in *Alosa* populations from Portugal were polymorphic; haemoglobin (HBA), adenosine deaminase (ADA), mannosephosphate isomerase (MPI) and alcohol dehydrogenase (ADH), (Table 1.18). Significant differences in allele frequency exist between *Alosa alosa* and *Alosa fallax*, with 57% of the total genetic variability being explained by between species differences. Similar findings were reported by Véron *et al.* (2001) for *A. alosa* and *A. fallax* from the Charente and by Le Corre *et al.* (1998) for *A. fallax rhodanensis*. Significant differences in allele frequency existed between the various populations of *Alosa fallax*, though this was not the case for *Alosa alosa* who exhibited low levels of polymorphism (Alexandrino, 1996a).

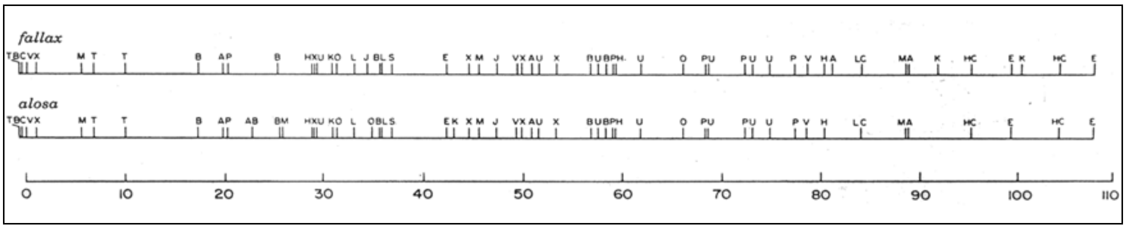


Figure 1.15: Restriction site maps of the mtDNAs of *Alosa alosa* and *Alosa fallax*. The map for each species corresponds to the most common genotype observed for that species. Abbreviated names of restriction sites are as follows: T, *Sst*II; P, *Pst*I; E, *Eco*RI; L, *Sal*I; S, *Sst*I; J, *Cla*I; C, *Eco*RV; X, *Xba*I; H, *Hpa*I; M, *Bst*EII; K, *Kpn*I; V, *Pvu*II; B, *Bgl*I; A, *Sca*I; U, *Stu*I; O, *Bcl*I. One map unit corresponds to approximately 168 base pairs (Bentzen *et al.,* 1993).

Alexandrino *et al.* (1996) used isoelectric focusing to detect polymorphic variation in haemoglobin and adenosine deaminase, allowing the proteins to be split into subunits. Haemoglobin was split into two subunits (HBA and HBB); no variation was detected at HBB, however, at the HBA zone two codominant alleles were present, HBA*F and HBA*S. HBA*F was nearly totally confined to *Alosa alosa* populations while HBA*S was the most common allele for *Alosa fallax* populations. ADA phenotypes were determined by three codominant alleles; ADA*1F, ADA*1S and ADA*2. ADA*1F and ADA*2 were present at a higher frequency in populations of *Alosa fallax*. Other protein polymorphisms were also detected in both species, *Alosa alosa* and *Alosa fallax,* namely, acid phosphatase (ACP) (Castro *et al.*, 1999), amylase (AMY) and malic enzyme (ME-2) (Alexandrino *et al.*, in preparation; Le Corre, 1999; Veron *et al.*, 2001).

Mitochondrial DNA of both *Alosa alosa* and *A. fallax* (Bentzen *et al.,* 1993) are polymorphic, approximately 18.3 kb in size and have a high degree of similarity (98.8%) (Figure 1.15). Alexandrino *et al.* (1996), combining the data from their study with that of Boisneau *et al.*(1992), concluded that *Alosa alosa* and *Alosa fallax* are still at an early stage of divergence. The findings are consistent with those of Bentzen *et al.* (1993), who found an absence of major difference in mitochondrial DNA (1.2%) between the two species, based on restriction site mtDNA data. Bentzen *et al.* (1993) estimated that the two genotypes may have diverged approximately 600,000 years ago. These findings are in concordance with recent molecular data (Alexandrino *et al.,* in preparation), based on direct sequencing of 360 bp of cytochrome b mtDNA gene, that reveals two distinct haplotype clades separated by 6 base substitutions (1.3% divergence), (Figure 1. 16).

Table 1.18: Allele frequency for four polymorphic loci; hemaglobin (HBA), adenosine deaminase (ADA), mannosephosphate isomerase (MPI) and alcohol dehydrogenase (ADH) in populations of *Alosa alosa* from the rivers Aulne (A), Charente (C), Mondego (M) and Lima (L) and the landlocked population of Castelo De Bode (CB) and *A.fallax* from the rivers Charente, Lima, Mondego, Tego (T), Guadiana (G) and Rhône (R) (Alexandrino, 1996a; Le Corre *et al.*, 1998; Véron *et al.*, 2001).

Locus	Allele	*Alosa alosa*					*Alosa fallax*					
		A	C	L	M	CB	C	L	M	T	G	R
HBA	HBA*F	0.85	0.77	1.00	0.97	1.00	0.00	0.12	0.15	0.02	0.00	0.01
	HBA*S	0.15	0.23	0.00	0.03	0.00	1.00	0.88	0.85	0.98	1.00	0.99
ADA	ADA*1F	0.08	0.03	0.00	0.04	0.00	0.15	0.43	0.63	0.32	0.52	0.96
	ADA*1S	0.79	0.95	0.99	0.92	1.00	0.35	0.23	0.06	0.10	0.00	0.01
	ADA*2	0.13	0.02	0.01	0.04	0.00	0.50	0.33	0.31	0.58	0.48	0.00
	ADA*3											0.03
MPI	MPI*1	0.11	0.05	0.10	0.00	0.00	0.97	0.64	0.74	0.75	0.91	1.00
	MPI*2	0.89	0.95	0.90	1.00	1.00	0.03	0.36	0.26	0.25	0.09	0.00
ADH	ADH*1	1.00	0.96	1.00	1.00	1.00	0.71	1.00	0.71	0.18	0.50	1.00
	ADH*2	0.00	0.01	0.00	0.00	0.00	0.29	0.00	0.29	0.82	0.50	0.00
	ADH*3		0.03				0.00					

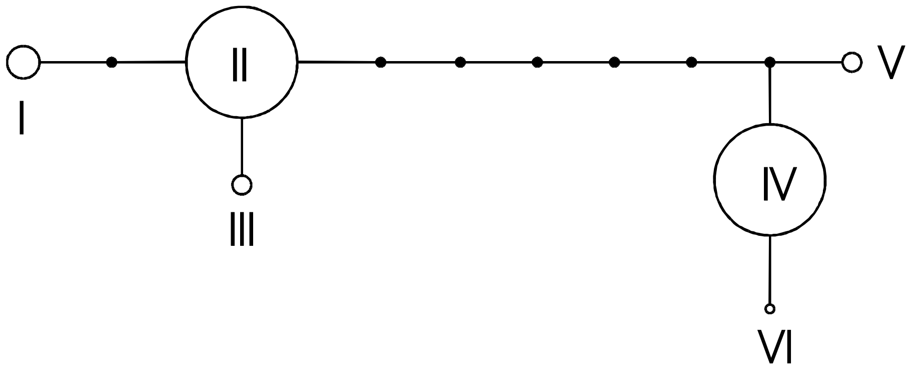


Figure 1.16: Network representing 6 mtDNA haplotypes (360 bp of the 5' -end mtDNA cytochrome b gene) found in 25 *Alosa spp* individuals. Each branch represent a single nucleotide change, solid circles represent missing haplotypes, and size of empty circles reflects the frequency of each haplotype. I, II and III: *Alosa fallax* haplotypes; IV, V and VI: *Alosa alosa* haplotypes (from Alexandrino *et al.,* in preparation).

- **Populations and/or stocks**

Protein, meristic and morphometric differences indicate separate populations of *Alosa* exist and that in order to maintain these differences homing must take place to their natal river (Alexandrino & Boisneau, 2000; Sabatié *et al*., 2000).

Protein differences indicated that of the eleven populations of *Alosa fallax* studied (Alexandrino, 1996a; Le Corre *et al*., 1998; Véron *et al*., 2001; Alexandrino *et al.,* in preparation; Sabatié, unpubl.) three groups are apparent (Figure 1.17). There is one group comprising *Alosa fallax rhodanensis* from the rivers Rhône, Herault and Aude draining into the Mediterranean and *Alosa fallax fallax* from the Sebou (Morocco) which drains into the Atlantic. The other two groups consist of *Alosa fallax fallax*; the first comprising the rivers Tejo, Mira and Guadiana in Southern Portugal and the second consisting of the Northern Portuguese rivers Mondego, Lima and Minho and the French river, Charente, all of which drain into the Atlantic Ocean. Within this group, the relative divergence of *Alosa fallax* from Mondego and Lima results from introgression with *Alosa alosa* due to the high level of hybridisation observed in those basins (Alexandrino, 1996a; Alexandrino *et al.,* 1996).

Alexandrino (1996a) concluded that the genetic dissimilarity between geographically close populations of *Alosa fallax fallax* could only be explained if fish were homing to their natal river. Similar conclusions were reached using meristic data (Sabatié *et al*., 2000). The characters having the greatest ability to discriminate between populations were; the total number of branchial gill rakers on the first gill arch, the total number of scales on the lateral median axis, the number of anal fin rays and the number of pre-pelvic scutes.

However, the same conclusion could not be reached for *Alosa alosa* because of the low level of polymorphism and population differentiation. From the six anadromous populations analysed only a slight divergence is observed in *Alosa alosa* from the southern and northernmost populations of Guadiana and Charente respectively (Fig 1.17).

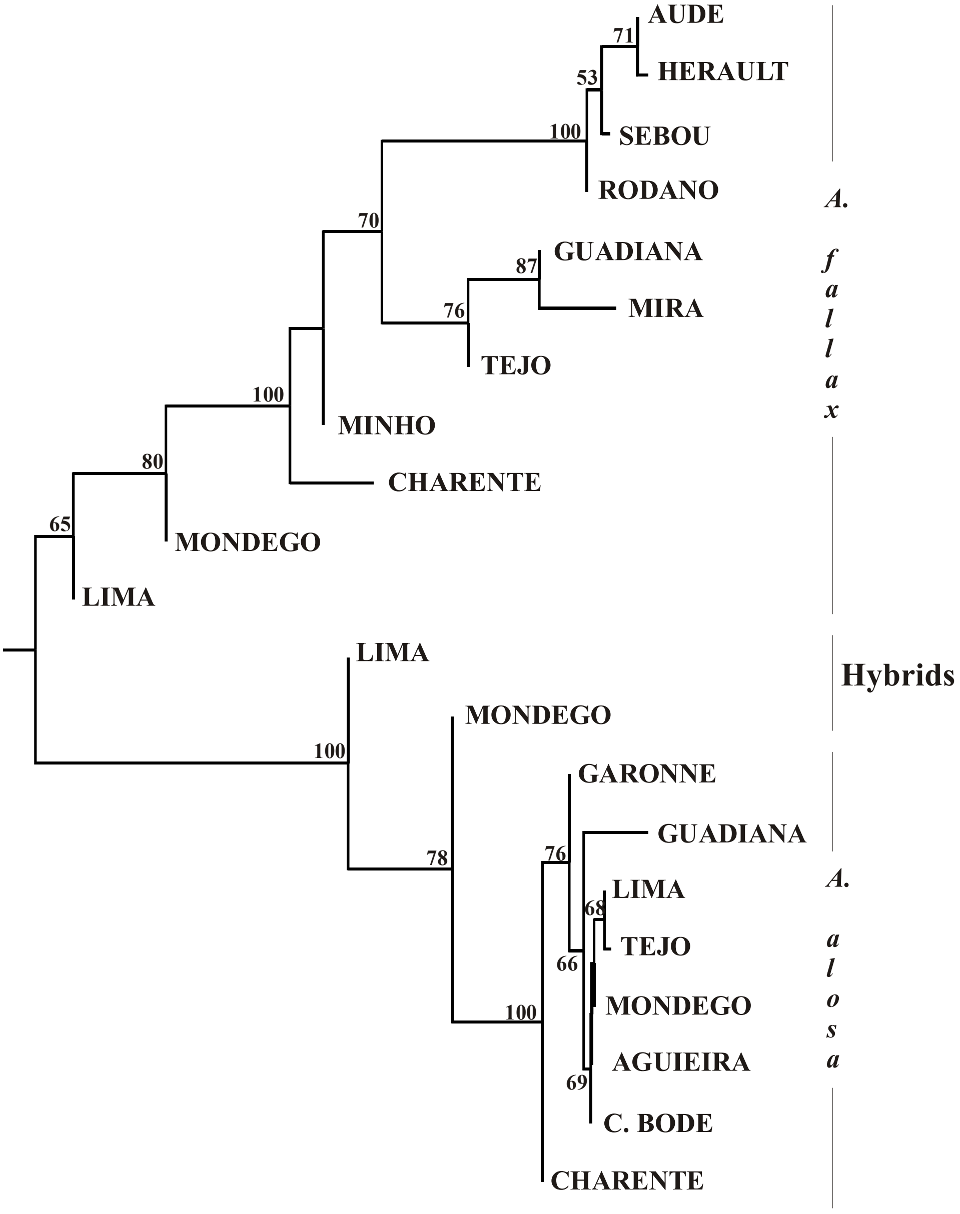


Figure 1.17: Neighbor-Joining tree based on Nei's genetic distances between population samples. Data are based on allelic variance at eihgt allozyme loci screened (data from Alexandrino, 1996a; Le Corre, 1999; Véron *et al.*, 2001; Alexandrino *et al.,* in preparation). Numbers above nodes represent percent bootstrap values (100 replicates). Aguieira and C. Bode *A. alosa* populations are land-locked populations from Mondego and Tejo basins respectively.

2. DISTRIBUTION

At sea *Alosa alosa* and *Alosa fallax* are coastal in their habit and are clumped in aggregations around the major catchments for reproduction (Quero *et al.,* 1989; Taverny, 1991a). *A. alosa* has been reported from depths ranging from 10 to 150m (Laroche, 1985; Taverny, 1991a) up to *c*. 300m (Roule, 1933; Dottrens, 1952; Lithogoe & Lithogoe, 1971) and *A. fallax* from 10 to 110m with a preference for water of 10 to 20m deep (Taverny, 1991a). Taverny & Elie (2001a) showed that the depth at which both species were caught was significantly positively correlated with their age and size.

In the Adriatic, Morović (1959) found that *A. fallax nilotica* could be caught at depths ranging from the surface to 160m, with the fish preferring to be close to the bottom during the winter months. In relation to water temperature Laroche (1985) observed that *A. alosa* in Moroccan coastal waters was closely associated with water in the temperature range of 14 to 18°C.

2.1 Total Area

The total distribution area is shown in Figure 2.1. It is realised that uncertainty exists with regard to which sub-species of *Alosa fallax* inhabit which rivers draining into the Mediterranean Sea. For the purposes of this review those species of *Alosa fallax* inhabiting the Mediterranean to the West of Italy have been classified as *Alosa fallax rhodanensis*, with the exception of those found around the North African coast which are *Alosa fallax algeriensis. Alosa fallax nilotica* has been considered to be confined to that area of the Mediterranean east of the Italian Peninsula.

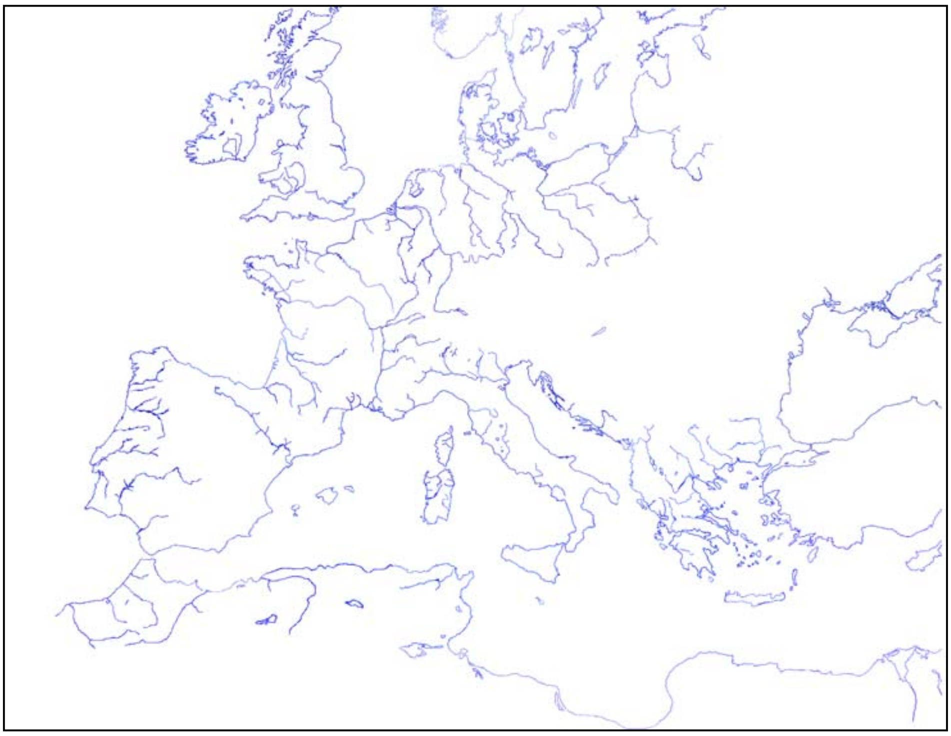


Figure 2.1: Distribution of *Alosa* spp. in Europe, the Mediterranean and North Africa

2.1.1 *Alosa alosa* and *Alosa fallax fallax*

Alosa alosa and *Alosa fallax* have been reported from Iceland (Saemundsson, 1949) at the northern most limit of their range, to Morocco in the south **(Furnestin, 1952; Dollfus, 1955; Blanc *et al.*, 1976; Matallanas *et al.*, 1981**) and as far east as Scandinavia (Pethon, 1979) and the Baltic Sea (Manyukas, 1989). *Alosa alosa* have been reported only from the western part of the Mediterranean (Sostoa & Sostoa, 1979; Douchement, 1981), while *Alosa fallax* are encountered through out the Mediterranean.

Both species of *Alosa* have been reported infrequently from around Scandinavia and there have been no reports of a spawning population existing in Norway or Finland. In Sweden *A. alosa* have been caught in the River Dalälven and *A. fallax* from the rivers Lagan and Nissan, though whether a spawning population exists remains uncertain (Nathanson pers. comm). Juvenile *A. fallax* (length 90 to 100 mm) have been found off the Swedish coast around the Skåne peninsula (Nathanson pers. comm.). In the 1930s *Alosa fallax* were considered abundant in the gulfs of Finland and Riga and particularly in the River Narva, Estonia, (Mikelsaar, 1984), which may represent the northern limit for a spawning population. In Estonian waters the species is now only rarely caught (Saat, 2002).

A spawning population of *A. fallax fallax* has been reported from the Nemunas (Nyamunas) River, Lithuania (Manyukas, 1989) [Figure 2.2]. However, since the construction of the Kaunas hydroelectric dam in 1959 and elevated pollution from poorly treated wastewater from paper mills in the lower river the population declined (Maksimov & Toliušis, 1999; Repečka, 1999). *A. fallax fallax* are only occasionally caught in the Curonian Lagoon (Mileriene, 1997; Repečka, 1999) as well as over the Baltic Sea region (**Wiktor, 1989; Winkler, 1991)** and are now considered very rare. In 1997, however relatively large numbers (160 kg) were caught (Maksimov & Toliušis, 1999). This may reflect a decrease in pollution as a result of the economic

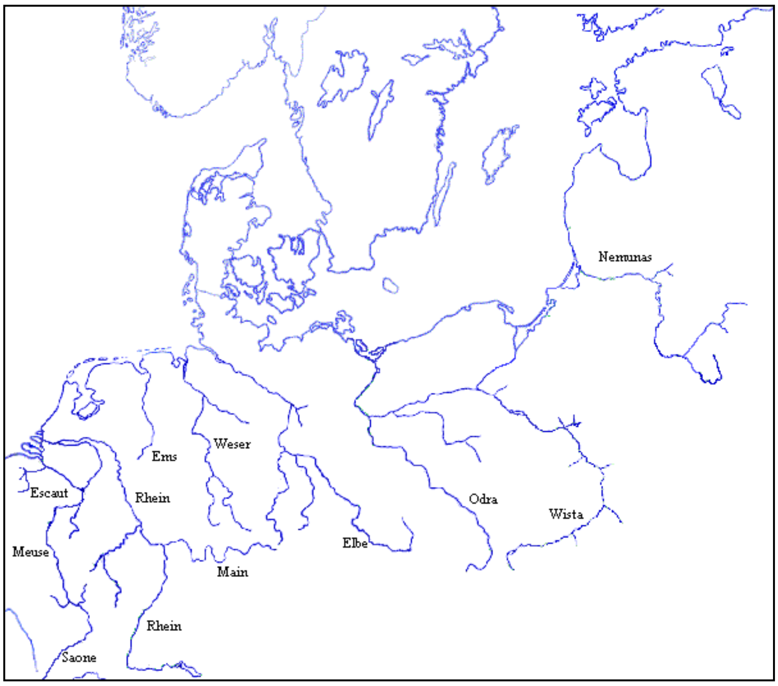


Figure 2.2: Distribution of *Aloso* spp. in Northeast Europe

recession and possibly also the opening of a shipping lane (1984-6) which improved water quality in the lagoon and access to the Nyamunas (Repečka, 1999). In the first half of the 20th century the Nyamunas river did support an important fishery with the average catch for the periods 1930-4; 1935-47; 1948-52 and 1953-57 being 16,100 kg, 28,500 kg, 29,800 kg and 2,200 kg, respectively (Manyukas, 1989), with a peak catch of 50,000 kg in 1948 (Repečka, 1999). After 1960 the fishery ceased.

On the south shore of the Baltic Sea *A. fallax fallax* have been found in the lower reaches of the River Wista (Vistula), Poland (Chmielewski, 1965). They have been reported sporadically in the River Odra (Oder) (Waterstraat, 1986) and from Szczecin Bay into which the Odra drains (Peczalska, 1973) [Figure 2.2]. In the first half of the twentieth century the rivers Elbe, Weser and Ems all supported commercial fisheries for *A. fallax* (Drimmelen, 1951; Nolte, 1976). Wilkens & Köhler (1977) mention that *A. alosa* is now extinct in the River Elbe, however Möller (1989) mentions that allis shad have never been reported from the lower Elbe, but Fric (1859) reports that a few specimens were caught in the 19th century far upstream. Duncker & Ladiges (1960) consider that the conflicting reports may be due to misidentification between the species.

Alosa alosa became extinct in the River Weser at the beginning of the twentieth century, as a result of over-fishing, channelisation and the construction of dams (Busch *et al*., 1988; 1989). A spawning population of *A. fallax* exists in both the River Elbe (Hass, 1965, 1968; Möller & Dieckwisch, 1991; Thiel *et al.,* 1996a) and the River Weser (Scheffel, **1988**, Scheffel & Schirmer, 1991). In the River Elbe, Möller (1989) showed that the abundance of 0+ *A. fallax* in the 1980s was between 3.9 and 9.3 times that of the estimate of Apstein (1895) in 1894. However, the population of *A. fallax* in the River Weser has declined dramatically since the 1950s because of channelisation and an increase in sewage and salt pollution. The increase in salt pollution is related to the expansion of the potash industry, as a result the salinity in the lower Weser is in the region of 1 to 2.5 ‰ (Busch *et al*., 1988; 1989). *Alosa fallax* has been reported from the River Ems in the past (Lohmeyer, 1909; Svetovidov, 1963), and the recent report that juveniles have been caught in the Ems Estuary during the 1990s (Hadderingh & Jager, 2002), suggests that a spawning population may still exist.

In the latter part of the eighteenth century a spawning population of *A. alosa* and *A. fallax* existed in the Rhein (Rhine) (Hoek, 1899; Regan, 1911; Redeke, 1938). A steep decline in numbers of *A. alosa* occurred *c*.1900 and of *A. fallax* after 1942 (Figure 2.3). The decline of *A. alosa* was due to over fishing, barriers to their migration and destruction of their spawning habitat (de Groot, 1989; Raat, 2001). The most significant factor in the decline of *A. fallax* was the damming of the river (closure of the Haringvliet in 1970) preventing the fish from spawning in the tidal freshwater portion of the river (de Groot, 1989) and the subsequent change in the tidal regime which resulted in an increase in sedimentation (De Nie, 1996). However, *A. fallax* were still spawning at the Biesbosch (where the Meuse meets the Rhine) in 1968 (**Boddeke, 1974)**. Lelek (1976) reported sightings of *A. fallax* in the Rhine and its tributary the River Main, but overall both species now appear to be only rarely encountered (Cazemier, 1988; **de Groot, 1990;** Bartl & Troschel, 1995; Buijse & Cazemier, 1998). Buijse & Cazemier (1998) concluded that *A. fallax* were unlikely to be successfully breeding in The Netherlands, at present.

At the turn of the nineteenth century both species of shad were present in Belgium (Anonymous, 1901a). Anonymous (1888) reported the presence of a spawning population of *Alosa alosa* and *A. fallax* in the River Meuse (Figure 2.2). However, by 1925 *A. alosa* and by 1950 *A. fallax,* were no longer found in the Walloon part of the rivers Escaut and Meuse (Poll, 1947; Philippart & Vranken, 1981, 1982) as a result of over-exploitation, pollution, habitat destruction and the building of weirs (Philippart *et al.*, 1988). There have been no recent reports of the occurrence of either species in the Flemish lowland rivers (**Bervoets *et al.*, 1990**).

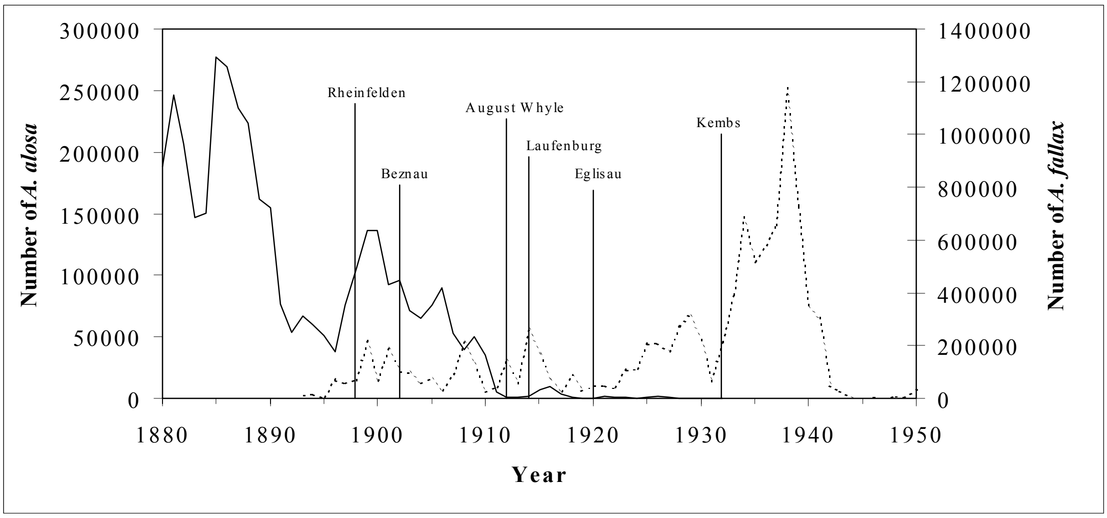


Figure 2.2: The catch of *Alosa alosa* (solid line) between 1880 and 1934, and of *A. fallax* (dotted line) between 1893 and 1950, from the lower Rhine (Data from de Groot, 1989, 1990). Vertical lines show the dates when dams were built.

Alosa alosa and *A. fallax* have been recorded from most areas around the British Isles (Maitland, 1972, 1979; O'Maoileidigh *et al.,* 1988; Potts & Swaby, 1993a; Aprahamian *et al.,* 1998). Spawning populations of *A. fallax* exist in the rivers Severn, Wye, Usk and Tywi (UK) and in the Barrow, Nore and Suir in Ireland (Aprahamian & Aprahamian, 1990) [Figure 2.4].

Figure 2.3: Spawning distribution of *A. fallax* in the UK, 1 = Lough Leane.

A spawning population of *A. alosa* existed in the River Severn until the middle of the nineteenth century. Its decline has been attributed to navigation weirs constructed *c.* 1842 (Day, 1890). The River Thames supported a spawning population of *A. fallax* up until the middle of the nineteenth century, though its decline appears more attributable to a deterioration in water quality than to the construction of navigation weirs (Aprahamian & Aprahamian, 1990). There is also good evidence to suggest that a population of *Alosa* spp. used to exist in the River Trent (Anon. 1622; Deering, 1751; Anon. 1890).

Along the North French coast a spawning population of both species previously existed in the Seine (Vincent, 1889; Roule 1920a), becoming extinct following the construction of the Poses and Martot dams in 1887 at Rouen (LeClerc, 1941). Spawning populations of *A. fallax fallax* have been reported in the rivers Orne (lower Normandy) and the Brittany rivers Aulne, Blavet and Vilaine (Véron, 1999) [Figure 2.5].

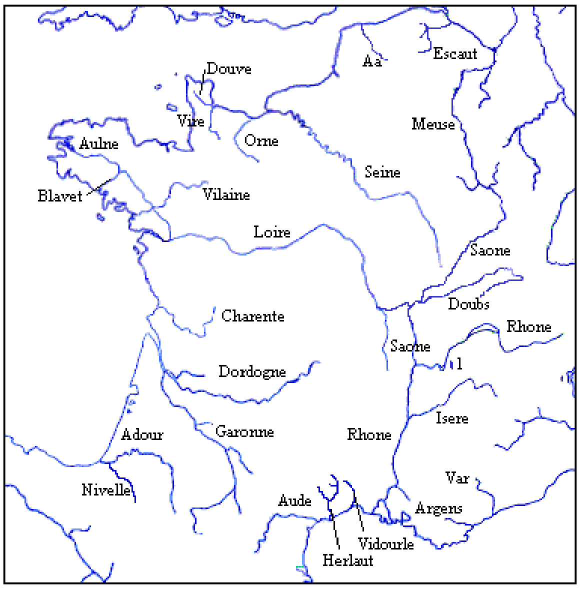


Figure 2.4: Spawning distribution of *Alosa* in France. 1 = Lake Bourget

Of the rivers entering the Atlantic spawning populations of *A. alosa* and *A. fallax* are present in the Loire, Charente, Garonne and Dordogne, Adour and Nivelle (Mennesson-Boisneau & Boisneau, 1990; Taverny, 1991a; Prouzet *et al.,* 1994a; Véron, 1999; Baglinière, 2000) [Figure 2.5]. In the Garonne and Dordogne the original distribution of *A.alosa* had become restricted because of dams at Bazacle (1774), Mauzac (1843) and Golfech (1971). However, the construction of fish pass facilities at these obstructions since 1987 have been successful in extending access for *A. alosa* to the upper river (see section 6.3).

Along the Atlantic coast of the Iberian Peninsula spawning populations of both species of shad have been reported in the rivers Miño (Minho), Lima, Douro, Vouga, Mondego, Tejo and the Guadiana (Capello, 1880; Regalla, 1888; Nobre, 1932; Ribeiro, 1971; Eiras 1980, 1981b, Alexandrino, 1996a&b; Collares-Pereira *et al.*, 2000; Costa *et al.*, 2001) [Figure 2.6]. However, dam construction on a number of Portuguese rivers has had a dramatic impact on populations (Costa *et al.*, 2001). In the Douro, the Crestuma-Lever dam constructed in 1985 21 km upstream from the river mouth has resulted in the populations of *A. alosa* and *A. fallax* virtually becoming extinct (Alexandrino, 1996b).

While in the rivers Tejo and Miño the populations of *A. alosa* have declined dramatically (Figure 2.7) to the extent that only a residual population now exists in the Tejo (Alexandrino, 1996b). In the Tejo this decline is associated with the construction of the Castelo de Bode and Belver dams in 1951 and 1952 respectively (Costa *et al.*, 2001). Though a Borland fish lift has been installed on the Douro at Crestuma-Lever and on the Tejo at Belver (170 km from the mouth of the Tejo) they do not appear to be effective in passing *Alosa* spp. upstream (Bochechas, 1995). Spawning populations of *A. fallax* exist in the rivers Mira and probably also in the Cavedo and the Sado (Alexandrino, 1996b). Lozano Rey (1935, 1947) has reported both species in the River Guadalquivir (Quadalquivir), though recent evidence suggests only a spawning population of *A. fallax* now exists (Doadrio, 1991; Alexandrino, pers. comm.). In Portugal there are two landlocked populations of *A. alosa*; one in the Castelo de Bode reservoir on the River Tejo (Eiras 1981a, 1983) and one in the Aguieira Reservoir on the River Mondego (Collares-Pereira *et al.*, 1999) [Figure 2.6]. These are thought to be the result of the impoundment of the rivers in 1951 and 1981, respectively. In Spain a landlocked population of *A. alosa* exists in the River Guadalquivir (Moron, pers. comm.).

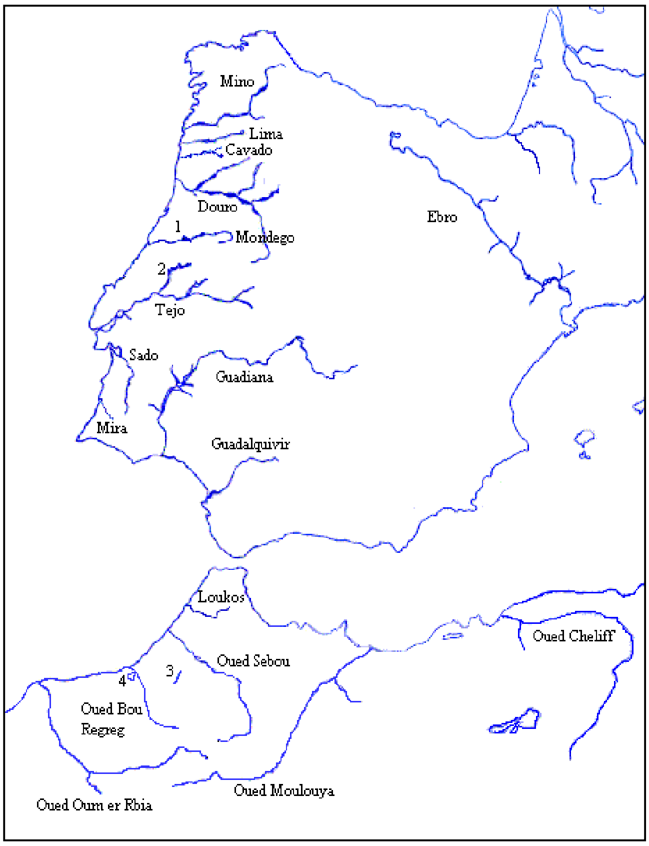


Figure 2.5: Distribution of *Alosa* in Southwest Europe and Northwest Africa. 1 = Aguieira Reservoir, 2 = Castelo de Bode Reservoir, 3 = El Kansera, 4 = Sidi Mohamed Ben Abdallah.

In the Moroccan Oueds draining into the Atlantic Ocean spawning populations of *Alosa fallax* are now only present in the Loukos and Sebou (Sabatié, 1993) [Figure 2.6]. At the start of the 20th century the total annual catch of shad from Moroccan waters (including the Oued Moulouya) was in the region of 1000 t (Watier, 1918). However, the construction of barrages and degradation of the habitat has resulted in a number of populations becoming extinct. A spawning population of the anadromous form of *Alosa alosa* existed in the Sebou but became extinct following the construction of a barrage at Idriss ler and from pollution derived from the processing of sugar (Figure 2.8) [Sabatié, 1993]. Other Oueds which used to support spawning populations of *Alosa alosa* were the Bou Regreg, Oum er Rbia and the Massa (south of Oued Oum er Rbia). The populations have become extinct following the construction of weirs in 1968-69, 1929 and 1973 respectively.

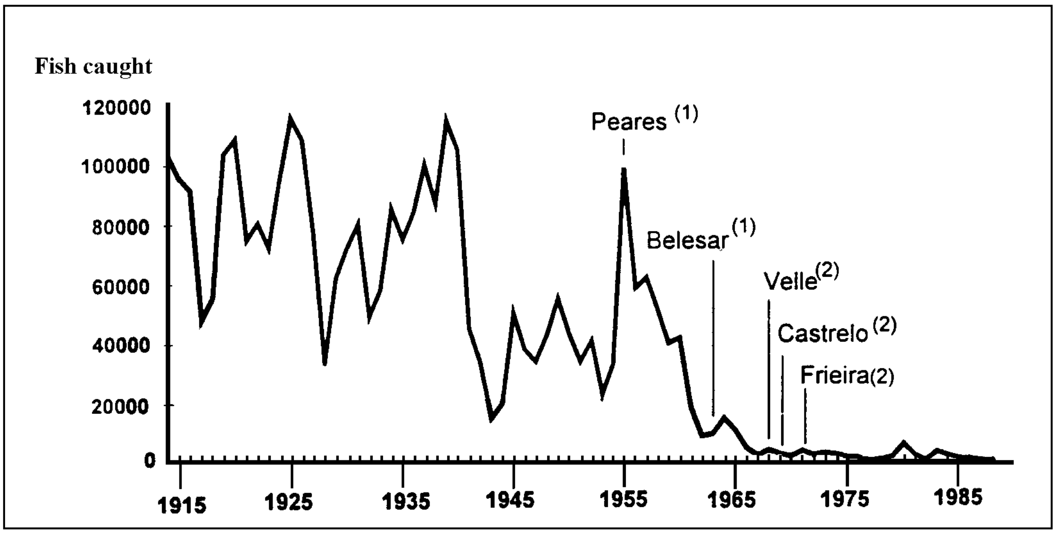


Figure 2.6: The catch of *Alosa alosa* between 1914-1988 from the River Miño, and the dates when barrages were constructed; 1 = Lugo province, 2 = Orense province (Alexandrino, 1996b).

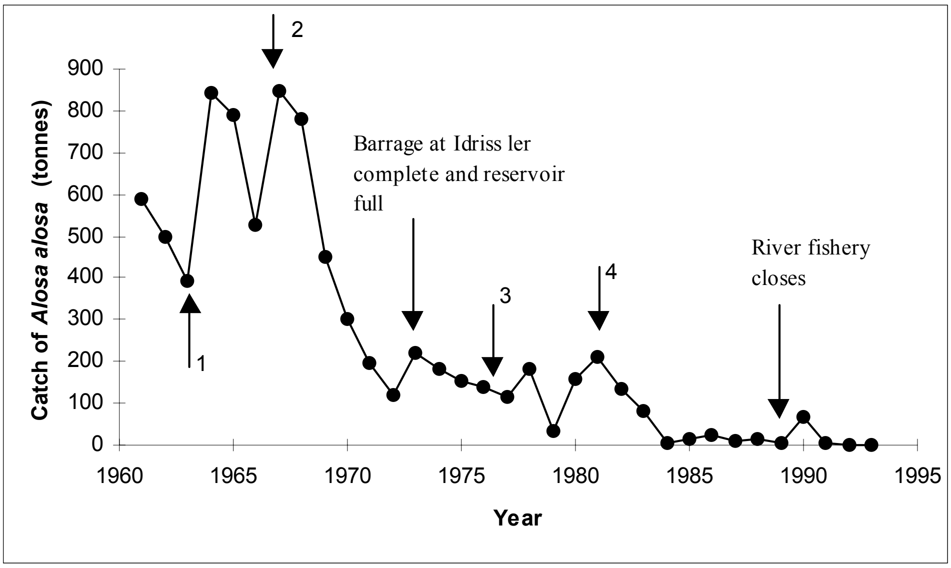


Figure 2.8: The combined marine and river catch of *Alosa alosa* from the Oued Sebou (Morocco) between 1961 and 1993. Numbers refer to when different sugar refineries were constructed (Sabatié, 1993).

The construction of dams has created a number of landlocked populations. Landlocked populations of *Alosa alosa* and *Alosa fallax* have been reported from Lake El Kansera (Furnestin, 1952; Furnestin & Vincent, 1955; Lahaye, 1960a, 1966; Sabatié, 1993) probably resulting from dam completition in 1951. The landlocked population of *A. alosa* is now extinct (Sabatié, 1993). A landlocked population of *A. fallax* also exists in Lake Sidi Mohamed Ben Abdallah (Oued Bou Regreg) which was probably formed after the dam was constructed in 1970 (Sabatié, 1993) [Figure 2.6].

In the Mediterranean, Lozano Rey (1935, **1950**) mentions the occurrence of *A. alosa* in the Ebro (Spain). However, the construction of the Ribarroja (1967) and Mequinenza (1964) reservoirs in the lower reaches has meant that they are now confined to the river's delta (Sostoa & Sostoa, 1979; Sostoa & Lobon-Cervia, 1989) [Figure 2.6]. Of the French rivers draining into the Mediterranean, Douchement (1981) mentions the presence of a spawning population of *A. alosa* in the rivers Aude and Rhône, though the number of gillrakers suggests that they may have been hybrids (Section 1.3.1.1). The presence of *A. alosa* in the Rhône was also reported by Le Roux (1928) and Rameye *et al.* (1976), but not by Roule (1924b). Rameye *et al.* (1976) considered them to be rare. In a recent intensive study on the Rhône by Le Corre *et al.* (1997) none were recorded, suggesting that the population may now be extinct. A population of *A.alosa* may also exist in the River Argens (Didry, 1953; Changeux & Pont, 1995) [Figure 2.5].

Of the Moroccan rivers draining into the Mediterranean a spawning population of *A.alosa* used to exist in the Oued Moulouya, but became extinct in 1953 following the construction of the Mechra-Hommadi dam (Sabatié, 1993).

2.1.2 *Alosa fallax rhodanensis*

Alosa fallax rhodanensis is distributed along the northern coast of the western Mediterranean Sea ranging from Spain to southern Italy. In Spain it has been reported in the River Ebro (Lozano Rey 1929, 1950; Sostoa & Lobon-Cervia, 1989; Elvira, 1995a) [Figure 2.6] and in France in the rivers Aude, Hérlaut, Vidourle, Rhône and Argens (Gallois, 1946a, 1947a; Rameye *et al.,* 1976; Douchement, 1981; Changeux & Pont, 1995; Le Corre *et al.,* 1997) [Figure 2.5]. In the past the sub species used to persist in the rivers Gapeau and Siagne (Lebel *et al*., 2001).

In the River Ebro *A. fallax rhodanensis* are now confined to the river's delta (Sostoa & Sostoa, 1979; Sostoa & Lobon-Cervia, 1989), similarly in the rivers Aude, Hérlaut, Vidourle, Argens and Tavignano, dams now confine the populations to the lower river (Lebel *et al*., 2001). The population in the River Ebro may, however, now be extinct (B. Elvira, pers comm. cited by Bianco, 2002). Kiener (1985) reported their presence in the River Var, however, Changeux & Pont (1995) have doubts as to the validity of this report. In the Rhône the original spawning migration was over 600 km (Quignard & Douchement, 1991c) entering several tributaries including the Saône (Roule, 1933; Gallois, 1946a), the Doubs (Ogerien, 1863; Olivier, 1882; Verneaux, 1971) and Lake Bourget (Roule, 1924a; Le Roux, 1928; Leger, 1943) [Figure 2.5]. Their progress has since been restricted by the construction of hydroelectric dams (Figure 2.9).

In 1952 the construction of the Donzère Mondragon dam 150 km from the river's mouth reduced the amount of river available to the shad by 70% and in 1974, the Vallabregges dam reduced it by a further 15% (Keith & Allardi, 1996). This restricted the population to the lower 60km of the river (Rameye *et al.,* 1976; Quignard & Kartas, 1977; Larinier *et al.,* 1978; Petit, 1979; Douchement, 1981; Kiener, 1985). In recent years the construction of two fish passes (Vialle, 1987; Zylberblat *et al.,* 1991) and the use of navigation locks for fish passage has allowed the subspecies to extend its distribution up to the Donzère Mondragon dam and into the lower reaches of the Ardèche (Lebel *et al*., 2001).

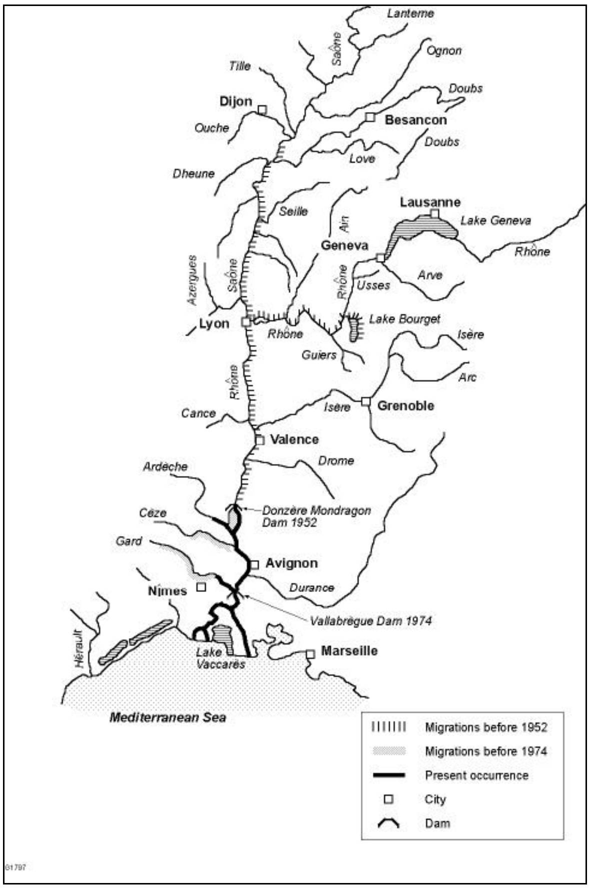


Figure 2.9: The past and present distribution of *Alosa fallax rhodanensis* in the River Rhône, modified from Pattée (1988).

In Corsica *Alosa fallax rhodanensis* has been reported from the rivers Golo and Tavignano (Casabianca *et al.,* 1972-73; Kiener, 1985; Changeux & Pont, 1995; Le Corre *et al*., 2000), and in Sardinia from the rivers Barca, Cedrino, Coghinas, Flumendosa, Posada, Temo and Tirso (Cottiglia, 1968) [Figure 2.10].

In the past they have been reported from the Italian rivers Arno, Ombrone, Tiber, Volturno and the Sele (Barbieri, 1907a; D'Ancona, 1928a; Berg, 1933; Ferrero, 1951; Bini, 1970; Sammicheli, 1998), but there are no recent records. In the Tiber the fish could migrate to the Paglia River a distance of 210 km from the mouth (D' Ancona, 1927b), a dam near Rome presently blocks their migration.

2.1.3 *Alosa fallax nilotica*

This sub-species is distributed around the eastern Mediterranean (Economidis, 1974) with its range extending southward down to the River Nile (Boulenger, 1907; Ladiges & Vogt, 1965). In Italy they persist in the River Po, (Florin, 1949; Ferrero, 1951; Gandolfi & Le Moli 1977; Vitali & Braghieri, 1981;Vitali *et al.,* 1983; Chiaudani & Marchetti, 1984; Serventi *et al.,* 1990) and in the River Brenta (Rizzotti & Gioppato, 1997) [Figure 2.9]. *Alosa fallax nilotica* have also been repoted from the rivers Adige and Veneto (NE Italy) [Gridelli, 1935; Pomini, 1937].

Figure 2.10: Distribution of *Alosa* in Southeast Europe.

1 = Orta, 2 = Maggiori, 3 = Lugano, 4 = Como, 5 = Iseo, 6 = Garda, 7 = Bolsena, 8 = Vico, 9 = Bracciano, 10 = Omodeo, 11 = Flumendosa, 12 = Bacin, 13 = Ichkeul

Alosa fallax nilotica are often found in the Adriatic Sea (Soljan, 1963; Vukovic, 1961a; Nikolaeva, 1966; Bini, 1970; Tortonese 1970) and entering the Croatian rivers Neretva, Drin and Bojona to spawn (Vukovic, 1961a; Vukovic & Ivanovic, 1971; **Kosoric *et al.,* 1989a&b**) [Figures 2.10 & 2.11]. Landlocked populations have also been reported from lakes Skadar (Scutari / Shkodra), Bačin and Sasko in Montenegro and from Lake Ohrid on the border between Croatia and Albania (Tocko & Jovanovic, 1959; Vukovic, 1961a; Vukovic & Ivanovic, 1971; Knezevic *et al.,* 1977, 1986; Pavlović & Pantić, 1975) [Figures 2.10 & 2.11]. In Lake Skadar both the anadromous *Alosa fallax nilotica* and the non-migratory *Alosa fallax nilotica* exist in sympatry (Rakaj & Crivelli, 2001). The population of the migratory *A. fallax nilotica* in Lake Skadar has declined since the construction of a dam in 1960 on the River Bojana (Figure 2.12), though access to the lake is maintained via a canal (Bianco, pers. comm.).

Figure 2.11: Distribution of *Alosa* in Greece and Southeast Europe.

1 = Scutari, 2 = Ohrid, 3 = Sasko, 4 = Vistonis

In Greece, *A. fallax nilotica* is present in the rivers Evros, Strymon, Pinos, Acheloos and Thyamis and there exists strong evidence that they exist in Loudias, Louros and Arachthos (Economidis, 1974; Bobori *et al*., 2001) [Figure 2.11]. A population used to exist in the River Nestos however, the construction of a dam near the Bulgarian border and associated change in flow regime has meant that *A. fallax nilotica* no longer migrates into the Nestos (Bobori *et al*., 2001). The sub species is also caught by trawlers in the Thermaikos Gulf and populations may therefore exist in the rivers Aliakmon, Loudias and Axios (Bobori *et al*., 2001). Bobori *et al*. (2001) also reported their presence in LakeVistonis.

Kuru (1980) and Balik (1995) reported this sub-species all along the coasts of Turkey, and Bacescu (1982) [cited by Quignard & Douchement, 1991d] reported them as abundant in the Bosporous. A spawning population exists in the Yeşilirmak which drains into the Black Sea and have been reported from the Sakarya (Black Sea), Menderes (Aegean Sea) and in the Seyhan and Ceyhan rivers (E. Mediterranean) [Turan & Basusta, 2001; Turan, pers.comm.].

There are no reports of *Alosa fallax nilotica* from the Eastern Mediterranean countries of Syria and Lebanon and they have been only rarely reported from Israel (Golani, pers. comm.). The most southerly population has been reported from the River Nile (Egypt) by Boulenger (1907), though this population may now be extinct as a result of dam construction (Bishai & Khalil, 1997).

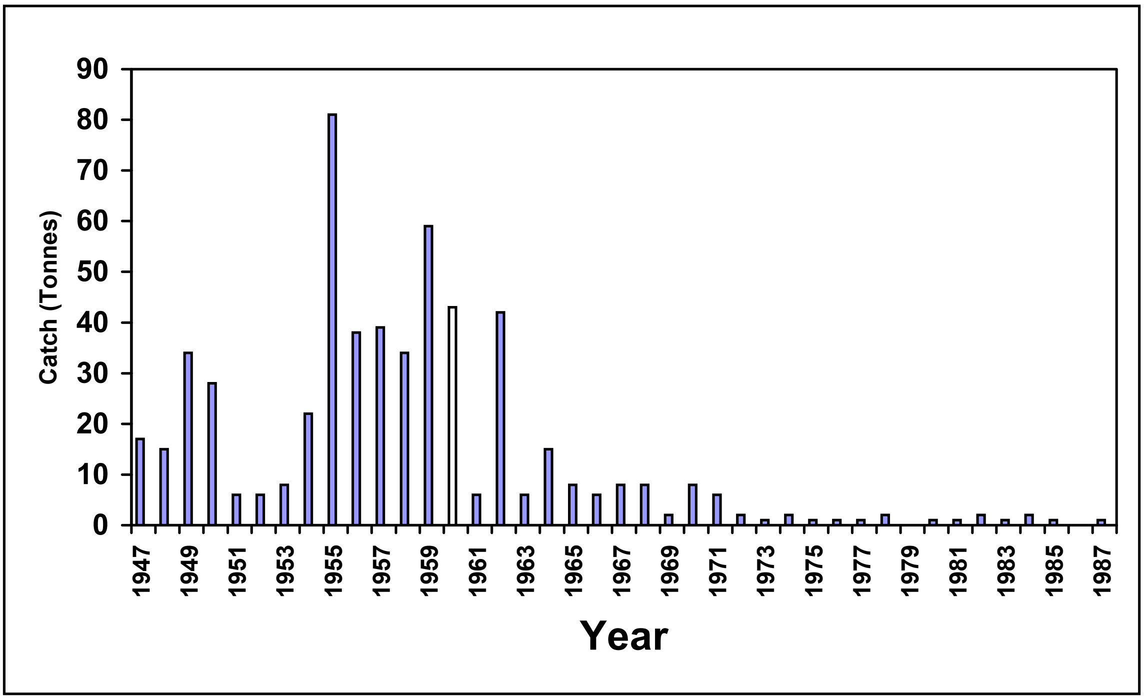


Figure 2.12: Catch of *Alosa fallax nilotica* from Lake Skadar (Montenegro), between 1947 and 1987 (Stein *et al.,* 1981; Maric, 1990), the dam on the River Bojana was constructed in 1960, from Bianco (2002).

2.1.4 *Alosa fallax algeriensis*

Alosa fallax algeriensis is found along the North African coast from the Rif Peninsula (Lozano Rey, 1929) to Tunisia. In Tunisia they have been reported in oueds Miliane and Medjerdah (Quignard & Kartas, 1977; Kartas, 1981) [Figure 2.10] A landlocked population exists in Lake Ichkeul (Kartas, 1981). In Algeria spawning populations exist in the oueds Chelif, Mazafran, Seybouse and Oubeira and in associated lakes (Bounhiol, 1917; Dieuzeide *et al.,* 1959; Quignard & Kartas, 1977) [Figure 2.6].

In Morocco a spawning population of *Alosa fallax* (possibly *Alosa fallax algeriensis*) used to exist in the Oued Moulouya but became extinct in 1953 following the construction of the Mechra-Hommadi dam (Sabatié, 1993) [Figure 2.6].

2.1.5 *Alosa fallax lacustris*

Alosa fallax lacustris is the name given to the subspecies of *Alosa fallax* found in landlocked Italian lakes and which Cottiglia (1963b) gave to those found in Sardinia. They are present in lakes Maggiori, Orta, Lugano, Como, Mergozzo, Iseo and Garda (Vogel, 1903; Barbieri, 1907a; Fatio, 1890; Ferrero, 1951; Berg, 1966a; Giussani & Grimaldi, 1975; Müller, 1990; Müller & Meng, 1992; Luzzana *et al.*, 1996; Bianco, 2002) [Figure 2.10].

In 1921 Pirola (1930) introduced the landlocked form of *A. fallax* from the northern lakes of Como and Garda into the lakes of middle Italy; lakes Bolsena, Vico and Bracciano (Chiappi, 1933a; Gallois, 1946b; Ferrero, 1951; Tortonese, 1970). *Alosa fallax lacustris* are still present in Lake Bracciano (Bianco, 2002) but have disappeared from lakes Bolsena (Taddei *et al.*, 1999) and Vico (P. G. Bianco pers. obs., cited by Bianco, 2002).

In Sardinia, landlocked populations developed in several artificial lakes (Cottiglia, 1963b, 1968; Quignard & Douchement, 1991f) [Figure 2.10]. In the River Tirso landlocked populations developed in lakes Omodeo, Castel Doria, Del Posada and Villanovatulo following completion of a dam in 1922. Similarly following the closure of a dam in 1957 on the River Flumendosa a population subsequently developed in Lake Flumendosa.

2.1.6 *Alosa fallax killarnensis*

In Southwest Ireland, a landlocked population of *A. fallax*, (*A. fallax killarnensis*) exists in Lough Leane (Regan, 1911; Trewavas, 1938; Went, 1946; Gibson, 1956; O'Maoileidigh *et al.,* 1988) [Figure 2.4]. The isolation of this population was possibly due to local tectonic changes (Wheeler, 1977).

2.2 Determination of Distribution Changes

Changes in distribution have arisen mainly as a result of the construction of barriers, pollution, over-fishing and their translocation to new sites, see section 2.1 and Taverny *et al.* (2000a).

2.3 Hybridization

Based on the number of gill rakers, hybrids of *A. alosa* x *A. fallax fallax* have been reported from the Rhine, Germany (Hoek, 1899), the French rivers Loire (Douchement, 1981; Boisneau *et al.,* 1992) and Aude (Douchement, 1981), from the Lima, Portugal (Alexandrino *et al.,* 1996) and from the Sebou, Morocco (Sabatié, 1993). Hybrids of *A. alosa* x *A. fallax rhodanensis* have been observed from the Rhône, France (Douchement, 1981).

These hybrids have been confirmed genetically with morphometric and meristic characteristics intermediate between the two species and appear fertile (Alexandrino & Biosneau, 2000). The prevalence of hybridization appears related to the presence of obstructions to the free passage of migrants upstream resulting in the use of communal areas for spawning (Biosneau *et al.*, 1992).

3. BIONOMIC AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality, sexual differentiation/dimorphism

Alosa alosa and *Alosa fallax* spp. are heterosexual. The inter-sexual differences in morphology have not been well studied. Visually there is little external difference between the sexes except that, once mature, females are on the whole larger than males (see Section 3.4.3) and have an enlarged cloaca.

Alosa alosa

Female *A. alosa* have a higher mean number of scales along the mid-line in the River Loire (Boisneau, 1990), a smaller head length in relation to total length in the Loire and Sebou (Boisneau, 1990; Sabatié, 1993) and a lower mean number of pre-pelvic scutes in the River Sebou (Sabatié, 1993), when compared with males.

Alosa fallax fallax

In the River Loire no significant difference in morphology or meristic characteristics has been found between the sexes (Biosneau, 1990). In the River Sebou female *A. fallax* had a higher number of dorsal and anal fin rays and a greater pre-anal distance in relation to total length than males (Sabatié, 1993).

3.1.2 Maturity

Alosa alosa

The majority of studies have estimated the age at first spawning from catch data that consisted of a number of different cohorts with no correction applied for gear selectivity. The exception is the study of Lambert *et al*. (2001) who estimated the age at maturity for three year-classes of *Alosa alosa* from Gironde-Garonne-Dordogne (France). Anadromous populations of *Alosa alosa* mature at between 3 and 8 years (Table 3.1), with the majority of females maturing at ages 5 and 6 years and males at 4 and 5 years.

On the River Loire (France), Mennesson-Boisneau & Boisneau (1990) reported that female *A. alosa* mature at between 4 and 7 years old and the males a year earlier at 3 to 6 years old. The mean (standard deviation) age at which fish spawn for the first time was 4.9 (± 0.6) and 4.3 (± 0.7) years for females and males respectively. On the Gironde-Garonne-Dordogne (France) the age at which 50% of the individuals have matured (95% CI) was 4.864 (4.858 - 4.865) years for females and 4.831 (4.819 - 4.831) years for males (Martin-Vandembulcke, 1999).

Landlocked populations of both sexes of *Alosa alosa* in the Castelo do Bode reservoir (River Tejo, Portugal) and in the Aguieira reservoir (River Mondego, Portugal) mature at the age of 3 years (Eiras, 1983; Collares-Pereira *et al.,* 1999).

Table 3.1: The percentage of *Alosa alosa* maturing at different ages in different river systems.

River	Sex	Age (year)						No.	Reference
		3	4	5	6	7	8		
Loire (France)	F			63.4	33.3	3.3		31	Douchement (1981)
	M		11.8	75.0	13.2			68	
Charente (France)	F	2.5	12.5	52.5	22.5	10.0		40	Véron *et al.* (2001)
	M	11.7	17.6	47.1	17.6	6.0		17	
Gironde-Garonne-Dordogne (France)	F	3.5	11.5	53.1	29.5	2.4		373	Taverny (1991a)
	M	3.1	13.1	74.3	9.5			390	
	F			39.1	60.9			46	Douchement (1981)
	M		25.7	48.6	25.7			36	
	F	1.1	10.7	62.4	24.7	1.1		956	Lambert *et al.* **(2001)**
	M	1.0	19.7	67.1	11.3	1.0		1191	
Adour (France)	F		35.3	52.9				17	Douchement (1981)
	M	1.4	66.7	30.5	1.4			72	
Sebou (Morocco)	F		2.9	25.8	52.1	17.5	1.7	240	Sabatié (1993)
	M	1.1	23.9	49.3	24.6	1.1		280	

Alosa fallax fallax

Anadromous populations of *Alosa fallax* mature from 2 to 9 years old (Table 3.2) with the majority of females maturing at age 4 and 5 years and the males at 3 and 4 years. Mennesson-Boisneau & Boisneau (1990) reported that female *A. fallax* on the River Loire (France) mature at between 2 and 5 years old and the males at 2 to 4 years old. The mean (standard deviation) at which fish spawn for the first time was 3.55 (± 0.6) and 2.96 (± 0.5) years for females and males respectively. There was no evidence of any latitudinal cline in the mean age at maturity

Alosa fallax rhodanensis

On the Rhône (France) *Alosa fallax rhodanensis* mature at between 2 and 6 years old with the majority of females maturing at age 4 and 5 and the males at ages 3 and 4 (Table 3.3). A similar maturation schedule has been reported from the Aude, Hérault and the Tavignano (Douchement, 1981; Le Corre *et al*., 2000).

In the rivers Rhône, Aude, Hérault and Tavignano, the mean age at maturation for males was 3.34, 3.60, 3.57 and 3.40 years, respectively, while for females in the Rhône, Aude and Tavignano the mean age was 4.03, 4.80 and 4.28 years, respectively (Le Corre *et al*., 2000). The data for the rivers Hérault and Tavignano must be interpreted with caution as the sample size was small (≤ 12 individuals).

Table 3.2: Percentage of *Alosa fallax fallax* maturing at different ages from different river systems.

River	Sex	Age (year)								Mean (±95CI)	No.	Reference
		2	3	4	5	6	7	8	9			
Wye	Female			46.6	51.4	2.0				4.55 (0.09)	148	Aprahamian
(Wales)	Male		17.8	79.5	2.7					3.85 (0.10)	73	(1982 & unpubl.)
Tywi	Female		3.2	61.3	32.3	3.2				4.36 (0.23)	31	Aprahamian
(Wales)	Male		10.0	40.0	50.0					4.50 (0.38)	10	(unpubl.)
Severn	Female		2.2	33.2	48.8	14.5	1.3	0.1		4.80 (0.02)	5090	Aprahamian
(England)	Male	0.7	30.8	50.9	16.6	0.8	0.1		0.1	3.87 (0.04)	1527	(1982 & unpubl.)
Barrow	Female		4.7	57.2	33.3	4.8				4.38 (0.31)	21	O'Maoileidigh
(Ireland)	Male		36.8	39.5	21.1	2.6				3.90 (0.27)	38	(1990)
	Female		19.5	67.5	13.0					3.94 (0.13)	77	Aprahamian
(Holland)	Male	1.4	71.5	25.7	1.4					3.27 (0.12)	74	(1982)
Loire	Female		8.3	65.0	18.4	8.3				4.27 (0.20)	56	Douchement
(France)	Male	2.6	84.2	10.6	2.6					3.13 (0.16)	38	(1981)
	Female									3.55 (0.20)	34	Mennesson-
	Male									2.96 (0.20)	26	Boisneau & Boisneau (1990)
Charente	Female		17.9	71.4	10.7					3.93 (0.21)	28	Véron (unpubl.)
France	Male			80.0	20.0					4.20 (0.56)	5	
Gironde-	Female		11.1	51.1	37.8					4.27 (0.20)	45	Douchement
Garonne-	Male		75.7	18.9	5.4					3.30 (0.19)	37	(1981)
Dordogne												
(France)	Female		37.1	51.7	11.2					3.74 (0.14)	89	Taverny (1991a)
	Male		45.5	43.2	4.5	6.8				3.73 (0.26)	44	
Adour	Female			65.2						4.35 (0.21)	23	Douchement
(France)	Male		50.0	50.0	34.8					3.50 (0.92)	4	(1981)
Sebou	Female		5.3	40.5	35.7	18.5				4.67 (0.13)	152	Sabatié
(Morocco)	Male	0.6	27.3	57.5	14.6					3.86 (0.09)	205	(1993)

Table 3.3: Percentage of *Alosa fallax rhodanensis* maturing at different ages.

River	Sex	Age (year)					No.	Reference
		2	3	4	5	6		
Rhône (France)	F		1.6	38.7	50.0	9.7	64	Douchement (1981)
	M		21.6	63.1	15.3		109	
	F	0.2	12.6	53.0	31.3	2.9	1065	Le Corre *et al.* (2000)
	M	3.2	43.4	45.9	7.3	0.2	705	
Aude (France)	F			20.0	45.0	35.0	38	Douchement (1981)
	M		28.0	41.3	30.7		74	
	F			36.0	43.0	21.0	14	Le Corre *et al.* (2000)
	M		39.0	61.0			25	

Alosa alosa x Alosa fallax hybrids

Female and male hybrid *Alosa alosa* x *Alosa fallax* from the River Loire (France), have both been found to mature at between 3 and 5 years old (Mennesson-Boisneau & Boisneau, 1990). The mean (standard deviation) age at which fish spawn for the first time was 3.89 (± 0.4) and 3.54 (± 0.6) years for females and males respectively. Sabatié (1993) found on the River Sebou (Morocco) that the mean (range) age at which female *A. alosa* x *A. fallax* hybrids spawn for the first time was at 5 (4 to 6) years old and males at age 4 (4 to 6) years.

Alosa fallax nilotica

Vukovic (1961a) reported that the populations in lakes Skadar (Albania) and Bačina (Croatia) become sexually mature in their second year of life while those from the lower Neretva river (Montenegro) mature from age 2 onwards. The anadromous population of *A. fallax nilotica* in Lake Skadar mature between 3 and 8 years old while the landlocked population in the lake mature between 2 and 5 years old (Rakaj & Crivelli, 2001).

Alosa fallax algeriensis

Kartas (1991) reported that male *Alosa fallax algeriensis* mature at three to four years old and females at age four to five years.

Alosa fallax lacustris

Berg & Grimaldi (1966a) reported that *Alosa fallax lacustris* in Lake Maggiore (Italy), normally reaches maturity at two years of age, at a minimum length (total) of 180 to 190 mm.

Alosa fallax killarnensis

In Lough Leane (Ireland), O'Maoileidigh (1990) reported that *Alosa fallax killarnensis* mature at age 3 and 4 years (Table 3.4).

Table 3.4: Percentage of *Alosa fallax killarnensis* maturing at different ages (O'Maoileidigh, 1990).

Lake	Sex	Age (year)			No.
		3	4	5	
L. Leane (Ireland)	Female Male	50.0% 60.0%	50.0% 40.0%		18 35

3.1.2.1 Variation in age at maturity

The age at first spawning of *Alosa fallax fallax* for a particular year-class has been found to vary (Aprahamian & Lester, 2001). Figure 3.1 shows that the mean age at first spawning for female *A. fallax* ranged from 4.41 to 5.40 years over the 20-year period studied. This was found to be significantly ($P<0.05$) related to the combined biomass of the 0 to 2 ($r^2 = 0.41$) and 0 to 3 age groups ($r^2 = 0.32$) [Figure 3.2]. The relationship indicates that at low population levels the fish mature early, maturing later with increasing size of the stock up to an asymptote of *c.* 5 years.

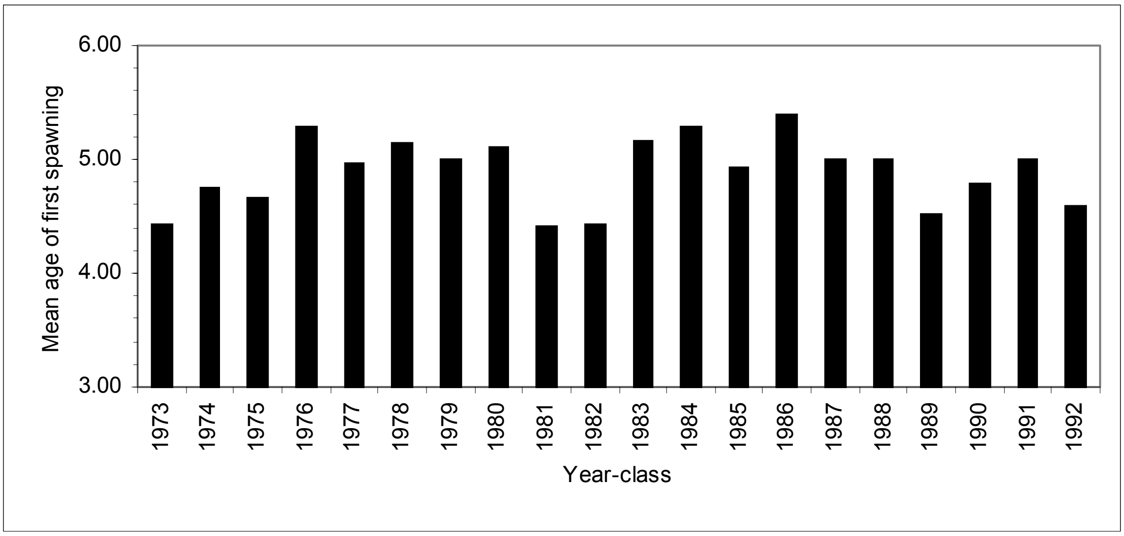


Figure 3.1:The mean age at first spawning for female *Alosa fallax fallax* from the River Severn for the 1973 to 1992 year-classes (Aprahamian & Lester, 2001).

The relationship suggests that the onset of maturity is related to density dependent processes, such as the effect of intra specific competition for food on growth.

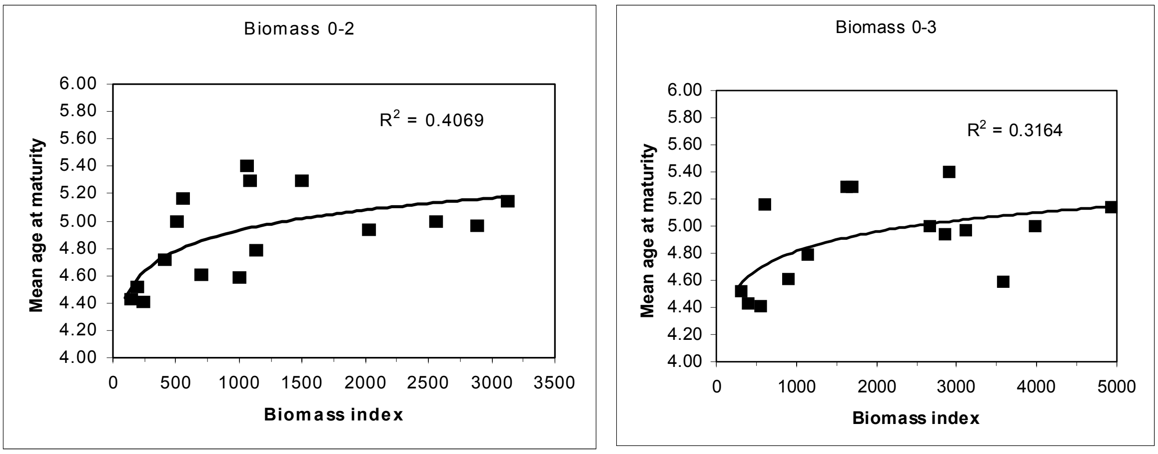


Figure 3.2:The relationship between age at maturity for female *Alosa fallax fallax* and an index of biomass for age groups 0-2 and 0-3 inclusive, only those year-classes where more than 10 fish were sampled have been included (Aprahamian & Lester, 2001).

Aprahamian (1982) suggested that female *A. fallax* from the River Severn (England) must reach a critical size of approximately 330 mm (L_f), before they enter the adult population. Aprahamian & Lester (2001) analysed the growth rates of female *A. fallax* from four cohorts and found that the faster growing fish of a particular cohort matured first (Table 3.5).

Table 3.5. Mean fork length ∀95%CI (mm) at age of four year-classes of female *Alosa fallax fallax* prior to maturation (Aprahamian & Lester, 2001).

Age at Maturity	Year Class	Age (year)						Sample size
		1	2	3	4	5	6	
3	1989	120±9.8	235±10	314±9.0				11
4	1982	**76±5.0**	193±5.9	271±5.5	330±4.5			30
	1983	92±4.4	188±5.4	267±6.6	321±6.3			29
	1989	80±6.7	194±10.3	272±11.0	327±10.8			30
5	1982	66±4.2	172±6.1	244±5.6	304±5.6	341±5.5		28
	1983	75±3.7	161±7.2	233±8.1	290±6.8	334±6.0		30
	1984	77±4.0	149±8.3	224±8.3	285±7.4	332±5.1		27
	1989	69±3.9	158±8.4	234±7.4	298±5.1	347±4.6		30
6	1982	66±6.7	156±7.5	227±6.6	284±8.2	320±11.4	348±14.5	6
	1983	72±4.1	150±7.3	221±8.7	278±8.1	325±7.8	355±5.9	28
	1984	72±3.4	138±6.8	205±6.6	266±6.1	315±5.9	354±5.5	29
	1989	61±3.8	134±10.2	205±10.6	268±9.7	317±10.2	348±8.8	20

This difference in growth rate was evident at an early age with fish of 120 mm at age 1 maturing at age 3; between 76 and 92 mm maturing at age 4; between 66 and 77 mm at age 5 and between 61 and 72 mm at age 6. For fish maturing at ages 5 and 6 years old there was some overlap in the length at age between the two groups until the age of 4 with those maturing at age 5 being on average ∃ 285 mm (L_f) compared with those maturing at age 6 years which were < 285 mm.

3.1.3 Number of spawnings

The spawning history of alosoids can be determined from their scales (Section 1.3.1.2) and in theory can be used to characterise populations, for example variation in the proportion of repeat spawners. For such a purpose it is important that sampling is carried out over the same time period in order to take account of variation in year-class strength, and that for each population sampled the gear is equally selective. The selectivity of the gear may mean that the younger fish are under represented in the population and thus the sample may not represent the true spawning structure of the population. For example, <30% of the *Alosa fallax fallax* sample taken from the River Severn (England) were spawning for the first time (Table 3.6). These data do, however, give an estimate of the number of spawnings a fish may make.

Alosa alosa

Douchement (1981) found no evidence of fish making more than one spawning migration for three French anadromous populations of *Alosa alosa* in the rivers Loire, Garonne and Adour. Similar findings were reported for *A. alosa* by Véron *et al.* (2001) from the Charente (France) and by Sabatié (1993) from the Sebou (Morocco) where the populations have a semelparous life history.

In contrast to the findings of Douchment (1981), Taverny (1991a) reported a higher level of repeat spawning 17.9% and 9.1% for females and males respectively (Table 3.7), while on the Loire 0.8% of males and 1.8% of females have been found to spawn more than once (Mennesson-Boisneau & Boisneau, 1990). A small proportion (20%) of female repeat spawners was also reported in the River Aude (France), though the sample size on which it is based was small, comprising only five fish (Douchement, 1981).

Table 3.7: Percentage of *Alosa alosa* from the Gironde-Garonne-Dordogne (France) spawning one or more times

		Spawning number				
Location	Sex	1st	2nd	3rd	No.	Reference
Gironde-Garonne-Dordogne (France)	F	82.1	17.1	0.8	480	Taverny (1991a)
	M	90.9	8.9	0.2	481	

The landlocked population of *Alosa alosa* in the Castelo de Bode reservoir (Portugal) has a similar semelparous life history with the fish failing to survive spawning (Eiras, 1983). In contrast Collares-Pereira *et al*. (1999) reported that *A.alosa* from the Aguieira reservoir (River Mondego, Portugal) has an iteroparous life history, with a high proportion of the fish spawning more than once. The maximum number of spawnings recorded was three.

Alosa fallax fallax

Nearly all anadromous populations have an iteroparous life history with the populations having a high proportion of repeat spawners (Table 3.6), the exception being the Moroccan populations in the Sebou and Loukos which are semelparous (Sabatié, 1993). The maximum number of spawnings recorded has been seven and most have a high proportion of fish spawning two or three times. There is some indication that the number of spawnings, and as such the proportion of repeat spawners increases, with latitude (Mennesson-Boisneau *et al*., 2000a).

Alosa fallax rhodanensis

On the River Rhône (France) studies on spawning frequency have been carried out by Baglinière *et al*. (1996), Douchement (1981) and by Le Corre *et al*. (1997a), the latter study incorporated the findings of Baglinière *et al*. (1996a). On the Rhône, specimens of *Alosa fallax rhodanensis* have been recorded as having spawned up to five times (Table 3.8). The proportion of repeat spawners in the Rhône population has varied from 13.7% to 62.0% for females and from 11.6% to 40.0% for males (Lebel *et al*. 2000).

Table 3.8: Percentage of *Alosa fallax rhodanensis* from the Rhône (France) spawning one or more times.

Location	Sex	Spawning number						No.	Reference
		1st	2nd	3rd	4th	5th	6th		
Aude	F	62.7	30.5	1.7	1.7	3.4		59	Douchement
(France)	M	87.9	8.8	3.3				91	(1981)
Rhône	F	42.7	29.7	19.0	7.5	0.9	0.2	436	LeCorre *et al.*
(France)	M	64.1	20.1	13.9	1.6	0.3	0.0	302	(1997a)
	F	74.7	14.5	9.6	1.2			152	Douchement
	M	76.8	21.1	0.7	0.7	0.7		83	(1981)

Alosa fallax nilotica

Vukovic (1961a) reported that *Alosa fallax nilotica* can spawn up to eight times. The spawning history of three populations, were the fish have spawned more than once, is shown in Table 3.9.

Table 3.9: Percentage of fish with more than one spawning mark on their scales, for three populations of *Alosa fallax nilotica* (Vukovic, 1961a).

		Spawning number						
Location	Sex	2nd	3rd	4th	5th	6th	7th	8th
Lake Scutari	F & M	20.19	50.98	19.60	8.04	0.39	0.58	0.19
River Neretva	F & M	20.65	48.41	18.25	7.14	5.55		
Lake Bačina	F & M	35.53	40.00	22.25	2.22			

Table 3.6: Percentage of *Alosa fallax fallax* from a number of populations spawning one or more times

Location	Sex	Spawning number								No.	Reference
		1st	2nd	3rd	4th	5th	6th	7th	8th		
River Severn (England)	Female	29.9	27.1	22.6	13.4	5.1	1.6	0.2	<0.1	4868	Aprahamian (1982 & unpubl.)
	Male	23.8	21.0	23.0	17.6	10.8	3.2	0.6		1613	
River Wye (Wales)	Female	56.8	34.6	3.3	2.6	2.0	0.7			153	Aprahamian (1982)
	Male	53.8	25.6	16.7	2.6	1.3				78	
River Tywi (Wales)	Female	3.2	19.4	16.1	51.6	9.7				31	Aprahamian (unpubl.)
	Male			30.0	40.0	30.0				10	
River Barrow (Ireland)	Female	42.9	47.6	9.5						21	O'Maoileidigh (1990)
	Male	21.1	44.7	31.6		2.6				38	
Loire (France)	Female	47.4	37.5	12.3	1.4	1.4				73	Douchement (1981)
	Male	75.9	22.4	1.7						58	
	Female	70.0	21.0	9.0						34	Mennesson-Boisneau & Boisneau (1990)
	Male	54.0	38.0	8.0						26	
Charente (France)	Female	53.5	42.9	3.6						28	Véron *et al*. (2001)
	Male	60.0	40.0							5	
Gironde-Garonne-Dordogne (France)	Female	20.7	67.3	9.8	2.2					92	Taverny (1991a)
	Male	16.3	65.3	18.4						49	
	Female	36.0	44.6	15.1	3.6	0.7				139	Douchement (1981)
	Male	58.2	29.1	10.9	1.8					55	
Adour (France)	Female		52.2	30.4	13.0	4.4				23	Douchement (1981)
	Male		50.0	25.0	25.0					4	
Loukos (Morocco)	Female	100								26	Sabatié (1993)
	Male	100								30	
Sebou (Morocco)	Female	100								152	Sabatié (1993)
	Male	100								205	

Alosa fallax lacustris

Berg (1966a) observed the development of spawning marks on the scales of *A. fallax lacustris* from Lake Maggiore (Italy). For males maturing at age 2, between 75 and 89% formed a spawning mark following spawning. However, as no fish aged 3 were caught they appear to suffer a high post spawning mortality, and may in fact only spawn once. For females age 2, between 43% and 54% had spawning marks, which increased to 87% for those aged three, indicating that females are multiple spawners.

Alosa fallax killarnensis

O'Maoileidigh (1990), for *Alosa fallax killarnensis,* observed fish with at least two spawning marks on their scales (Table 3.10) indicating that fish can spawn up to three times. There is some indication that males may suffer higher post-spawning mortality than females.

Table 3.10: Percentage of *Alosa fallax killarnensis* from Lough Leane (Ireland) spawning one or more times (O'Maoileidigh, 1990).

Location	Sex	Spawning number			No.
		1st	2nd	3rd	
Lough Leane (Ireland)	F	5.6	61.1	33.3	18
	M	14.3	71.4	14.3	35

3.1.4 Mating / Spawning behaviour

Alosa alosa

The spawning activity has been described by Cassou-Leins *et al.* (2000). During the day the fish shelter in groups along the shore or on the bed of the river. At dusk the fish move on to the spawning shoals. During the night the fish come up to the surface. The males and females, half submerged and along side each other swim in a circular motion violently thrashing the surface of the water with their caudal fin, releasing sperm and eggs (Figure 3. 3 & 3.4). The spawning activity lasts between 3 and 10s (Cassou-Leins, 1995) and produces a sound of between 35 and 50 dB at 1m (Cassou-Leins *et al.* 2000). The number of separate spawning activities undertaken by a female was estimated to be between 5 and 7 by Cassou-Leins & Cassou-Leins (1981) and between 10 and 12 by Fatin & Dartiguelongue (1995).

Alosa alosa spawn at night (Couch, 1877; Wheeler, 1978b; Cassou-Leins & Cassou-Leins, 1981; Boisneau *et al.,* 1990; Mennesson-Boisneau & Boisneau, 1990; Fatin & Dartiguelongue, 1995). The time of peak spawning activity was observed by Cassou-Leins & Cassou-Leins (1981) to be between 00:00 and 02:00 (Figure 3.5) and by Boisneau *et al.* (1990) to be from 00:30 to 03:30. Similar findings were also reported by Fatin & Dartiguelongue (1995), who observed little spawning before 01:00 and after 04:00 with the peak of activity between 02:00 and 03:30. In quantitative terms, Cassou-Leins *et al.* (1990) reported that 62.18 ± 3.20% of the spawning activity took place between 0200h and 0400h.

Figure 3.3: ***Alosa alosa*** **congregating for spawing (from Baglinière & Elie, 2000).**

Figure 3.4: The spawning activity (from Baglinière & Elie, 2000).

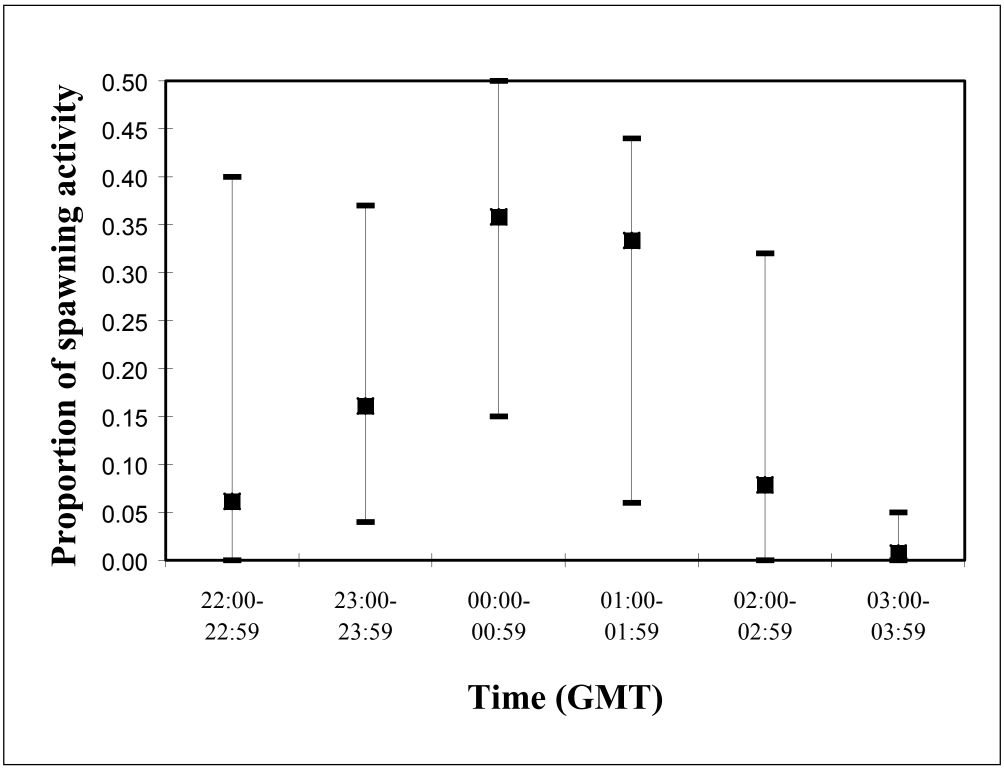


Figure 3.5: Spawning activity of *Alosa alosa* on the Garonne river (France), from Cassou-Leins & Cassou-Leins (1981). Squares represent the mean and dashes the upper and lower limit of the proportion of the spawning activity undertaken each hour between 22:00 and 03:59 (n=8).

Temperature at the onset of spawning has been reported to be in the range of; 15°C to 16°C (Roule, 1922a), 15°C to 18°C (Cassou-Leins & Cassou-Leins, 1981); ≈15°C (Boisneau *et al.,* 1990); 15°C to 25°C (Mohr, 1941); 16°C to 22°C (Phillipart & Vranken, 1982); 17°C to 18°C (Dottrens, 1952); 17°C to 19°C (Duhamel du Monceau, 1772; Roule, 1925), and 18°C (Hoestlandt, 1958). The optimum temperature for spawning was reported by Dottrens (1952) to be 22°C to 24°C. However, Boisneau *et al.* (1990) found that spawning activity was not correlated with temperature but was inversely related to flow, with mean daily flow accounting for 14.8% of the variability in spawning activity.

Cassou-Leins & Carette (1992) observed that spawning activity stopped when flows reached 2.5 ms^{-1} and during heavy night rain.

Alosa fallax fallax

Alosa fallax spawn during the night (Yarrell cited in Day, 1880-84; Couch, 1877; Jenkins, 1942; Wheeler, 1978b; Aprahamian, 1982). Some authors have narrowed down the actual spawning time to between 22:00 and 02:00 (Breder & Rosen, 1966), between 01:00 and 03:00 (Cassou-Leins & Cassou-Leins, unpubl. [in Cassou-Leins *et al.*, 2000]) and others to between 00:00 and 02.00 (Roule, 1922a, Anon., 1979a).

A commotion can be heard whilst the fish are spawning (Aprahamian, 1982; Edwards & Brooker, 1982; LeClerc, 1941; Yarrell cited in Day 1880-84). This has been described as a swishing noise (Jenkins 1942) and as "rushing about on top of the water in the evenings" by Bracken & Kennedy (1967). It is believed that this surface tail splashing of the water is only done by the males (Edwards & Brooker, 1982), and is less violent in *A. fallax* than in *A. alosa* (Quignard & Douchement, 1991b). The spawning activity is relatively brief lasting *c.* 2 to 3s (Cassou-Leins, 1995).

Temperature appears to play an important role in the onset of spawning. Breder & Rosen (1966) and Spillman (1961) have recorded a range of 18°C to 22°C. Wheeler (1978b) states that a drop below 18°C causes spawning to stop, but temperatures below that mark have been noted; 15°C to 16°C in Northern Europe (Svetovidov 1963), 17°C to 18°C in the Seine (Roule, 1925) and 18°C to 20°C in the Rhine (Redeke, 1939).

Alosa fallax rhodanensis

The spawning activity is relatively short lasting around 2 to 5 s (Cassou-Leins, 1995; Le Corre *et al*., 1999b) and in most instances (>70%) involves only one partner (Le Corre *et al*., 1999b; Genoud 1999b, 2001). The fish assemble on the spawning grounds between 2230 and 2300h. Spawning takes place between 2300h and 0300h on the River Rhône, France, (Le Corre *et al.,* 1999b; Roure *et al.,* 1997a) with peak activity being between 2300 and 0200h (Le Corre *et al*., 1999b; Genoud, 2001). In the Aude spawing occurs between 0000 and 0500h with maximum activity between 0200 and 0400h (Cassou-Leins, 1995). Similar findings, of fish spawning at night, were reported by D'Ancona (1926) from the River Tiber.

In the River Rhône (France) *A. fallax rhodanensis* have been reported to spawn within the temperature range 16°C to 18°C (Roule, 1922a, 1925), 17°C to 19°C (Gallois, 1946a, 1947b), 17°C to 22°C (Genovel, 2001), 18°C to 20°C (Le Corre *et al.,* 1997b; Roure *et al.,* 1997a), 18°C to 24°C (Rameye *et al.,* 1976) and at 20.5°C (Hoestlandt, 1947). Spawning activity was not correlated with flow, lunar cycle or turbidity but was negatively correlated with rain and wind (Le Corre *et al.,* 1999b; Roure *et al.,* 1997a). In the Tiber, spawning takes place once water temperatures are between 22°C and 25°C (D'Ancona, 1926, Svetovidov, 1963).

Alosa fallax nilotica

Relatively little information exists only that spawning takes place once water temperatures are between 18°C and 22°C (Vukovic, 1961a).

Alosa fallax lacustris

Spawning occurs at night between 22:00 and 03:00 in water temperatures ranging from 18.8°C to 19.8°C (**Dottrens, 1952**).

3.1.4.1 Sex ratio

The sex ratio of three year-classes of *Alosa alosa* from the Gironde-Garonne-Dordogne (France) at maturity was estimated by Lambert *et al*. (2001) to range from 43.2% to 59.1% male. (The sex ratio of the mature population is dealt with in section 4.1).

3.1.4.2 Induction of spawning.

The induction of spawning is discussed in section 7 (Culture).

3.1.5 Fertilisation

Fertilisation is external, eggs and sperm being broadcast into the water column.

3.1.6 Gonad development and fecundity.

3.1.6.1 Coefficient of fecundity

Alosa alosa

The gonad somatic index (gonad weight*100/somatic weight) for females from the Douro (Portugal) increased during the migration period from a mean of 8.40-9.31% to 9.80-10.13% and for males from 4.71-4.84 to 5.19-6.02% (Eiras, 1981b). In the Sebou the index for the males was similar (4.06 to 6.80%) while for females the index (mean ± 95%CI) at the start of the migration was lower 2.48 ± 7.88%, increasing steadily to 12.66 ± 5.07% at the end of the period (Sabatié, 1993). In the Loire the index for females varied between 6.0 and 17.8% with a mean of 12.2%, and in the Gironde-Garonne-Dordogne system from 9.1 to 22.5% with a mean of 15.0% (Douchement, 1981). For both male and female fish from the Douro the gonad somatic index was higher for fish on the spawning ground when compared with those in the estuary, by between 0.25 and 1.99% for males and 1.90 to 4.23% for females (Eiras, 1981b).

Alosa fallax fallax

For anadromous populations of *A. fallax fallax* the mean (± 95%CI) weight of the ovary as a percentage of somatic weight was 20.6% (± 0.87) in the Loire, 27.8% (± 1.02) in the Gironde-Garonne-Dordogne system and 24.7% (± 1.48) in the Adour (Douchement, 1981). In the Sebou the mean index declined from 16.4% (± 4.56) at the start of the migration period to 8.6% (± 4.55) at the end (Sabatié, 1993). In the Severn the mean index for female *A. fallax*, over a seven year period varied from 13.8% (± 0.48) to 17.3% (± 0.77) (Aprahamian, unpubl.). For males from the Severn the gonad somatic index ranged from 8.8 ± 0.5 to 10.3 ± 0.5 over the same period.

Alosa fallax rhodanensis

In the rivers Aude and Rhône (France) the mean gonad-somatic index declined from a pre-spawning level of 15.2% and 16.5% to 3.3% and 1.3% post-reproduction for females and from 6.4% and 7.1% to 1.8% and 0.5% for males, respectively (Douchement, 1981).

Alosa fallax algeriensis

For mature fish, the ovaries constitute 13.80% (mean) with a maximum of 23.83% of somatic weight (Kartas, 1991).

3.1.6.2 Description and development

The biochemical changes associated with the final stages of maturation are reported in the Section 3.5.1 (Adult spawning migration). This section deals with the histology of the gonads and the maturation process.

Alosa alosa

The histology and maturation of the ovaries has been described by Bengen *et al.* (1991), Bengen (1992), Eiras (1981b), Lahaye (1960a, 1961, 1962a&b), Lahaye *et al.* (1963) and by Sabatié (1993). Oocyte development can be classified into six stages; oogenesis, primary oocyte growth, cortical aveolus stage, vitellogenesis, maturation and ovulation (Bromage & Cumaranatunga, 1988). Within the ovary, oocyte development is not synchronous, oocytes passing through a number of the phases simultaneously.

At sea, approximately six months prior to spawning the oocytes range in size from 83 to 166µ. The primary oocyte contains a distinct yolk nucleus (germinal vesicle), Balbiani body (a complex of cytoplasmic organelles which include mitochondria, multivesicular bodies, endoplasmic reticulum and Golgi elements (Tyler & Sumpter, 1996)), and an acellular vitelline envelope (zona radiata) around the oocyte. Present at the periphery of the nucleus, situated on the nuclear membrane, are numerous nucleoli. At this stage the nucleus represents 45% of the volume of the oocyte (RNP ratio). As the oocyte grows the zona radiata thickens and becomes surrounded by granulosa (follicle) and theca cells (Table 3.11), the latter layers being separated by a basal membrane.

Table 3.11: Change in thickness of the zona radiata and granulosa and theca cells associated with oocyte maturation in *Alosa alosa* (Bengen, 1992).

Stage of development	Oocyte Diameter (µ)	Zona radiata (µ)	Granulosa layer (µ)	Thecal cells (µ)
Primary oocyte	< 120		2 - 2.5	
Cortical aveolus	400 - 900	3 - 4	3 - 5	1 - 2
Vitellogenesis	900 - 1400	12 - 31	5 - 7	2 - 4
Mature	1400 - 1800	17 - 23	15 - 18	4 - 7

As the oocyte develops, cortical aveoli (15 to 40µ in diameter) develop within the cell. These structures contain a polysialoglycoprotein (Tyler & Sumpter, 1996). Eventually the cortical aveoli come to fill the entire cytoplasm of the oocyte. During this phase lipid bodies (3 to 10µ in diameter) appear in the oocyte, coinciding with the appearance of the yolk vesicles (the orange colour being attributable to the carotenoid pigments in the lipid component of the vitellogenin (Tyler & Sumpter, 1996)). During the vitellogenic phase, vitellogenin is sequestered into the cell and accumulates in globules (yolk vesicles), measuring 10 to 35µ in diameter. The yolk vesicles eventually completely fill the oocyte, displacing the cortical alveoli towards the periphery. As the oocyte matures the RNP Ratio decreases to 25% and finally stabilises at around 15%. The final stages of maturation are characterised by the fusion of the yolk vesicles, resulting in the formation of a continuous mass of yolk, and the up take of water by the oocyte. The hydration phase results in the eggs becoming translucent and an increase in diameter of approximately 30% from 1200-1500μ to 1700-1800μ. Just before ovulation the oocyte becomes separated from the granulosa and thecal cells.

The reported size range of eggs before and after water absorption are shown in Table 3.12. Some of the differences may be associated with stock differences, but may also relate to the stage in the reproductive cycle that the measurements were taken. Lahaye *et al.* (1963) showed that the modal size of eggs increased from 400μ three to four months before spawning, to 650μ one month prior to spawning (Figure 3.6).

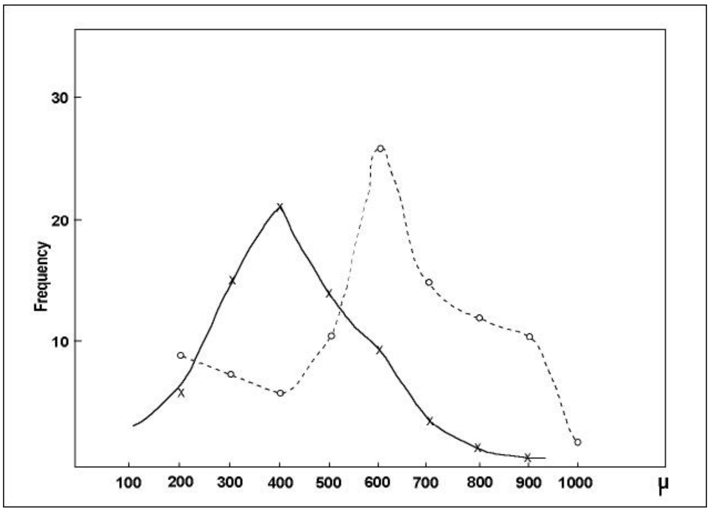


Figure 3.6: Interovarian egg size in *Alosa alosa* three to four months (solid line) and one month (dashed line) prior to spawning (Redrawn from Lahaye *et al.*, 1963).

Bengen *et al.* (1991) also observed a gradual increase in inter-ovarian egg size, from a modal value of 0.6 to 1.0 mm at the start of freshwater phase of their spawning migration in April, to c. 1.4 to 1.8 mm in June and July (Figure 3.7).

Table 3.12: Size of eggs of *Alosa alosa* before and after hydration.

Size before hydration (mm)	Size after hydration (mm)	Reference
0.3-1.4		Sabatié (1993)
0.3-1.5		Cassou-Leins & Cassou-Leins (1981)
0.99 ± 0.01 ($\bar{x} \pm$ 95CI)		Taverny (1991a)
1.0		Mohr (1941)
1.5	4.5	Duncker & Ladiges (1960)
1.5-1.6	4.2-4.6	Ehrenbaum in Cunningham (1896)
1.5-1.8	3.0-3.6	Roule (1925)
1.8	2.5	Hoestlandt (1958)
2.0		Vincent (1894a); Dottrens (1952)
	4.0-5.0	Maitland (1972)

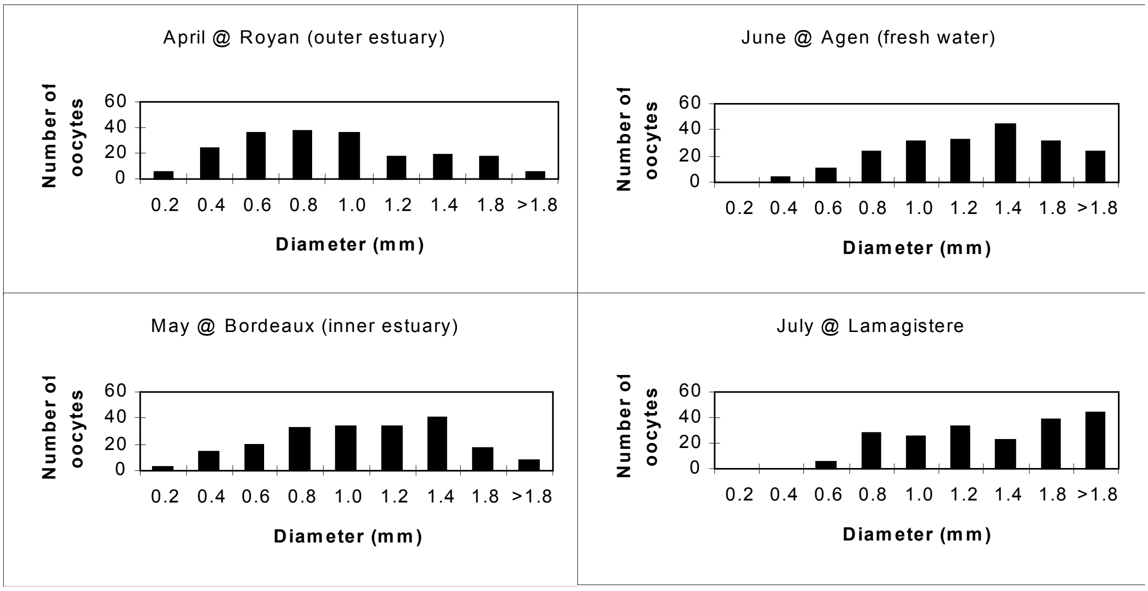


Figure 3.7: The change in oocyte diameter of *Alosa alosa* from the Garonne (France) in relation to maturation, redrawn from Bengen *et al. (1991)*

Part of the difference may also depend on whether fresh or preserved material was studied. If measurements were made on the latter, then a shrinkage of about 7% might be expected (Hiemstra, 1962).

Alosa fallax

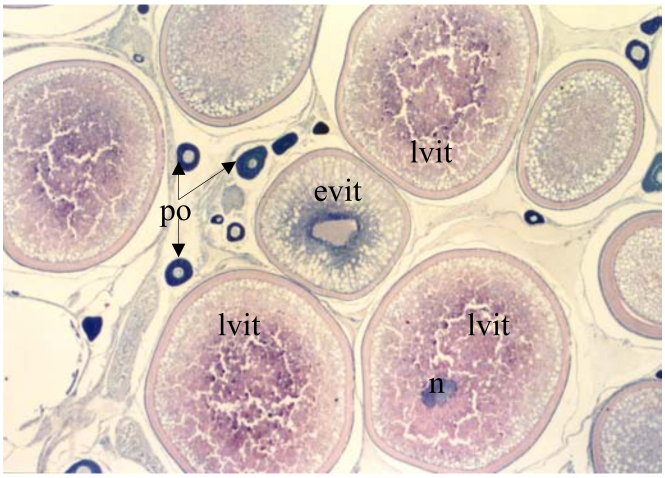
The development and growth of the eggs of *Alosa fallax fallax* has been described by Lahaye (1962c), Lahaye *et al.* (1963), Sabatié (1993) and by Pina (2000), and of the sperm by Pina (2000). The structure of the ovary and testis for fish close to spawning are shown in Figure 3.8 a-c. Eight maturity stages have been described (Table 3.13 a&b). Lahaye (1962c) mentions that the development of the oocytes in *A. fallax* is similar to that described for *A. alosa* with a number of important differences:

1.The cortical alveoli in *A. fallax* are larger (>30µ compared with <20µ in an oocyte 600µ in diameter) and the contents more homogenous. In *A. alosa* the cortical alveoli at the periphery are small (10µ) compared with those at the centre.

2. The lipoproteins appear earlier in the developmental process in *A. fallax*, being present in oocytes of 350µ compared with oocytes of 500µ for *A. alosa*.

3.The thickness of the envelope (zona radiata, granulosa and thecal cells) is 25µ in *A. fallax* compared with 35µ for *A. alosa.*

In *Alosa fallax* there exist two populations of developing oocytes; a population of primary oocytes and a population of larger oocytes from which the current batch of eggs develop (Aprahamian, 1982; Sabatié, 1993; Pina, 2000). In pre-spawning *Alosa fallax*



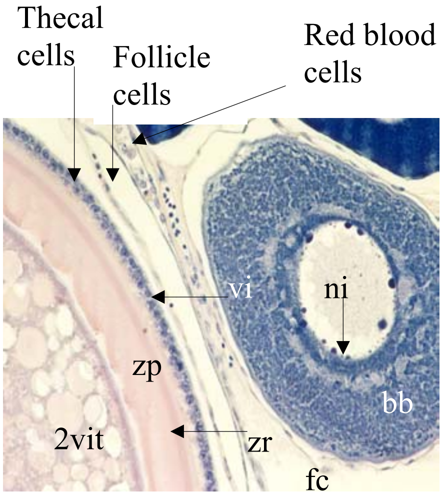


Figure 3.8a: Late vitellogenic female *Alosa fallax* ovary, showing numerous late vitellogenic oocytes (lvit) and early-mid stage vitellogenic oocyte (evit), interspersed with several primary oocytes (po). Nucleus (n), Mayer's Haematoxylin & Eosin x40.

Figure 3.8b: Transverse section through a secondary oocyte and a primary oocyte to illustrate the formation and development of the "egg shell" or chorion. The primary (balbiani body stage) oocyte (bb) is surrounded by a single layer of follicle cells (fc), whereas the more advanced (secondary) vitellogenic ooctye (2vit) is surrounded by a chorion composed of; zona pellucida (zp), zona radiata (zr), villi (vi), thecal cells (te) and follicle cells (fc), Nucleoli can be clearly seen on the periphery of the nucleus of the primary oocyte, Mayer's Haematoxylin & Eosin x400.

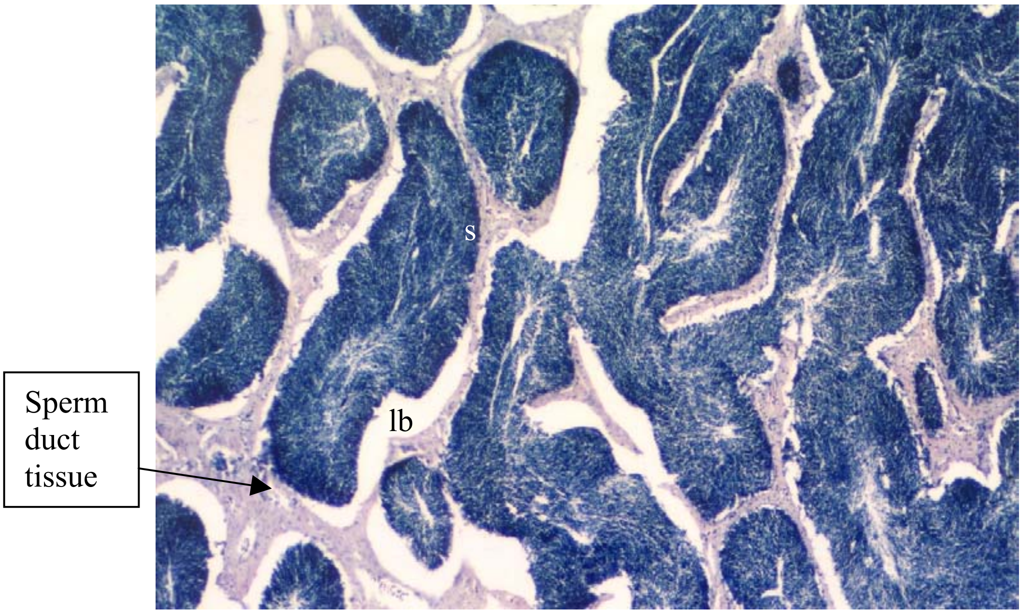
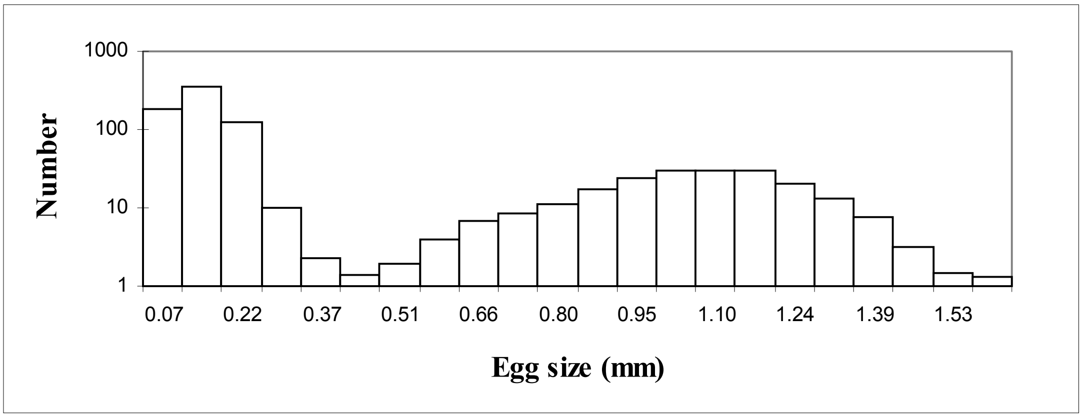


Figure 3.8c: Transverse sections through the testes of *Alosa fallax*, illustrating normal testicular organisation during the later stages of the reproductive cycle (stage IV-V). Histologically, the testes of shad are of a lobular type, in which the connective tissues divide stroma into a complex network of tightly packed lobules, each comprised of numerous cysts Fully mature shad testes at spermiation showing enlargement of the lobules (lb) and loss of cysts. Spermatozoa (s), Mayer's Haematoxylin & Eosin x100.

the larger size group of oocytes contained yolk and were shed during spawning (Figure 3.9) [Aprahamian, 1982]. Eggs in the smaller size group were white and irregularly shaped. The size which effectively separates the two populations of eggs was 0.44 mm in the Severn (Aprahamian, 1982), 0.20 mm in the Mira (Pina, 2000) and 0.166 mm in the Sebou (Sabatié, 1993).

The reported size range of eggs before and after water absorption is shown in Table 3.14. For fish close to spawning, Sabatié (1993) observed three modes of egg size at 0.90, 1.41 and 2.08 mm, indicating that *A. fallax* are asynchronous ovulators, eggs ripening progressively with spawning taking place in batches.

A)



B)

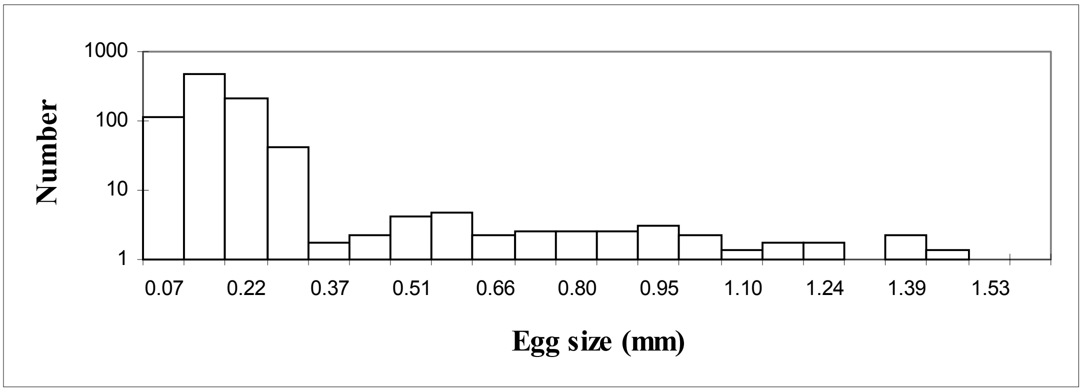


Figure 3.9: A&B. Interovarian egg size in prespawning (A) and postspawning (B) *Alosa fallax fallax* from the R. Severn (England) (Aprahamian, 1982).

Table 3.13a: – Macroscopic characteristics and histological description of the maturity stages of the ovary of *Alosa fallax fallax* (Pina, 2000).

Maturity stage	Macroscopic description	Histological description
I. Immature/ II. Resting (*)	Small thread-like ovary, pinkish in colour, no oocytes visible	Well spaced ovigerous fold, orientated towards the centre of the ovary, containing both oogonia and chromatin nucleolus and early perinucleolus stage; oogonia generally occur in nests. Oocyte size 0.01-0.04 mm (I); 0.01-0.06 mm (II)
III.Early development	Ovaries one-third of ventral cavity, yellowish in colour, opaque oocytes visible through the tunica	Oogonia still present, ovigerous folds fill cavity, late perinucleolus and cortical alveoli oocytes present Oocyte size 0.04-0.64 mm
IV. Maturing	Ovaries two-thirds of ventral cavity, yellowish in colour, opaque and translucent oocytes visible, increasing vascularization	Cortical alveoli and yolk granule oocytes predominate; late perinuceolus and vitologenic oocytes can also be observed. Oocyte size 0.03-1.106 mm
V. Ripe	Ovaries highly vascularized occupy most of ventral cavity, opaque, translucent and dominant hyaline oocytes visible	Oocytes observed in previous stage still present; predominance of GVM stage oocytes. Oocyte size 0.03-1.052 mm.
VI. Spawning	Ovaries occupying most of ventral cavity, eggs released under slight pressure of the abdomen	Predominance of GVM oocytes and POFs. Oocyte size 0.03-1.211 mm.
VII. Partially spent	Ovaries flaccid, deep red in colour, occupying two-third of ventral cavity, with hyaline oocytes visible	Irregular convoluted ovigerous folds, conspicuous spaces in the septa and POFs in the lumen, early perinucleolus and atresia oocytes present. Oocyte size 0.04-1.319 mm.
VIII. Spent	Ovaries flaccid and fully empty, a few residual oocytes visible	Ovigerous folds reorganizing, containing atretic follicles and perinucleolus oocytes. Oocyte size 0.04-1.415 mm.

Table 3.13b: – Macroscopic characteristics and histological description of the maturity stages of the testis of *Alosa fallax fallax* (Pina, 2000).

Maturity stage	Macroscopic description	Histological description
I. Immature/ II. Resting (*)	Small thread-like testis, transparent and prismatic with triangular section	Primary spermatogonia occupying the germinal epithelium, seminiferous tubules not well evident
III.Early development	Flattened and grey testis increasing in length and width, one fourth of body cavity	Seminiferous tubules now evident, interstitial tissues thick, secondary spermatogonia in the tubules and primary spermatocytes in the lumen
IV. Maturing	Testis occupying two-thirds of ventral cavity, increasing vascularization	Interstitial tissue and seminiferous tubules still clearly visible, spermatogonia near the tubule wall ; primary spermatocytes, secondary spermatocytes and spermatids closer to the lumen ; some spermatozoa might occur
V. Ripe	Testis pinkish very firm texture fill almost entire ventral cavity, with star-like figures clearly visible	Spermatozoa increasing in number, initially occurring in cysts are released in the lumen ; younger stages occur near the tubule wall
VI. Spawning	Milt runs from the genital pore on slight pressure, testis turgid and large ammoounts of milt are produced when they are dissected	Spermatozoa fill the entire seminiferous tubules ; the sperm heads are tightly packed and arranged spirally
VII.Partially spent	Testis flacid occupying two-thirds of ventral cavity, milt is often present in the seminiferous duct	Spermatozoa still present in the seminiferous tubules ; tubule walls thicker from the cortex to the medula ; no other germ cell stages present
VIII. Spent	Testis very flaccid with dark areas throughout the surface, occupying one-third of ventral cavity	Interstitial tissue unevenly thick ; spermatogonia near the tubule walls and residual spermatozoa in the lumen on empty tubules ; tubules start to reorganize

* *Stage I and Stage II have similar macroscopic and histological characteristics but are distinguished by length at first maturity.*

Aprahamian (1982) found a positive correlation between egg size and fish size. The study of fecundity of *Alosa fallax* from the River Severn involved separating the eggs into three size classes; 0.5-0.7 mm, 0.7-1.0 mm and >1.0 mm, and summing the number in each size category to determine the overall fecundity. Figure 3.10 shows that the proportion of eggs >1.0 mm in diameter increased significantly with the size of fish.

Table 3.14: Size of eggs of *Alosa fallax fallax* before and after hydration.

Size before hydration (mm)	Size after hydration (mm)	River, Country	Reference
<0.7-1.8		Nyamunas, Lithuania	Manyukas (1989)
0.72	1.5	Elbe, Germany	Jenkins (1902)
0.8-2.3		Sebou, Morocco	Sabatié (1993)
1.0		Morocco	Lahaye (1962c)
1.01 ± 0.02[1]		Gironde-Dordogne-Garrone, France	Taverny (1991a)
	1.68-2.41	Mira, Portugal	Esteves (pers. comm.)
1.01 ± 0.03[1]	2.67 ± 0.03[1]	Severn & Wye, Britain	Aprahamian (1982)
1.1[2] (0.4-1.6)		Barrow, Ireland	O'Maoileidigh (1990)
1.2-1.5			Spillman (1961)
1.5		Seine, France	Vincent (1894b)
1.5-1.6	4.2-4.6	Elbe, Germany	Ehrenbaum (1894)
1.5-1.8	3.0-3.6		Roule (1925)
1.6			Mohr (1941)
1.6	2.0-3.0	Rhine, Germany	Redeke (1939)
	3.85	Elbe, Germany	Hass (1968)
	4.0-5.0		Maitland (1972)
	4.5		Cunningham (1896)

[1] Mean ± 95% confidence intervals;
[2] Mode

Alosa fallax rhodanensis

The diameter of eggs of *Alosa fallax rhodanensis* has been reported for relatively few fish. For one female eggs ranged in size from 0.8 to 1.20 mm with a mean size of 1.02 mm (Gallois, 1946a) and of another from 0.8 to 1.85 mm (Hoestlandt (in Gallois, 1946a)). Prior to hydration the eggs have a diameter of 1.7 and 1.85 mm, and following water absorption their diameter increases to 2.4 mm (Hoestlandt, 1947; Hoestlandt (in Gallois, 1946a)). Chiappi (1933a) reported a slightly larger size, with a fertile egg having a mean diameter of 2.9 mm.

Alosa fallax nilotica

Vukovic (1961a) found that fertile eggs of *Alosa fallax nilotica* maintained in an aquarium, ranged in size from 2.9 to 3.1 mm in diameter which compares closely with those eggs collected from the substrate of Lake Bačina of 2.7mm.

Alosa fallax lacustris

The average size of eggs of *Alosa fallax lacustri*s, following water absorption, was 2.6 mm from Lake Vico (Chiappi, 1933a), 2.0 mm from Lake Como (Pirola, 1930) and 1.5 mm from lakes Lugano and Maggiore (Fatio, 1890).

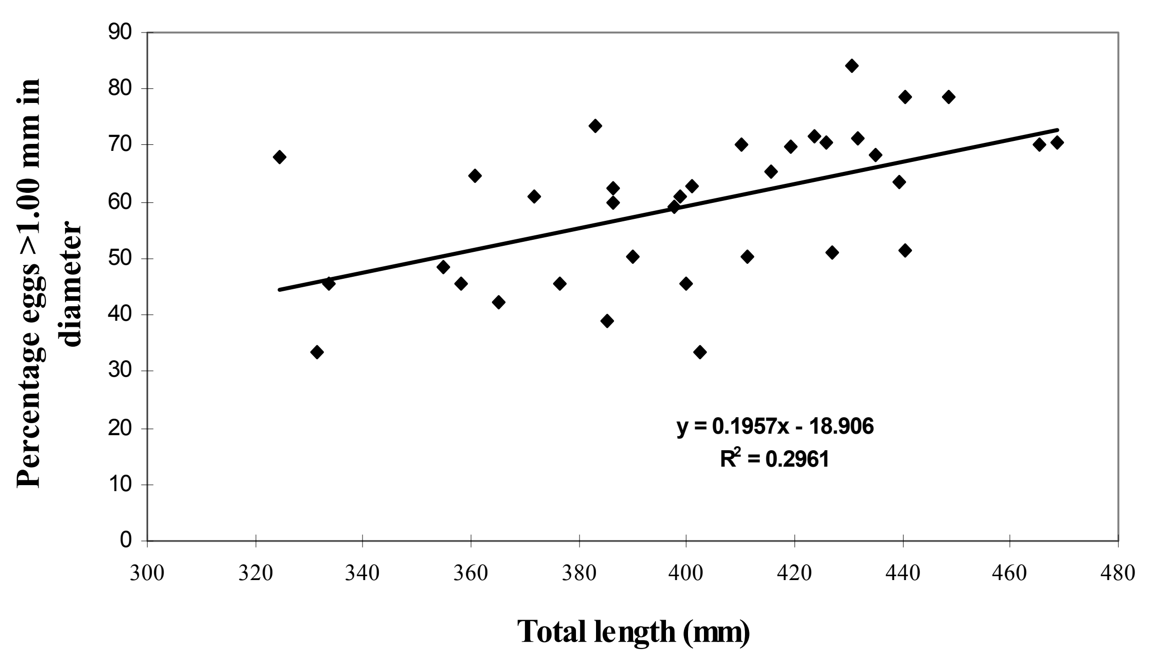


Figure 3.10: The relationship between egg size (percentage of eggs >1.00 mm in diameter) and length (total) of *Alosa fallax fallax* from the River Severn (Aprahamian, 1982).

Alosa fallax killarnensis

The interovarian egg size of *Alosa fallax killarnensis* ranged from 0.3 to 1.33mm in diameter (Figure 3.11). Eggs of <0.5mm were irregularly shaped and pale in colour and represented recruitment eggs for the following year (O'Maoileidigh, 1990). Eggs ranging between 0.5 and 1.33mm, with a modal size of 0.9mm in diameter were orange or yellow in colour and were shed during spawning. Egg size was not correlated with either length or weight.

3.1.6.2 Fecundity and egg size

The comparison and interpretation of some of the data is complicated by the fact that in some of the studies it was not clear whether the estimate of fecundity was based on the total number of eggs (primary oocytes and those going through vitellogenesis) or on just the number of ripe eggs. Except for the study of Sabatié (1993) who provided estimates of both total and absolute fecundity it has been assumed that the authors have estimated absolute fecundity, defined as the number of ripe eggs in the ovaries prior to the next spawning period (Bagenal & Braum, 1978). Similarly in the majority of cases no information was provided on the method used to estimate fecundity. Where the methods have been described the estimates have been based on volume (Cassou-Leins & Cassou-Leins, 1981; Dautrey & Lartigue, 1983; Sabatié, 1993), weight (Eiras, 1981b; Aprahamian, 1982; Pina, 2000) or stereological analysis (Pina, 2000). Pina (2000) compared the histological and gravimetric methods and reported that fecundity estimated using histology was approximately 3 times (2.98 ± 0.30) that based on weight. Sub-sampling to improve the precision of the estimate has been reported in a few studies. Where this has been reported it has ranged from three (Sabatié, 1993) to 12; four from each of three size classes; 0.5-0.7mm, 0.7-1.0mm and >1.0mm (Aprahamian, 1982). In the case of the latter the precision of the method was estimated to be ± 6.26% with 95% confidence.

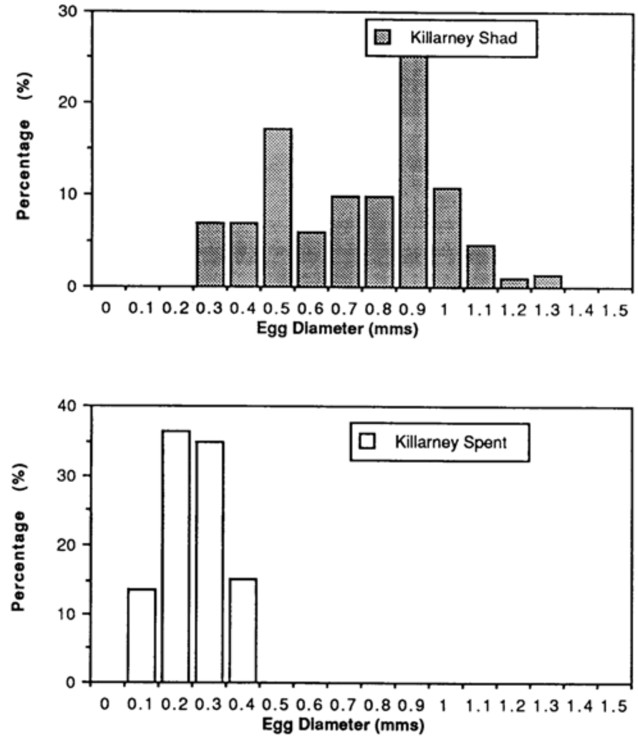


Figure 3.11: Interovarian egg size for pre-spawning and spent *Alosa fallax killarnensis* from Lough Leane, Ireland; for pre-spawning fish only eggs >0.3mm were counted (Reproduced from O'Maoileidigh, 1990).

Alosa alosa

In *Alosa alosa* the absolute fecundity has been reported to range from 50,000 to 636,000 eggs (Hoek, 1888; Fatio, 1890; Vincent, 1894c; Roule, 1925; Dottrens, 1952; Hoestland, 1958**;** Spillman, 1961; Rameye *et al.,* 1976; Cassou-Leins & Cassou-Leins, 1981; Eiras, 1981b; Philippart & Vranken, 1982; Dautrey & Lartigue, 1983; Sabatié, 1993).

The relative fecundity, defined as the number of eggs per kilogram total weight, has ranged from 60,000 egg kg^{-1} in the Sebou, Morocco (Sabatié, 1993) to 236,000 egg kg^{-1} in the Garonne river, France (Cassou-Leins & Cassou-Leins, 1981) [Table 3.15]. There is an indication of an increase in relative fecundity with increasing latitude from *c.* 60,000 in Morocco to *c*. 200,000 in the Loire (Table 3.15).

Table 3.15: The relative fecundity (Mean ± 95CI) of populations of *Alosa alosa.*

River (Country)	Eggs per kg total weight	No.	Reference
Loire (France)	233,400[1]	26	Mennesson-Boisneau, Boisneau & Sabatié (unpubl.)
Gironde-Garonne-Dordogne (France)	125,000 156,600 236,316 ± 17,799 104,325 ± 8,070	>200 30 25 74	Hoestland (1958) Dautrey & Lartigue (1983) Cassou-Leins & Cassou-Leins (1981) Taverny (1991a)
Douro (Portugal)	79,910 ± 12,727	27	Eiras (1981b)
Sebou (Morocco)	59,560[2] ± 3,117 76,780[3] ± 2,807	25	Sabatié (1993)

[1] Eggs per kg somatic weight; [2] Number of oocytes ≥ 166μ; [3] Total number of oocytes.

The relationship between fecundity and size (Table 3.16) has been determined for populations in the Gironde-Garonne-Dordogne system (France), the River Douro (Portugal) and the River Sebou (Morocco). Significant correlations existed between absolute fecundity and length, weight and ovarian weight. In the River Douro the relationship between fecundity and ovarian weight was not examined (Eiras, 1981b).

Table 3.16: The relationship between fecundity and fish size for *Alosa alosa.*

A) Length

River (Country)	Fecundity - Total Length (cm)	No.	r^2	Reference
Gironde-Garonne-Dordogne (France)	$F = -2.71.10^5 + 7.97.10^3 L_t$	76	0.114	Taverny (1991a)
Douro (Portugal)	$F = 3.72.10^{-2} L_t^{3.72}$	27	0.391	Eiras (1981b)
Sebou (Morocco)	$F = 2.28.10^{-4} L_t^{4.92}$	25	0.152	Sabatié (1993)

B) Weight

River (Country)	Fecundity - Total weight (g)	No.	r^2	Reference
Gironde-Garonne-Dordogne (France)	$F = 6.41.10^4 + 59.78 W_t$	73	0.155	Taverny (1991a)
Douro (Portugal)	$F = -6.52.10^4 + 1.07.10^2 W_t$	27	0.332	Eiras (1981b)
Sebou (Morocco)	$F = -1.72.10^5 + 1.13.10^2 W_t$	25	0.237	Sabatié (1993)

C) Ovarian weight

River (Country)	Fecundity - Ovary weight (g)	No.	r^2	Reference
Gironde-Garonne-Dordogne (France)	$F = 1.14.10^5 + 2.85.10^2 OW_t$	74	0.139	Taverny (1991a)
Sebou (Morocco)	$F = -3.79.10^3 + 5.78.10^2 OW_t$	25	0.195	Sabatié (1993)

The relationship between fecundity and age was examined by Taverny (1991a) for *Alosa alosa* from the Gironde-Garonne-Dordogne system (France). A comparison of the fecundity of fish aged between 5 and 6 years indicated that there was no significant difference ($P>0.05$) in either absolute or relative fecundity between the two age groups.

No information was found on the fecundity of landlocked populations of *Alosa alosa*.

Alosa fallax fallax

The absolute fecundity of *Alosa fallax fallax* has been reported to range from 25,942 to 675,000 eggs (Vincent, 1894b&c; Jenkins, 1902; Bounhiol, 1917; Hass, 1965; Manyukas, 1989; Aprahamian, 1982; Dautrey & Lartigue, 1983; Taverny, 1991a; Sabatié, 1993; Pina, 2000). The relative fecundity for an individual fish has been reported to range from 42,540 to 403,562 egg kg^{-1} (Vincent, 1894b; Manyukas, 1989; Aprahamian, 1982; Taverny, 1991a; Sabatié, 1993; Pina, 2000). The mean relative fecundity for four anadromous populations of *A. fallax* is shown in Table 3.17.

Table 3.17: The relative fecundity (Mean ± 95CI) of populations of *Alosa fallax fallax.*

River (Country)	Eggs per kg total weight	No.	Reference
Severn (England)	139,479 ± 10,435	35	Aprahamian (unpubl.)
Gironde-Garonne-Dordogne (France)	147,378 ± 19,272	35	Taverny (1991a)
Mira (Portugal)	403,562[1] ± 55,162 142,848[2] ± 26,225	14	Pina (2000)
Sebou (Morocco)	86,700[3] ± 3,206 103,270[4] ± 5,881	31	Sabatié (1993)

[1] Stereological estimate; [2] Gravimetric estimate (number of oocytes ≥ 200µ);
[3] Number of oocytes ≥ 166µ; [4] Total number of oocytes.

The population of *A. fallax fallax* showing the greatest fecundity was from the Guadiana River where the number of eggs ranged from 101,878 to 673,533, followed by the River Mira (110,669 - 445,051) (Pina, 2000) and the Nyamunas River (83,900 – 362,700) (Manyukas, 1989). However, direct comparisons are difficult as the estimate of fecundity for the Portuguese population was through stereological analysis and the estimate is approximately three times greater than that based on weight (Pina, 2000).

A significant relationship between fecundity and size (Table 3.18) has been determined for a number of populations. The relationships for the Nyamunas River which drains into the Kurshskiy Bay (Manyukas, 1989) and the River Elbe (Hass, 1965) have been derived from mean values. In the latter case data was only available for the relationship between fecundity and total length. All the studies, except that of Taverny (1991a) found a significant relationship between fecundity and length and with the exception of Manyukas (1989) all observed a significant relationship between total weight and ovarian weight.

Table 3.18: The relationship between fecundity and fish size for *Alosa fallax fallax.*

A) Length

River (Country)	Fecundity - Total Length (cm)	No.	r^2	Reference
Severn (England)	$F = 1.31L_t^{3.00}$	35	0.506	Aprahamian (1982)[1]
Nyamunas (Lithuania)	$F = - 4.28.\ 10^5 + 1.3.10^4\ L_t$	26		Manyukas (1989)[2]
Elbe (Germany)	$F = 1.25.\ 10^{-2}L_t^{4.22}$	19		Hass (1965)
Mira (Portugal)	$F = 2.04.\ 10^2L_t^{.1.93}$	47	0.295	Pina (2000)
Guadiana (Portugal)	$F = 1.55.\ 10^2L_t^{2.05}$	38	0.213	Pina (2000)
Sebou (Morocco)	$F = 1.72.10^{-5}L_t^{5.97}$	31	0.388	Sabatié (1993)

[1] Fork length (L_f) converted to total length (L_t) using $L_t = 1.13\ L_f + 0.353$ (Douchement, 1981).
[2] Calculated from mean values; standard length (L_s) converted to total length (L_t) using $L_t = 1.19\ L_s + 0.594$ (Douchement, 1981).

B) Weight

River (Country)	Fecundity - Total weight (g)	No.	r^2	Reference
Severn (England)	$F = 1.82.10^2 W_t^{0.96}$	35	0.620	Aprahamian (1982)
Gironde-Garonne-Dordogne (France)	$F = 1.25.10^2 W_t^{0.98}$	35	0.268	Taverny (1991a)
Mira (Portugal)	$F = 9.77.\ 10^2 W_t^{.0.87}$	47	0.490	Pina (2000)
Guadiana (Portugal)	$F = 4.79.\ 10^2 W_t^{0.99}$	38	0.405	Pina (2000)
Sebou (Morocco)	$F = -3.34.10^4 + 1.44.10^2 W_t$	31	0.494	Sabatié (1993)

C) Ovarian weight

River (Country)	Fecundity - Ovary weight (g)	No.	r^2	Reference
Severn (England)	$F = 6.61.10^3 OW_t^{0.59}$	35	0.580	Aprahamian (1982)
Gironde-Garonne-Dordogne (France)	$F = 3.30.10^3 OW_t^{0.66}$	35	0.535	Taverny (1991a)
Mira (Portugal)	$F = 2.19.\ 10^4 OW_t^{.0.25}$	47	0.542	Pina (2000)
Guadiana (Portugal)	$F = 1.91.\ 10^4 OW_t^{0.27}$	38	0.345	Pina (2000)
Sebou (Morocco)	$F = -1.62.10^4 + 1.10.10^3 OW_t$	31	0.494	Sabatié (1993)

D) Age

River (Country)	Fecundity - Age (year)	No.	r^2	Reference
Severn (England)	$F = 3.55.10^4 A^{0.52}$	35	0.098	Aprahamian (1982)
Nyamunas (Lithuania)	$F = 3.02.10^4 A^{1.04}$	26		Manyukas (1989)[3]

[3] Calculated from mean values.

Information on age was only available for the populations in the River Severn and the Nyamunas River, both of which showed a significant relationship between fecundity and age. However, for fish from the Gironde-Garonne-Dordogne river system, the inclusion of age in a multiple regression relating fecundity to length (total) and weight (total) did not significantly improve the relationship (Taverny, 1991a).

There are few studies relating fecundity to spawning history. On the Elbe Jenkins (1902) observed that those fish spawning for a second time had a higher fecundity than those spawning for the first time. Similarly on the Severn Aprahamian (unpubl.) found a significant correlation ($P<0.05$) between fecundity and number of spawnings ($r^2 = 0.114$).

Aprahamian (1982) examined the effect of using more than one independent variable to estimate fecundity for fish from the River Severn. Of the four variables tested, total weight and age accounted for a significant proportion of the variability (61.9% and

13.1% respectively). The inclusion of total length and spawning history did not significantly improve the relationship.

The relationship between fecundity and length for the various populations of *A. alosa* and *A. fallax fallax* is presented in Figure 3.12. The Gironde-Garonne-Dordogne *A. alosa* population appears the most fecund when compared to those from the Douro and Sebou. The latter populations showed a very similar fecundity to size relationship.

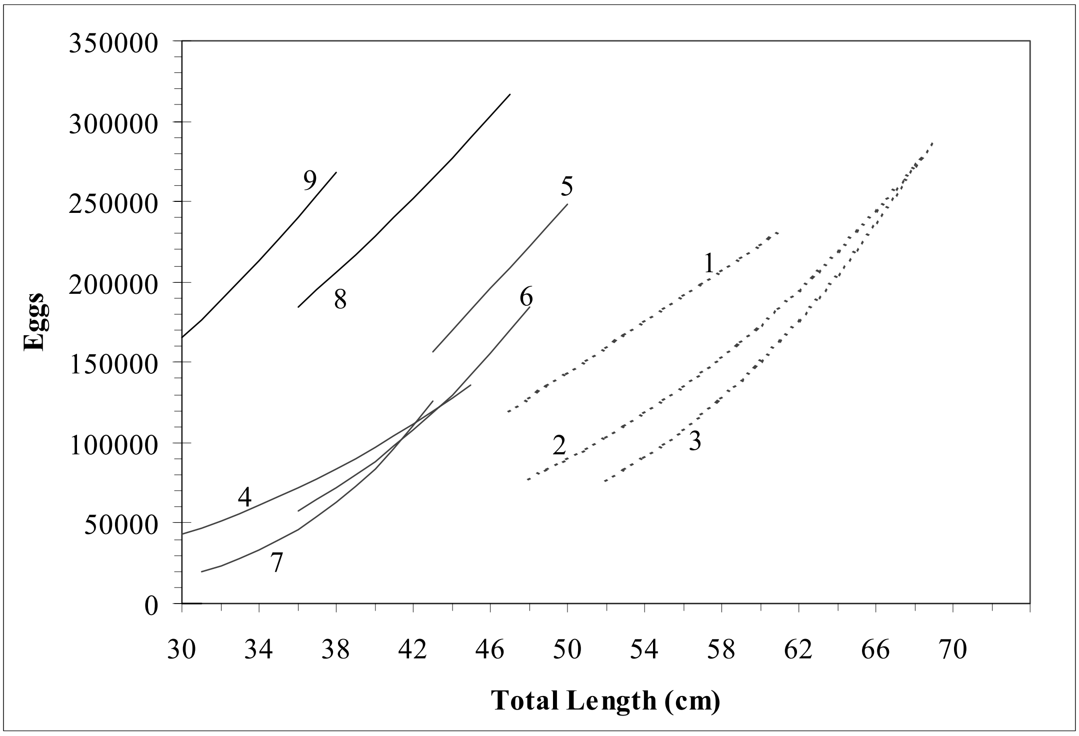


Figure 3.12: A comparison of the relationship between fecundity and length for a number of populations of *Alosa alosa* (dashed line) and *Alosa fallax fallax* (solid line). 1= Gironde-Garonne-Dordogne (France), Taverny (1991a); 2 = Douro (Portugal), Eiras (1981b)*;* 3 & 7 = Sebou (Morocco), Sabatié (1993); 4 = Severn (England), Aprahamian (1982); 5 = Nyamunas (Lithuania), Manyukas (1989); 6 = Elbe (Germany), Hass (1965); 8 = Mira (Portugal), Pina (2000); 9 = Guadiana (Portugal), Pina (2000).

The population of *A. fallax fallax* showing the greatest fecundity for a fish of a given size was from the River Guadiana followed by the River Mira and Nyamunas River. The relationship for the other three populations in the Severn, Elbe and Sebou, was very similar. Direct comparisons are difficult as the estimate of fecundity for the Portuguese populations was through stereological analysis and the estimate is approximately three times greater than that based on weight (Pina, 2000).

Alosa fallax rhodanensis

Gallois, Hoestlandt and Germand (Gallois, 1946a) estimated the fecundity of three specimens of *Alosa fallax rhodanensis* ranging in size (L_t) from 400 to 430 mm to be between 114,000 and 175,000 eggs. The mean estimated relative fecundity was estimated by Le Corre and Sabatié (unpubl.) to be 109,149 egg kg^{-1}somatic weight (n=9), and by Cassou-Leins & Panisello (unpubl.) t6 be 100,000 egg kg^{-1} total weight.

Alosa fallax nilotica

Vukovic (1961a) estimated the absolute fecundity of three Yugoslavian populations of *Alosa fallax nilotica* to be between 25,624 and 336,592 eggs (Table 3.19). There was no significant correlation between the number of eggs per gram of ovary and weight of the fish. The relative fecundity of the landlocked population of *Alosa fallax nilotica* in Lake Skadar (Albania) was between 200,000 and 300,000 egg kg^{-1} (Rakaj & Crivelli, 2001).

Table 3.19: The absolute and relative fecundity of *Alosa fallax nilotica* (Vukovic, 1961a).

Weight Group (g)	Absolute Fecundity			Relative Fecundity (egg g^{-1})		
	Lake Scutari	Lake Bacin	River Neretva	Lake Scutari	Lake Bacin	River Neretva
0-250	30,123	25,624		831	789	
251-500		26,001	46,716		729	916
501-750	103,919	51,528	64,320	863	683	800
751-1000	105,585	56,525	74,533	830	595	752
1001-1500	164,537	109,441	141,372	932	735	816
1501-2000	219,320	197,959	229,646	746	858	740
2001-2500	336,592		238,901	872		821

Alosa fallax algeriensis

The absolute fecundity has been reported to range from 50,000 to 269,000 eggs (Bounhiol, 1917; Kartas, 1991) with a mean relative fecundity of 200,000 egg kg^{-1} (Kartas, 1991). The relationship between fecundity and size is presented in Table 3.20.

Table 3.20: The relationship between fecundity (F) and total length (L_t), weight (W_t) and ovary weight (OW_t) for *Alosa fallax algeriensis* (Kartas, 1981).

Relationship	No.	r^2
$F = 9.60.10^{-4}L_t^{3.51}$	64	0.423
$F = 0.21.10^{2}W_t^{0.992}$	64	0.410
$F = 3.02.OW_t^{0.84}$	64	0.846

In relation to age, Bounhiol (1917) reported that fish aged three years old produced between 50,000 and 60,000 eggs, increasing to 150,000 by the age of five.

Alosa fallax lacustris

The absolute fecundity has been reported to range from 15,000 to 20,000 eggs (Tortonese, 1970).

Alosa fallax killarnensis

In Lough Leane (Ireland), O'Maoileidigh (1990) examined the fecundity of *Alosa fallax killarnensis*. The absolute fecundity ranged from 10,700 to 30,560 eggs and relative fecundity (eggs per 100g total weight) from 7,605 to 22,741 with a mean ± 95% confidence limits of 14,934 ± 2,830 eggs (n=11). There was no significant correlation between fecundity and age (r^2=0.284), total weight (r^2=0.005) and length (fork) (r^2=0.148).

3.1.6.3 Resorbtion of spawn

Berg (1966b) mentions that under unfavourable conditions females of *Alosa fallax lacustris* may resorb their eggs.

3.1.7 Spawning grounds

Alosa alosa

Alosa alosa spawn in fresh water. Spawning takes place in the main river and major tributaries of the catchment, the width of the sites range from 15 m in the River Aulne (Véron, pers. comm.) to 200 m in the River Loire (Boisneau *et al.,* 1990). The fish deposit their eggs onto a substrate which can vary from sand (20µ to 2mm) to pebbles (20 to 200 mm), in water of depth 0.5 to 3.0m and where the current ranges from 0.5 to 2.0ms^{-1} (Roule, 1923; Ellison, 1935; LeClerc, 1941; Mohr, 1941; Dottrens, 1952; Hoestlandt, 1958; Anon. 1979a; Cassou-Leins & Cassou-Leins, 1981; Dautrey & Lartigue, 1983; Boisneau *et al.,* 1990; Fatin & Dartiguelongue, 1995; Belaud *et al.*, 2001).

On the River Garonne (France) the substrate of the spawning grounds was dominated by pebbles of mean size 70 to 80 mm and with a range of 30 to 160 mm (Cassou-Leins & Cassou-Leins, 1981). On the River Dordogne, Fatin & Dartiguelongue (1995) reported that the majority of the spawning took place over a substrate composed mostly of pebbles ranging in size from 20 to 200 mm. Similarly on the River Adour, Boigontier (1987) reported a mean (range) in particle size of 70 (30 – 80) mm and 50 (20 –130) mm. In contrast, on the River Loire (France), Boisneau *et al.* (1990) reported that the spawning site consisted mainly of sand followed by gravel (2 to 20 mm).

Alosa fallax fallax

Alosa fallax fallax spawn in both the tidal and non-tidal river. Spawning has been reported in the tidal freshwater section of estuaries (Hass, 1968; Taverny, 1991a; Thiel *et al.,* 1996a), as well as in the river (Ehrenbaum, 1894; Meek, 1916; Mohr, 1941; Hoestlandt, 1958; Maitland, 1972; Aprahamian, 1982).

The spawning habitat of twaite shad in the rivers Wye, Usk, Tywi and Teme (UK) comprises a fast-flowing shallow area of unconsolidated gravel/pebble and/or cobble substrate (Caswell & Aprahamian, 2001). The mean size of the substrate at one site on the River Garonne was 70 mm with a range of between 30 and 120 mm (Cassou-Leins & Cassou-Leins, 1981). The River Habitat Survey (Raven *et al.*, 1997) flow types 'smooth flow', 'rippled flow' and 'unbroken standing waves' were significantly ($P<0.05$) associated with the presence or absence of shad eggs. The presence of eggs was significantly associated with the higher energy flow types 'rippled flow' and 'unbroken standing waves', and the absence of eggs was significantly associated with the lower energy flow type 'smooth flow' (Caswell & Aprahamian, 2001). Similar findings were also reported by Bracken & Kennedy (1967), Philippart & Vranken (1982) and Wheeler (1969a). In tidal waters of the River Dordogne, *Alosa fallax* spawned over substrate ranging in size from 20 to 100 mm at one site and between 2 and 20 mm at another (Taverny, 1991a), while in the River Garonne (France), eggs were reported deposited over mud (Anon. 1979a).

The fish accumulate in pools during the day, moving out onto the shallow / riffle areas to spawn during the night. The depth of water at spawning can range from >0.15m (Figure 3.13) to 1.20m (Caswell & Aprahamian, 2001). The fact that egg density was found to decline with increasing depth suggests that, in these particular rivers *A. fallax* prefer to deposit their eggs in the shallow areas where the water depth is <0.45m (Figure 3.14).

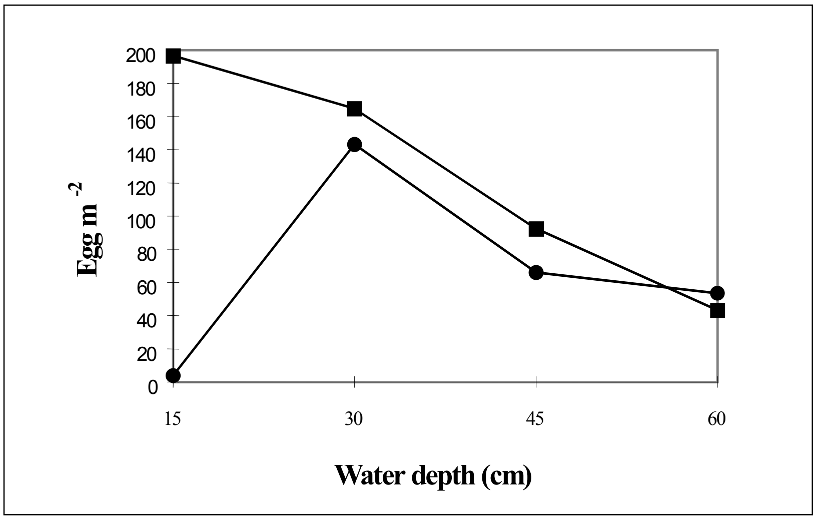


Figure 3.13 Mean density of eggs of *A. fallax* at two sites on the River Wye (Wales); Monmouth (■) and Courtfield (•) from Aprahamian (1981).

On the River Elbe (Germany), Hass (1968) and Thiel *et al.* (1996a) reported *Alosa fallax* spawning in the upper reaches of the estuary where the salinity was in the region of 0.3‰. The current stirs up the eggs and there is a general increase in egg density with water depth (Figure 3.14).

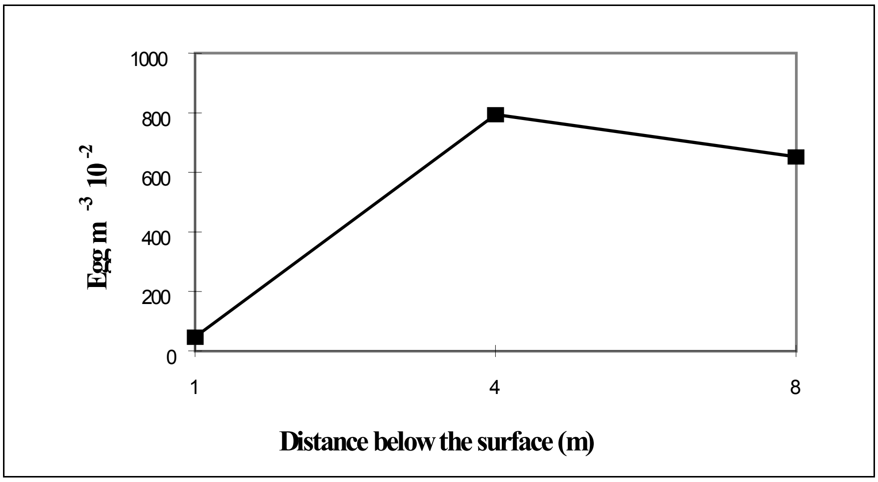


Figure 3.14 Mean density of eggs of *A. fallax* in relation to water depth in the estuary of the River Elbe (Germany) from Thiel *et al.* (1996a).

Alosa fallax rhodanensis

In the River Rhône (France) *A. fallax rhodanensis* spawn in fresh water at a depth ranging from 0.8 to 2.0 m (Cassou-Leins & Panisello, unpubl. [in Cassou-Leins *et al.*, 2000]) over a sandy-muddy substrate (Gallois, 1946a), and/or over a clean gravel substrate (Rameye *et al.,* 1976), where the current velocity id between 0.5 and 2.0 ms^{-1} (Genoud, 1997; Moulin, 1997; Genoud, 1999b). At spawning sites the size of the substrate ranges from 10 to 400mm (Mazens, 1997; Roure *et al.*, 1997a) and the median particule size at these locations from 11 to 84.4 mm (Genoud, 1997; Mazens, 1997; Roure *et al.*, 1997a). In the River Aude (France), Cassou-Leins (1995) observed fish spawning over cobbles ranging in size from 50 to 150 mm with a median size of 90 mm. If, however, the (gravel) substrate is covered by mud the eggs are likely to be asphyxiated (Rameye *et al.,* 1976).

Alosa fallax nilotica

Vukovic (1961a) and Ivanovic (1977) report that *Alosa fallax nilotica* spawn over a sandy-muddy substrate in water depths ranging from 1 to 6m.

Alosa fallax lacustris

Alosa fallax lacustris spawn near the shore of the lake (**Dottrens, 1952**; Tortonese, 1970).

3.2 Preadult Phase

3.2.1 Ontogeny

Alosa alosa

Hatching takes place, depending on temperature, between 240 h and 65 h following fertilisation (Table 3.21), and is well described by the equation:

$H = -220.98\mathrm{Log}_e T + 770.6$ $r^2 = 0.84$

Where: H = hatching time in hours; T = temperature in degrees centigrade.

Table 3.21: Incubation time for eggs of *Alosa alosa* in relation to temperature.

Temperature (^{o}C)	Incubation time (hours)	Reference
12	240	Hoek (1888)
14	160	Hoek (1888)
18	168	Cassou-Leins & Cassou-Leins (1981)
19	96	Pouchet & Bietrix (1889a); Ehrenbaum (1936)
20	126	Cassou-Leins & Cassou-Leins (1981)
20-21	80	Hoestlandt (1958)
22	96	Cassou-Leins & Cassou-Leins (1981)
23	84	Cassou-Leins & Cassou-Leins (1981)
24-25	65	Hoestlandt (1958)

Hoestlandt (1958) mentions that at temperatures below 16^{o}C the larvae die in the eggs. At temperatures below18^{o}C the larvae are not in good condition and have difficulty in emerging from the egg (Cassou-Leins & Cassou-Leins, 1981). The upper survival limit would appear to be *c*. 26^{o}C, with all eggs dying at a temperature $\geq$26.3^{o}C (Cassou-Leins & Cassou-Leins, 1990).

At hatching the larvae measure between 7 and 12 mm (L_t) [Vincent, 1894b; Hoestlandt, 1958; Wheeler, 1969a; Cassou-Leins & Cassou-Leins, 1981; Veron *et al*., 2003]. The larvae are transparent with few chromatophores, a well-developed yolk sac and large pigmented eyes. The gill arches bear short gill filaments and are clearly visible, as are the otoliths and the auditory vesicle - the caudal fin contains primary rays (Pouchet & Bietrix, 1889a; Cassou-Leins & Cassou-Leins, 1981; Quignard & Douchement, 1991a). The change in certain morphometric characteristics through development are shown in Table 3.22, scales first appear in the lateral anteroventral part at a L_{st} of 20-25 mm, in the caudal part at a length of 25-27 mm and in the anterodorsal part at 25-31mm (Bergot *et al*., unpublished).

Table 3.22: Ontogenetic change in certain morphometric characteristcs of *Alosa alosa*, measured as a percentage of standard length (Mean ± SD) [Bergot *et al.*, unpublished].

Life stage	L_{st} (mm)	Snout length (%)	Eye Diam. (%)	Predorsal length (%)	Preanal length (%)	Caudal fin length (%)	Body height (%)
Larvae	8.8±0.2	2.5±0.3	4.8±0.4	59.0±2.3	81.7±0.8	3.4±0.8	10.9±0.8
	15.0±0.5	3.4±0.9	6.3±0.5	57.9±2.1	80.6±0.7	9.4±1.1	12.8±1.4
Pre-juvenile	16.8±0.4	3.3±0.9	7.0±0.6	56.1±1.1	78.7±1.1	12.2±1.6	14.4±1.0
	20.5±0.1	5.6±0.7	7.9±0.2	52.3±1.0	73.7±0.4	15.2±1.4	15.7±0.9
Juvenile	23.0±0.5	5.3±0.4	9.0±0.8	49.0±1.8	70.8±0.7	16.7±1.3	18.9±1.6
	40.8±0.9	5.8±0.7	8.6±0.7	44.8±2.0	69.9±0.6	20.0±1.4	25.6±0.8

Alosa fallax fallax

Vincent (1894b) reported that eggs could successfully develop between 15 and 25°C. Incubation takes 72 to 120 h at 16.4°C (Ehrenbaum, 1894) and 96 to 120 h at 19°C (**Pouchet & Bietrix, 1889b; Vincent, 1894b;** Mohr, 1941; **Wheeler, 1969a**).

No pigmentation is present on the embryo or yolk sac, though in the latter stages of development the eye capsules become heavily pigmented (Aprahamian, 1982). At hatching larvae measure between 4 and 9 mm (total length) (**Vincent, 1894b;** Ehrenbaum, 1894, **1936**; Redeke, 1939**;** Mohr, 1941; Aprahamian, 1982). At hatching the yolk sac is slightly oval, with a number of oil droplets scattered through it, and there is a very slight pigmentation of the ventral and posterior regions of the yolk sac as well as the ventral region of the larvae (Aprahamian, 1982).

Morphometric indices (mean ± 95% CI, in relation to total length) for newly hatched larvae are; standard length 0.968 ± 0.0032; snout to anus 0.788 ± 0.0069; yolk sac 0.217 ± 0.012; snout to back of head 0.125 ± 0.0056; snout to back of eye 0.072 ± 0.0037 and eye diameter 0.050 ± 0.0025 (Aprahamian, 1982).

Ehrenbaum (1894) and Mohr (1941) have described the juvenile stages (Figure 3.15) and have been reported by Quignard & Douchement (1991b) in quotes, as follows:

“ The 8-9 mm stage – 6 days old:

- The yolk sac is being resorbed;
- The gill arches are visible, not covered completely by the very tiny operculum;
- The unpaired fins are not distinguishable in the primordial finfold. The rays of the caudal fin are beginning to appear.
- The pectoral fins are rather large and already have fleshy bases;
- Star-shaped chromatophores are distributed on the ventral sides of the gut, yolk sac and body, even beyond the anus which is situated in a very posterior position on the body;
- The head is relatively short and blunt, with large dark eyes.

The 13-15 mm stage – 15 to 20 days old:

- The place of the fully resorbed yolk sac is taken by a rather elongated liver which bears a small gall bladder;
- The swim bladder is hardly distinguishable;
- The operculum is still rather small, and a large part of the gills is still uncovered;
- Otoliths, one large and one small are visible within the auditory organ;
- The dorsal fin, with 10-12 rays, is already well developed. Though difficult to see, the rays of the primordial anal fin are growing. The pelvic fins are present as skin folds only and, like the dorsal fin, very posteriorly situated. The pectoral fins have shown no change.

The 16-20 mm stage:

- The fish has already assumed its typical shape;
- The swim bladder is visible, dorsal to the gut and anterior to the base of the dorsal fin;
- The dorsal and anal fin rays can be counted;
- Although it is externally symmetrical, a heterocercal development of the caudal fin is apparent;
- It is possible to count the vertebrae;
- Teeth are evident on the upper and lower jaws."

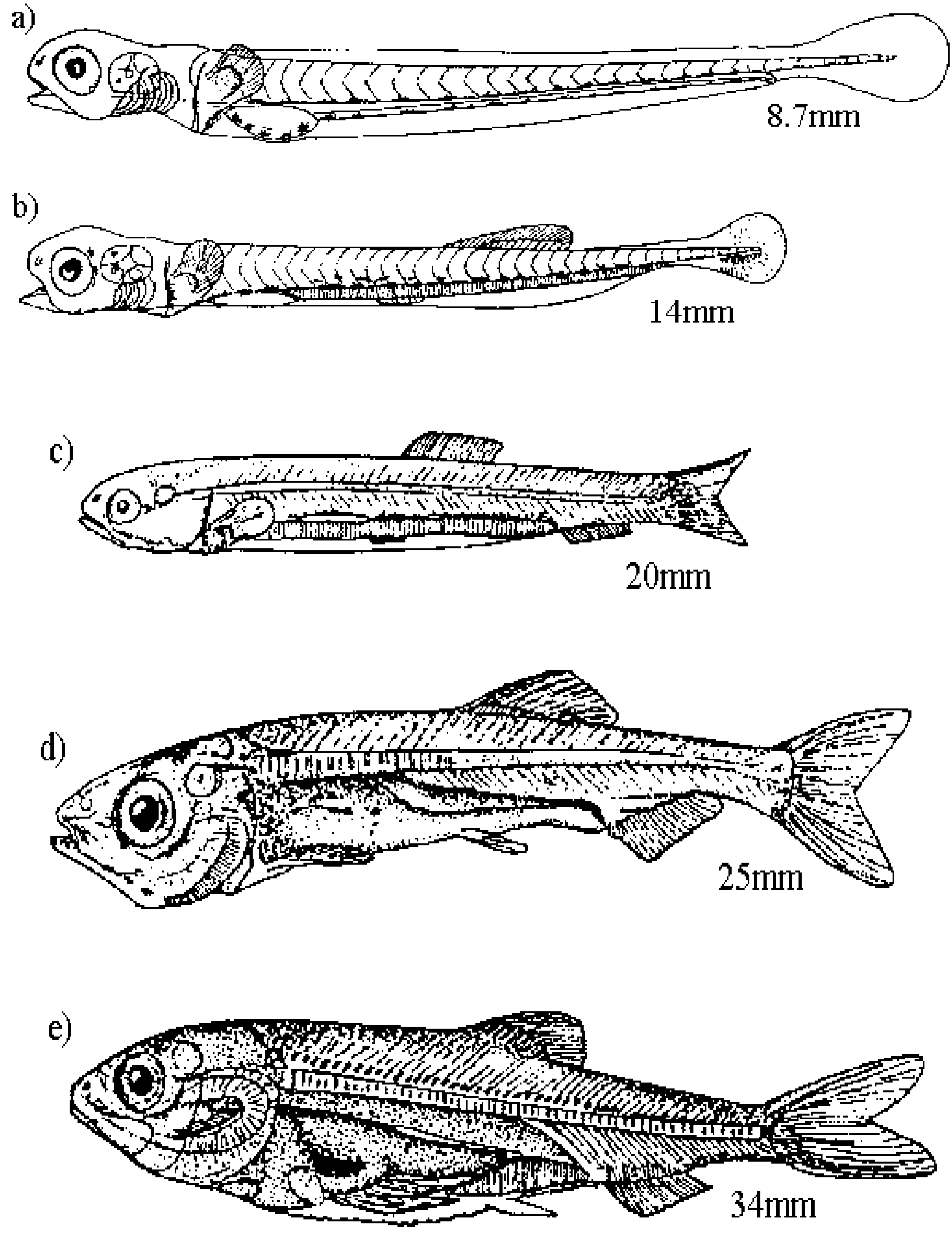


Figure 3.15: Diagrams of twaite shad from Quignard and Douchement (1991b) from the figures of Ehrenbaum (1894) and Mohr (1941); (a) pro-larva six days after hatching, (b) and (c) post-larvae, (d) transitional larva, (e) juvenile.

The level of pigmentation appears dependent on location; those from heavily turbid waters of the Severn Estuary, England had little or no pigmentation compared with those from the relatively clear freshwater reaches of the River Wye, Wales which were heavily pigmented (Aprahamian, 1982).

The migration anteriorly of the dorsal and anal fins occurs at a fork length of between 25 to 28 mm as the larvae transform into a fully metamorphosed juvenile (Aprahamian, 1982). Scales completely cover the body once the juveniles have reached a total length of 30 to 32 mm (Mohr, 1941).

Alosa fallax rhodanensis

Hoestlandt (1947) reported that the eggs do not hatch at temperatures less than 18°C. Hatching takes 96 h at 18 to 20°C (Chiappi, 1933a) and 80 h at 20.5 to 23.5°C (Hoestlandt, 1947). At hatching the larvae measure 7mm (Chiappi, 1933a; Hoestlandt, 1947). Larval development has been described by Chiappi (1933a) (Figure 3.16 a-c).

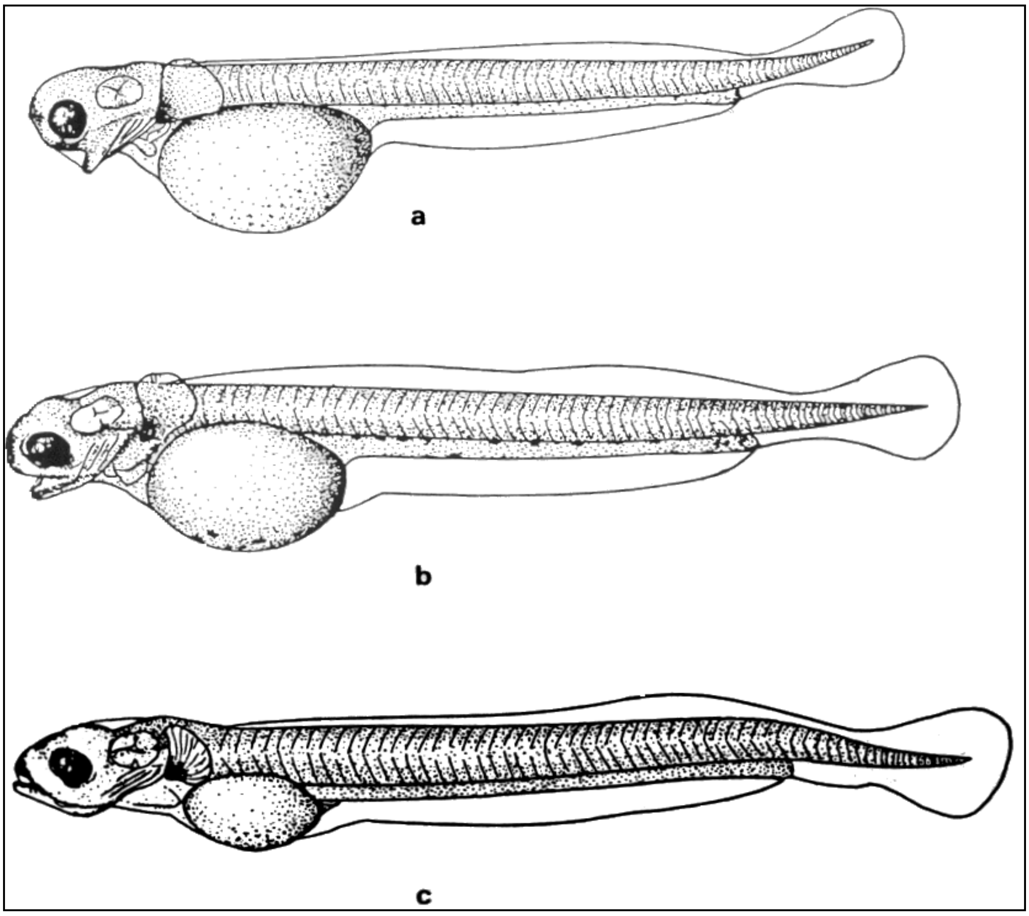


Figure 3.16: Immature stages of *Alosa fallax rhodanensis*, from Quignard & Douchement (1991c) from the figures of Chiappi (1933a). (a) newly hatched larva of 7mm; (b) 7.8mm larva, four to five days after hatching; (c) six days after hatching.

At hatching the larvae have a well-developed yolk sac. Chromatophores are present on the yolk sac and on the dorsal and ventral surface of the gut, and absent from the post-anal area. The pectoral fins are approximately twice the diameter of the eye. Hoestlandt (1947) reported that the yolk sac becomes completely absorbed 24h after hatching, however Chiappi (1933a) observed that the yolk sac, though partly resorbed, was still present six days after hatching.

Alosa fallax lacustris

The time from fertilisation to hatching takes *c*. 115 h at 17 to 20°C (A. Negri, pers. comm. in Luzzana *et al.,* 1996) and 75 to 96 h at 20 to 24°C (Pirola, 1930; Chiappi, 1933a) and could be described by the equation:

Hatching time (hours) = 1800 / Temperature (°C) (Pirola, 1930).

The larvae are 6.5 to 7.0 mm in length at hatching (Pirola, 1930; Chiappi, 1933a). The yolk sac on newly hatched larvae is small (Figure 3.17a) and is fully absorbed by the time the larvae have reached 7 to 8 mm (Figure 3.15b). At hatching the pectoral fins are small and are approximately equal in length to that of the radius of the eye. Chromatophores are most abundant on the dorsal surface but are also present on ventral surface, the head, and the post-anal region (Chiappi, 1933a).

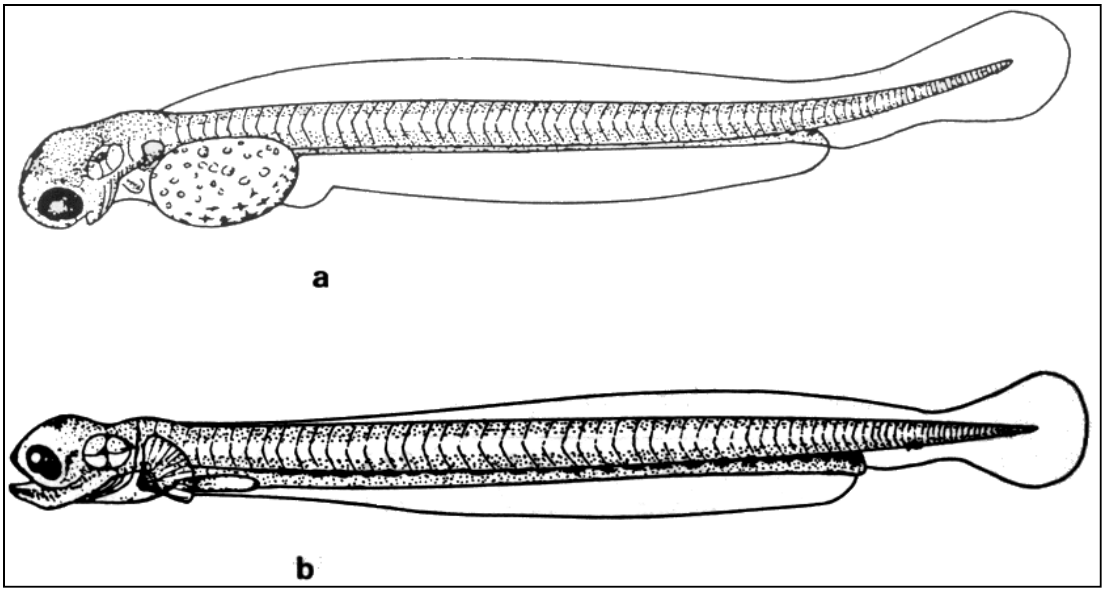


Figure 3.17: Juvenile stages of *Alosa fallax lacustris*, according to Chiappi (1933a). (a) just hatched, length 6.5mm; (b) four days after hatching, length 7mm.

3.2.2 Larval and juvenile (age 0) phase

Alosa alosa

Laboratory studies (Veron *et al*., 2003) indicate that prolarvae swim actively to the surface on hatching. During the first 48 hours the prolarvae would swim to the surface, then sink pasively towards the bottom before returning again to the surface. After this phase and until day 19 the larvae showed a preference for the top 50mm of the water column. After this the proportion at the surface decreased as larvae started to use a greater proportion of the water column, there was also an increase in larvae drifting downstream.

In the wild the larvae, after hatching, migrate transversely into areas of lower current velocity where the juvenile stages can be found from mid-May until mid September (Cassou-Leins *et al.,* 1988a).

Alosa fallax fallax

In the Elbe estuary twaite shad spawn along the southern shore of the main channel over a distance of *c*.12 km (Dieckwisch, 1987). The larvae (L_t = 7.7-23.8 mm) on the other hand were more abundant in the side-channels, which because of their slower currents compared to the main channel, were considered to be better nursery and feeding areas (Gerkens & Thiel, 2001). It appeared that the larvae actively avoided shallow areas, close inshore. Temperature preferences for larvae between 7.7 and 15.2 mm were in the range 17.0 to 20.0^{o}C and for larvae from 18.4 to 23.8 mm were between 17.0 and 21.5^{o}C. Juveniles (age 0+) avoided areas of low dissolved oxygen (<4 mgL^{-1}), the majority being caught in water of between 4 and 5 mgO$_2$L^{-1} (Möller & Scholz, 1991).

3.3 Adult Phase

The adult phase starts when the fish reach sexual maturity (see section 3.1.2 Maturity).

3.3.1 Longevity

Alosa alosa

The maximum age observed for females of anadromous populations of *Alosa alosa* is 8 years and for males 7 years (Sabatié, 1993; Prouzet *et al*., 1994a). Differences existed between populations, but it is unclear whether they reflect actual population differences or sampling effects. In the Adour and Sebou the maximum age recorded for females was 8 years (Sabatié, 1993; Prouzet *et al*., 1994a), in the Loire, Gironde-Garonne-Dordogne, Lima and Mondego 7 years was the oldest observed (Anon. 1979a; Mennesson-Biosneau & Boisneau, 1990; Alexandrino, 1996b) while in the Aude, Rhône, Douro and Loukos the greatest age recorded was 6 years (Douchement, 1981; Eiras, 1981b; Sabatié, 1993). The maximum age for males was the same as for females in the Gironde-Garonne-Dordogne, Lima and Douro (Anon. 1979a; Eiras, 1981b; Alexandrino, 1996b). It was one year younger in the Loire, Adour and Loukos

(Mennesson-Biosneau & Boisneau, 1990; Sabatié, 1993; Prouzet *et al.*, 1994a) and 2 years younger in the Sebou (Sabatié, 1993).

The maximum age recorded for landlocked populations was 5 years in the Aguieira reservoir on the Mondego (Collares-Pereira *et al.*, 1999) and in El Kansera on the Sebou (Furnestin, 1952). In the Aguieira reservoir the maximum age reported was 5 years for females and 4 years for males (Collares-Pereira *et al.*, 1999) while for both sexes in Castelo do Bode reservoir on the Tejo the oldest fish were aged 4 years (Alexandrino, 1996b).

Alosa fallax fallax

The oldest fish (female) recorded were 12 years of age taken from the Severn (Mennesson-Boisneau, *et al.* 2000a). Females up to the age of 9 years have been reported from the Nyamunas, from Holland and the Wye (Manyukas, 1989; Aprahamian, 1982 & unpubl.) and up to 8 years old from the Elbe, Tywi and Adour (Hass, 1965; Aprahamian, unpubl.). The oldest female recorded in the Barrow was 7 years (O'Maoileidigh, 1990), while in the Loire, Gironde-Garonne-Dordogne, Guadiana and Sebou age 6 was the maximum (Anon. 1979a; Douchement, 1981; Sabatié, 1993; Alexandrino, 1996). Females of age 5 were the oldest reported fish from the Seine, Lima, Mondego, Tejo and Loukos (Roule, 1922a; Sabatié, 1993; Alexandrino, 1996b).

The oldest male fish recorded was 10 years old from the Severn (Aprahamian, unpubl.). Males of 9 years old were reported from Holland (Aprahamian, 1982) and fish of up to 8 years old from the Elbe, Wye, Tywi and Barrow (Hass, 1965; O'Maoileidigh, 1990; Aprahamian, unpubl.) and up to 7 years old on the Nyamunas (Manyukas, 1989). In the Loire, Gironde-Garonne-Dordogne, Adour, Lima, Mondego, Guadiana, Loukos and Sebou males aged 5 years were the oldest recorded (Douchement, 1981; Sabatié, 1993; Alexandrino, 1996b), while in the Tejo fish aged 4 years is the maximum (Alexandrino, 1996b).

A latitudinal cline exists with fish at the northern limit of their range living longer, between 7 and 12 years compared to those at the southern limit where longevity of 5 or 6 years appears normal (Figure 3.18). The fact that the fish live longer further north and that there is little difference in the age at which fish mature (Table 3.2) would suggest that the proportion of repeat spawners in the population should increase with latitude.

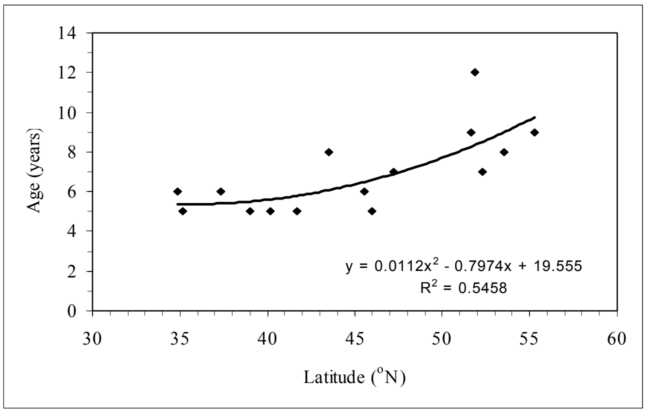


Figure 3.18: Longevity of various populations of female *Alosa fallax fallax* in relation to latitude; see Table 3.47 for sources of data.

Alosa fallax rhodanensis

The maximum age of female *Alosa fallax rhodanensis* recorded was age 9 years in the Tiber (D'Ancona, 1927c) while in the Rhône and Aude the oldest fish was 8 years old (Douchement, 1981; Le Corre *et al*., 1997a). The longevity for males is 8 years in the Rhône and Tiber (D'Ancona, 1927c; Le Corre *et al*., 1997a) and 5 years in the Aude (Douchement, 1981).

Alosa fallax nilotica

The oldest fish recorded for both sexes was 10 years old from the Neretva (Vukovic, 1961a). Female *Alosa fallax nilotica* from the lakes Skadar and Bačin had a maximum age of 10 and 9 years respectively and the males a year younger (Vukovic, 1961a). In the Po (Italy) the maximum age for both sexes was 7 years (Serventi *et al*. 1990).

Alsoa fallax algeriensis

In the Miliane and Medjerah the oldest fish recorded was 9 years, for both sexes, while in Lake Ichkeul the maximum age recorded for males and females was 7 years (Kartas, 1981). In the Mazafran, Bounhiol (1917) reported the oldest fish for both sexes was aged 5 years.

Alosa fallax lacustris

For the populations in lakes Garda and Maggiore the maximum age of both sexes is 4 years (Berg & Grimaldi, 1966a; Oppi & Novello, 1989). Bianco (2002) reported longevity of up to 5 – 6 years for *Alosa fallax lacustris* from Italian fresh waters.

Alosa fallax killarnensis

In Lough Leane the oldest fish reported was aged 5 years for females and 4 for males (O'Maoileidigh, 1990).

3.3.2 Hardiness

No information was found relating to hardiness.

3.3.3 Competition

Alosa fallax lacustris

Berg & Grimaldi (1966b) studied the relationship between *Alosa fallax lacustris* and *Coregonus macrophthalmus* Nusslin in Lake Maggiore (Italy). Any competition between the two species was small and relates mainly to the lack of overlap in the food spectrum in spring and autumn, when food is more limiting than in summer. *Alosa fallax lacustris* prey on copepods as opposed to cladocerans, which are consumed by the coregonids. Any interaction is further limited by the fact that the species are spatially segregated. During the winter the coregonids live nearer the shore and in summer occupy the cooler deeper waters of the lake, whereas *A. fallax lacustris* remain in open water all year round, preferring the warmer surface layers during the summer. In addition at temperatures lower than 14°C *Alosa fallax lacustris* feed less than *C. macrophthalmus*. *Alburnus alburnus alborello* (bleak), which are present in the lake also feed on copepods, the larger cladocerans, and on algae, insects and the smaller cladocerans (Giussani & Grimaldi, 1975).

Similar findings have been reported for the sympatric populations of alosoids, coregonids and *A. alburnus alborello* in Lake Garda, and for *A. fallax lacustris* and *A. alburnus alborello* in Lake Lugano (Giussani & Grimaldi, 1975). In Lake Como the diet of *A. fallax lacustris*, *Coregonus* spp. and *A. alburnus alborello* was dominated by the larger cladoceran species (Giussani & Grimaldi, 1975).

3.3.4 Predators

Alosa alosa

Le Clerc (1941) reported that yearling *Alosa alosa* in the River Maine, France were preyed upon by *Alburnus alburnus*.

Alosa fallax fallax

On the River Wye, Wales Gough (pers. comm.) [cited by Edwards & Brooker, 1982] found that *Esox lucius* L. had been feeding on adult *Alosa fallax*. Otters (*Lutra lutra*) have also been found to predate on adult *Alosa fallax fallax* in fresh water.

In the Sado estuary (Portugal) *Alosa fallax* form an important prey item of the bottlenose dolphin (*Tyrsiops truncatus*) [Dos Santos & Lacerda, 1987].

3.3.5 Parasites and disease.

3.3.5.1 Parasites

Alosa alosa and Alosa fallax

The species of parasite recorded from *Alosa alosa* and the various subspecies of *Alosa fallax* are presented in Table 3.23a-f. Most of those parasites reported from anadromous *Alosa* populations in the western Atlantic, have been reported from both *A. alosa* and *A. fallax.* Exceptions are *Pomphorhynchus laevis* and *Caligus elongatus* which have been found in *A. fallax* from the River Severn, England (Aprahamian, 1985), and *Mazocraes harengi* which have only been reported from *A. alosa* in southern England (Baylis & Jones, 1933), and *M. vilelai* from the River Tego, Portugal (Tendeiro & Valdez, 1955).

Table 3.23: Parasites recorded from *Alosa alosa*, *A. fallax fallax*, *A. fallax nilotica*, *A. fallax rhodanensis*, *A. fallax algeriensis* and *A. fallax lacustris*.

a) Anadromous populations *of Alosa alosa*

Family	Site of infection	Species	Location of record and reference
Copepoda	Gills	*Clavellisa emarginata* (Krøyer, 1837)	North Sea (Boxshall,1974) Gironde-Garonne-Dordogne, France (Taverny, 1991a) Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
	Body	*Lernaeeniscus encrasicoli* (Turton, 1807)	Not Recorded (Markevich, 1956; Kabata, 1979)
Cestoda	Pyloric caeca	*Scolex pleuronectis* (Rudolphi, 1802) syn. *Scolex polymorphus*	Holland (Willemse, 1968)
		Eubothrium fragile (Rudolphi, 1802)	Rhine, Switzerland (Fatio, 1890) Europe (Yamaguti, 1959) Not Recorded (Protasova, 1977)
	Intestine	*Eubothrium fragile* (Rudolphi, 1802)	Baltic, North & Irish sea (Joyeux & Baer, (1936)
Monogena	Gills	*Mazocraes alosae* (Herman, 1782) syn. *Octobothrium lanceolatu* (Euckart, 1828)	Severn, Wye, Plymouth, Britain (Finlayson, 1981) Rhine, Switzerland (Fatio, 1890) Waterford Estuary, Ireland (Doherty & McCarthy, 2002) Not Recorded (van Beneden, 1858; Sproston, 1946; Yamaguti, 1968)
		Mazocraes harengi (Beneden & Hesse, 1863)	Plymouth, England (Yamaguti, 1963)
		Mazocraes vilelai (Tendeiro & Valdez, 1955)	Tejo, Portugal (Tendeiro & Valdez, 1955)

Digenea	Intestine	*Hemiurus appendiculateus* (Rudolphi, 1802)	Grionde-Garonne-Dordogne, France (Taverny, 1991a) Rhine, Switzerland (Fatio, 1890) Waterford Estuary, Ireland (Doherty & McCarthy, 2002) Europe (Yamaguti, 1971); Not Recorded (Dawes, 1947)
		Pronoprymna venticosa (Rudolphi,1819)	Belgian Coast, Rhine at Basle and Celtic Sea **(** Bray & Gibson, 1980) Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
		Pronopyge ocreata (Rudolphi, 1802)	Rhine, Switzerland (Fatio, 1890)
	Stomach	*Hemiurus appendiculateus* (Rudolphi, 1802)	**Rhine, Switzerland (Fatio, 1890)**
	Eye	*Diplostomum gasterostei* Williams	Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
		Diplostomum spathaceum Rudolphi	Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
Nematoda	**Intestine and stomach**	*Hysterothylacium aduncum* (Rudolphi, 1802) syn. *Thynnascaris aduncum* syn. *Contracaecum aduncum*	North Sea (Punt, 1941) Baltic (Markowski, 1937) Rhine, Switzerland (Fatio, 1890) Grionde-Garonne-Dordogne, France (Taverny, 1991a) Tejo, Portugal (Almaça, 1988a) Waterford Estuary, Ireland (Doherty & McCarthy, 2002) Not Recorded (Yamaguti, 1961)
		Hysterthylacium osculatum	Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
		Agamonema capsularia (Rudolphi, 1802)	Rhine, Switzerland (Fatio, 1890)
Acantho-cephala	Intestine	*Rhadinorhynchus lintoni* (Cable & Lindroth,1963) syn. *Echinorhynchus subulatus* (Zeder, 1800)	Rhine, Switzerland (Fatio, 1890)
		Echinorhynchus alosae (Hermann, 1782)	Rhine, Switzerland (Dujardin, 1845)
		Pomphorhynchus tereticollis (Rudolphi, 1809)	Not Recorded (Golvan, 1969)

b) *Alosa fallax fallax*

Family	**Site of infection**	**Species**	**Location of record and reference**
Copepoda	Gill arches & pseudobranch	*Clavellisa emarginata* (Krøyer, 1837)	Severn, England (Aprahamian,1985) Gironde-Garonne-Dordogne, France (Taverny,1991a) **Rhine, Germany** (Hoek, 1899; Redeke, 1939) Waterford Estuary, Ireland (Doherty & McCarthy, 2002) Not recorded (Fatio, 1890; Brian, 1906; Scott & Scott, 1913; Mohr, 1941; Kabata, 1979; Fryer, 1982)
	Skin	*Caligus elongatus* (Nordmann, 1833)	Severn, England (Aprahamian, 1985)
Cestoda	Pyloric caeca/ intestine	*Scolex pleuronectis* (Muller, 1788) syn. *Scolex polymorphus* (Rudolphi, 1810)	Holland (Willemse, 1968)
	Intestine	*Eubothrium fragile* (Rudolphi, 1802)	Severn, England (Kennedy, 1978; Kennedy, 1981; Andersen & Kennedy, 1983; Aprahamian, 1985) North & Irish seas (Joyeux & Baer, 1936); Baltic Sea (Nybelin, 1922; Joyeux & Baer,1936) **Rhine, Germany (**Hoek, 1899); Holland (Willemse,1968) Waterford Estuary, Ireland (Doherty & McCarthy, 2002) Not recorded (Mohr,1941; Protasova, 1977)
Monogena	Gills	*Mazocraes alosae* (Hermann, 1782) syn. *Octobothrium lanceolatum*	Severn, Wye, Britain (Finlayson, 1981; Aprahamian, 1985) Plymouth, England (Sproston, 1946; Finlayson, 1981) Gironde, Garonne, Dordogne, France (Taverny, 1991a) **Rhine, Germany** (Hoek, 1899; Redeke, 1939) Waterford Estuary, Ireland (Doherty & McCarthy, 2002) Not recorded (Mohr, 1941; Yamaguti, 1968)

Digenea	Intestine	*Hemiurus appendiculateus* (Rudolphi 1802)	Severn, England (Aprahamian, 1985) Gironde, Garonne, Dordogne, France (Taverny, 1991a) **Rhine, Germany** (Hoek, 1899; Redeke, 1939) Holland (Willemse, 1968) Waterford Estuary, Ireland (Doherty & McCarthy, 2002) Atlantic coast of Africa & Portugese coast (Rodrigues *et al.,*1972) Not recorded (Mohr, 1941)
		Pronopyge ocreata (Rudolphi 1802)	Not recorded (Dawes, 1947)
		Pronoprymna ventricosa (Rudolphi 1819)	Severn, England (Aprahamian,1985) NE.Atlantic, Severn, Scarboro, England (Bray & Gibson,1980) Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
	Eye	*Diplostomum gasterostei* Williams	Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
		Diplostomum spathaceum Rudolphi	Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
Nematoda	Stomach and Intestine	*Hysterothylacium aduncum* (Rudolphi 1802) syn. *Contracaecum aduncum* syn. *Thynnascaris aduncum*	North Sea, (Punt, 1941) Fjords near Bergen & Tromso, Norway (Berland, 1961) Baltic Sea (Markowski, 1937) NE Atlantic, N.Europe seas (Petter & Cabaret, 1995) Severn, England (Aprahamian, 1985) Gironde-Garonne-Dordogne, France (Taverny, 1991a) **Rhine, Germany** (Hoek, 1899; Redeke, 1939) Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
		Hysterthylacium osculatum	Waterford Estuary, Ireland (Doherty & McCarthy, 2002)
Acantho-cephala	Intestine	*Rhadinorhynchus lintoni* (Cable & Linderoth,1963)	Sebou, Morocco (Golvan, 1969)
		Pomphorynchus laevis (Muller, 1776)	Severn, England (Aprahamian, 1985)

c) *Alosa fallax nilotica*

Family	Site of infection	Species	Location of record and reference
Copepoda	Gill arches & pseudobranch	*Clavellisa emarginata* (Krøyer, 1837)	**Black Sea** (Markevich, 1952) Not recorded (Tortonese, 1970)
	Skin	*Caligus minimus* (Otto, 1848)	**Not recorded** (Tortonese, 1970)
	Eyes	*Pseudoeucanthus alosea* (Brian, 1906)	**Not recorded** (Tortonese, 1970)
Digenea	Stomach Intestine	*Hemiurus appendiculateus* (Rudolphi, 1802)	**Adriatic Sea** (Nikolaeva, 1966) **L.Skadar, Montenegro** (Kazic & Cankovic, 1969; Ubelaker *et al.*, 1981)
		Hemiurus lühei (Rudolphi, 1802) syn. *Hemiurus ocreatus* (Looss, 1879)	**Split, Adriatic Sea** (Sey, 1968)
		Orientophorus petrowi (Layman, 1930)	**L.Skadar, Montenegro** (Kazic & Cankovic, 1969; Ubelaker *et al.*, 1981)
	Intestine	*Pronopyge ocreata* (Rudolphi, 1802)	Trieste, Italy (Yamaguti, 1971)
		Distoma catervarium (Loss, 1896)	Egypt (Yamaguti, 1971)
Cestoda	Intestine	*Eubothrium crassum* (Bloch, 1779)	**L.Skadar, Montenegro** (Ubelaker *et al.*, 1981)
		Ligula intestinalis (Linnaeus, 1758)	**L.Skadar, Montenegro** (Ubelaker *et al.*, 1981)
		Proteocephalus (Weinland, 1858) spp.	**L.Skadar, Montenegro** (Ubelaker *et al.*, 1981)
Nematoda	Stomach & intestine	*Hysterothylacium aduncum* (Rudolphi 1802)	**L.Skadar, Montenegro** (Ubelaker *et al.*, 1981) **Split, Adriatic Sea** (Sey, 1970)
		Rhabdochona sp.	**L.Skadar, Montenegro** (Ubelaker *et al.*, 1981)
		Contracaecum clavatum (Rudolphi, 1809)	**Split, Adriatic Sea** (Sey, 1970)
		Goezia ascaroides (Goeze, 1782)	Montenegro (Moravec & Ergens, 1971)
		Raphidascaris acus (Bloch, 1779)	Montenegro (Moravec & Ergens, 1971)
Acantho-cephala	Intestine	*Pomphoryncus bosniacus* (Kiskaroj & Cankovic, 1968)	**L.Skadar, Montenegro** (Ubelaker *et al.*, 1981)

d) *Alosa fallax rhodanensis*

Family	Site of infection	Species	Location of record and reference
Nematoda	Stomach & intestine	*Hysterothylacium aduncum* (Rudolphi 1802)	Western Mediterranean (Petter & Maillard, 1987)

e) *Alosa fallax algeriensis*

Family	Site of infection	Species	Location of record and reference
Copepoda	Gill arches & pseudobranch	*Ergasilus nanus* (Van Beneden, 1871)	Lake Ischkaul, Tunisia (Raibaut *et al.*, 1971)

f) *Alosa fallax lacustris*

Family	Site of infection	Species	Location of record and reference
Cestoda	Intestine	*Proteocephalus agonis* (Barbieri, 1909) Syn. *Ichthyotaenia agonis*	**Lake Maggiore**, Italy (Pecorini, 1959)
		Proteocephalus longicollis (Zeder, 1800) Syn. *Ichthyotaenia longicollis*	**Lake Maggiore**, Italy (Pecorini, 1959)

In terms of distribution*,* *Eubothrium fragile* would appear to have a limited distribution compared with that of its host. It has only been reported from *Alosa* in England (Kennedy, 1978 & 1981; Anderson & Kennedy, 1983), Ireland (Doherty & McCarthy, 2002), Holland (Willemse, 1968), Germany (Redeke, 1939) and the Baltic North and Irish seas (Nybelin, 1922; **Joyeux & Baer, 1936**), but not from populations south of the Bay of Biscay.

Older fish are more heavily infected than juveniles (Claridge & Gardner, 1978; Quignard & Douchement, 1991b), and this is certainly the case for *Mazocraes alosae* (Finlayson, 1981; Aprahamian, 1985) and *Eubothrium fragile* (Kennedy, 1981), where infection is only evident in the adult population.

- Spatial or temporal differences

Spawning migration into fresh water has been reported to have effects on parasites, by a number of authors (Kennedy, 1981; Aprahamian, 1985; Taverny, 1991a). For *A. fallax* migration into fresh water does not appear to affect the relative density or the prevalence of *Eubothrium fragile, Hemiurus appendiculateus* and *Pomphoryhynchus laevis*. However, for *Clavellisa emarginata* and *Hysterothylacium* (syn. *Thynnascaris*) *aduncum*, prevalence and relative density were both found to have declined in fresh water when compared with pre-spawning fish in the estuary or at sea (Table 3.24 & 3.25). In contrast for *A.alosa* there was a decline of 58.5% in the prevalence of *H.appendiculateus* and an increase of nearly 40% for *H. aduncum* for fish from the Gironde-Dordogne-Garrone system (Table 3.25).

Table 3.24: Prevalence and relative density of parasites from the branchial chamber and alimentary tract of adult *Alosa fallax fallax* taken in the Severn estuary and fresh water (Aprahamian, 1985).

Parasite	Estuary			Fresh water		
	Prevalence (%)	Relative density	N	Prevalence (%)	Relative density	N
Mazocraes alosae	77.7	13.4	112	78.9	4.5	57
Clavellisa emarginata	30.4	2.5	112	12.3	1.2	57
Thynnascaris aduncum[1]	64.3	13.2	42	11.4	0.3	35
Hemiurus appendiculateus	88.1	5.2	42	77.1	5.8	35
Pronoprymna ventricosa	95.0	*	20	100	*	11
Pomphorhynchus laevis	10.0	0.3	20	9.1	0.3	11
Eubothrium fragile	54.5	1.1	33	69.6	1.0	23

[1] *Hysterothylacium aduncum* (Rudolphi 1802); * Numerous, relative density not determined.

Both *A. alosa* and *A. fallax* appear to become infected with *Hemiurus appendiculateus* and *Hysterothylacium aduncum* during the marine phase of their life history (Table 3.25).

The prevalence of infection of *H. aduncum* for both juvenile and adult *A. fallax* caught at sea (Table 3.25b) and from fish caught at the start of their spawning migration (Table 3.24) was c. 60%. This is approximately twice that reported by Hillman (2002) of

25.7% (n=35) for adult twaite shad caught at sea around the South West Coast of England between January and April.

Table 3.25: The prevalence of infection of a) *Hemiurus appendiculateus* and b) *Hysterothylacium aduncum* in *Alosa alosa* and *A. fallax* in relation to life stage and location, sample size in brackets (Taverny, 1991a).

a) *Hemiurus appendiculateus*

Life stage	Location	*Alosa alosa*	*Alosa fallax*
Juvenile (age 2 & 3)	Estuary	53.6% (28)	53.8% (39)
Juvenile & Adult	Sea	87.0% (171)	94.5% (174)
Adult	Fresh water	28.5% (35)	91.0% (21)

b) *Hysterothylacium aduncum*

Life stage	Location	*Alosa alosa*	*Alosa fallax*
Juvenile (age 2 & 3)	Estuary	3.57% (28)	0.0% (39)
Juvenile & Adult	Sea	55.5% (171)	61.0% (174)
Adult	Fresh water	94.5% (35)	32.0% (21)

- Inter- and intra-specific differences

In the marine environment, Taverny (1991a) reported the existence of a higher relative density of *Hemiurus appendiculateus* in *Alosa fallax* than in *Alosa alosa* (90.9 individuals per fish in *A. fallax* compared with 40.9 for *Alosa alosa*). In contrast, Doherty & McCarthy (2002) found a greater prevalence and abundance of *H. appendicuateus* in *A. alosa* compared with *A. fallax*.

Alosa fallax contained a higher relative density and prevalence of *P. ventricosa* and the eye parasites (*D. gasterostei* and *D. spathaceum*) compared with *A. alosa* and *E. fragile* were only reported from *A. fallax* (Doherty & McCarthy, 2002). Taverny (1991a) observed little difference in the densities of *Hysterothylacium aduncum* between species: 16.6 individuals per fish for *A. fallax* and 11.2 for *A. alosa*.

An assessment of the relative density of *Hysterothylacium aduncum* and *Hemiurus appendiculateus* in *A. fallax* from the Bay of Biscay (Taverny, 1991a) and Severn Estuary (Aprahamian, 1985) indicated that the relative densities of *Hysterothylacium aduncum* were similar: 16.6 individuals per fish (Bay of Biscay) compared with 13.2 (Severn Estuary). However, the relative density of *Hemiurus appendiculateus* was substantially higher in the marine environment; 90.9 compared with 5.2 individuals per fish in the Severn Estuary. This may reflect differences in the infection rate and/or abundance of prey organisms, or alternatively it may relate to the fact that the population on the Severn was not actively feeding, having commenced the freshwater phase of their spawning migration.

A comparison between *A. fallax* caught in fresh water on their spawning migration indicated a higher intensity and prevalence of *M. alosae* and *H.aduncum* in fish from the River Barrow when compared with those from the River Severn (Table 3.26). The levels for *C. emarginata* were similar while the prevalence of *H. appendiculateus* was higher in the Severn (Table 3.26).

Table 3.26: Prevalence and relative density of parasites from adult *A. fallax* from freshwater reaches of the River Barrow (Doherty & McCarthy, 2002) and the River Severn (Aprahamian, 1985).

Parasite	Barrow (Ireland)			Severn (England)		
	Prevalence (%)	Relative density	N	Prevalence (%)	Relative density	N
Mazocraes alosae	100.0	43.4	60	78.9	4.5	57
Clavellisa emarginata	25.0	2.6	60	12.3	1.2	57
Diplostomum gasterostei	21.7	1.3	60	Eyes not examined		
Diplostomum spathaceum	90.0	10.5	60			
Hysterthylacium aduncum	81.7	36.9	60	11.4	0.3	35
Hysterthylacium osculatum	63.3	7.6	60	Not detected		35
Hemiurus appendiculateus	25.0	5.6	60	77.1	5.8	35
Pronoprymna ventricosa	100.0	353.1	60	100.0	Not counted	11
Pomphorhynchus laevis	Not detected		60	9.1	0.3	11
Eubothrium fragile	58.3	1.1	60	69.6	1.0	23

More than 80% of juvenile (age 0+) *A. alosa* living in the estuary of the Sebou (Morocco) had Hemiurid spp. present in their stomachs (Sabatié, 1993). This is higher than that reported by Taverny (1991a) for juvenile *A. alosa* in the Gironde estuary (Table 3.25A), and by Doherty & McCarthy (2002) from the Waterford estuary (Ireland) of 41.7% for *A. alosa* (L_t 386-504 mm).

The spawning of *A. fallax* and the presence of *M. alosae* have been shown to be closely synchronised (Bychowsky, 1957). Table 3.27 shows the relative density and prevalence of *M. alosae* in relation to various life stages of *A. fallax* from the Severn Estuary, England (Aprahamian, 1985). Fish spawning for the first time were relatively lightly infected in contrast to the repeat spawners, who had a 100% infection and a significantly heavier burden (Figure 3.19). This may explain the higher prevalence and level of infection reported by Doherty & McCarthy (2002) for fish from the River Barrow compared to that observed by Aprahamian (1985) in the Severn (Table 3.26).

Table 3.27: The relative density and prevalence of *M. alosae* between juvenile (age 0 + & 1+) *A. fallax*, adult *A. fallax* on their first spawning migration, and from repeat spawners (Finlayson, 1981; Aprahamian, 1985).

Life stage	Relative Density (range)	Prevalence (%)
Juvenile (age 0+&1+)	0.0 (0-0)	0.0
First time spawners	1.5 (0-18)	54.5
Repeat spawners	24.8 (2-83)	100

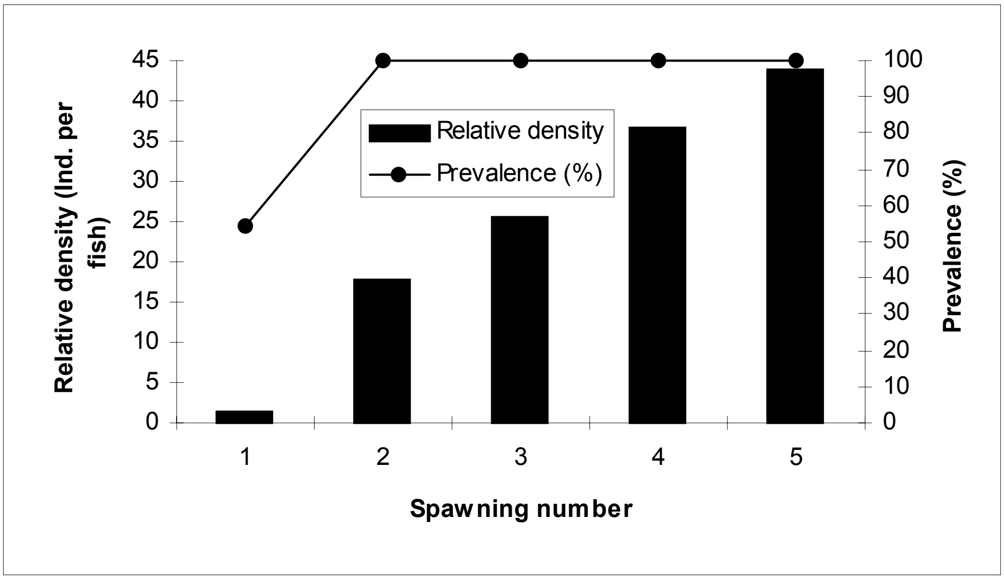


Figure 3.19: The relative density of *Mazocraes alosae* found in samples of *Alosa fallax fallax* from the Severn estuary in relation to the number of previous spawnings of individual fish (from Aprahamian, 1985).

3.3.5.1 Disease

Alosa fallax lacustris

Vogel (1903) reported the occurrence of the bacterium *Colibacillosis alosa fintae* in specimens of *Alosa fallax lacustris* in Lake Lugano (Italy). Fish that were infected with the bacterium did not feed or try to escape when handled. They had also lost their sense of balance, and the rear portion of the body was paralysed. The body organs, anus and cloaca were inflamed and small tumour-like thickenings were present on the gills and fins. Infected fish had a higher respiration rate (90 to 96 times min^{-1}) than healthy fish (28 to 36 times min^{-1}).

3.4 Nutrition and Growth

3.4.1 Feeding

3.4.1.1 Food intake

Alosa fallax fallax

The daily ration of 0+ *A. fallax* in the Elbe estuary decreased with fish size from 45% of their body weight (wet) per day in May to a minima of 1.3% in December for 0+ fish (Oesmann & Thiel, 2001). The daily ration for 1+ fish was lower at between 5 and 6 % day^{-1}, part of the difference may be related to size but also to the lower temperatures prevalent in 1993 (Figure 3.20).

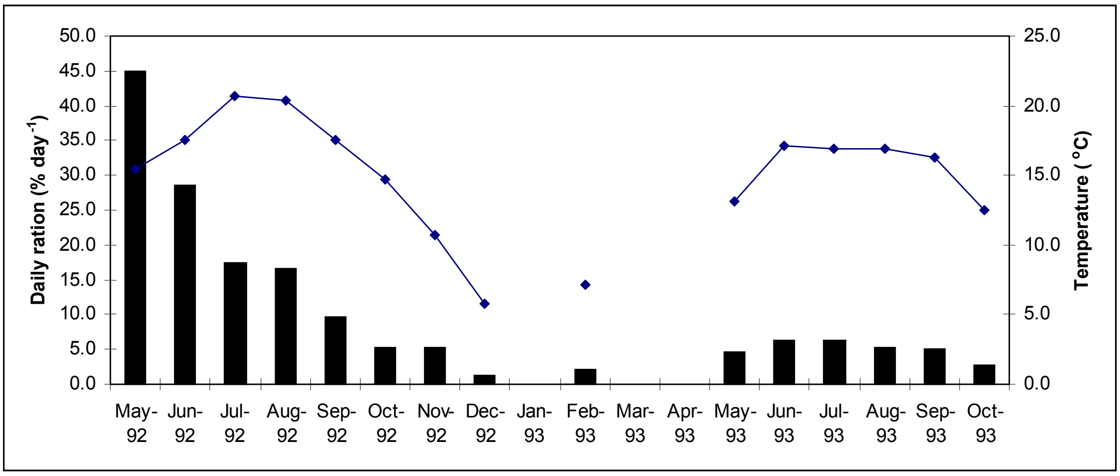


Figure 3.20: Winberg's (1956) daily ration and mean water temperature of the 1992 year class of *A. fallax* from the Elbe Estuary (Reproduced from Oesmann & Thiel, 2001).

3.4.2 Food

3.4.2.1 Diet of larvae

Alosa fallax fallax

In the freshwater reaches of the River Wye (Wales) the diet of the larvae (mean L_f 22.2 ± 0.4 mm) was dominated by Uniramia, particularly the orders Ephemeroptera and Diptera. The Diptera, specifically the families Chironomidae (pupae and larvae) and Simulidae (larvae), accounted for more than 80% (by number) of all the food items recorded (Aprahamian, 1989).

In relation to time of day, Esteves (pers. comm.) reported no diurnal pattern in feeding activity for larvae (4.65 – 18.10 mm L_{st}) from the Mira estuary, Portugal.

3.4.2.2 Diet of juveniles

Alosa alosa

In fresh water, the diet of the juvenile anadromous *Alosa alosa* (32 to 112mm L_t) consisted mainly of insects from the Order Ephemeroptera, Trichoptera, Diptera (in particular Chironomidae, both adult and larval stages) and Hemiptera (specifically Corixidae) (Wheeler, 1969a; Cassou-Leins & Cassou-Leins, 1981; Dautrey & Lartigue, 1983; Sabatié, 1993).

Cassou-Leins & Cassou-Leins (1981) observed that in the River Garonne (France), the main feeding activity occurred between 1000 and 2200 h. Diet was dominated by Diptera between 1000 and 1800 h and by Ephemoptera between 2200 and 1000 h (Figure 3.21).

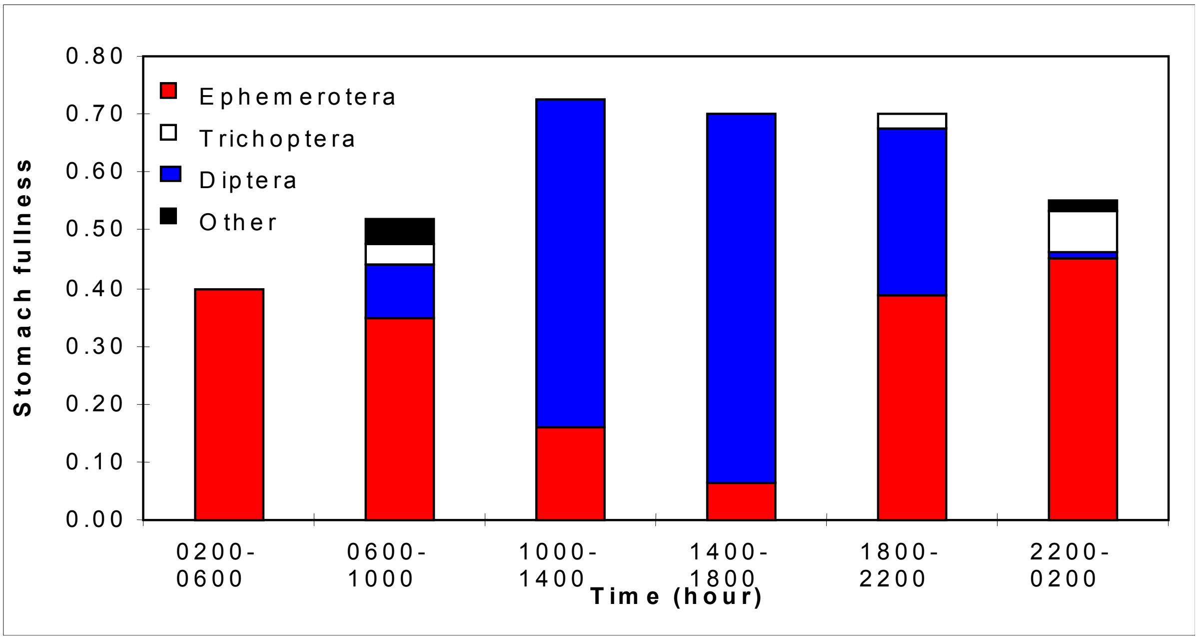


Figure 3.21: Diet of juvenile *Alosa alosa* from the River Garonne (France) in relation to time of day (Cassou-Leins & Cassou-Leins, 1981).

In relation to size, Cassou-Leins & Cassou-Leins (1981) reported that *A. alosa*, less than 40mm in length, fed equally on Ephemeroptera and Diptera, while those greater than 40mm fed primarily on Ephemeroptera and secondarily on Diptera. Trichoptera were only consumed by fish larger than 40mm. In the Sebou (Morocco), Sabatié (1993) found that only those alosids over 60mm in length fed on adult insects, specifically from the Order Hymenoptera.

Juvenile *Alosa alosa* (ranging in total length from 50 to 115mm) caught in estuarine waters fed mainly on crustaceans, particularly those from the orders Isopoda, Amphipoda and Mysidacea, and from the Class Copepoda (Anon., 1979a (in Taverny, 1991a); Sabatié, 1993). Ehrenbaum (1936) and Mohr (1941) also reported that juvenile *A. alosa* included the larvae of *Clupea harengus* in their diet.

A detailed description of the diet of immature (>0+) *Alosa alosa* at sea (Table 3.28) has been reported by Taverny (1991a) and is similar to that reported by Poll (1947), Bracken & Kennedy (1967), Wheeler (1969a), Quero (1984) and Maitland & Lyle (1991c).

In the Bay of Biscay euphausids were the preferred prey item through out the year followed by copepods, the other prey items were consumed infrequently, fish became more important in the diet during the summer and autumn months (Taverny & Elie, 2001b).

Table 3.28: Stomach contents of *Alosa alosa* (181-538 mm L_t) from the Bay of Biscay, France (Taverny, 1991a).

Phylum	Class	Order	Species
Algae	Rhodophyceae		*Rhodymenia palmata*
	Chlorophyceae		*Ulva lactuca*
Crustacea	Copepoda	Calanoidea	*Calunus helgolandicus*
			Calunus spp.
			Aetideus armatus
			Candacia armata
			Diaxis pigmaea
	Malocostraca	Mysidacea	*Gastrossacus* spp.
			Mysis spp.
		Isopoda	*Sphaeroma rugicauda* or *S. monodi*
		Euphausiacea	*Nyctiphanes couchi*
		Gammaridae	
Mollusca	Bivalvia	Mytiloida	*Mytilus spp.* (veliger stage)
	Cephalopoda	Sepioidea	*Sepiola atlantica*
Chordata	Osteichthyes	Clupeiformes	*Sprattus sprattus*
			Engraulis encrasicolus

In brackish water close to estuaries, *A. alosa* fed mainly on Crustacea; Calanoidea (*Eurytemora affinis* Pope), Mysidacea (*Neomysis vulgaris* Thomps) and Amphipoda (*Corophium grossipes* L.) [**Ehrenbaum, 1936**; Mohr, 1941]. In the Waterford estuary (Ireland), the diet of *Alosa alosa* measuring between 386 and 504 mm (L_t) consisted of the marine mysid *Pranus neglectus* (G.O.Sars) and the fish species *Merlangus merlangus* (L.), *Sprattus sprattus* and *Osmerus eperlanus* L., and a small quantity of the shrimp *Crangon allmani* Kinahan (Doherty & McCarthy, **2002**).

Alosa fallax fallax

In fresh water the diet of juvenile (age 0+) *Alosa fallax fallax* has been reported from the River Wye, Wales (Aprahamian, 1989) and from the River Sebou, Morocco (Sabatié, 1993). In both systems diet was dominated by Uniramia, particularly the orders Ephemeroptera, Diptera and Trichoptera. The main groups of Diptera found were Chironomidae (all life stages), and, in the Wye, the larval stage of Simuliidae. In the Sebou the juveniles were also found to consume fish larvae, Decapoda (*Atyaephira desmarestii*) and adult insects from the Order Hymenoptera. Planktonic Crustacea (Copepoda and Cladocera) were not found to be a significant food source in the freshwater reaches of either river system. For those fish ranging in size from 35 to 115 mm (L_t) there was no significant change in diet with size (Sabatié, 1993).

In the Severn estuary, the diet of the 0+ age group was dominated by the Crustacea Harpacticoidea (mainly *Tachidius discipes* and a few *Microarthridion*) and Mysidacea

(*Neomysis integer*), followed by Gammaridae and Calanoidea (*Eurytemora affinis*) [Aprahamian, 1989]. The smaller members of the zooplankton (Copepoda; Harpacticoidea and Calanoidea, and Cladocera; Daphnidae and Chydoridae) were more prominent in the diet during July and August than in September and October. In the autumn months the larger Crustacea members of the zooplankton; Mysidacea (*N. integer*), Amphipoda (*Gammarus zaddachi, G. salinus* and *Corophium volutator*) and Isopoda (*Eurydice pulchra*) together with fish species predominated. This may be a function of size (the mean size of juvenile *A. fallax* in July and August being 32.5 ± 1.2 mm (L_f) compared with 50.2 ± 2.5 mm in September and October), or it may reflect variation in the abundance of prey organisms.

In the Elbe estuary the diet in July was similarly dominated by copepods in terms of number (83%), but in terms of biomass fish dominated the diet (46%), followed by insects (32%), mysids (15%), plants (4%) and copepods (2%) [Oesmann & Thiel, 2001]. In August mysids (*N. integer*, *Mesopodopsis slabberi*) dominated the diet in terms of both number and biomass, followed by fish (*Sprattus sprattus*, *Osmerus eperlanus*, *Pomatoschistus* spp.) with a significant relationship between diet and fish size. The proportion of fish and *N.integer* in the diet increased and of *M. slabberi* and copepods decreased with fish size. *A. fallax* showed a preference for *M. slabberi* and *S. sprattus* larvae, cladocerns were consumed according to their availability and *O. eperlanus*, *Pomatoschistus* spp, *C. crangon*, *N. integer* and copedods were negatively selected (Figure 3.22).

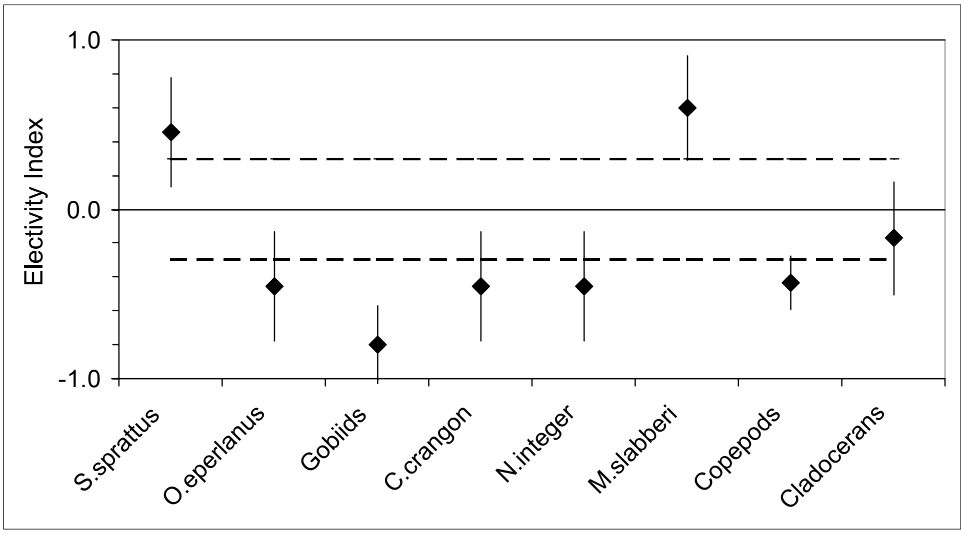


Figure 3.22: Daily mean of Ivlev's (1961) electivity index with regard to the main food items in the stomachs of age 0+ *A. fallax* from the Elbe Estuary between July 8th –9th 1993. Bars: confidence limits; broken lines: levels of significance according to Lazzaro (1987) [Reproduced from Oesmann &Thiel, 2001].

In the estuary of the Sebou, juvenile fish (55 to 105 mm (L_t)) fed primarily on Crustacea, (Amphidopa, Mysidacea, Isopoda and Decapoda (*Palaemon longirostris garciadii* and *P. varians*)) and consumed few of the smaller crustacean members of the zooplankton (Copepoda) (Sabatié, 1993). Also consumed, though infrequently, were Uniramia, (Diptera (adult Chironomidae), Hymenoptera) and fish.

Sabatié (1993) found that fish between 60 and 80 mm in length fed primarily on Isopoda (Gnathidae) and secondarily on Decapoda (Palaemonidae), while those between 80 and 100 mm fed almost exclusively on Palaemonidae. In the Gironde estuary (France) Uniramia were a much more important component of the diet in juvenile fish between 50 and 100 mm (total length) than in fish between 30 and 50 mm. In the smaller size range the diet consisted mainly of Uniramia and Crustacea (Mysidacea) and allochthonous plant material (Anon., 1979a in Taverny, 1991a).

The diet of fish (age 1) in the Elbe estuary was dominated by copedod eggs and copepodids, 96% and 4% in terms of number, respectively; copepods dominated the biomass (49%), followed by detritus (26%), mysids (10%) and plant material (10%) [Oesmann & Thiel, 2001]. In the outer Severn Estuary in May their diet was dominated by Gammaridae followed by Calanoidea (Aprahamian, 1989). However, during June and August the fish fed mainly on Mysidacea (*Neomysis integr*) followed by Gammaridae and fish (*Sprattus sprattus* and members of the Gobiidae).

At sea immature fish, between 50 and 130 mm in length possessed a similar diet of Mysidacea, Copepoda and 0+ Clupeidae and Gobiidae (Svetovidov, 1963; Wheeler, 1969a).

- Diurnal and tidal effects

Diurnal and tidal effects on diet have been reported by Oesmann & Thiel (2001) and Aprahamian (1988), respectively. In the Elbe Estuary fish dominated the diet during the day, their importance declining during the night (Figure 3.23). During dusk and dawn mysids became more important. At night insects dominated the diet with copepods (*Eurytemora affinis*) increasing in significance towards the end of the night / early morning (Oesmann & Thiel, 2001). The diurnal change in composition may reflect a change in feeding behaviour from particulate feeding during the day on the larger food items (fish and mysids) to filter feeding on insects and copepods during the night.

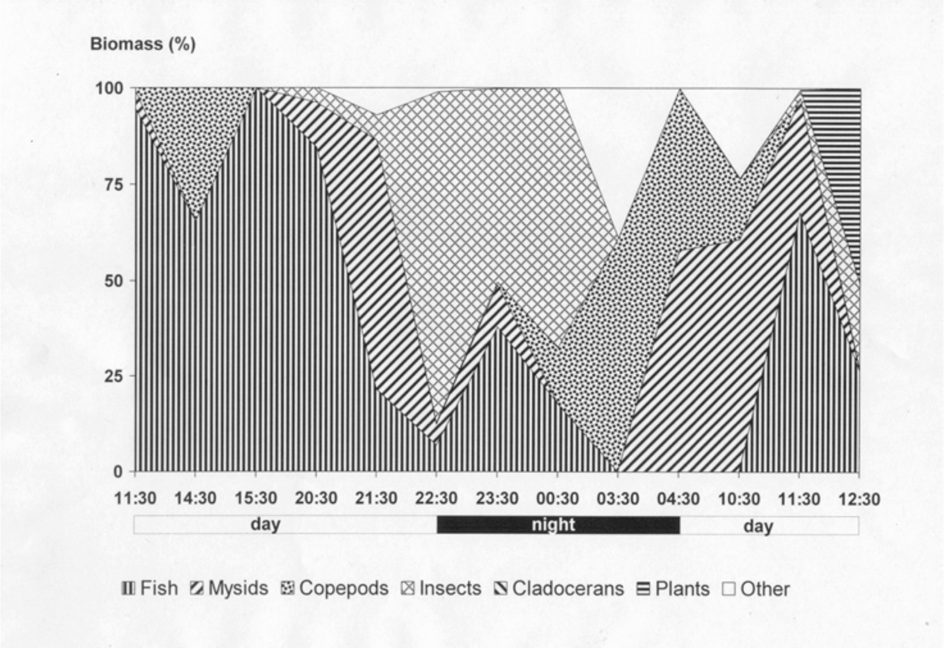


Figure 3.23: Diet (% biomass) of age 0 *A. fallax* shad in the Elbe Estuary during a 24 h period between 8th and 9th July 1993 (Oesmann & Thiel, 2001).

The influence of tidal height on the diet of juvenile (0+) *A. fallax fallax* in the Severn Estuary is shown in Figure 3.24. On spring tides the diet was almost equally dominated by Harpacticoidea copepods and Mysidacea, while under neap tides the Mysidacea were absent from the diet which was dominated by Harpacticoidea copepods (Aprahamian, 1988).

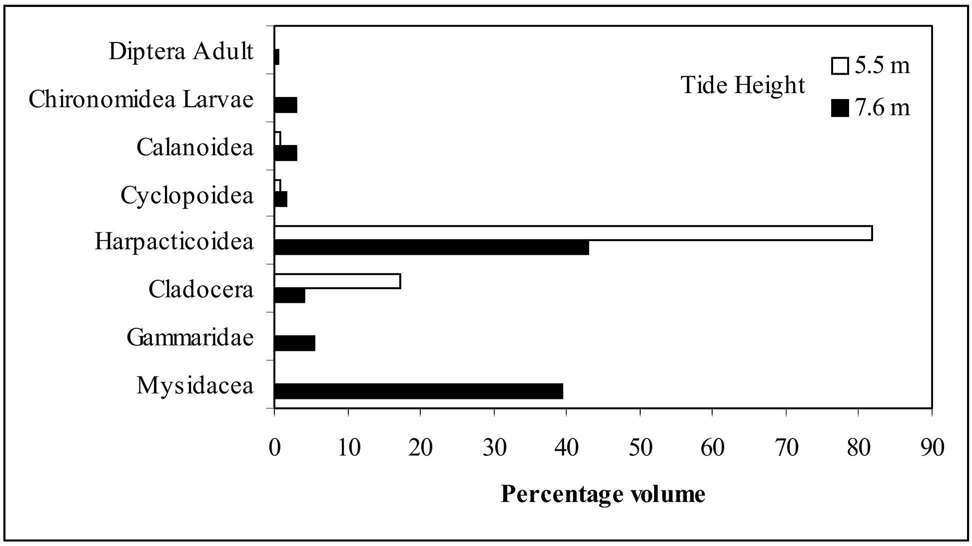


Figure 3.24: The diet of juvenile (0+) *Alosa fallax fallax* from the Severn Estuary (England) in relation to tidal height (Aprahamian, 1988).

- **Size effects**

The influence of size can be seen from Figure 3.25. The diet of one year old fish (L_f 96.6 ± 2.73 mm) from the Severn Estuary (England) was dominated by Mysidacea, and did not include smaller members of plankton. In contrast the Copepoda and Cladocera constituted *c*.50%, in terms of volume, of the diet of the 0+ age-class (L_f 32.5 ± 1.2 mm).

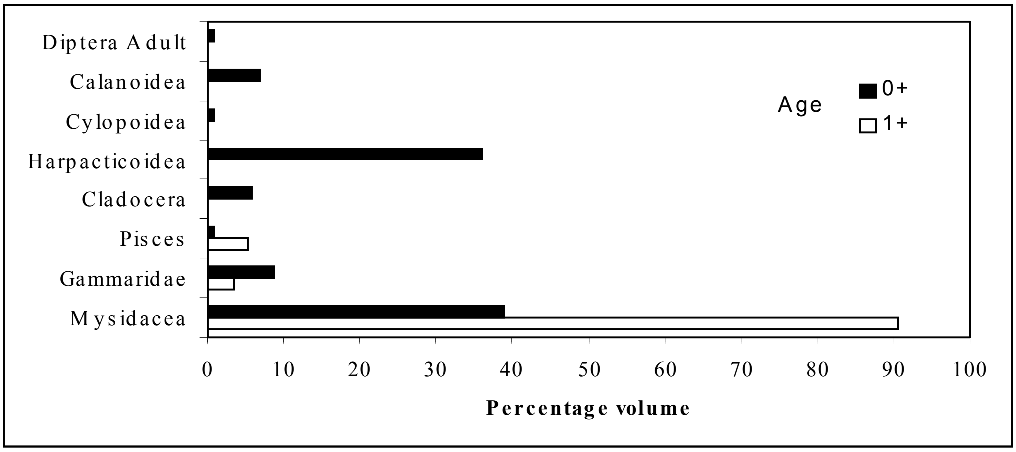


Figure 3.25: The diet of *Alosa fallax fallax* age 0+ (July and August) and 1+ (June to August) from the Severn Estuary, England (Aprahamian, 1989). [Only includes those food items that constituted >1% by volume.]

Alosa fallax rhodanensis

In the River Tiber, Italy, juveniles (40 to 90 mm) in length fed on Crustacea, which included Arthropoda and Uniramia (D'Ancona, 1928a). In the Rhône, Genoud (1999a) reported the diet from two fish (99&106 mm L_t). The fish consumed Simulidae adults, Ephemeroptera and fish larvae.

Alosa fallax nilotica

Vukovic (1961a) described the diet of 0+ fish from Lake Skadar and 1+ fish from Lake Bačin (Table 3.29). The diet of those aged 0+ consisted of Crustacea (Branchiopoda and Copepoda), Uniramia (Diptera) and Rotifera, as well as plant material, particularly Algae from the phylums Euglenophyta, Chrysophyta, Chlorophyta and Bacillariophyta. In contrast the 1+ *A. fallax nilotica* fed mainly on Crustacea and Rotifera and Algae from the Phylum Dinophyta. This difference may reflect the larger fish size or it may be that the other species of algae were not present in Lake Bačin.

Table 3.29: Diet of 0+ *A. fallax nilotica* from Lake Skadar and 1+ *A. fallax nilotica* from Lake Bačin (Vukovic, 1961a).

Phylum	Class	Order	Species consumed by 0+ *A. fallax nilotica* from Lake Skadar	Species consumed by 1+ *A. fallax nilotica* from Lake Bačin
Cyanophyta (Blue-green Algae)			*Microcystis flos aqua* *M.aeruginosa*	
Euglenophyta (Green Algae)			*Euglena* spp.	
Chrysophyta (Golden-brown Algae)			*Dinobryon* spp.	
Chlorophyta (Green Algae)			*Oocystis solitaria* *Scenedesmus* spp. *Pediastrum* spp. *Mougeotia* spp. *Spirogyra* spp.	
Bacillariophyta (Diatoms)			*Amphora ovalis* *Pleurosigma* spp. *Nitschia* spp.	
Dinophyta (Dinoflagellates)				*Ceratium hirundinella*
Rotifera			*Asplanchna priodnta* *Polyarthra trigla* *Tetramastix opoliensis* *Notholca longispina*	*Asplanchna priodnta* *Brachionus falcatus*
Crustacea	Branchiopoda	Cladocera	*Daphnia longispina* *D.cuclata* *Leptodora kindti* *Sida cristalina*	*Daphnia longispina* *Diaphanasoma brachyurum* *Bosmina longirostris*
	Copepoda	Cyclopoidea	*Cyclops* spp. *Mesocyclops leukarti* *Eudiaptomus gracilis*	*Moina* spp. *Cyclops* spp. *Canthocamptus staphylinus*
Uniramia (Insects)	Pterygota	Diptera	Chironomidae (larvae)	

3.4.2.3 Diet of adults

Alosa alosa

The diet of adult *A.alosa* at sea was similar to that for immature fish.

During the freshwater phase of their spawning migration, adult *A. alosa* do not feed (Eiras, 1981b). In those fish examined, the stomach usually contained a whitish or greenish fluid (Quignard & Douchement, 1991a).

- Landlocked *Alosa alosa*

The diet of the landlocked population of *Alosa alosa* in the Castelo de Bode reservoir (Portugal), was found to consist of Copepoda: *Copidodiaptomus* spp., *Cyclops* spp. and *Acanthocyclops* spp. (Eiras, 1981a). Similar findings were reported by Correia *et al.* (2001) were calanoid copepods (*Dussartius baeticus*) and cladocerans (Family Daphniidae) were preferentially consumed with cylopoid copepods (*Acanthocyclops* spp.) being of secondary importance. Ostracods, insects and algae were consumed very infrequently.

In Aguieira reservoir (Portugal) cladocerans (Family Daphniidae) and cylopoid copepods (*Acanthocyclops* spp.) occurred most frequently in the diet of both juvenile and adult *A. alosa* (Correia *et al*., 2001). Calanoid copepods (*Copidodiaptomus numedicus*) and ostrocods are consumed less frequently and insects only rarely. For the adults, calanoid copepods were more important during the autumn and winter months and ostrocods during the summer months, but the diet was still dominated by cladocerans and cylopoid copedods.

Alosa fallax fallax

Pre-spawning adult fish, on their spawning migration into fresh water were not found to be feeding actively (Bracken & Kennedy, 1967; Claridge & Gardner, 1978; Aprahamian, 1989; Doherty & McCarthy, 2002). Where fish had been feeding the total volume of food per feeding fish was low, less than 0.1% that of post-spawning fish (Aprahamian, 1989).

In fresh water, the stomach of those fish that had fed contained plastic, allochthonous plant material and emergent adult Trichoptera, suggesting that the fish had been feeding on relatively large particles in the drift or at the water surface (Bracken & Kennedy, 1967; Aprahamian, 1989).

The diet of post-spawning adult *A. fallax* in the Severn Estuary, England was dominated by Mysidacea (*Neomysis integer*) followed by Gammaridae (*Gammarus zaddachi*) and Crangonidae (*Crangon crangon*), and the occasional fish species (*Platichthys flesus, Sprattus sprattus* and Gobiidae) (Aprahamian, 1989). Similarly in the Waterford Estuary (Ireland), Doherty & McCarthy (2002) reported adult *A. fallax* to be feeding almost exclusively on the marine mysid *Praunus neglectus*.

In contrast, in the Tagus Estuary, Portugal, fish species dominated the diet. The main species were *Sardina pilchardus, Engraulis encrasicolus, Pomatoschistus minutus, Pomatoschistus microps* and *Atherina boyeri* (Assis *et al.,* 1992a). Food items which were considered of secondary importance were Mysidacea (*Neomysis integer*), Crangonidae (*Crangon crangon* and *Palaemon* spp.), Isopoda (Gnathiidae, Sphaeromatidae, Idoteidae, Cirolanidae and Limnoriidae) and Uniramia (Diptera, Coleoptera and Lepidoptera). The occasional specimens of Annelida (*Neris diversicolor*), Mollusca: Gastropoda (*Hydrobia ulvae*) and Cephalopoda (*Sepia officinalis*) were also found.

The diet of adult fish in the marine environment consisted of small fish and Crustacea, mainly Mysidacea, Isopoda and Euphausiacea (Murie, 1903; Redeke, 1939; Colette in Mohr, 1941; Rae & Wilson, 1952, 1956a & b, 1961; Rae & Lamont, 1961, 1962a; Svetovidov, 1963; Bracken & Kennedy, 1967; Wheeler, 1969a; Minchin, 1977; Taverny, 1991a).

In the Bay of Biscay, the preferred diet of *Alosa fallax* was fish, in particular *Engraulis encrasicolus* and *Sprattus sprattus,* but also including *Trisopterus luscus* and *Merlangius merlangius merlangus* followed by Euphausiacea (Taverny, 1991a; Taverny & Elie, 2001b). Peak feeding activity from April to December occurred between 4 and 8 hours after sunrise (Taverny & Elie, 2001b). Small fish dominated the diet throughout the year, while Euphausiacea were only a major component during the winter and spring months. Prey size, in particular that of *Engraulis encrasicolus,* increased with the size of *A. fallax* and could be explained by the equation (Taverny, 1991a):

$$Lt_{Ee} = 0.1788\ Lt_{Af} + 10.4611 \qquad (n = 61;\ r^2 = 0.25;\ P < 0.001)$$

Where: Lt_{Ee} = Total length (mm) of *Engraulis encrasicolus*;
Lt_{Af} = Total length (mm) of *Alosa fallax.*

Similar findings were reported for *A. fallax* caught off the South West coast of England between January and April where their diet was dominated by *Sprattus sprattus* (Hillman, 2002). In contrast, fish caught during the autumn in Cardigan Bay (West Wales) were found to be feeding almost entirely on Mysidacea (*Schistomysis spiritus*), with fish, mainly 0+ Clupeiformes, being of lesser importance (Aprahamian, 1989).

Alosa fallax rhodanensis

Adult fish did not feed on their spawning migration into the River Tiber (D'Ancona, 1928a).

From the Mediterranean Sea around the mouth of the River Tiber, D’Ancona (1928a) found that adult fish, less than 200 mm in length, fed on Crustacea: Amphipoda (*Gammarus pungens*) and Decapoda (*Palaemonidae* spp.); small fish of the family Engraulidae and Mugilidae, and the larval stages of Uniramia. The diet of those fish less than 200mm in length was similar, and consisted of Crustacea: Amphipoda (*G. pungens*), Decapoda (larval stages) and Isopoda (*Zenobiana prismatica, Idotea basteri*); and small fish of the families Engraulidae, Clupeidae (*Sardina pilchardus*) and Gobiidae.

Alosa fallax nilotica

A significant portion of the sexually mature fish in the Lower Neretva River and in Lake Bačin fed during the spawning period (April to May), with the percentage of stomachs which contained food ranging from 9.1 to 50.0%, and 20.0 and 72.3%, for the Lower Neretva River and Lake Bačin respectively (Vukovic, 1961a). In contrast in Lake Skadar the majority of the fish had empty stomachs, with less than 9.5% of the fish feeding. After spawning all fish commenced feeding.

In fresh water, the diet included fish (Table 3.30); Crustacea: Amphipoda and Decapoda; and Uniramia larvae, specifically of the Order Diptera (Vukovic, 1961a).

Table 3.30: Species of fish consumed by *A. fallax nilotica* from the River Neretva and from lakes Bačin and Skadar (Vukovic, 1961a).

Family	R. Neretva	Lake Bačin	Lake Skadar
Cyprinidae	*Alburnus albidus alborella* *Chondrostoma kneri* *Leuciscus svallize*	*Alburnus albidus alborella* *Chondrostoma kneri* *Leuciscus* spp.	*Alburnus scoranza* *Chondrostoma kneri* *Scardinius crytrophtalmus scardafa*
Mugilidae	*Mugil* spp.	*Mugil* spp.	
Gobiidae	*Pomatoschistus microps* *Gobius* spp.	*Gobius panizzai* *Gobius* spp.	
Poecilidae	*Gambusla* spp.	*Gambusla* spp.	

The marine diet of *A. fallax nilotica* has been reported by Canestrini (1885), Zompolas (1939) and Morovic (1959). During the winter months fish feed on the sea bottom at depths of 160m, on fish (*Cepola rubescens*, *Gobius* spp., *Brachyochirus pellucidus*, *Smaris vulgaris*, *S. alcedo*, *Box boops*, *Trisopterus capelanus*, *Mullus barbatus*) and Crustacea; Decapoda (*Leander* spp., *Penaeus* spp.) and Mysidacea (*Gastrosaccus normani, Anhialina agilis*) [Morovic, 1959]. During the summer months fish feed close to the surface on *Sprattus sprattus*, *Sardina pilchardus*, *Engraulis encrasicholus* and *Atherina* spp. (Canestrini, 1885; Morovic, 1959).

Zompolas (1939) reported similar findings for *Alosa fallax* from both the East and West coasts of Italy and therefore the samples were likely to have contained both *A.fallax rhodanensis* and *A.fallax nilotica.* The diet was found to consist mainly of fish (*Engraulis encrasicholus*, *Sardina pilchardus,Cepola rubescens*, *Aphia meridionalis*) and Crustacea; Decapoda (*Leander xiphias*, *Crangon spinosus*, *Pasiphae norvegica*), Mysidacea (*Mysis oculata*) and Ampipoda (*Gammarus pulex*, *G.rhipidiophorus*, *G.duebeni*, *Sextonia longirostris*, *Hyperoche kroyeri*). The fish were also found to have consumed Uniramia larvae (Chironomidae) and Algae.Those fish which were about to enter fresh water for spawning were not found to be feeding actively.

Alosa fallax algeriensis

The adults do not feed during their upstream migration (Kartas, 1981). At sea and while in the estuary, the shad consume small fish (*Engraulis*, *Sardina* and *Sardinella*) and small benthic crustaceans, mainly isopods and amphipods (Dieuzeide *et al.,* 1959; Kartas, 1981).

Alosa fallax lacustris

The diet of *A. fallax lacustris* has been described, for fish greater than 150mm (total length), from the lakes Maggiore, Como, Garda, Iseo and Lugano, (Italy/Switzerland) by Guccini (1904a&b), Malfer (1907), Barbieri (1908a), Ferrero, (1951), Berg & Grimaldi, (1966b), Grimaldi (1966), Guissani & Grimaldi (1975) and Oppi & Novello (1989). *A. fallax lacustris* were found to predominantly consume plankton, particularly Cladocera and Copepoda, whilst those fish over 300mm (total length) from Lake Maggiore also preyed on fish. The adult fish in Lake Maggiore did not feed during their spawning period in July (Quignard & Douchement, 1991f).

In Lake Maggiore the main species consumed were Cladocera: *Daphnia hyalina*, *Bythotrephes longimanus, Leptodora kindti, Sida cristallina and Diaphanosoma brachyurum*, and Copepoda: *Cyclopidae* spp*.,Diaptomidae* spp. and *Heterocope saliens* (Berg & Grimaldi, 1966b; Grimaldi, 1966). In the winter months diet was dominated by Copepoda, the shad then switching to prey on *D.hyalina* during the spring when production was reaching a maximum. At the end of the summer, once production of Cladocera (*D. hyalina* and *B. longimanus*) began to decline, the shad returned to feeding on Copepoda.

Influence of eutrophication on the diet of *A. fallax lacustris* from Lake Lugano has been discussed by Guissani & Grimaldi (1975). The Copepoda were a more significant food source during the spring and summer months in Lake Lugano than the larger Cladocera (*Daphnia hyalina*, *Bythotrephes longimanus, Leptodora kindti*), in contrast to the situation in the less productive lakes Maggiore, Como, and Garda.

In Medio Flumendosa Lake, Sardinia, Cottiglia (1969(70)) reported that the adults fed almost exclusively on plankton except during their reproductive period (March to May) when they fed on benthic Decapoda and Uniramia larvae. In Lake Omodeo (Sardinia) their diet consisted entirely of cladocerans and copepods (Cottiglia *et al*., 1982).

Alosa fallax killarnensis

Very little information exists on the diet of *A. fallax killarnensis.* A sample of fish (L_f 170 to 224mm) were found to contain almost entirely plankton (Table 3.31), specifically Cladocera (*Daphnia longispina*) and Copepoda (Trewavas, 1938; O'Maoileidigh, 1990).

Table 3.31: The stomach contents of 32 *Alosa fallax killarnensis* from Lough Leane (Ireland) caught during June (O'Maoileidigh, 1990).

Food category	Occurrence (%)	Number (%)
Crustacea		
Copepoda	82.1	4.76
Branchiopoda -cladocera (*Daphnia longispina*)	100.0	93.20
Branchiura	14.3	0.02
Uniramia		
Diptera (pupae)	14.3	0.03
Chironomidae (pupae)	35.7	0.06
Ceratopogonidae (pupae)	7.1	<0.01
Arachnida		
Hydracarina	25.0	0.03
Osteichthyes		
Clupeiformes		
Alosa (scales)	17.8	0.02

The fact that all Uniramia found in the stomach were pupating suggests that they were migrating up through the water column.

3.4.3 Growth rate

The description of growth concentrates mainly on growth in length, as weight varies with nutritional condition and reproductive state. For the mature population weight at age data is presented, where possible, for pre-spawned fish. The effect of spawning on condition and on the relationship between length and weight is discussed in Section 3.5 (Adult spawning migration).

Length has been reported in terms of total length, fork length and standard length. Total length has been adopted as the standard measurement and data was converted using the relationships reported in Douchement (1981).

- Estimation of age

Age has been estimated using both scales and otoliths and their structure has been described in Section 3.1.4, see also Baglinière *et al.* (2001). Scales on the whole are more difficult to interpret than otoliths (Mennesson-Boisneau & Boisneau, 1990) for the following reasons:

- The variability in scale morphology is large when compared to otoliths. However, using scales from the optimum part of the body (above the mid-line and in line with the dorsal fin) can reduce this.
- The intensity of the annulus differs on scales on the same fish and between fish.
- The loss of scale material associated with spawning, can in some cases eliminate the annulus or spawning mark from the previous year.

Mennesson-Boisneau & Boisneau (1990) compared estimates of age from both scales and otoliths and found for both *A. alosa* and *A. fallax fallax* the level of agreement between both methods to be greater than 90%. However, for hybrids (*A. alosa* x *A. fallax*) the level of agreement was lower (77% for females and 81.1% for males). Similarly for *A. fallax fallax*, O'Maoileidigh (1990) reported excellent agreement between the two methods up to age four, however, for fish older than 4 years it was considered more accurate to estimate age from otoliths because of the difficulties created by loss of scale material associated with spawning.

The level of precision was greater for age estimated from otoliths, as compared with estimates from scales (Mennesson-Boisneau & Boisneau, 1990). For otoliths, mean percentage error for both species was less than 1% (upper 95% confidence interval) compared with less than 2% from scales from *A. alosa* and less than 4% for *A. fallax fallax*.

- Reconstruction of growth history

For the anadromous populations in particular, where it has not been possible to sample all the age groups, the only approach to estimating length for the younger age groups is by backcalculation. The method depends on the annual nature of the annulus, and that the relationship between the size of the fish and its scale/otolith is directly proportional. Both scales (Berg & Grimaldi, 1966a; Douchement, 1981; Aprahamian, 1982; O'Maoileidigh, 1990; Sabatié, 1993) and otoliths (Taverny, 1991a; Gordo, 2002) have been used to reconstruct growth history.

On their spawning migration into fresh water, *Alosa* erode and /or absorb scale material that later regenerates and forms a characteristic scar or spawning mark (Section 3.1.4). Such loss of scale material could effectively bias the results. This was examined by Aprahamian (1982), who found that though the scale radius (measured at the apex) for a given size of fish was smaller for fish that had previously spawned, this difference was not significant ($P>0.05$).

The length at age from both scales and otoliths was compared by Taverny (1991a). The backcalculated length at age 1 was significantly greater ($p<0.05$) when estimated from otoliths than from scales, by 116% and 125% for *A. alosa* and *A. fallax fallax* respectively.

Comparison between length at age backcalulated from scales and that observed directly has been undertaken by Aprahamian (1982), Douchement (1981) and Sabatié (1993). Aprahamian (1982) reported no significant difference in the mean length of fish caught in one year with the mean (backcalculated) length of fish, from the same year-class, caught at a later date ($P>0.05$). In contrast Sabatié (1993) found that in the majority of cases the actual length observed was significantly greater ($P <0.05$) than that backcalculated. Similarly Douchement (1981) reported that the actual length was greater than the backcalculated length. The difference was greatest for the one year old age group by factor of between 2.19 and 2.10, while for fish two years and older the difference was between 1.19 and 0.99 that of the backcalculated value. Except for the one-year-olds, part of this difference may relate to the fact that the lengths of different year-classes were being compared.

Alosa alosa

For anadromous populations spawning takes place between May and July (Section 4.9.2) and at hatching the larvae measure between 7 and 12 mm (total length) [Vincent, 1894b; Le Clerc, 1941]. Samples of juvenile *A. alosa* from the Rhine (Germany) and from the Loire (France), taken in July approximately two months after spawning, ranged in length (total) from 30 to 69 mm (Hoek, 1899) and from 35 to 50 mm (Le Clerc, 1941), respectively. After three months the juveniles ranged from 30 to 97 mm in the Rhine and between 60 to 75 mm in the Loire. Juveniles sampled on the spawning grounds in the Garonne (France), during July, measured (mean ± 95% confidence intervals) 18.4 ± 0.38 mm (total length) [Cassou-Leins *et al.,* 1988a]. Their growth until emigration in October is shown in Table 3.32.

In then Loire juveniles caught on their downstream migration in August had reached a total length of between 50 and 83 mm, by September they ranged from 66 to 111 mm, by October from 57 to 124 mm and in November from 72 to 105 mm (Luquet, 1990). In the Gironde, after approximately 4 to 6 months, at the time of their seaward migration (October to December) the young range in size from 27 to 117 mm with mean length (± 95% confidence intervals) of 63.0 ± 0.6 mm (Anon., 1979a; Taverny, 1991a). Other studies have reported similar growth rates with fish reaching, by the autumn of their first year: 40 to 140 mm in the Rhine (Hoek, 1899); 80 to 110 mm in the Seine (Vincent, 1894b); 80 to 120 mm from Schleswig-Holstein (probably the Elbe) [Dunker & Ladiges, 1960; Ladiges & Vogt, 1965]; 150 mm in the Dordogne (Hoestlandt, 1958), 82 to 135 mm in the Lima (Alexandrino, 1996b) and 65 to 115 mm in the Sebou (Sabatié, 1993).

Table 3.32: Mean total length (± SD) in mm of juvenile (0+) *Alosa alosa* from the Gironde-Garonne-Dordogne system (France), data from Cassou-Leins *et al.* (1988a) and Taverny (1991a). Samples from different years have been combined.

Location Year	Agen (Garonne) 1986	Bergerac (Dordogne) 1988	Inner Estuary 1985 & 1986	Outer Estuary 1985 & 1988
Month				
July	18.4 ± 2.2	40.0 ± 4.4		
August	37.6 ± 7.5	50.2 ± 6.7	77.9 ± 7.4	
September	57.7 ± 8.3	52.7 ± 5.9	72.2 ± 9.7	86.4 ± 9.2
October			73.5 ± 9.6	78.7 ± 10.3

Little growth occurs over winter with fish in the Garonne measuring 68 mm by the following March, 81 mm by May and 91mm (80 to 120 mm) by July, when the fish are just over one year old (Anon. 1979a). Hoek (1899) reported similar findings for *A. alosa* from the Rhine (Table 3.33).

Table 3.33: Range in total length (mm) of *A. alosa* from the River Rhine (Hoek, 1899) and Gironde (Cassou-Leins *et al.*, 1988a and Taverny, 1991a).

Month	Total length (mm)	
	Rhine	Gironde
July	30 – 69	
August	30 – 97	
September	50 – 129	64-100
October	40 – 140	58-105
November	71 – 100	52-109
December	No samples	52-112
January		61-112
February		64-115
March		61-118
April	90 – 160	67-94
May	93 – 160	
June	96 – 194	
July	100 – 187	

For male and female *Alosa alosa* the length and weight at age for a number of populations is shown in Tables 3.34 & 3.35 and Tables 3.36& 3.37, respectively. The population in the River Douro represented the fastest growing population (Eiras, 1981b), followed by those from the rivers Mondego, Loire, Lima and Sebou (Alexandrino, 1996b; Mennesson-Boisneau & Boisneau, 1990; Sabatié, 1993; Gordo, 2002). On those systems where studies had been carried out over a number of years significant temporal differences were evident, particularly on the Loire, Gironde-Garonne-Dordogne and Adour.

The parameters for the von Bertalanffy growth model (von Bertalanffy, 1957) have been recalculated using data from Tables 3.34 & 3.36, and are presented in Table 3.38 for both male and female *A. alosa.* There was a significant correlation between the growth coefficient (K) and L4 for both male ($r^2 = 0.72$) and female ($r^2 = 0.79$) *A. alosa*. Though differences in the parameters existed between the sexes and populations the growth performance index (Pauly, 1979) varied little with a mean (± 95% CI) of 3.19 (± 0.03) and a coefficient of variation of 2.0%.

The seasonality of growth of *A. alosa* from Gironde-Garonne-Dordogne can be expressed by the equation (Taverny, 1991a):

$$L_t = L_\infty\{1\text{-exp-}[K(t\text{-}t_o)\text{-}(KC/2\pi\ (\sin(2\pi\ (t\text{-}t_s))))]\}$$

where: L_∞= 702.5(M), 745.0(F); K = 0.4655(M), 0.6996(F);

t_o = -0.4512(M), -0.3375(F); t_s = 0.3126(M), 0.6527(F) and C = 1(M&F).

The maximum length recorded for *A. alosa* was for a female fish of 830 mm from the rivers Mondego (Gordo, 2002) and Sebou, the details of the latter were reported to, but not corroborated by Sabatié (1993).

For male *A. alosa* the maximum size differed between river systems and ranged from 670 mm in the Douro (Eiras, 1981b) and Sebou (Sabatié, 1993) to 530 mm in the Adour (Douchement, 1981). Weight ranged from 3275 to 1350g (Table 3.39). For females the maximum length ranged from 680 to 740mm and weight from 3550 to 4430g, except in the Rhine and Adour (Table 3.39). In the case of the latter two rivers the sample size was small. Comparable findings were reported by **Ehrenbaum (1894, 1936), Roule (1925, 1929),** Poll (1947), **Dottrens (1952),** Dunker & Ladiges (1960), **Ladiges & Vogt (1965)** and Castelnaud (1978)**.**

The relationship between length and weight for fish caught during the freshwater phase of their spawning migration are presented in Tables 3.40 & 3.41, and for juvenile fish in Table 3.42. For those populations where a reasonable number of fish were sampled, the allometric growth parameter (b) for males ranged from 2.55 to 3.27 and for females from 2.61 to 3.52. Significant temporal differences were evident from Gironde-Garonne-Dordogne populations (Taverny, 1991a) with values over a three year study ranging from 2.85 to 3.27 for males and 2.61 to 3.52 for females. For juvenile (age 0+) *Alosa alosa* from the Gironde-Garonne-Dordogne and the Sebou the exponent varied from 2.78 to 3.03 (Sabatié, 1993; Taverny, 1991a).

Growth of the landlocked populations in their first year of life is greater than that in the anadromous populations, with fish capable of reaching 315 mm (Table 3.43). Subsequently growth slows, and their length at age becomes comparable with anadromous populations. The maximum length attained by landlocked populations is less than that of anadromous populations, with *A. alosa* from the Aguieira Reservoir (River Mondego, Portugal) reaching a maximum of *c.* 630 mm (male) and *c.* 590 mm (female) [Gordo, 2002]. The von Bertalanffy parameters are shown in Table 3.44 for Aguieira and El Kansera, the parameters for the latter were calculated using the middle value of the range in length for each age group quoted by Furnestin (1952). For the landlocked populations L4 was less and K was towards the upper end of the values observed in migratory populations. The highest value of the Brody growth coefficient was for the El Kansera population.

Table 3.34: Total length and standard deviation (mm) of anadromous male *Alosa alosa.*

River Country	Actual / Backcalculated	Age (year)								**Reference**
		1	2	3	4	5	6	7	8	
Aulne France	Actual				460.6 (25.3)	462.5 (38.8)				Véron (1999)
Loire France	Backcalculated	89.6 (13.9)	225.9 (28.6)	333.8 (35.6)	430.5 (36.1)	493.2 (28.5)	521.1 (23.4)			Douchement (1981)
	Actual[1]			427.0 (27.8)	478.8 (30.6)	532.2 (27.9)	578.8 (24.2)			Mennesson-Boisneau & Boisneau (1990)
Charente France	Actual			467.5 (81.3)	506.7 (43.7)	546.9 (28.9)	523.3 (37.5)	560.0		Véron (1999)
Gironde – Garonne – Dordogne France	Backcalculated[1]	93.2 (4.7)	222.4 (8.0)	348.1 (16.0)	455.7 (14.8)	499.8 (11.4)	527.0 (13.7)	556.4 (20.5)		Anon. (1979a)
	Backcalculated[2]	97.5 (8.7)	217.1 (9.1)	317.8 (12.2)	418.7 (22.1)	488.4 (19.3)	531.1 (12.3)			Cassou-Leins & Cassou-Leins (1981)
	Backcalculated	74.9 (15.0)	204.3 (28.5)	335.2 (36.5)	436.1 (31.8)	496.7 (26.0)	526.1 (24.4)			Douchement (1981)
	Backcalculated[2]	98.2 (14.5)	237.8 (35.2)	404.4 (37.7)	493.2 (34.2)	555.3 (29.4)	586.3 (31.6)			Dautrey & Lartigue (1983)
	Backcalculated	90.4 (12.5)	183.8 (26.2)	307.2 (39.4)	419.9 (34.3)	511.9 (29.8)	540.1 (29.8)			Taverny (1991a)
Adour France	Backcalculated	89.2 (19.4)	242.2 (34.1)	373.9 (40.9)	460.6 (29.4)	491.4 (19.0)				Douchement (1981)
	Actual[1]				488.0 (23.5)	510.6 (27.8)	539.5 (20.5)	567.9 (32.2)		Prouzet *et al.* (1994a)
Aude France	Backcalculated[3]	109.3 (18.0)	221.5 (8.6)	320.8 (14.1)						Douchement (1981)
Rhône France	Backcalculated[3]	101.7 (13.9)	226.2 (19.8)	318.5 (16.7)	412.3 (25.8)	454.0 (22.9)	490.0			Douchement (1981)
Lima Portugal	Actual			421.0 (54.4)[4]	469.8 (16.4)[4]	550.2 (11.7)[4]	589.2 (17.2)[4]	655.5 (54.4)[4]		Alexandrino (1996b)
Douro Portugal	Actual			440 - 510	500 - 575	576 - 620	610			Eiras (1981b)

Table 3.34: (cont.) Total length and standard deviation (mm) of anadromous male *Alosa alosa*.

River Country	Actual / Backcalculated	Age (year)								**Reference**
		1	2	3	4	5	6	7	8	
Mondego Portugal	Backcalculated	223.0 (31.6)	341.5 (26.0)	436.0 (19.1)	504.0 (11.8)	560.2				**Gordo (2002)**
Loukos Morocco	Actual[3]		216.0 (11.0)		487.0 (67.0)	576.0 (7.0)				**Sabatié (1993)**
Sebou Morocco	Backcalculated ([5]Actual)	133.6 (34.1)	309.7 (61.6)	434.7 (47.2)	501.2 (40.5)	547.0 (46.2)	582.1[5] (48.2)			**Sabatié (1993)**

[1] Fork length (L_f) converted to total length (L_t) using $L_t = 1.1325\ L_f + 2.6556$ (Douchement, 1981).
[2] Standard length (L_{st}) converted to total length using $L_t = 1.1882\ L_{st} + 9.4799$ (Douchement, 1981).
[3] Total sample ≤ 10.
[4] 95% Confidence intervals.

Table 3.35: Mean weight (standard deviation) in relation to age for anadromous male *Alosa alosa.*

River Country	Age (year)							Reference
	2	3	4	5	6	7	8	
Loire, France		653 (187)	979 (247)	1310 (254)	1658 (265)			Mennesson-Boisneau & Boisneau (1990)
Adour, France			1099 (30)	1352 (18)	1657 (27)	2114 (133)		Prouzet *et al.* (1994a)
Loukos, Morocco	84 (139)		995 (64)	1950 (175)				**Sabatié (1993)**
Sebou, Morocco		1407 (128)	1619 (324)	1948 (406)	2225 (513)	1703 (285)		**Sabatié (1993)**

Table 3.36: Total length and standard deviation (mm) of anadromous female *Alosa alosa*.

River Country	Actual / Backcalculated	Age (year)								Reference
		1	2	3	4	5	6	7	8	
Aulne France	Actual			545.0	556.7 (10.4)	560.0 (21.2)	540.0			Véron (1999)
Loire France	Backcalculated	94.1 (16.1)	224.6 (25.5)	350.7 (34.3)	455.5 (40.3)	528.0 (39.3)	538.4 (24.3)			Douchement (1981)
	Actual ^{1}				519.8 (28.3)	574.3 (24.5)	614.7 (22.3)	649.1 (19.3)		Mennesson-Boisneau & Boisneau (1990)
Charente France	Actual			530.0	558.0 (26.8)	572.4 (44.0)	580.0 (48.5)	552.5 (36.6)		Véron (1999)
Gironde – **Garonne – Dordogne** France	Backcalculated^1	78.5 (4.7)	202.0 (10.3)	318.6 (13.7)	437.5 (19.4)	522.5 (23.9)	559.8 (17.1)	575.5 (31.9)		Anon. (1979a)
	Backcalculated^2	95.3 (9.1)	247.6 (28.0)	380.3 (52.3)	482.3 (48.4)	547.3 (32.4)	580.6 (9.4)	598.1 (5.1)		Cassou-Leins & Cassou-Leins (1981)
	Backcalculated	73.1 (10.8)	198.6 (23.6)	326.7 (34.7)	444.5 (33.1)	530.0 (32.5)	573.2 (25.1)			Douchement (1981)
	Backcalculated^2	97.0 (19.0)	220.2 (43.4)	384.8 (41.1)	510.4 (37.2)	595.8 (40.0)	625.3 (43.7)	646.9		Dautrey & Lartigue (1983)
	Backcalculated	101.0 (16.9)	205.9 (35.5)	329.9 (44.3)	438.6 (41.5)	530.5 (40.2)	571.5 (23.4)	601.0		Taverny (1991a)
Adour France	Backcalculated	72.2 (12.0)	208.0 (29.6)	339.3 (39.6)	454.0 (50.9)	521.9 (38.6)	554.7 (31.6)			Douchement (1981)
	Actual ^{1}				529.3	548.5 (23.3)	590.2 (22.8)	610.2 (20.8)	622.7 (4.0)	Prouzet *et al.* (1994a)
Aude France	Backcalculated^3	107.7 (13.3)	231.9 (25.1)	340.9 (21.5)	433.8 (27.5)	489.7 (27.1)	536.1 (34.1)			Douchement (1981)
Rhône France	Backcalculated^3	101.1 (10.7)	266.4	363.7	415.0	476.5	520.0			Douchement (1981)
Lima Portugal	Actual					585.9 (16.0)^4	643.4 (11.3)^4	666.0 (18.2)^4		Alexandrino (1996b)
Douro Portugal	Actual			500 – 580	570 - 630	610 – 690	690 - 730			Eiras (1981b)
Mondego Portugal	Actual					625.5 (34.4)^4	635.0 (42.2)^4	680.0 (84.3)^4		Alexandrino (1996b)

Table 3.36: (cont.) Total length and standard deviation (mm) of anadromous female *Alosa alosa*.

River Country	Actual / Backcalculated	Age (year)								**Reference**
		1	2	3	4	5	6	7	8	
Mondego Portugal	Backcalculated	155.9 (52.0)	319.8 (35.7)	443.9 (37.9)	548.6 (29.6)	642.8 (27.9)	733.7 (14.0)	782.4		**Gordo (2002)**
Loukos Morocco	Actual[3]		270		463.0 (42.0)		605.0			**Sabatié (1993)**
Sebou Morocco	Backcalculated ([5]Actual)	119.4 (9.9)	322.5 (47.0)	437.5 (42.6)	528.8 (34.9)	587.8 (33.3)	619.1 (22.7)	633.0 (26.3)	666.7[5] (9.3)	**Sabatié (1993)**

[1] Fork length (L_f) converted to total length (L_t) using $L_t = 1.1325\ L_f + 2.6556$ (Douchement, 1981).

[2] Standard length (L_{st}) converted to total length using $L_t = 1.1882\ L_{st} + 9.4799$ (Douchement, 1981).

[3] Total sample $\leq$ 10.

[4] 95% Confidence intervals.

Table 3.37: Mean weight (standard deviation) in relation to age for anadromous female *Alosa alosa.*

River Country	Age (year)							Reference
	2	3	4	5	6	7	8	
Loire, France			1307 (312)	1716 (345)	2174 (363)	2665 (489)		Mennesson-Boisneau & Boisneau (1990)
Gironde – Garonne Dordogne, France				1880 (344)	2172 (323)	2565 (230)		Taverny (1991a)
Adour, France			1285	1701 (27)	2266 (24)	2599 (54)	3050 (50)	Prouzet *et al.* (1994a)
Loukos, Morocco	152		852 (72)		2005			Sabatié (1993)
Sebou, Morocco			2171 (377)	2872 (494)	3162 (343)	3368 (398)	3580 (202)	Sabatié (1993)

Table 3.38: von Bertalanffy growth parameters for male and female anadromous *Alosa alosa*, 95% confidence intervals in brackets.

River Country	Male			Female			Reference
	K	L_∞	T_o	K	L_∞	T_o	
Loire, France	0.288 (0.105)	663.9 (110.7)	0.502	0.277 (0.099)	701.4 (118.4)	0.496	Douchement (1981)
Gironde – Garonne – Dordogne France	0.280 (0.035) 0.184 (0.044) 0.279 (0.100) 0.315 (0.109) 0.124 (0.096)	683.7 (41.1) 825.9 (114.4) 688.5 (119.5) 727.7 (113.7) 1108.9 (603.4)	0.489 0.327 0.600 0.550 0.337	0.332 (0.057) 0.383 (0.064) 0.173 (0.080) 0.213 (0.113) 0.150 (0.105)	658.2 (33.5) 656.7 (26.6) 954.1 (277.5) 939.0 (291.6) 1006.0 (443.4)	0.628 0.597 0.550 0.508 0.312	Anon. (1979a) Cassou-Leins & Cassou-Leins (1981) Douchement (1981) Dautrey & Lartigue(1983) Taverny (1991a)
Adour, France	0.404 (0.163)	596.7 (93.6)	0.608	0.236 (0.104)	783.3 (190.1)	0.597	Douchement (1981)
Mondego, Portugal	0.259 (0.105)	746.2 (110.6)	-0.372	0.184 (0.041)	1058.9 (99.2)	0.706	Gordo (2002)
Sebou , Morocco	0.450 (0.205)	632.3 (95.0)	0.474	0.402 (0.061)	699.6 (21.3)	0.534	Sabatié (1993)

Table 3.39: Maximum length (total) and weight of anadromous *A.alosa* recorded from a number of river systems.

River (Country)	Male		Female		Reference
	L_{max}	W_{max}	L_{max}	W_{max}	
Rhine (Germany)	590	3000	624	3000	Hoek (1899)
Loire (France)	560 643	2180 2487	630 687	2470 3800	Douchement (1981) Mennesson-Boisneau & Boisneau (1990)
Gironde-Garonne-Dordogne (France)	613 517 565 659 597	2600 1890 2775	681 591 650 710 650	3240 2520 3020 3550	Anon. (1979a) Cassou-Leins & Cassou-Leins (1981) Douchement (1981) Dautrey & Lartigue(1983) Taverny (1991a)

Table 3.39: (cont) Maximum length (total) and weight of anadromous *A.alosa* recorded from a number of river systems.

Adour (France)	530	1350	595	1980	Douchement (1981)
Lima (Portugal)	666	3215	733	4400	Alexandrino (1996b)
Douro (Portugal)	670	3200	740	4430	Eiras (1981b)
Mondego (Portugal)	614	2287	680 830	3571	Alexandrino (1996b) Gordo (2002)
Sebou (Morocco)	670	3275	720	4525	Sabatié (1993)

Table 3.40: Parameters for the equation weight (g) = aLength^{b} (mm) for male *Alosa alosa*, (Imm. = immature).

River (Country)	Life stage	Length	a	b	n	R^2	Range (L_t)	Range (weight)	Reference
Rhine (Germany)	Adult	L_t (mm)	$2.716.10^{-8}$	3.965	8	0.91	499-590	1290-3000	Hoek (1899)
Loire (France)	Adult	L_f (mm) L_t (mm)	$5.507.10^{-3}$ $1.679.10^{-5}$	3.114 2.924	1172 89	0.66 0.82	349-643 440-570	174-2487 830-2180	Mennesson-Boisneau & Boisneau (1990) Douchement (1981)
Gironde – Garonne – Dordogne France	Adult	L_t (mm)	$7.510.10^{-5}$ $1.801.10^{-6}$ – $2.574.10^{-5}$	3.045 2.853 – 3.271	51 83-152	0.90 0.61-0.87	420-560 383-597	740-1890 580-2775	Douchement (1981) Taverny (1991a)
Adour France	Adult Imm.	L_t (mm)	$1.662.10^{-4}$ $1.774.10^{-5}$	2.551 2.868	120 31	0.66 0.95	420-530 150-300	750-1570 35-216	Douchement (1981) Douchement (1981)
Aude France	Imm.	L_t (mm)	$3.119.10^{-6}$	3.189	79	0.97	150-380	34-480	Douchement (1981)

Table 3.40: (cont) Parameters for the equation weight (g) = aLength^b (mm) for male *Alosa alosa*, (Imm. = immature).

Rhône France	Imm.	L_t (mm)	$4.963.10^{-6}$	3.104	23	0.97	150-340	28-345	Douchement (1981)
Lima Portugal	Adult	L_t (cm)	0.011	2.981	86	0.96	400-666	668-3215	Alexandrino (1996b)
Douro Portugal	Adult	L_t(mm)	$1.778.10^{-5}$	2.903	69	0.84	480-670	1100-3200	Eiras (1981b)
Mondego Portugal	Adult Juv & Adult	L_t (cm) L_t (mm)	0.018 $3.6.\ 10^{-3}$	2.854 3.249	9 37	0.93 0.99	535-614 80-*c*.680	1553-2287	Alexandrino (1996b) Gordo (2002)
Loukos Morocco	Juv & Adult[1]	L_t(mm)	$2.536.10^{-6}$	3.216	17	0.73	210-585	75-2125	Sabatié (1993)
Sebou Morocco	Adult	L_t(mm)	$2.071.10^{-6}$	3.259	482	0.93	445-670	850-3275	Sabatié (1993)

[1] Male & Female combined

Table 3.41: Parameters for the equation weight (g) = aLength^b (mm) for female *Alosa alosa*, (Imm. = immature)

River Country	Life stage	Length	a	b	n	R^2	Range (L_t)	Range (weight)	Reference
Rhine, Germany	Adult	L_t (mm)	$1.172.10^{-6}$	3.374	16	0.85	467-625	1050-3000	Hoek (1899)
Loire, France	Adult	L_f (mm) L_t (mm)	$7.298.10^{-3}$ $2.769.10^{-5}$	3.019 2.852	1054 26	0.65 0.75	423-687 500-630	500-3800 1450-2470	Mennesson-Boisneau & Boisneau (1990) Douchement (1981)
Gironde – Garonne – Dordogne, France	Adult	L_t (mm)	$4.656.10^{-7}$ $3.958.10^{-7}$ – $1.227.10^{-4}$	3.497 2.610 – 3.518	58 79 -188	0.78 0.62-0.71	500-650 436-650	1130-3020 1150-3550	Douchement (1981) Taverny (1991a)
Adour France	Adult Imm.	L_t (mm) L_t (mm)	$1.867.10^{-5}$ $9.302.10^{-6}$	2.915 2.868	21 31	0.61 0.95	500-590 150-300	1350-2460 35-216	Douchement (1981) Douchement (1981)
Aude France	Imm.	L_t (mm)	$5.518.10^{-6}$	3.088	71	0.85	150-380	34-480	Douchement (1981)
Rhône France	Imm.	L_t (mm)	$2.592.10^{-6}$	3.221	24	0.98	150-340	28-345	Douchement (1981)
Lima Portugal	Adult	L_t (cm)	0.036	2.717	71	0.71	480-733	1237-4400	Alexandrino (1996b)
Douro Portugal	Adult	L_t(mm)	$1.193.10^{-5}$	2.970	91	0.89	540-730	1530-4430	Eiras (1981b)
Mondego Portugal	Adult Juv & Adult	L_t (cm) L_t(mm)	0.158 $4.2.\ 10^{-3}$	2.333 3.201	11 40	0.53 0.99	583-680 80-830	1984-3571	Alexandrino (1996b) Gordo (2002)
Sebou Morocco	Adult	L_t (mm)	$8.206.10^{-7}$	3.411	317	0.72	490-720	1250-4525	Sabatié (1993)

Table 3.42: Parameters for the equation weight (g) = aLength^{b} (mm) for juvenile *Alosa alosa.*

River Country	Life stage	Length	a	b	n	R^2	Range (length) mm	Range (weight) g	Reference
Gironde - Garonne - Dordogne, France	0+	L_t(mm)	$6.511.10^{-6}$ – $2.02.10^{-5}$	2.777 – 3.031	179-806	0.86-0.96	27-117	0.1-11.3	Taverny (1991a)
Sebou, Morocco	0+	L_t(mm)	$8.308.10^{-6}$	3.008	47	0.96	5.5-11.5	1.4-12.1	Sabatié (1993)

Table 3.43 Range in total length (mm) or mean (SD or 95% confidence intervals) of landlocked male and female *Alosa alosa.*

Waterbody, River Country	**Sex**	**Age (Year)**						**Reference**
		1	**2**	**3**	**4**	**5**	**6**	
Aguieira, Mondego, Portugal	**M**	298	375	430	567	502		Collares-Pereira *et al.* (1999)
	F	315	404	453	500			
	M	236.7 (36.3)^{1}	345.2 (32.7)^{1}	430.0 (28.0)^{1}	**484.8 (24.8)^{1}**	**536.2 (31.4)^{1}**	**563.8**	Gordo (2002)
	F	237.5 (36.6)^{1}	353.6 (37.7)^{1}	431.2 (26.4)^{1}	**486.1 (28.6)^{1}**	**539.8 (26.3)^{1}**		
Castelo do Bode, Tejo Portugal	**M**	<274	268 – 413	407 – 491				Eiras (1983)
	F	<313	299 – 450	446 – 498				
	M				420.7 (12.8)^{2}			Alexandrino (1996b)
	F			320.0 (74.7)^{2}	400.3 (18.7)^{2}			
El Kansera, Sebou Morocco	M&F	180 – 270	310 – 360	350 – 400	400 – 450	>450		Furnestin (1952)

^{1} = SD; ^{2} = 95%CI

Table 3.44: von Bertalanffy growth parameters for male and female landlocked *Alosa alosa*, 95% confidence intervals in brackets.

Waterbody, River Country	Sex	Growth parameter			Reference
		K	L_∞	T_o	
Aguieira, Mondego, Portugal	M	0.363 (0.009)	610.1 (4.4)	-0.780	Collares-Pereira *et al.* (1999)
	F	0.373 (0.017)	586.1 (7.6)	-1.077	
	M	0.279 (0.082)	660.8 (50.9)	-0.048	Gordo (2002)
	F	0.291 (0.227)	672.4 (194.6)	-0.513	
El Kansera, Sebou, Morocco	M&F	0.543 (0.018)	467.1 (3.8)	-0.224	Furnestin (1952)

Alosa fallax fallax

In the Elbe (Germany), larval *A. fallax fallax* measure 4.25 to 6.0 mm (Ehrenbaum, 1894) while in the Wye (Wales) larvae measured 6.2 to 9.2 mm (Aprahamian, 1982), at hatching. Their growth rate during their first year until their emigration has been reported from the Severn, England (Claridge & Gardner, 1978; Aprahamian, 1988), Elbe, Germany (Ehrenbaum, 1894; Möller, 1988; Oesmann, 1994; Thiel *et al.,* 1996a), Gironde-Garonne-Dordogne, France (Anon., 1979a; Taverny, 1991a) and from the Sebou, Morocco (Sabatié, 1993) [Table 3.45].

Table 3.45: Mean total length (SD) in mm of *Alosa fallax fallax* from the rivers Elbe (Ehrenbaum, 1894; Möller, 1988; Oesmann, 1994), Severn (Aprahamian, 1988), Gironde estuary (Taverny, 1991a) and Sebou (Sabatié, 1993).

Month	Elbe (Germany)			Severn[1] (England)	Gironde (France)	Sebou (Morocco)
	Ehrenbaum (1894)	Möller (1988)	Oesmann (1994)			
June		46.3 (12.2)	34.2 (2.7)			
July	49.9 (8.5)	49.0 (9.2)	48.6 (7.7)	30.9 (4.2)	36.5 (5.0)	64.6 (9.6)
August	57.3 (11.4)	61.2 (18.5)	75.6 (12.3)	44.0 (7.7)	44.1 (7.0)	69.7 (6.0)
September	91.6 (12.3)	72.0 (9.1)	81.3 (16.1)	58.9 (11.6)	54.6 (11.5)	75.1 (10.8)
October	89.0 (6.3)	76.0 (9.6)	94.2 (13.0)	68.7 (11.3)	63.4 (10.8)	
November	104.3 (10.7)	74.5 (9.3)	104.0 (8.2)			78.8 (10.3)
December			101.0 (18.1)			79.2 (10.2)

[1] Fork length (L_f) converted to total length (L_t) using $L_t = 1.1264\ L_f + 3.5260$ (Douchement, 1981).

Little growth occurs over winter (Anon. 1888; Claridge & Gardner, 1978; Anon. 1979a; Aprahamian, 1988; Taverny, 1991a; Thiel *et al.,* 1996a) [Figure 3.26].

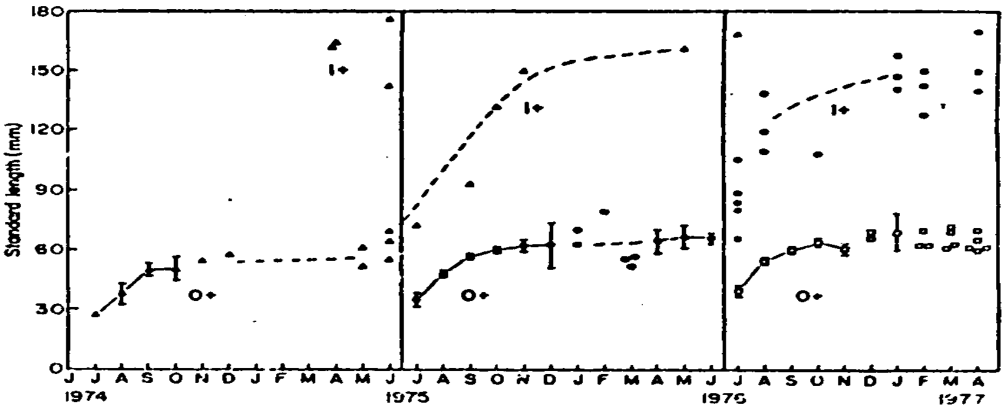


Figure 3.26: The standard length (mean ± 95% confidence intervals) of 0+ *Alosa fallax fallax* from the Severn Estuary (England) between July 1974 and April 1977 (Reproduced from Claridge & Gardner, 1978).

The growth of juvenile (age 0+) twaite shad from the Elbe during their first 18 months; June until October the following year, could be described using the equation (Thiel *et al.,* 1996a):

$$L_t = L_\infty\{1\text{-}\exp(-K(t\text{-}t_o)\text{-}[KC/2B\ (\sin(2\pi\ (t\text{-}t_s))\text{-}\sin(2\pi\ (t_o - t_s)))]\}$$

where:

$L_\infty = 61.29$;

$K = 0.2$;

$t_o = 0.336$;

$t_s = 0.538$

$C = 1.219$.

The equation accurately described the pattern of growth ($r^2 = 0.994$) and correctly reflected the period of little growth over the winter period.

Length and weight at age data for various populations are shown in Tables 3.46 & 3.47 and 3.48 & 3.49 for *A. fallax fallax*, respectively. The fastest growing populations were in the rivers Nyamunas, Lithuania (Manyukas, 1989) and in the Loire and Charente, France (Mennesson-Boisneau & Boisneau, 1990; Véron, 1999). There was little difference in length at age between the other populations ranging from the Sebou (southern limit of range) to those in the Severn (northern limit of range). However, growth in the first year was higher in fish from the Sebou and in females from the Gironde-Garonne-Dordogne. Except for the Nyamunas and Loire stocks there was little difference in weight at age for the males. Females from the French populations in the rivers Loire and Gironde-Garonne-Dordogne were heavier compared with fish of the same age from other stocks. However, the sample from the Gironde-Garonne-Dordogne was small (Taverny, 1991a).

The values of the exponent reported by Aprahamian (unpubl.) for the 0+ and 1+ populations from the Severn and Wye were higher than values found by other studies (Claridge & Gardner, 1978; Taverny, 1991a; Sabatié, 1993). The findings indicate that fish become heavier for their length, partly reflecting the transformation from larvae to juvenile for the 0+ age group. Fish aged 1+ and where the sample was taken over the entire year it may reflect the improvement in feeding conditions between spring and autumn.

The parameters for the von Bertalanffy growth model have been recalculated using data from Tables 3.46 & 3.48, and are presented in Table 3.50 for both male and female *A. fallax.* No significant correlation ($\alpha = 0.05$) existed between the growth coefficient (K) and L_9 for male ($r^2 = 0.45$) and female ($r^2 = 0.43$) *A. fallax*. Combining the data for the two sexes indicated a significant negative relationship (Figure 3.27). The value of K ranged from 0.265-0.543 year^{-1}for males and 0.259-0.403 year^{-1} for females. L_9 varied between 384-531 mm and 467-577 mm for males and females, respectively. Of the various populations, significant differences ($P<0.05$) were only evident between females from the Gironde-Garonne-Dordogne (Anon. 1979a) and the Severn and Adour (Aprahamian, unpubl.; Douchement, 1981). There was no trend in either parameter from North to South. The growth performance index (Ø') varied little between the sexes and between populations with an overall mean (n=15) of 2.90 (± 0.04) and a coefficient of variation of 2.6%.

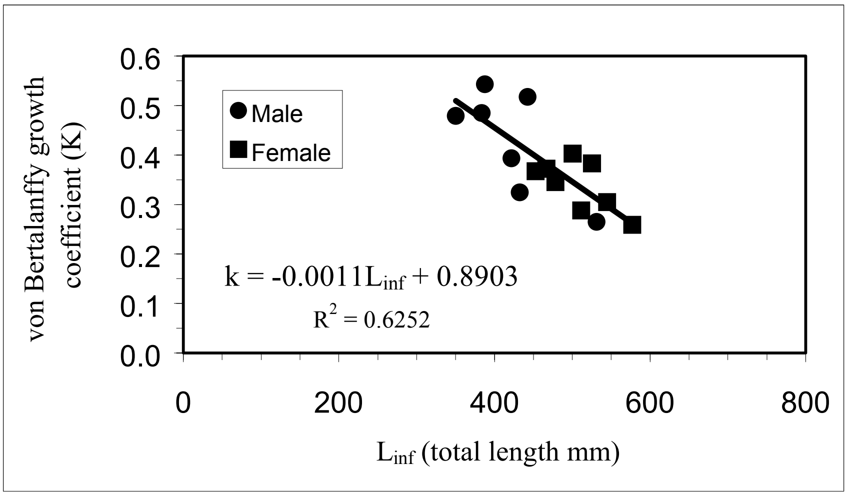


Figure 3.27: Relationship between von Bertalanffy coefficient (K) and the asymptotic length (L_∞).

The seasonality of growth of *A. fallax* from the Gironde-Garonne-Dordogne can be expressed by the equation (Taverny, 1991a):

$L_t = L_\infty\{1\text{-}\exp\text{-}[K(t\text{-}t_o)\text{-}(KC/2\pi\ (\sin(2\pi\ (t\text{-}t_s))))]\}$

where:

L_∞ = 478.5(M), 621.0(F);
K = 0.6551(M), 0.5286(F);
t_o = -0.0948(M), -0.1593(F);

t_s = 0.6038(M), -3.9127(F);
C = -0.6658(M), 0.5844(F).

Females obtain a larger size than males (Table 3.51). Manyukas (1989) reported that the largest specimen from the River Nyamunas (Lithuania) measured 568mm (L_t) and 1520g. For other populations the maximum length obtained ranged from approximately 460 to 520 mm for females and from 430 to 500 mm for males. There was reasonable agreement between L_{max} and L_∞ for both female and male *A. fallax*, with the exception of the studies by Anon. (1979a) and Taverny (1991a) from the Gironde-Garonne-Dordogne. The maximum weight for females was approximately 1.1 to 1.5kg, and for males was 0.6 to 1.0kg.

For those populations where adequate samples were obtained the allometric growth parameter (b) for males ranged from 2.62-3.38, and for females from 2.49-3.37 (Table 3.52 & 3.53). For juvenile (age 0+) *Alosa fallax* from the Severn, Wye, Gironde-Garonne-Dordogne and Sebou the exponent varied from 2.73-4.36 (Claridge & Gardner, 1978; Taverny, 1991a; Sabatié, 1993; Aprahamian, unpubl.) [Table 3.54]. For the 1+ age group the exponent was 3.82 (Aprahamian, unpubl.) [Table 3.54].

Table 3.46: Total length and standard deviation (mm) of anadromous male *Alosa fallax fallax*.

River Country	Measured / Backcalculated	Age (year)										Reference
		1	2	3	4	5	6	7	8	9	10	
Nyamunas Lithuania	Measured[2]			367.0	405.0	439.6	458.6	488.3				Manyukas (1989)
Elbe Germany	Measured			321.5	354.4	385.2	389.5	405.7	401.8			Hass (1965)
Holland	Measured					354.5 (22.2)	373.9 (15.5)	386.0 (19.8)	395.0	400.0		Aprahamian (1982 & unpubl.)
Severn England	Measured[2]			284.4 (22.2)	341.7 (14.9)							Claridge & Gardner (1978)
	Backcalculated[1] * Measured	85.5 (14.8)	181.9 (35.5)	270.7 (35.1)	325.1 (24.1)	349.8 (23.5)	365.8 (21.7)	386.4* (21.0)	400.7* (17.2)	407.6* (22.2)	408.0* (32.8)	Aprahamian (Unpubl.)
Wye Wales	Measured[1]			317.4 (4.8)	316.1 (20.1)	348.4 (20.3)	348.9 (18.9)	412.1	373.7			Aprahamian (Unpubl.)
Tywi Wales	Measured[1]						364.8	364.2 (12.2)	381.9 (14.0)			Aprahamian (Unpubl.)
Barrow Ireland	Backcalculated[1] Male & Female	87.7	161.9	239.7	293.7	360.3	389.5	397.4				Bracken & Kennedy (1967)
	Backcalculated[1]	64.0 (10.4)	166.5 (23.2)	265.6 (31.6)	322.0 (20.2)	347.8 (38.4)	350.1 (12.1)	374.9	391.8			O'Maoileidigh 1990
	Measured Male & Female		209.0	351.0	368.0	390.0	400.0	429.0				**Doherty & McCarthy (2002)**
Seine France	Measured[3]		223.5	292.5								Roule (1922a)

Table 3.46: (cont) Total length and standard deviation (mm) of anadromous male *Alosa fallax fallax*

Loire France	Measured[1]			353.5 (29.4)	391.8 (40.5)							**Mennesson-Boisneau & Boisneau (1990)**
	Backcalculated	86.3 (8.7)	227.5 (20.6)	319.2 (21.8)	367.5 (21.8)	397.5 (10.6)						Douchement (1981)
Charente France	Measured				376.0 (29.2)							Véron (1999)
River Country	Measured / Backcalculated	Age (year)										Reference
		1	2	3	4	5	6	7	8	9	10	
Gironde – Garonne – Dordogne France	Backcalculated[1]	66.3 (8.3)	161.9 (19.6)	266.8 (17.2)	317.4 (12.6)	391.8 (50.2)						Anon. (1979a)
	Backcalculated	74.1 (10.1)	196.0 (22.4)	292.2 (21.9)	323.4 (25.8)	348.1 (29.6)						Douchement (1981)
	Backcalculated	76.8 (16.4)	180.6 (27.3)	245.8 (28.0)	285.1 (27.9)	308.7						Taverny (1991a)
Adour France	Backcalculated[3]	78.1 (5.9)	191.8 (19.0)	276.3 (14.8)	342.2 (12.5)	407.5 (31.8)						Douchement (1981)
Lima Portugal	Measured		289.0 (37.0)[4]	360.7 (24.2)[4]	391.5 (14.7)[4]	439.4 (24.2)[4]						Alexandrino (1996b)
Mondego Portugal	Measured			372.0 (13.4)[4]	397.5 (9.9)[4]	430.0 (11.6)[4]						Alexandrino (1996b)
Tejo Portugal	Measured		293.4 (18.3)[4]	327.0 (13.1)[4]	390.5 (25.0)[4]							Alexandrino (1996b)
Guadiana Portugal	Measured			322.0 (25.0)[4]	374.5 (5.2)[4]	407.0 (25.0)[4]						Alexandrino (1996b)
Loukos Morocco	Measured		224.0 (24.0)	283.0 (27.0)	312.0 (16.0)	333.0 (17.0)						Sabatié (1993)
Sebou Morocco	Backcalculated * Measured	100.5 (19.0)	190.6 (33.3)	261.1 (27.0)	304.9 (23.9)	342.1* (22.3)						Sabatié (1993)

[1] Fork length (L_f) converted to total length (L_t) using $L_t = 1.1264\ L_f + 3.5260$ (Douchement, 1981).

[2] Standard length (L_{st}) converted to total length using $L_t = 1.1896\ L_{st} + 5.9359$ (Douchement, 1981).

[3] Total sample ≤ 10.

[4] 95% Confidence intervals.

Table 3.47: Mean weight (g) and standard deviation (in brackets) in relation to age for anadromous male *Alosa fallax fallax.*

River Country	Age (year)											Reference
	1	2	3	4	5	6	7	8	9	10	11	
Nyamunas , Lithuania			323	552	624	735	890					Manyukas (1989)
Severn , England		166	183 (53) 293 (74)	290 (62) 355 (70)	428 (86)	467 (90)	537 (110)	602 (107)	640 (122)	608 (90)		Claridge &Gardner (1978) Aprahamian (Unpubl.)
Wye, Wales			320 (56)	272 (58)	380 (84)	385 (66)	643	478				Aprahamian (Unpubl.)
Tywi, Wales						360	423 (64)	449 (66)				Aprahamian (Unpubl.)
Seine, France		92	208									Roule (1922a)
Loire, France			390 (85)	505 (189)								Mennesson-Boisneau & Boisneau (1990)
Loukos, Morocco		231 (260)	238 (74)	316 (63)	361 (76)							Sabatié (1993)
Sebou, Morocco		118	280 (95)	329 (46)	390 (64)							Sabatié (1993)

Table 3.48: Total length and standard deviation (mm) of anadromous female *Alosa fallax fallax*.

River Country	Measured / Backcalculated	Age (year)											Reference
		1	2	3	4	5	6	7	8	9	10	11	
Nyamunas Lithuania	Measured[2]			368.2	388.2	450.3	477.6	496.6	521.6	563.2			Manyukas (1989)
Elbe Germany	Measured			364.6	407.2	410.2	446.8	446.8	471.6				Hass (1965)
Holland	Measured				365.0	412.1 (21.8)	416.4 (27.2)	453.8 (36.4)	452.5 (31.8)	465			Aprahamian (1982 & unpubl.)
Severn England	Measured[2]				365.3 (19.8)	394.9 (18.7)	410.6 (6.6)						Claridge & Gardner (1978)
	Backcalculated[1] [4] Measured	88.6 (15.4)	189.1 (30.8)	279.8 (35.6)	348.0 (28.6)	385.9 (19.8)	406.2 (18.4)	419.4 (20.6)	434.0[4] (21.3)	446.6[4] (21.9)	460.7[4] (21.9)	479.7[4] (28.4)	Aprahamian (Unpubl.)
Wye Wales	Measured[1]				357.1 (15.0)	380.8 (16.0)	394.3 (16.4)	416.5 (8.4)	432.3	449.2 (28.3)			Aprahamian (Unpubl.)
Tywi Wales	Measured[1]						410.1 (21.9)	428.5 (24.0)	409.4 (36.0)				Aprahamian (Unpubl.)
Barrow Ireland	Backcalculated[1]	60.6 (12.6)	161.9 (28.3)	263.4 (36.8)	330.9 (31.1)	363.7 (21.7)	433.5	453.8					O'Maoileidigh 1990
Seine France	Measured[3]			358.0	450.0	447.5							Roule (1922a)
Loire France	Measured[1]			404.1 (21.3)	450.4 (33.3)	451.5 (23.2)							Mennesson-Boisneau & Boisneau (1990)
	Backcalculated	90.5 (9.4)	228.7 (26.8)	325.7 (28.3)	388.1 (25.9)	428.9 (16.2)	462.8 (15.9)						Douchement (1981)
Charente France	Measured			418.8 (14.3)	438.7 (24.9)	467.7 (39.1)							Véron (1999)

Table 3.48: (cont) Total length and standard deviation (mm) of anadromous female *Alosa fallax fallax*.

River Country	Measured / Backcalculated	Age (year)											Reference
		1	2	3	4	5	6	7	8	9	10	11	
Gironde – Garonne – Dordogne France	Backcalculated[1]	68.5 (3.5)	169.9 (9.2)	264.5 (11.4)	356.9 (17.1)	397.4 (13.7)	428.9 (33.0)						Anon. (1979a)
	Backcalculated	67.0 (8.3)	205.0 (26.7)	311.7 (27.3)	372.1 (20.7)	412.5 (21.1)							Douchement (1981)
	Backcalculated	101.0 (13.8)	201.7 (30.4)	284.4 (36.2)	347.8 (32.2)	369.3 (18.2)							Taverny (1991a)
Adour France	Backcalculated	83.8 (10.4)	205.1 (18.3)	294.2 (17.3)	361.2 (15.7)	408.0 (16.8)	445.0 (16.3)	468.8 (8.9)	490.5 (5.0)				Douchement (1981)
Lima Portugal	Measured			386.9 (17.2)[4]	412.5 (11.2)[4]	455.5 (15.8)[4]							Alexandrino (1996b)
Mondego Portugal	Measured				431.2 (11.2)[4]	468.0 (8.9)[4]							Alexandrino (1996b)
Tejo Portugal	Measured			365.0 (5.9)[4]	408.6 (8.6)[4]	439.3 (23.9)[4]							Alexandrino (1996b)
Guadiana Portugal	Measured				404.7 (20.0)[4]	420.0 (72.0)[4]	465.0 (72.0)[4]						Alexandrino (1996b)
Loukos Morocco	Measured		215.0 (10.0)	275.0 (7.0)	376.0 (32.0)	393.0 (15.0)							Sabatié (1993)
Sebou Morocco	Backcalculated * Measured	98.2 (21.0)	199.7 (33.4)	292.0 (41.5)	350.0 (27.3)	386.4 (20.1)	406.2* (17.2)						Sabatié (1993)

[1] Fork length (L_f) converted to total length (L_t) using $L_t = 1.1264\, L_f + 3.5260$ (Douchement, 1981).

[2] Standard length (L_{st}) converted to total length using $L_t = 1.1896\, L_{st} + 5.9359$ (Douchement, 1981).

[3] Total sample ≤ 10.

[4] 95% Confidence intervals

Table 3.49: Mean weight (g) and standard deviation (in brackets) in relation to age for anadromous female *Alosa fallax fallax*.

River Country	Age (year)											Reference
	1	2	3	4	5	6	7	8	9	10	11	
Nyamunas Lithuania			353	448	643	769	810	1183[1]	1487			Manyukas (1989)
Severn England				283	526 (103)	568 (81)						Claridge &Gardner (1978)
			426 (81)	535 (101)	596 (102)	661 (109)	725 (133)	834 (159)	921 (176)	968 (178)	1031 (165)	Aprahamian (Unpubl.)
Wye Wales				446 (58)	556 (76)	556 (97)	635 (81)	745	775 (247)			Aprahamian (Unpubl.)
Tywi Wales						582 (93)	568 (85)	576 (149)				Aprahamian (Unpubl.)
Seine France			380	565	798							Roule (1922a)
Loire France			647 (144)	870 (184)	848 (162)							Mennesson-Boisneau & Boisneau (1990)
Gironde – Garonne – Dordogne France				696 (78)	885 (214)	842 (414)						Taverny (1991a)
Loukos Morocco		84 (15)	161	551 (170)	328 (81)							Sabatié (1993)
Sebou Morocco			502 (103)	548 (116)	626 (119)	759 (138)						Sabatié (1993)

[1] Estimated

Table 3.50: von Bertalanffy growth parameters for male and female anadromous *Alosa fallax fallax*, 95% confidence intervals in brackets.

River Country	Male			Female			Reference
	K	L_∞	T_o	K	L_∞	T_o	
Severn England	0.393 (0.083)	421.7 (20.4)	0.428	0.345 (0.058)	478.1 (20.2)	0.413	Aprahamian (unpubl.)
Barrow Ireland	0.485 (0.128)	383.8 (28.2)	0.634	0.288 (0.184)	511.4 (169.4)	0.570	O'Maoileidigh (1990)
Loire France	0.517 (0.130)	442.8 (33.6)	0.582	0.383 (0.103)	525.5 (50.0)	0.506	Douchement (1981)
Gironde – Garonne – Dordogne France	0.265 (0.187) 0.543 (0.210) 0.479 (0.415)	531.3 (225.6) 387.6 (56.7) 350.2 (129.3)	0.441 0.612 0.484	0.259 (0.005) 0.403 (0.152) 0.367 (0.216)	577.1 (5.2) 500.4 (82.3) 453.0 (102.7)	0.552 0.644 0.317	Anon. (1979a) Douchement (1981) Taverny (1991a)
Adour France				0.305 (0.035)	544.8 (17.7)	0.451	Douchement (1981)
Sebou Morocco	0.324 (0.238)	432.6 (136.6)	0.184	0.372 (0.154)	466.6 (63.6)	0.379	Sabatié (1993)

Table 3.51: Maximum length (total) and weight of anadromous *A. fallax fallax* recorded from a number of river systems.

River (Country)	Male		Female		Reference
	L_{max}	W_{max}	L_{max}	W_{max}	
Nyamunas (Lithuania)	508.5	930	568.0	1520	Manyukas (1989)
Rhine (Germany)	378.0	430	500.0	1350	Hoek (1899)
Severn (England)	482.8	951	513.4	1448	Aprahamian (unpubl)
Loire (France)	410.0	510	500.0	940	Douchement (1981)
	501.0	1000	523.6	1408	Mennesson-Boisneau & Boisneau (1990)
Gironde-Garonne-Dordogne (France)	399.0	550	489.6	1120	Anon. (1979a)
	380.0	340	510.0	750	Douchement (1981)
	450.0	610	519.0	1210	Taverny (1991a)
Lima (Portugal)	468.0	1040	560.0	1920	Alexandrino (1996b)
Mondego (Portugal)	440.0	762	486.0	1123	Alexandrino (1996b)
Tejo (Portugal)	418.0	612	460.0	905	Alexandrino (1996b)
Guadiana (Portugal)	407.0	670	465.0	912	Alexandrino (1996b)
Adour (France)	430.0	660	495.0	925	Douchement (1981)
Sebou (Morocco)	430.0	620	460.0	1080	Sabatié (1993)

Table 3.52: Parameters for the equation weight (g) = aLength^b (mm) for male *Alosa fallax fallax.*

River (Country)	Life stage	Length	a	b	n	R^2	Range (L_t)	Range (weight)	Reference
Nyamunas, Lithuania	Adult	L_t (mm)	$9.658.\ 10^{-7}$	3.327			342-509	274-930	Manyukas (1989)
Rhine, Germany	Adult	L_t (mm) L_t (mm)	$9.772.\ 10^{-4}$ $2.003.\ 10^{-7}$	2.205 3.630	8 13	0.73 0.74	316-378 330-350	280-430 283-327	Hoek (1899) **Jenkins (1902)**
Severn (England)	Adult[1]	L_{st}(mm) L_t (mm)	$1.014.10^{-5}$ $9.775.10^{-6}$	3.038 2.992	39 1329	0.98 0.84	288-416 259-481	183-568 143-951	Claridge & Gardner (1978) Aprahamian (unpubl.)
Wye (Wales)	Adult	L_t (mm)	$2.173.10^{-6}$	3.237	77	0.88	266-412	157-643	Aprahamian (unpubl.)
Barrow (Ireland)	Adult	L_f (cm)	$1.445.10^{-2}$ - $4.786.10^{-3}$	3.28 – 2.93	16 - 17	0.76 – 0.83	320-423		O'Maoileidigh (1990)
Loire (France)	Adult	L_t (mm) L_f (mm)	$6.168.10^{-5}$ $1.578.10^{-2}$	2.677 2.696	63 26	0.90 0.92	270-420 290-501	225-635	Douchement (1981) Mennesson-Boisneau & Boisneau (1990)
Gironde-Garonne-Dordogne, France	Adult	L_t (mm)	$7.109.10^{-5}$	2.620	66	0.81	270-380	155-430	Douchement (1981)
Lima (Portugal)	Adult	L_t (cm)	0.003	3.319	49	0.90	284-468	163-1040	Alexandrino (1996b)
Mondego (Portugal)	Adult	L_t (cm)	0.011	2.912	25	0.81	349-440	348-762	Alexandrino (1996b)
Tejo (Portugal)	Adult	L_t (cm)	0.006	3.090	21	0.88	274-418	177-612	Alexandrino (1996b)
Guadiana (Portugal)	Adult	L_t (cm)	0.014	2.884	25	0.55	322-407	268-670	Alexandrino (1996b)
Loukos (Morocco)	Adult[1]	L_t (mm)	$2.616.10^{-6}$	3.377	56	0.98	195-415		Sabatié (1993)
Sebou (Morocco)	Adult	L_t (mm)	$6.503.10^{-6}$	3.069	271	0.86	245-390	118-500	Sabatié (1993)

[1] Male & Female combined

Table 3.53: Parameters for the equation weight (g) = aLength^b (mm) for female Alosa fallax fallax.

River (Country)	Life stage	Length	a	b	n	R^2	Range (L_t)	Range (weight)	Reference
Nyamunas, Lithuania	Adult	L_t (mm)	$5.076.10^{-6}$	3.060			354-568	325-1535	Manyukas (1989)
Rhine, Germany	Adult	L_t (mm)	$5.395.10^{-7}$	3.479	5	0.86	396-500	630-1350	Hoek (1899)
		L_t (mm)	$3.095.10^{-6}$	3.187	10	0.83	380-480	503-1041	**Jenkins (1902)**
Severn, England	Adult	L_t (mm)	$1.147.10^{-5}$	2.977	3784	0.76	295-530	220-1448	Aprahamian (unpubl.)
Wye (Wales)	Adult	L_t (mm)	$2.080.10^{-4}$	2.486	150	0.67	326-477	333-1050	Aprahamian (unpubl.)
Barrow, Ireland	Adult	L_f (cm)	$3.090.10^{-3}$	3.390	19	0.85	342-456		O'Maoileidigh (1990)
Loire, France	Adult	L_t (mm)	$1.944.10^{-5}$	2.892	76	0.90	350-500	520-1230	Douchement (1981)
		L_f (mm)	$4.914.10^{-2}$	2.286	34	0.57	377-524		Mennesson-Boisneau & Boisneau (1990)
Gironde-Garonne-Dordogne, France	Adult	L_t (mm)	$3.256.10^{-5}$	2.787	165	0.72	330-510	335-2480	Douchement (1981)
Lima, Portugal	Adult	L_t (cm)	0.004	3.260	45	0.72	342-560	388-1920	Alexandrino (1996b)
Mondego, Portugal	Adult	L_t (cm)	0.030	2.670	13	0.40	425-486	551-1123	Alexandrino (1996b)
Tejo, Portugal	Adult	L_t (cm)	0.295	2.051	78	0.71	316-460	318-905	Alexandrino (1996b)
Guadiana, Portugal	Adult	L_t (cm)	0.818	1.287	15	0.30	306-465	531-912	Alexandrino (1996b)
Sebou, Morocco	Adult	L_t (mm)	$1.127.10^{-6}$	3.374	180	0.93	315-460	310-1080	Sabatié (1993)

Table 3.54: Parameters for the equation weight (g) = aLength^b (mm) for juvenile (age 0+ and 1+) *Alosa fallax fallax.*

River (Country)	Life stage	Length	a	b	n	R^2	Range (L_t) mm	Range (weight) g	Reference
Elbe, Germany	0+&1+	L_t(cm)	$1.248.10^{-2}$	2.755	177	0.99	36-126	0.1-13.6	Oesmann (1994)
Severn, England	0+	L_{st}(mm)	$4.256.10^{-5}$ – $4.786.10^{-6}$	2.725 – 3.248	21- 400	0.80 – 0.93			Claridge & Gardner (1978)
	0+	L_t(mm)	$3.330.10^{-7}$	3.700	796	0.96	24-95	0.02-4.7	Aprahamian (unpubl.)
	1+	L_t(mm)	$1.327.10^{-7}$	3.824	84	0.98	57-168	0.7-34.8	Aprahamian (unpubl.)
Wye, Wales	0+	L_t(mm)	$2.237.10^{-8}$	4.363	216	0.93	24-54	0.01-0.7	Aprahamian (unpubl.)
Gironde - Garonne - Dordogne, France	0+	L_t(mm)	$7.363.10^{-6}$ – $1.986.10^{-5}$	2.772 - 2.986	64 -1189	0.96 - 0.98	52-118	1.0-12.9	Taverny (1991a)
Sebou, Morocco	0+	L_t(mm)	$5.419.10^{-6}$	3.124	386	0.95	35-149	0.9-14.6	Sabatié (1993)

Alosa fallax rhodanensis

In the Rhône, France, spawning takes place during May and June (Baglinière *et al.*, 2001; Le Corre, pers. comm.). By June – July the juveniles in the main river had reached a modal length (L_t) of 34 mm while that had migrated in to the Vaccarès lagoon were slightly larger with a modal size of 40 mm (Crivelli & Poizat, 2001). The modal length for those in the main river had increased to between 80 and 90 mm by September while those in the Lagoon were significantly ($P<0.001$) larger at between 120 and 140 mm. For those fish that remained in the Lagoon until January, the fish had reached a mean length of 182.9 ± 24.3 mm and weight of 53.9 ± 22.4 g (Crivelli & Poizat, 2001). In the lagoon the growth rate between July 17th and December 17th was linear and varied from 0.86 and 1.36 mm day^{-1} between years, once temperatures fell to below 10 to 11°C little growth occurred (Crivelli & Poizat, 2001). In an earlier study, Gallois (1947a) reported that by November the 0+ age group had reached between 57 and 109 mm (L_t) with a mean (± 95% CI) of 68.8 ± 12.0 mm, which is smaller than that reported by Menella & Tabardel (1994), Tabardel *et al.* (1995) and Gendre *et al.* (1997a). These authors reported a range in size from 67 to 197 mm[1] by the autumn of their first year. The mean length of the 0+ juveniles in those years when reasonable numbers were obtained was 98.9 and 91.0 mm[1], for fish caught between September and November.

In the Tiber (Italy) growth in the first year was faster than in French populations, though not for those which had migrated into the Vaccarès lagoon (Crivelli & Poizat, 2001); however in older age groups growth was faster in French stocks (Tables 3.55 & 3.57). French stocks were heavier than those from the Tiber when fish of the same age were compared (Tables 3.56 & 3.58).

The parameters for the von Bertalanffy growth model have been recalculated using data from Tables 3.55 & 3.57, and are presented in Table 3.59 for both male and female *A. fallax rhodanensis*. The value of K ranged from 0.272 to 0.377 year^{-1}for males and 0.137 to 0.347 year^{-1} for females. L_∞ varied between 549 to 566 mm and 602 to 801 mm for males and females, respectively. There was no significant difference between the K and L_∞ for the rivers Aude and Rhône ($P>0.05$). No comparison with the parameters from the Tiber was possible as the latter were based on mean length at age data and no information on variability was available.

The maximum length (total) and weight recorded for *Alosa fallax rhodanensis* from the Rhône was 569 mm[1] and 676 mm[1] and 1627 g and 3010 g for males and females, respectively (Le Corre *et. al.*, 1997a). From the Aude, France, Douchement (1981) reported a maximum length of 505 for males and 615 mm for females. For stock from the River Tirso, Sardinia, the maximum length recorded was smaller, 440 mm for females and 402 mm for males (Cottiglia, 1963a). For both sexes from the rivers Aude and Rhône there was reasonable agreement between the maximum length recorded and L4.

---

[1] Fork length (L_f) converted to total length (L_t) using $L_t = 1.1264\ L_f + 3.5260$ (Douchement, 1981).

The allometric growth parameter (b) for both adult and immature male *Alosa fallax rhodanensis* ranged from 2.34 to 3.42, and for females from 2.54 to 3.29 (Tables 3.60 & 3.61).

Table 3.55: Total length and standard deviation (mm) of male *Alosa fallax rhodanensis*.

River Country	Measured / Backcalculated	Age (year)									Reference
		1	2	3	4	5	6	7	8	9	
Aude France	Backcalculated	86.7 (15.7)	225.0 (29.2)	330.7 (26.5)	401.7 (25.1)	448.0 (18.8)					Douchement (1981)
Rhône France	Backcalculated	97.0 (12.8)	237.0 (24.7)	336.2 (22.5)	409.9 (18.1)	448.3 (20.5)					Douchement (1981)
	Measured [1]			398.9 (32.0)	422.5 (29.9)	470.6 (41.7)	501.2 (34.6)	543.9	532.5		Le Corre *et al.* (1997a)
Tiber Italy	Backcalculated[1]	143.3	230.9	305.3	366.3	414.1	448.5	469.7	477.6		D'Ancona (1927c)

[1] Fork length (L_f) converted to total length (L_t) using $L_t = 1.1264\ L_f + 3.5260$ (Douchement, 1981).

Table 3.56: Mean weight and standard deviation (g) in relation to age for anadromous male *Alosa fallax rhodanensis.*

River Country	Age (year)									Reference
	1	2	3	4	5	6	7	8	9	
Aude, France	17	156	395	659	900					Douchement (1981)
Rhône, France	19	166	409	667	896					Douchement (1981)
			540 (114)	620 (142)	911 (278)	1033 (277)	1436 (149)	1007		Le Corre *et al.* (1997a)
Tiber, Italy	20	50	140	305	510	645	700	720		D'Ancona (1927c))

Table 3.57: Total length and standard deviation (mm) of female *Alosa fallax rhodanensis*.

River Country	Measured / Backcalculated	Age (year)									Reference
		1	2	3	4	5	6	7	8	9	
Aude France	Backcalculated	89.1 (15.2)	236.0 (29.3)	338.4 (31.4)	425.7 (28.5)	483.0 (21.0)	535.2 (21.4)	557.6 (25.2)	586.3 (16.5)		Douchement (1981)
Rhône France	Backcalculated	101.0 (11.9)	238.2 (22.4)	349.1 (27.7)	433.4 (27.7)	485.3 (25.9)	510.7 (15.6)	536.1 (25.0)			Douchement (1981)
	Measured [1]			445.3 (36.9)	494.3 (31.7)	524.4 (31.6)	557.2 (32.1)	576.3 (39.4)	596.4 (34.7)		Le Corre *et al*. (1997a)
Tiber Italy	Backcalculated [1]	149.2	227.7	299.1	362.8	420.9	471.4	518.4	551.3	572.5	D'Ancona (1927c)

[1] Fork length (L_f) converted to total length (L_t) using $L_t = 1.1264 L_f + 3.5260$ (Douchement, 1981).

Table 3.58: Mean weight and standard deviation (g) in relation to age for anadromous female *Alosa fallax rhodanensis.*

River Country	Age (year)									Reference
	1	2	3	4	5	6	7	8	9	
Aude, France	10	136	418	792	1190	1563	1890	2161		Douchement (1981)
Rhône, France	19	190	498	847	1172	1443	1657			Douchement (1981)
			917 (266)	1128 (276)	1361(289)	1642 (307)	1683 (396)	2169 (370)		Le Corre *et al*. (1997a)
Tiber, Italy	20	55	130	295	575	885	1125	1250	1300	D'Ancona (1927c)

Table 3.59: von Bertalanffy growth parameters for male and female anadromous *Alosa fallax rhodanensis*, 95% confidence intervals in brackets.

River Country	Male			Female			Reference
	K	L_∞	T_o	K	L_∞	T_o	
Aude France	0.353 (0.144)	566.0 (103.0)	0.531	0.297 (0.053)	657.9 (42.0)	0.511	Douchement (1981)
Rhône France	0.377 (0.137)	552.4 (87.1)	0.490	0.347 (0.076)	601.6 (46.5)	0.477	Douchement (1981)
Tiber Italy	0.272 (0.003)	549.2 (2.4)	-0.077	0.137 (0.002)	800.5 (6.3)	-0.469	D'Ancona (1927c)

Table 3.60: Parameters for the equation weight (g) = aLength^b (mm) for male *Alosa fallax rhodanensis.*

River (Country)	Life stage	Length	a	b	n	R^2	Range (L_t)	Range (weight)	Reference
Aude France	Imm.	L_t (mm)	$3.431.10^{-6}$	3.158	427	0.98	130-380	16-490	Douchement (1981)
	Adult		$2.176.10^{-5}$	2.864	83	0.88	330-500	385-1365	Douchement (1981)
Rhône France	Juv.	L_f (mm)	$4.420.10^{-6}$	3.198		0.96	60-120	2-20	Tabardel *et al.* (1995)
	Imm.	L_t (mm)	$3.605.10^{-6}$	3.147	146	0.97	170-380	30-525	Douchement (1981)
	Adult	L_t (mm)	$1.317.10^{-5}$	2.944	196	0.88	330-500	365-1290	Douchement (1981)
	Adult	L_f (mm)	$1.000.10^{-6}$ – $6.000.10^{-4}$	2.340 – 3.420	79-314	0.67-0.92	135-500	335-1627	Le Corre *et al.* (1997a)
Tiber Italy	Juv & Adult	L_t (mm)	$2.201.10^{-6}$	3.174					D'Ancona (1927c)

Table 3.61: Parameters for the equation weight (g) = aLength^b (mm) for male *Alosa fallax rhodanensis.*

River (Country)	Life stage	Length	a	b	n	R^2	Range (L_t)	Range (weight)	Reference
Aude France	Imm.	L_t (mm)	$2.786.10^{-6}$	3.198	429	0.98	130-380	16-490	Douchement (1981)
	Adult		$1.611.10^{-6}$	3.294	43	0.64	450-580	1000-2060	Douchement (1981)
Rhône France	Imm.	L_t (mm)	$4.615.10^{-6}$	3.102	135	0.98	170-380	30-525	Douchement (1981)
	Adult	L_t (mm)	$7.516.10^{-6}$	3.051	102	0.86	410-600	650-2480	Douchement (1981)
	Adult	L_f (mm)	$1.000.10^{-4}$ – $2.000.10^{-4}$	2.540 – 2.660	154-342	0.54-0.67	335-595	110-3010	Le Corre *et al*. (1997a)
Tiber Italy	Juv & Adult	L_t (mm)	$9.779.10^{-7}$	3.320					D'Ancona (1927c)

Alosa fallax nilotica

For male and female *A. fallax nilotica*, length and weight at age data are shown in Tables 3.62 & 3.63 and 3.64 & 3.65. For fish of a given age the River Po population is smaller at ages one and two compared with populations from the Balkans, though for fish three years and older there is little difference in length at age (Vukovic, 1961a; Serventi *et al.,* 1990). The maximum size would appear to be greater in the Balkan populations, with males reaching at least 508 to 543 mm and females 546 to 560 mm, compared with 454 and 477 mm for males and females from the Po river. Females were heavier than males with a maximum weight of 2.4 kg compared to 1.9 kg for males.

The value of the von Bertalanffy parameters K and $\mathbf{L_\infty}$were calculated from the length at age data in Tables 3.62 & 3.64, and ranged from 0.07 to 0.30 year^{-1}and from 521 to 973 mm for males and between 0.11 and 0.27 year^{-1}and from 567 to 792 mm for females (Table 3.66). There was no significant difference in K and L4 between the stocks for either sex (P>0.05)**.** The allometric growth coefficient (b) was based on mean length and weight at age data and ranged from 3.18 to 3.61 for males and 2.72 to 3.46 for females (Table 3.67).

Alosa fallax algeriensis

Growth rate was faster for females than for males in terms of length (Tables 3.68 & 3.70) and weight (Tables 3.69 & 3.71). Significant differences (P<0.05) existed in the von Bertalanffy growth parameters between the sexes and between stocks (Table 3.72), based on mean values. The coefficients for the length - weight regression are shown in Table 3.73.

Alosa fallax lacustris

In Lake Maggiore, Italy, Berg & Grimaldi (1966a) reported that the growth rate of female *Alosa fallax lacustris* was greater than that for males (Table 3.74). Ferrero (1951) reported a range in size of 182 to 268 mm for mature *Alosa fallax lacustris* at age 2 in Lake Maggiore, which was similar to that reported for specimens from Lake Iseo of between 171 and 237 mm. Oppi & Novello (1989) reported a similar growth rate for the Lake Garda population (Table 3.74). For the populations inhabiting the mid-Italian lakes Bracciano and Bolsena, growth rate was greater than that for populations from Northern Italy, with fish reaching 253 mm at age two and 303 mm at age three (Ferrero, 1951).

For the populations inhabiting the lakes of Northern Italy the maximum length of populations was 500 mm (Lake Maggiore) [Berg & Grimaldi, 1966a] and 400 mm (Lake Garda) [Fatio, 1890]**.** For Sardinian stocks the maximum length reached for males and females in Lake Flumendosa was 396 and 395 mm (L_f) respectively (Cottiglia, 1969) while in Lake Omodeo males reach 256 mm and females 277mm (L_t) [Cottiglia, 1963b].

Table 3.62: Total length and standard deviation (mm) of male *Alosa fallax nilotica.*

River Country	Measured / Backcalculated	Age (year)										Reference
		1	2	3	4	5	6	7	8	9	10	
Po Italy	Backcalculated	136.8 (25.8)	228.5 (31.4)	308.6 (32.1)	364.0 (28.7)	405.3 (27.4)	429.7 (34.1)	453.5 (75.7)				Serventi *et al.* (1990)
Neretva	Backcalculated [4] Measured	202.8 (14.6)	268.0 (14.8)	312.6 (16.5)	355.8 (18.4)	396.4 (17.9)	438.3 (14.1)	482.5 (15.2)	512.0	521.0	543.0[4]	Vukovic (1961a)
L.Skadar	Backcalculated	207.2 (13.4)	272.3 (16.9)	322.3 (20.4)	369.1 (17.3)	400.5 (18.0)	441.7 (13.2)	475.2 (9.0)	495.0 (5.2)	520.0		Vukovic (1961a)
L.Bačin	Backcalculated [4] Measured	200.0 (12.9)	262.3 (11.9)	307.9 (17.6)	343.9 (20.4)	383.3 (22.3)	446.6 (7.0)	480.0	508.0[4] (12.2)			Vukovic (1961a)

Table 3.63: Mean weight (g) in relation to age for male *Alosa fallax nilotica.*

River Country	Age (year)										Reference
	1	2	3	4	5	6	7	8	9	10	
Neretva		213	466	621	893	1377	1569	1920			Vukovic (1961a)
L.Skadar	101	198	275	658	785	1045	1198	1366	1372		Vukovic (1961a)
L.Bačin	41	144	254	348	552	871	1200	1213			Vukovic (1961a)

Table 3.64: Total length and standard deviation (mm) of female *Alosa fallax nilotica.*

River Country	Measured / Backcalculated	Age (year)										Reference
		1	2	3	4	5	6	7	8	9	10	
Po Italy	Backcalculated	135.1 (23.6)	231.7 (37.7)	310.4 (38.1)	376.3 (37.4)	423.1 (33.9)	457.0 (31.8)	477.3 (29.0)				Serventi *et al.* (1990)
Neretva	Backcalculated ^{4} Measured	213.9 (13.8)	280.4 (14.4)	331.1 (15.2)	378.4 (16.4)	418.4 (17.8)	459.3 (16.3)	492.1 (15.3)	524.0 (22.6)	552.5 (19.2)	560.0^4	Vukovic (1961a)
L.Skadar	Backcalculated	212.9 (14.1)	283.3 (17.2)	337.2 (18.6)	382.9 (18.7)	422.7 (17.2)	455.9 (16.0)	487.8 (13.0)	516.1 (13.2)	538.8 (16.9)	554.0 (14.1)	Vukovic (1961a)
L.Bačin	Backcalculated ^{4} Measured	201.9 (14.5)	267.8 (19.1)	319.0 (13.0)	362.2 (19.0)	407.2 (18.4)	445.2 (15.3)	478.5 (13.5)	510.0 (13.1)	546.0^4 (19.3)		Vukovic (1961a)

Table 3.65: Mean weight (g) in relation to age for female *Alosa fallax nilotica.*

River Country	Age (year)										Reference
	1	2	3	4	5	6	7	8	9	10	
Neretva			467	759	1158	1481	1663	1980	2379		Vukovic (1961a)
L.Skadar	92	208	234	788	972	1182	1492	1496	1840	1953	Vukovic (1961a)
L.Bačin	38	147	284	385	645	995	1359	1480	1701		Vukovic (1961a)

Table 3.66: von Bertalanffy growth parameters for male and female anadromous *Alosa fallax nilotica*, 95% confidence intervals in brackets.

River Country	Male			Female			Reference
	K	L_∞	T_o	K	L_∞	T_o	
Po, Italy	0.296 (0.167)	521.3 (115.1)	-0.016	0.269 (0.130)	567.0 (104.0)	-0.001	Serventi *et al.* (1990)
Neretva	0.073 (0.078)	972.9 (658.4)	-2.283	0.115 (0.047)	772.1 (152.0)	-1.857	Vukovic (1961a)
L.Skadar	0.153 (0.047)	646.3 (76.4)	-1.536	0.155 (0.038)	667.2 (59.6)	-1.503	Vukovic (1961a)
L.Bačin	0.088 (0.047)	873.3 (262.8)	-2.024	0.106 (0.046)	792.1 (172.0)	-1.826	Vukovic (1961a)

Table 3.67: Parameters for the equation weight (g) = aLength^b (mm) for male and female *Alosa fallax nilotica,* based on mean length and weight at age data.

River (Country)	Life stage	Length	Male		Female		Reference
			a	b	a	b	
Neretva	Adult	L_t (mm)	$3.327.10^{-7}$	3.612	$8.155.10^{-5}$	2.716	Vukovic (1961a)
L.Skadar	Juv & Adult	L_t (mm)	$3.770.10^{-6}$	3.181	$1.224.10^{-6}$	3.366	Vukovic (1961a)
L.Bačin	Juv & Adult	L_t (mm)	$1.351.10^{-6}$	3.321	$6.042.10^{-7}$	3.460	Vukovic (1961a)

Table 3.68: Mean or range in total length (mm) of male *Alosa fallax algeriensis.*

River Country	Actual / Backcalculated	Age (year)										Reference
		1	2	3	4	5	6	7	8	9	10	
L. Ichkeul Tunisia		136	216	263	290	306	315	320				Kartas (1981)
Miliane & Medjerah, Tunisia		118	203	268	319	358	388	412	430	444		Kartas (1981)
Mazafran, Algeria		130	180-190	250-260	270-280	290-300						Bounhiol (1917)

Table 3.69: Mean weight (g) of male *Alosa fallax algeriensis.*

River Country	Age (year)										Reference
	1	2	3	4	5	6	7	8	9	10	
L. Ichkeul, Tunisia	17	84	164	229	274	303	321				Kartas (1981)
Miliane & Medjerah, Tunisia	11	64	156	273	396	512	621	713	790		Kartas (1981)

Table 3.70: Mean or range in total length (mm) of female *Alosa fallax algeriensis.*

River Country	Measured / Backcalculated	Age (year)										Reference
		1	2	3	4	5	6	7	8	9	10	
L. Ichkeul Tunisia		136	223	279	316	340	355	366				Kartas (1981)
Miliane & Medjerah, Tunisia		119	206	276	331	376	411	439	461	479		Kartas (1981)
Mazafran, Algeria		160-170	220-230	300-320	330-350	380-400						Bounhiol (1917)

Table 3.71: Mean weight (g) of female *Alosa fallax algeriensis.*

River Country	Age (year)										Reference
	1	2	3	4	5	6	7	8	9	10	
L. Ichkeul Tunisia	17	88	187	282	360	417	458				Kartas (1981)
Miliane & Medjerah Tunisia	11	66	170	306	462	617	764	895	1013		Kartas (1981)

Table 3.72: von Bertalanffy growth parameters for male and female anadromous *Alosa fallax algeriensis*, 95% confidence intervals in brackets.

River Country	Male			Female			Reference
	K	L_∞	T_o	K	L_∞	T_o	
L. Ichkeul Tunisia	0.543 (0.010)	327.6 (1.1)	0.013	0.429 (0.007)	384.6 (1.5)	-0.018	Kartas (1981)
Miliane & Medjerah, Tunisia	0.257 (0.003)	492.0 (2.0)	-0.070	0.227 (0.003)	548.8 (2.5)	-0.073	Kartas (1981)
Mazafran, Algeria	0.385 (0.014)	344.2 (4.0)	-0.194	0.186 (0.010)	593.8 (15.7)	-0.711	Bounhiol (1917)

Table 3.73: Parameters for the equation weight (g) = aLength^b (mm) for male and female *Alosa fallax algeriensis,* based on mean length and weight at age data.

River (Country)	Life stage	Length	Male		Female		Reference
			a	b	a	b	
L. Ichkeul Tunisia	Juv & Adult	L_t (mm)	$9.171.10^{-7}$	3.409	$1.372.10^{-6}$	3.325	Kartas (1991)
Miliane & Medjerah Tunisia	Juv & Adult	L_t (mm)	$2.495.10^{-6}$	3.211	$2.106.10^{-6}$	3.239	Kartas (1991)
Oubeira, Algeria	Juv & Adult	L_t (mm)	$1.326.10^{-6}$	3.327	$1.326.10^{-6}$	3.327	Kartas (1991)

Table 3.74: Length (total) of male and female *Alosa fallax lacustris* from the Italian lakes Maggiore (Berg & Grimaldi, 1966a) and Garda (Oppi & Novello, 1989).

Lake	Sex	Age (year)			
		1	2	3	4
Maggiore	M	143.6	214.0	246.1	273.7
	F	142.6	222.7	264.8	289.4
Garda	M&F	130	225	256	273

Based on mean length at age data (Table 3.74) the von Bertalanffy growth parameters for *Alosa fallax lucustris* are presented in Table 3.75. There was no significant difference in K (P>0.05) between the sexes, while $L_\infty$for females was significantly greater than that for males (P<0.05).

Table 3.75: von Bertalanffy growth parameters for male and female *Alosa fallax lacustris*, 95% confidence intervals in brackets, calculated from the mean length at age data presented in Table 3.74.

Lake	Sex	von Bertalanffy growth parameters		
		K	L_∞	T_o
Maggiore	M	0.557 (0.027)	301.5 (3.7)	-0.167
	F	0.608 (0.024)	317.2 (3.2)	0.018
Garda	M&F	0.987 (0.031)	279.3 (1.5)	0.364

Alosa fallax killarnensis

Mean length at age for male and female *Alosa fallax killarnensis* is presented in Table 3.76. There is little difference in growth rate between the sexes. The sub-species reach a maximum length of *c*. 240 mm (Trewavas, 1938; Gibson, 1956; Twomey, 1958; O'Maoileidigh, 1990). There was no significant difference (P>0.05) in the von Bertalanffy growth parameters K and L4 between the sexes (Table 3.77).

Table 3.76: Backcalculated length (total) and standard deviation (mm) of male and female *Alosa fallax killarnensis* from Lough Leane, Ireland (O'Maoileidigh, 1990). [Fork length (L_f) converted to total length (L_t) using L_t = 1.1264 L_f + 3.5260 (Douchement, 1981)].

Sex	Age (year)				
	1	2	3	4	5
M	45.3 (9.9)	124.2 (13.8)	186.4 (9.0)	210.9 (6.8)	
F	50.2 (13.5)	127.9(16.3)	191.6 (10.9)	219.1 (12.4)	234.1

Table 3.77: von Bertalanffy growth parameters for male and female *Alosa fallax killarnensis* from Lough Leane, Ireland, 95% confidence intervals in brackets. Parameters calculated from data presented in Table 3.76.

Male			Female		
K	L_∞	T_o	K	L_∞	T_o
0.533 (0.202)	255.3 (36.7)	0.643	0.465 (0.261)	279.2 (69.2)	0.586

The coefficients for the geometric mean regression relating length to weight of pre-spawned *Alosa fallax killarnensis* are presented in Table 3.78 for both males and females.

Table 3.78: Parameters for the equation: weight (g) = aLength^b (cm) for adult pre-spawned male and female *Alosa fallax killarnensis* from Lough Leane, Ireland (O'Maoileidigh, 1990).

Length (cm)	Male		Female	
	a	b	a	b
L_f	$2.29.10^{-4}$	4.43	$4.79.10^{-2}$	2.63

- Comparison of growth parameters

The relationship between the von Bertalanffy growth coefficient (K) and the asymptotic length for *Alosa alosa* and *Alosa fallax* spp. is shown in Figure 3.28. The population of *Alosa* furthest removed from the overall trend was that of *Alosa fallax lacustris* from Lake Garda.

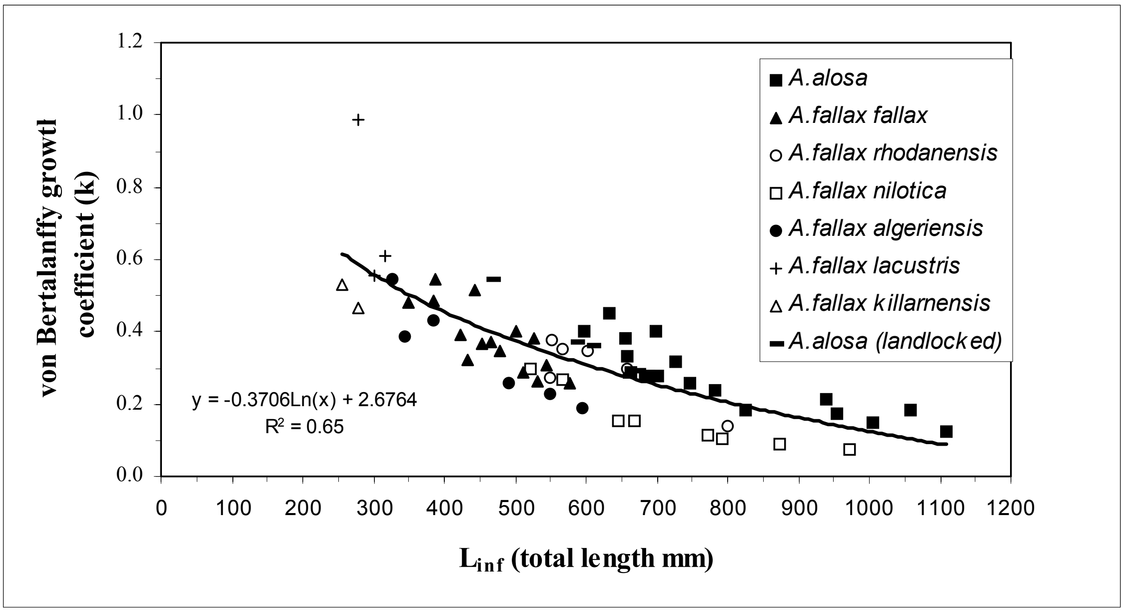


Figure 3.28: Auximetric plot for *Alosa alosa* and *Alosa fallax* spp.

3.4.4 Metabolism

Alosa alosa

During the freshwater pahse of the spawning migration there was a gradual loss of condition (weight.100/length^3) during the period (Cassou-Leins & Cassou-Leins, 1981). The weight loss associated with the migration and spawning has ranged from 30 to 59% being generally higher for females than for males (Cassou-Leins & Cassou-Leins, 1981; Mennesson-Boisneau & Boisneau, 1990; Pustelnik, unpublished). At the start of the migration the white muscle exhibits the classic structure of alternating white and dark bands, rich in myofibrils and incorporating lipid deposits (Bengen, 1992). However, on the spawning grounds the myofibrils are much less abundant, having become separated, giving a disorganised appearance. The hepatocytes of the liver at the start of the migration are rich in glycogen and lipid. As the fish migrate to their spawning grounds the granular reticulum in the females undergoes further development attaining its maximum by the time the fish have reached the spawning ground. In contrast, no such change was observed in the male. The mitochondria develop a crest, suggesting intense secretary activity, so that by the time the fish have reached the spawning grounds only a few lipid droplets and granules of glycogen remain (Bengen, 1992). Vacuoles appear in the cytoplasm, which has a much more heterogeneous appearance compared with fish from the estuary. Many of the cells have atrophied and their diameter has declined from 4.1μ ± 0.15 to 3.6μ ± 0.19 (Eiras, 1981b).

In the River Douro and in the Gironde-Garonne-Dordogne system (France) the amount of protein and lipid in the muscle decreased (Tables 3.79 & 3.80) as *Alosa alosa* migrate from the estuary into fresh water for spawning (Eiras, 1981b; Bengen, 1992). In both studies the lipid concentration for both sexes in the liver also declined. The protein content of female fish declined in the River Douro stock, while in the Gironde-Garonne-Dordogne Bengen (1992) reported a slight increase.

Table 3.79: The range in mean monthly percentage water, protein, lipid and carbohydrate in the muscle, gonad and liver of *Alosa alosa* from the River Douro, Portugal (Eiras, 1981b), (Est. = estuary; FW = fresh water).

Organ	Sex	Water		Protein		Lipid		Carbohydrate	
		Est.	FW	Est.	FW	Est.	FW	Est.	FW
Muscle	**M**	67.2 – 71.5	72.8 – 76.6	14.9 – 16.7	10.1 – 14.2	8.2 – 10.3	4.6 – 8.2	1.53 – 1.70	1.67 – 1.83
	F	66.9 – 71.3	73.3 – 76.1	15.6 – 17.1	10.5 – 12.7	9.0 – 11.3	4.3 – 9.5	1.35 – 1.49	1.49 – 1.59
Gonad	**M**	74.7 – 77.8	75.2 – 78.9	11.0 – 12.2	12.0 – 13.7	4.5 – 5.8	3.2 – 5.0	1.62 – 1.8	1.69 – 2.22
	F	72.2 – 74.8	72.5 – 75.3	13.7 – 15.0	14.2 – 16.1	5.9 – 6.7	4.3 – 6.0	1.59 – 1.70	1.62 – 1.79
Liver	**M**	61.3 – 68.7	72.1 – 75.9	9.2 – 11.1	5.8 – 8.1	17.1 – 19.2	11.2 – 15.2	1.19 – 1.25	1.30 – 1.47
	F	62.3 – 68.4	71.4 – 76.4	9.7 – 10.2	4.3 – 8.2	16.5 – 18.5	9.7 – 15.1	1.19 – 1.24	1.30 – 1.35

The decline in lipid and protein content in the muscle and liver relates in part to the energetic costs of migration, as the adults do not feed during the freshwater phase of the spawning migration (Section 3.4). It also relates partly to the remobilization of the lipid and protein, associated with maturation of the gonads. The lipid and protein content of the ovary and testis increase as spawning is approached.

Table 3.80: The percentage protein and lipid in the muscle, gonad and liver of *Alosa alosa* obtained from the outer estuary of River Gironde-Garonne-Dordogne (France) in April and from fresh water in July (Bengen, 1992).

Organ	Sex	Protein		Lipid	
		Outer estuary (April)	Freshwater (July)	Outer estuary (April)	Freshwater (July)
Muscle	**M**	18.2	12.9	9.5	0.8
	F	21.5	13.9	14.6	0.8
Gonad	**M**	14.6	17.6	2.1	3.2
	F	17.1	22.1	3.9	5.2
Liver	**M**	11.2	9.1	15.2	5.1
	F	15.2	16.9	12.9	3.4

Lahaye (1966) observed an increase in thyroid activity associated with fish entering fresh water to spawn. For females there was a decrease from 200 to 100 μ in the diameter of the follicle cells while the epithelium increased from 4-5 μ to c. 16μ. A similar pattern was also observed for the males. For *Alosa alosa* from the River Douro, Portugal (Table 3.81), Eiras (1981b) reported a significant increase in activity of PLH, TSH and GTH cells of the pituitary as the fish migrated from the estuary into fresh water. There was no significant change reported in the area of ACTH (19.6 ± 0.7 μ^2) and STH (12.9 ± 0.8 μ^2) cells.

Table 3.81: The mean (SE) area (μ^2) of the adenohypophyseal cells of *Alosa alosa* during the freshwater phase of their spawning migration (Eiras, 1981b).

Cell type	Estuary	Fresh water
Prolactin	25.9 (1.1)	35.5 (1.4)
Thyrotropic	23.2 (1.0)	24.1 (1.0)
Gonadotropic	15.3 (0.5)	24.1 (1.2)

Alosa fallax fallax

In the River Severn (England), where the fish migrate a maximum of 15 km upstream of the limit of tide reversal, the somatic weight loss of female *Alosa fallax* ranged from 6 to 25%, being highest in those migrating earlier in the season (Aprahamian, 1982). In the Oued Sebou, the somatic weight loss for some females (which had migrated 220 km from the sea) ranged from 32 to 37% (Sabatié, 1993). For female *A. fallax* in the Severn, lipid levels in the muscle fell by 59.1% during the spawning migration. The mean (± SE) percentage composition of lipid in the muscle and ovaries of pre-spawning fish was 3.66 ± 0.40 % (wet weight) and 4.50 ± 0.08 % respectively. Following spawning the percentage declined significantly to 1.50 ± 0.17 % and 2.66 ± 0.34 % in the muscle and ovaries respectively (Aprahamian, 1982).

The change in the level of calcium, copper, iron, manganese and zinc in the scales, bone (operculae) liver, muscle and ovary of female *Alosa fallax fallax* from the Severn during the freshwater phase of their spawning migration is shown in Table 3.82. Non-parametric analysis (Mann-Whitney test) suggested a significant increase ($P<0.05$) in the levels of calcium and iron in the liver, muscle and ovary, but only in the muscle and ovary for zinc in spent females. Copper decreased significantly in the liver but was significantly higher in the ovaries while the manganse concentration in the ovaries decreased significantly following sapwning.

Table 3.82 The mean (± SE) concentration (μgg^{-1}) of calcium (Ca), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) in the scales, bone (operculae) liver, muscle and ovary of pre- (n=22) and post (n=15) spawned female *Alosa fallax fallax* from the Severn Estuary (Aprahamian, unpubl).

Trace Element	Scale		Operculae		Liver		Muscle		Ovary	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Ca	107.0 ±2.1	103.5 ±1.3	155.5 ±3.5	148.3 ±3.7	273.0 ±15.7	1195.0 ±193.0	483.0 ±78.0	768.0 ±146.0	362.0 ±158.0	597.0 ±48.0
Cu	7.55 ±0.46	6.34 ±0.55	10.63 ±1.09	8.42 ±0.59	20.96 ±1.62	14.63 ±1.42	6.69 ±0.95	5.24 ±0.74	6.18 ±0.66	8.61 ±1.00
Fe	112.0 ±24.0	76.1 ±8.1	73.5 ±16.6	89.6 ±23.4	1246.0 ±67.0	2463.0 ±439.0	59.7 ±8.9	72.6 ±8.8	80.9 ±6.2	330.0 ±52.0
Mn	22.55 ±1.89	24.05 ±2.32	38.70 ±3.60	44.7 ±3.9	7.13 ±0.37	6.94 ±0.38	1.41 ±0.11	1.35 ±0.29	5.75 ±0.34	3.96 ±0.38
Zn	121.5 ±17.3	89.2 ±5.9	92.9 ±3.4	90.92 ±2.7	120.7 ±6.6	120.8 ±5.3	18.4 ±1.5	24.5 ±2.1	129.0 ±22.0	913.0 ±493.0

Alosa fallax rhodanensis

On the Rhône, somatic weight loss during the fresh water phase of their spawning migration was *c*. 40% for fish, for fish which had migrated 60km upstream to spawn (Rameye *et al.,* 1976). This figure was higher than that of 21.6% for males and 22.7% for females reported by Douchement (1981). A weight loss of *c.* 20% was also reported from the River Aude (Douchement, 1981).

Alosa fallax nilotica

The volume of the various regions of the pituitary (Table 3.83) changed during the sexual cycle, with a significant ($P<0.01$) increase in the size of all three regions (see Section 1.3.2.5), as the fish commence the freshwater phase of their spawning migration in April.

Hypertrophy was observed in all cell types during their spawning migration (Table 3.84) with a significant increase in volume (P<0.01) as the fish migrated into fresh water and approached spawning.

Table 3.83: The mean (SE) volumes of the hypophyseal regions (PDR = pars distalis rostralae; PDP = pars distalis proximalae; NIL = neurointermedial lobe) of *Alosa fallax nilotica* during different periods of the sexual cycle in μcm^3 (Pavlović & Pantić, 1975).

Period in sexual cycle	PDR	PDP	NIL
Before migration Autumn	150,360 (6,835)	50,827 (2,501)	60,689 (1,909)
Before migration March	180,420 (8,113)	80,295 (3,146)	70,689 (2,437)
Migration April	799,392 (18,305)	209,166 (7,737)	150,190 (6,022)
Spawning April	787,266 (20,469)	246,765 (7,912)	150,961 (5,648)
Spawning May	809,392 (18,702)	409,166 (10,350)	149,027 (6,103)

Table 3.84: The mean (SE) volumes (μm^3) of the adenohypophyseal cells (PLH = prolactin; ACTH = adrenocorticopic; TSH = thyrotropic; STH = somatotropic; GTH = gonadotropic; PAS+ = stain positive with alcian blue-PAS-orange and MSH = melanostimulating cells) and their nuclei of *Alosa fallax nilotica* during different seasons of the sexual cycle (Pavlović & Pantić, 1975).

Cell type	Autumn	Before migration - March	Migration April	Before spawning - April	Spawning season – May
PLH	79.8 (8.2)	200.2 (16.3)	654.9 (36.1)	621.3 (44.2)	672.1 (45.6)
nuclei	33.2 (4.1)	37.6 (3.7)	139.2 (10.0)	145.2 (8.4)	142.0 (9.0)
ACTH	60.9 (5.2)	175.4 (15.5)	300.0 (24.2)	150.2 (8.6)	194.8 (18.4)
nuclei	35.5 (2.2)	65.7 (5.2)	86.3 (9.4)	46.6 (3.9)	56.2 (6.0)
TSH	175.4 (15.2)	442.0 (28.7)	534.6 (30.1)	300.7 (27.4)	288.3 (29.1)
nuclei	55.7 (4.0)	87.0 (6.8)	78.6 (6.4)	66.8 (6.0)	57.8 (6.2)
STH	56.4 (4.1)	79.1 (6.4)	112.1 (8.1)	144.0 (11.7)	300.7 (20.3)
nuclei	30.7 (2.4)	38.2 (3.9)	56.6 (4.2)	55.7 (4.3)	76.3 (5.6)
GTH	87.0 (7.1)	89.1 (7.7)	175.4 (14.2)	356.4 (28.4)	853.3 (60.0)
nuclei	44.5 (3.1)	45.7 (3.9)	87.0 (9.8)	94.5 (13.3)	124.4 (16.5)
PAS +	114.4 (8.2)	129.2 (8.7)	175.7 (11.2)	154.6 (9.9)	170.2 (8.7)
nuclei	44.5 (3.1)	46.6 (3.7)	66.8 (5.5)	55.7 (5.0)	62.8 (4.8)
MSH	55.7 (4.1)	66.8 (5.2)	72.0 (7.0)	69.9 (8.0)	65.5 (5.9)
nuclei	33.5 (2.6)	35.0 (2.7)	35.2 (3.1)	34.0 (2.2)	33.8 (2.3)

Alosa fallax lacustris

The annual cycle in fat content and fatty acid composition has been reported for *Alosa fallax lacustris* by Luzzana *et al.* (1996) from Lake Como, Italy. The lipid content of the liver and muscle in both sexes was higher in October, prior to spawning in June (Table 3.85). The fats stored in the muscle were mobilised to a greater extent in males

Table 3.85: Percentage fatty acid composition of liver/muscle/gonad total lipids of *Alosa fallax lacustris* from Lake Como, Italy (Luzzana *et al.,* 1996); SFA = saturated fatty acid; MUFA = monounsaturated fatty acid; PUFA = polyunsatured fatty acid and HUFA = highly unsaturated fatty acid.

Fatty Acids	**Liver**						**Muscle**						**Gonad**		**Perivisceral Fat**			
	August		October		June		August		October		June		June		August		October	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
14:0	3.4	4.9	4.0	3.9	2.6	2.2	4.3	4.7	5.3	5.4	3.8	4.3	1.6	2.0	4.9	5.1	5.9	5.5
16:0	19.6	26.0	16.5	16.5	18.7	21.4	19.7	21.2	23.4	23.8	20.1	19.7	25.2	23.4	19.8	23.9	21.4	21.7
18:0	6.5	5.0	5.9	5.8	6.0	8.5	4.4	3.7	3.9	4.0	4.2	3.4	6.4	6.4	3.3	3.9	4.1	4.2
∑SFA	30.6	36.7	27.2	26.9	28.5	33.5	30.0	31.0	34.5	34.8	29.5	28.9	34.5	33.2	29.6	34.4	32.6	32.4
16:1ω7	2.2	3.5	2.0	2.0	2.5	2.3	3.5	4.3	3.9	4.0	4.1	5.0	0.9	2.4	3.9	4.0	3.8	4.0
18:1ω9	25.5	28.8	44.4	43.5	18.5	12.0	19.9	18.9	21.3	22.4	19.3	19.3	9.2	11.5	27.6	22.5	24.0	25.3
18:1ω7	3.3	3.6	2.0	2.0	4.2	5.8	3.9	4.2	3.4	3.7	3.8	3.8	4.3	4.0	4.2	4.6	3.7	3.8
20:1ω9	1.3	2.0	3.4	3.4	0.7	0.5	1.0	1.0	1.3	1.4	1.0	0.9	-	-	1.3	1.0	1.2	1.4
∑MUFA	32.7	38.4	52.5	51.6	26.2	20.9	28.7	28.7	30.2	31.8	28.6	29.4	14.8	18.5	37.3	32.5	33.2	35.0
18:2ω6	2.4	1.9	2.1	2.5	3.0	2.2	4.8	4.8	6.6	6.6	4.5	4.8	2.2	2.2	5.1	5.1	7.5	7.3
18:3ω3	2.0	1.7	1.3	1.6	2.9	2.2	4.2	5.2	4.6	4.5	3.7	4.0	1.6	2.3	4.8	5.8	5.4	5.2
18:4ω3	1.0	1.0	0.7	0.9	2.1	2.1	2.2	2.9	2.3	2.2	2.1	2.2	0.6	2.2	2.7	3.4	2.9	2.9
20:4ω6	6.5	3.9	2.5	3.1	6.2	6.3	5.3	4.6	4.6	4.5	5.0	4.6	9.5	6.3	4.2	3.5	4.0	3.5
20:4ω3	1.4	0.8	0.8	0.7	1.9	2.5	1.6	1.8	1.4	1.2	1.6	1.7	1.2	2.2	1.2	1.0	1.1	1.0
20:5ω3	5.5	3.0	1.6	1.8	6.1	6.3	7.1	7.8	4.3	4.3	6.9	7.9	10.4	8.3	6.9	6.9	4.6	4.4
22:4ω6	2.4	1.0	1.2	1.0	3.2	1.5	1.0	0.8	0.7	0.7	0.6	0.5	2.2	1.8	0.6	0.9	0.6	0.5
22:5ω6	1.1	0.7	0.2	1.1	1.4	1.5	1.3	1.9	1.3	1.1	1.6	1.4	1.8	1.4	0.6	0.3	1.0	0.8
22:5ω3	1.6	0.9	0.6	0.7	2.6	3.0	2.5	2.1	1.4	1.3	2.6	2.4	4.7	3.3	1.9	1.5	1.2	1.2
22:6ω3	9.8	6.7	4.4	4.5	12.8	14.9	8.0	5.8	4.5	3.7	9.6	7.6	14.9	15.2	1.9	1.6	2.7	1.5

Table 3.85: (cont) Percentage fatty acid composition of liver/muscle/gonad total lipids of *Alosa fallax lacustris* from Lake Como, Italy (Luzzana *et al.*, 1996); SFA = saturated fatty acid; MUFA = monounsaturated fatty acid; PUFA = polyunsatured fatty acid and HUFA = highly unsaturated fatty acid.

∑PUFA	36.8	24.9	20.2	21.5	45.3	45.6	41.3	40.0	35.2	33.4	41.8	41.7	50.7	48.2	33.1	33.2	34.2	32.7
ω3	21.3	14.2	9.9	10.3	28.3	31.1	25.7	25.7	18.6	17.3	26.8	27.4	33.5	33.4	19.5	20.3	17.8	17.3
ω6	13.8	8.6	8.0	8.9	15.4	13.5	13.9	12.6	14.7	14.5	12.9	12.5	16.5	13.5	11.9	11.0	14.5	13.5
ω3 HUFA	16.9	10.6	7.1	7.1	21.4	24.3	17.6	15.7	10.3	9.3	19.1	17.8	30.0	26.7	10.7	10.1	8.5	8.1
ω6 HUFA	10.0	5.6	4.9	5.2	10.8	9.3	7.6	6.1	6.7	6.3	7.2	6.4	13.5	9.5	5.5	4.8	5.6	4.8
Total lipids %	6.9	11.6	16.3	22.1	4.7	4.7	5.1	8.4	8.5	9.9	4.4	6.9	3.3	3.7				

(declining by 48.2%) than in females, where levels fell by 30.3% between October and June. In October, the lipid content of the liver was higher in females than in males (22.1% and 16.3% respectively), however, by the time spawning was complete (June) the level for both sexes was the same (4.7%). There was no perivisceral fat present in the body cavity at spawning time. The findings suggest that liver and muscle lipids are used for gonadal development and to meet energy requirements when the fish are not feeding, while those of the body cavity are used solely to meet the overwintering needs of the fish.

The development of the gonads and the energy requirements of the fish resulted in a selective reduction of saturated fatty acids (SFA) in the muscle and of mono-unsaturated fatty acid (MUFA) in the liver, and an increase in polyunsaturated fatty acids (PUFA) in both the muscle and liver.

The predominant fatty acid in both the liver and muscle, though not the gonads, was 18:1ω9. This suggests that its mobilisation, after feeding stops in October, was for energy purposes as opposed to development of the gonads. Specific muscle and liver ω3 and ω6 highly unsaturated fatty acids (HUFA) retention was evident for both sexes and was associated with development of the gonads. The precursors of ω3 and ω6 HUFA (18:2ω6, 18:3ω3 and 18:4ω3) were mobilised in particular from the muscle.

3.5 Behaviour

3.5.1 Migration

- Adult spawning migration

Alosa alosa

The timing of the freshwater phase of their spawning migration is dependent on latitude. Populations towards the south of the range migrate earlier in the year than those further north (Table 3.86).

Temperature has long been considered one of the main factors affecting the timing of the freshwater phase of their spawning migration (**Duhamel Du Monceau, 1772;** Pennant, 1777) with migration starting once temperatures have reached 10 to 12°C (Roule, 1925). In the case of the Sebou, temperature at the start of migration was 16°C, but decreased to 12°C at the peak (Sabatié, 1993). This accounts for the negative correlation between the number of fish caught in the estuary per unit of effort and water temperature 14 days prior to capture ($r^2 \approx 0.2$). Sabatié (1993) reported a significant correlation between fish abundance and the flow 5 days prior to capture, and between abundance and flow in combination with temperature between 5 and 12 days prior to entry into the Sebou estuary ($r^2 \approx 0.2$). On the Adour, flow was of secondary importance to the strength of the tidal current in explaining variation in the catch of *A. alosa* (Prouzet *et al.,* 1994a). In the Gironde estuary the temperature at the start of the migration varied between years ranging from 7.5 to 10.0°C (N = 4), with 50% of the migration occurring at temperatures <15.0 to <16.0°C and 90% from temperatures ranging from <17.5 to <20.0°C (Rochard, 2001).

Table 3.86: Timing of the freshwater phase of the spawning migration of *Alosa alosa.*

River, Country	Start	Peak	End	Reference
Sebou, Morocco	XII (XI)	II-III	IV (V)	Sabatié (1993)
Lima, Portugal	II-III	III-IV	V	Alexandrino (1996b)
Miño, Portugal	II (I)	IV-V	VI	Lozano Rey (1935)
Douro, Portugal	III	V	VI	Eiras (1981b)
Adour, France	III (II)	IV-V	VI (VII)	Prouzet *et al.* (1994a)
Gironde, France	III (II)	V	VI (VII)	Anon. (1979a); Cassou-Leins & Cassou-Leins (1981); Rochard (2001)
Loire, France	III	IV-V	VI	Mennesson-Boisneau & Boisneau (1990)
Seine, France	III	IV		Vincent (1894b); Roule (1920, 1925)
Rhine, Germany	III (IV)	IV-V	VI	Hoek (**1888,**1899); Fatio (1890); Mohr (1941)
Severn, England		IV-V		Salmon Fisheries Commission (1861)

Tidal state explained the greatest proportion of variation in catch of *A. alosa* in the Loire (Mennesson-Boisneau *et al.,* 1999) with catches increasing towards spring tides and decreasing as tidal height declined (Figure 3.29). Tidal state accounted for between 23.2 and 53.1% of the overall variability followed by flow (1.0 to 16.1%) and temperature (0.1 to 15.8%). However, in the Gironde, Rochard (2001) found that peak catches were correlated with neap tides, and the relationship between catch and tidal state was not consistent between years with catch significantly correlated with tidal state 0 to 6 days prior to capture.

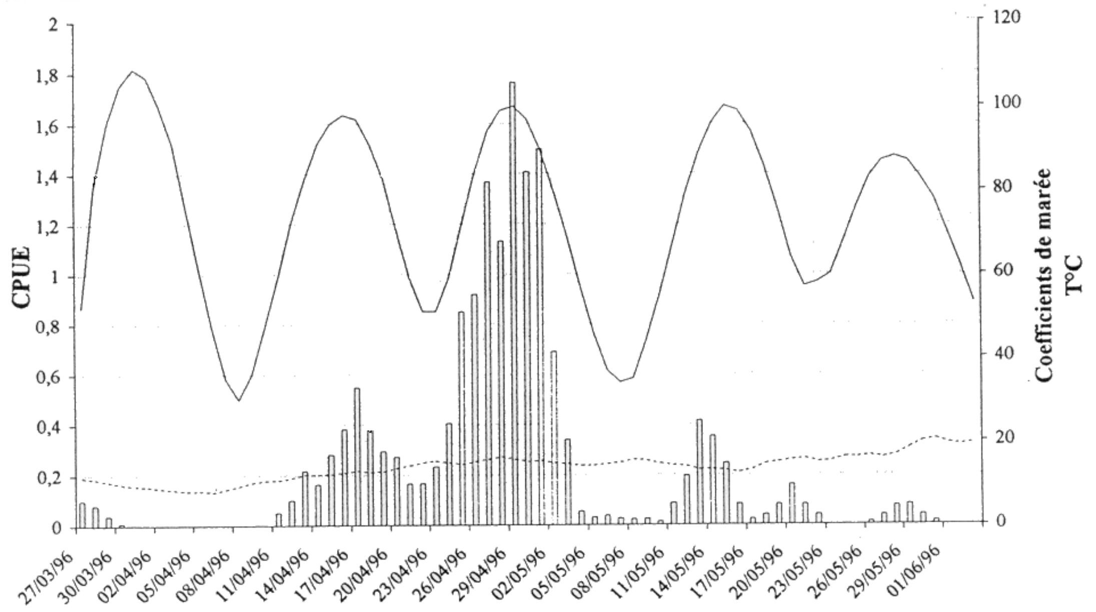


Figure 3.29: The abundance of *Alosa alosa* in the Loire (*c.*150 km from the ocean) and the relationship with tidal state (11 days prior to capture) and temperature (Mennesson-Boisneau *et al.,* 1999).

In fresh water, Mennesson-Boisneau & Boisneau (1990), Dartiguelongue (1996a&b) and Travade *et al.* (1998) have shown that *Alosa alosa* migrate upriver in several waves (Figure 3.30). On the Loire, Boisneau *et al.* (1985) reported a positive correlation between the daily change in water temperature and the number of *A. alosa* caught per hour ($r^2 = 0.18$), numbers declining with a fall in temperature and increasing with increasing temperature. No relationship between abundance and flow or the daily change in flow was apparent (Boisneau *et al.* 1985).

The speed of migration in the Loire has been estimated at 20 km day^{-1} for the fluvial part (Steinbach *et al.*, 1986) and 21 km day^{-1} for migration through the estuary and river (Mennesson-Boisneau & Boisneau, 1990; Mennesson-Boisneau *et al.,* 1999). Through the Gironde estuary, Rochard (2001) estimated the speed of migration to vary between 17 and 23 km day^{-1}.

The timing of the migration has varied between years. Travade *et al.* (1998) observed that the date at which 50% of the *Alosa alosa* population had been recorded migrating past a particular point, varied by up to a month between years. Part of this variation may be related to temperature, little up-river movement being reported at temperatures less than 11°C (Boisneau *et al.,* 1985) or below 15 to 16°C (Vincent, 1894a; Belaud *et al.,* 1985). Certainly, Dautrey & Lartigue (1983) and Bellariva & Belaud (1998) reported a significant positive correlation between the abundance of *A. alosa* and temperature ($r^2 = 0.26\text{-}0.50$ and 0.56 respectively). The association with temperature may relate to the swimming capabilities of *A. alosa,* as their swimming speed is inhibited when water temperatures fall below 12°C (Steinbach *et al.* 1986).

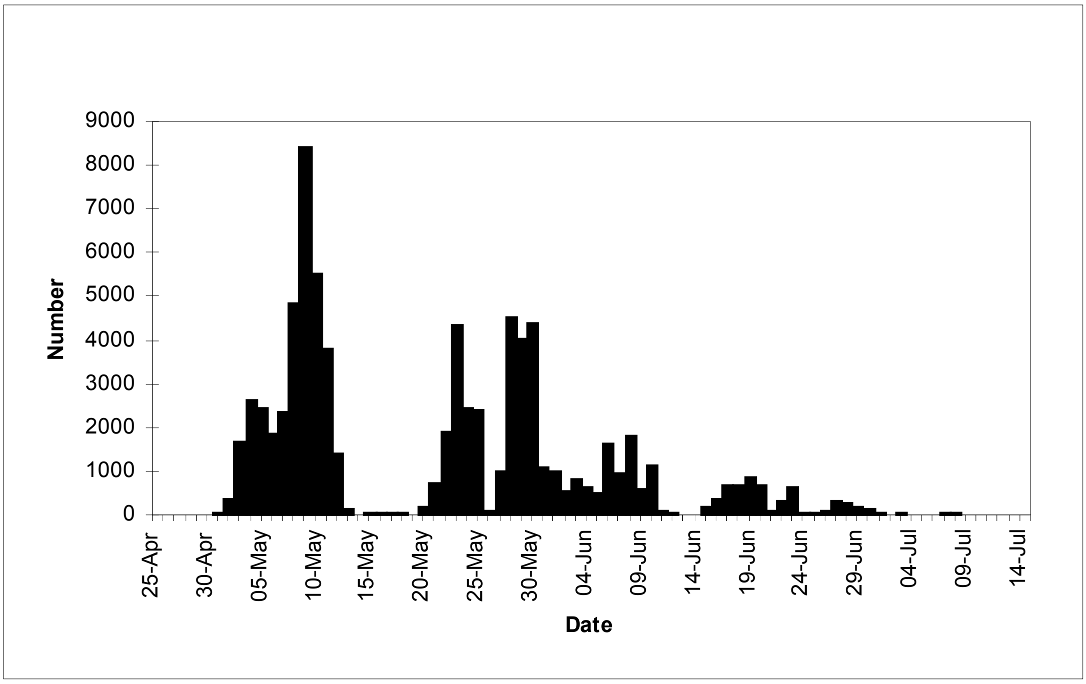


Figure 3.30: The daily count of *Alosa alosa* at Tuilièrs fish pass on the River Dordogne, France, in 1995 (Dartiguelongue, 1996a).

In relation to discharge, Dautrey & Lartigue (1983) observed a negative correlation with flow (r^2 = 0.28-0.29) though Bellariva & Belaud (1998) found the relationship with discharge was inconclusive except that at high discharges (mean = 721 m^3s^{-1}) migration ceased.

Migration upstream occurs mainly during the day (Figure 3.31); it increased gradually from 0800h, reaching a peak at 1900h after which it declined steadily until 2300h. There was little upstream movement between 0000 and 0700h (Travade *et al.,* 1998).

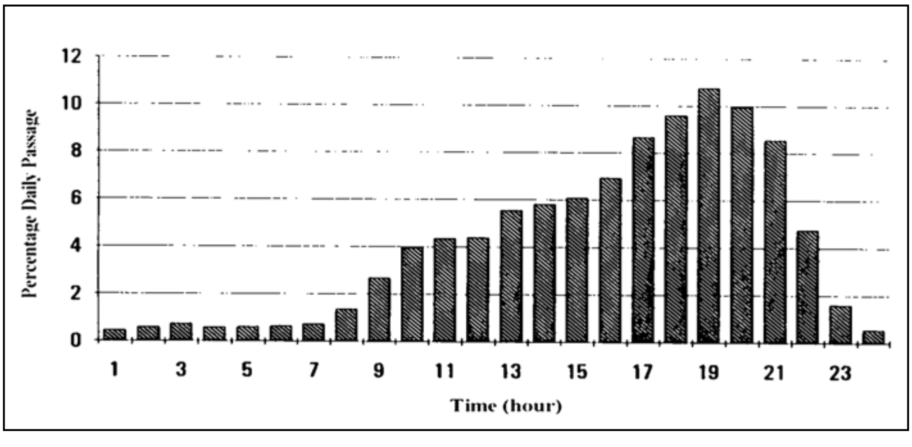


Figure 3.31: The daily pattern of movement of *Alosa alosa* at Tuilièrs fish pass on the River Dordogne, France, in 1995 (Reproduced from Travade *et al.,* 1998).

The larger and older males and females were the first to migrate and the condition of the fish deteriorates during the migration period (Dautrey & Lartigue, 1983; Sabatié, 1993). The early part of the migration was characterised by a higher proportion of males (Mennesson-Boisneau & Boisneau, 1990; Sabatié, 1993). However, in the Lima (Portugal) there was no significant difference (P>0.05) in the sex ratio during the migration period (Alexandrino, 1996b).

Alosa fallax fallax

Migration into the estuary begins between February (for stocks at the southern limit of their range) and May (for those at the northern limit), and usually extends for three months (Table 3.87). The timing of the onset of migration has been associated with temperatures reaching 10 to 12^{o}C (Roule, 1922a, 1925). Similar findings have been observed on the Severn (Claridge & Gardner, 1978; Aprahamian, 1982, 1988), the Sebou (Sabatié, 1993) and the Loire (Mennesson-Boisneau & Boisneau, 1990). In warmer years migration can commence approximately a month earlier than normal (Mennesson-Boisneau & Boisneau, 1990).

Shad migrate mainly during the day between 0500 and 2000 (Figure 3.32), in the lower half of the water column close to the river bed, where water velocity is lowest (Clabburn, 2002). The fish enter the river in a series of waves (Aprahamian, 1981). There is a higher proportion of males at the start of the migration (Roule, 1922a; Hass, 1965; Claridge & Gardner, 1978; Aprahamian, 1981, 1982; Alexandrino, 1996b). Of the females, the larger fish were the first to migrate and this was also apparent with fish of the same age and spawning history (Aprahamian, 1981; 1982; Sabatié, 1993). Similar findings were reported for males from the Sebou (Sabatié, 1993) but not for the Severn, and for the latter the lack of size differentiation may reflect gear selectivity (Aprahamian, 1982).

Table 3.87: Timing of the freshwater phase of the spawning migration of *Alosa fallax fallax*.

River, Country	Start	Peak	End	Reference
Sebou, Morocco	II (XII-I)	IV	V	Sabatié (1993)
Guadiana, Portugal	I	V	VI	Esteves (pers. comm.)
Mira, Portugal	II	IV	VI	Esteves (pers. comm.)
Tejo, Portugal	II		VI	Baglinière *et al.* (2001)
Lima, Portugal	III (II)	IV-V	VI	Alexandrino (1996b)
Adour, France		V-VI		Douchement (1981)
Gironde, France	IV (III)	V	VI	Anon. (1979a)
Loire, France	V (IV)	V	VII	Mennesson-Boisneau & Boisneau (1990)
Seine, France	IV	V	VI	Roule (1922a)
Rhine, Germany	IV	V	VI	Böcking (1982)
Elbe, Germany	IV	V	VI (VII)	Hass (1965); Thiel *et al.* (1996a)
Nyamunas, Lithuania	V	VI	VII	Manyukas (1989)
Barrow-Nore-Suir, Ireland	IV	V	VI	Bracken & Kennedy (1967)
Wye, Wales	IV	V	VI	Aprahamian (1982); Gregory (pers. comm.)
Severn, England	IV	V	VI	Aprahamian (1981,1982)

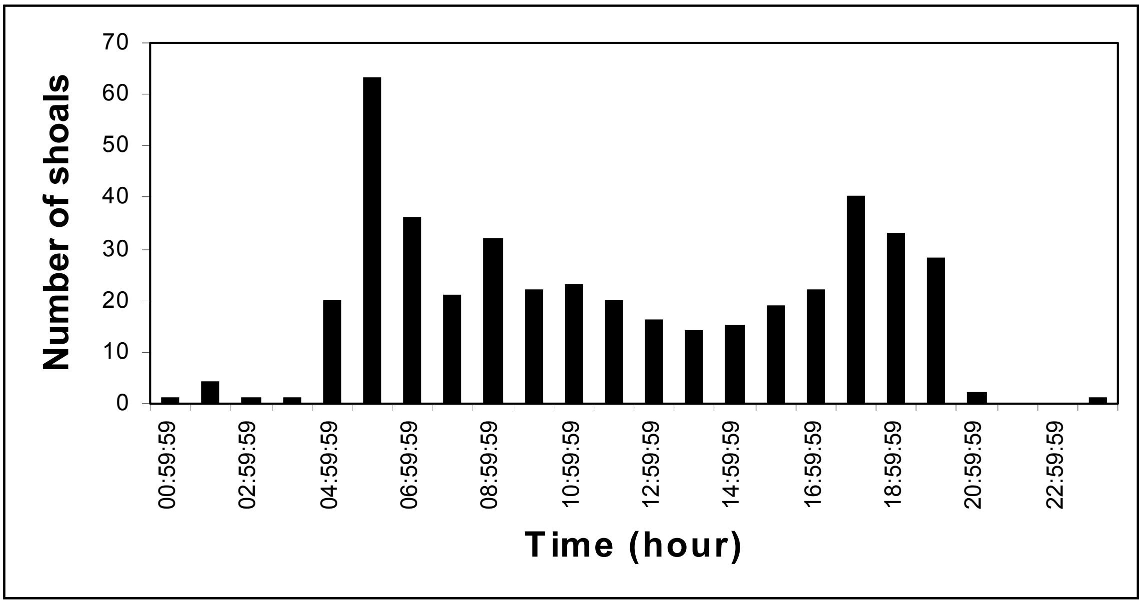


Figure 3.32: The diel movement of *Alosa fallax fallax* shoals in the River Wye, Wales (J. Gregory, pers. comm.).

Fish entering the estuary near the end of the migration period were lighter for a given size both in terms of total weight and somatic weight when compared to those that migrated earlier (Aprahamian, 1982). In some years there was an indication that fish which had spawned previously migrated first, though in other years this was not the case; no trend was apparent.

After spawning the spent fish migrate downstream in the middle to upper part of the water column where water velocities are greatest (Clabburn, 2002).

Alosa fallax rhodanensis

On the River Rhône migration takes place between mid-March and the beginning of July, with a peak in April to May (Roule, 1924c; Gallois, 1946a, 1947a; Rameye *et al.,* 1976; Douchement, 1981; Baglinière *et al.,* 1996; Le Corre *et al.,* 1997a; Lebel *et al.,* 1999). The main migration period is similar on the Aude (Douchement, 1981). On the River Tiber the onset of the migration begins during the first half of March (D'Ancona, 1928a) and on the Tirso the migration period extends from February or March until the end of April (Cottiglia, 1963a).

The temperature at the statrt of the freshwater phase of the migration has been reported to range from about 10°C to 14°C (Gallois (1947a; Rameye *et al.*, 1976; Baglinière *et al.,* 1996). Guillard & Colon (2000) showed that there was a significant positive correlation between the number of fish migrating upstream over a four day period and water temperature (r^2 = 0.42 – 0.86), up until the migration reached its peak. No relationship was found with, conductivity, pH or oxygen content of the Rhône, however, with flow the results were inconclusive, with a significant negative relationship in one year and an absence of any relationship in the other year of study. The migration can be delayed due to poor weather conditions, in some cases by up to a month (Rameye *et al.,* 1976). At flows greater than 2500 $m^3 s^{-1}$, Baglinière *et al*. (1996) observed that upstream migration on the Rhône ceased.

At the start of the migration there is a higher proportion of males which declines during the period of the run (D'Ancona, 1928a; Quignard & Douchement, 1991c; Baglinière *et al.,* 1996). The weight of both male and female fish of a given length was greater at the start of the migration period than that of later migrants (Baglinière *et al.,* 1996).

Alosa fallax nilotica

The onset of the migration into fresh water begins in March or April with a peak in April or May, though the timing of the migration has been shown to vary by approximately one month between years (Vukovic, 1961a; Vitali *et al.,* 1983; Serventi *et al.,* 1990). In the River Evros (Greece) the sub species migrates upriver from the end of March to the end of May and into Lake Vistonis between April and June (Bobori *et al*., 2001). Temperature at the start of the migration in the River Po ranged from 8 to 12°C and upstream movement of fish was positively correlated with temperature but not with flow (Vitali *et al.,* 1983; Serventi *et al.,* 1990).

In the River Po (Italy) males predominated at the start of the migration (Vitali *et al.,* 1983). In the River Neretva, females dominated throughout the spawning period in particular at the start and at the end where they were *c.* 3 times more abundant than males For the remaining periods the sex ratio was approximately 1:1 (Vukovic, 1961a).

Alosa fallax algeriensis

The migration period extends from mid-March to the end of May, with the temperature at the start of migration varying between 14 and 17.8°C (Bounhiol, 1917; Kartas, 1991). Males were predominant at the start of the migration (Kartas, 1991).

- Juvenile seaward migration

Alosa alosa

By the end of summer or early autumn, most 0+ juveniles are in the estuary (Poll, 1947; Hoestlandt, 1958; Anon. 1979a), the largest arriving at the river mouth around August and the smallest remaining in fresh water until September or October (Quignard & Douchement, 1991a). In the Sebou (Morocco) it was relatively rare to find juvenile *A. alosa* in the estuary during July to September, though numbers increased by December (Sabatié, 1993). During their period in the estuary juveniles tend to be found at the surface and close inshore (Taverny, 1991a). Certainly, Castelnaud *et al*. (2001) reported the juveniles to be ~ 10 times more abundant in the surface layers compared with samples taken 0.2 m above the bottom.

In the Gironde estuary, the juveniles first arrive in the estuary in August. Migration from estuary to sea of the 0+ age group commenced in October, reaching a peak in

December and ceasing by the end of February (Albiges *et al.,* 1985a; Elie *et al.,* 1988a; Sertier *et al.,* 1990; Taverny, 1991a). The 1+ age group showed a similar pattern with December being the main month for migration seaward. This suggests that a portion of the juvenile population may remain in the river or estuary for a second year. A similar conclusion was reached by **Hoek (1888), Meek (1916), Roule (1925), Lithogoe & Lithogoe (1971) and Wheeler (1969a).** The downstream migration of the juveniles did not appear to be initiated either by a change in temperature or flow (Taverny, 1991). However in the Sebou (Morocco), the downstream migration of both juvenile *A. alosa* and *A. fallax* was found to be closely associated with the autumn floods (Sabatié, 1993). During the summer months the fall in water level results in the juvenile populations becoming isolated by the development of impassable fords, which only become passable with increasing discharge during the autumn.

At the time of migration the majority of the 0+ population in the Gironde ranged in size (upper and lower 95% confidence intervals) from 54.5 to 79.6 mm (total length) and the 1+ from 138.2 to 161.2 mm (Taverny, 1991a). In the Rhine, Anon. (1888) reported a size range of between 72 and 143 mm for fish caught in October, the largest may, however, not be young of the year.

Alosa fallax fallax

The seaward migration of juvenile *Alosa fallax fallax* has been studied on the River Severn, England (Claridge & Gardner, 1978; Aprahamian, 1988), the River Elbe, Germany (Thiel *et al.,* 1996a) the Gironde, France (Boigontier & Mounié, 1984; Taverny, 1991a; Castelnaud & Rochard, 1993, 1994a) and the Oued Sebou, Morocco (Sabatié, 1993).

The juveniles can be found through out the water column but have a preference for the surface layers where the fish were ~ 9 times more abundant when compared with samples taken 0.2 m above the bottom (Castelnaud *et al*., 2001). The 0+ fish migrate seaward during the autumn (Figure 3.33) in the surface layers of the water column (Taverny, 1991a). In the Severn and Elbe the majority have left the estuary by the end of October (Claridge & Gardner, 1978; Thiel *et al.,* 1996a), while in the Garonne it is not until the end of February that the majority have migrated seaward (Taverny, 1991a).

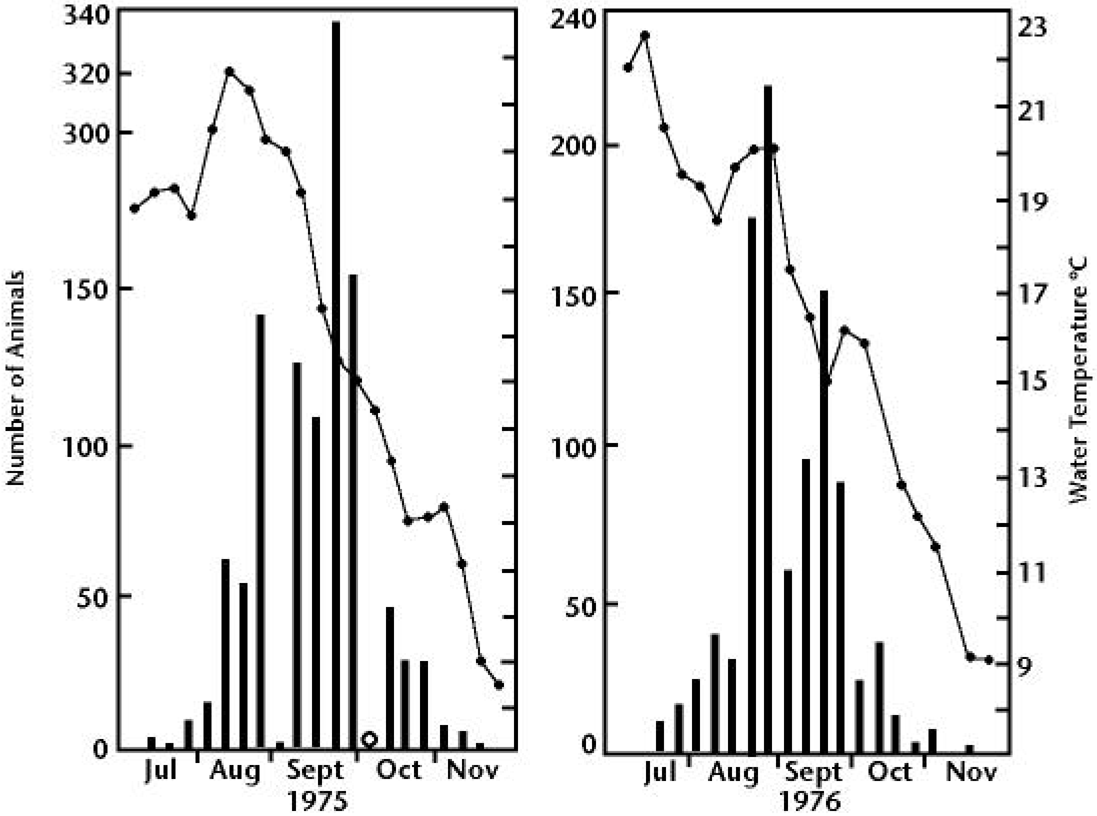


Figure 3.33: The weekly 24-h sample size of 0+ *Alosa fallax* from the Severn Estuary (England) between July and November in 1975 and 1976, and the mean water temperature for the week prior to the collection. 'o' indicates that no collection was made, from Claridge & Gardner (1978).

Claridge & Gardner (1978) considered the main environmental factor involved with the initiation of the seaward migration to be declining temperature. In the Severn estuary the authors found the peak migration of juvenile *Alosa fallax* to be associated with a decline in temperature below 19°C, with virtually none being caught once temperatures had fallen to less than 9°C. The effect of discharge alone did not appear to affect the timing of the juveniles' seaward movement (Aprahamian, 1982).

In the rivers Severn and Elbe, juvenile *A. fallax* (Age 1) reappear in the estuary in the spring (April to May) and remain until the autumn (October) (Claridge & Gardner, 1978; Aprahamian, 1988; Taverny, 1991a; Thiel *et al.,* 1996a). It has been suggested that a small portion of the population overwinters in the estuary and emigrates seaward once the temperature reaches 7°C (Claridge & Gardner, 1978). However, studies carried out over a wider spatial scale suggest that the juveniles may, in fact, be making an onshore migration into the estuary at this time (Aprahamian, 1988; Thiel *et al.,* 1996a), and similar conclusions were also reached by Hass (1965).

In the Gironde, however, it would appear that a portion of the juvenile population do in fact reside overwinter in the estuary and/or in fresh water, and migrate seaward during the following October to March (Taverny, 1991a).

The size (L_t) of the 0+ juveniles (upper and lower 95% CI) in the autumn on their seaward migration ranged from 45 to 76mm on the Severn (Aprahamian, 1988[2]; Claridge & Gardner, 1978[3]), 72 to 118mm on the Elbe (Thiel *et al.,* 1996a) and between 71and 84mm on the Gironde (Taverny, 1991a). In the Rhine, Anon. (1888) reported a size range of between 54 and 150 mm for fish caught in October-November, the largest may, however, be one year old.

Alosa fallax rhodanensis

In the Rhône, Crivelli & Poizat (2001) found that the juveniles could start their downstream migration between mid June and mid July, approximately 3 to 5 weeks after spawning had ceased. Their seaward migration occurring between the end of August and the end of October at a length (L_t) ranging from 68 to 161mm[2] (Menella & Tabardel, 1994; Tabardel *et al.,* 1995; Gendre *et al.,* 1997a), with a maximum of 213 mm (Crivelli & Poizat, 2001). In the Aude the main migration period is between July and September (Cassou-Leins, 1995).

Alosa fallax algeriensis

Kartas (1991) reported that in the Tunisian rivers Miliane and Medjerdah the juveniles migrate seaward in September.

- Migration at sea

Alosa alosa

Except for the study by Sabatié (1993) little information exists on their movements at sea. Sabatié (1993) reported that juvenile *A. alosa* from the River Sebou in Morocco migrate south to an area of upwelling between Essaouira and Agadir (Latitude 31^{o}N) a distance of approximately 1,200 km. The fish remain in this rich feeding area until they mature when they return to the Sebou to spawn.

---

[1] Fork length (mm) converted to total length using $L_t = 1.1264L_f + 3.526$ (Douchement, 1981).

[2] Standard length (mm) converted to total length using $L_t = 1.1896L_{st} + 5.9359$ (Douchement, 1981).

3.5.2 Swimming speed

There is little information about the swimming ability and endurance of *Alosa alosa* and *Alosa fallax*. Litaudon (1985) estimated that the burst swimming speed of *Alosa alosa* ranged from 3.1 ms^{-1} to 4.7 ms^{-1} at temperatures of 16 to 17°C. At these temperatures the fish could maintain such speed for approximately 6.5s. The maximum speed was estimated at between 4.1 ms^{-1} and 6.1ms^{-1}, but could only be sustained for a few seconds. Table 3.88 summarise the swimming capabilities of shad measuring 0.30 to 0.50 m in length (Larinier, 1996).

Table 3.88: Swimming capabilities of shad (0.30 to 0.50 m in length) from Larinier (1996).

Temperature (°C)	Maximum speed (ms^{-1})	Endurance at maximum speed (sec)	Cruising speed (ms^{-1})
10	2.75 – 3.30	15 – 60	0.8 – 1.5
15	3.50 – 4.30	10 – 25	
20	4.40 – 5.40	5 – 10	

Anon (1975) mentions that the swimming speed of *A. fallax rhodanensis*, as measured in a fish ladder which had been fitted with baffles (Lachadenc model), varied between 1.5 and 2.3 ms^{-1}. Anon (1975) and Larinier *et al.* (1978) both report that at current speeds greater than 1.5 ms^{-1} shad did not enter the fish pass. Gendre (1997a) reported that *A. fallax rhodanensis* could maintain a swimming speed of < 1.4 ms^{-1} for several hours (cruising or sustained swimming speed), while speeds of between 2 to 2.4 ms^{-1} could only be maintained for a few minutes, with a maximum (burst) swimming speed of 2.4 to 3.1 ms^{-1}.

4. POPULATION (SPAWNING STOCK)

This section is confined to characterising the adult component of the stock, except section 4.5.1, which deals with production. Interpretation of data is complicated by the fact that in all circumstances, except for the study of Lambert *et al.* (2001), there has been no correction for gear selectivity. In addition, because different methods operate in different locations, comparisons between systems and between species must be made with caution.

4.1 Structure

4.1.1 Sex Ratio

Sex ratio has been taken as the number of males in relation to the number of females (male/female).

Alosa alosa

In the Loire (France) the sex ratio of the population over a six-year period varied from 0.84:1 to 4.5:1. In three of the six years there was no significant difference from a 1:1 ratio, and in the other years there were significantly more males than females ($P<0.01$) (Mennesson-Boisneau & Boisneau, 1990).

In the Gironde-Garonne-Dordogne (France) system the sex ratio of fish caught in the estuary (Anon., 1979a; Taverny, 1991a) and on the spawning grounds (Cassou-Leins & Cassou-Leins, 1981) showed no significant difference from parity ($P>0.05$). However, over a three-year period Lambert *et al.* (2001) found the sex ratio to range from 0.76:1 to 1.47:1 and how it varied with age is shown in Table 4.1.

Table 4.1: Range in the annual sex ratio of *A. alosa* from the Gironde-Garonne-Dordogne (Lambert *et al.*, 2001).

Age	Sex ratio (M / F)	
	Mean	Range
3	6.82	4.23 - 10.71
4	2.99	1.99 - 3.56
5	1.08	0.51 - 1.63
6	0.29	0.16 - 0.44
7	0.13	0.00 - 0.26
Total	1.15	0.76 - 1.47

No significant difference from a 1:1 ratio was reported from the Portuguese rivers Douro (Eiras, 1981b) and Lima (Alexandrino, 1996b). In the Oued Sebou (Morocco), Sabatié (1993) studied the sex ratio in four years between 1978 and 1985 and observed the annual sex ratio to vary from a preponderance of females (0.5:1) to one where males dominated (4.8:1).

Alosa fallax fallax

For samples obtained using rod and line from the rivers Wye (Wales), Severn (England) and Barrow (Ireland), Aprahamian (1982) and O'Maoileidigh (1990) reported no significant difference (P>0.05) from a 1:1 sex ratio. Similar findings were reported by Douchement (1981) for *A. fallax* from the Loire, by Anon. (1979a) for the Gironde-Garonne-Dordogne system and by Alexandrino (1996b) for the Lima. In contrast, in the Sebou males were more abundant with the sex ratio varying between years from 1.35:1 to 2.15:1 (Sabatié, 1993), while in the Tejo females predominated (0.36:1) [Alexandrino, 1996b].

Alosa fallax rhodanensis

In the Rhône (France), the sex ratio has been found to vary between years, from parity to a preponderance of females (0.24:1) and then to a dominance of males (4.15:1) (Douchement, 1981; Le Corre *et al.,* 1997a). On the Tiber (Italy), D'Ancona (1928a) reported a dominance of males with a sex ratio of 2.44:1 at the start of the migration period (March-April) to 1.30:1 in May and June.

Alosa fallax nilotica

In the River Neretva the population was dominated by females, while in lakes Bačin and Skadar the sex ratio was close to1:1 (Vukovic, 1961a).

Alosa fallax killarnensis

Gill net (50.8 to 63.5 mm) samples of *Alosa fallax killarnensis* from Lough Leane (Ireland) showed no significant difference from a 1:1 sex ratio (O' Maoileidigh, 1990).

4.1.2 Age composition

Alosa alosa

The age structure of the spawning population ranges from 3 to 8 years old for both sexes (Tables 4.2 & 4.3). The majority of the catch consisted of females aged 5 or 6 years old and 4 or 5 year old males. Similar findings were reported from the River Lima, Portugal (Alexandrino, 1996b).

Alosa fallax fallax

In the more northerly populations (Severn, England) the spawning stock consists of females mainly aged between 5 and 7 years old and males of 4 to 6 years old, with a maximum age of 12 and 10 years for females and males, respectively (Tables 4.4 & 4.5). At the southern limit (Sebou, Morocco) of their range the spawning population consists of fish aged 3 or 4 years old, with a maximum age of 6 and 5 years for females and males respectively.

Table 4.2: Age structure (mean percent and range) of the spawning population of female *Alosa alosa* (N = number of years sampled; n = number of fish aged).

River	Age (Years)							N	n
	3	4	5	6	7	8	9		
Aulne, France (Véron, 1999)	14.29	42.85	28.57	14.29				1	7
Loire, France (Douchement, 1981)			64.50	32.30	3.20				31
Loire, France (Mennesson-Boisneau & Boisneau, 1990)		28.84 (1.6-60.9)	49.94 (30.4-79.5)	17.74 (2.7-50.8)	3.48 (0.0-12.7)			6	1054
Charente, France (Véron, 1999)	2.50	12.50	52.50	22.50	10.00			1	40
Gironde-Garonne-Dordogne, France (Douchement,1981)			39.10	60.90					46
Gironde-Garonne-Dordogne, France (Anon., 1979a)				25.00	45.00	30.00		1	20
Gironde-Garonne-Dordogne, France (Cassou-Leins & Cassou-Leins, 1981)		33.50 (20.0-47.0)	54.25 (48.5-60.0)	10.00 (0.0-20.0)				2	98
Gironde-Garonne-Dordogne, France (Martin-Vandembulcke, 1999)		4.15 (3.1-5.4)	66.94 (59.9-78.0)	27.65 (18.2-36.1)	1.25 (0.0-3.1)			3	585
Gironde-Garonne-Dordogne, France (Lambert *et al*., 2001)	0.74 (0.4-1.2)	13.42 (11.5-16.7)	61.34 (53.0-68.4)	23.91 (17.9-34.4)	0.60 0.0-1.0)			3	956
Adour, France (Douchement, 1981)			11.80	35.30	52.90				17
Adour, France (Prouzet *et al.,* 1994a)		0.40	35.08	49.60	14.11	0.81		5	248
Douro, Portugal (Eiras, 1981b)	23.03 (8.7-46.2)	17.80 (13.7-20.1)	41.67 (23.1-60.7)	16.90 (5.3-35.0)	0.40 (0.0-1.2)			3	270
Sebou, Morocco (Sabatié, 1993)		3.19 (0.0-6.5)	28.53 (11.9-42.9)	49.60 (38.1-60.0)	17.43 (6.7-31.3)	2.26 (0.0-4.8)		4	240

Table 4.3: Age structure (mean percent and range) of the spawning population of male *Alosa alosa* (N = number of years sampled; n = number of fish aged).

River			Age	(Years)				N	n
	3	4	5	6	7	8	9		
Aulne, France (Véron, 1999)		69.23	30.77					1	13
Loire, France (Douchement, 1981)	11.80	75.00	13.20						68
Loire, France (Mennesson-Boisneau & Boisneau, 1990)	7.35 (0.0-18.2)	49.77 (20.2-86.9)	37.87 (9.9-72.6)	5.01 (0.0-15.6)				6	1173
Charente, France (Véron, 1999)	11.76	17.65	47.06	17.65	5.88			1	17
Gironde-Garonne-Dordogne, France (Douchement,1981)		25.00	50.00	25.00					36
Gironde-Garonne-Dordogne, France (Anon., 1979a)			26.00	40.00	26.00	8.00		1	35
Gironde-Garonne-Dordogne, France (Cassou-Leins & Cassou-Leins, 1981)	4.85 (0.0-9.7)	54.05 (50.0-58.1)	41.10 (32.2-50.0)					2	93
Gironde-Garonne-Dordogne, France (Martin-Vandembulcke, 1999)		15.61 (8.9-22.0)	71.23 (64.8-80.9)	13.05 (3.2-22.8)	0.11 (0.0-0.3)			3	682
Gironde-Garonne-Dordogne, France (Lambert *et al*., 2001)	4.12 (2.9-6.6)	34.18 (27.8-43.9)	54.08 (42.6-60.8)	6.56 (2.3-10.4)	0.05 (0.0-0.1)			3	1191
Adour, France (Douchement, 1981)	1.40	66.70	30.50	1.40					72
Adour, France (Prouzet *et al.,* 1994a)		12.97	62.34	21.76	2.93			5	239
Douro, Portugal (Eiras, 1981b)	20.03 (5.0-55.8)	24.33 (5.0-37.2)	29.03 (10.0-41.6)	23.43 (3.3-45.0)				3	239
Sebou, Morocco (Sabatié, 1993)	0.86 (0.0-2.4)	22.27 (11.3-37.4)	48.92 (39.6-54.9)	27.07 (11.0-49.1)	0.88 (0.0-3.5)			4	240

Table 4.4: Age structure (mean percent and range) of the spawning population of female *Alosa fallax fallax* (N = number of years sampled; n = number of fish aged).

River	Age (Years)										N	n
	3	4	5	6	7	8	9	10	11	12		
Severn, England (Aprahamian, 1982 & unpubl.)	0.44 (0.0-5.5)	11.72 (0.0-67.0)	23.43 (0.4-78.6)	25.49 (0.0-74.7)	20.26 (0.5-61.8)	11.28 (0.2-42.3)	6.21 (0.0-42.1)	1.20 (0.0-5.6)	0.19 (0.0-1.9)	0.04 (0.0-0.5)	17	4598
Wye, Wales (Aprahamian, 1982)		21.28	70.21	4.26	4.26						1	47
Barrow, Ireland (O'Maoleideigh, 1990)		18.20	59.10	13.60		9.1					1	22
Holland (Aprahamian, 1982)		1.29	80.54	9.09	5.19	2.60	1.29				1	77
Loire, France (Douchement, 1981)	5.40	30.20	41.10	21.40	1.80							56
Charente, France (Véron, 1999)	17.86	71.43	10.71								1	28
Gironde-Garonne-Dordogne, France (Douchement, 1981)	6.70	26.70	66.70									45
Adour, France (Douchement, 1981)			30.40	43.60	13.00	13.00						23
Sebou, Morocco (Sabatié, 1993)	8.81 (2.5-20.0)	48.19 (33.3-75.0)	28.42 (0.0-49.0)	14.58 (5.0-25.0)							3	151

Table 4.5: Age structure (mean percent and range) of the spawning population of male *Alosa fallax fallax* (N = number of years sampled; n = number of fish aged).

River	Age (Years)									N	n
	2	3	4	5	6	7	8	9	10		
Severn, England (Aprahamian, 1982 & unpubl.)	0.02 (0.0-0.4)	5.57 (0.0-46.0)	20.48 (0.5-75.7)	21.68 (0.0-78.9)	21.61 (0.0-65.3)	17.83 (1.0-61.5)	8.62 (0.0-34.2)	2.21 (0.0-10.2)	0.28 (0.0-2.6)	17	1527
Wye, Wales (Aprahamian, 1982)			63.46	34.62	1.92					1	52
Barrow, Ireland (O'Maoleideigh, 1990)			16.20	73.00	2.70	2.70	2.70	2.79		1	37
Holland (Aprahamian, 1982)				66.22	24.32	6.76	1.35	1.35		1	74
Loire, France (Douchement, 1981)	26.00	60.50	31.60	5.30							38
Charente, France (Véron, 1999)			100.0							1	5
Gironde-Garonne-Dordogne, France (Douchement,1981)		51.40	29.70	16.20	2.70						37
Sebou, Morocco (Sabatié, 1993)	0.37 (0.0-1.1)	35.86 (23.8-57.1)	49.37 (28.6-61.1)	14.41 (11.1-17.8)						3	205

The age structure of the Portuguese populations (Table 4.6) is similar to that of the more southern stocks, with the exception of the River Tejo, which appears younger than other populations.

Table 4.6: Age structure of the adult population of *Alosa fallax fallax* from four Portuguese rivers (Alexandrino, 1996b).

River	Sex	Mean ± SD	Range	n
Lima	M	3.83 ± 0.85	2-5	51
	F	4.04 ± 0.70	3-5	54
Mondego	M	4.08 ± 0.76	3-5	25
	F	4.62 ± 0.51	4-5	13
Tejo	M	2.77 ± 0.69	2-4	22
	F	3.38 ± 0.56	3-5	78
Quadiana	M	4.00 ± 0.29	3.5	25
	F	4.20 ± 0.56	4-6	15

Alosa fallax rhodanensis

The age of the spawning population ranges from 3 to 8 years old for both sexes, with the majority being between 5 and 6 years old for females and 4 and 5 years old for males (Tables 4.7 & 4.8). Though both sexes can mature as young as 2 years old (Le Corre *et al.*, 2000). The average age for the upstream migrants in the Rhône was 4.16 years for males and 5.05 for females and in the Aude 4.7 years and 5.7 years for male and females, respectively (Le Corre *et al.*, 2000). In the Hérault and Tavignano the males ranged in age from 4 to 5 and 3 to 6 years and the females 4 to 6 and 5 to 6 years, respectively, though caution must be exercised as sample sizes were small (Le Corre *et al.,* 2000).

Alosa fallax nilotica

The age structure of the anadromous population in the River Neretva ranged from 2 to 10 years old with the majority consisting of fish aged 5 years (Table 4.9). In the River Po (Italy) the maximum age recorded was 7 years old for both sexes (Serventi *et al.,* 1990). The range in the age structure for the landlocked population in Lake Skadar reflects samples taken using two different methods, trawl and seine net (Vukovic, 1961a).

Alosa fallax lacustris

The maximum population age is *c*. 5 years old in Lake Maggiore (Table 4.10) and four in Lake Garda (Oppi & Novello, 1989).

Alosa fallax killarnensis

The majority of the spawning population consisted of fish aged 4 years old (Table 4.10).

Table 4.7: Age structure (mean percent and range) of the spawning population of female *Alosa fallax rhodanensis* (N = number of years sampled; n = number of fish aged).

River	Age (Years)								N	n
	2	3	4	5	6	7	8	9		
Aude, France (Douchement, 1981)			15.80	23.70	44.70	5.30	10.50			38
Rhône, France (Douchement, 1981)		4.70	29.70	46.90	10.90	6.40	1.60			64
Rhône, France (Le Corre *et al.*, 1997a)		1.82 (0.0-3.5)	19.22 (6.1-26.7)	47.27 (46.4-47.7)	23.47 (14.0-35.5)	7.40 (4.6-10.7)	0.82 (0.0-1.3)		3	436

Table 4.8: Age structure (mean percent and range) of the spawning population of male *Alosa fallax rhodanensis* (N = number of years sampled; n = number of fish aged).

River	Age (Years)								N	n
	2	3	4	5	6	7	8	9		
Aude, France (Douchement, 1981)		27.00	33.80	36.70	2.70					74
Rhône, France (Douchement, 1981)		15.60	62.40	21.10						109
Rhône, France (Le Corre *et al.*, 1997a)		16.33 (7.3-23.4)	48.31 (36.4-57.5)	26.30 (19.1-38.2)	7.49 (2.6-14.5)	0.96 (0.0-1.8)	0.61 (0.0-1.8)		3	302

Table 4.9: Age structure (mean percent and range) of the spawning population of female and male *Alosa fallax nilotica* (N = number of years sampled; n = number of fish aged).

River	Age (Years)										N	n
	1	2	3	4	5	6	7	8	9	10		
Neretva, (Vukovic, 1961a)		0.29	2.92	9.94	51.75	16.66	9.94	4.38	3.53	0.58		
Bačin, (Vukovic, 1961a)	0.39	29.13	14.17	8.66	22.83	12.99	5.11	4.72	1.96			
Skadar (Vukovic, 1961a)	0.16-5.94	6.30-29.38	2.36-21.49	9.21-11.94	26.38-47.80	3.44-19.43	3.07-8.11	1.75-3.09	0.45-0.56	0.16-0.45		

Table 4.10: Age structure (mean percent and range) of the spawning land locked populations (N = number of years sampled; n = number of fish aged).

River	Age (Years)								N	n
	1	2	3	4	>4	5	6	7		
Alosa fallax lacustris (Berg, 1966a)										
Lake Maggiore, Italy (sexes combined)	49.10 (3.3-93.0)	42.9 (3.0-78.7)	5.83 (1.0-14.5)	1.33 (0.4-2.6)	0.37 (0.1-0.5)				3	1461
Alosa fallax killarnensis (O'Maoleideigh, 1990)										
Lough Leane, Ireland Female				62.50 (50.0-75.0)		33.35 (16.7-50.0)	4.15 (0.0-8.3)		2	38
Lough Leane, Ireland Male			2.65 (0.0-5.3)	76.05 (63.2-88.9)		21.35 (11.1-31.6)			2	56

4.2 Abundance and Density

Alosa alosa

Estimates of abundance in terms of the total size of the spawning stock are presented in section 4.5 (Dynamics of the population). Some catch per unit effort data (number of fish caught per net per day) does exist for the Gironde system for the period 1984 to 1999 (Figure 4.1), the mean ± 95% CI CPUE was 33.3 ± 3.3 and a coefficient of variation of 20.43% (Castelnaud *et al.*, 2001). The data suggests that that the population remained relatively stable up until 1993 and then started to increase which may be related to the provision of fish pass facilities in the Garonne and Dordogne (see section 6.3.5).

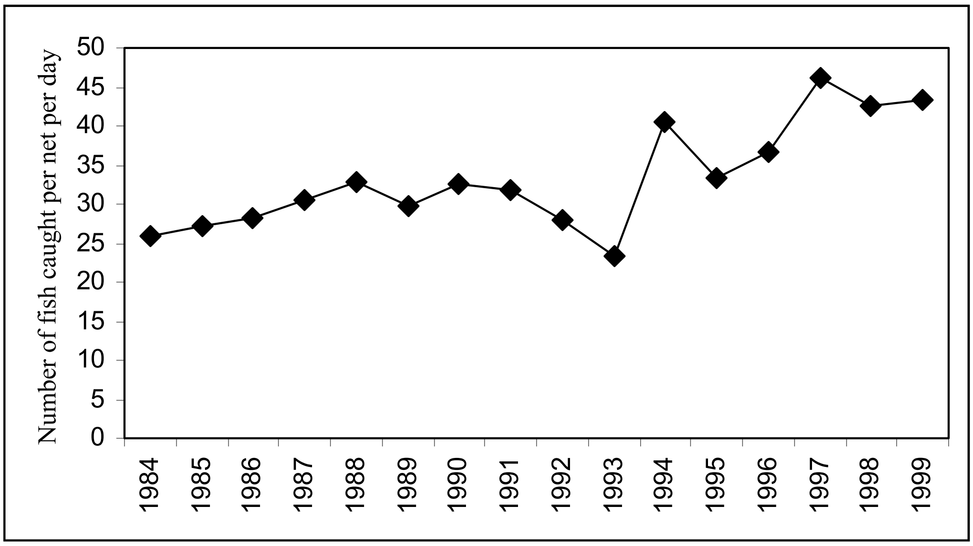


Figure 4.1: Annual variation in the number of *Alosa alosa* caught in the Gironde per net per day between 1984 to 1999 (Castelnaud *et al.*, 2001).

Alosa fallax fallax

Variation in a catch per unit effort estimate of abundance (Aprahamian & Aprahamian, 2001) of the female portion of the spawning population is shown in Figure 4.2 for *Alosa fallax fallax*, the coefficient of variation for the period was 39.3%.

Abundance (ind ha^{-1}) has been reported for the Elbe, downstream of Hamburg, for the period 1985 and 1986 (Möller, 1988) and from 1989 to 1994 (Thiel *et al.*, 1996a). During the period 1989 to 1994 the abundance of individuals in the spawning stock ranged from 1.75 to 11.72 ind h^{-1} with a mean (SD) of 6.41 (4.37) ind h^{-1} and coefficient of variation of 68.3%.

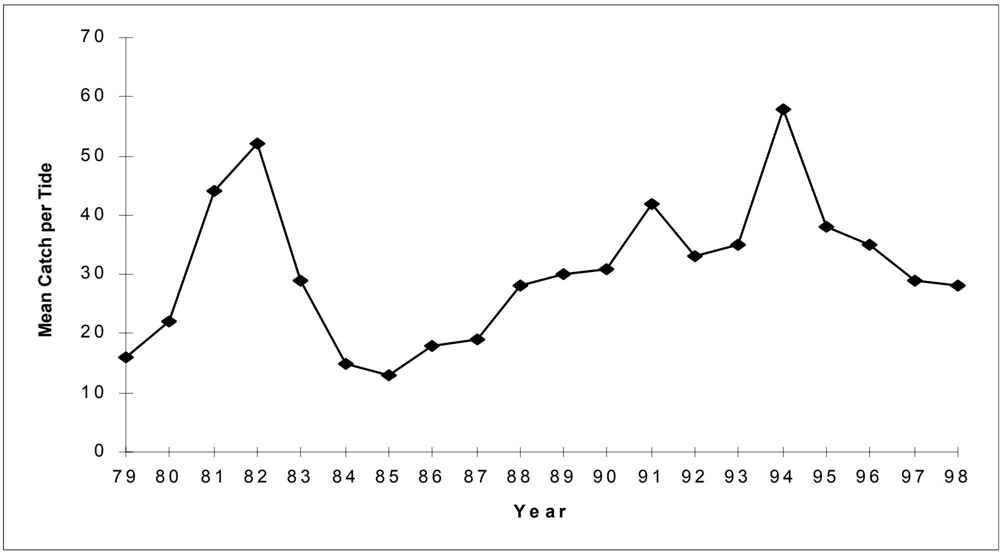


Figure 4.2: The CPUE index of female Alosa fallax fallax from the Severn Estuary (England) between 1979 and 1998.

4.3 Natalaty and Recruitment

4.3.1 Recruitment

Alosa alosa

The relationship between stock and recruitment for *Alosa alosa* from the Gironde-Garonne-Dordogne (France) was found to fit a Ricker curve (Figure 4.3) [Martin-Vandembulcke, 1999]:

$$R = aSe^{-bS} \qquad r^2 = 0.45$$

where:
R = Number of recruits (0+ juvenile in autumn)
S = Parent stock (weight of female stock in kilograms)
a = 99.191
b = 7.717 10^{-6}

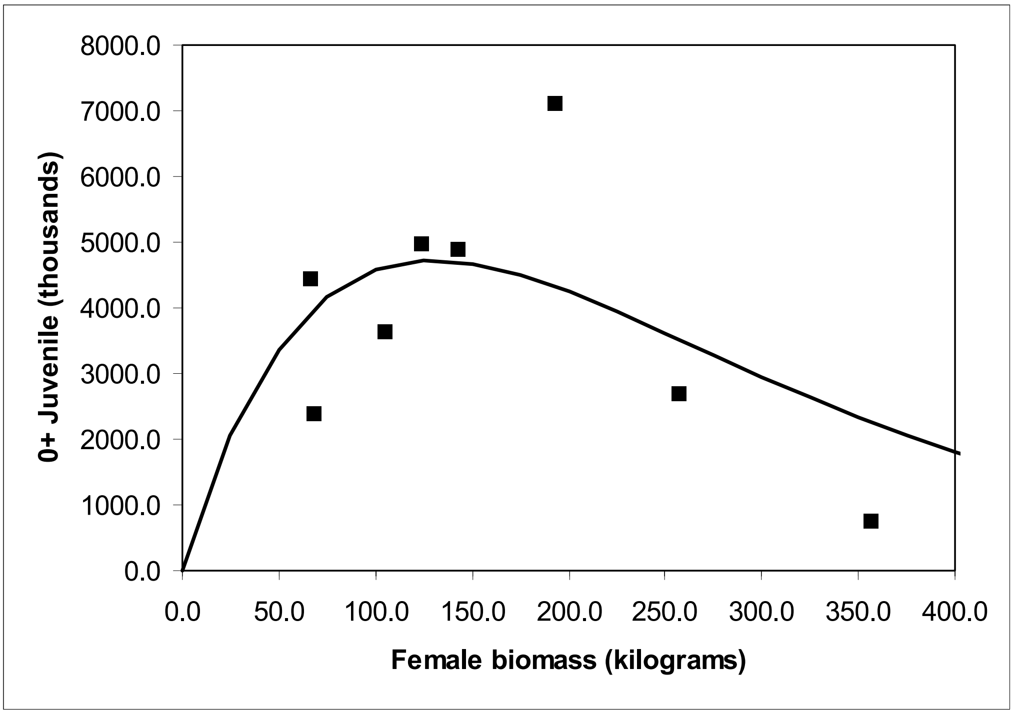


Figure 4.3: The stock recruitment relationship for *Alosa alosa* in the Gironde-Garonne-Dordogne (Martin-Vandembulcke, 1999).

On the Loire (France), Mennesson-Boisneau *et al.* (1999) found recruitment was significantly correlated with flow during the period of upstream migration (March 15th to June 15th), though the relationship is heavily influenced by the flow in one year. The relationship between year-class strength and flow can be described by the equation:

$$\mathrm{YCS} = 0.068e^{(0.0016F)}$$

where:
YCS = year-class strength
F = mean flow (m^3s^{-1}) for the period March 15th to June 15th.

The resultant implication is that in the Loire the population is regulated by the amount of spawning and/or nursery area available. High flows allow the fish to penetrate further up the river system and increase the amount of rearing area available, reducing the level of density dependent mortality.

The coefficient of variation in recruitment for the 1980 to 1992 year-classes was estimated as 124.4%. However, the spawning in 1983 coincided with a 1:100 year flood, which opened up much of the Loire that was usually inaccessible to allis shad for reproduction. If the 1983 year-class was excluded then the coefficient of variation reduced to 55.8%. The level of variation in year-class strength is lower than that from the Gironde-Garonne-Dordogne system of 79.7% for the period 1979 to 1996 (Martin-Vandembulcke, 1999).

Alosa fallax fallax

Drimmelen (1951) observed similar patterns of recruitment in relatively disparate stocks suggesting that large-scale climatic factors might be responsible, particularly flow and temperature.

Variation in recruitment, as measured by the coefficient of variation was estimated for 0+ *Alosa fallax* from the Severn Estuary to be 110.34 % (n = 18; 1981 to 1998) [Henderson & Seaby, 1999]. This compares well with the estimate of 124.45% (n=20; 1972 to 1991) for female *A. fallax* age 6 years old (Aprahamian & Aprahamian, 2001). In the Elbe (Germany), Thiel *et al.* (1996a) observed a coefficient of variation of 118.1% (n=5; 1989 to 1994) for the 0+ age group. Further south in the Gironde (France) the coefficient of variation was lower at 67.0% (n=9; 1979 to 1987) [Taverny *et al.*, 2000b]. However, more recent studies carried out between 1992 and 1999 indicated a higher level of variability with a CV of 113.8% (Taverny, pers. comm.).

Part of this variation can be associated with variation in temperature for example, Holmes & Henderson (1990) reported that good recruitment was associated with warm years. Aprahamian & Aprahamian (2001) found that mean July temperature explained the greatest proportion of the variance (67.1%) in year class strength, followed by August (50.9%) and June (30.9%). Taking the mean temperature for the three month period improved the proportion of variability explained to 77.1% (Figure 4.4)[Aprahamian & Aprahamian, 2001].

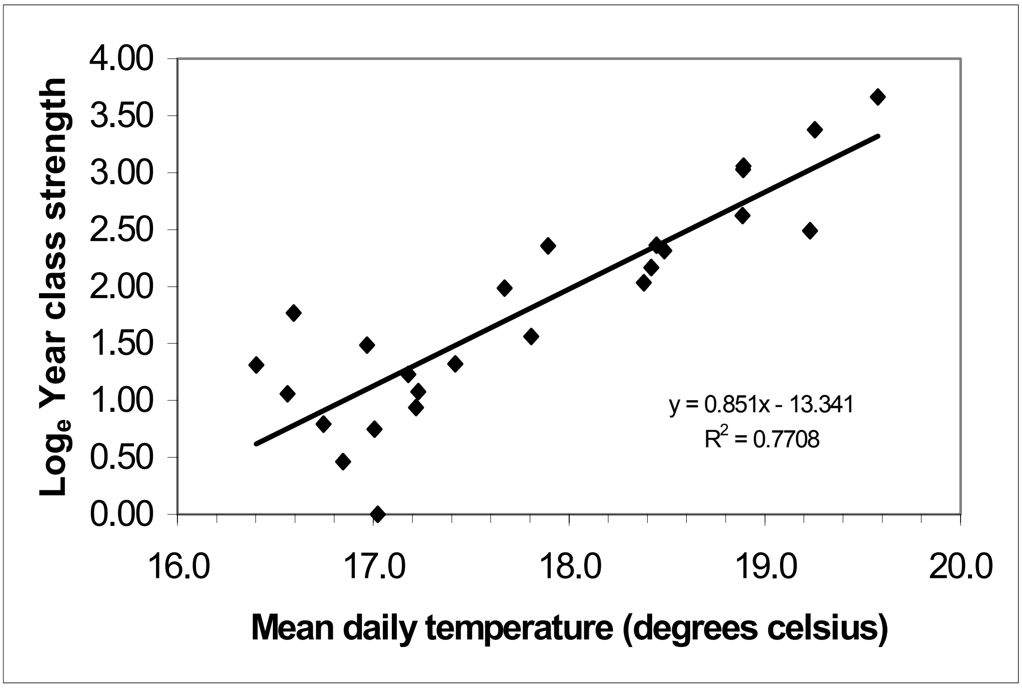


Figure 4.4: The relationship between year class strength of *Alosa fallax fallax* from the Severn Estuary, England between 1972 and 1996 and mean water temperature between June and August inclusive (Aprahamian & Aprahamian, 2001).

River flow was found to be inversely related to year-class strength, though flow and temperature were significantly inversely related ($P<0.05$) during the summer months (June to August). The greatest proportion of the variability (42.3%) was explained by August flows, followed by July flows (36.8%) and June (27.7%) flows. Flows during the main upstream migration period in May were not significantly correlated ($P>0.05$) with year-class strength.

4.4 Mortality and Morbidity

4.4.1 Mortality rates

Alosa alosa

The instantaneous rate of natural mortality (95% CI) for *A. alosa* from the Gironde-Garonne-Dordogne system was estimated to be 0.3528 (0.3527-0.3542) for females and 0.3445 (0.3385-0.3445) for males respectively (Martin-Vandembulcke, 1999). This rate effectively represents the mortality rate of immature fish at sea. Estimates of abundance existing for 0+ fish in the autumn and of adult fish from the same cohort when they mature four to seven years later.

Alosa fallax fallax

The mean (±S.D.) instantaneous mortality rate for adult *Alosa fallax fallax* from the Severn Estuary was 0.58 (± 0.24) for males and 0.49 (± 0.13) for females (Aprahamian, 1988). These rates were not significantly different ($P>0.05$); combining the sexes gave an instantaneous rate of 0.53 (± 0.18). The instantaneous mortality rate for adult female *Alosa fallax fallax* from the Severn was similar to that estimated by Aprahamian & Lester (2001) from the number of fish caught at age 6 in year n and the number of 7 year olds caught in year n+1 of 0.472.

4.5 Dynamics of the Population

No information exists on the total size of the population. Some estimates of the size of the spawning population are available for the Gironde-Garonne-Dordogne system and Aulne (Véron, unpublished).

Alosa alosa

In the Gironde-Garonne-Dordogne system, Martin-Vandembulcke (1999) estimated the size of the spawning population between 1989 and 1996 to range from *c.* 270,000 to 615,000 individuals with a mean of 481,000 individuals (Figure 4.5).

Levels of exploitation have been calculated for *A. alosa* on the Gironde-Garonne-Dordogne (France) by Martin-Vandembulcke (1999) and by Chanseau *et al.* (unpubl.). Percentage exploitation over the period 1987 to 1998 (excluding 1988) ranged from 47.5% to 87.5% with a mean (∀95% CI) of 67.8% (∀8.2%). Annual exploitation rates by age and sex is presented in Table 4.11.

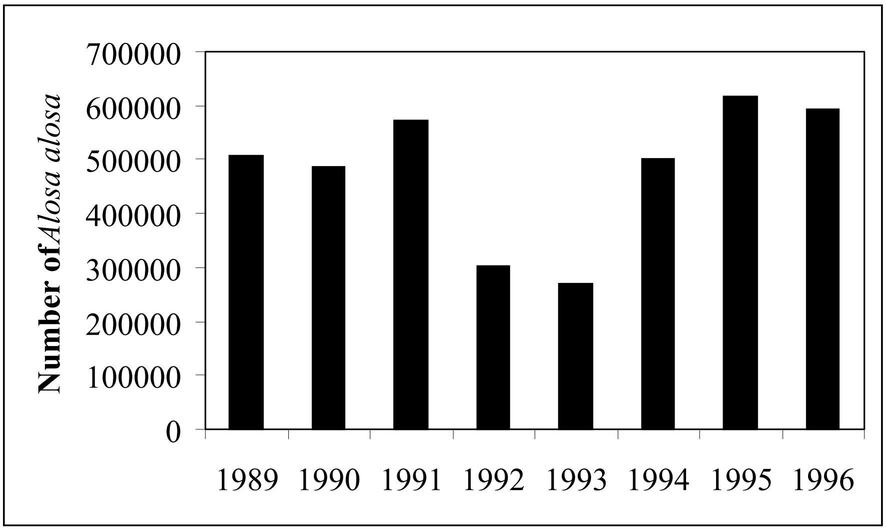


Figure 4.5: Size of the adult population between 1989 and 1996 in the Gironde-Garonne-Dordogne system (Martin-Vandembulcke, 1999).

Table 4.11: Range in the annual level of exploitation of *A. alosa* from the Gironde-Garonne-Dordogne by age and sex (Lambert *et al.*, 2001).

Sex	Age (years)				
	3	4	5	6	7
Female	0.00	0.04-0.13	0.46-0.54	0.39-0.61	1.00
Male	0.00	0.14-0.17	0.50-0.64	0.81-0.92	1.00

In the River Aulne, Véron (unpublished) estimated the size of the spawning population to be 2,182 individuals in 2000.

4.5.1 Production

Alosa fallax fallax

Thiel (2001) estimated production for fish age 0+ and 1+ in the Elbe estuary to be 759.6 g WW ha^{-1} yr^{-1} and 2.0 g WW ha^{-1} yr^{-1}, respectively.

5. EXPLOITATION

Details of the main fishing methods can be found in Elie *et al*. (2000) and Sabatié *et al.* (2002).

5.1 Fishing Equipment

- Stow nets

Stow nets are bag nets where the opening is held open by a frame and the net is kept stretched by the current. They can be staked out in rows fishing adjacent to each other as in the River Weser (Von Brandt, 1972) or fished pelagically either side of a boat as in the Elbe (Figure 5.1) [Thiel *et al*., 1995]. In the Elbe the net has an opening of $90m^2$, a mesh at the cod end of 8 mm and at least one non-return valve (Thiel *et al*., 1995). Eels are the main target species, reflecting the small mesh size, shad being taken as a by-catch.

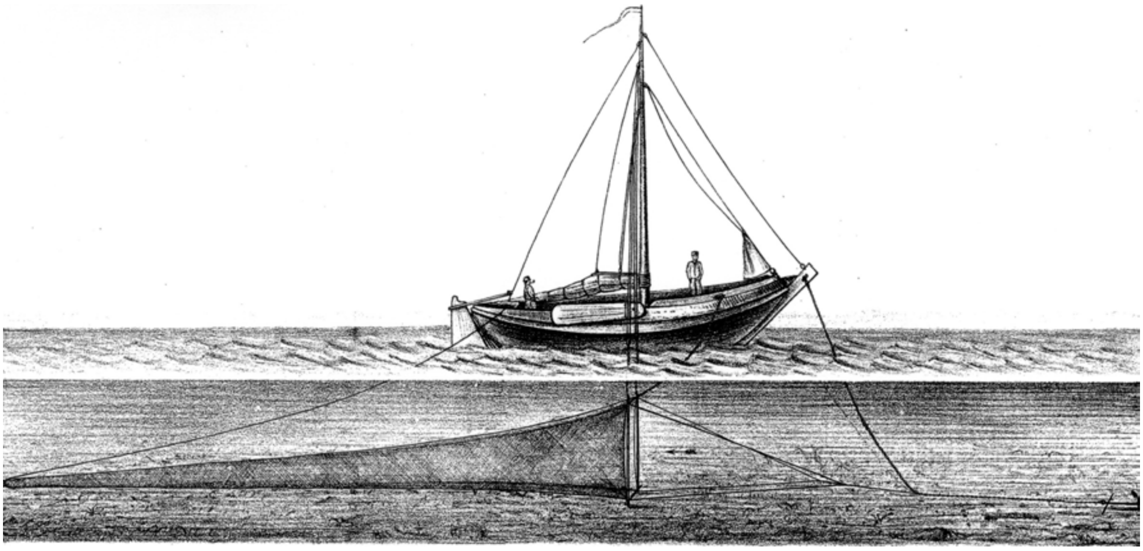


Figure 5.1: A schematic diagram of a stow net being fished (Anon. 1888).

- Putts and Putchers

Putts and putchers are characteristic of the Severn Estuary, England (Figures 5.1 & 5.2). These devices are mainly used for catching salmon and in the case of putts also shrimp. Putts are conical in shape and consist of four parts, the kype, forewheel, butt and bung, they are usually made from closely woven whitethorn or hazel twigs. Putts measure about 2m in diameter at the open end and the whole trap is about 4 m long. Putchers are more coarsely constructed trumpet shaped traps designed solely for taking fish, mainly salmon. Historically they were made from willow or hazel but recently they have been constructed from metal wire. They can vary in size from being round with a diameter of 0.76m at the mouth tapering to 0.07m at the tail, to square being 0.91 x 1.06m at the mouth. Several hundred putchers are supported in a framework on the foreshore, to form a rank or fishing weir, where it will be covered by the tide at high water some of the traps are positioned to fish the ebb tide (more common) and others the flood tide.

The fish swimming with the tide pass through the mouth and become jammed by the head and are soon drowned by the flow of water past the gills.

Figure 5.2: Putts.

Figure 5.3: Putchers.

- "Filet-barrage"

The *filet-barrage* is used on the rivers Loire, Lima and in Morocco, to catch shad as well as salmon and lamprey. In the Loire a net (mesh 110 to 180 mm knot to knot) is installed perpendicular to the bank, held in place by cables and stakes anchored into the bed of the river. A flat-bottomed boat, locally called a *toue*, approximately 9 to 15 m in length supports a fishing net of mesh 40 mm knot to knot (Figure 5.4). The fish are stopped by the larger mesh net, but not gilled. They search along the net until they find the gap, which leads into the smaller mesh net. The fishermen detect when fish are in the net from vibrations felt from thin nylon lines, which run from the base of the net to the fishermen. Once the fish are in the net a counter weight is released and the net raised. The arrangement of the *filet-barrage* in Portugal (River Lima) and Morocco is similar with the exception that in Morocco the large mesh net is set in the form of a "V" with the point facing upstream (Sabatié, 1993). In Morocco the fish are caught in a triangular holding net placed at the end of the "V" while in Portugal the shad are caught downstream of the net using seine nets. In the River Weser shad were caught in fyke nets placed at either end of the net barrier (Schnakenbeck, 1928).

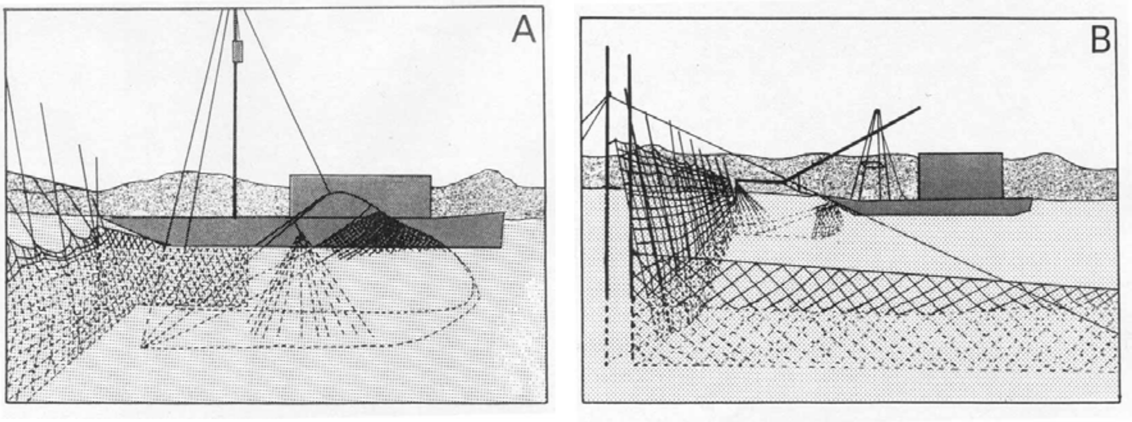


Figure 5.4: A schematic diagram of a *filet-barrage* (A) downstream of Tours and (B) upstream of Tours, from Mennesson-Biosneau & Boisneau (1990).

The *filet-barrage* can be fished either with the net under the boat as is done downstream of Tours on the Loire where the boat is placed adjacent to a bank (Figure 5.4A). Alternatively the net can be fished in front of the boat as is done upstream of Tours, in which case the boat is fished in the middle of the barrage (Figure 5.4B).

There are a number of regulations imposed on the fishery in the Loire;

- no fishing from two hours before sunset to two hours before sunrise,
- no fishing between 1800 h on Saturday and 0600 h on Monday,
- no fishing after June 15th.

- Fishing wheel / "baro" (or "vire-Blanchard" on the lower Rhône)

The "baro" is a stationary fishery which is carefully positioned on a channel or installed on a landing stage, boat or raft which is solidly attached to the river bank (Figure 5.5). The gear consists of two rectangular shaped nets made of regular or metal netting, attached to a horizontal axis and equipped with a funnel positioned towards the interior axis. The "baro" is driven by the current, so that the nets turn like the vanes of a windmill. The immersed rotating nets effectively scoop up fish moving upstream, the fish are then lifted out of the water and slide through the spout into the holding tank.

This automatic fishing gear was used to catch shad, salmon and lamprey. Today it is presently used on the lower Rhône where it is known as "vire-Blanchard" (Rameye *et al.*, 1976). It has almost disappeared from most of the larger rivers; Loire, Garonne and Adour in France and the Tiber in Italy where they were locally known as “giornelli” or “girarelli” (Von Brandt, 1972).

Figure 5.5: Fishing wheel / "baro" (from Baglinière & Elie, 2000)**.**

- The square dip net

This type of fishing gear is mainly used by amateur fishermen on the lower Rhône, downstream of Beaucaire-Vallabrègues where it is known as "Le carrelet" (Figure 5.6) [Rameye *et al*., 1976]. The fishing gear can be loaded onto a boat or raft or installed on the bank. The net, with a mesh size of between 30-40 mm, is stretched on a metal frame (4m x 4m) and suspended under a pole to which a pulley is attached. Lowered to a depth of two meters, it is regularly raised up by a hand winch. Larger tipping square dip nets are used, either in association with or independent of stop nets, in strong currents.

Figure 5.6: "Le carrelet" (from Baglinière & Elie, 2000)**.**

- "Globe-net" fishing

The "globe-net" is a stationary Mediterranean-type fishing gear found, in the Languedoc region of France. It consists of a large rectangular net with fine mesh (15-20 mm), which is lowered to the bottom across a waterway and regularly lifted by means of complex mechanical devices, operated either by hand or automatically, and which require considerable skill. Several of these fisheries exist on the canals and streams draining into the lower reaches of the Rhône and the Aude Rivers.

- Stopping boats

The stopping boat is characteristic of the Severn and Wye estuaries (Figure 5.7), but few remain today. They are wide-beamed stoutly built boats up to 7m in length with a shallow draft. They are moored at right angles to the tide, attached to a cable and generally fish the ebb tide. A "V" shaped bag net is attached to poles about 6.7m in length and with a gape of 9.75m when open and suspended below the boat. Taut cords ("babbling lines") run to various parts of the nets so that a fish striking the nets can be easily detected. The whole structure is very finally balanced with a counterweight, which is used to lift the net above the water surface once a fish has been detected.

Figure 5.7: Stopping boats in the Severn Estuary.

During the floods on the Loire River, a barge ("toue") is placed in a counter-current and the dip net, without a stop net, is directed downstream. The migrating fish, which let themselves be carried along by the counter-current in an upstream direction, brush against the nylon lines held by the fisherman who then raises the net.

- Seine nets

Seine nets are used in the Severn Estuary, in the Garonne and Dordogne (Figure 5.8) and in the past in the Elbe. In the Severn the nets measure 160m in length with a depth at the centre of 1.9 m and a mesh size of 50 mm knot to knot. The net is selective catching *A.fallax* in the length (L_f) range ≥ 300 mm.

Figure 5.8: Seine netting for *Alosa alosa* in the lower Garonne (from Baglinière & Elie, 2000)**.**

- Trammel and drift nets

The nets can be either fixed as in the Rhône and Charente or attached to a boat, which drifts for several kilometres with the tide as in the Gironde and in the Bristol Channel. The nets used are either multi or monofilament gill nets or trammel nets. They can vary from 30 to 1000 m long, 2 to 15 m deep and with mesh between 40 to 110 mm dependent on local regulations. The size of the net are adapted to the depths encountered and the types of fish targeted.

In the Gironde-Garonne-Dordogne the mesh of the central sheet of the trammel net ranges from 45 to 60 mm (Rochard, 1985) and the selectivity curve for the net has been reported by Martin (1995). The mesh size used in other river systems is as follows: 55 mm in the Adour (Prouzet *et al*., 1994c), >60 mm in the Rhône (Changeux & Zylberbat, 1993a), 80 mm in the Tage and 100 mm in other Portuguese rivers (Elie *et al*., 2000). The mesh of the outer net can vary from 220mm (Rameye *et al*., 1976) to 400 mm (Rochard & Castelnaud, 1986). In the Bristol Channel a single net of mesh 50 mm is used which catches *A. fallax* >330 mm (L_f).

Experimental netting carried out by Ruchon *et al*. (1994) on th Rhône provides some estimate of gear selectivity for *Alosa fallax rhodanensis*. A Mesh of 40 mm caught *A. fallax rhodanensis* ranging in size from 350 to 600 mm (L_t) while a 60 mm mesh caught fish between 410 and 620 mm. The smaller mesh net caught mostly males (61%) while females predominated (89%) in the 60 mm net. In the Bristol Channel a single net of mesh 50 mm is used which catches *A. fallax* >330mm (L_f).

- Landing net fishing.

This technique uses a large landing net (80 cm in diameter; 40 mm monofilament or braided mesh, depending on local regulations) with a long handle which is operated manually in currents where shad congregate. In the River Wye, Wales, the *Clinching net* was triangular in shape approximately 1.8 m wide at the base, the net measured 1.8 m in length with mesh of between 38 to 50 mm. The net was attached to a handle of between 1.8 and 2.1 m in length.

On the Severn Estuary triangular nets with a mesh of 50 mm called a *Lave net* (Figure 5.9) are used to catch shad but the nets are mainly used for catching salmon. The net is suspended from a collapsible Y shaped frame about 2.5m high and with a gape of about 3m. A lave net can either be fished passively waiting for the fish to swim into the net or actively which depends on the fishermen seeing the wake of a fish and running towards it and scooping it up.

- Angling

Recreational fishing of shad with a rod is widely practised in the British Isles, but is a recent phenomenon in France particularly in the rivers Charente, Garonne and Rhône as well as in a number of the small rivers. Fishermen either use a light fishing rod and small rubber sandeels, or small white or golden coloured fly spoons fitted with a single hook (mepps) or lures or spinners that are retrieved slowly using jerky movements in fast currents. It is also possible to catch them using a taut line with two or three leaders, each one equipped with a spinner. Shad can also be caught with a fly rod for which it is necessary to use a sinking line and a large nymph covered with bright colours so that it sparkles. The hooks need to be needle sharp as shad have a hard and bony mouth and unless sharp a high percentage of hooked fish will be lost.

Figure 5.9: A fishermen with lave net, from the Severn Estuary.

5.2 Fishing Areas

Today the main fishing area for *Alosa alosa* and *Alosa fallax fallax* is in the Gironde-Garonne-Dordogne system in France and in Lake Garda (Italy) for the landlocked sub-species, *Alosa fallax lacustris* (see section 5.4).

5.3 Fishing Seasons

For the anadromous populations the main fishing season is associated with the commencement of the freshwater phase of their spawning migration (section 3.5.1). The migration / fishing season starting earlier in the year for populations at the southern limit of their range, becoming later with increasing latitude (table 3.85 and 3.86). For example, in France, where there are no restrictions as to when fishing for *Alosa* spp. can occur, the main season for fishing in the Loire is between March 15th and June 15th. While in the Gironde estuary the season is from February 1st to June 30th extending up until July15th for fishing in the freshwater reaches of the Garonne and Dordogne. In Portugal the legal season for fishing runs from February 1st to June 15th.

5.4 Fishing Operations and Results

Shad are essentially harvested by commercial fisheries over their current distribution area. They can be fished in an estuary or in the mid sections of rivers for anadromous form, or in lakes for resident form. The fish are generally caught when they migrate from their feeding areas towards their spawning grounds. A few catches are recorded at sea or along the coast. As a general characteristic, commercial fisheries are not targeted at allis shad as Atlantic salmon, sea trout, eel (glass and adult), river and marine lampreys and twaite shad are caught according to the country, the geographical position and the fisheries regulations. Also sport fishing for *Alosa alosa* has recently developed in France mainly in the Charente river and the Gironde-Garonne-Dordogne System and in England and Wales for *Alosa fallax*.

Shad are marketed for human consumption, either fresh, frozen or smoked. Shad are a traditional dish in Portugal and Morocco (Baglinière & Elie, 2000). In France, this tradition has always been very localized in the past (Lacépède, 1803) and is even more localized today, mainly in the south-west of France, and their quality has been praised for a long time (Rondelet, 1558; Quatrefages, 1849).

Alosa alosa

The FAO reports on fishing statistics present nominal catches of shad. Indeed, these data either underestimate or overestimate the catch and do not make the distinction between the two species of eastern Atlantic shad. It is therefore more reliable to present data derived from local fishery surveys. However, data are only available for a few river systems and no angling catch data are recorded.

From 1978 to 1999, approximate total landings ranged from 357 to 1,198 tonnes in their current distribution area (Figure 5.10). On average 72.5 % and 98.7 % of the total landings come from France and the Gironde-Garonne-Dordogne system respectively. In this watershed catches range from 338 to 1007 tonnes and are much higher when compared to other rivers. In the Gironde-Garonne-Dordogne system part of the decline in catch may relate to the decline in effort which has decreased steadily since 1984 (Castlenaud *et al*. (2001).

In France, catches in Loire River are low, do not often exceed 10 t and have decreased to about 1t in 1995 and 1996. Average annual catches in the River Adour are approximately 19 tonnes between 1985 and 1999. Catches at sea catches have been recorded off the Aquitaine coasts and exceed the total catch from all French rivers, except from the Gironde system, between 1994 and 1999.

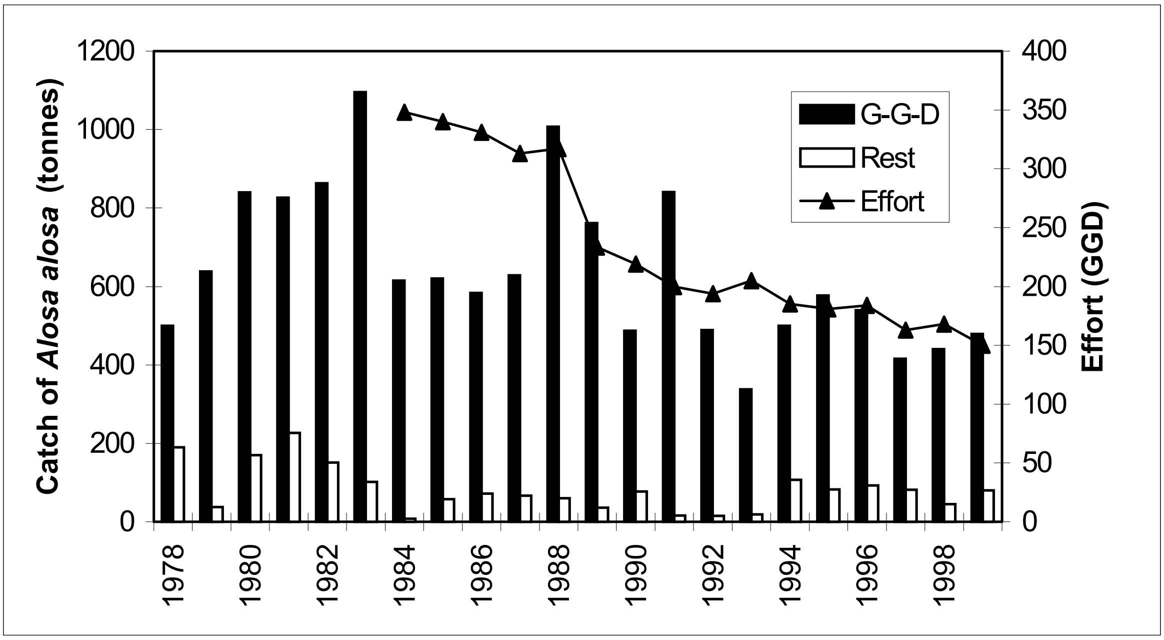


Figure 5.10: Total landings of *Alosa alosa* from 1978 – 1999 and effort data from the Gironde-Garonne-Dordogne system. Solid area indicates catches from the Gironde-Garonne-Dordogne system and clear area represents the combined catches from other river systems and at sea, data from Baglinière *et al.* (2002) and Castelnaud *et al.*, (2001).

In Portugal, the total catch is small and comes mainly from small rivers such as the Lima where the catch was abundant at the beginning of the 1990's, 2 to 10 tonnes annually, but has recently decreased markedly (1998). The fishery ceased operating in 1999. In the Sebou Wadi (Morocco) which was the main and last river to support an important allis shad fishery in Africa, the total catch has fallen over a 25 year period from 846 t in 1968 to 2 t in 1993 (Figure 2.7).

In France, during the 1989-1997 period, shad landings, of which 98% were of *A. alosa*, were the highest production of anadromous fish and agnathans (33.1 % of the total production) with a turn–over of 1.3 million euros (Baglinière *et al*., 2002). In 1997, 280 commercial fishermen were recorded fishing for allis shad; equivalent to 19.8 % of the total number of fishermen (Castelnaud, 2000).

Alosa fallax fallax.

Assessing the economic importance of *A. fallax fallax* is complicated by the fact that the *Alosa* catch is not separated by species and the majority of the catch is of *A. alosa* (Baglinière *et al.* 2002). In some countries notably Germany *A. fallax fallax* has been of considerable economic importance with catches in the Lower Rhine in the late 1930s exceeding a million fish per year (de Groot, 1989). Their importance increasing with the decline in the population of *Alosa alosa*. Similarly in the North Sea catches between 1910 – 1914 and from 1915 – 1919 averaged 900 and 200 tonne per year, respectively and that in the Baltic Sea were 2,100 and 1,700 tonnes per year respectively

(Svetovidov 1952). In the Nyamunas river the average catch for the periods 1930-4; 1935-47; 1948-52 and 1953-57 were 16,100 kg, 28,500 kg, 29,800 kg and 2,200 kg, respectively (Manyukas 1989). After 1960 the fishery ceased. In the Seine the annual catch at the end of the nineteenth century ranged from 7,490 to 32,869 kg y^{-1} (Vincent 1894b). In the River Elbe the reported catch (five year mean) between 1886 and 1919 ranged from 11 to 83 t y^{-1}, mostly sold in the Rhine area following the collapse of it's *A. alosa* fishery at the start of the 19th century (Möller, 1989). Today *A. fallax* is no longer acceptable to consumers. In the River Weser shads represented between 10 and 15% of the catch during the period between 1891 to 1930, after which their contribution was negligible (Busch *et al*., 1988).

In the Sebou, prior to the construction of the barrage at Idress ler annual landings of *Alosa fallax* ranged from 15 to 79 tonnes after which, the catches declined markedly and show a similar trend to that of *Alosa alosa* (Figure 2.8) [Sabatié, 1993].

Currently the best estimates of their importance for various rivers systems is shown in Table 5.1 (Baglinière *et al.* 2001). The major fishery is on the Gironde-Garonne-Dordogne system with an estimated annual catch of between 13 and 15 tonnes per year. Prior to 1989 the annual catch was higher at between 60 and 192 tonnes with a value ranging from 46,000 to 229,000 euros (Castelnaud *et al*., 2001). The fishery on the Severn was very much a by-catch to the salmon (*Salmo salar*) fishery and in most cases the fish are discarded. The catch after 1999 is insignificant as the start of the fishing season changed from April 15th to June 1st, by which time the majority of the fish had migrated from the estuary into the river. In France, a small marine fishery exists for *A. fallax fallax* with the declared annual catch from 1994 to 1999 of between 1.2 to 3.6 tonnes per year.

Table 5.1: Annual catch (tonnes) of *Alosa fallax fallax* from various river systems.

River	Annual catch (tonnes)
Severn (England)	5-6 (prior to 1999) - Insignificant after 1999
Loire (France)	0.6-2
Dordogne & Garonne (France)	13-15
Lima (Portugal)	0.5-1.5
Tage (Portugal)	Insignificant
Guadiana (Portugal)	Insignificant
Sebou (Morocco)	0.2-0.6

Alosa fallax rhodanensis

Prior to the construction of the Donzère Mondragon in 1952 a fishery for *Alosa fallax rhodanensis* existed in the upper Rhône, with an estimated annual catch of 50 kgy^{-1} in the Rhône and 5 kgy^{-1} in the Ain (Tripier, 1903 (cited by Bravard, 1985)). Estimates for various sections have been provided for the lower Rhône by Pattée (1988). In the section of river between Lyon and Serrières (58 km) 15,000 shad were caught in 1944, between Serrières and the Ardèche confluence (133 km) 6,010 were caught in 1926 and between the Ardèche confluence and Arles (89 km) 13,000 were captured in 1937. If these are taken as annual averages then this represents a total catch by both legal (professional and amateur fisherman) and illegal (poaching) means of 34,000 individuals. For the whole river upstream of Arles, Gallois (1950) reported a total catch of 53 tonnes for 1927. In the Petit Rhône estuary at the end of the 19th century annual catches ranged from 2,300 kg to 6,400 kg (1890-1895) [Gourret, 1897].

In 1974 the year of the construction of the most downstream barrier at Vallabrègues situated 58 km from the sea 23 t were caught (Rameye, *et al.*, 1976). More recently catches have declined being estimated at 6.3 t in 1988 and 1989 (Changeux & Zylberblat, 1993b) and 8.3 t in 1997 (Lebel *et al.*, 1997). Barral (2001) reported the total average catch in 1997, 1998 and 2000 (in 1999 there was no estimate of the catch taken by amateur fishermen) was 11.3 t yr^{-1} with 50.2% being taken by recreational (rod and line) anglers, 29.5% by professional and 20.3% by amateur fishermen.

Alosa fallax lacustris

The trend in catch of *Alosa fallax lacustris* in lakes Maggiore and Garda are shown in Figure 5.11. In Lake Garda the annual catch appears to have stabilised at between 150 and 200 tons. In Lake Como, between 1996 and 1999, approximately 30 tons are caught per year, with catches ranging from 19 to 39 tons (Negri, pers. comm. cited by Bianco, pers. comm.).

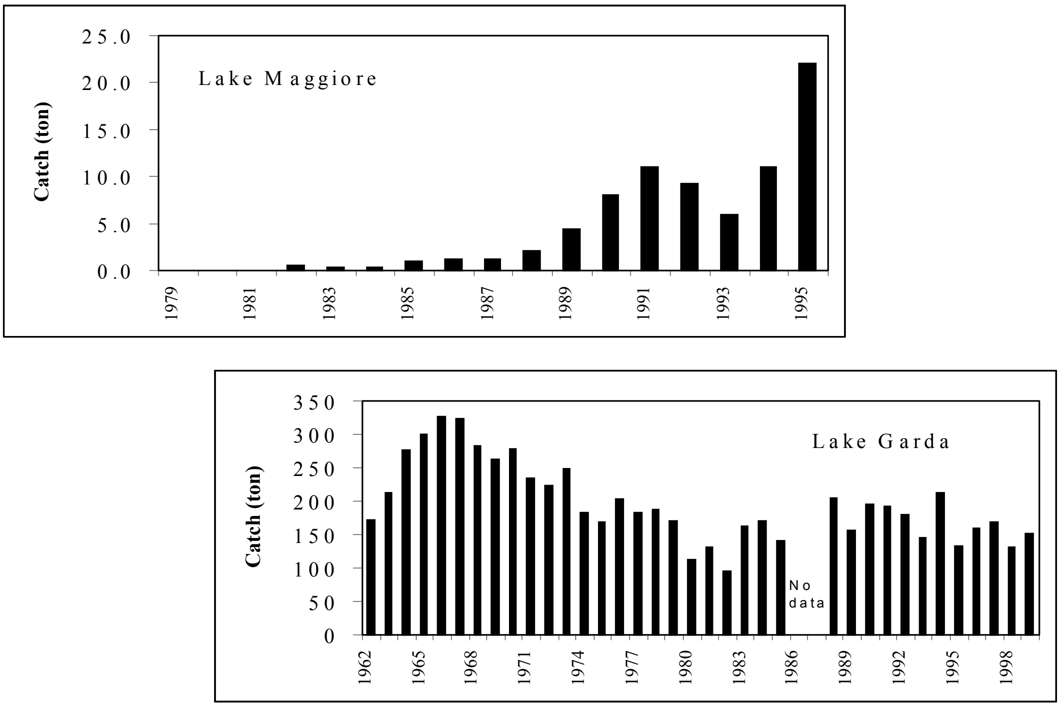


Figure 5.11: Catch of *Alosa fallax lacustris* from lakes Maggiore (Grimaldi, 1997) and Garda (Novello & Oppi, 1985; Confortini, 1998; pers. comm.), from Bianco (2002).

Alosa fallax nilotica

Catches prior to the construction of the dam on the River Bojana in 1960 ranged from 6 to 81 tons per year after which catches declined markedly such that today relatively few are taken (Figure 2.12).

5.5 Climate Influences

The influence of temperature and flow on recruitment is dealt with in section 4.3, Natalaty and recruitment.

Alosa fallax fallax

The possibility that large scale environmental factors may act on quite disparate populations in a similar way was postulated by Drimmelen (1951) who observed similar patterns of recruitment in *Alosa fallax* suggesting that large-scale climatic factors might be responsible, particularly flow and temperature. Certainly a similar pattern of recruitment exists in the Severn and Elbe (Aprahamian & Aprahamian, 2001) with higher recruitment in 1989 and 1990 compared with the period 1991-1994 (Figure 5.12). Alternatively, Thiel *et al.* (1996b) concluded that the lower catches of juvenile *A. fallax* between 1991 and 1993 compared with 1989 and 1990 were the result of a change in spawning area as a consequence of an improvement in water quality in 1991(see section 6.2.2). It was suggested that the lower abundance of juveniles in the period after 1991 was due to the higher level of power station mortality because the adults had moved 20 km upstream, and thus closer to Stade power station, to spawn.

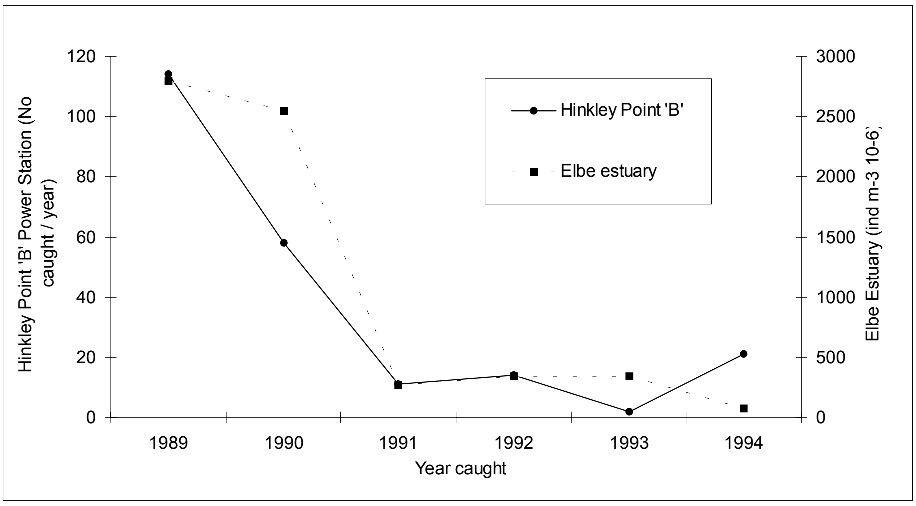


Figure 5.12: The number of juvenile (age 0+) *Alosa fallax* from the Bristol Channel, at Hinkley Point 'B' Power Station and from the Elbe Estuary between 1989 and 1994 (Aprahamian & Aprahamian, 2001).

The summer weather pattern in England is strongly influenced by the position of the north wall of the Gulf Stream (Willis *et al.*, 1995). If large-scale global weather patterns are impacting on the population then any change in its position should manifest itself in terms of a change in recruitment, with higher recruitment the further north the north wall is positioned. Aprahamian & Aprahamian (2001) suggested there might be (Figure 5.13). The two outliers (1976 and 1989) corresponded to two very hot summers and, if the relationship is true then, it is likely that local meteorological conditions overrode the wider global weather pattern.

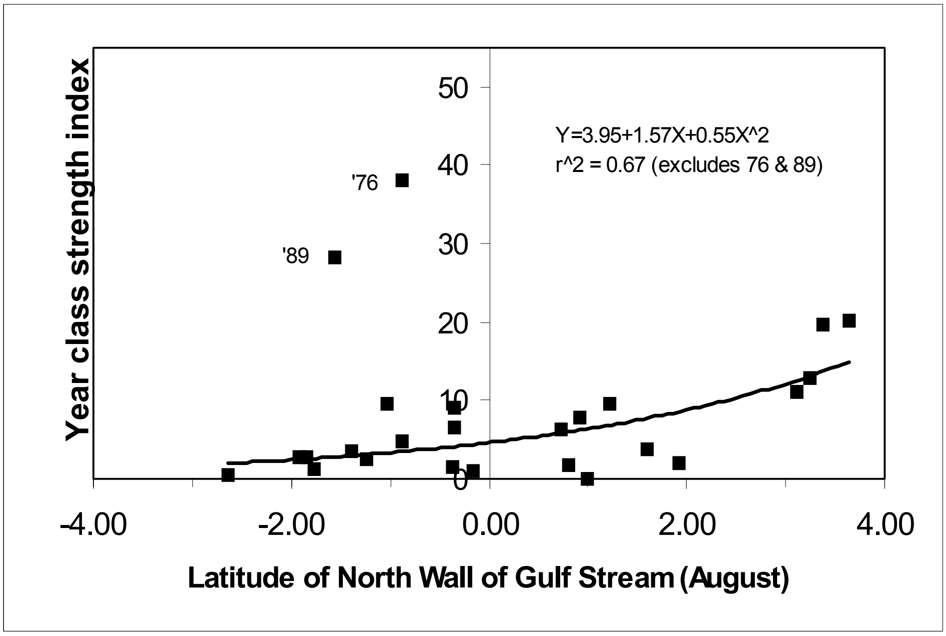


Figure 5.13: The relationship between year-class strength of *Alosa fallax* from the Severn Estuary and the position of the North Wall of the Gulf Stream (First principal component of the position of the North wall of the Gulf Stream), August 1976 and 1989 year-classes marked (Data from A. H. Taylor; http://www.pml.ac.uk/gulfstream/ inetdat.htm), from Aprahamian & Aprahamian, 2001.

6. PROTECTION AND MANAGEMENT

There has been a considerable decline in abundance of *Alosa* spp. throughout their geographic range (see section 2, Distribution), but also Keith *et al.* (1992) specifically for France. It is for this reason that the species have been included in Appendix III of the Bern Convention (Anon., 1982) and into Annexes II and V of the EC Habitats Directive. The main reason for this decline has been the construction of dams preventing access to their spawning grounds (see section 2). In some river systems this has resulted in the extinction of one and / or both species of *Alosa*. Examples include the loss of *Alosa alosa* from the Severn (Aprahamian & Aprahamian, 1990), *Alosa fallax rhodanensis* from the Tiber (Bianco, 2002) and both species *A. alosa* and *A. fallax* from the Rhine (de Groot, 1989; Raat, 2001). The effect of barriers may have been exacerbated by overfishing as fish congregate and become easier to capture below obstructions. Such a situation may well have developed on the Rhine (see Figure 2.3). Pollution (poor water quality), especially in the lower reaches and estuaries has also been identified as a threat. For example in the Baltic Sea region (Repečka, 1999), Thames (Aprahamian & Aprahamian, 1990), Weser (Busch *et al.*, 1988, 1989) and in the Sebou (Sabatié, 1993) as well as for some of the landlocked population such as *Alosa fallax lacustris* in Lake Maggiore (Grimaldi, 1997). Habitat destruction has also been implicated for their decline. This can occur as part of a reengineering scheme to improve navigation and for flood defence purposes as on the Rhine (de Groot, 1989; Raat, 2001), or as a consequence of gravel extraction effectively impacting on the species spawning habitat (Taverny *et al.*, 2000a).

The conservation options available for the protection and enhancement of *Alosa* populations has been reviewed by Maitland & Lyle (1992, 1993) and by Maitland (1994). Generic guidelines for the protection of endangered species have been described by Costello *et al.* (2002). These include unhindered access to their spawning grounds where this is not possible, their migration being blocked by a physical barrier, then the obstruction must support an effective and efficient fish pass. Similarly there should not be a water quality barrier preventing access to their spawning areas and no siltation of their spawning grounds (see section 3.1.7.1).

6.1 Conservation Status

Populations of *Alosa* have declined throughout their range and in many instances have become extinct, mainly through the construction of barriers, pollution and over fishing (Section 2). The rare and threatened status of *Alosa alosa* and *Alosa fallax* spp. (Table 6.1) is reflected in their occurrence on nationally and internationally based protective legislative schedules. However, in some cases there is some uncertainty over the species actual conservation status. For example in Spain both species were classified as "endangered" by Elvira (1997) while Blanco & Gonzalez (1992) and Elvira (1996) categorised them as "vulnerable". Similarly for *Alosa fallax* from Germany the species is classified as "vulnerable" by Freyhof (2002) and as "endangered" by Nowak *et al.* (1994).

Figure 6.1: Location of Special Areas of Conservation (SAC) or Sites of Community Interest (SCI) under the EC Habitats Directive, for *Alosa alosa.* Where a number of sites on a particular river have been designated the whole river has been included for clarity. The individual sites are presented in Appendix 1.

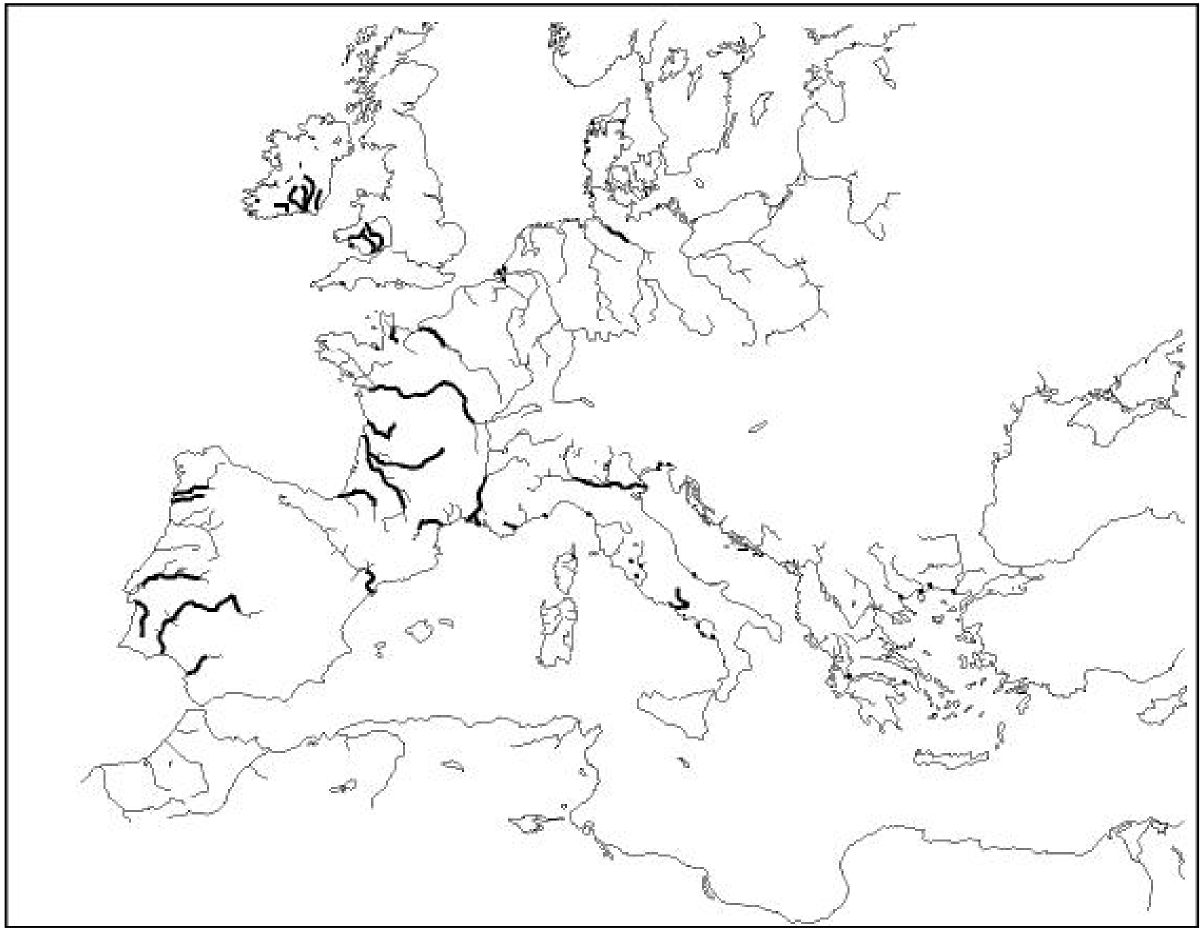


Figure 6.2: Location of Special Areas of Conservation (SAC) or Sites of Community Interest (SCI) under the EC Habitats Directive, for *Alosa fallax* spp. Where a number of sites on a particular river have been designated the whole river has been included for clarity. The individual sites are presented in Appendix 2.

Table 6.1: Conservation status of *Alosa alosa* and *Alosa fallax* spp., data from P. Maitland (pers. comm.) unless otherwise stated.

Conservation status (IUCN, 1990)	*Alosa alosa*	*Alosa fallax fallax*	*Alosa fallax nilotica*
Extinct 'when there is no reasonable doubt that the last individual has died'	Poland[11] Luxembourg Czech Republic[1]	**Luxembourg** Netherlands	
Critically Endangered 'when it is facing an extremely high risk of extinction in the wild in the immediate future'	Denmark	Denmark	
Endangered 'when it is not critically endangered but is facing an extremely high risk of extinction in the wild in the near future'	Germany[9] Ireland[2] Spain[5] Netherlands Belgium[13] UK	Lithuania[10] Poland[11] Spain[5] **Belgium[13]**	Croatia[6] Montenegro[6] Albania[7]
Vulnerable 'when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future'	France[3] Portugal[4]	France[3] Portugal[4] Ireland[2] UK Germany[9]	Italy[8]
Not Evaluated 'when it has not been assessed against the criteria'	Finland	Finland	
Absent from red data book or equivalent	Austria Greece Italy	Austria	
Data Deficient	Sweden[12]	Sweden[12]	

[1] Lusk (1996); [2] Whilde (1993); [3] Keith *et al.* (1992); Keith & Allardi (1996); [4] SNPRCN (1991); [5] Elvira (1997); [6] Mrakovcic *et al.* (1995); [7] Rakaj & Flloko (1995); [8] Bianco (1998); [9] Freyhof (2002); [10] Balevičiene, *et al.* (1992); [11] Skora (1996); [12] Kullander (2002); [13] Vandelannote & Coeck (1998).

Alosa alosa and *Alosa fallax* are both included in Appendix III of the Bern Convention (Anon., 1982) which requires member states to carry out provisions to ensure conservation of flora and fauna and their habitats with particular attention to endangered and vulnerable species, including migratory species. Both species are incorporated into Annexes II and V of the EC Habitats Directive (EC Directive on the conservation of natural habitats and wild flora (92/43/EEC)). This places an obligation of members of the European Union to assess numbers and exploitation of the populations and to designate Special Areas for Conservation (SAC) / Sites of Community Interest (SCI) to safeguard populations (Figures 6.1 & 6.2). The individual sites are listed in Appendix 1 and 2 for *Alosa alosa* and *Alosa fallax* spp. respectively.

6.2 Habitat Protection and Management

6.2.1 Physical habitat

Other than maintaining access to their spawning grounds (see section 6.3) and safe passage for the juveniles on their out-migration (Travade & Larinier, 1992a), the other main habitat features that need to be maintained are:

Deep pools where the adults can congregate prior to spawning (see section 3.1.7.1).
Silt free spawning gravels to ensure that the eggs do not suffocate (see section 3.1.7.1).
Areas of reduced current / backwaters as these are the preferred habitat of the juveniles in fresh and estuarine waters (see section 3.2.2).

Particularly sites (sanctuary areas) important for the persistence of the population can be given special protection. For example on the River Garonne at Agen (France) a sanctuary for *Alosa alosa* was created by Ministry decree on May 15th 1981. The site measures 4.78 km^2 and is one of the main spawning areas on the river. Prior to 1981 the size of the spawning ground was decreasing because of gravel extraction. The effect of the decree is to ban exploitation of the species, any flood defence works and gravel extraction in the area.

For *Alosa fallax fallax* a sanctuary area exists on the River Garonne at Tartifume (France).

6.2.2 Water quality

Barriers to migration can be created as a result of poor water quality in particular low levels of dissolved oxygen. In estuaries this can arise naturally in the upper estuary where re-suspension of the sediment is maximised causing a sag in dissolved oxygen, this condition can be exacerbated by input of organic matter from domestic sewage and industry causing a water quality barrier (Pomfret *et al.*, 1991). Such a barrier was perceived to exist in the Elbe estuary (Germany). The improvement in water quality after 1991 (Gerkens & Thiel, 2001) was considered to be the main reason why *Alosa fallax* currently migrate a further 20 km upstream to spawn (Costa *et al.*, 2002) compared to the situation in the 1960s (Hass, 1968) and 1980s (Möller & Dieckwisch, 1991).

At present there is little information that can be used to derive a water quality standard which will safeguard shad in estuaries. However, the study by Möller & Scholz (1991) on juvenile *Alosa fallax* suggests a dissolved oxygen level of >4 mgL^{-1} (section 3.2.2) would protect shad.

6.3 Fish Passes

The construction of physical barriers, preventing the adult fish reaching their spawning grounds, has been one of the main reasons for the decline of *Alosa* populations throughout Europe, see section 2. Differences between upstream and downstream water level of ~1m and especially if the flows are plunging will create a barrier to shad

(Larinier & Travade, 1992a; 2002a). Fish passes designed for salmonids are not altogether suitable for shad because passes are generally characterised by turbulent flow patterns, whereas shad prefer smooth, laminar flow. The swimming capability of shad is summarised in section 3.5.2 and flows in excess of 3.5 to 4 ms^{-1} will generate difficulties for *Alosa* spp. (Larinier & Travade, 1992a; 2002a).

Fish passes for shad, mainly *Alosa alosa* and *Alosa fallax rhodanensis*, have been described by Larinier *et al.* (1978), Larinier (1983), Vialle (1987), Baril (1988), Larinier & Travade (1992a, 2002a), Travade *et al.* (1992) and Travade *et al.* (1998).

Larinier & Travade (1992a; 2002a) have outlined some of the requirements, which are necessary to ensure effective passage for shad. Shad are a shoaling species, which swim close to the surface and tend to bypass obstructions by swimming rather than leaping. As such, flow should be "streaming" as opposed to "plunging". The species are sensitive to changes in flow direction, therefore unidirectional flow running parallel is required in a shad pass. Where there is a change in flow direction the fish can get trapped in the currents and in some cases the whole shoal may drop back downstream. In addition shad appear sensitive to sudden changes in light intensity, therefore it may be necessary to light particular sections in a fish pass. The entrance to the pass must be situated along the bank and the velocity at the entrance of the pass should be about 2 ms^{-1}.

6.3.1 Pool passes

Pool type passes have been shown to be effective for passing shad, however, there have been few studies on their efficiency. For the Ramier pool pass (R. Garonne, France) the efficiency was estimated at 70% (Dartiguelongue, 1990). This was regarded as high and considered to be the result of favourable hydrological conditions (low flows) making the pass more attractive in that particular year (Larinier & Travade, 1992a). On the Dordogne (France) the annual efficiency of the pool pass at Mauzac varied between 6 and 56%, the variation being largely dependent on flow conditions during the migration period (Larinier & Travade, 2002a).

Pool passes (Figure 6.3) must meet the following requirements:

- Drop between pools should not exceed 0.30m, preferably lower, between 0.20 and 0.25m.
- Flow should be "streaming" as opposed to "plunging".
- Gaps or slots must have a minimum width of 0.45 to 0.50m and must be along the wall. Central gaps must be avoided. There must be no submerged orifices.
- Large recirculation eddies must be avoided.
- Pools must be at least 1.20m deep, have a volume in excess of 12m^3 and have a maximum mean power dissipation of 150 watts m^{-3}.

6.3.2 Baffled passes

Studies carried out in France indicate that Denil fish passes have not proved suitable for passing shad. This is the case for two passes in France, at Beaucaire on the Rhône and at Bazacle on the Garonne. The pass at Beaucaire has two Denil flights, flat baffles, gradients of 8% and 10% and measures 1.30m wide with an overall length of 40m

(CTGREF, 1981). The pass at Bazacle has three Denil flights, broad arrow-shaded baffles, a gradient of 17% and measures 1.50m wide by 12m long. Poor performance in the Beaucaire pass is attributed to the hydraulic conditions in the fish pass, and in the Bazacle pass poor positioning of the entrance is thought to be the problem. The efficiency (minimum estimate) of the Bazacle fish pass was estimated to range from 6% to 34% with a mean of 18.5% (Larinier & Travade, 2002).

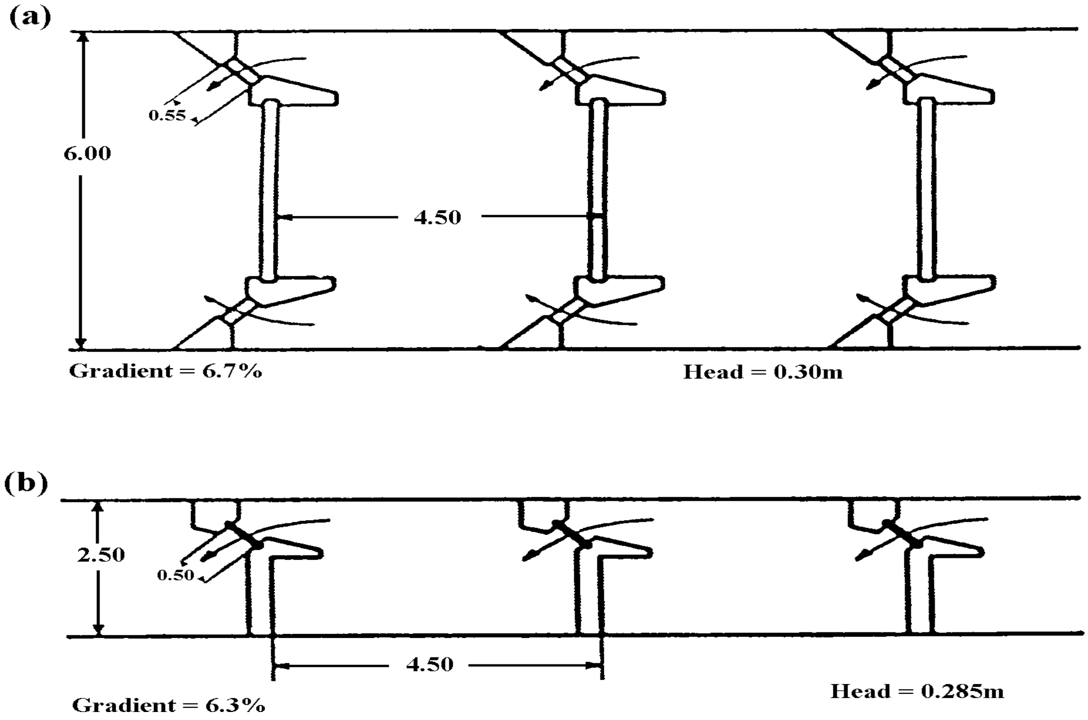


Figure 6.3: Pool fish passes (a) at Bergerac (R. Dordogne, France) and (b) at Ramier (R. Garonne, France), from Larinier & Travade (1992a).

Baril (1988) carried out studies on the River Rhône, France, using a Denil fish pass with broad arrow-shaped baffles (gradient 16%, width 1.80m, length 10m, baffle cross section 0.10 x 0.10m) and found that shad passed at flows of 300 to 750 $l^{-1}s^{-1}m^{-1}$. However, the efficiency of the pass was closely related to the flow pattern at the entrance to the pass.

Chevron type baffeld fish ways may be suitable for passing shad over relatively low obstacles (Richard pers. comm., cited by Larinier & Travade, 2002a).

6.3.3 Fish lifts

Fish lifts which have been designed to pass *Alosa* spp. are situated at Golfech on the River Garonne, France (Figure 6.4) and at Tuilières on the River Dordogne, France. Travade & Larinier (2002a) have described the working principle of the fish lift. It involves trapping the fish in a tank, which is then raised and emptied upstream. The fish are caught and held in a large holding pool fitted with a non-return device. Before the tank is raised the vertical screens on the crowder are shut and moved horizontally, confining the fish to a space just above the tank. The tank, situated in the floor of the holding pool, is then raised and the fish are emptied out into a channel via a chute. After the fish have been released, the trap and crowder return to their original position and the vertical screens on the crowder are re-opened.

Fish lifts must meet the following requirements:

- The lift must be designed to take between 1.5 and 2% of the total run at each operation.
- The large holding pool used to trap the fish must be at least 5m x 2.5m x 1.5m with a minimum water volume of 30 litres per shad.
- The volume of the tank into which the fish are crowded must be $\geq$10 litres per shad.
- The spacing of the bars on the screens must be < 25 mm.
- The auxiliary flow must be fed in upstream of the tank and the velocity at the entrance to the holding pool must be around $1 ms^{-1}$.
- The width of the channel leading out of the tank and allowing the fish to progress upstream must be >1.5m wide.
- The water velocity in the channel leading out of the tank must be > $0.3 ms^{-1}$.

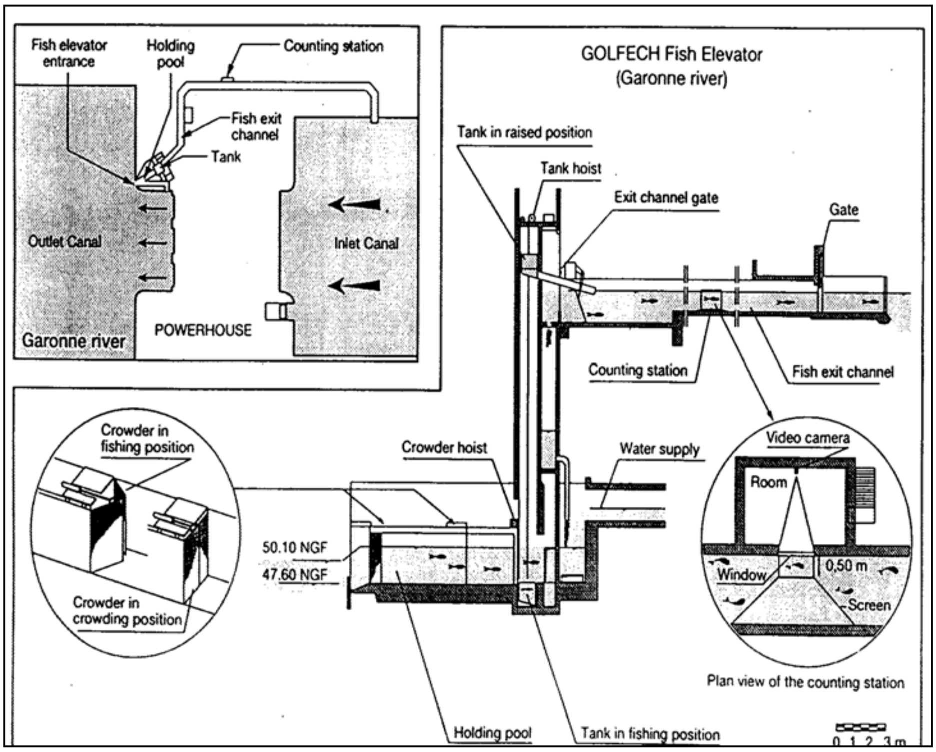


Figure 6.4: The Golfech fish lift on the River Garonne, France (Travade *et al.*, 1998).

A Borland fish lift has been installed at the Crestuma-Lever dam on the Douro and on the Belver dam on the Tejo, both appear to be ineffective for passing *Alosa* spp.

upstream (Bochechas, 1995). This is thought to be due to the location of the entrance in that it can't be easily found by the migrating species and that the attraction flow is small in relation to the competing flow.

6.3.4 Navigation locks

The use of navigation locks to circumvent barriers has been reported by Zylberblat & Menella (1996) for *Alosa fallax rhodanensis* from the Rhône. The main criterion for successful operation was ensuring adequate attraction flow, which was estimated at 10.5% of the conventional low-water flow for 20 minutes. Extending the period to 40 minutes did not significantly increase the number of shad entering the lock.

For locks operated using vertical gates, the recommended exit conditions were with the gates fully opened (down) as opposed too partially opened.

6.3.5 Performance

Comparison between installations is difficult because of differences in counting devices and the number of fish available to migrate (Travade *et al.*, 1998). The number of shad passing two sites on the Garonne (France) has ranged from 14,000 to 106,000 at Golfech and from 1,000 to 21,000 at Le Bazacle (Figure 6.5) [Travade *et al.*, 1998; Larinier pers. comm.]. At three sites on the Dordogne (France) the counts have ranged from 2,000 to 78,000 at Bergerac, from 2,000 to 87,000 at Tuiliérs and from 100 to 34,000 at Mauzac (Figure 6.5) [Dartiguelongue, 1996; Travade *et al.*, 1998; Larinier, pers. comm.].

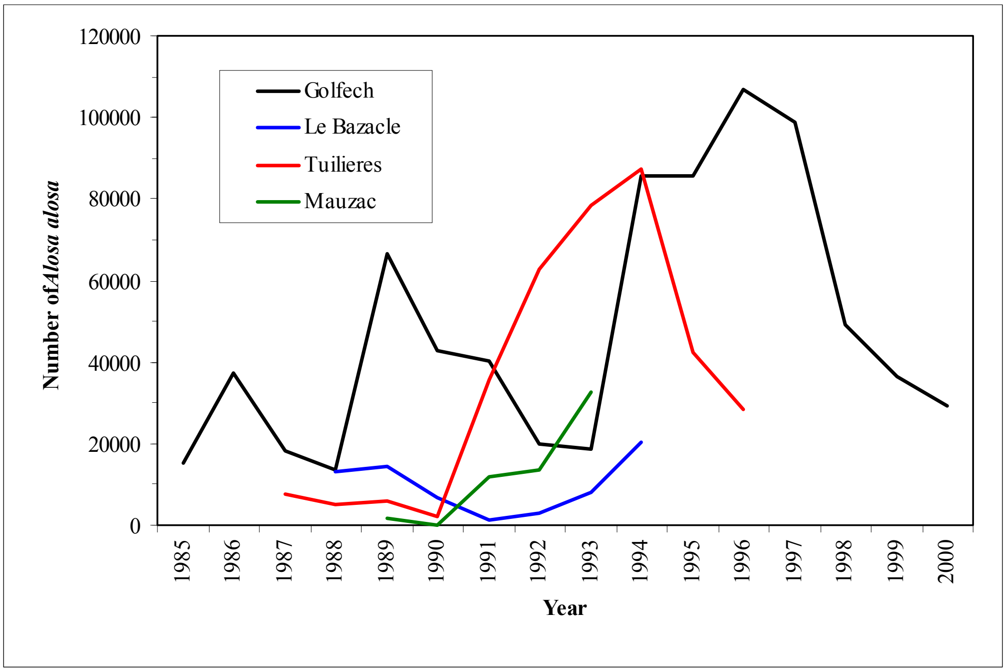


Figure 6.5:The count of shad at four fish passes; Golfech and Bazacle on the River Garonne and Tuiliéres and Mauzac on the River Dordogne, France.

6.4 Screens

Impingement at water intakes does provide a potential threat. Hadderingh & Jager (2002) estimated that in the region of 54,000 *Alosa fallax*, mainly juveniles were impinged annually by the Eems power station in the Ems Estuary (The Netherlands - Germany). Quantitative estimates also exist for the Blayais power station in the Gironde Estuary (France) where Taverny (1990) estimated that 434,860 *Alosa alosa* and 713,800 *Alosa fallax* were entrained in 1986.

Larinier & Travade (2002b) provide details of the various methods and types of screens that can be used to reduce entrapment at water intakes. Acoustic deterrents offer one of the most promising ways of reducing the level of impingement as *Alosa* spp. are known to be sensitive to a frequency of 200 kHz (Gregory, 1999) [section 1.3.2.7], though some development work will undoubtedly be needed. A frequency of 200 kHz was found to act as a barrier to the upstream migration of *Alosa fallax*, such that the fish would accumulate in shoals downstream of the acoustic beam, once the barrier was removed the adults would continue on their upstream migration (Gregory, 1999).

6.5 Translocation / Transplantation.

Translocation or transportation is the movement of any taxon from one place to another; guidelines for which have been proposed by Williams *et al.* (1988) and by Maitland & Lyle (1992). Hoestlandt (1958) transferred approximately 500,000 eggs of *Alosa alosa* from the Dordogne to the Rhône in 1953. Evidence of whether the transfer was successful is difficult to determine for though *A. alosa* was recorded by LeRoux (1928) in the Rhône it wasn't by Roule (1924), suggesting uncertainty as to whether a population did already exist. By the mid-1970s Rameye *et al.* (1976) considered them to be rare. In the more recent study by Le Corre *et al.* (1997) none were recorded, suggesting that the population may now be extinct.

Persat and Keith (2002) mention that *Alosa fallax* spp. have been introduced into some rivers of the Côte d' Azur in Southern France.

The translocation of *Alosa fallax lacustris* to the lakes of central Italy has been described by Chiappi, 1929, 1933). In 1921 alevins derived from fish from Lake Garda were stocked into Lake Vico, this stocking failed. In June 1922 500,000 fry from stock from Lake Como were introduced into Lake Vico, by 1924 the population had matured and were reproducing naturally. Fry derived stock from Lake Vico were used to populate lakes Bracciano and Bolsena where yields in the three lakes in subsequent years reached 40-50 tons year^{-1}. In 1926-27 the species was introduced into the central Italian lakes; Castel Gandolfo, Piediluco and Albano. By 1930 a total of 16.65 million 0+ *Alosa fallax lacustris* had been introduced over a six year period (1924/5-1929/30) into the lakes of middle Italy (Brunelli, 1926; MAF, 1931; Chiappi, 1933; Bianco, 1998, P. G. Bianco, Department of Zoology, University of Federico II, Naples, Italy, personal communication). At the end of the twentieth century a self-sustaining population still existed in Lake Bracciano but had disappeared from Lake Bolsena (Taddei *et al.*, 1999) and lakes Albano, Castel Gandolfo and Piediluco (P. G. Bianco, pers. comm.) and Lake Vico (P. G. Bianco pers. obs. cited by Bianco, 2002).

7. CULTURE

There were a number of studies carried out during the second half of the eighteenth – first half of the nineteenth century which were concerned with the artificial propagation of European alosines (Eckart, 1877; Pouchet & Bietrix, 1889; Vincent, 1894; Hoek, 1899; Pirola, 1930; Chiappi, 1933; Le Clerc, 1941; Mohr, 1941; Hoestlandt, 1958). Since then there has been little published information on their culture (Ramos, 1977). In recent years there have been great advances in the techniques used in the artificial culture of *Alosa*, especially in the USA, and this information forms the basis of the summary for alosine culture.

7.1 Collection of Spawn

The collection of spawn can either be achieved through the stripping of ripe fish on their spawning grounds, the fish in general being caught using gill nets, or by inducing fish to spawn in captivity. The eggs can be fertilised "dry" with the eggs stripped manually into a bowl and sperm added and mixed for a few minutes. Water is then added to activate the sperm and fertilisation takes place within 30 seconds. The eggs are then rinsed with water to remove excess milt and poured into a container to water harden (*c.* 1hr). Alternatively the eggs can be fertilised "wet" where the eggs and milt are mixed in a small amount of water (Edsall, 1970; Heinrich, 1981).

Eggs can be transported to the hatchery in plastic bags, in oxygen enriched water (dissolved oxygen >6 mgl^{-1} (Bradford *et al*., 1966)), placed in styrofoam cartons. Eggs should be placed in at least an equal volume of water (Wiggins *et al*., 1984; Howey, 1985).

For fish being transported back to the hatchery rod and line caught fish experience less stress and survive better than those obtained, for example, from a fish lift but did have similar spawning success (Minkkinen *et al.,* 1997). Fish are transported back to the hatchery in water of 5 ppt salinity, with a dissolved oxygen concentration of >7 mgl^{-1} (Minkkinen *et al.,* 1999).

For fish being induced, implantation with Gonadotropin-Releasing Hormone analogue (GnRHa) can take place either at site of capture (preferred) or in the hatchery (Minkkinen *et al.,* 1999). Fish are anaesthetised in aerated water containing 0.02g NaCl l^{-1} using a concentration of 0.25 mll^{-1} of 2-phenoxyenthanol (Mylonas *et al.,* 1995). Effective doses of hormone are:

- 25-50 µg kg^{-1} body weight (Minkkinen *et al.,* 1999)
- 117 (± 28) µg kg^{-1} (Male), 77 (± 8) µg kg^{-1} (Female) (Mylonas *et al.,* 1995).

At the hatchery fish are placed into circular tanks, at a density of 1 to 2.2 fish m^{-3} and maintained in water of between 2 and 3 ppt salinity. The sex ratio in the tanks range from unity to between 1.5 and 4 males for every female (Mylonas *et al.,* 1995; Minkkinen *et al.,* 1997). Spawning takes place in the tank and the eggs are collected using inline, outflow collectors on a daily basis (Mylonas *et al.,* 1995).

7.2 Incubation of Eggs

Eggs can be incubated in 6.5 L hatching jars with about 2.5 L of eggs per jar (Howey, 1985; Wiggins *et al.*, 1985, 1986), which can have a 2.5cm deep layer of gravel at the base of each jar (Howey, 1985). Alternatively a fine mesh metal screen can be used and has the advantage of being easier to clean than gravel (M. Hendricks, pers. comm. Pennsylvania Fish and Boat Commission, 1225 Shiloh Rd., State College, PA 16801, USA.). A flow of 1.2 to 2.0 $Lmin^{-1}$ was sufficient to keep the eggs rolling and allow dead eggs to accumulate near the surface for easy removal (Howey, 1985). Prophylactic treatments have included:

- Daily treatment of formalin at a concentration of 1667 to 1670 mgl^{-1} for 17 minutes (Wiggins *et al.*, 1984; Howey, 1985).
- Daily treatment of formalin at a concentration of 1.67 mll^{-1} for 10 minutes (Zydlewski & McCormick, 1997).
- Twice daily treatment of formalin (600:1) for 20 minutes (Minkkinen *et al.,* 1999).

Gerstell (1998) suggested that if the eggs were from different sources they should be disinfected by immersion in iodine for a short period of time.

Favourable conditions for incubation are; temperature between 18 and 22°C (see section 4.3), ammonia nitrogen < 0.025 mgl^{-1} (Wiggins *et al.*, 1984), dissolved oxygen *c.* 9 mgl^{-1} (Wiggins *et al.*, 1984) and pH > 7.5 (Leach & Houde, 1999). However, lower temperatures (15 to 16°C) are preferred as at these temperatures the risk of fungal problems is reduced (M. Hendricks, pers. comm.).

Once eggs start to hatch, hatching can be synchronised by placing the jars in sunlight and stirring occasionally with a feather (Minkkinen *et al.,* 1999).

7.3 Larval and Juvenile Rearing

At hatching the larvae are transferred to rearing tanks at densities ranging from 50 – *c.* 300 fish per litre (Howey, 1985; Wiggins *et al.*, 1985, 1986). Circular rearing tanks being preferred to rectangular tanks (M. Hendricks, Pers. comm.).

Feeding regimes are as follows:

- Brine shrimp (*Artemia*) nauplii (>2000 nauplii L^{-1}) at 5 min intervals throughout the day (from day 1-42) and Biokyowa fry feed (250-400µ, day 1-48; 700µ day 38-62; 1000µ day 49 onwards; salmon no.2 day 69 onwards), dry food fed at 5% of total mass per day (Zydlewski & McCormick, 1997).
- Brine shrimp nauplii and Zieglers AP100 (100µ) larval diet fed for 5 seconds at 5 minute intervals for 10-12 hr, during daylight hours (Peterson *et al.,* 1994).
- Brine shrimp nauplii and Zieglers AP100 (100µ) larval diet fed three times daily (Minkkinen *et al.,* 1999).
- Brine shrimp nauplii (12-24 nauplii $fish^{-1}$ day^{-1}) fed for 5 seconds at 5 minute intervals for 24hr per day (Wiggins *et al.*, 1985, 1986).

- Brine shrimp nauplii (20-40 nauplii $fish^{-1}$ day^{-1}) fed at 15 minute intervals for 18 hr day^{-1} for a minimum of 50 days (Howey, 1985).

Dissolved levels of nitrogen (N_2) need to be kept low as levels of 109% saturation resulted in gas bubble disease (Peterson *et al.,* 1994). Optimum rearing conditions are; dissolved oxygen from 5.6 to 9.1 mgl^{-1} (Murai *et al*., 1979; Peterson *et al.,* 1994), pH from 7.2 to 7.5 (Peterson *et al.,* 1994; Leach & Houde, 1999), ammonia < 0.35 mgl^{-1} (Murai *et al*., 1979) and temperature $18^{o}C$ to reduce fungal problems (M. Hendricks, Pers. comm.).

Howey (1985) used a prophylactic treatment of formalin at a concentration of 167 mgl^{-1} for 1hour per week to protect the juveniles against *Saprolegnia* and other fungal infections. In order to reduce stress the juveniles were transferred in a 1% salt (NaCl) solution.

REFERENCES

(Not cited in the Bibliography)

Bradford, A. D., Miller, J. G. and Buss. K. (1966). Final Report Summary on Phase B-2: To determine by bioassay techniques the inherent tolerance of the shad during its egg and larval stages to specific environemntal factors of the Susquehanna River and its tributaries, Pennsylvania Fish Commission. Division of Research and Fish Management, Benner Spring Fish Research Station.

Bromage, N.R. & Cumaranatunga, P.R.T. (1987) Oocyte development in the rainbow trout with special reference to vitellogenesis and atresia. In Idler, D. Crim,L. & Walsh, J., eds. *Proc. Third Int. Symp.Reproductive Physiology of Fish.* St. John's, Newfoundland, Canada: Memorial University Press, pp 194.

Edsall, T. A. (1970). The effect of temperature on the rate of development and survival of alewife eggs and larvae. (*Alosa pseudoharengus*). *Transactions of the American Fisheries Society* **99**(2), 376-380.

Gerstell, R. (1998). Rebuilding the Shad Population. American Shad: A Three-Hundred Year History in the Susquehanna River Basin, Pennsylvania State University Press.

Heinrich, J. W. (1981). Culture, feeding and growth of alewives hatched in the laboratory. *The Progressive Fish Culturist* **43**(1), 3-7.

Hiemstra, W. H. (1962). A correlation table as an aid for identifying pelagic fish eggs in plankton samples. *J. du Conseil* **27**:100-108

Howey, R. G. (1985). Intensive culture of juvenile American shad. *The Progressive Fish Culturist* **47**(4), 203-212.

Ivlev, V. S. (1961). Experimental ecology of the feeding of fishes. Yale University Press, New Haven, 302p.

Lazzaro, X. (1987). A review of planktivorous fishes: Their evolution, feeding behaviours, selectivities and impacts. Hydrobiologia 146, 97-167.

Leach, S. D. & Houde, E. D. (1999). Effects of environmental factors on survival, growth, and production of American shad larvae. *Journal of Fish Biology* **54**(4), 767-786.

Minkkinen, S. P., Richardson, B. M. & Morin, R. P. (1997). Report pursuant to Federal Aid #NA66FA0208. The Use of Cultured Alosids for Stock Restoration in Maryland. Fisheries Service, Maryland Department of Natural resources, 580 Taylor Avenue, Annapolis, Maryland 21401.

Minkkinen, S. P., Richardson, S. B. & Morin, R. P. (1999). Report pursuant to Federal Aid #NA86FA0330. Assessment of Alosid Stocking and Natural Reproduction in a restoration Setting. Fisheries Service, Maryland Department of Natural Resources, 301 Marine Academy Drive, Stevensville, MD 21666.

Murai, T., Muller, J. W. & Andrews, J. W. (1979). Dietary studies with American shad fry. *The Progressive Fish Culturist* **41**(2), 61-63.

Mylonas, C. C., Zohar, Y., Richardson, B. M. & Minkkinen, S. P. (1995). Induced spawning of wild American shad *Alosa sapidissima* using sustained administration of Gonadotropin-Releasing Hormone Analog (GnRHa). *Journal of the World Aquaculture Society* **26**(3), 240-251.

Nei, M. (1972). Genetic distance between populations. *Am. Nat.* **106,** 283-292

Pauly, D. (1979). Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula. *Ber. Inst. Meereskd. Christian Albrechts. Kiel* **63**, 156p.

Peterson, D. L., Burnett, T. F. & Odum, M. C. (1994). Virginia's American Shad 1994 Restoration Project Report. Chapter 2: Harrison Lake National Fish Hatchery. 1994 American Shad Restoration Project. U.S. Fish and Wildlife Service. U.S. Fish and Wildlife Service / Virginia Department of Game and Inland Fisheries**:** 2-1 to 2-11.

Tyler, C.R. & Sumpter, J.P. (1996). Oocyte growth and development in teleosts. *Reviews in Fish Biology* **6,** 287-318.

von Bertalanffy, L. (1957). Quantitative laws in metabolism and growth. *Q. Rev. Biol.* **32,** 217-231.

Wiggins, T. A., Bender, Jr., T. R., Mudrak, V. A. & Kremmel, J. R. (1984). The influence of rolling on the hatch of American shad eggs. *The Progressive Fish Culturist* **46,** 51-52.

Wiggins, T. A., Bender, Jr., T. R., Mudrak, V. A. & Coll, J. A. (1985). The development, feeding, growth and survival of cultured American shad larvae through the transition from endogenous to exogenous nutrition. *The Progressive Fish Culturist* **47**(2), 87-93.

Wiggins, T. A., Bender, Jr., T. R., Mudrak, V. A., Coll, J. A., & Whittington, J. A. (1986). Effect of intial feeding rates of artemia nauplii and dry-diet supplements on the growth and survival of American shad larvae. *The Progressive Fish Culturist* **48,** 290-293.

Williams, J. E., Sada, D. W., Williams, C. D. *et al.* (1988). American Fisheries Society guidelines for introductions of threatened and endangered fishes. *Fisheries (Bethesda, Maryland)* **13,** 5-11.

Willis, A. J., Dunnett, N. P., Hunt, R. & Grime, J. P. (1995). Does the Gulf Stream position affect vegetation dynamics in Western Europe? *Oikos* **73**, 408-410.

Winberg, G. G. (1956). Rate of metabolism and food requirements of fish. *Fisheries Research Board of Canada Translation Series* **194**, 1-202.

Zydlewski, J. M. & McCormick, S. D. (1997). The ontogeny of salinity tolerance in the American shad, *Alosa sapidissima*. *Canadian Journal of Fish and Aquatic Sciences* **54,** 182 189.

BIBLIOGRAPHY

Aflalo, F. G. (1904). *British Salt-Water Fishes.* London: Hutchinson & Co.

Afonso, A. (1992). *Les pêches estuariennes Portugal.* Les journées de la pêche professionnelle - Environnement, Réglementation, Production. 77-79. Nantes, France. IFREMER.

Afz. (1892). Die Wanderung der Mainfische im Frühjahr 1892. *Allgem Fischerei Zeitung* **XVII,** 266.

Afz. (1894). Der Wanderzug der Mainfische im Frühjahr 1894. *Allgem Fischerei Zeitung* **XIX,** 277-278.

Alberquerque, R. A. (1954-56). Peixes de Portugal et ilhas adjacentes.Chaves para a sua determinaçao. *Portugaliae Acta Biologica* **16,** 1-1164.

Albiges, C., Elie, P. and Rigaud, C. (1985). *Intérêt et bases d'un schéma d'orginisation pour la gestion des stocks de poissons et d'agnathes amphihihalins.* 20 pp. Coll. Restauration des Rivières à Saumon. Bergerac, France.

Albiges, C., Rochard, E., Elie, P. and Boigontier, B. (1985a). *Étude de suivi halieutique de l'estuaire de la Gironde, 1984.* 175pp. Bordeaux. CEMAGREF Bordeaux / EDF.

Albiges, C., Rochard, E. and Castelnaud, G. (1986). *Étude de l'estuaire de la Gironde, 1985: étude de la faune circulante, évaluation de la production 1984 et calcul de CPUE.* 175 pp. Bordeaux. CEMAGREF Bordeaux / EDF.

Alegre, M., Lleonart, J. and Veny, J. (1992). *Espècies pesqueres d'interès comercial. Nomenclatura oficial catalana.* Barcelona. Departament de Cultura, Generalitat Catalunya.

Alexandrino, P. J. (1990). *Primeiros dados sobre e eficácia da eclusa Borland da barragem de Belver, rio Tejo. Alguns aspectos sobre a biologia das espécies migradoras.* Actas 2^{e} Conferência Nacional Sobre a Qualidade do Ambiente. **2**, 1-15.

Alexandrino, P., Ferrand, N. and Baglinière, J. L. (1992). Preliminary results on the genetic differentiation between the two species of shad (*Alosa alosa* L. and *Alosa fallax* Lacépède) occurring in Portugal. *ICES-CM-1992/M:***17**. 1-10.

Alexandrino, P. J., Sousa, C., Pereira, A. and Ferrand, N. (1993). Genetic Polymorphism of adenosine deaminase (ADA; E.C. 3.5.4.4.) in allis shad *Alosa alosa* and twaite shad, *Alosa fallax. Journal of Fish Biology* **43,** 951-953.

Alexandrino, P. J., Ferrand, N. and Rocha, J. (1996). Genetic polymorphism of a haemoglobin chain and adenosine deaminase in European shads: evidence for the existence of two distinct genetic entities with natural hybridization. *Journal of Fish Biology* **48,** 447-456.

Alexandrino, P. (1996). *Genetic and morphological differentiation among some Portuguese populations of allis shad Alosa alosa (L., 1758) and twaite shad Alosa fallax (Lacépède, 1803).* Fishes and their environment. Proceedings of the 8th Congress of Societas Europaea Icthyologorum (SEI). **22**, 15-24. Oviedo, Spain. (September 26-October 2, 1994). Publicaciones Especiales, Instituto Espanol de Oceanografia.

Alexandrino, P. (1996a). Genetic and morphological differentiation among some Portuguese populations of allis shad *Alosa alosa* (L., 1758) and twaite shad *Alosa fallax* (Lacépède, 1803). *Publicaciones Especiales Instituto Español de Oceanografía* **21,** 15 24.

Alexandrino, P. (1996b). *Estudo de populações de sável (Alosa alosa L.) e savelha (Alosa fallax Lacépède). Análise da diferenciação interspecífica, substruturação e hibridaçao. [Study of allis shad (Alosa alosa L.) and twaite shad (Alosa fallax Lacépède) populations: Population structure, differentiation between the two species and hybridisation].* 185 pp. Tese de doutoramento. Porto: Universidade do Porto.

Alexandrino, P. and Boisneau, P. (2000). Diversité génétique. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations.* (Baglinière, J. L. and Elie, P. eds.), 179-196. Paris:INRA-CEMAGREF.

Allardi, J. and Keith, P. (1991). Atlas préliminaire des poissons d'eau douce de France. In: *Collection Patrimones Naturels*. 4 - Série Patrimone Génétique, (Secretariat de la Faune et la Flore, ed.), 42-48. Paris:Muséum National d'Histoire Naturelle, Conseil Supérieur de la Pêche, CEMAGREF, Ministère de L'Environnement.

Allois, C. (1946). L' alosa du Rhône. *Bulletin Français de la Pêche et de la Pisciculture* **144,** 130-136.

Almaça, C. (1965). Contribution à la connaissance des Poissons des eaux intérieures du Portugal. *Revta Fac. Ciênc. Univ. Lisb.* **13,** 225-62.

Almaça, C. (1988). Compte-Rendu de la Table Ronde: les poissons des îles de la Méditerrané Occidentale (Baléares, Corse, Sardaigne, Sicile). *Bull. Ecol.* **19,** 2-3.

Almaça, C. (1988a). Fish and their environment in large European river ecosystems. Tejo and Guadiana. *Sciences de L'Eau* **7,** 3-19.

Almaça, C. (1995). Freshwater fish and their conservation in Portugal. *Biological Conservation* 125-127.

Almeida D'Eca, V. (1929). A Pesca. Exposiçao Portugesa am Savilha. *Impiensa Nacional.* 24pp.

Ananiadis, C. I. (1949). Le lac Haghios Vassilios (Koronia). Contribution à l'étude des lacs piscicoles de la Macédoine. *Bulletin de la Chambre du Commerce & Industrie.* **3,** 21-32, 81-89.

Ananiadis, C. I. (1951). A preliminary survey of the Haghios Vassilios Lake. *Praktika of Hellenic Hydrobiological Institute* **5,** 25-71.

Andersen, K. and Kennedy, C. R. (1983). Systematics of the Genus *Eubothrium* Nybelin (Cestoda, Pseudophyllidea) with partial re-description of the species. *Zoological Scripta* **12,** 95-105.

Andersson, K. A. (1942). *Fiskar och fiske i Norden.* 1, Fiskar och fiske i Havet., pp.540. Stockholm: Bokförlaget Natur och Kultur.

Andrews, M. J. (1977). Observations on the fauna of the Metropolitan River Thames during the drought in 1976. *The London Naturalist* **56,** 44-56.

Andrews, M. J. and Wheeler, A. (1985). Rare and little known fishes in the Thames Estuary. *Journal of Fish Biology* **27,** 59-71.

Anon. (1861). *Report of the Commissioners appointed to enquire into salmon Fisheries (England and Wales), London.* Her Majesty Stationery Office. London.

Anon. (1866). Occurrence of the Allice Shad (*Alosa communis*) on the Aberdeenshire Coast. *The Zoologist* **24,** 349.

Anon. (1881). *Catalogue of vertebrate animals now or lately in the Perth Museum.* Unpublished manuscript Literature and Antiquarian Society.

Anon. (1884-1901). *Donation Book.* Unpublished manuscript Perthshire Natural History Museum.

Anon. (1888). Bevattende een rapport over Ankerkuil - en Staalboomen-Visscherij. *Tijdschrift der Nederlandsche Dierkundige Vereeniging* **Supplement Deel II,** 1-331.

Anon. (1888a). Mitteilungen unter der Rubrik "Vereinsnachrichten". *Allgem Fischerei Zeitung* **13,** 214-215.

Anon. (1888b). Mitteilungen unter der Rubrik "Vereinsnachrichten". *Allgem Fischerei Zeitung* **13,** 286-289.

Anon. (1892). Die Wanderung der Mainfische im Frühjahr 1892. *Allgem Fischerei Zeitung* **17,** 266.

Anon. (1894). Der Wanderung der Mainfische im Frühjahr 1894. *Allgem Fischerei Zeitung* **19,** 277-278.

Anon. (1901-1918). *Accession Book.* Unpublished manuscript Perthshire Natural History Museum.

Anon. (1901a). Les aloses en Belgique. *Pêche et Pisciculture.* 12 Avril 1901. 65-70.

Anon. (1918). *Catalogue of the mammals, reptiles, amphibians and fishes in the Perthshire Natural History Museum.* Unpublished manuscript Perthshire Natural History Museum.

Anon. (1957). Standardization of biometric and observation methods for Clupeidae (especially *Sardinia pilchardus*)used in Fisheries Biology. *Stud. Rev. gen. Fish. Coun. Medit.* **1,** 1-35.

Anon. (1960). *La pisciculture et la pêche dans les eaux continentales, du Maroc.* 68**pp,** Ministère de l' Agriculture, Royaume du Maroc.

Anon. (1963). Des échelles à poissons et du franchissement des barrages par les aloses. *Bull. ann. pisci. Maroc* 20-35.

Anon. (1964). The 'fishing' notable fish list. *Fishing.* **78,** 22.

Anon. (1975). Les obstacles a la migration des poissons du Rhone dans le Department du Gard. *Etud. Cent. Tech. Genie Rural Eaux For.* **8,**

Anon. (1977). *L'alose dans les 7 départments de l'Ouest de la France.* 3 pp. CSP 2e Région Piscicole.

Anon. (1979). *Annuaine statistique des peches - FAO.* **48,** Captures et quantites debarquees, O.N.U.A.A,.

Anon. (1979a). *Étude halieutique de l'estuaire de la Gironde.* 189 pp. Bordeaux. CTGREF de Bordeaux, Division ALA/EDF.

Anon. (1981). *Migration des aloses dans le bas-Rhône: observations effectuées en 1979 et 1980.* **Unpublished,** 10 pp. CTEGREF.

Anon. (1981). Twaite and allis shad. *New Fisherman's Handbook* **59,** 1636-1641.

Anon. (1981). *Annuaire FAO. Statistique des pêches. Captures et quantités débarquées.* **52,** 357 pp. ONUAA.

Anon. (1982). *The convention on the conservation of European wildlife and natural habitats ("The Bern Convention").* Bern, Switzerland.
Anon. (1985). High Spring Tides, River Barrow. *Angling Times.* **1664,** 2.

Anon. (1988). *Schéme départmental de vocation piscicola du var.* Report de Synthèse, Montpellier. Direction Départmentale de I'Agriculture et de la Forêt du Var/Ministère de l' Environnement/ Conseil Supérieur de la Pêche.

Anon. (1990). Cockles tempt record shad. December 15th. 33.

Anon. (1990). *Centrale de Golfech, étude ichtyologique. Actualisation du point zéro.*pp. 15-22. Toulouse. ENSAT, Lab. Ichthyol. Appl.

Anon. (1991). *Schéma de vocation piscicole du Rhône.* DIREN Rhône-Alpes, Délégation de Bassin Rhône-Méditerranée-Corse. Service de la Navigation Rhône-Saône.

Anon. (1991). *Contrôle de la migration des poissons à la passe du Bazacle (Garonne).* pp. 12-16. Toulouse. Cons. Sup. Pêche.

Anon. (1992). Rare catches! *Grimsby Evening Telegraph.* May 6, 1992. 2.

Anon. (1992). *Contrôle de la migration des poissons à la passe du Bazacle (Garonne).* pp. 16-23. Toulouse. Cons. Sup. Pêche.

Anon. (1992). *Annuaire FAO. Statistique des pêches. Captures et quantités débarquées 1990.* **70,** 647 pp. ONUAA.

Anon. (1992). *Le seuil d'Agen-Beauregard: observations sur le passage des aloses et des mulets (mai-juin 1992).* 83 pp. ENSAT.

Anon. (1993). *Statistiques de pêches. Captures et quantités débarquées.* FAO annuaire FAO. Rome.

Anon. (1993). Plan migrateurs Rhône:c'est parti! *Pêcheur professionnel* **6,** 14-15.

Anon. (1994). Species File. The shad. *Glas y Dorlan.* **18,** 8.

Anon. (1994). *Impact de la centrale nucléaire de Golfech sur l'ichtyofaune. Suivi 1993.* 75 pp. EDF / ENSAT.

Anon. (1994). *Estuaire de la Gironde: livre blanc.* Agence de l'Eay Adour Garonne/IFREMER.

Anon. (1995). Allis' Adventure in Waterland. *Fisheries News.* **4,** 12.

Anon. (1995). Youngster lands a million to one longshot. *Angling Times.* **2201,**

Anon. (1995). Rare fish makes an appearance on the Tay. *Dundee Courier.* 2nd. August.

Anon. (1995). Eine Fischerfamilie an der Schwarzen Elster zwischen 1936 bis 1945. Betrachtungen zu fischereilichen und sozialen Verhaeltnissen in Sachsen-Anhalt. [A fisher family at the river Schwarze Elster between 1936 and 1945. Contributions to fisheries and social affairs in Sachsen-Anhalt.]. *Fischer und Teichwirt.* **46,** 86-87.

Anon. (1995). *Plan de gestion des poissons migrateurs 1995-1999.* Rapport de synthèse 33 pp. + annexes. Comité de Gesion des Poissons Migrateurs du Bassin Rhône Méditerranée-Corse.

Anon. (1996). Return of the Shad. *News Reels for Anglers.* **6,** 3.

Anon. (1996). Action plan protects threatened Shad. *Fisheries News.* **6,** 8.

Anon. (1996). Shad caused racked brains. *Anglers Mail.* 31st August.

Anon. (1997). Wonderland as Allis makes a comeback. *Angling Times.* 5.

Anon. (1999). *Annuaire FAO. Statistique des pêches. Captures 1996.* **82,** 678 pp. ONUAA.

Anon. (2000). *Recontquête des axes vie piscicole.* Note Technique SDAGE N^{o}3**,** 84 pp. SDAGE Rhône-Méditerranée-Corse. Comité de Bassin RMC, Agence de l'Eau RMC, Préfet Coordonnateur de Bassin RMC, DIREN Rhône-Alpes Délégation de Bassin RMC.

Applied Environmental Research Centre. (1996). *Identification of spawning areas of the Allis and Twaite Shad in the rivers flowing into Wigtown Bay.* **SNH/129/95 HS,** Scottish Natural Heritage.

Aprahamian, M. W. (1981). *Aspects of the biology of the Twaite shad (Alosa fallax) in the Rivers Severn and Wye.* Second British Freshwater Fish Conference. pp. 373-381. Liverpool: University of Liverpool.

Aprahamian, M. W. (1982). *Aspects of the biology of the twaite shad, Alosa fallax fallax (Lacépède), in the Rivers Severn and Wye.* 349 pp + annexes. Ph.D. University of Liverpool, Liverpool.

Aprahamian, M. W. (1985). The effect of the migration of *Alosa fallax fallax* (Lacépède) into freshwater, on branchial and gut parasites. *Journal of Fish Biology* **27,** 521-532.

Aprahamian, M. W. (1988). The biology of the twaite Shad, *Alosa fallax fallax* (Lacépède), in the Severn Estuary. *Journal of Fish Biology* **33,** 141-152.

Aprahamian, M. W. (1989). The diet of juvenile and adult twaite shad *Alosa fallax fallax* (Lacépède) from the rivers Severn and Wye (Britain). *Hydrobiologia* **179,** 173 182.

Aprahamian, M. W. and Aprahamian, C. D. (1990). Status of the genus *Alosa* in the British Isles; past and present. *Journal Fish Biology* **37,** 257-258.

Aprahamian, M. W., Lester, S. M. and Aprahamian, C. D. (1998). *Shad conservation in England and Wales.* R&D Technical Report **Technical Report W110,** pp. 133. Bristol. Environment Agency.

Aprahamian, M. W. and Aprahamian, C. D. (2001). The influence of water temperature and flow on year class strength of twaite shad (*Alosa fallax fallax*) from the River Severn, England. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 953-972.

Aprahamian, M. W. and Lester, S. M. (2001). Variation in the age at first spawning of female twaite shad (*Alosa fallax fallax*) from the River Severn, England. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 941-951.

Apstein, C. (1895). *Bericht Über die im Auftrage des Deutschen Seefischerei – Vereins unternomme Untersuchung der Steerthamen in der unterelbe.* Unpublished Manuscript pp. 229. Zoological Institute, University of Kiel, Germany.

Arrignon, J. (1988). Fish and their environment in large European river ecosystems: The Loire. *Sciences de l'eau* **7,** 21-34.

Arruda, L. M., Andrade, J. P. and Cunha, M. M. (1988). Abundance, diversity and community structure of the fish population in the Ria de Aveiro (Portugal). *Oceanologica Acta* **11,** 235-240.

Assis, C., Costa, J. L., Costa, M. J., Moreira, F., Almeida, P. and Goncalves, J. (1989). Ameaças à sobrevivência dos peixes migradores do Tejo. Sugestões para a sua conservação. *Actas do Coloquio Sobre a Conservação dos recursos vivos marimhos*

Assis, C. A. (1990). Threats to the survival of anadromous fishes in the River Tagus, Portugal. *Journal of Fish Biology* **37,** 225-226.

Assis, C., Costa, J. L., Moreira, F., Almeida, P. R. and Gonçalves, J. J. (1992). Ameaças à sobrevivência dos peixes migradores do Tejo. Sugestões para a sua conservação. *Publicações Avulsas do INIP* **17,** 429-441.

Assis, C. A., Almeida, P. R., Moreira, F. M., Costa, J. L. and Costa, M. J. (1992a). Diet of the twaite shad *Alosa fallax* (Lacépède) (Clupeidae) in the River Tagus Estuary, Portugal. *Journal of Fish Biology* **41,** 1049-1050.

Athanassopoulos, G. (1917). Quelques éléments de recherches hydrobiologiques en Grèce 3. Désignation de certaines espèces de Poissons. *Bulletin station Hydrobiologique grecque* **1,** 19-25.

Athanassopoulos, G. (1921). Description et caractéristiques de quelques eaux piscicoles. *Bulletin Station Hydrobiolgique grecque* **3,** 70-88.

Avlovic, M. (1976). Hypothalmus and pituitary gland of fishes during migration and changes of water salinity. *Rev. Trav. Inst. Pêches Marit.* **40,** 705-706.

Babin, D. (1989). *Résultats de l'enquête express 1988; étude socio-économique de la pêche professionnelle continentale sur les bassins Seine, Loire-Allier, Vilaine pour l'année civile 1988 (Marins pêcheurs exclus).* 4 pp. CEMAGREF.

Babin, D. (1993). *Contribution à l'étude d'une ressource renouvelable: la pêche professionnelle en eau douce en France.* 300 pp. Thèse de Doctorat. Rennes: CEMAGREF / Université de Haute Bretagne (Rennes II).

Bach, J. M., Bruyere, F. and Rancon, J. (1988). *Etude d'efficacitié de la passe à poissons du barrage de Decize.* LOGRAMI pour VNF 31pp.

Backiel, T. (1995). Ichtiofauna. In: *Korytarz ekologiczny doliny Wisly stan – funkcjonowanie - zagrozenia. [Vistula as an ecological corridor state - functioning – threats.].* (E. Gackiej-Grzesikiewicz, ed.), 125-139. Warsaw:Fundacja IUCN Poland.

Badia, J. and Prouzet, P. (1996). Modeles loglineaires pour l'etude des associations entre captures par unite d'effort et variables hydroclimatiques. *Aquatic living resources.* **9,**217 223.

Bagenal, T. B. (1965). *The Fauna of the Clyde Sea Area, Fishes.* Scottish Marine Biological Association. Millport.

Bagenal, T. B. and Braum, E. (1978). Eggs and early life history. In: *Methods for the assessment of fish production in fresh waters. International Biological Programme Handbook No. 3.* (T. B. Bagenal, ed.), 165-201. Oxford.:Blackwell.

Baglinière, J. L. and Le Louarn, H. (1987). Caractéristiques scalimétriques des principales espèces de poissons d'eau douce de France. *Bulletin Français de la Pêche et de la Pisciculture* **306,** 1-39.

Baglinière, J. L., Boisneau, C. and Boisneau, P. (1988). *Étude de la Grande Alose (Alosa alosa) dans le bassin de la Loire.* 15 pp. Rap. Lab. Eco. Aquat., contrat INRA Rennes / Ministère de l'Environnement (SRETIE)CSP.

Baglinière, J. L., Castanet, J., Conand, F. and Meunier, F. J. (1992). *Tissus durs et âge individuel des vertébrés. [Hard tissues and individual age of vertebrates].* Colloque national, Bondy, France, 4-6 Mars 1991. Paris: ORSTOM - INRA.

Baglinière, J. L. (1995). *Les aloses : Description, Systematique, Repartition, Interets Socio-Economique, Scientifique, Ecologique et Patrimonial.* contract no. 93020, Laboratoire d'Ecologie Aquatique, INRA & Ministère de l'Environment.

Baglinière, J. L. (1996). *Programme d'action pour la diversite biologique chez les aloses (Alosa sp.).* Laboritoire d'Ecologie aquatique INRA.

Baglinière, J. L., Sabatié, M. R., Le Corre, M., Menella, J. Y. and Pont, D. (1996). *Premiers éléments de caractérisation biologique et taxinomique de l'alose feinte du Rhône (1994 et 1995). [First elements of the biology and taxonomy of the twaite shad from the Rhone (1994 and 1995)].* 23 pp. Rennes. INRA-ENSA Rennes-Ministère de l'Environnement, DIREN Rhône-Alpes.

Baglinière, J. L. (2000). Le genre *Alosa* sp. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations.* (J. L. Baglinière and P. Elie, eds.), 3-30. Paris:INRA-CEMAGREF.

Baglinière, J. L. and Elie, P. (2000). *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations.* 275 pp. Paris: INRA-CEMAGREF.

Baglinière, J. L., Sabatié, M. R., Aprahamian, M. W., Alexandrino, P., Aprahamian, C. D., Assis, C., Cassou-Leins, J. J., Le Corre, M., Mennesson-Boisneau, C., Martin Vandembulcke, D., Rochard, E. and Teixeira, C. (2001). Guide pour l'interpétation des écailles et l'estimation de l'âge chez les aloses (Alosa spp.) de la façade Atlantique-Est et de la Méditerranée-Ouest. *Bulletin Français de la Pêche et de la Pisciculture* **357/360,** 485-530.

Baglinière, J. L., Sabatié, M. R., Rochard, E., Alexandrino, P. and Aprahamian, M. W. (2003). The Allis shad (*Alosa alosa* Linneus, 1758): biology, ecology, range and status of populations. *Transactions of the American Fisheries Society*

Baillie, J. and Groombridge, B. (eds.). (1996). *1996 IUCN red list of threatened animals.* pp. 378. Gland, Switzerland: IUCN.

Baker, W. (1908). Fishes. In: *The Victoria history of the County of Somerset.* 1, (W. Page, ed.), 135.

Baldner, L. (1666). *Vogel, Fisch und Thierbuch.* Stuttgart: Schindler Verlag.

Balevičiene, J., Balevičius, K., Budrys, E., Drobelis, E., Duburaite, R., Gricius, A., Grigaite, O., Jankevičiene, R., Lonaitis, V., Jukoniene, I., Juškaitis, R., Kazlauskas, R., Kesminas, V., Kutorga, E., Lapele, M., Lazdauskaite, Z., Lekacičius, A., Matelis, A., Monsevičius, V., Monsevičius, V., Motiejūnaite, J., Naujalis, J., Paltanavičius, S., Pauza, D., Pieckis, S., Rašomavičius, V., Repečka, R., Sinkevičiene, Z., Stanionyte, A., Trainauskaite, I.., Tupčiauskaite, J., Urbonas, V., Uselis, V., Vaičiūnaite, R., Vaitonis, G., Zapkuviene, D., Žiliukas, V. (1992), Red data book of Lithuania. 362 pp. Vilnius: Lietuvos Respublikos aplinkos apsaugos departamoplas.

Balik, S. (1985). Trakya Bölgesi Içsu Baliklarinin Bugünkü Durumu ve Taksonomik Revizyonu. *Doga Bilim Dergisi* **9 (2),** 147-160.

Balik, S. (1995). Freshwater fish in Anatolia, Turkey. *Biological Conservation* **72,** 213 223.

Banarescu, P. (1960). Einige Fragen zur Herkunft und Verbreitung der Süsswasserfischfauna der europäischmediterranean Unteregion. *Arch. Hydrobiol.* **57,** 16 134.

Banarescu, P. (1964). *Fauna Republici populare Romini, Vol. XIII. Pisces-osteichtyes [Fauna of the Romanian People's Republic Pisces - Osteichthyes].* 13, 959pp (Alose : 237-246). Bucuresti: Ed. Academiei R.P.R.

Banarescu, P., Blanc, M., Gaudet, J.-C. and Hureau, J.-C. (1971). *Poisson des eaux continentales d'Europe.* Aloses No 20 et 38, 186 pp. London: Fishing News (Books).

Baras, E. and Lucas, M. C. (2001). Impact of man's modifications of river hydrology on the migration of freshwater fishes: a mechanistic perspective. *Ecohydrology & Hydrobiology* **1,** 291-304.

Barbieri, C. (1907). Le Alose del Mediterraneo e gli Agoni dei laghi Lombardi. Studio preliminare. *Rivista mensile di Pesca* **9,** 1-32.

Barbieri, C. (1907a). Le Alose del Mediterraneo e gli Agoni dei laghi Lombardi. *Rivista mensile di Pesca* **9,** 125-143.

Barbieri, C. (1907b). Le Alose del Mediterraneo e gli Agoni dei laghi Lombardi. *Rivista mensile di pesca* **9,** 69-82.

Barbieri, C. (1908). Gli Agoni (*Alosa finta*) dei laghi dell'Italia settentrionale ed alcune brevi considerazioni intorno alla loro origine. *Riv. Fisica. Mat. Sci. Nat. Pavia* **XVIII,**

Barbieri, C. (1908a). L'alimentazione naturale delgi agoni. *Rivista mensile di pesca* **10,** 237-241.

Barbieri, C. (1909). Ueber eine neue Species der Gattung *Ichthyotaenia* und ihre Verbreitungsweise. *Centrabl. Bakt.* **49,** 334-340.

Barfurth, D. (1875). Über Nahrung und Lebenweise der Salme, Forellen und Maifische. *Archiv für Naturgeschichte* **41,** 122-158.

Barfurth, D. (1876). The food and mode of living of the salmon, the trout and the shad. *Report of Commissioner of Fish and Fisheries* **3,** 735-759.

Baril, D. (1988). *Etude des conditions de franchissement par l'alose (Alosa ficta rhodannensis) d'une passe à ralentisseurs de fond expérimentale (Site experimental de Beaucaire). [Study of the conditions for the passage of shad (Alosa ficta rhodannesnis) in an experimental Denil fishway (experimental site at Beaucaire)].* pp. 36 + annexes. Montpellier. CSP.

Barrois, J. P. (1997). *Reproduction de la grande alose (Alosa alosa L.) entre Agen et Golfech.* 60 pp + annexes. Mémoire IUT de Tours.

Bartel, R., Wilkonska, H. and Borowski. (1996). *Changes of the ichthyofauna in the Vistula Lagoon.* Proceedings of the international meeting on Baltic Network of Biodiversity and productivity of selected species in coastal ecosystems, 4-8 October 1995. 12-24. Nida, Lithuania. Lithuania Acedemy of Sciences, Vilnius, Lithuania.

Barthelemy, C. (1997). *À l'abri des acacias en fleurs.....les pêcheurs d'aloses du Rhône. Campagne d'études 1995.* **1995-N°6/8,** 102 pp. + annexes. CNRS, DESMID. Association Migrateurs Rhône-Méditerranée.

Barthelemy, C. and Mazens, Y. (1997). *Suivi de la pêcherie en aval de l'usine-écluse de Vallabrègues. Estimation des captures des pêcheurs amateurs aux engins. Campagne d'études 1996.* **1996-N°6/8,** 42 pp. + annexes. CNRS, DESMID. Association Migrateurs Rhône-Méditerranée.

Bartl, G. and Troschel, H. J. (1995). *Maifische im Rheinsystem: Historische und aktuelle Situation von Alosa alosa und A. fallax im Rheingebeit.* Limnofisch.

Bartl, G. and Troschel, H. J. (1997). Historische Verbreitung, Bestandsentwicklung und aktuelle Situatio von *Alosa alosa* und *A. fallax* in Rheingebeit. *Zeitschrift fur Fischkunde.* **4,** 119-162.

Bauch, G. (1966). *Die einheimischen Süsswasserfische.* pp. 153-155. Leipzig: J.Neumann-Neudamm.

Bauzá Rullán, J. (1958). Otolitos de peces actuales. *Boletin Real Sociedad Espanola de Historia Natural* **56,** 111-126.

Baylis, H. A. and Jones, E. I. (1933). Some records of parasitic worms from marine fishes at Plymouth. *Journal of the Marine Biological Association U.K.* **18,** 627-634.

Baysal, A. and Tuncer, S. (1994). Radioactivity levels in fish, shellfish, algae and seagrass collected from the eastern Black Sea coast of Turkey, 1992. *Toxicology and Environmental Chemistry* **42,** 149-153.

Beaudoin, F. (1993). Paris/Seine, Ville fluviale son histoire des origines à nos jours.. 190 pp. Paris:De la Martiière.

Beer, J. (1996). Time for shad to come out of the shade. *Daily Telegraph.* Saturday May 25th.

Belaud, A. and Labat, R. (1985). Le comportement migratoire des Aloses (*Alosa alosa* L) dans le canal de restitution de l'usine de Golfech. Effects de la température. [The migratory behaviour of the aloses in the restitution canal of Golfech hydroelectric power plant: Effects of temperature]. *Ichtyophysiologica acta* **9,** 177-186.

Belaud, A., Dautrey, R., Labat, R., Lartigue, J. P. and Lim, P. (1985). Observations sur le comportement migratoire des Aloses (*Alosa alosa* L.) dans le canal artificiel de l'usine de Golfech. [Observations on the migration behavior of Allis shad (*Alosa alosa L.*) in the artificial canal of Golfech hydroelectric plant]. *Annales de Limnologie* **21,** 161-172.

Belaud, A., Labat, R., Trivellato, D. and Tison, G. (1987). Expérimentations hydrauliques et ichtyologiques d'un système de piégeage automatique des poissons migrateurs à Golfech.[Hydraulic and ichthyological experiments with an automatic trapping system for migrating fish at Golfech]. *La Houille Blanche* **1/2,** 73-80.

Belaud, A., Cassou-Leins, F., Cassou-Leins, J. J. and Labat, R. (1991). La ponte d'un poisson migrateur de la Garonne la grande alose (*Alosa alosa* L.) [Spawning of a migratory fish from River Garonne, the Allis shad (*Alosa alosa* L.)]. *Ichtyophysiology Acta* **14,** 123-126.

Belaud, A. and Labat, R. (1992). Études ichthyologiques préalables à la conception d'un ascenseur à poissons à Golfech (Garonne, France). *Hydroecologie Appliquée* **4,** 65-89.

Belaud, A. and Carette, A. (1998). *Suivi 1998 de la qualité des milieux et de la reproduction des aloses sur le tronçon Agen-Golfech de la Garonne.* 36 pp. Rapport de l'Association pour la Gestion de la Réserve naturelle de la Frayère d'Alose.

Belaud, A. and Carette, A. (1999). *Suivi 1999 de la qualité des milieux et de la reproduction des aloses à Agen et en moyenne Garonne.* 44 pp. + annexes [61p in total]. Rapport de l'Association pour la Gestion de la Réserve naturelle de la Frayère d'Alose.

Belaud, A., Carette, A., Cassou-Leins, F. and Cassou-Leins, J. J. (2001). Choix des sites de fraie par la grande alose (*Alosa alosa* L.) en moyenne Garonne. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 869-880.

Bellariva, J. L. and Belaud, A. (1998). Environmental factors influencing the passage of Allice Shad *Alosa alosa* at the Golfech Fish Lift on the Garonne river, France. In: *Fish migration and fish bypasses.* (M. Jungwirth, S. Schmutz and S. Weiss, eds.), 170-179. Fishing News Books - Blackwell Sciences Ltd.

Bellariva, J. L. (1998). *Contribution à l'étude du déroulement de la migration et de la reproduction de la grande alose (Alosa alosa L.) en Garonne: étude prospective de la dévalaison des juvéniles.* 113 pp. Thèse de Doctorate. Toulouse: Ecole National Polytechnique de Toulouse.

Bellec, S. (1981). *Étude des conditions de pêche sur le domaine public fluvial de la Loire.* 231 pp. MECV.

Ben Hassine, O. K. (1981). Ètude de l'infestation des poissons (autres que les muges)par les copepodes parasites dans les lacs de Tunis et de l'Ischkaul. *Rapports P - V Reun. Commn. int. Explor. scient . mer . Mediterr.* **27,4,** 126-129.

Benecke, B. (1881). *Fische, Fischerei und Fischqucht in Ost- und Westpreussen.* 183pp. Konigsberg (Kaliningrad, USSR):

Bengen, G., Kugler, J. and Pequignot, J. (1991). Étude des ovocytes d'*Alosa alosa* (Clupeidae) au cours de sa migration anadrome en Garonne. [Study of the ovocytes of *Alosa alosa* L. during spawning migration in the Garonne River]. *Cybium* **15,** 229-238.

Bengen, G. S. H. (1992). *Suivi de la migration gonadique des aloses, Alosa alosa L, lors de leur migration en Garonne.* 86 pp. Thèse de Doctorate. Toulouse: Institut National Polytechnique de Toulouse.

Bentzen, P., Leggett, W. C. and Brown, G. G. (1993). Genetic relationships between the shads (*Alosa*) revealed by mitochondrial DNA analysis. *Journal of Fish Biology* **43,** 909 917.

Berg, L. S. (1913a). (The Caspian herring collected during the expedition of 1912 along the western shore of the sea.) In Russian. *Materialy k Poznnaniyu Russkogo Rybolovstva.* **2,** 1-50.

Berg, L. S. (1913b). A review of the clupeoid fishes of the Caspian Sea, with remarkson the herring-like fishes of the Russian Empire. *Ann. Mag. Nat. Hist. Ser.* **8,** 472-480.

Berg, L. S. (1915). (A preliminary report on the herrings collected in the Caspian Sea by the Caspian expidition of 1913.) In Russian. *Materialy k Poznnaniyu Russkogo Rybolovstva.* **4,** 3-8.

Berg, L. S. (1933). Übersicht der Verbreitung der Süsswasserfische Europas 3. Clupeidae/Alosa. *Zoogeographia* **1,** 107-208.

Berg, L. S. (1948). *Fresh-water fishes of Soviet Union and adjacent countries.* 1. No.**27**, pp. 1-466.

Berg, L. S. (1962). *Freshwater fishes of the U.S.S.R. and adjacent countries. volume 1.* Jerusalem: Israel Program for Scientific Translation Ltd.

Berg, A., Borella, A. and Cocchi, M. (1965). *Statistical criteria and data processing procedures adopted for the study of two fish species.* **EUR 2545 e,** pp. 44. European Atomic Energy Community (EURATOM).

Berg, A. and Grimaldi, E. (1965). Biologia delle due forme di coregone (Coregonus sp.) del Lago Maggiore. *Memorie dell'Istituto Italiano di Idrobiologia* **18,** 25-196.

Berg, A. and Grimaldi, E. (1965). Ecological relationships between planktophagic fish species in the Lago Maggiore. *Verhein international Ver. Limnol.* 1065-1073.

Berg, A. and Grimaldi, E. (1966a). Biologia dell'Agone (*Alosa ficta lacustrus*) del Lago Maggiore. *Memorie dell'Istituto Italiano di Idrobiologia* **20,** 41-83.

Berg, A. (1966a). L'accrescimento annuale e stagionale dell'agone del Lago Maggiore. [Annual and seasonal growth of the shad "agone" of the Lago Maggiore]. *Memorie dell'Instituto Italiano di Idrobiologia* **20,** 58-78.

Berg, A. and Grimaldi, E. (1966b). Ecological relationships between planktophagic fish species in the Lago Maggiore. *Verhein International Verein. Limnol.* **16,** 1065-1073.

Berg, A. (1966b). Maturazione delle gonadi e riproduzione. *Memorie dell'Instituto Italiano di Idrobiologia* **20,** 79-83.

Berg, A. and Grimaldi, E. (1967). A critical interpretation of the scale structure used for the determination of annuli in fish growth studies. *Memorie dell'Istituto Italiano di Idrobiologia* **21,** 225-239.

Berg, A. (1972). Studies on the metabolism of calcium and strontium in FreshwaterFish. Calcium and strontium relationships in fishes of two Northern Italian Lakes and their general radioecological implications. *Memorie dell'Istituto Italiano di Idrobiologia.* **29,** 145-167.

Berg, R., Blank, S. and Strubelt, T. (1989). *Fische im Baden-Württemberg.* **158 S,** Ministerium für Ländlichen Raum, Ernährung, Landwirtschaft und Foresten Baden Württemberg.

Berg, R. (1995). Rote Liste - Gefährdete Fische und Neunaugen in Baden-Württemberg. In: *Fische in Baden Württemberg - Gefährdung und Schutz*. (Hoffmann *et al*.., eds.), 59 72. Stuttgart:Ministerium für Ländlichen Raum, Ernährung, Landwirtschaft und Foresten.

Berland, B. (1961). Nematodes from some Norwegian Marine Fishes. *Sarsia, Universitet I Bergen* **2,** 1-47.

Bernadi, R., Giussani, G., Manca, M. and Ruggiu, D. (1990). Trophic status and the pelic system in Lago Maggiore. *Hydrobiologia* **191,** 1-8.

Bernard, S. and Belaud, A. (1986). *Transfert d'aloses 1986 à Golfech. Expérimentations du système de piégeage définitif.* pp. 30. ENSAT.

Bernard, S. and Larinier, M. (1988). *Échantillonnages d'alosons dans les chambres anti vortex de l'usine hydro-électrique de Golfech.* pp. 32. CEMAGREF/CSP/Secrétariat d'État chargé de l'environnement.

Bernardeau, F. (1905). Pêche et reproduction du Saumon en Loire. . 51 pp. Berger Levrault & Cie

Berra, T. (1981). *An atlas of fish distribution of freshwater fish families of the world.*pp. 197. London: University of Nebraska Press.

Bertin, L. (1924). Poissons. In: *La Faune de la France en tableaux synoptiques illustrés de Perrier*. **10**, 2-81. Rémy.

Bertin, L. (1940). Catalogue des types des Poissons. *Bulletin de la Museum d'Histoire Naturel Paris* **2,** 6.

Bertin, L. (1949). La migration des aloses. In: *La vie des animaux*. I, 433. Paris:

Bertin, L. (1958). Squelette axial (des poissons). In: *Traite de Zoologie*. 13 (1), (Grasse, P.P. ed.), 688-709. Masson et Cie.

Bertrand, N. (1982). *Étude historique sur la remontée des poissons migrateurs dans le bassin de la Garonne.* Toulouse. Conseil Supérieur de la Pêche.

Bervoets, L., Coeck, J. and Verheyen, R. F. (1990). The value of lowland rivers for the conservation of rare fish in Flanders. *Journal of Fish Biology* **37,** 223-224.

Béchu, D., Blanchet, A., Tabardel, M., Menella, J. Y. and Gendre, L. (1995). *Suivi de la remontée des aloses au niveau de l'aménagement de Vallabrègues. Influence des conditions de milieu. Campagne d'études 1994.* **1994 N^{o}1/5,** 32 pp+ annexes. Association Migrateurs Rhône-Méditerranée.

Béchu, D., Blanchet, A., Tabardel, M., Menella, J. Y. and Gendre, L. (1995). *Etude préalable de franchissement par les aloses des écluses de navigation sur le Bas-Rhône. Plan Migrateurs Rhône-Méditerranée.* pp. 33. Association Migrateurs Rhône Méditerranée.

Bianco, P. G. and Taraborelli, T. (1988). I pesci rinvenibili in acqua dolce nelle isole mediterranee e presenza di Gasterosteus acul eatus del fenotipo semiarmatus in Sardegna. [Freshwater fishes from the Mediterranean islands and presence of *Gasterosteus aculeatus* (phenotype semiarmatus) from Sardinia island.]. *Bull. Ecol.* **19,** 247-254.

Bianco, P. G. (1989). *I pesci delle acque interne del Lazio.* 6, Rome: Regione Lazio. Piano pluriennale per la tutela della faune autoctona in vie di estinzione: Pesci. Regione Lazio, Assessorato Agricoltura.

Bianco, P. G. (1995). Mediterranean endemic freshwater fishes of Italy. *Biological Conservation* **72,** 159-170.

Bianco, P. G. (1998). Freshwater fish transfers in Italy: history, local changes in fish fauna and a prediction on the future of native populations. In: *Stocking and introductions of Fish*. (I. G. Cowx, ed.), 167-185. Oxford:Fishing News Books, Blackwell Science Ltd.

Bianco, P. G. (2002). The status of the Twaite shad, *Alosa agone* , in Italy and the Western Balkans. *Marine Ecology* **23 Supplement 1,** 51 - 64.

Billard, R. (1997). *Les poissons d'eau douce des rivières de France. Identification, inventaire et répartition des 83 espèces.* pp. 192. Laboratoire d'Ichthyologie Générale et Appliqué et le Service du Patrimoine Naturel de L'Institute d'Écologie et de Gestion de la Biodiversité, Muséum National d'Histoire Naturelle.

Bini, G. (1970). *Atlante dei pesci delle coste italiane.* **2**, . 48-54.

Biodiversity Steering Group. (1995). *The Biodiversity Steering Group Report.* Her Majesty Stationery Office HMSO.

Biousse, J., Kiener, A., Rameye, L. and Spillman, C. P. (1976). Aspects de la biologiede l'alose du Rhone: pêche et difficultés croissantes de ses migrations. *Bulletin Français de Pisciculture* **263,** 50-76.

Bird, D. J. (2002). *Environmental factors affecting migratory fish in the Severn Estuary with particular reference to species of shad and lamprey.* 66 pp. Bristol. University of the West of England.

Bishai, H. M. and Khalil, M. T. (1997). *Freshwater Fishes of Egypt.* **National Biodiversity Unit No. 9,** Egyptian Environmental Affairs Agency, Department of Natural Protectorate.

Blacker, R. W. (1969). Rare and unusual fish. *Transactions of the Suffolk Naturalists Society* **15,** 62-63.

Blacker, R. W. (1969). English observations on rare fish in 1968. *Annals Biology; Copenhagen* **25,** 257-259.

Blacker, R. W. (1975). English observations on rare fish in 1973. *Ann. Biol., Cons. Perm. Int. Explor. Mer., Copenh.* **30,** 208-209.

Blacker, R. W. (1977). English observations on rare fish in 1975. *Annals Biology, Copenhagen.* **32,** 184-185.

Blacker, R. W. (1977). English observations on rare fish in 1974. *Annals Biology, Copenhagen* **34,** 183.

Blackstock, T. H., Stevens, D. P. and Howe, E. A. (1996). Biological components of Sites of Special Scientific Interest in Wales. *Biodiversity and Conservation* **5,** 897-920.

Blanc, M., Banarescu, P., Gaudet, J. L. and Hureau, J. C. (1976). *European Inlandwater Fisheries.* London: Fishing News (Books) Ltd.

Blanchard, E. (1866). *Les poissons des eaux douces de la France.* 656 pp. Paris: J. B. Baillière et Fils.

Blanchard, E. (1880). *Les poissons des eaux douces de la France.*481 pp. Paris:

Blanco, J. C. and Gonzalez, J. L. (1992). *Libro rojo de los vertebrados de España.* Madrid. Serie Técnica, Instituto Nacional para la Conservación de la Naturaleza.

Bless, R. (1978). *Bestandsänderungen der Fishfauna in der Bundesrepublik Dueschland.* pp. 65. Greven: Kilda Verlage.

Bloch, M. E. (1783-1785). *Ökonomische Naturgeschichte der Fische Deutschlands.* I. 3, pp. 209. Berlin: Teil.

Board, C. F. (2000). *Carrick-on-Suir Urban Flood Relief Scheme: Report on mitigation investigations on status of shad (Alosa fallax) carried out in 1999-2000.* pp. 1-13. Dublin. Central Fisheries Board.

Bobori, D. C., Koutrakis, E. T. and Economidis, P. S. (2001). Shad species in Greek waters - an historical overview and present status. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 1101-1108.

Bocchi, G. D. (1965). La sagra dell'alosa. *Alieutica* **8,** 12-18.

Bocchi, G. D. (1965). La sagra dell'alosa. *Alieutica* **8,** 19-24.

Bochechas, J. (1995). *Preliminary data on Borland fish pass efficiency for non-salmonids in two Portuguese large rivers.* Proceedings of the International Symposium on Fishways'95 in Gifu. 377-383. Gifu, Japan.

Boddeke, R. (1974). *Vissen en vissen.* pp. 235. Amsterdam, Holland: Elsevier.

Boigontier, B. and Mounié, D. (1982). Etude des macro-organismes entraînes sur les filtres rotatifs de la centrale nucléaire du Blayais. *DEA. de l'ENSAT* 193 pp.

Boigontier, B. and Mounié, D. (1984). *Contribution à la connaissance de la dynamique de la macro-faune benthodémersale et pélagique en Gironde. Tentative et difficultés pour relativiser l'impact mécanique d'une centrale nucléaire: Le Blayais (Gironde).* 491 pp. + annexes. Thèse Doctorat 3e cycle. Toulouse: Université de Toulouse.

Boigontier, B., Filipozzi, P. and Taverny, C. (1985). *Etude de l'efficacité des nouveaux dispotifs de récupération des macro-organismes de la centrale nucléaire du Blayais (Gironde), Bordeaux.* CEMAGREF.

Boigontier, B. (1987). *Évaluation de l' impact du project de seuil et de recalibrage de l' Adour (Toulouzette) sur les populations piscicoles et principalement sur les aloses (août 1986 - juillet 1987).* 80 pp. Bordeaux. CEMAGREF div ALA Bordeaux / IIAH, bassin Adour.

Boigontier, B. (1988). *Bienvenue aux poissons migrateurs.* Plaquette CEMAGREF.

Boisneau, P. (1984). *Etude prélimimaire de la biologoe de la grande alose (Alosa alosa, L., 1758) de la Loire: activité de migration, biométrie et maturité sexuelle.* **32,** University of Paris Val de Marne ENPC/CSP Poiters.

Boisneau, P., Mennesson, C. and Baglinière, J. L. (1985). Observations sur l'activité de migration de la grande alose, *Alosa alosa L*, en Loire (France). [Observations on the migratory activity of shad *Alosa alosa* L. in the Loire (France)]. *Hydrobiologia* **128,**277 284. Boisneau, C., Boisneau, P. and Baglinière, J.-L. (1986). *Etude de la grande alose (Alosa alosa L.) dans le bassin de la Loire.*

Boisneau, P. (1988). *Les Aloses. In: Restoration des poissons migrateurs sur le Teritoire Francais.* Special **54,** Bull. liason du CSP.

Boisneau, P., Boisneau, C. and Baglinière, J.-L. (1989). *Migration et reproduction de la grande Alose (Alosa alosa L.) sur la Loire en 1988.* Rapport fin de contract. INRA, Rennes, Ministère de l'Environnement.

Boisneau, P., Mennesson-Boisneau, C. and Baglinière, J. L. (1990). Description d'une frayère et comportement de reproduction de la Grande Alose (*Alosa alosa* L.) dans le cours supérieur de la Loire. [Description of a spawning ground and reproductive behaviour of the allis shad (*Alosa alosa* L.) in the upper R. Loire]. *Bulletin Français de la Pêche et de la Pisciculture.* **316,** 15-23.

Boisneau, P. and Boisneau, C. (1990). *Migration de reproduction de la grande alose (Alosa alosa) le long de l'axe Loire et impact du seuil de St-Laurent des Eaux.* EDF, CPN St-Laurent des Eaux.

Boisneau, P. (1990). *Migration, répartition, reproduction et taxonomie des aloses (Alosa sp.) dans le bassin de la Loire.* 106 pp. Thèse de Docteur en sciences. Paris: University of Paris XII - Val de Marne.

Boisneau, P., Mennesson-Boisneau, C. and Guyomard, R. (1992). Electrophoretic identity between allis shad *Alosa alosa* L. and twaite shad , *Alosa fallax* (Lacépède). *Journal of Fish Biology* **40,** 731-738.

Boisneau, P. (1995a). *Connaissance de la migration des aloses dans le bassin de la Loire.* AAIPPBLB, DIREN/ Agence de l'eau?Conseil Régional Région Centre. 19 pp.

Boisneau, P. (1995b). *Estimation de l'abondance relative et des prélèvements de poissons migrateurs amphihihalins anadromes en Loire par lee pêcheries professionnelles continentales en 1994.* Minist. de l'Environnement/ AAIPPBLB/ AADPPMFLA 38 pp.

Boisneau, P. (1998). *Suivi de la migration de la grande Alose en Loire en 1997.* AAIPPBLB, DIREN / Agence de l'eau/ Conseil Régional Région Centre 19 pp.

Boisset, L. (1948). *Poissons des rivières de France.* 148 pp. Paris:

Borgea, M. I. (1933). *Livoneca pontica nov.Sp.* copépode parasite des aloses et sardines de la Mer Noire. *Bulletin de la Museum de Histoire Naturelle. (Paris)* **2,** 128-129.

Borne, M. V. D. (1882). *Die Fischerei-Verhältnisse des Deutchen Reiches, Öesterreich Ungarns, der Schweiz und Luxemburgs.* Berlin: Hofdrukerei W. Moeser.

Boulenger, G. A. (1900). Fishes. In: *The Victoria history of Hampshire and the Isle of Wight.* 1, 202.

Boulenger, G. A. (1901). Fishes. In: *The Victoria history of the County of Kent.* 1, 105 106.

Boulenger, G. A. (1902). Fishes. In: *The Victoria history of the County of Surrey.* (Maeden, H. E., ed.), 198.

Boulenger, G. A. (1907). The Fishes of the Nile. In: *Zoology of Egypt.* 578 pp. London:Hugh Rees Limited, London.

Boulenger, G. A. (1909). *Catalogue of the freshwater fishes of Africa in the British Museum (Natural History).* 1, London: Longmans & C0.

Bounhiol, J. P. (1917). Sur la biologie de l'Alose finte (*Alosa finta* Cuv.) des côtes d'Algérie. *Comp. Rend. Soc. Biol.* **80,** 480-483.

Bourgogne. (1988). *Rapport de synthèse.* Schème dèpartmental de vocation piscicole du Gard. Direction Dèpartmentale de l'Agriculture et de la Forêt du Gard/Ministère de l' Environnement/Conseil Supèrieur de la Pêche. Montpellier.

Bourquard, C. (1985). *Structure et mécanismes de mise en place, de maintien et d'évolution des peuplements ichthyique lagunaires du Golge du Lion.* 337 pp. Thèse de 3è cycle. Montpellier: Université des Sciences et techniques du Languedoc.

Boxshall, G. A. (1974). Infections with parasitic copepods in North Sea marine fishes. *Journal of the Marine Biological Association of the UK* **54,** 355-372.

Boyer-Bernard, S. (1997). *Étude des rythmes de migration des espèces amphibiotiques et holobiotiques de la Garonne au niveau de la station de contrôle de Golfech au cours de l'année 1996.* 31 pp. MI.GA.DO.

Böcking, W. (1982). *Nachen und Netze. Die Rheinfischerei zwischen Emmerich und Honnef - Werken und Wohnen.* 338 S, Köln: Rheinland - Verlag GmbH.

Bracken, J. and Kennedy, M. (1967). Notes on some Irish estuarine and inshore fishes. *Irish Fisheries Investigations, Series B (Marine)* **3,** 1-28.

Bravard, J. P. (1985). *Le Haut-Rhône français. Dynamique naturelle et impacts des travaux d'aménagement d'un fleuve et de sa vallée.* pp. 805. Lyon: University of Lyon III.

Bray, R. A. and Gibson, D. I. (1980). The Fellodistomidae (Digenea) of fishes from the NE Atlantic. *Bulletin of the British Museum of Natural History. (Zool)* **37,** 199-293.

Breder, C. M. and Rosen, D. E. (1966). *Modes of reproduction in Fishes.* pp. 85-86. Jersey City, New Jersey, U.S.A: T.F.H. Publications.

Brennan, D. (1963). The Allis and Twaite shads. *Angler's World.* **June, 1963,**

Brian, A. (1906). *Copepodi parassiti dei Pesci d'Italia.* 151 pp. Genoa:

Briocchi, A. (1896). *La pisciculture dans les eaux douces.* 325 pp. Paris: Bibliothèque des Sciences et de l'Industrie.

Bruce, J. R., Colman, J. S. and Jones, N. S. (1963). *Marine fauna of the Isle of Man.* Liverpool: Liverpool University Press.

Bruiant, L. (1991). *Valorisation de l'alose par la transformation.* 39 pp. Mémoire de DAA, Optio Halieutique ENSAR, IFREMER / CETEM.

Brunelli, G. (1926). Introduzione dell'agone del pesce persico e della pianuzza nelle acque dell'Italia centrale. *Boll.Pesca Piscic. Idrobiol* **2,** 3-5.

Brylinskiej, M. (2000). *Ryby stodkowodne Polski.* Warsaw: Wydawnictwo Naukowe PWN.

Buckland, F. T. and Walpole, S. (1879). *Report on the Sea Fisheries of England and Wales.* London. HMSO.

Buckland, F. (1880). *Natural History of British Fishes.* pp. 210-211. London: Society for promoting Christian Knowledge.

Buijse, T. and Cazemier, W. (1998). Fish. In: *Biological monitoring of national fresh waters: Water system report Rhine 1995.* (Bakker, C. Noordhuis, R. Prins, K.H. eds.),47 99.

Bukhanevich, I. B. (1986). Abundance control and prospects of increasing ichthyocoenosis production in the southeastern Caspian Sea. In: *Protection and development of fishery resources in the Caspian sea* (Khoroshko, A. I., Filippov, G. M., Vetchanin, V. I. , Khalilov, F. Sh. and Savenkova, T. P.eds.) 55-62.

Busch, D., Schröder, K. and Schuchardt, B. (1982). *Der Niedergang der Flußfischerei auf der Unterweser.* **Projektbericht FB2,** pp. 273. Bremen. Universität Bremen.

Busch, D., Haeslop, U., Scheffel, H.-J. and Schirmer, M. (1988). Fish and their environment in large european river ecosystems The river Weser, FRG. *Sciences de L'eau* **7,** 75-94.

Busch, D., Schirmer, M., Schuchardt, B. and Ullrich, P. (1989). Historical changes of the River Weser. In: *Historical Change of Large Alluvial Rivers: Western Europe* (Petts, G. E., Möller, H. and Roux, A.L., eds.), 297-321. Chichester:John Wiley & Sons Ltd.

Bürger, F. W. (1926). Die Fischereiverhältnisse im Bereich der preussischen Rheinprovinz. *Z. Fischerei* **24,** 217-399.

Bychowsky, B. E. (1957). *Monogenetic Trematodes their Systematics and Phylogeny.* Washington: American Institute of Biological Sciences.

Comité de gestion des poissons migrateurs du bassin R. M. C. (1995). *Plan de gestion des poissons migrateurs 1995-1999.* 33 pp + annexes. Unpublished Rapport de synthèse.

Cacutt, L. (1979). Lampreys, sturgeon, eel, shad and burbot. In: *British freshwater fishes: the story of their evolution*. 73-74. London:Croom Helm.

Canestrini, L. (1866). *Prospetto critico dei pesci d'acqua dolce d'Italia.* pp. 97. Modena: Soliani.

Canestrini, G. (1874). *Fauna d'Italia.* 22 pp. Milano:

Canestrini, R. (1885). *I pesci del Tretino e la pesca.* Rovereto - Tipografia roveretana.

Capello, F. B. (1880). *Catálogo dos Peixes de Portugal.* Catalogue Academia Real Sciencias de Lisboa.

Cara, A. (1912). Lista di animali eduli che suoglionsi vendere nel mercato di Cagliari e annotazoni relative. *Tip. Industriale Cagliari* **13,**

Carette, A. (1999). *La petite histoire de la grande alose et de la réserve d'Agen.* 31 pp.. Agen. Rapport de l'Association pour la Gestion de la Réserve naturelle de la Frayère d'Alose.

Carr, J. W. (1906). Fishes. In: *The Victoria history of the Counties of England Nottinghamshire*. (Page, W. ed.), 153.

Carstairs, M. A. S. (1998). *The ecology and conservation of Allis and Twaite shad.* M.Sc. Desk Study. University of Wales, College of Cardiff.

Carstairs, M. (2000). The ecology and conservation of Allis and Twaite Shad. *British Wildlife* **11,** 159-166.

Carus, J. V. (1893). *Prodromus Faunae Mediterraneae.* II, 552 pp.. Stuttgart:

Carvalho, F., Alexandrino, P., Ferrand, N. and Rocha, J. (1992). Polimorfismo genético da hemoglobina em sável (*Alosa alosa* L.) e savelha (*Alosa fallax* Lacépède). Resultas preliminares sobre a distribuição das frequências génicas em differentes populaçoes. *Journadas de Genética Luso-Espanholas* **XXVII,**

Casabianca, M. l. d., Kiener, A. and Huvé, H. (1972-1973). Biotopes et biocénoses des etangs saumâtres corses: Biguglia, Diana, Urbino, Palo. *Vie et milieu* **23,** 187-227.

Casalis, G. (1936). *Dizionario Geografico Storico Statistico Commerciale delgi Stati di S.M. il Re di Sardegna.* Torrino:

Cassou-Leins, F. and Cassou-Leins, J. J. (1979). Situation de l'alose (*Alosa alosa* L) dans la bassin de la Garonne. 18 pp.

Cassou-Leins, F., Cassou-Leins, J. J. and Labat, R. (1980). Rapport des recherches effectuées sur *Alosa alosa* durant la campagne de migration 1980. *ENSA Toulouse.* 16 pp.

Cassou-Leins, F. and Cassou-Leins, J. J. (1981). *Recherches sur la biologie et l'halieutique des migrateurs de la Garonne et principalement de l'alose, Alosa alosa L. [Research on the biology and halieutics of migratory species in the Garonne, mainly of Alosa alosa L.].* 382 pp. Thèse de Doctorate 3ème Series. Toulouse: Institute National Polytechnique de Toulouse.

Cassou-Leins, F. and Cassou-Leins, J. J. (1985). *Réserve naturelle de la frayère d'alose. Étude de l'halieutique et de la reproduction de l'alose. Campagne 1985.* 12 pp. Toulouse. ENSA.

Cassou-Leins, F. and Cassou-Leins, J. J. (1986). *Etude de la reproduction de l' alose.* ENSAT.

Cassou-Leins, F. and Cassou-Leins, J. J. (1986). *Réserve naturelle de la frayére d'alose campagne 1986, étude de la reproduction de l'alose.* **12,** ENSAT.

Cassou-Leins, F., Cassou-Leins, J. J., Dauba, F. and Lejolivet, C. (1986). *Réserve naturelle de la frayère d'Alose: Etude des oeufs de la grande Alose (Alosa alosa L.): répartition et dérive, taux de mortalité, influence des pollutions.* 12 pp. Toulouse. ENSAT.

Cassou-Leins, J. J. (1987). *Suivi de la réserve naturelle de la frayère d'alose année 1987.* 14 pp. + Annexes. Rapp. Dép. Lot et Garonne /DDE /ENSAT.

Cassou-Leins, J. J. (1988). *Suivi de la réserve naturelle de la frayère d'alose. Année 1988.* 47 pp.. Rapp. Dép. Lot et Garonne/DDE /ENSAT.

Cassou-Leins, F., Dauba, F. and Lejolivet, C. (1988*). Etude des oeufs de la grande alose (Alosa alosa L.). Répartition et dérive. Taux de mortalité. Influence des pollutions*. 12pp. ENSAT.

Cassou-Leins, F., Dauba, F. and Lejolivet, C. (1988). *Etude de l'alevin d'Alosa alosa L. Répartition. Croissance. Régime alimentaire.* ENSAT - Lycée Agricole Montauban 24 pp.

Cassou-Leins, J. J. and Carette, A. (1988). *Réserve naturelle de la frayère d'alose d'Agen: synthèse.* 30 pp. Rapport Assoc. de la Réserve naturelle de la Frayère d'Alose.

Cassou-Leins, F., Cassou-Leins, J. J., Dauba, F. and Lejolivet, C. (1988a). *Réserve naturelle de la frayère d'alose d'Agen, campagne 1988 étude d l'alevin d'alose Alosa alosa L, réparition, croissance, régime alimentaire.* 24 pp. + annexes. Rapp. Lycée Agricole de Montauban / ENSAT.

Cassou-Leins, J. J. and Carette, A. (1989). *Suivi de la réserve naturelle de la frayére d'alose. Année 1989.* 18 pp. ENSA Toulouse-Direction Départementale de l' Équipement Agen.

Cassou-Leins, F. and Cassou-Leins, J. J. (1990). *Réserve naturelle de la frayère d' aloses. Synthése quinquennale et observations complémentaires sur l'Alose, sa reproduction, les larves, les alosons, le milieu.* 57 pp. Toulouse. ENSAT.

Cassou-Leins, J. J., Carette, A. and Dulau, S. (1990). *Suivi de la réserve naturelle de la frayère d'alose. Année 1990. Étude de la reproduction de l'alose.* 40 pp. ENSA Toulouse Direction Départementale de l' Équipement Agen.

Cassou-Leins, F. and Cassou-Leins, J. J. (1990). *La frayère d'alose feinte (Alosa fallax) de Tartifume. Étude du milieu et de la reproduction.* 34 pp. ENSA Toulouse-Lycée Agricole Montauban.

Cassou-Leins, F. and Cassou-Leins, J. J. (1990). *Étude de la dévalaison des juvéniles d'Alosa alosa L., au cours de la campagne 1990.* 31 pp. ENSAT.

Cassou-Leins, J. J. and Carette, A. (1991). *Suivi de la réserve. Année 1991.* 10 pp. Agen. Comité de gestion de la Réserve Naturelle de la frayère d'alose.

Cassou-Leins, J. J. and Carette, A. (1992). *Suivi de la réserve d'alose d'Agen. Année 1992.* 6 pp. Agen. ENSA Toulouse-Lycée Agricole Montauban-Direction Départementale de l' Équipement Agen.

Cassou-Leins, J. J. and Carette, A. (1993). *Réserve naturelle de la frayère d'alose d'Agen. Campagne 1993. Étude de la reproduction de l'alose..* 6 pp. Agen. ENSA Toulouse Lycée Agricole Montauban-Cellule de L'Eau Agen.

Cassou-Leins, J. J. and Carette, A. (1994). *Réserve naturelle de la frayère d'alose d'Agen. Campagne 1994. Étude de la reproduction de l'alose.*16 pp. Agen. ENSA Toulouse Lycée Agricole Montauban-Cellule de L'Eau Agen.

Cassou-Leins, J. J. (1995). *L'alose de l'Aude. Suivi de la reproduction (1983-1995). Eléments de réflexion pour une décision d'arrêté de biotope.* 11 pp. ENSA Toulouse Association Migrateurs Rhône-Méditerranée.

Cassou-Leins, J. J. and Carette, A. (1995). *Réserve naturelle de la frayère d'alose d'Agen. Reproduction. Année 1995. Étude de la reproduction de l'alose.* 9 pp. Agen. ENSA Toulouse-Direction Départementale de l' Équipement Agen.

Cassou-Leins, J. J., Cassou-Leins, F., Boisneau, P. and Baglinière, J. L. (2000). La reproduction. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations.* (Baglinière, J. L. and Elie, P. eds.), 73-92. Paris: NRA-CEMAGREF.

Castelnaud, G. (1978). *Etude de la pêche aux filets et aux engins dans l'estuaire de la Gironde.* 189 pp. Thèse de Doctorat de 3ème cycle analyse et aménagement de l'espace. Bordeaux: University of Bordeaux III.

Castelnaud, G., Clement, O., Trouvery, M. and Verdilhac, P. d. (1980). *La pêche dans l'estuaire de la Gironde (France): Ses particularités et ses problèmes. [Fishery in the Gironde Estuary, France: Its characteristics and problems.].* Technical Consultation On Allocation Of Fishery Resources (Sponsored by EIFAC). 34-36. Vichy, France. FAO of the UN in co-operation with American Fisheries Society.

Castelnaud, G., Trouvery, M. and De Verdilhac, P. (1981). *La pêche des poissons migrateurs dans le bassin Garonne-Dordogne, 2. Evaluation de la production au moyen de carnets de pêche.* Actes du XXVIe Congrès A.F.L. 242-246. Orleans.

Castelnaud, G. and De Verdilhac, P. (1982). *Etat de la production des pêches d'estuaires: importance de cette évaluation et méthodologie.* Colloque sur la production et la commercialisation du poisson d'eau douce. **13 and 14**, 98-107. Dijon. Ass. Internat. Des Entretiens Ecologiques.

Castelnaud, G., Cerezuelle, D., Guchan, A. and Rochard, E. (1985). *La pêche des migrateurs en Gironde, deuxieme partie. Enquête socioprofessionnelle et propositions de gestion.* 110 pp. Bordeaux. CEMAGREF de Bordeaux Div. ALA.,MSHA./ Ministère Environnement.

Castelnaud, G., Coutancier, B., Cerezuelle, D. and Guchan, A. (1985). *La pêche des migrateurs en Gironde 1ère partie: Analyse historique: du 18 ème siècle à nos jours: bilan et perspectives.* 177 pp. + annexes. Bordeaux. CEMAGREF de Bordeaux, Division ALA/MSHA/Ministère de l'Environnement/Département de la Gironde.

Castelnaud, G., Coutancier, B., Cerezuelle, D., Guchan, A. and Rochard, E. (1986). *La pêche des migrateurs de Gironde : Analyse historique du XVII ème siècle à nos jours. Enquête socioprofessionnelle et propositions de gestion (Document de synthèse).* CEMAGREF de Bordeaux, Div. A.L.A./D.P.N./M.S.H.A.

Castelnaud, G. and Babin, D. (1990). *La pêche professionnelle aux filets et aux engins dans les eaux continentales français. 2^{e} partie: les bassins Rhône-Saône-Doubs, Rhin, Somme, Charente, Garonne- Dordogne-Adour, et les lacs alpins.* 141 pp.. Bordeaux. CEMAGREF Bordeaux / Ministère Environnement.

Castelnaud, G. and Babin, D. (1992). La pêche professionnelle fluviale et lacustre en France. Enquête au fil de l'eau. In: *Colloque Études. Ressources en Eaux.* 291pp.. CEMAGREF Bordeaux / Ministère Environnement.

Castelnaud, G. and Rochard, E. (1993). *Surveillance halieutique des migrateurs de l'estuaire de la Gironde. Suivi statistique 1991; étude de la faune circulante 1992.* 156 pp. Bordeaux. CEMAGREF de Bordeaux AP / EDF-CPN Blayais.

Castelnaud, G. and Rochard, E. (1994). *Setting up of a statistical system in the Gironde basin (France). First results on allis shad Alosa alosa (1982-1991).* Symposium and Workshop on 'Stock assessment in inland fisheries'. Hull.

Castelnaud, G. and Rochard, E. (1994a). *Surveillance halieutique de l'estuaire de la Gironde: suivi statistique 1992; étude de la faune circulante 1993.* 155 pp. Bordeaux. CEMAGREF Bordeaux AP / EDF-CPN Blayais.

Castelnaud, G. and Rochard, E. (1997). *Surveillance halieutique de l'estuaire de la Gironde: suivi statistique 1995 - étude de la faune circulante 1996.* **N° 25,** 152 pp. Bordeaux. CEMAGREF de Bordeaux / EDF.

Castelnaud, G., Lambert, P. and Rochard, E. (1998). *Surveillance halieutique des migrateurs de l'estuaire de la Gironde. Suivi statistique 1996; étude de la faune circulante en1997.*169 pp. Bordeaux. CEMAGREF de Bordeaux / EDF.

Castelnaud, G., Rochard, E. and Gazeau, C. (1999). *Surveillance halieutique de l'estuaire de la Gironde - suivi des captures 1997 - Étude de la faune circulante 1998.* **41,** 172 pp. Bordeaux. CEMAGREF Groupement de Bordeaux.

Castelnaud, G. (2000). Localisation de la pêche, effectifs de pêcheurs et production des espèces amphihalines dans les fleuves français. *Bulletin Français de la Pêche et de la Pisciculture* **357 / 358,**

Castelnaud, G., Rochard, E. and Le Gat, Y. (2001). Analyse de la tendance de l'abondance de l'alose *Alosa alosa* en Gironde à partir de l'estimation d'indicateurs halieutiques sur la période 1977-1998. [Abundance trend analysis of the allis shad *Alosa alosa* in the Gironde basin during the 1977-1998 period on the basis of estimated fishing indicators.]. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 989-1015.

Castelnaud, G. (2001). Localisation de la pêche, effectifs de pêcheurs et production des espèces amphihalines dans les fleuves français. *Bulletin Français de la Pêche et de la Pisciculture* **357/360,** 439-460.

Castelnaud, G., Girardin, M. and Rochard, E. (2001). *Surveillance halieutique de l'estuaire de la Gironde - Suivi des captures 1999 - Etude de la faune circulante 2000.* Rapport pour EDF CNPE du Blayais/ Etude Cemagref, groupement de Bordeaux. **71,**186 pp. Bordeaux. CEMAGREF.

Castro, F., Linhares, D. and Alexandrino, P. (1999). Acid Phosphatase Polymorphism in European Shad (Fish: Clupeids). *Biochemical Genetics* **37,** 251-256.

Caswell, P. A. and Aprahamian, M. W. (2000). *Physical characteristics of the spawning habitat of twaite shad (Alosa fallax fallax).* Freshwater Fish Conservation: Options for the Future. Algarve, Portugal. Unpublished

Caswell, P. A. and Aprahamian, M. W. (2001). Use of river habitat survey to determine the spawning habitat characteristics of twaite shad (*Alosa fallax fallax*). *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 919-929.

Cattoen, M., Larinier, M. and Thomas, N. (1999). Système et logiciels pour la surveillance des passes à poissons.[System and related software for monitoring fish passes]. *Bulletin Français de la Pêche et de la Pisciculture* **353/354,** 263-277.

Cazemier, W. G. (1988). Fish and their environment in large european river ecosystems. The dutch part of the River Rhine. *Sciences de l' Eau* **7,** 95-114.

Centre Technique de Genie Rural des Eaux et Forets (1977). *Preliminary observations on fishing resources in the Gironde estuary.* **1,** Ann. Cent. Tech.

Cetti, F. (1777). *Anfibi e pesci di Sardegna.* Sassari:

Chaine, J. (1938). Recherches sur les otoliths des poissons étude descriptive et comparative de la sagitta des Téléostéens. *Actes de la Société Linnéenne de Bordeaux* **89,** 166-182.

Champalbert, E. (1998). *Inventaire des frayères potentielles d'aloses sur les bas et moyens Gardons. Campagne d'études 1996.* **1996 N^{o}3/8.,** pp. 54p + annexes. EVI. Association Migrateurs Rhône-Méditerranée.

Changeux, T. and Zylberblat, M. (1989). *La pêche professionelle et amateur aux engins. Schéme de vocation piscicole du fleuve Rhône.* **7,** Ministére de l' Environment/Delegation de Bassin Rhône Mediterranee Corse/Service de la Navigation Rhône Saône.

Changeux, T. and Zylberblat, M. (1993a). Analyse des statistiques de pêche aux engins dans le bassin du Rhône. Première partie: étude de l'effort de pêche. [Analysis of fishing gear fishery statistics in the Rhone River basin. Part one: Study of the effort]. *Bulletin Français de la Pêche et de la Pisciculture* **330,** 245-269.

Changeux, T. and Zylberblat, M. (1993b). Analyse des statistiques de pêche aux engins dans le bassin du Rhône. Seconde partie:étude des captures. [Analysis of fishing gear fishery statistics in the Rhone River basin. Part two: Study of the catch.]. *Bulletin Français de la Pêche et de la Pisciculture* **330,** 271-294.

Changeux, T. and Pont, D. (1995). Current status of the riverine fishes of the French Mediterranean Basin. *Biological Conservation* **72,** 137-158.

Chanseau, M., Dartiguelongue, J. and Larinier, M. (2000). *Analyse des données sur les passages enregistrés aux stations de contrôle des poissons migrateurs de Golfech et du Bazacle (Garonne) et de Tuilières (Dordogne).* 63 pp. Rapport MI.GA.DO. GHAAPPE.

Chapuis, M. (1958). La pêche de l'alose au Maroc. *Fishing Game Club du Moyen-Atlas* **4,** 14-16.

Chapuis, M. (1975). L'alose au Maroc. *Nature Forets* **5,** 50-53.

Chavanne, J. and Chantelat, J.-C. (1994). *Faszination Sportfischen. Ein Handbuch für die Praxis.* pp. 1-271. München: Copress Verlag GmbH.

Chereshnev, I. A. (1990). Ichthyofauna composition and features of freshwater fish distribution in the northeastern USSR. *Journal of Ichthyology* **30,** 110-121.

Chiappi, T. (1933). *La pesca e la piscicultura nella provincia di Roma.* 28pp. Roma. Consorzio Provinciale Economico.

Chiappi, T. (1933a). Note su alcuni stadi di sviluppo dell'agone, introdotto nei laghi laziali e della cheppia del Tevere. *Bolletino di Pesca Piscicoltura e Idrobiologia* **9,** 1052 1061.

Chiaudani, G. and Marchetti, R. (1984). Po. In: *Ecology of European rivers*. (B. A. Whitton, ed.), 402-429. Oxford:Blackwell Scientific Publications.

Chiaudani, G. and Premazzi, G. (1990). *Il lago di Garda, Evoluzione trofica e condizioni ambientali.* **EUR 12925 IT,** Commissione delle Comunita Europee. Lussemburgo.

Chmielewski, S. (1965). From the history of frsh-water fisheries in Poland. In: *Fresh water Fisheries of Poland.* XV! Limnologorum Conventus in Polonia MCMLXV, (Backiel, T. ed.), 5-13. Cracow:Polish Academy of Sciences Hydrobiological Committee.

Cihar, J. (1993). *Guide des poissons d'eau douce en Europa.* pp. 184. Paris: Hatier.

Ciolac, A. and Razlog, G. (1995). The influence of some medium factors on *Alosa pontica* captures in the lower Danube. In: *Aquaculture and fishing. Extended abstracts and papers of contributions presented at the international symposium : Aquarom '95 Galati - Romania 18 -- 22 September 1995.* (Rauta, M and Oprea, L. eds.), 57-60. Galatia:Universitatea "Dunarea de Jos" Galatia and Asociatia Piscicultorilor si Pescarilor din Romania.

Clabburn, P. A. T. (2002). *Monitoring shad migrating in the Wye. Results from the Redbrook acoustic counter: 2000.* **TM/EASE/02/09,** pp. 5 pp. Cardiff. Environment Agency in Wales.

Claridge, P. N. and Gardner, D. C. (1978). Growth and movements of the twaite shad, *Alosa fallax* (Lacépède), in the Severn Estuary. *Journal of Fish Biology* **12,** 203-211.

Claridge, P. N., Potter, I. C. and Hardisty, M. W. (1986). Seasonal changes in movement, abundance, size, composition and diversity of the fish fauna of the Severn Estuary. *Journal of the Marine Biology Association* **66,** 229-258.

Clausse, P. (1982). *Contribution à l'étude de la biologie de la grande alose (Alosa alosa, L. 1758) de la Garonne.* Mémoire de fin d'études E.N.I.T.E.F. **69,** CEMAGREF div ALA.

Clover, C. (1997). There's new life in Old Father Thames. *Daily Telegraph.* Monday October 27th. 10.

Colclough, S. R., Gray, G., Bark, A. and Knights, S. (2002). Fish and fisheries of the tidal Thames: management of the modern resource, research aims and future pressures. *Journal of Fish Biology* **61 (Supplement A),** 64-73.

Collares-Pereira, M. J., Cowx, I. G., Sales Luis, T., Pedrosa, N. and Santos-Reis, M. (1999). Observations on the ecology of a landlocked population of allis shad in Aguieira Reservoir, Portugal. *Journal of Fish Biology* **55,** 658-664.

Collares-Pereira, M. J., Cowx, I. G., Ribeiro, F., Rodrigues, J. A. and Rogado, L. (2000). Threats imposed by proposed water resource development schemes on the conservation of endangered fish species in the Gaudiana River Basin in Portugal. *Fisheries Management and Ecology* **7,** 167-178.

Colossi, G. (1928). Caratteri faunistica della Sardegna. *L'Universo* **9,**

Confortini, I. (1998). *Evoluzione della comunita ittica del lago di Garda. Situazione attuale e passata.* pp. 77-86. Regione Liguria, Prov. della Spezia. ATTI 6 Conv. AIIAD.

Conseil, Général des Pêches pour la Méditerranée (1982). *Rapport de la premiére Consulation Technique sur l'Evaluation des Stocks dans la Méditerranée Centrale. Tunis, 19-23 Avril 1982.* **Rapp. Pêches 266,** 125pp. Rome. FAO.

Cope, K. (1979). *The Angling Times Book of the Severn.* Devon: David & Charles Limited, Brunel House, Newton Abbot.

Coppola, S. R., Fischer, W., Garibaldi, L., Scialabba, N. and Carpenter, K. E. (1994). *SPECIESDAB: Global species database for fishery purposes. User's manual.* **9**,103 pp. Rome: FAO.

Correia, M. J., Costa, J. L., Teixeira, C., Almeia, P. R., Domingos, I. and Costa, M. J. (2001). Feeding habits and condition of two landlocked populations of allos shad (*Alosa alosa*) in Portugal. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 823-835.

Costa, M. J. (1986). Les poissons de l' estuaire du Tage. *Cybium* **10,** 57-75.

Costa, F. (1991). *Atlante ei pesci dei mari italiani.* S.P.A.

Costa, M. J., Almeia, P. R., Domingos, I. M., Costa, J. L., Correia, M. J., Chaves, M. L. and Teixeira, C. M. (2001). Present status of the main shads' populations in Portugal. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 1109-1116.

Costa, M. J., Cabral, H. N., Drake, P., Economou, A. N., Fernandez-Delgado, C., Marchand, J. and Thiel, R. (2002). Recruitment and production of commercial species in estuaries. In: *Fishes in Estuaries*. (Elliott, M. and Hemingway, K. eds.), 54-123. Oxford:Blackwell Science.

Costello, M., Elliott, M. and Thiel, R. (2002). Endangered and rare species. In: *Fishes in Estuaries*. (Elliott, M and Hemingway, K. eds.), 217-265. Oxford:Blackwell Science.

Cottiglia, M. (1963a). Studi sull'ittiofauna dulciacquicola della Sardegna. I. L'alosa migratice del Tirso. *Bollettino di Pesca Piscicolture E Idrobiologia* **18,** 15-38.

Cottiglia, M. (1963b). Studi sull'ittiofauna dulciaquicola della Sardegna - II L'Agone del Lago Omodeo. *Bollettino di Pesca Piscicoltura e Idrobiologia* **18,** 125-142.

Cottiglia, M. (1965). Sur la distribution de la ichthyiofaunedulciacquacole en Sardinia. *Comm. int. Explor. sci. M. Médit. Rapp. P. V.* **XVIII,**

Cottiglia, M. (1965). La distribzione dell'ittiofauna dulciacquicola in Sardegna. *Riv. Idriobiol. Piscic., Perugia* **7,** 63-116.

Cottiglia, M. and Mascia, C. (1967). Acque Lacustris in Sardegna. In: *Il problema delle acque in Italia. Parte II: Le acque dolci superficali*. Milano:

Cottiglia, M. (1968). La distribuzione della ittiofauna dulciacquicola in Sardegna.[The distribution of freshwater fishes in Sardinia]. *Rivista di Idrobiologia* **VII,** 63-116.

Cottiglia, M. (1969). L'*Alosa_* del Flumendosa. *Boll. Zool.* **35,** 361-362.

Cottiglia, M. (1969 (1970)). Nuovi dati sullà biologia e sulla sistematica di *Alosa fallax Lac.* della Sardegna. *RC. Semin. Fac. Sci. Univ. Cagliari.* **39,** 351-365.

Cottiglia, M., Mascia, C., Melis, M., Porcu, M., Roni, C. and Tagliasacchi Masala, M. L. (1982). Concentrazione ed accumulo di metalli pesanti in alcuni compomenti di un ecosistema lacustre [Concentration and accumulation of heavy metals in some components of a lacustrine ecosystem]. *Rivista di Idrobiolgia.* **21,** 125-152.

Couch, J. (1877). *A history of the fishes of the British Islands.* IV, London: Bell, G.

Couderc, J. M. (1970). *Etude ichthyogéographique de la Touraine.* 93rd Congrès Nat. des Soc. Savantes, Géographie. 137-174.

Coull, K. A., Jermyn, A. S., Newton, A. W., Henderson, G. I. and Hall, W. B. (1989). *Length/Weight relationships for 88 species of fish encountered in the North East Atlantic.* **43,** 80 pp. Scottish Fisheries Research Report.

Coupaye, N. and Boisneau, P. (1996). *Variabilité de l'abondance de la grande alose (Alosa alosa L. 1758) dans le Loire: mise au point d'un indicateur à partir des données acquises depuis 1984 et intégrant les années 1995 et 1996, analyses des variations inter annuelles enrelation avec les facteurs environnementaux et anthropiques.* AAIPPBLB< DIREN/Agence de l'eau / Conseil Régional Région Centre 33 pp..

Coward, T. A. (1910). *The Vertebrate Fauna of Cheshire and Liverpool Bay.* 2, London: Witherby & Co.

Cowx, I. G. and Collares-Pereira, M. J. (2000). Conservation of endangered fish species in the face of water resource development schemes in tthe Guadiana River, Portugal: harmony of the incompatable. In: *Management and Ecology of River Fisheries*. (Cowx, I G. ed.), 428-438. Oxford:Fishing News Books. Blackwell Science Ltd.

Crespo, J., Gajate, J. and Ponce, R. (2001). *Clasificación cientifica e identificación de nombres vernáculos existentes en la base de datos de seguimiento informático de recursos naturales oceánicos.* Madrid: Instituto Espanol de Oceanografia.

Cristea, A., Iorga, M., Demetriuc, B. and Teodor, V. (1980). Some Considerations About the Biology of the Danubian Herring (*Alosa pontica* , Eichw.) Migrating Into Danube River for Spawning. Contributii cu Privire la Biologia Scrumbiei de Dunare (*Alosa pontica* Eichw.), Care Migreaza in Dunare Pentru Reproducere. *Bull.-Cercet. Piscic.- Ser.-Noua* **1,** 85-96.

Crivelli, A. J. and Poizat, G. (2001). Timing of migration and exceptional growth of YOY *Alosa fallax rhodanensis* (Roule, 1924) in a lagoon in southern France. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 761-772.

Cruz, O. (1989). *Rapport de synthèse.* Schème Départmental de vocation piscicole de l'Hérault Direction Départmentale de l'Agriculture et de la Forêt de l'Hérault/Ministère de l' Environnement/ Conseil Supérior de la Pêche. Montpellier.

CTGREF. (1977). *Premières observations sur les resources halieutiques de l'estuaire de la Gironde.* Annual **1 - 84p,** CTGREF. Division A.L.A.

CTGREF. (1980). *Situation de la pêche aux filets et aux engins en Gironde. Etude générale de l'impact des extractions de granulats sur les espèces migratrices et la pêche dans la Dordogne.* CTGREF.

CTGREF. (1981). *Migration des aloses dans le bas-Rhône: observations effectuées en 1979 et 1980 [Migration of shad in the Lower Rhône: observations made in 1979 and 1980.].* Unpublished report, 10 pp.

Cunningham, J. T. (1891-92). On the rate of growth of some sea fishes, and the age and size at which they begin to breed. *Journal of the Marine Biology Association* **II,** 222-264.

Cunningham, J. T. (1895). Experiments and observations made at the Plymouth laboratory. *Journal of the Marine Biology Association* **3,** 247-277.

Cunningham, J. T. (1896). *The Natural History of the Marketable Marine Fishes of the British Islands.* MacMillan and Co. Ltd.

Cunningham, J. T. (1903). Fishes. In: *The Victoria history of the County of Devon.* 1, 277.

Cunningham, J. T. (1906). Fishes. In: *The Victoria history of the County of Cornwall.* 1, (Page, W. ed.),

Cunningham, J. T. (1911). Fishes. In: *The Victoria history of Suffolk.* (Page, W. ed.), 170.

Curry-Lindahl, K. (1957). *Fiskarna i Färg.* Stockholm: Almqvist & wiksell.

Cuvier, G. (1817). *Le règne animale.* **2**, 319 pp. Paris: Deterville.

Cuvier, G. (1829). *La règne animals distribué d'aprés son organisation, pour servir de base à l'histoire naturelle des animaux et d'introduction à l'anatomie comparée.* pp. 406. Paris: Deterville.

Cuvier, G. and Valenciennes, A. (1847). *Histoire naturelle des poissons.* **20**, 472 pp. Paris: Bertrand.

Cuvier, G. (1863). *The Animal Kingdom, arranged according to its organization.* London and New York: Henry G. Bohn.

D'Ancona, U. (1925). Richerche sull'accrescimento e sulla maturità sessuale dell'*Alosa finta* (Cuv.). *Rendiconti della R. Accademia Nazionale dei Lincei* **1,** 43.

D'Ancona, U. (1926). Richerche sulla riproduzione dell'*Alosa finta* (Cuv.). *Rendiconti della R. Accademia Nazionale dei Lincei* **4,** 333-335.

D'Ancona, U. (1927). Il problema dell'accrescimento dei pesci studiato sull'*Alosa finta* del Tevere [Tiber]. *Atti. Acad. naz. Lincei Memorie.* **2,** 494-540.

D'Ancona, U. (1927a). Sul valore sistematico delle unità morfologiche di numero variabile ed in particolare modo sulla sistematica delle Alose méditerranée.(On the systematic value of the variable number in morphological units with special reference to the Mediterranean *Alosa*). *Monitore Zoologico Italiano* **38,** 187-191.

D'Ancona, U. (1927b). *Notizie sulla biologia dell' Alosa finta Cuv. del bacino del Tevere.* pp. 19. Madrid. ministero de Marina, Direccion General de Pesca. Notas y Resumenes Inst. Esp. Ocean. Serie 2.

D'Ancona, U. (1927c). L'accrescimento dell'alosa del Tevere [Tiber]. *Rendiconti della R. Accademia Nazionale dei Lincei* **5,** 214-219.

D'Ancona, U. (1928a). La biologia dell'Alosa del Tevere in confronto a quella di altre regioni. (The biology of the *Alosa* from the Tiber in comparison with *Alosa* from other regions). *Int. Revue Ges. Hydrobiol. Leipzig* **20** (5/6), 430-456.

D'Ancona, U. (1931). Clupeidae. *Fauna Flora Napoli, Monogr.* **38,** 1-16.

Dando, P. R. (1969). Lactate metabolism in fish. *Journal of the Marine Biology Association* **49,** 209-223.

Dartiguelongue, J. (1987). *Suivi de la migration des aloses à Golfech en 1987. Expérimentations du dispositif de transport des poissons.* 71 pp. Assoc. Toulousaine d'Ichtyologie Appliquée.

Dartiguelongue, J. (1988). *Mise au point du dispositif de transfert des poissons à Golfech. Suivi de l'activité ichtyologique en 1988.* ATIA 57 pp.

Dartiguelongue, J. (1990a). *Suivi de l'efficacité de la passe à poisson au barrage de St-Léger-des-Vignes sur la Loire en 1989.*

Dartiguelongue, J. (1990b). *Suivi de la migration de dévalaison et de montaison à la passe à poissons du Ramier au printemps 1990.(Monitoring the downstream and upstream migration at the Ramier fish passage facility in spring 1990).* 41 pp. CSP.

Dartiguelongue, J. (1991). *Contrôle du fonctionnement et de l'efficacité des passes à poissons installées au Bazacle en 1990 [Monitoring the operation and efficiency of the fish passage facility built at Bazacle in 1990].*

Dartiguelongue, J. (1991). *Suivi de la centrale nucléaire de Golfech. Étude de l'ichtyofaune.* pp. 42-53. Toulouse. ENSAT, Lab. Ichtyol. Appl.

Dartiguelongue, J., Larinier, M. and Travade, F. (1992). *Etude du comportement de d'alose dans la passe à poissons à l'usine de Tuilières sur la Dordogne. (Study of the behaviour of shad in the fish passage facility at the Tuilières power station on the Dordogne.).* 55 pp. CSP-EDF.

Dartiguelongue, J. (1992). *Contrôle du fonctionnement et de l'efficacité des passes à poissons installées au Bazacle. Suivi de l'activité ichtyologique en 1991. [Monitoring the operation and efficiency of the fish passage facility built at Bazacle in 1990. Report on fish activity].*

Dartiguelongue, J. (1994). *Suivi du fonctionnement de la passe à poissons de Mauzac. Contrôle des passages de poissons de mai à juillet 1994.* E.D.F. - D.T.G.

Dartiguelongue, J. (1994). *Contrôle du fonctionnement des passes à poissons installées au Bazacle. Suivi de l'activité ichtyologique en 1993. [Monitoring the operation of the fish passage facility built at Bazacle in 1993. Report on fish activity].* 27 pp. MI.GA.DO.

Dartiguelongue, J. (1996a). *Contrôle du fonctionnement de l'ascenseur à poissons de Tuilières en 1995. Suivi de l'activité ichtyologique.* Toulouse. Servces et Conseils en Environnement Aquatique, Toulouse.

Dartiguelongue, J. (1996b). *Suivi du fonctionnement de la passe à poissons de Mauzac. Controlé des passages de poissons de mai a juillet 1995.* Toulouse. Services et Conseils en Environnement Aquatique, Toulouse.

Dartiguelongue, J. (1997). *Contrôle du fonctionnement de l'ascenseur à poissons de Tuilières en 1996. Suivi de l'activité ichtyologique.* 29 pp. MI.GA.DO.

Dautrey, R. and Lartigue, J. P. (1983). *Recherches sur la migration des aloses (Alosa alosa) et des truites de mer (Salmo trutta) en Garonne (Site de Golfech).* 212pp. Thèse Doctorat 3^{e} cycle. Toulouse: Institut National Polytechnique de Toulouse.

Davies, B. (1964). The Mayfish (Or Twaite Shad). *Angler's World.* **May 1964,** 14.

Davis, P. S. and Edwards, A. J. (1988). New records of fishes from the North East coast of England, with notes on the rediscovery of part of the "type collection" of marine fishes from the Dove Marine Laboratory, Cullercoats. *Transactions of the Natural History Society of Northumbria* **55,** 39-46.

Dawes, B. (1946). *The Trematoda of British Fishes.* pp. 138-139. Cambridge: Cambridge University Press.

Dawes, B. (1947). *The Trematoda of British Fishes.* 364 pp. London: Ray Society.

Day, F. (1880-1884). *The fishes of Great Britain and Ireland.* London: Williams and Norgate.

Day, F. (1890). Notes on the Fish and Fisheries of the Severn. *Proceedings of the Cotswold Naturalists Field Club* **9,** 202-219.

Day, L. (1933). Mersey Fish in 1773 - History of Liverpool. *Northwest Naturalist*

De Beaufort, L. F. (1909). Die schwimmblase der Malacopterygii. *Morphologisches Jahrbuch* **39,** 526-644.

De Betta, E. (1862). *Ittioligia veronese ad uso popolare.* pp. 153. Verona: Vicentini e Franchini.

De Betta, E. (1863). *Materiali per una fauna veronese.* pp. 144. Verona: Vicentini e Franchini.

De Buen, F. (1925). Estudio de la edada por las escamas en Sardina de Vigo. *Notas y Résumenes. Min. de Marina Direc. Gen. de Pesca* **Ser.II,**

De Buen, F. (1930). Les Clupeidès et leur Pêche. *Rapp. Proc. Verbaux Réum. CISM* **5,** 173-194.

De Groot, S. J. (1989). The former allis and twaite shad fisheries of the lower Rhine, The Netherlands. *International Council Exploration Sea, Anadromous and Catadromous Fish Commission.* **ICES-CM-1989/M:19,** 1-4.

De Groot, S. J. (1990). The former allis and twaite shad fisheries of the lower Rhine, The Nederlands. *Journal of Applied Ichthyology* **6,** 252-256.

De la Fontaine, A. (1872). *Faune du pays de Luxembourg ou Manuel de zoologie contenant la description des poissons observés dans le pays de Luxembourg.* pp. 1-89. Luxembourg:

De Nie, H. W. (1996). *Atlas van de Nederlandse Zoetwatervissen. Stichting Atlas Verspreiding Nederlandse Zoetwatervissen.* 151 pp. Doetinchem: Niewegein: Media Publishing.

De Rada, R. (1954). *Introduccion a una Estadistica de Pesca Fluvial.* Ministerio de Agricultura.

Decamps, H., Fortune, M. and Gazelle, F. (1989). Historical changes of the Garonne River, southern France. In: *Historical change of large aluvial rivers: western Europe.* (Petts, G. E., Möller, H., and Roux, A.L., eds.), 249-267. Chichester:John Wiley & Sons Ltd.

Delisle, F. (1991). Le bel avenir des aloses. *Pêcheur Fr., spécial vacances* **96,** 81-85.

Della Marmora, F. A. (1828). *Viaggio in Sardegna.* 1, pp. 146. Cagliari: Il Nuraghe.

Demestre, M., Sánchez, P. and Abelló, P. (2000). Demersal fish assemblages and habitat characteristics on the continental shelf and upper slope of the north-western Mediterranean. *Journal of the Marine Biological Association of the UK* **80,** 981-988.

Demetropoulos, A. and Neocleous, D. (1969). *The Fishes and Crustaceans of Cyprus.* Fisheries Bulletin **1,** pp. 21. Nicosia. Ministry of Agriculture and Natural Resources Fisheries Department.

Derschau, W. (1894). Zur Frage der Maifisch-Erbrütung. *Allgem. Fisherei-Zeitung* **XIX,** 33-36.

Desjames. (1988). Rapport de synthèse. *Schéma déparemental de vocation piscicole de l'Aude Direction Départementale de l' Agriculture et de la Forêt de l' Aude/Ministère de l' Environnement/Conseil Supérieur de la Pêche, Montpellier*

Décamps, H., Capblancq, J. and Tourenq, J. N. (1984). Lot. In: *Ecology of European rivers*. (Whitton, B. A. ed.), 208-232. Oxford:Blackwell Scientific Publications.

Délégation de bassin, R. (1989). *La pêche professionnelle et amateurs aux engins sur le Rhône-Suivi des captures. Schéma de vocation piscicole du fleuve Rhône.* 41 pp. + annexes. Document No. 7.

Délégation de bassin, R. (1990). *Suivi de la migration des aloses à l'écluse de navigation de Beaucaire sur le Rhône. Schéma de vocation piscicole du fleuve Rhône.* 7 pp. + annexes. Document No. 4.

Délégation de bassin, R. (1991). *Schéma de vocation piscicole du fleuve Rhône.* 202 pp. + annexes. Rapport de synthèse.

Didry, A. (1953). Considerations sur les poissons d'eaux douces des Alpes Maritimes. *Reviera scient.* **40,** 1-6.

Dieckwisch, B. (1987). *Die Verteilung der Fischbrut in der Unterelbe 1985.* Diplomarbeit. Kiel.

Diercking, R. and Wehrmann, L. (1991). Artenschutzprogramm Fische und Rundmaüler in Hamburg. *Schiftenreihe der Umweltbehörde* **38,** 22-24.

Dieuzeide, R., Novella, M. and Roland, J. (1959). Catalogue des Poissons des Côtes Algériennes. pp. 20-23. Alger:

Doadrio, I., Elvira, B. and Bernat, Y. (1991). *Peces Continentales Españoles. Inventario clasificacion de zonas fluviales.* Madrid: Ministerio de Agricultura Pesca y Alimentacion.

Doherty, D. and McCarthy, T. K. (2002). Aspects of the ecology, parasites and future conservation of twaite shad, *Alosa fallax,*and allis shad, *Alosa alosa,*in south-eastern Ireland. In: *Conservation of Freshwater Fishes: Options for the Future.* (Collares-Pereira, M. J., Cowx, I. G. and Coelho, M. M. eds.), 98-112. Oxford:Fishing News Books, Blackwell Science.

Dolgov, A. V. (2000). New data on composition and distribution of the Barents Sea ichthyofauna. *ICES CM2000/Mini* **12,** 12 pp.

Dollfus, R. P. (1953). Apercu general sur l'histoire naturelle des parasites animaux de la morue atlanto-arctique *Gadus callarias L. (= morhua L.). Encycl. biol.* **43,**

Dollfus, R. P. (1955). Fichier ichthyologique du Maroc Atlantique. *Trav. Inst. Sci. Cherifien, Ser. Zool.* **6,** 1-226.

Donovan, E. (1802 - 8). *The natural History of British Fishes.* London:.

Dorel, D. (1985). *Poissons de l'Atlantique nord-est relations taille-poids.* Institut Francais de Recherche pour l'Exploitation de la Mer.

Dorgambide, P. (2001). *Etude de la reproduction et des caracteristiques mesologiques d'une frayere de grandes aloses (Alosa alosa) sur la Nivelle.* 16 pp. Author's Degree: Maitrise (Biologie des Populations et des Ecosystemes, Ecotoxicologie aquatique). Univ. Bordeaux-1..

Dorier, A. (1954). Carte piscicole du département de la Drôme. (Grenoble. ed.)

Dorier, A. (1956). Carte piscicole du département de l'Ardèche. (Grenoble. ed.)

Dos Santos, M. E. and Lacerda, M. (1987). Preliminary observations of the bottlenose dolphin (*Tursiops truncatus*) in the Sado Estuary (Portugal). *Aquatic Mammals* **13,** 65-80.

Dottrens, E. (1952). *Les poissons d'eau douce.* II. Des Siluridés aux Cyprinidé:17. pp. 18-24. Paris & Neuchâtel: Delachaux et Niestlé.

Douchement, C. (1978). *Contribution à l'étude biologique des zones d'estuaire. Les populations d'aloses migratrice des côtes atlantiques et méditerranéennes (Alosa alosa L. 1758 et Alosa fallax Lac. 1803 Pisces. Teleostei, Clupeidae).* Montpellier.

Douchement, C. (1981). *Les Aloses des fleuves français (Alosa fallax Lacépède 1803 et Alosa alosa Linné, 1758). Biométrie, écobiologie, Autonomie des populations. [The French rivers shad Alosa fallax Lacépède, 1803 and Alosa alosa Linne, 1758. Biometry, ecobiology: Population autonomy.].* 377 pp. Thèse Doctorat 3è cycle. Montpellier: Université des Sciences et Techniques du Languedoc Montpellier.

Drecun, D. and Miranovic, M. (1962). Ulov ribe na Skadarskom jezeru 1947-1960 Godine. *Hydrobiologia Montenegrina* **1,** 1-19.

Drimmelen, D. E. V. (1951). Beschouwingen over de Fintvansten. *Visserij-Nieuws* **4,** 21-24.

Duffield, J. E. (1939). Fishes. In: *The Victoria history of the County of Oxfordshire.* (Salzman, L. F. ed.), 197 pp..

Duhamel du Monceau, H. L. (1769-1782). *Traité général des pêches et histoire des poissons ou des animaux qui vivent dans l'eau.* Paris:

Duhamel du Monceau, H. L. (1772). *Traité général des pêches et histoires des poissons qu'elles fournissent.* 2^{e} partie Section 3, 579 pp. Paris: Saillant et Nyon.

Dujardin, F. (1845). *Histoire naturelle des Helminthes ou Vers intestinaux.* 652 pp. + 1-12 pl. Paris: Libr. Encyclop. Roret.

Dulude, P. (1994). *The restoration of migratory fish in the Dordogne River (France, S.W.).* Migratory fish restoration papers of the migrateurs. Actes du colloque. agence de l'eau adour Garonne. 156-159. Toulouse, France.

Duncker, G. and Ladiges, W. (1960). *Die Fische der Nordmark.* 432 pp.. Hamburg: Kommissionsverlag Cram, de Gruyter & Co.

Dyrynda, P. and Lancaster, J. (1991). *Preliminary assessment of marine fish within the Usk estuary (S.Wales).* Unpublished Report to Newport Borough Council School of Biological Sciences, University of Wales, Swansea.

Dzhumaliev, M. K. (1980). Capillary blood supply to the esophagus and the cardial part of the stomach in fishes from some orders. *Vopr. Ikhtiol.* **20,** 79-85.

E.D.F. (1981). *La capture et le transfert des aloses en amont de la centrale de Golfech.* Laboratoire d'Ichtyologie Appliqueé de l'E.N.S.A. Toulouse 28 pp.

Eckardt, R. (1877). The experiments in propogating Maifische (*Alosa Vulgaris*), in 1876 and 1877. *U.S. Fish Commission. Report of Commissioner of Fish and Fisheries.* **5,** 853-866.

Economidis, P. S. (1973). Catalogue des poissons de la Grèce (en grec, résumé en francais). *Hellenic Océanologie et Limnologie* **11,** 421-598.

Economidis, P. S. (1974). *Étude morphologique systématique et zoogéographique des poissons d'eau douce de la Macédoine orientale et de la Thrace occidentale (régions grecques) [Morphological, Systematic and Zoogeographical study of the freshwater fishes of Eastern Macedonia and Western Thrace]*. Thessaloniki.

Economidis, P. S. and Sinis, A. I. (1982). Les poissons du système des lacs Koronia et Volvi (Macédoine,Grèce) Considérations systématiques et zoogéographiques. *Biologia Gallo - Hellenica* **9,** 291-316.

Economidis, P. S. and Sinis, A. I. (1986). Situation taxinomique et comparaisons des Aloses (Pisces, Clupeidae) provenant des lacs Volvi et Vistonis (Grèce). Description d'une nouvelle sous-espèce: *Alosa caspia vistonica ssp. Journal of Natural History* **20,** 723-734.

Economidis, P. S. (1991). Checklist of freshwater fishes of Greece. *Hellenic Society for the Protection of Nature, Athens* **Special Publication,** 48 pp.

Economidis, P. S. and Sinis, A. I. (1991). *Alosa caspia vistonica* (Economidis et Sinis 1986). In: *Handbook of Freshwater Fishes of Europe*. 2 Clupeidae, Anguillidae, (Hoestlandt, H. ed.), 199-209. Wiesbaden:Aula Verlag.

Economidis, P. S. and Sinis, A. I. (1991a). Alosa macedonica (Vinciguerra, 1921). In: *Handbook of Freshwater Fishes of Europe*. 3 Clupeidae Anguillidae, (Hoestlandt, H. ed.), 297-308. Wiesbaden:Aula Verlag.

Economidis, P. S. (1995). Endangered freshwater fishes of Greece. *Biological Conservation* **72,** 201-211.

Edwards, R. W. and Brooker, M. P. (1982). *The Ecology of the Wye.* 50, Dr. W. Junk Publishers. The Hague-Boston-London.

Edwards, R. W. and Brooker, M. (1984). Wye. In: *Ecology of European Rivers*. (Whitton, B. A. ed.), 52-82. Oxford:Blackwell Scientific Publications.

Edwards, M. (1985). Shad from the Severn. *Coarse Angler.* **8, 12,** 32-34.

Ehrenbaum, E. (1894). Beiträge zur Naturgeschichte einiger Elbfische (*Osmerus eperlanus L., Clupea finta Cuv., Acerina cernua L., Acipensar sturio L.*). *Wissenschaftliche Meersunterchungen Helogoland* **1,** 35-79.

Ehrenbaum, E. (1895). Der Shad und die künstliche Fischzucht (Bericht über eine Reise nach den Vereinigten Staaten). *Mitt. D.S.V.* **Beilage S.,** 101-113.

Ehrenbaum, E. (1909). *Eier und Larven von Fischen.* Kiel: Lipsius & Tischer.

Ehrenbaum, E. (1921). Mitteilungen über die Levensverhältnisse unserer Fische. 17. Die

Maifischarten, Der Fischerbote. *Fischerbote* **17 and 18,** 681-726 and 726-731.

Ehrenbaum, E. (1936). *Handbuch der Seefischerei Nordeuropas.* Stuttgart: E.Schweizerbart.

Eiras, J. C. (1977). Algumas medidas de protecção ao sável (*Alosa alosa* L.) do Rio Douro. *Publicacoes do Instituto de Zoologia Dr Augusto Nobre* **124,** 11-16.

Eiras, J. C. (1980). *Alosa fallax* from North and South of Portugal: Study of its numerical characters. *Publcaçoes do Instuto de Zoologia Dr. Augusto Nobre* **155,** 7-15.

Eiras, J. C. (1980). *Alosa fallax* from north and south of Portugal: Study of its numerical characters. *Anais da Faculdade de Ciencias do Porto* **LXII (67),** 19-27.

Eiras, J. C. (1981a). Sur une population d'*Alosa alosa* L., poisson migrateur amphibiotique, thalassotrophe, bloquée en eau douce au Portugal. [About a Landlocked Population of *Alosa alosa* L., Amphibiotical and Thalassotrophic fish, in Fresh Waters of Portugal.]. *Cybium, 3^{e} série* **5,** 69-73.

Eiras, J. C. (1981b). *Contribuição para o conhecimento da biologia de Alosa alosa L. Estudo de algumas modificaçoes somáticas, fisiológicas e bioquimicas durante a migraçao anádroma no Rio Douro.* 228 pp. Tese de doutoramento. Porto: University of Porto, Portugal.

Eiras, J. C. (1983). Some aspects on the biology of a landlocked population of anadromous shad *Alosa alosa* L. *Publicações do Instituto de Zoologia Dr.Augusto Nobre* **180,** 1-16.

Elie, P. (1977). *Étude préliminaire sur les problèmes écologiques relatifs aux espèces de poissons migrateurs dans la Loire.*84 pp. Université Sciences Rennes / Ministère Environnement.

Elie, P. and Castelnaud, G. (1983). *Étude du suivi halieutique de l'estuaire de la Gironde, 1982.* 77 pp. Bordeaux. EDF/CEMAGREF Div. ALA Bordeaux.

Elie, P., De Verdilhac, P., Castelnaud, G. and Gadrat, S. (1983). *Étude du suivi halieutique de l'estuaire de la Gironde, 1981.*78 pp. Bordeaux. EDF/CEMAGREF Div. ALA Bordeaux.

Elie, P. (1985). *Les aloses en France: importance état des connaissances et propositions d'un cadre pour la gestion de ces ressources.* Note technique. 26 pp. Bordeaux. Ministère de l'Environment, CEMAGREF de Bordeaux, ALA.

Elie, P. (1986). *Les productions halieutiques et aquacoles dans les eaux continentales françaises.* Symposium FAO-CECPI. 4 pp. + annexes. Bordeaux.

Elie, P., Rochard, E. and Boigontier, B. (1988). *Étude du suivi halieutique de l'estuaire de la Gironde, 1987.* 212 pp. Bordeaux. EDF/CEMAGREF Div. ALA Bordeaux.

Elie, P., Boigontier, B. and Rochard, E. (1988a). *Étude du suivi halieutique de l'estuaire de la Gironde (1987).*210 pp. Bordeaux. EDF/CEMAGREF Div. ALA Bordeaux.

Elie, P. and Taverny, C. (1989). *Les aloses du systeme estuarien Gironde-Garonne-Dordogne. Mortalites engendrees par l'industrie et la peche dans le cas des juveniles d'Alosa alosa et d'Alosa fallax de 1985 a 1988. [Shads of the estuarian system Gironde-Garonne-Dordogne. Mortalities generated by industry and fishing on Alosa alosa and Alosa fallex juveniles 1985-1988.].* pp. 252. Bordeaux. Centre National du Machinisme Agricole du Genie Rural des Eaux et des Forets, Groupement de Bordeaux, Cestas (France).

Elie, P., Rochard, E. and Boigontier, B. (1989). *Étude du suivi halieutique de l'estuaire de la Gironde, 1988.*175 pp. Bordeaux. EDF/CEMAGREF Div. ALA Bordeaux.

Elie, P. (1990). *Les aloses (Alosa alosa L. et Alosa fallax Lac.). Assises de l'eau, groupe de travail "Gestion des migrateurs Amphihalins", Avril 1990.* 12 pp. Ministère de l'Environment, Cemagref de Bordeaux, ALBX.

Elie, P., Taverny, C. and Rochard, E. (1993). *Die Maifische (Alosa alosa L. und Alosa fallax Lac.) Biologie, Ökologie und Vorbereitung für ihre Wiedereinführung in ein Einzugsgebeit wie das des Rheins.* Schriftliche Fassung des Vortags vor der 10. Sitzung der Untergruppe Kf der Internationalen Kommission zum Schutze des Rheins am 24.06.1993. 1-14. Koblenz.

Elie, P. (1994). *Migratory species of the Garonne River. Biology, economics and exploitation.* Migratory fish restoration. 91-94. Toulouse France.

Elie, P., Taverny, C., Mennesson-Boisneau, C. and Sabatié, M. R. (2000). L'exploitation halieutique. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations.* (Baglinière, J. L. and Elie, P. eds.), 199-226. Paris:INRA-CEMAGREF.

Ellison, F. B. (1935). Shad. *Transactions of the Woolhope Naturalists Field Club* 135 139.

Ellison, N. F. and Chubb, J. C. (1962). The Marine and Freshwater Fishes. *The Fauna of Lancaster and Cheshire.* **41,** 1-34.

Ellison, N. F. and Chubb, J. C. (1972). *The Marine and Freshwater Fishes of Lancashire and Cheshire. Supplement no. 2.* pp. 1. Lancashire and Cheshire Fauna Society.

Elvira, B., Doadrio, I., Lobón-Cervia, J. and Sostoa, A. d. (1988). *Red list of the freshwater fishes of Spain.* In: Abstracts of the VIth Congress of European Ichthyologists. Budapest.

Elvira, B. (1990). Iberian endemic freshwater fishes and their conservation status in Spain. *Journal of Fisheries Biology* **37,** 231-232.

Elvira, B. (1995a). Conservation status of endemic freshwater fish in Spain. *Biological Conservation* **72,** 129-136.

Elvira, B. (1995b). Native and exotic freshwater fishes in Spanish river basins. *Freshwater Biology* **33,** 103-108.

Elvira, B. (1996). Endangered freshwater fish of Spain. In: *Conservation of freshwater fish in Europe.* 55-60. Basel Boston Berlin:Birkhäuser Verlag.

Elvira, B. (1997). Peces fluviales en España. *Trofeo Pesca* **56,** 48-50.

Eschmeyer, W. N. (1998). *Catalog of Fishes.* San Francisco: Calofornia Academy of Sciences.

Esteves, E., Coelho, M. L., Pina, T., Chicharo, M. A. and Andrade, J. P. (1999). *Diel variation of the RNA/DNA ratios in field caught (Alosa fallax) larvae in the River Mira (SW Portugal).* Environment, development and growth of fishes. University of St Andrews, Scotland. Academic Press. Abstracts

Esteves, E. B. O. (1999). *Factores que influenciam a abundãncia e a condiçao nutricional das larvas de peixes nos rios Mira e Guadiana.* Masters. Coimbra, Portugal.

Esteves, E., Pina, T. and Andrade, J. P. (2000). *The Mira and Guadiana estuaries (Southern Portugal) as spawning and nursery grounds for twaite shad, Alosa fallax fallax (Lacépède, 1803).* Freshwater Fish Conservation : Options for the Future. Algarve, Portugal. Abstracts

Fage, L. (1920). Engraulidae, Clupeidae. *Rep. Dan. Ocean, Exp. 1908-1910* **II,**

Fahy, E. (1982). A commercial net fishery taking twaite shad *Alosa fallax* (Lacépède) in the estuary of the River Slaney. *Irish Naturalists Journal* **20,** 498-500.

FAO. (1957). Standardization of biometric observation methods for *Clupeidae* use in fisheries biology. *Stud. Rev. gen. Fish. Coun. Medt.,* **1,** 1-35.

FAO. (1973). Catalogue. Nom des Poissons. Rome. *Cons. gén. Pêches méditer.* **Aloses,** 54-55.

Farooqi, M. (1988). *The Twaite and Allis shad in Europe (Part 1) The fisheries status of the lower River Lugg. A study of the adult fish population (Part 2).* M. Sc. Cardiff: University of Wales. Institute of Science and Technology, Cardiff.

Farran, G. P. (1946). Local Irish names of fishes. *The Irish Naturalists' Journal* **8,** 1-30.

Fatin, D. and Dartiguelongue, J. (1995). *Etude préliminaire de la reproduction des aloses en 1995 entre Tulières et Mauzac sur la Dordogne.* 39 pp. + planches, graphiques et annexs. Services et Conseils en Environnement Aquatique pour EFD Energie Aquitaine D.T.E.

Fatio, V. (1890). Histoire naturelle des Poissons, Part 2. In: *Faune des vertébrés de la Suisse.* 5, (Georg, ed.), 29. Genêve-Bale:

Feltgen, E. (1902). *Vademecum des Luxemburgischen Fischerei-Liebhabers.* pp. 1-148. Luxemburg: P.Worré-Mertens.

Felton, R. (1972). Shad time on the Severn. *Anglers Mail.*

Felton, R. (1975). The Shad Mystery. *Angler's Mail.*

Ferrero, L. (1946). Studio comparativo sulle Cheppie del Mediterraneo e gli Agoni delle acque interne D'Italia (Nota preliminaire). *Bollettino di Pesca Piscicoltura e Idrobiologia.* **1,** 54.

Ferrero, L. (1951). Studio comparativo sulle Cheppie del Mediterraneo e gli Agoni delle acque interne d'Italia. *Bollettino di Pesca Piscicoltura e Idrobiologia.* **6,** 108-133.

Fiedler, K. (1991). Fische. In: *Lehrbuch der speziellen Zoologie*. 2, (Starck, D. ed.), Jena:Gustav Fischer.

Fiedler, K. (1991). *Die Bedeutung von Makrozoobenthos und Zooplankton der Unterelbe als Fischnahrung.* Dissertation. Kiel.

Filippi De, F. (1844). Pesci finora osservati in Lombardia. *Notizie Nat. Ciiv. su la Lombardia* **1,** 389-406.

Finlayson, J. E. (1981). *The biology of the mazocraeid gill parasites of mackerel, sprat and shad.* Ph.D. University of Birmingham.

Fischer, W., Schneider, M. and Bauchot, M. L. (1987). *Fiches FAO d'identification des espèces por les besoins de la pêche. (Révision 1). Méditerranéet mer Noire. Zone de pêche 37. Volume II. Vertébrés.* Volume II. Vertébrés, pp. 761-1530. Rome: FAO.

Fisher, H. (1975). The shad. *Newsletter Hereford, Radnor Nat Trust.* 5-6.

Fitter, R. S. R. (1945). *Londons' Natural History.* London:

Florin, J. (1949). Ergebnisse aus biometrischen Untersuchen an *Alosa finta* , Cuv. Des Stromgebeites des Po. *Verh. int. Ver. Limnol.* **10,** 134-140.

Fontaine, M. and Leloup, J. (1949). Sur l'iodémie de deux téléostéens migrateurs potomatoques Salmo salar L. et Alosa alosa L. au début de leur montée reproductrice. *C. R. Acad. Sc. Paris* **230,** 775-777.

Forrest, H. E. (1907). *The Vertebrate Fauna of North Wales.* pp. 508-509. High Holborn, London: Witherby & Co.

Forrest, H. E. (1908). Fishes. In: *The Victoria History of Shropshire*. 1, (Page, W. ed.),

Fowler, H. W. (1936). The marine fishes of West Africa, based on the collection of the American Museum Congo Expidition 1909-15. *Bull. am. Mus. nat. Hist.* **70,** i-vii, 1-606 plus 607-1493.

Fredj, G. and Maurin, C. (1987). Les poissons dans la banque de données Medifaune. Application à l'étude des caractéristiques de la faune ichtyologique méditerranéenne. *Cybium* **11,** 217-299.

Freyhof, J. (2002). Freshwater fish diversity in Germany, threats and species extinction. In: *Conservationn of freshwater fishes: options for the future.* (Collares-Pereira, M. J., Coelho, M. M. and I. G. Cowx, I. G. eds.), 3-22. Oxford:Fishing News Books.

Fric, A. (1859). Kritisches verzeichnis der fische Böhmens. *Lotos* **9,** 199-205.

Friedrich, G. and Müller, D. (1984). Rhine. In: *Ecology of European rivers*. (Whitton, B. A. ed.), 265-309. Oxford:Blackwell Scientific Publications.

Fries, B., Ekstrom, C. U., Sundevall, C. and Smitt, F. A. (1895). *An history of Scandinavian Fishes.* Text Part II, pp. 567-1240.

Frost, G. A. (1925). A comparative study of the otoliths of the Neopterygian fishes I Order Isopondyli. *Ann, mag. Nat. Hist* **9,** 151-163.

Fryer, G. (1982). *The Parasitic Copepoda and Branchiura of British Freshwater Fishes. A Handbook and Key.* Scientific Publication No. 46, Freshwater Biological Association.

Furnestin, J. (1952). L'Alose d'El Kansera, cas d'une adaptation totale d'une espèce anadrome aux eaux douces. *Comptes Rendues de l'Académie de Sciences de Paris* **234,** 2018-2020.

Furnestin, J. and Vincent, A. (1955). Persistance de la phase migratoire chez l' Alose marocaine adaptée aux eaux douces. *Comptes Rendues de l'Académie de Sciences de Paris* **240,** 355-357.

Furnestin, J. and Vincent, A. (1958). Variations des branchiospines dans le genre *Alosa.* [Variations in branchiospines in the genus *Alosa*]. *Comptes Rendues de l'Académie de Sciences de Paris* **246,** 3376-3379.

Furnestin, J., Dardgnac, J., Maurin, L., Vincent, A., Coupe, R. and Boutiere, H. (1958). Données nouvelles sur les poissons du Maroc atlantique. *Rev. Trav. Inst. Pêch. marit.,* **22,** 383-493.

Gabelaye, T. D. (1975). On the phylogeny of the Clupieidae. *Bulletin of the Academy of Sciences of the Georgian SSR* **80,** 213-216.

Galkin, G. G. (1958). Atlas of scales of freshwater bony fishes. *Izv. VNII ozer. i rech. ryb. khoz-va.* **46,** 1-105.

Gallois, C. (1945). Eclusage d'Aloses. *Bull. Fr. Piscic* **137,** 209-210.

Gallois, C. (1946). L' alose du Rhône. *Bulletin Français de Pisciculture* **143,** 72-79.

Gallois, C. (1946). L' alose du Rhône. *Bulletin Français de Pisciculture* **145,** 198.

Gallois, C. (1946a). L' alosa du Rhône. *Bulletin Français de Pisciculture* **141,** 162-176.

Gallois, C. (1946b). L' alose du Rhône. *Bulletin Français de Pisciculture* **142,** 5-14.

Gallois, C. (1947a). L'aménagements du Rhône vivarais par la Compagnie Nationale du Rhône, ses incidences sur l' économie piscicole. Mesures tendent à les atténuer. *Bulletin Français de Pisciculture* **146,** 25-34.

Gallois, C. (1947b). L'alose du Rhône. *Bulletin Français de Pisciculture* **144,** 130-136.

Gallois, C. (1950). Les migrateurs du Rhône. Situation actuelle. Conditions de son amélioration. *Bulletin Officiel du Conseil Supérieure de la Pêche* **2,** 33-44.

Gallwey, E. (1938). *The Naturalist.* Annual Report pp. 9. Yorkshire Naturalists' Union.

Gandolfi, G. and Le Moli, F. (1977). Indagine sulla qualità delle acque del fiume Po. Cap. 18: Distribuzione della fauna ittica nelo Po [Survey on the water quality of the river Po: Fish distribution in the river Po. Chapter 18]. 32, 723-745. Quaderno Istituto di Ricerca sulle Acque.

Gandolfi, G., Ioannilli, E. and Vitali, R. (1985). Caratteristiche biologiche delle comunita ittiche, studi sulle migrazioni e aspetti quantitativi alieutiche nel delto del Po. *Nova Thalassia* **7,** 281-309.

Gandolfi, G., Zerunian, S., Torricelli, P. and Marconato, A. e. (1991). *I pesci delle acque interne Italiane.* 616pp. Roma: Ministero dell' Ambiente e Unione Zoologica Italiana. Instituto Poligrafico e Zecca dello Stato.

Garbini, A. (1897). *Osservazioni e dati statistico - economici sui pescai e sulla pesca del Benaco.* Verona:

Garbini, A. (1904). Fauna del Veronese. In: *Sormani Moretti, Regno Animale*. 289-368. Verona:Vincetini e Franchini.

Gaudant, J. (1989). Sur une alose (Poisson téléostéens, Clupeidae) du Pannonien inférieurdes environs de Rudábanya (Hongrie). *M. áll. földt. Intéz. évi. Jel., Budapest* 281-291.

Gaudant, J. (1991). Paleontology and History of Clupeoid Fishes. In: *The Freshwater Fishes of Europe*. 2 Clupeidae, Anguillidae, (Hoestlandt, H. ed.), 35-42. Wiesbaden:Aula-Verlag.

Gaumert, D. and Kämmereit, M. (1993). Süsswasserfische in Niedersachsen. In: *Niedersächsisches Landesamt für Okologie, Dezernat Binnenfischerei*. 32-35. Hildesheim:Oppermann Druk.

Gayou, F. (1981). *Les différents modes de pêche de l'alose sur la Garonne. Contribution à l'étude des populations.* 36 pp. Conseil Supérieur de la Pêche Midi-Pyrénées-Aquitaine.

Gazeau, C., Lefrançois, T. and Rochard, E. (2001). Mise en place d'une démarche qualité dans le cadre de l'échantillonnage d'une population de grande alosa (*Alosa alosa*). [Set-up of "a quality assurance" as part of sampling of an allis shad (*Alosa alosa*) population. *Bulletin Français de la Pêche et de la Pisciculture* **362/363**, 1017-1024.

Gebler, R. J. (1992). *Potentielle Laichplätze für Kieslaicher und Wanderungshindernisse im Oberrhein Bestandsaufnahme.* Institute Wasserbau u. Kulturtechnik, Universitat Karlsruhe.

Geisenheyer, L. (1888). *Wirbeltirfauna von Bad Kreuznach unter Berücksichtigung des ganzen Nahegebeits. I. Teil Fische Amphibien, Reptilien.* Wissenschlaftliche Beilagen zum Programm des Kgl. Gymnasiums zu Kreuznach.

Geliday, R. and Balik, S. (1996). *Türkiye Tathsu Baliklari.* **46 (Dizin No 16),** pp. 210 217. Ege Universitesi Su Ürünleri Fakültesi Yainlari.

Gendre, L. (1995). *Validation de la manoeuvre d'abaissement partiel de la porte amont. Campagne d'étude1995. Plan Migrateurs Rhône-Méditerranée.* **1995 N^{o}2/8,** 31 pp. Association Migrateurs Rhône-Méditerranée.

Gendre, L. (1997). *Franchissement par les aloses de l'aménagement de Beaucaire Vallabrègues. Campagne d'études 1995.* **1995 No 1/8,** 73 pp.+ annexes. Association Migrateurs Rhône-Méditerranée.

Gendre, L., Menella, J. Y. and Dumas, C. (1997). *Suivi de la reproduction de l' alose feinte du Rhône. Campagne d'étude 1995.* **1995 N^{o}8/8,**46 pp. Association Migrateurs Rhône-Méditerranée.

Gendre, L., Menella, J. Y. and Corrao, B. (1997a). *Suivi de la dévalaison des alosons, campagne d'étude 1995.* **1995 N^{o}3/8,** 28 pp.+ annexes. Association Migrateurs Rhône Méditerranée.

Genoud, D. (1996). *Suivi des frayères potentielles d'aloses sur la rivière Ardèche en Aval de Saint-Martin et le Rhône court-circuité. Campagne d'étude 1996.* **1996 N^{o}5/8,**19 pp.+ annexes. FRAPNA Ardèche. Association Migrateurs Rhône-Méditerranée.

Genoud, D. (1997). *Recherche et caractérisation des frayères actives d'aloses sur le Rhône court-circuité entre Viviers et Pont-Saint-Esprit. Campagne d'étude 1997.* **1997 N^{o}4/6,** 40 pp. + annexes. Fédération de Pêche de l' Ardèche, C.O.R.A. Ardèche. FRAPNA Ardèche. Association Migrateurs Rhône-Méditerranée.

Genoud, D. (1999). *Suivi de la pêche d'aloses en Ardèche. Rivière Ardèche et fleuve Rhône. Campagne d'étude 1998.* **1998 N^{o}4/7,**30 pp. + annexes. Fédération de Pêche de l' Ardèche, Conseil Supérieur de la Pêche. Association Migrateurs Rhône-Méditerranée.

Genoud, D. (1999). *Suivi quantitatif de la frayère de Saint-Montan; Rhône court-circuité de Donzère-Mondragon.* **1999 N^{o}2/2,** 23 pp. + annexes. Fédération de Pêche de l'Ardèche. Association Migrateurs Rhône-Méditerranée.

Gensoul, J. (1908). *Monographhie des Poissons du département de la Saône-et-Loire. Autun.*

Georffroy Saint-Hilaire, E. (1808). Poissons du Nil. In: *Description de l'Egypte ou recueil des observations et des recherches qui ont été faites en Egypte pendant l'expédition de l'armé française.* 1, Poissons, pl.1-17. Paris:Panckoucke.

Georffroy Saint-Hilaire, E. (1827). Histoire naturelle des poissons du Nil. In: *Description de l' Egypte*. **1**, 265-310. Paris:

Gerkens, M. and Thiel, R. (2001). Habitat use of age - 0 twaite shad (*Alosa fallax* Lacépède, 1803) in the tidal freshwater region of the Elbe river, Germany. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 773-784.

Gerstmeier, R. and Romig, T. (1998). *Die Süßwasserfische Europas: für Naturfreunde und Angler.* pp. 368. Stuttgart: Franckh-Kosmos Verlag.

Gervais, H. and Boulart, B. (1897). *Les poissons d'eau douce.* pp. 157. Paris:

Getsevichiute, S. (1958). Parasite fauna of fish in Kursiu Maru Bay (Russian text – Lithuanian Summary). *Biology Inst. Darbai, Lietuvos TSR moks. Akad* **3,** 101-139.

Gibson, F. A. (1956). Further specimens of shads from Irish waters. *Irish Naturalists Journal* **12,** 109.

Gill, T. N. (1861). Notes on the nomenclature of North American Fishes. *Proceedings of the Academy of Natural Sciences of Philadelphia* **12,** 19-21.

Giussani, G. and Grimaldi, E. (1975). Analogie e difformitã nel regime alimentare dei pesci planctofaghi di quattro grandi laghi terminali troficamente differenziati. [Similarity and differences in feeding habits of planktophagous fishes in four large trophically different lakes]. *Memorie dell'Istituto Italiano di Idrobiologia* **32,** 349-363.

Giussani, G. (1989). Lago Maggiore fish community evolution. *Memorie dell' Istituto Italiano di Idrobiologia* **46,** 125-135.

Gladstone, H. S. (1912). *A catalogue of the vertebrate fauna of Dumfriesshire.* Dumfries: J. Maxwell and Son.

Gmelin, J. F. (1800). Genuine and Universal system of Natural History. XI, (Linnaeus, S. C. A. ed.), 96-98.

Goinard, N. (1993). *Importance économique des espèces à écophase estuarienne dans les pêcheries du Golfe de Gascogne.* **2201 AB,** APEEL / ADERET.

Golvan, Y. J. (1969). Systematique des Acanthocéphales. Ordre Palaeacanthocephala. *Mem. Mus. Hist. Nat. Paris, Ser. A., Zool. N. S.* **57,** 1-373.

Golvan, Y. J. and de Buron, I. (1988). Les hotes des Aconthocephales. II - Les hotes definitifs. I. Poissons. *Annales de Parasitologie Humaine et Comparee. Paris* **63,** 349 375.

Gordo, L. (2002). Growth characteristics of an anadromous and a landlocked population of allis shad, *Alosa alosa*, from the River Mondego, Portugal. In: *Freshwater Fish Conservation: Options for the Future*. (Collares-Pereira, M. J., Coelho, M. M and Cowx, I. G. ed.), 113-120. Oxford:Fishing News Books.

Gordon, W. J. (1902). *Our Country's Fishes.* London: Simpkin,Marshall,Hamilton,Kent & Co. Ltd.

Gordon, J. G. (1921). The marine and freshwater fishes of Wigtownshire. *Trans. Dumfries. Gall. Nat. Hist. Soc* **7,** 137-159.

Gourret, P. (1897). Les étangs saumâtres du Midi de la France et leurs pêcheries. *Ann. Mus. Hist. Nat., Marseille, série zool.* **5,** 1-386.

Grabda, E. and Heese, T. (1991). *Polskie nazewnictwo popularne kraglouste i ryby. Cyclostomata et PISCES.* pp. 171. Koszalin, Poland: Wysza Szkola Inzynierska w Koszalinie.

Green, C. (1993). The Severn Fisheries. 69-73.

Greer-Walker, M. and Pull, G. A. (1975). A survey of red and white muscle in marine fish. *Journal of Fish Biology* **7,** 295-300.

Gregory, J. (1999). *An appraisal of Hydroacoustic Techniques for monitoring the spawning migration of Shad in the River Wye.* R&D Technical Report **W226,** Bristol: Environment Agency..

Grégoire, P. (1983). *Contribution à la connaissance de la répartition des poissons d'eau douce de France.* pp. 117. DEA. Paris: University of Paris VII.

Grégoire, A. and Travade, F. (1987). L'experiénce d'EDF dans le domaine des passes à poissons: Conception et suivi d'efficacité. [EDF's experience relating to fish ladders and efficiency follow-up.]. *La Houille Blanche* **1/2,** 65-72.

Gridelli, E. (1935). *I pesci d'acqua dolce della Venezia Giulia.* pp. 68. Udine:

Griffith, D. (1997). The status of the Irish fish fauna: a review. *Journal of applied Ichthyology* **13,** 9-13.

Grimaldi, E. (1966). Il regime alimentare dell'agone del lago Maggiore. *Memorie dell'Instituto Italiano di Idrobiologia* **20,** 45-57.

Grimaldi, E. and Oppi, E. (1977). Pesci e pesca nel Garda che cambia. *Natura e Montagna* **4,** 23-30.

Grimaldi, E. (1997). Richerche sulle acque Italo Svizzere nel quadriennio 1992-1995. *Commissione Italo Svizzera per la pesca* **2,** 1-83.

Grimm, R. (1993). *Historische Fischvorkommen im baden-württembergischen Oberrhhein. Literaturausswertung.* Staatl. Lehr-und Versuchsanstalt Aulendorf, Fischereiforschungsstelle des Landes Bad,-Württ. (Hrsg.) Langenargen.

Grote, W., Vogt, C. and Hofer, B. (1909). *Die Süsswasserfische von Mittel-Europa.* Lipsk.

Guccini, L. (1904a). Sul contenuto gastro-enterico dei pesci del Ticino. *Rend. Istituto Lombardo* **37,** 3.

Guccini, L. (1904b). *L'alimentazione naturale dei pesci del lago d'Iseo.* Atti, e Resoconto delle discussioni del Convegno degli Acquicultori Italiani. Brescia.

Gueneau, P. (1986). Radio-pistage de poissons en riviere. (Radiotelemetry of fish in a wide river). *Bull. Fr. Peche Piscic.* **302,** 79-85.

Guérault, D., Desaunay, Y. and Beillois, P. (1993). *La pêche prefessionnelle des poissons migrateurs dans l'estuaire de la Loire en 1989.* IFREMER RIDRV.

Guérault, D., Desaunay, Y. and Beillois, P. (1994). La pêche prefessionnelle des poissons migrateurs dans l'estuaire de la Loire en 1989. In: *Les pêche prefessionnelle des poissons migrateurs dans les estuaires de la Loire et de l'Adour.* 6, 5-28. Repères Océan, IFRENER, INRA, ENSAT.

Guigue, T. (1994). *Étude socio-economique de la pêche professionnelle en eau douce dans le département de la Gironde et proposition d'un programme d'appui technique à la profession.* 77 pp. DDA Option Halieutique ENSAR / AADPPEDG.

Guillard, J., Mennella, J.-Y. and Therry, F. (1996). *Shad migrations in a lock using horizontal split-beam transducers.* Shallow water fisheries sonar workshop.

Guillard, J., Therry, F. and Colon, B. (1996). *Etude de la migration des aloses. Utilisation des techniques acoustiques. Campagne d'études 1996. [Study of Alosid migration using acoustics. Summer 1996].* **1996-N^{o} 7/8,** pp. 42 + annexes. Thonon. Institut National de la Recherche Agronomique (INRA), Association Migrateurs Rhône-Mediterranee (MRM).

Guillard, J. and Colon, B. (1997). *Etude de la migration des aloses. Utilisation des techniques acoustiques. Campagne d'études 1997. [Study of Alosid migration using acoustics. Summer 1997].* **1997-N^{o} 5/6,** pp. 32 + annexes. Thonon. Institut National de la Recherche Agronomique (INRA), Association Migrateurs Rhône-Mediterranee (MRM).

Guillard, J. and Colon, B. (1998). Behaviour of migratory fish passing a lock on the River Rhône, France. *Shad Journal* **3,** 4-5.

Guillard, J. and Colon, B. (1998). Estimation hydroacoustique du nombre de poissons migrateurs franchissant l'ecluse de Beaucaire-Vallabregues (Rhone). [Hydoacoustic estimation of the number of fish passing through Beaucaire-Vallabregues lock (Rhone).]. *Bulletin Français de la Pêche et de la Pisciculture.* **348,** 79-90.

Guillard, J., Colon, B., Therry, F. and Vidal, N. (1998). *La migration des aloses (Alosa fallax rhodanensis) dans l'écluse de Beaucaire-Vallabrègues étudiée par un sondeur acoustique à faisceaux partagés: synthèse des campagnes 1996 à 1998.* **1998-N^o 5/7,** 48 pp. Thonon. Institut National de la Recherche Agronomique (INRA), Association Migrateurs Rhône-Mediterranee (MRM).

Guillard, J. and Vidal, N. (1998). *Etude de la migration des aloses. Utilisation des techniques acoustiques. Campagne d'études 1998. [Study of Alosid migration using acoustics. Summer 1998].* **1998-N^o 5/7,** pp. 22 + annexes. Thonon. Institut National de la Recherche Agronomique (INRA), Association Migrateurs Rhône-Mediterranee (MRM).

Guillard, J. and Colon, M. (2000). First results on migrating shad (*Alosa fallax*) and mullet (*Mugil cephalus*) echocounting in a lock on the Rhone River (France) using a split-beam sounder, and relationships with environmental data and fish caught. *Aquatic Living Resources.* **13,** 327-330.

Guissani, G., Ruffoni, T. and Cerutti, I. (1989). Indagini sul popolamento ittico. In: *Richerche sull'evoluzione del lago Maggiore. Aspetti Limnologici.Programma quinquennale 1983-1987*. (Istituto Italiano di Idrobiologia CNR, ed.), 111-123. Milano:Commissione Internazionale per la protezionedelle acque italo-svizzere.

Guissani, G. (1989). Lago Maggiore fish community evolution. *Mem. Ist. Ital. Idrobiol.* **46,** 125-135.

Gulson, J. (1994). *Species Management in Aquatic Habitats. Phase 1 - Development of priority lists of rare and nuisance species.* National Rivers Authority **R & D Note 285,** Medmenham. WRc plc.

Gulson, J. (1994). *Species Management in Aquatic Habitats.* National Rivers Authority **R & D Project Record 461/9/ N & Y,** Medmenham. WRc plc.

Günther, A. (1853). *Die Fische des Neckars.* pp. 136. Stuttgart: Verlag von Ebner & Seubert.

Hadderingh, R. H. and Jager, Z. (2002). Comparison of fish impingement by a thermal power station with fish populations in the Ems Estuary. *Journal of Fish Biology.* **61 (Supplement A),** 105-124.

Harder, L. (1975). *Anatomy of fishes, Part 1 and 2.* Stuttgart: E. Schweizerbart'sche Verlagsbuckhand Lung (Nagele V. Obermiller).

Hardisty, M. W. and Huggins, R. J. (1975). A survey of the fish populations of the middle Severn estuary based on Power Station sampling. *Intern. J. Environmental Studies* **7,** 227-242.

Hartley, P. H. T. (1939). The Saltash Tuck-net fishery and the ecology of some estuarine fishes. *Journal of Marine Biological Association of the United Kingdom* **24,** 1-68.

Hartmann, G. L. (1827). *Helvetische Ichthyologie, oder ausführliche Naturgechichte der in der Schweiz sich vorfindenden Fische.* pp. 1-240. Zürich: Füßli und Compagnie.

Hass, H. (1965). Untersuchungen über den Laichfischbestand der Elbfinte, *Alosa fallax* (Lacépède 1803). *Archive für Fischereiwissenschaft* **16,** 150-168.

Hass, H. (1968). Untersuchungen über die vertikale und horizontale Verteilung der Eier der Finte. *Alosa fallax* (Lacépède, 1803) in der Elbe. *Archiv für Fischereiwissenschaft* **19,** 46-55.

Hass, H. (1969). Unterscheidungsmerkmale dottersackloser Larven von Clupeiformes aus der Unterelbe [The distinguishing marks of the yolk-sac lacking larvae of Clupeiformes from the lower-Elbe]. *Archiv für Fischereiwissenschaft* **20,** 22-25.

Hatton-Ellis, T. (2000). *LIFE in UK Rivers: conservation, monitoring and management strategies for freshwater and migratory fish.* Freshwater Fish Conservation: Options for the Future. Algarve, Portugal. Abstract.

Havinga, B. (1938). *De kust-, Rivier- en Binnenvisserij.* pp. 494-497. W. G. de Van Holkema en Warendorf N. V. Amsterdam.

Heckel, J. J. and Kner, R. (1858). *Die Susswasserfische der Osterreichen Monarchie.*228 pp. Leipzig:

Henderson, P. A. and Seaby, R. M. (1999). Population stability of the sea snail at the southern edge of its range. *Journal of Fish Biology* **54,** 1161-1176.

Henderson, P. A. and Seaby, R. M. H. (2001). *Fish and crustacean captures at Hinkley point B Nuclear power station: report for the year April 2000 to March 2001.* Electronic report 25 pp.. Lymington, Hampshire, UK. Pisces Conservation Ltd.

Henderson, P. A., Seaby, R. M. H. and Somes, R. (2002). *Fish and crustacean captures at Hinkley point B Nuclear power station: report for the year April 2001 to March 2002.* Electronic report **http://www.powerstationeffects.co.uk/reports/hinkfish2002.pdf,** 21 pp. Lymington, Hampshire, UK. Pisces Conservation Ltd.

Herdman, W. A. and Dawson, R. A. (1902). *Fishes and fisheries of the Irish Sea.* **Memoir No. 2,** Lancashire Sea Fisheries.

Hesselio, M. P. (1675). *Hertzfliessende Betrachtungen von dem Elbe-Strom.* 156 pp. Hamburg.: Eigenverlag Altona.

Hilton-Taylor, C. (2000). *2000 IUCN red list of threatened species.* pp. xviii + 61 pp. (with 1 CD-ROM). Gland, Switzerland and Cambridge, UK: IUCN.

Hislop, J. R. G. and Shanks, A. M. (1981). Recent investigations on the reproductive biology of the haddock *Melanogrammus aeglifinus*, of the northern North Sea and the effects on fecundity of infection with the copepod parasite *Lernaeoura branchialis*. *J. Cons. Int. Explor Mer* **39,** 244-251.

HMSO. (1861). *Report of the Commissioners appointed to inquire into Salmon fisheries (England and Wales).* Her Majesty Stationery Office. London.

Hoek, P. P. C. (1888). Bemerkungen über Larven und Junge einiger wichtigeren in dem Berichte behandelten Fischarten. *Tijdschrift der Nederlandsche Dierkundige Vereeniging.* **Supplement Deel II,** 274-319.

Hoek, P. P. C. (1894). De elft op onze rivieren. *Meded. Vissch.* **1,** 49-54, 65-69, 81-86.

Hoek, P. P. C. (1897). Rapport over het visschen met ankerkuilen, zoowel in den gesloten tjid als daarna. *Versl. Staat Ned. Zeevischenijen over 1896.* **Bijl. V.,** 267-416.

Hoek, P. P. C. (1899). Neuere Lachs- und Maifisch-studien. *Tijdschrift der Nederlandsche dier kundige Vereeniging* **2,** 156-242.

Hoek, P. P. (1900). Neuere lachs und Maifish-studien die beiden Arten Maifish und Finte. *Tijdschr. ned. dierk. Vereen., Leiden* **2,** 212-240.

Hoestlandt, H. (1947). Fécondation artificielle et incubation chez un Téléostéien : *Paralosa rhodanensis* Roule. *C.R. Acad. Sci. Paris* **141,** 937-938.

Hoestlandt, H. (1948). Fécondation artificielle et incubation de l'Aose du Rhône: *Paralosa rhodanensis* Roule. *Ann. Stat. Centr. Hydrobiol. Appl.* **2,** 223-228.

Hoestlandt, H. (1958). Reproduction de l'alose atlantique (*Alosa alosa* Linné) et transfert au bassin méditerranéan. *Verhandlunden Internationale Vereinigung für Theoretische und Angewandte Limnologie.* **13,** 736-742.

Hoestlandt, H. (1991). Clupeidae - Subfamily Alosinae (Svetodidov, 1952). In: *The freshwater fishes of Europe. Volume 2.* 2, (H. Hoestland, ed.), 85-368.Wiesbaden: Aula-Verlag.

Holmes, R. H. A. and Henderson, P. A. (1990). High fish recruitment in the Severn Estuary: the effect of a warm year? *Journal of Fish Biology.* **36,** 961-963.

Hortique, M. (1976). Les poissons. In: *Animaux de Bourgogne*. Strasbourg:Mars et Mercure.

Houghton, W. (1879). *British Fresh-Water Fishes.* 256 pp. London: Webb & Bower.

Huschenbeth, E. (1985). Zur Kontamination der Fische der Nord und Ostsee mit Organochlorpestidzen und polychlorierten Biphenylen [Contamination of North Sea and Baltic fishes with organochlorinated pesticides and polychlorinated biphenyls]. *Informationen fur die Fischwirtschaft.* **32,** 175-176.

Hutton, J. A. (1916). Coarse fish and the food supply. *Fishing Gazette.* **March 18, 1916,**

ICONA. (1986). *Lista roja de los vertebrados de España.* Ministerio de Agricultura, Pesca y Alimentación.

IKSR. (1991). Ökologisches Gesamtkonzept für den Rhein. In: *Komm. zum Schutze des Rheins*. 1-119. Koblenz:

IKSR. (1996). Lachs 2000. Stand der Projekte Anfang 1996. In: *Komm. zum Schutze des Rheins*. 1-48. Koblenz:

IMFT. (1985). *Aménagement hydraulique de Golfech. Franchissement par les poissons migrateurs, étude du débit d'attrait.* **402.1** 105 pp.**,** IMFT.

International Commision for the Protection of the Rhine against Pollution (ICPR). (1991). *Ecological Master Plan for the Rhine "Salmon 2000".* Booklet 23 . Publ. ICPR.

Isaksson, A. (1994). Report of activities 1993 for the Anadromous and Catadromous Fish Committee. *Copenhagen Denmark Ices* **109,**

IUCN. (1994). *Catégories de l'UICN pour les listes rouges.* Commission de la sauvegarde des espèces de l'UICN.

Ivanov, L. and Beverton, R. J. H. (1985). The fisheries resources of the Mediterranean. Part two: Black sea. *Studies and Reviews FAO* 45-126.

Ivanovic, B. M. (1973). *Ichthyofauna of Skadar Lake.* 146 pp. Titograd (Serbia): Institution for Biological and Medical Research in Montenegro.

Ivanovic, B. (1977). Sexual maturity and spawning of *Alosa fallax nilotica* in lake Skadar. *Acta Biology Iugosl. E Ichthyol* **9,** 25-29.

Ivolas, J. (1893). *La pêche en Loire. Etude de géographie économique.* 123 pp. Charles Boehm.

Ivoy de la Poype, P. (1901). *La Question de le pêche dans le bassin de la Loire.* 318 pp. Poitiers.

Jankovic, D. (1977). *Effects of anthropogenic factors on the zonal distribution of fishes in the Danube River system in Serbia (Yugoslavia).* Internationale Vereinigung fur Theoretische und Angewandte Limnologie. **20**, 2150-2153. Denmark.

Jenkins, J. T. (1902). Altersbestimmung durch otolithen bei den Clupeiden. *Wissenschaft Meeresuntersuchungen kiel Neue Folge Sochster Band, (Abt. kiel)* **6,** 83-122.

Jenkins, J. T. (1942). *The fishes of the British Isles.* pp. 262 - 265. London & New York: Frederick Warne & Co.Ltd.

Jens, G. (1971). Fische und Fischerei des Rheins. *Beiträge zur Rheinkunde 2.* **23,** 8-14.

Joensen, J. S. and Vedel Tåning, A. (1970). *Marine and freshwater fishes.* **LXII-LXIII**, pp. 241.

Johnstone, J. (1906). Fishes. In: *The Victoria History of Lancashire.* I, 179.

Jolimaitre, J. F. (1992). *Franchissement par l'alose feinte de l'aménagement de la chute de Vallabrèuges. Étude du franchissement de l'écluse de navigation. Avant-projet de passe à poissons sur le seuil de Beaucaire.* 42 pp. + annexes**,** Montpellier. Conseil Superieur de la Pêche.

Jones, G. (1992). *Shad - their status and exploitation in Welsh Region.* Internal report National Rivers Authority.

Jonsson, G. (1992). *Islenskir fiskar.* 568 pp. Reykjavik: Fiolvi.

Joubin, L., Le Danois, E. (1924). Catalogue illustré des animaux marins comestibles des côtes de France et des mers limitrophes avec leurs norms français et étrangers. *Mem. Off. Sci. Tech. Pêches marit. (série spéciale)* **1,** 1-220.

Jouffre, L. (1995). *Etude de fraisabilé d'une technique de comptage par échosondage des poissons transitant par l'écluse de Beaucaire-Vallabrègues. Campagne d'étude 1995. Plan Migrateurs Rhône-Méditerranée.* **1995 N^{o}5/8.,** 33 pp. + annexes. Association Migrateurs Rhône-Méditerranée.

Joyeux, C. and Baer, J. G. (1936). Cestodes. In: *Faune de France 30.* Paris:Lechevvalier et fils.

Kabata, Z. (1979). Parasitic copepoda of British Fishes. *The Royal Society, London.* **152,** 409-410.

Kafemann, R., R., T. and Sepulveda, A. (1996). Die fischökologische bedeutung der nebenstromgewässer der Unterelbe [The importance of the marginal areas in the lower Elbe River for fishes]. *Archives Hydrobiology Supplement* **110,** 199-214.

Kalfa-Papaioannou, A. M. and Sinis, A. I. (1985). Metacercariae of *Diplostomum spathaceum* in Freshwater Fish of the Lake System Koronia and Volvi (Macedonia, Greece). *Zbl. Vet. Med. B,* **32,** 65-70.

Karakoc, F. T., Tuli, A., Hewer, A., Gaines, A. F., Phillips, D. H. and Uensal, M. (1998). Adduct Distributions in Piscine DNA: South-Eastern Black Sea. *Marine Pollution Bulletin* **36,** 696-704.

Kartas, F. (1981). *Les clupéidés de Tunisie. Caractéristiques biométriques et biologiques. Etude comparée des populations de l'Atlantique est de la Méditerranée. [The Clupeidae of Tunisia: Their biometrical and biological characteristics, a comparative study of eastern Atlantic and Mediterranean populations.].* 608pp. Thèse de Doctorat d'Etat. Tunis,Tunisia: Université de Tunis.

Kartas, F. (1991). *Alosa fallax algeriensis* (Regan, 1916). In: *The freshwater fishes of Europe. Volume 2. Clupeidae, Anguillidae.* 2, (Hoestlandt, H. ed.), 213-224. Wiesbaden:Aula-Verlag.

Kazic, D. and Cankovic, M. (1969). Parazitofauna riba Skadarskog jezera I. [Neke kad nas Neutvrotene Vrste trematoda]. [Parasitofauna of fishes in the Lake Skadarsko Jezero I]. *Veterinaria Sarajevo* **18,** 473-484.

Keith, P., Allardi, J. and Moutou, B. (1992). *Livre Rouge : Des especes menacees de poissons d'eau douce de France et bilan des introductions.* 10, 111pp. Paris: Museum Natioal d'Histoire Naturelle, Secretariat de la Faune et de la Flore, Conseil Supérieur de la Pêche , CEMAGREF and Ministère de l'Environment.

Keith, P. and Allardi, J. (1996). *Endangered freshwater fish: The situation in France.* Basel: Birkhäuser Verlag.

Kence, A. and Bilgin, C. C. (1996). *Turkiye Omurgalilar Tur Listesi.* Ankara:
Kennedy, M. (1954). *The Sea Anglers Fishes.* pp. 416-421. London: Hutchinson.

Kennedy, C. R. (1978). The biology,specificity and habitat of the species of Eubothrium (Cestoda: Pseudophyllidae) with reference to their use as biological tags : a review. *Journal of Fish Biology* **12,** 393-410.

Kennedy, C. R. (1981). The occurrence of *Eubothrium fragile* (Cestoda: Pseudophyllidae) in twaite shad, *Alosa fallax* (Lacépède) in the River Severn. *Journal of Fish Biology* **19,** 171-177.

Kerville, G. d. (1897). Faune de Normandie. Fasicule 4: Reptiles, Brataciens et Poissons, 532 pp.

Kerville, G. d. (1897). Reptiles, Batraciens et Poissons. In: *Faune de Normandie*. **4**, 532. Paris:

Kieckhäfer, H. (1982). Rhein : Meerfollen, Lachse und zwei Finten. *Fisch und Fang* **2,** 99-100.

Kiener, A. and Quignard, J. P. (1982). *L' alose du Rhône. Diminution progressive de ses captures et de sa commercialisation.* **13/14**, pp. 125-136. Dijon:

Kiener, A. (1985). *Au fil de l'eau en pays méditerranéen: milieux aquatiques, poissons et pêche, gestion.* pp. 308. Avignon: Aubanel.

Kissack, K. (1978). *The River Wye.* T. Dalton Limited, Lavenham, Suffolk.

Klausewitz, W. (1974). Die frühere Fischfauna des Untermains. Mitt. Forschungsprojekt Untermain, Nr. 8. *Natur und Museum* **104,** 1-7.

Klimaj, A. and Rutdewicz, S. (1970). *Atlas ryb polnocnego Atlantydu.* 73 pp. Morskie, Warszawa: Wudawn.

Klucz do oznaczania kregowcow Polski.. (1962). *cz. 1. Kraglouste i Ryby.* Warszawa-Krakow: Pr. zbiorowa.

Klunzinger, C. B. (1881). Die Fische im Württemburg, faunistisch-biologisch betrachtet und die Fischereiverhältnisse daselbst. *Jahr. Ver. vaterl. Naturk. Württ.* **37,** 172-304.

Knezevic, B., Kazic, D., Nedic, D., Kavaric, M. and Ivanovic, B. (1977). *Unique Characteristics of Ichthyofauna and Ichthyoparasites of Skadar Lake.* Internationale Vereinigung fur Theoretische und Angewandte Limnologie. **20**, 2166-2171. Denmark.

Knezevic, B. (1981). Fishes of Lake Skadar. In: *The biota and limnology of Lake Skadar.*(Karaman, G. S. and Beeton, A. M. eds.), 312-316. Titograd; Washington and Wisconsin.:Univerzitet Veljko Vlahovic, Titograd; Smithonian Institute, Washington; Centre for Great Lakes Studies, University of Wisconsin, Wisconsin.

Knezevic, B., Mandic, S. and Jardas, I. (1986). Immigrant fish species in Skadar and Sasko lakes and some of their specificities (Montenegro, Yugoslavia). *Commn. Int. Explor. Scient Mer Mediterr* **30,** 223.

Koch, W. (1929). Ernste Gefährdung unserer Rheinfischerei. *Badische Fischereizeitung*, **4,**

Koch, W. (1955). Die Rheinfischerei in Vergangenheit, Gegenwart und Zukunft unter dem Einfluss der Rhein korrektion und Energiewirtschaft. *Arch. Hydrobiol./Suppl.* **22,** 369-380.Koehler, A. (1981). Fluktuationen der Fischfauna im Elbe-Astuar als Indikator fur ein Gestortes Okosystem. [Fluctuations of the Ichthyo-Fauna in the Elbe Estuary: An Indicator for a Disturbed Ecosystem]. *Helgolander Meeresuntersuchungen* **34,** 263-285.

Kolayli, S., Arikan, M., Uzunosmanoglu, D., Vanizor, B., Kiran, E. and Sagban, R. (1997). Comparative studies on antioxidant enzyme activities and lipid peroxidation in different fish species. *Turkish Journal of Zoology* **21,** 171-173.

Kolb, F. H. (1970). Vangst van een elft in Friesland. *Vissorij* **23,** 85-86.

Koli, L. (1990). *Suomen kalat. [Fishes of Finland.].* 357 pp.. Helsinki: Werner Söderström Osakeyhtiö.

Kosoric, D., Vukovic, T., Kapetanovic, N. and Guzina, N. (1989a). Ihtiofauna rijeke Neretve i njene promjene posljedicno izgradnji Hidroelektrana. *Zbornik radova – Savjetovanje o ribarstvu na Hidroakumulacijama, Mostar* 133-138.

Kosoric, D., Vukovic, T., Kapetanovic, N. and Guzina, N. (1989b). Sadasnje stanje i mogucnosti razvoja ribarstva sliva neretve. *Zbornik radova - Savjetovanje o ribarstvu na Hidroakumulacijama, Mostar* 193-211.

Kotlyar, A. N. (1984). *Dictionary of names of marine fishes on the six languages.* 288pp. Moscow: All Union Research Institute of Marine Fisheries and Oceanography.

Kottelat, M. (1997). European Freshwater Fishes. *Biologia Bratislava* **52,** 1-271.

Kreitmann, L. (1932). Les grande lignes de l'économie piscicole du bassin français du Rhône. *Trav. Lab. Hydrobiol. Pisc. Grenoble* **27,** 127-131.

Kuhn, G. (1976). *Die Fischerei am Oberrhein.* Hohenheimer Arbeiten, Schriftenreihe d. Univ. Hohenheim, Agrarökonomie.

Kuru, M. (1980). *Türkiye Tatlisu Baliklari Katalogu. Pisces.* 12, Ankara: Buro Zelal Matbaasi.

Kushnarenko, A. I. (1986). Ecological principles and prospects of development of Caspian shad fishery. *Vopr.-Ikhtiol* **26,** 48-55.

Küel, H. (1976). Zum stand der Hamenfischerei in der Unterelbe [Hamen fishery in the lower Elbe]. *Neues Arch. Niedersachsen* **25,** 315-324.

Kyle, H. M., Ehrenbaum, E. (1927). Teleostei Physostomi, 1 Clupeiformes (Clupeidae) IX (XII). In: *Die Tierwelt der Nord- und Ostsee.* (Grimpe, W. ed.), 9-84. Leipzig:

La Pointe, B. (1994). Alose, la ruée vers l'argent. *Annuel de la pêche* **1,** 63-69.

Labat, R., Cassou-Leins, F. and Cassou-Leins, J. J. (1983). Problèmes posés par les poissons migrateurs dans le bassin de la Garonne: Case de l'Alose (*Alosa alosa* L) [(Problems posed by fish migration in the Garonne Basin: the case of *Alosa alosa L*]. *Bull. Soc. Hist. Nat. Toulouse* **119,** 99-102.

Lacepède, B. G. E. (1803). *Histoire naturelle des Poissons.* 5, pp. 803 p. Paris: Plassan.

Ladet, A. (1996). *Inventaire des frayères potentielles d'aloses sur le bassin de l' Ardèche et le Rhône court-circuité. Campagne d'études 1995.* **1995 N°4/8,** 167 pp. FRAPNA. Association Migrateurs Rhône-Méditerranée.

Ladiges, W. and Vogt, D. (1965). *Die Süsswasserfische Europas.* 250pp. Hamburg und Berlin: P.Parey.

Ladiges, W. (1967). Pisces. In: *Limnofauna Europaea.* (Illies, J. ed.), 427-439. Stuttgard und New York:Gustav Fischer.

Ladle, M. (1991). Twaite for it! *Sea Angler.* September 1991, 30-31.

Lahaye, J. (1959). Topographie de la region thyroidienne chez L'alose (*Alosa alosa Linné*). *Bull. Soc. Sci. Nat. Maroc.* **39,** 219-227.

Lahaye, J. (1960a). Croissance et maturation des ovocytes chez la forme totalment adaptée aux eau douces chez l'alose marocaine (*Alosa alosa*, L.). Evoloution cytologique. Stade sexuel et cycle biologique. *Revue des Travaux de l'Institut des Pêches Maritimes* . **24,** 499-511.

Lahaye, J. (1961). Etude histologique et histochimique de l'ovogénèse chez *Alosa alosa* I et II. *Bulletin de la Societe des Sciences naturelles et physiques du Maroc* **7,** 151-156.

Lahaye, J. (1962a). Étude histologique et histochemique de l'ovogénèse chez *Alosa alosa*. III: L'ovocyte mûr et ses membranes. *Bulletin de la Societe des Sciences naturelles et physiques du Maroc* **28,** 29-32.

Lahaye, J. (1962b). Étude histologique et histochemique de l'ovogénèse chez *Alosa alosa* IV: L'ovaire après la ponte. *Bulletin de la Societe des Sciences naturelles et physiques du Maroc* **28,** 49-51.

Lahaye, J. (1962c). L'ovogenèse chez *Alosa finta*. *Revue des Travaux de l'Institut des Pêches Maritimes* **26,** 457-466.

Lahaye, J., Attais, H. and Leviel, Y. (1963). L'ovogenese chez quelques poissons teleosteans des eaux douces Marocaines. *Bulletin de la Societe des Sciences Naturelles et Physiques du Maroc* **43,** 202-270.

Lahaye, J. (1966). Variations cycliques de l'activité thyroïdienne chez des aloses migrant normalment en mer et chez des aloses bloquées en eau douce. *Revue des Travaux de l'Institut des Pêches Maritimes* **30,** 347-355.

Lambert, P., Pronier, O., Rochard, E. and Martin Vandembulcke, D. (1997). *Analyse des données issues du suivi de la faune circulante aux abords de la centrale de Braud-et-Saint-Louis - Cas des juvéniles d'aloses (Alosa alosa), des crevettes blanches (Palaemon longirostris) et des civelles d'anguilles (Anguilla anguilla).* **28,** 36 pp. Bordeaux. CEMAGREF de Bordeaux / EDF.

Lambert, P., Martin Vandembulcke, D., Rochard, E., Bellariva, J. L. and Castelnaud, G. (2001). Âge à la migration de reproduction des géniteurs de trois cohortes de grande aloses (*Alosa alosa*) dans le bassin versant de la Garonne (France). [Age of migration for spawners from three cohorts of allis shad (*Alosa alosa*) in the Gironde watershed (France).] *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 973-987.

Landau, D. (1865). Geschichte der Fischerei in beiden Hessen. *Z. d. Vereins f. hess. Geschichte* **Suppl. 10,** 1-107.

Langon, M. (1999). *Etude des aloses des fleuves côtiers méditerranéens : l'Argens (été 1999).* pp. 21p+annexes. Association Migrateurs Rhône-Méditerranéen, CSP Délégation de Montpellier, DIREN Délégation de Bassin RMC , ENSA Rennes.

Langon, M. (1999). *Etude des aloses des fleuves côtiers méditerranéens : le Tavignano (Juin 1999).* pp. 19p+annexes. Association Migrateurs Rhône-Méditerranéen, CSP Délégation de Montpellier, DIREN Délégation de Bassin RMC , ENSA Rennes.

Lapshin, O. M. (1993). Effectiveness of coastal fishery on complex artificial reefs. In: *Commercial Fishery Technology. Fishing And Fish Behavior. Theoretical And Practical Aspects*. 210-218. Moscow:Povedeniya Gidrobiontov.

Largaiolli, V. (1902(6). *I pesci del Trentino.* 2, Trento.

Larinier, M., Rivier, B., Allardi, J. and Trocherie, F. (1978). Possibilites de franchissement du seuil de beaucaire par les aloses du Rhône [Dam passing possibilities for Rhone shads at Beaucaire]. *Bulletin Français de Pisciculture* **268,** 107-120.

Larinier, M. (1981). *Migration des aloses dans le Bas Rhône. Observations effectuées en 1979 et 1980.* Internal Report CTGREF-DQEPP

Larinier, M. (1983). Guide pour la conception des dispositifs de franchissement des barrages pour les poissons migrateurs. *Bulletin Français Pisciculture, numéro spécia,* 39 pp..

Larinier, M. and Trivellato, D. (1987). Etude sur modèle réduit de la passe à poissons de Bergerac sur la Dordogne. [Hydraulic model studies for Bergerac dam fishway on the Dordogne river]. *La Houille Blanche* **1/2** 135-142.

Larinier, M. and Bernatd, S. (1988). *Echantillonnages d'alosons dans les chambres antivortex de l'usine hydro-électrique de Golfech.* **32,** CEMAGREF/CSP/DRAE/PB/CD.

Larinier, M. (1991). *Utilisation de l'écluse de navigation pour le franchissement de l'usine de Beaucaire par les poissons migrateurs. Campagne 1991 et propositions.* pp. 5. Unpublished report.

Larinier, M., Travade, F. and Dartiguelongue, J. (1992). *Suivi de la passe à poissons de Tuilières en 1991. Mortalité et comportement des aloses.* E.D.F. - D.E.R.

Larinier, M. and Travade, F. (1992). La conception des depositifs de franchissement pour les aloses. In: *Passes à poissons - Expertise, Conception des ouverages de franchissement.* (Gosset, C., Larinier, M., Porcher, J. P. and Travade, F. eds.), 190-203. Paris:Counseil supérieur de la pêche.

Larinier, M. and Travade, F. (1992a). La conception des dispositifs de franchissement pour les aloses. *Bulletin Français de la Pêche et de la Pisciculture.* **326-327,** 125-133.

Larinier, M. (1993). *L'aménagement des obstacles pour la migration.* Pour un retour des poissons migrateurs: Adour-Charente-Dordogne-Garonne. 110-116. Hotel-Dieu, Toulouse. Agence de 'eau Adour-Garonne, CSP, CNRS.

Larinier, M. (1996). Fish pass design criteria and selection. In: *Fishpass Technology Training Course*. (Mann, R. H. K. and Aprahamian, M. W. eds.), 51-74. Dorset:Institute of Freshwater Ecology.

Larinier, M. (1998). Upstream and downstream fish passage experience in France. In: *Fish migration and fish bypasses*. (Jungwirth, M., Schmutz, S. and Weiss, S. eds.), 127-145. Oxford:Fishing News Books, Blackwell Science Ltd.
Larinier, M. and Travade, F. (2002a). The design of fishways for shad. *Bulletin Français de la Pêche et de la Pisciculture.* **364 Supplément,** 135-146.

Larinier, M. and Travade, F. (2002b). Downstream migration: problems and facilities. *Bulletin Français de la Pêche et de la Pisciculture.* **364 Supplément,** 181-207.

Laroche, J. (1985). *Contribution à la connaissance des peuplements de poissons démersaux des côtes atlantiques marocaines, du cap Spartel au cap Juby.* **58,**. 27pp. Tavaux Doc. Dév. Pêches, Maroc.

Lasker, R. (1989). Les déterminants du recrutements. In: *L'homme et les ressources aquatiques*. (Troadec, J. P. ed.), 189-222. IFREMER.

Latappy, F. (2001). *Etude de la reproduction et de la dispersion en milieu naturel des jeunes stades de grande alose (Alosa alosa).* 25 pp. Author's Degree: Maitrise (Biologie des Populations et des Ecosystemes, mention Environnement). Bayonne (France). Univ. Pau et Pays de l'Adour.

Lauterborn, R. (1903). Beiträge zur Fauna und Flora des Oberrheins und seiner Umgebung. *Mitt. Pollichia* **60,** 42-130.

Lauterborn, R. (1903). *Das Vogel-,Fisch- und Thierbuch des Strassburger Fischers Leonhard Baldner aus dem Jahr 1666.* pp. 1-179. Ludwigshafen: Verlag A. Lauterborn.

Lauterborn, R. (1916). Die geographische und biologische Gliederung des Rheinstroms I. *Sitzungsber. Heidelberger Akad. Wiss., math-nat. kl. Abt. B.Biol. Wiss* **1,** 1-61.

Lauterborn, R. (1917). Die geographische und biologische Gliederung des Rheinstroms II. *Sitz. ber. Akad. Wiss. math.nat.KI. Abt. B, Biol. Wiss. Heidelberg,* **8,** 1-70.

Lauterborn, R. (1918). Die geographische und biologische Gleiderung des Rheinstroms III. *Sitzungsber Heidelberger Akad. Wiss., math. nat. KI., Abt. B Biol. Wiss* **III,** 1-87.

Laver, H. (1903). Fishes. In: *The Victoria history of the County of Essex*. **1**, 227.

Le Clerc, M. (1941). Note sur les essais de multiplication artificielle de l'alose dans le bassin de la Loire. *Bulletin Français de Pisciculture* **123,** 27-37.

Le Corre, M., Baglinière, J. L., Sabatié, M. R., Menella, J. Y. and Pont, D. (1996). *Caractérisation morphologique et biologie de l'Alose feinte du Rhône. Campagne d'études 1996.* Rapport final **1996 N^{0}8/8,** pp. 13. Laboratoire Ecologie Aquatique INRA Rennes, Laboratoire Halieutique ENSA Rennes, Laboratoire Ecologie des Systèmes Fluviaux CNRS Arles. Association Migrateurs Rhône-Méditerranée.

Le Corre, M., Baglinière, J. L., Sabatié, R., Menella, J. Y. and Pont, D. (1997a). Données récentes sur les caractéristiques morphologiques et biologiques de la population d'Alose feinte du Rhône (*Alosa fallax rhodanensis* Roule, 1924). [Recent developments on biological and morphological characteristics of twaite shad (*Alosa fallax rhodanensis* Roule, 1924) population in the River Rhône]. *Bulletin Français de la Pêche et de la Pisciculture.* **346,** 527-545.

Le Corre, M., Moulin, L., Sabatié, M. R. and Baglinière, J. L. (1997b). *La reproduction de alose feinte du Rhône (Alosa fallax rhodanensis, Roule 1924) en aval du barrages de Vallabrègues.Campagne d'études 1997.* **1997 N^{o} 2/6,** 10 pp. Laboratoire Ecologie Aquatique INRA Rennes, Laboratoire Halieutique ENSA Rennes, Association Migrateurs Rhône-Méditerranée.

Le Corre, M., Alexandrino, P., Baglinière, J. L. and Sabatié, M. R. (1998). *Caractérisation taxanomique et suivi biologique de la population d'aloses du Rhône (Alosa fallax rhodanensis, Roule 1924). Campagne d'études 1997.* **1997 N^{o} 6/6,** 24 pp. Laboratoire Ecologie Aquatique INRA Rennes, CECA-ICETA Université de Porto, Laboratoire Halieutique ENSA Rennes, Association Migrateurs Rhône-Méditerranée.

Le Corre, M., Linhares, D., Castro, F., Alexandrino, P., Sabatié, R. and Baglinière, J. L. (1998). Premiers éléments de caractérisation génétique de l'Alose du Rhône (*Alosa fallax rhodanensis*, Roule 1924). *Bulletin Français de la Pêche et de la Pisciculture* **350-351,** 635-645.

Le Corre, M., Baglinière, J. L. and Sabatié, M. R. (1998). *Caractérisation écobiologique et génétique des populations d'aloses (Alosa sp) présentes sur l'Aude. Campagne d'études 1998.* **1998 N^{o} 7/7,** 15 pp. +annexes. Laboratoire Ecologie Aquatique INRA Rennes,Laboratoire Halieutique ENSA Rennes, Association Migrateurs Rhône-Méditerranée.

Le Corre, M. (1999). *Eco-biologie et génétique des populations d'aloses (Alosa fallax spp.) de la Méditerranée française.* 189 pp.+ annexes. Thèse de Doctorat. Rennes: Ecole Nationale Supérieure Agronomique de Rennes.

Le Corre, M., Sabatié, M. R. and Baglinière, J. L. (2000). Caractérisation démographiquede populations d'*Alosa fallax rhodanensis* (Roule 1924) (*Clupeidae*) de al Méditerranée française. *Cybium* **24,** 119-128.

Le Cren, D. (1993). The conservation of some Cumbrian Freshwater Fish. *Cumbrian Wildlife* **36,** 10-14.

Le Roux. (1928). Recherches biologiques dans les grands lacs de Savoie. Lacs du Bourget et d' Annecy. (Abry, J. ed.), 146. Annecy:

Lebel, I. (1997). *Caractérisation de la migration des aloses du Rhône; suivi de la pêcherie en aval du barrage de Vallabrègues. Étude comparative des méthodologies d'approche de la migration des aloses.* 109 pp.. Mémoire DAA, Option halieutique ENSAR.

Lebel, I., Le Corre, M., Sabatié, M. R. and Baglinière, J. L. (1997). *Suivi de la migration et de la pêcherie d'aloses feintes du Rhône (Alosa fallax rhodanensis Roule, 1924) au niveau du barrage de Vallabrègues.* **1997-N^{o}1/6,** 74 pp.. Laboratoire Ecologie aquatique INRA Rennes, Laboratoire Halieutique ENSA Rennes. Association Migrateurs Rhône-Méditerranée.

Lebel, I., Baglinière, J. L., Porcher, J. P. and Sabatié, M. R. (1999). *Bilan des actions et des études menées par l'Association Migrateurs Rhône-Méditerranée de 1991 à 1998.* **1998-N°1/7,** 57 pp. + annexes. Laboratoire Ecologie aquatique INRA Rennes, Counseil Supérieur de la Pêche Délégation Régionale de Rennes. Association Migrateurs Rhône-Méditerranée.

Lebel, I. (1999). *Suivi de la pêcherie d'alose feinte du Rhône (Alosa fallax rhodanensis, Roule 1924) sur le bassin du Rhône. Campagne d'études 1999.* **1999 N°1/2,** 66 pp. Association Migrateurs Rhône-Méditerranée.

Lebel, I., Menella, J. Y. and Le Corre, M. (2001). Bilan des actions du plan migrateurs concernant l'alose feinte (*Alosa fallax rhodanensis*) sur le bassin Rhône-Méditerranée. [Balance sheet of the migratory fish program actions for the twaite shad population (*Alosa fallax rhodanensis*) on the Rhone-Mediterranean-Corsica Basin.]. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 1077-1100.

Leclerc, J. L. (1979). *Contribution à l'étude socio-économique de la pêche dans l'estuaire de la Gironde.* 88 pp.. Mémoire ENITA / CTGREF.

Legault, A. (1993). *Expertise pour a'accès des aloses et des anguilles aux affluents du Rhône.* pp. 97. FISH-PASS.

Leger, L. (1943). Etude sur l'hydrographie et l'économie piscicole du département de la Savoie. *Trav. Lab. Hydrobiol. Pisc Univ. Grenoble* **34-36,** 51-66.

Leger, L., Burdin, M. G. and Arnaud, M. A. (1945). Carte piscicole départment du Rhône avec une notice sur l'hydrographie et l'économie piscicole des cours d'eau. *Travaux du laboratoire Hydrobiologie et de Pisciculture de l'Université de Grenoble. Grenoble*

Lelek, A. (1976). Veränderungen der Fischfauna in einigen Flüssen Zentraleuropas (Donau, Elbe und Rhein) [Changes of the freshwater fish fauna in some Central European streams (Danube, Elbe and Rhine)]. *Schriftenreihe für Vegetationskunde* **10,** 295-308.

Lelek, A. (1980). *Les poissons d'eau douce menacés en Europe. [Threatened freshwater fishes of Europe].* **Nature and Environment series no. 18.,** pp. 276. Strasburg. Conseil de l'Europe. European committee for the conservation of nature and natural resources.

Lelek, A. (1980). *Threatened freshwater fishes of Europe.* **8**, pp. 42-46. Strasburg: Council of Europe.

Lelek, A. (1980). Vorläufige Rote Liste der Fische (Pisces) Hessens. In: *Rote Liste der in Hessen ausgestorbenen, verschollenen und gefährdeten Wierbeltiere*. (Stand, ed.), 33-38 & 43-47. Wiesbaden:Hessiche Landenstalt für Umwelt.

Lelek, A. (1987). Threatened fishes of Europe. In: *The freshwater fisheries of Europe*. **9**, (European committee for the conservation of Nature and Natural Resource - Council of Europe, ed.), 343. Wiesbaden:AULA - Verlag.

Lelek, A. and Köhler, C. (1990). Restoration of fish communities of the Rhine river two years after a heavy pollution wave. *Regulated rivers: Research and Management* **5,** 57-66.

Lelek, A. and Buhse, G. (1992). *Fisches des Rheins - früher und heute.* pp. 1-214. Berlin. Heidelberg. New York: Springer-Verlag.

Leonardi, A. (1960). L'ittiofauna del "fripoli" de miocene superiore Bessima (Enna). *Palaeontogr. Ital.* **54,** 115-173.

Leonte, T. R. (1957). Citeva date asupra reproducerii scrumbiei de Daunare. *Bulgarian I.C.P.* **XVI,** 37-46.

Leuthner, F. (1877). *Mittelrheinische Fischfauna mit besonderer Berücksichtigung des Rheins bei Basel.* pp. 1-59. Basel-Genf-Lyon: Georg-Verlag.

Lewis, D. (1994). Fancy a Shad? *Coarse Fishing Today.* **April/May,** 22-24.

Lewis, D. (1996). I suppose a shad's out of the question? *Sea Angler.* September 1996, 53.

Lewis, D. (1997). Tiny Terrors! *Angling Times.* May 28th 1997,52-53.

Lévêque, C., Paugy, D. and Teugels, G. G. (1991). Annotated check-list of the freshwater fishes of the Nilo-sudan river basin, in Africa. *Rev. Hydrobiol. Trop.* **24,** 131-154.

Link, H. F. (1790). Versuch einer Einteilung der Fische nach den Zähnen. *Mag. Phys. Naturgesch* **6,** 28-38.

Linneus, C. (1758). *Systema Naturae per Regna Tria Naturae secundum Classes, Ordinus, Genera, Species cum Characteribus, Differentiis Synonymis, Locis.* 1, 824 pp. Holmia: Salvi.

Litaudon, A. (1985). *Observations préliminaires sur le franchissement du seuil de Saint-Laurent-des-Eaux (Loire) par l'alose (Alosa alosa). [Preliminary observations on shad (Alosa alosa) passing the Saint-laurent-des-Eaux (Loire) sill].* **HE/31/85-37,** 63 pp. EDF.

Lithogoe, J. and Lithogoe, G. (1971). *Fishes of the sea. The coastal waters of the British Isles, northern Europe and Mediterranean.* London: Blandford Press.

Llewellyn, J. (1972). Behaviour of Monogeneans: In Behavioural Aspects of Parasite Transmission. *Zoo. J. Linn. Soc.* **51,** 19-30.

Llewellyn, J., Green, J. E. and Kearn, G. C. (1984). A check-list of monogenean (platyhelminth) parasites of Plymouth hosts. *Journal of the Marine Biological Association of the United Kingdom* **64,** 881-887.

Lloyd, A. J. (1940). Biology of the Bristol Channel. *Proceedings of the Bristol Naturalist's Society* **9,** 210-211.

Lloyd, A. J. (1941). The marine fish fauna of the southern shores of the Bristol Channel. *Proceedings of the Bristol Naturalist Society* **9,** 202-230.

Lobon-Cervia, J., Elvira, B. and Rincon, P. A. (1989). Historical changes in the fish fauna of the River Duero basin. In: *Historical Change of Large Alluvial Rivers: Western Europe.* (Petts, G. E., Möller, H. and Roux, A. L. eds.), 221-232. Chichester:John Wiley & Sons Ltd.

Lobón-Cervia, J. and Elvira, B. (1989). Estado de conservación de los pesces fluviales ibéricos. *Quercus* **44,** 24-27.

Lobragt, P. and Van, O. J. (1977). De laatste riviervissers. *Stichting Riviervisserij Nederland, De Walburg Pars. Heerewaarden.*131 pp.

Lohmeyer, C. (1909). Übersicht der Fische des unteren Ems-, Weser- und Elbegebeites. *Abh. Naturwiss. Ver Bremen* **XIX,** 149-180.

Lorda, E. and Crecco, V. A. (1987). Stock-Recruitment Relationship and Compensatory Mortality of American Shad in the Connecticut River. *American Fisheries Society Symposium* **1,** 469 - 482.

Loro, R., Zanetti, M. and Turin, P. (1994). *Carta ittica.* 184 pp. Treviso. Provincia di Treviso, Ass Caccia Pesca Ecologia.

Lowe, J. (1901). Fishes. In: *The Victoria history of Norfolk.*
Lozano Rey, L. (1929). Los Clupeidos de la peninsula Iberica y del Rif. *Mem. Real. Soc. esp. Hist. Nat.* **42,** 647-666.

Lozano Rey, L. (1935). Los peces fluviatiles de España. *Mem. Acad. Cienc. Exact. Fis. y Nat.* **5,** 1-390.

Lozano Rey, L. (1947). Peces ganoideos y fisóstomos. In: *Ictiologia Ibérica*. II, 42-47. Madrid:Valverde.

Lozano Rey, L. (1950). Étude systématique des Clupéides et des Engraulidés de l'Espagne, du Maroc et du Sahara espagnols. *Rapport du Conseil international pour l'Exploration de la Mer, Copenhagen.* **126,** 7-20.

Lozano-Cabo, F. (1964). *Los peces de las aguas continentales espanolas.* pp. 91-95. Madrid: Servicio Nacional de Pesca fluvial y Caza.

Luquet, J. F. (1990). *Observations d'alosons piégés dans les prises d'eau de la centrale de St Laurent des Eaux en 1989. Contribution à la connaissance de la biologie des aloses en Loire.* 24 pp. Poitiers. CSP.

Lusk, S. (1988). Gene pool of fishes in Czechoslovakia: Present state and conservation efforts. *Prace VURH Vodnany* **18,** 11-26.

Lusk, S., Lohniskì, K. and Vostradovskì, J. (1994). *The Red List of lampreys and fishes of the Czech Republic.* Sb. Icht. konference. pp. 187-193. Vodnany.

Lusk, S. (1996). The status of the fish fauna in the Czech Republic. In: *Conservation of Endangered Freshwater Fish in Europe*. (Kirchhofer, A and Hefti, D. eds.), pp. 89-97. Basel:Birkhäuser Verlag.

Lusk, S., Lusková, V., Halacka, K., Slechta, V. and Slechtová, V. (2002). Status and protection of species and intraspecific diversity of the ichthyofauna in the Czech Republic. In: *Conservationn of freshwater fishes: options for the future.* (Collares-

Pereira, M. J., Coelho, M. M. and Cowx, I. G. eds.), pp. 23-33. Oxford:Fishing News Books.

Luts, G. I., Rogov, S. F., Pryakhin, Y. V. and Nikul'-shin, I. M. (1984). Population dynamics of tyulka, *Clupeonella delicatula delicatul*a , shad, *Alosa pontica pontica* (Clupeidae) and anchovy, *Engraulis encrasicholus maeoticus* (Engraulidae), of the Sea of Azov. *Journal of Ichthyogology* **24,** 1-9.

Luts, G. I., Rogov, S. F., Pryakhin, Y. V. and Nikul'-shin, I. M. (1984). Some patterns of fluctuations in the abundance of main pelagic fishes of the Sea of Azov: Tyulka *Clupeonella delicatula delicatula* (Nordmann), Black Sea shad *Alosa pontica pontica* (Eichwald) (Clupeidae) and Azov anchovy *Engraulis encrasicolus maeoticus* Pusanov (Engraulidae). *Vopr.-Ikhtiol* **24,** 3-10.

Luzzana, U., Serrini, G., Grimaldi, P., Moretti, V. M. and Vallfre, F. (1992). Comparazione del profilo lipidico di due specie ittiche planctofaghe coesistenti nel pelago die grandi laghi glaciali del Nord Italia, l'Agone (*Alosa fallax lacustris*) e il coregone bondella (*Coregonus macrophthalmus*). [Comparison of lipid profiles in two planktophagic fish species co-existing in the large glacial lakes of northern Italy: Shad (*Alosa fallax lacustris*) and coregonid "bondella" (*Coregonus macrophthalmus).*]. *Rivista italiana di acquacoltura.* **27,** 169-191.

Luzzana, U., Serrini, G., Moretti, V. M., Grimaldi, P., Paleari, M. A. and Valfrè, F. (1996). Seasonal variations in fat content and fatty acid composition of male and female coregonid 'bondella' from Lake Maggiore and landlocked shad from Lake Como (Northern Italy). *Journal of Fish Biology* **48,** 352-366.

Lützow, H. (1938). *Die Biologie der Rheinfische auf der Strecke zwischen Bonn und Duseldorf.* Staatsexamensarbeit. Köln.

Lyashenko, S. F. (1958). Biology of juvenile commercial fish species from the Dnieper-Bug Liman. *Vid-vo AN UkrSSR, Kiev* 115 pp.

MacMahon, A. F. M. (1946). *Fishlore.* 208 pp. Harmondsworth, Middlesex: Penguin Books.

Macpherson, H. A. (1892). *A Vertebrate Fauna of Lakeland.* Edinburgh:

MacPherson, H. A. (1901). Fishes. In: *The Victoria history of the County of Cumberland*. 1, 83-84.

MAF. (1931). *La pesca nei mari e nelle acque interne Italiane. Volume 2.* 710 pp. Roma. Ministero Agricoltura e Foreste. Istituto Poligrafico dello stato.

Maio, G. and Turin, P. (1999). *Carta ittica della Provincia di Rovigo.* 278 pp. Provincia di Rovigo. Assessorato Caccia Pesca.

Maitland, P. S. (1972). *A key to the freshwater fishes of the British Isles with notes on their distribution and ecology.* 27, 139 pp. Titus Wilson & Son Ltd. Kendal.

Maitland, P. S. (1977 (1976)). *Les poissons des lacs et des rivières d'Europe.* 255 pp. Elsevier.

Maitland, P. S. (1979). *The status and conservation of rare freshwater fishes in the British Isles.* Proceedings of the British Freshwater Fish Conference. 1, 237-248. University of Liverpool, Liverpool.

Maitland, P. S. (1980). The freshwater fish fauna of the Forth area. *Forth naturalist and historian.* **4,** 33-47.

Maitland, P. S. (1985). Criteria for the selection of important sites for freshwater fish in the British Isles. *Biological Conservation* **31,** 335-353.

Maitland, P. S. and Lyle, A. A. (1990). Practical conservation of British fishes: Current action on six declining species. *Journal of Fish Biology* **37,** 255-256.

Maitland, P. S. (1990). Rare and endangered species. Allis shad *Alosa alosa* and Twaite shad *Alosa fallax*. In: *The conservation of rare British freshwater fish*. pp. 7-9. Peterborough:Nature Conservancy Council.

Maitland, P. S. (1991a). *Climate change and fish in northern Europe: some possible scenarios.* Institute of Fisheries Management Annual Study Course. **22**, 97-110.

Maitland, P. S. (1991b). *Conservation of threatened freshwater fish in Europe.* Nature and Environment Series **46,** Council of Europe Press.

Maitland, P. S. and Lyle, A. A. (1991c). Conservation of freshwater fish in the British Isles: The current status and biology of threatened species. *Aquatic Conservation: Marine and Freshwater Ecosystems* **1,** 25-54.

Maitland, P. S. and Lyle, A. A. (1992). Conservation of freshwater fish in the British Isles: proposals for management. *Aquatic Conservation: Marine and Freshwater Ecosystems* **2,** 165-183.

Maitland, P. S. and Campbell, R. N. (1992). Shads. In: *Freshwater Fishes of the British Isles.* pp. 93-97. Harper Collins.

Maitland, P. S. and Lyle, A. A. (1993). Freshwater fish conservation in the British Isles. *British Wildlife* **5,** 8-15.

Maitland, P. S. (1993). *Sites in Great Britain for Freshwater and Estuarine Fish on the EC Habitats and Species Directive* ***In Confidence***. **JNCC Contract No. F71-12-119,** Stirling. Fish Conservation Centre.

Maitland, P. S. (1993). Threatened freshwater fishes of the Brtish Isles, with special reference to Ireland. In: *The Conservation of Aquatic Systems.* (Reynolds, J. D. ed.), pp. 84-100. Dublin:Royal Irish Academy.

Maitland, P. S. (1994). *Conservation of Freshwater fish in Europe.* **Nature and environment, No. 66,** 50 pp. Strasburg. Council of Europe.

Maitland, P. S. and Lyle, A. A. (1995). *Shad and Smelt in the Cree estuary, S.W. Scotland.* Contract SNH/11A/93/AEB AND SNH/11B/93/AEB Unpublished report to Scottish Natural Heritage.

Maitland, P. S. (1995). *Freshwater fish of annexes II and IV of the EC Habitats Directive.* **B4-3040/94/000439/MAR/B2,** 181 pp.

Maitland, P. S. and Lyle, A. A. (1996). Threatened freshwater fishes of Great Britain. In: *Conservation of Endangered Freshwater Fish in Europe*. (Kirchofer, A. and Hefti, D. eds.), pp. 9-21. Basel (Switzerland):Birkhäuser Verlag.

Makeeva, A. P. and Pavlov, D. S. (2000). Morfologicheskaya kharakteristika i osnovnye priznaki dlya opredeleniya pelagicheskoj ikry ryb presnykh vod Rossii. [Morphological features and general characters for identification of pelagic eggs of the fresh-water fishes of Russia]. *Voprosy ikhtiologii. Moscow.* **40,** 780-791.

Maksimov, Y. and Toliušis. (1999). *Water pollution effect on abundance of coastal herring (Clupea harengus) and twaite shad (Alosa fallax Lacépède) in the Curonian Lagoon (Lithuania).* Proceedings of Symposium on Freshwater Fish and the Herring (*Clupea harengus*) Populations in the Coastal Lagoons Environment and Fisheries. 153-160. Sea Fisheries Institute, Gdynia (Poland).

Malesani, V. (1973). Studio delle distribuzioni e delle aree di riprodzione delle specie ittiche de lago di Garda. *Boll. Pesca Piscic. Idrobiol.* **28,** 122-193.

Malfer, F. (1905). Sul cotenuto gastro-enterico del *Salmo carpio* e dell' *Alosa lacustris benasenci*. *Neptunia* **10,** 153-155.

Malfer, F. (1907). L'Alosa e la sua pesca nel lago di Garda. *Atti Accad. Sci. Lett. Verona* **VII,** 7-40.

Malfer, F. (1922). Sui Clupeidi del Benaco. Caratteri somatici e biologici. *Atti Accad. Agric. Sc. Lettere, Verona* **24,** 151-195.

Malfer, F. (1927). *Il Benaco "La tipografia Veronese".* 411 pp. Verona:

Mallesani, V. (1979). L'Agone *Alosa fallax* Lacapede nel lago di Garda. *Atti Museo Civ. St. nat., Trieste* **31,** 155-180.

Malloch, P. D. (1910). *Life History and Habits of the Salmon, Sea-Trout and other freshwater fish.* pp. 258 - 260. London: Adam and Charles Black.

Malm, A. W. (1877). *Göteborg och Bohusläus fauna, Ryggradsdjuren.* 674 pp. Göteborg:

Mann, H. (1970). *Copepoda and Isopoda as parasites of marine fishes.* Symposium on diseases of fishes and shellfishes. **5**, pp.117-189. American Fisheries Society Washington, D. C. Special Publication.

Mann, R. H. K. (1989). *The management problems and fisheries of three major British rivers: The Thames, Trent and Wye.* International Large River Symposium. **106**, pp. 444 - 454. Canadian Special Publication of Fisheries and Aquatic Sciences.

Mann, D. A., Lu, Z. and Popper, A. N. (1997). A clupeid fish can detect ultrasound. *Nature* **389,** 341.

Manyukas, I. L. (1959). Ichthyofauna, condition of stocks, and harvest of fishes in the Bay of Kurshyu mares [Kurshyu mares. Itogi kompleksnogo issledovaniya]. *Inst. biologii AN LitSSR, Vil'nyus,* 297-298.

Manyukas, Y. L. (1989). Biology of the Atlantic shad, *Alosa fallax fallax* , in Kurshskiy Bay. *Journal of Ichthyology* **29,** 125-128.

Marchand, J. (1980). Distribution saisonnière, abondance et diversité de l'ichthyofaune de l'estuaire interne de la Loire. *Annales de L'institut Océanographique. Paris* **2,** 127-137.

Marchis, E. (1929). *Poissons d'eau douce et d'eau salée. Saumon - Alose - Esturgeon – Anguille - Muge. Poissons d'estuaires, étangs et lacs salés.* 115 pp. Paris: Société d'Éditions géographiques, maritimes et coloniales.

Marconato, A., Salviati, S., Maio, G. and Marconato, E. (1986). *La distribuzione dell'ittiofauna nella provincia di Vicenza.* 149 pp. Vicenza: Provincia di Vicenza.

Margolis, L. (1970). Nematode diseases of marine fishes. *American Fisheries Society Washington, D. C. Special Publication.* **5,** 190-208.

Mari, S., Labonnne, J. and Gaudin, P. (2002). A conservationn strategy for Zingel asper, a threatened endemic percid of the Rhône Basin. In: *Freshwater Fish Conservation: Options for the Future.* (Collares-Pereira, M. J.,Coelho, M. M. and Cowx, I. G. eds.), pp.149-156. Oxford:Fishing News Books.

Maric, D. and Kazic, D. (1990). Qualitative and quantitative composition of ichthyofauna of Skadar Lake sublacustrine springs in winter period from 1967-1987. *Glas. Republ. Zavoda Zast. Prioride-prirodnjackog Muzeja Titograd* **23,** 85-96.

Maric, D. (1995). Endemic fish species of Montenegro. *Biological Conservation* **72,** 187-194.

Marine Biological Association of the United Kingdom. (1957). *Plymouth Marine Fauna.* Plymouth: Marine Biological Association UK. pp. 388.

Marinov, B. (1963). About the systematic situation of puzanok of Veleka river. *God. Sof. Univ. Biol. (Zool.)* **56,** 205-225.

Markevich, A. P. (1952). Parasitic copepods of fish in the Black Sea. *Pratsi. Inst. Zool. Akad. Nauk Ukrain RSR* **8,** 91-99.

Markevich, A. P. (1956). *Parasitic copepods of fishes of the USSR.* 259 pp. Kiev: Izd. Akad. Nauk. Ukr. S. S. R.

Markowski, S. (1937). Uber die entwicklungsgeschichte und biologie des nematoden *Contracaecum aduncum* (Rudolphi, 1802). *Bull. Ac. Polon., Ser. B.* **II,** 227.

Marsialis, E. (1914). Piccolo vocabolario Sardo Italiano della fauna del Golfo di Cagliari e fauna degli altri mari sardi. *Soc, Tip. Sarda, Cagliari*

Marsili, L. F. (1725). *Il lago di Garda.* pp. 1-126. Bologna: Zanichelli.

Marteja, R., Orcel, L. and Truchet, M. (1985). Accumulation de metaux et de metaloides dans differents visceres de poissons (foie, rate, rein). *Annales Inst. Oceanogr, Paris* **60,** 115-127.

Martin, D., Lambert, P., Rochard, E. and Elie, P. (1995). Modelisation de la dynamique de population de la grande alose (*Alosa alosa*) dans le bassin versant Gironde-Garonne-Dordogne. In: *Les modèles au Cemagref: formulation, validation, pertinence.* 1, (Pave,
A. and Urien, R. eds.), pp. 309-320. Gif-sur-Yvette (France).CEMAGREF Editions,
B. Antony (France).

Martin, D. (1996). Global model of the dynamics and ecology of the population of allis shad (*Alosa alosa*) in the Gironde-Garonne-Dordogne watershed. *International Council for the Exploration of the Sea. Anadromous and Catadromous Fish Committee.* **ICES-CM-1996/M:11,** 17 pp.

Martin-Vandembulcke, D. (1999). *Dynamique de population de la grande Alose (Alosa alosa L. 1758) dans le bassin versant Gironde-Garonne-Dordogne (France): Analyse et prévision par modélisation.* 114 pp. + annexes. Thèse de Doctorat. Toulouse: Institut National Polytechnique de Toulouse.

Martinez, G. (1999). *Controle de la migration et de la reproduction de l'alose sur le bassin du Tarn et de l'Aveyron.* Association Migrateurs Garonne-Dordogne.

Matallanas, J., Ibanez, M., San Millan, M. D. and Riba, G. (1981). Catalogo de los Pesces marinos. *Trabajos de Deptartamento de Zoologia, Barcelona.* **1,** 1-138.

Mater, S. and Meric, N. (1996). Deniz Baliklari. In: *Türkiye Omurgahlar Tür Listesi.* 3, (Kence, A. and Bilgin, C.Ceds.), pp. 131-172 DPT/BAG Cev.

Matthews, J. D. (1887). *On the structure of the herring and other Clupeoids.* Appendix F, Sessial Papers, House of Commons **21 (1886),** pp. 274-292, Fisheries Board of Scotland.

Matthews, L. H. (1933). The sea fish and fisheries of the Bristol district. *Proceedings of the Bristol Naturalist Society* **7,** 442-462.

Maudet, F. (1983). *L'alose à Agen.* Rapp. de Stage. 108 pp. ENSAT.

Mauduyt, P. (1849). Ichthyologie de la Vienne. *Bull. Soc. Acad. Agric. Belle Lettres Sci. Arts Poitiers, Nouv. Sér.* **3,** 8-49.

Maurer, A. (1961). Ehemaliges Mitglied der Fischerzunft Ober und Niederhausen.

Maurin, H. and Keith, P. (1994). *Le livre rouge, inventaire de la faune menacée en France.* 175 pp. Nathan: MNHN WWF.

Maxwell, H. (1904). *British Freshwater Fishes.* pp. 288 - 291. London: Hutchinson & Co.

Mayne, R. C. (1861). Allis shad exhibited on behalf of Rev. Mayne by Prof. Kinahan. *Zoologist* **19,**

Mayr, E. (1963). *Animal Species and Evoloution.* 797pp. Cambridge, USA: Harvard University Press.

Mayr, E. (1974). *Populations, espèces et évolution.* 496 pp. Paris: Hermann.

Mazens, Y. and Corrao, B. (1997). *Suivi de la migration des aloses au niveau de l'aménagement de Beaucaire-Vallabrègues. Campagne d'études 1996.* **1996 N^{o}1/8,** 28 pp. + annexes. Association Migrateurs Rhône-Méditerranée.

Mazens, Y. (1997). *Suivi de la reproduction de l'alose feinte du Rhône en aval du carrage de Beaucaire-Vallabrègues. Campagne d'études 1996.* **1996 N^{o}2/8,** 28 pp. + annexes. Association Migrateurs Rhône-Méditerranée.

McDowall, R. M. (1988). *Diadromy in fishes. Migrations between freshwater and marine environments.* 308 pp. London: Croom Helm and Timber Press.

Meek, A. (1905). Fishes. In: *The Victoria history of the County of Durham.* **1**, (Page, W. ed.), 172.

Meek, A. (1916). *The Migrations of fish (Caspian Herring, Sprats, Sardined, Shads).* pp. 101-106. London: Arnold.

Menella, J. Y. and Tabardel, M. (1994). *Suivi de la dévalaison des alosons à Carderousse. Définition d'un protocole d'évaluation des résults. Campagne d'études 1993.* 33 pp. Association Migrateurs Rhône-Méditerranée.

Mennenson-Boisneau, C., Aprahamian, M. W., Sabatié, M. R. and Cassou-Leins, J. J. (2000). Remontée migratoire des adultes. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations*. (Baglinière, J. L. and Elie, P. ed.), pp. 55-72. Paris:INRA-CEMAGREF.

Mennesson-Boisneau, C., Boisneau, P. and Baglinière, J. L. (1986). *Etude de la grande alose (Alosa alosa) dans le bassin de la Loire.* Rapp. d' activité **7,**

Mennesson-Boisneau, C., Boisneau, P. and Baglinière, J. L. (1986). Premières observations sur les caractéristiques biologiques des adultes de grande alose (*Alosa alosa* L) dans le cours moyen de la Loire. [First observations on biological characteristics of shad (*Alosa alosa* L.) adults in the middle part of the Loire River]. *Acta Oecologica Applicata* **7,** 337-353.

Mennesson-Boisneau, C. and Boisneau, P. (1990). *Migration, répartition, reproduction, caractéristiques biologiques et taxonomie des aloses (Alosa sp) dans le bassin de la Loire.* 143 pp.+Annexes. Thèse le Grade de Docteur en Sciences de l'Universite. University of Rennes I, Paris XII Val de Marne.

Mennesson-Boisneau, C. (1990). *Migration, répartition, reproduction et caractéristiques biologiques des aloses (Alosa sp) dans le bassin de la Loire.* 105 pp. Thèse Doctorat. Rennes: Université de Rennes I.

Mennesson-Boisneau, C. (1991). *Intérêt du recueil des caractéristiques biologiques des aloses de la Loire.* Cons. Sup. Pêche, 6 pp.

Mennesson-Boisneau, C. and Baglinière, J. L. (1992). Mise au point d'une méthode de détermination de l'âge de la grande alose *(Alosa alosa*) à partir des écailles. In: *Tissus durs et âge individuel des vertébrés. [Hard tissues and individual age of vertebrates]. Colloque national, Bondy, France, 4-6 Mars 1991.* (Baglinière J. L., Castanet, J., Conand F. and Meunier, F. J. eds.), pp. 221-231. Paris:ORSTOM - INRA.

Mennesson-Boisneau, C., Boisneau, P. and Baglinière, J.-L. (1993). Migration de reproduction des aloses dans le bassin de la loire de 1986 à 1991, Incidence des obstacles. [Shads spawning migration in the Loire Basin. Incidences of obstacles.]. *Bulletin scientifique et technique. Departement d'Hydrobiologie, Institut national de la Recherche agronomique (France).* **27,** 23 pp.

Mennesson-Boisneau, C., Boisneau, P. and Postic, A. (1999). *Abondance de la grande Alose (Alosa alosa , L. 1758) dans la Loire: Analyses des facteurs de variabilité de 1984 à 1998; étude des caractéristques biologiques des géniteurs de 1994 à 1998 Mise au point d'un modèle de recruitment. [Abundance of allis shad in the Loire; An analysis of variability and biological characteristics 1984 -1998.].* 47 pp. DIREN Centre/Agence.

Mennesson-Boisneau, C., Aprahamian, M. W., Sabatié, M. R. and Cassou-Leins, J. J. (2000). Remontée migratoire des adultes. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations.* (Baglinière, J. L. and Elie, P. eds.), pp. 55-72. Paris:INRA-CEMAGREF.

Mennesson-Boisneau, C., Aprahamian, M. W., Sabatié, M. R. and Cassou-Leins, J. J. (2000a). Caractéristiques des adultes. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations*. (Baglinière, J. L. and Elie, P. ed.), pp. 33-53. Paris:INRA-CEMAGREF.

Meny, J. and Goubault, O. (1995). *Plan de gestion des poissons migrateurs des bassins de Garonne-Dordogne et Charente-Seudre. 1 - Document de synthèse des données existantes.* 82 pp. Bordeaux. DIREN Aquitaine.

Metzger, A. (1888). Ueber steerthamenfischerei in der Elbe, Weser und Ems,. *Tijdschrift der Nederlandsche Dierkundige Vereeniging.* **Supplement Deel II,** 256-273.

Meyer, L. and Brunken, H. (1997). Historisches Vorkommen, aktuele Verbreitung und Einschaetzung der zukuenftigen Bestandsentwicklung wandernder Fischarten und Rundmaeuler (Osteichthyes et Cyclostomata) im Allersystem (Niedersachsen). [Historical occurrence and current distribution of migrating fishes and lampreys (Osteichthyes et Cyclostomata) in the drainage system of the river Aller (Lower Saxony) with an evaluation of future development of their stocks.]. *Braunschweiger Naturkundliche Schriften* **5,** 281-303.

Meyer, L., Bruemmer, I., Brunken, H., Kolster, H. and Mosch, E. C. (2000). Zur Fischfauna von Ilmenauniederung und Winsener Elbmarschen (Niedersachsen) unter besonderer Beruecksichtigung von Fischen und Rundmaeulern des Anhangs II der FFH-Richtlinie. [The fishes and lampreys of the flats between the Rivers Ilmenau and Elbe (Lower Saxony, Germany) under special consideration of species according to the council directive 92/43/EEC, annex II.]. *Braunschweiger Naturkundliche Schriften* **6,** 1-38.

Micha, J.-C. and Borlee, M.-C. (1989). Recent historical changes on the Belgian Meuse. In: *Historical changes of large alluvial rivers: western Europe*. (Petts, G. E., Möller, H. and Roux, A.L., eds.), pp. 269-295. Chichester:John Wiley & Sons Ltd.

Mikelsaar, N. (1984). *Eesti NSV Kalad. [Fishes of the Estonian SSR.].* 432 pp. Tallinn: Valgus.

Mileriene, E. (1997). *Investigations on the fish fauna in the Lithuanian parts of Kurshiu (Curonian) lagoon.* **FAO Fisheries Report No. 541 Supplement,** pp. 74-78. Food and Agriculture Organization of the United Nations.

Minchin, D. (1977). Fish and benthos from the southern Irish sea. *Irish Naturalists' Journal* **19,** 128-129.

Minchin, D. and Molloy, J. (1978). Notes on fishes taken in Irish waters in 1976. *Irish Naturalists Journal* **19,** 160-162.

Mirre, V.(2001). *Etude experimentale du comportement des larves d'alose (Alosa alosa L.).* 19 pp. Author's Degree: Maitrise (Biologie des Populations et des Ecosystemes, mention Environnement). Bayonne (France): Univ. Pau et Pays de l'Adour.

Moeller, H. and Mueller, H. (1984). Ein Vergleich von Hamenfischereiertraegen auf der Unterelbe in den Sommern 1894 und 1982. [A comparison of catches from anchor nets in the lower Elbe River during summer 1894 and summer 1982.]. *Fischwirt.* **34,** 26-30.

Mogil'chenko, V. I. (1977). On the structure of the spawning stock and the time of migration in the Don River of *Alosa kessleri pontica* (Eichwald). *Gidrobiol. Zh. Hydrobiol. J.* **13,** 91-97.

Mogil'chenko, V. I. (1980). *Biology and the state of stock of the Lower Don shad.* pp. 132. Naukova Dumka Kiev (USSR).

Mohr, E. (1941). Maifische (Clupeiden). In: *Handbuch der Binnenfischerei Mitteleuropas*. 3-A(7), (Demoll, R. and Maier, H. N. ed.), pp.527-551. Stuttgart:Schweizerbart'sche Verlagsbuchhandlung.

Mola, P. (1926). Pesca ed ambiente peschereccio delle acque dolci della Sardegna. *Acquicoltura Sarda. L.I.S. Sassari*

Mola, P. (1941). Contributo alla piscicultura della Sardegna. *Acquicoltura Sarda. L.I.S. Sassari*

Mommsen, T. P. and Walsh, P. J. (1988). Vitellogenesis and oocyte assembly. In: *Fish Physiology*. XI, (Hoar, W. S. and Randall, D.J., eds.), pp. 347-406. London:Academic Press.

Moravec, F. and Ergens, R. (1971). The parasite fauna of fishes from Montenegro II. Nematoda. *Poljopriv. i Shumarstro* **17,** 1-18.

Moreau, E. (1881). *Histoire naturelle des Poissons de la France.* 3, 697 pp. Paris:

Moreira, F., Assis, C. A., Almeida, P. R., Costa, J. L. and Costa, M. J. (1992). Trophic relationships in the community of the Upper Tagus Eustuary (Portuga): a preliminary approach. *Estuarine, Coastal and Shelf Science* **34,** 617-623.

Morel, M. (1974). Identification de espèces de poisson par électrophorèse des protéines du muscle. Science et Pêche. *Bull. Inst. pêches marit.* **234,** 1-16.

Morovic, D. (1959). *Contribution à la connaissance de l'alimentation de l'alose (Clupea finta Cuv.) en Adriatique. [Contribution to the knowledge of the feeding habits of the shad (Clupea finta cuv.) in the Adriatic].* Proc. Gen. Fisher Counc. Medit. **5**, 365-368.

Möller, H. (1983). *A survey on fish stocks of the lower Elbe River.* **48**, 26 pp. ICES, Copenhagen ICES - CM 1983.

Möller, H. (1984). *Daten zur Biologie der Elbefische.* 217 pp. Kiel: Verlag Möller.

Möller, H. (1987). *Spawning and feeding migrations of fishes in the Elbe estuary.* Proceedings of the 5th International Wadden Sea Symposium. Pp. 87-101. Copenhagen. The national Forest and Nature Agency.

Möller, H. (1988). *Fischbestände und Fischkrankheiten in der Unterelbe 1984-1986. Untersuchung im Auftrage der Arbeitsgemeinschaft für die Rheinhaltung der Elbe.* 344 pp. Kiel: Verlag H.Möller.

Möller, H. (1989). Changes in fish stocks and fisheries: the lower Elbe River. In: *Historical change of large aluvial rivers: western Europe.* (Petts, G. E., Möller, H. and Roux, A.L., eds.), pp. 203-220. Chichester:John Wiley & Sons Ltd.

Möller, H. and Dieckwisch, B. (1991). Larval fish production in the tidal River Elbe 1985-1986. *Journal Fish Biology* **38,** 829-838.

Möller, H. and Scholz, U. (1991). Avoidance of oxygen-poor zones by fish in the Elbe River. *Journal of Applied Ichthyology* **7,** 176-182.

Möller, H. (1991). Der Zustand der Fischfauns in der Unterelbe. *Fischökologie* **4,** 23-44.

Möller, H. (1993). *Status of the fish fauna of the lower Elbe River and concepts for its protection.* Fish: ecotoxicology and ecophysiology. pp.159-172. Proceedings of an International Symposium, Heidelberg 1991. VCH.

Mrakovcic, M., Misetic, S. and Povz, M. (1995). Status of freshwater fish in Croation Adriatic river systems. *Biological Conservation* **72,** 179-185.

Munro, T., Cave, J., Saunders, A., Smith, J., Smith, S., Robinson, M., Conroy, C. and Erskine, T. (2002). *Environment Agency Kent Fisheries Department Medway Estuary Fisheries Survey 2001.* 67 pp. Bristol. Environment Agency.

Murie, J. (1903). *Thames Estuary Sea Fisheries. I. Kent and Essex.* Kent and Essex Sea Fisheries Committee, London.

Muus, B. J. and Dahlstrom, P. (1966). *Guide des poissons de mer et de pêche.* 244 pp. Neuchatel: Delachaux & Niestlé.

Muus, B. J. and Dahlström, P. (1968). *Süßwasserfische.* 224 pp. München: BLV Verlagsgesellschaft.

Muus, B. J. and Dahlström, P. (1981). *Guide des poissons d'eau douce et de pêche.* 242 pp.

Muus, B. J. and Dahlstrøm, P. (1989). *Havfisk og Fiskeri i Nordvesteuropa.* 244 pp. København: GEC Gads Forlag.

Muus, B. J. and Dahlstrøm, P. (1990). *Europas ferskvandsfisk.* 224 pp. København: GEC Gads Forlag.

Muus, B. J. and Nielsen, J. G. (1999). *Sea fish.* 340 pp. Hedehusene, Denmark: Scandanavian Fishing Year Book.

Müller, R. (1990). *Management practices for Lake Fisheries in Switzerland.* Management of Freshwater Fisheries. Proceedings of a Symposium organised by the European Inland Fisheries Advisory Commission. pp. 477-492. Göteborg, Sweden, 31 May - 3 June 1988. Pudoc. Wageningen.

Müller, R. and Meng, H. J. (1992). Past and Present State of the Ichthyofauna of Lake Lugano. *Aquatic Sciences* **54,** 338-350.

Navodaru, I., Constantin, G. and Staras, M. (1995). Hidrometeorological factors influencing the run migration of pontic shad (*Alosa pontica* Eichwald) base of the fishing. In: *Aquaculture and fishing. Extended abstracts and papers of contributions presented at the international symposium: Aquarom '95 Galatia - Romania*. (Rauta, M. and Oprea, L. eds.), pp. 421-426. Galatia:Universitatea "Dunarea de Jos" Galatia and Asociatia Piscicultorilor si Pescarilor din Romania.

Navodaru, I. (1996). Exploitation of *Alosa pontica* in the Danube Delta, Romania. In: *Stock assessment in inland fisheries*. (Cowx, I. G. ed.), pp. 448-453. Oxford:Fishing News Books.

Nebolsina, T. K. (1960). In Russian. Infection of young fish of the Caspian species of *Alosa* with the trematode *Mazocraes alosa*. *Dolk. Akad. Nauk. SSSR* **131,** 1478-1480.

Nedic, D., Kavaric, N., Ivanovic, B., Knemevic, B. and Kazic, D. (1977). Some distinctions of ichthyofauna and ichthyoparasites of Skader Lake in Montenegro. 306. Copenhagen:DIS Congress Service.

Negri, A. (1993). *La biologia dell'agone del Lago di Como. Prima Parte.* 99 pp. Como. Amminiistrazione Provinciale, Assessorato Caccia Pesca.

Nelson, G. J. (1967). Gill arches of teleostean fishes of the family clupeidae. *Copeia* **2,** 389-399.

Nelson, J. S. (1994). *Fishes of the World.* 600 pp. New York: John Wiley & Sons.

Neufville-Taylor, J. (1974). *Fishing on the Lower Severn.* 22 pp. Gloucester: Glevum Press.

Neville-Jones, A. (1972). Notes on the origin of the freshwater fish of West Wales. *Nature in Wales* **13,** 2-10.

Newell, G. E. (1954). The marine fauna of Whitstable. *Annals and Magazine of Natural History* **(12) 7,** 321-350.

Nicola, G. G., Elvira, B. and Almodóvar, A. (1996). Dams and fish passage facilities in the large rivers of Spain: effects on migratory species. *Archive für Hydrobiologia* **113,** 375-379.

Nicoll, W. (1915). A list of the trematode parasites of British marine fishes. *Parasitology* **7,** 339-378.

Nijssen, H. and De Groot, S. J. (1974). Catalogue of fish species of the Netherlands. *Beaufortia* **21,** 173-207.

Nijssen, H. and de Groot, S. J. (1997). De Vissen van Nederland. In: *Natuurhistorische Bibliotheek van de KNNV*. 43, (van Bohemen, H. D., Buzier, D. A. G. and Littel, A. eds.), Den Haag:CIP-Gegevens koninklijke Bibliotheek.

Nikolaeva, V. M. (1966). Trematodes of the suborder *Hemiurata* invading fish of the Mediterranean basin [Russian text]. *Respublik. Mezhvedomstv. Sborn. Akad. Nauk Ukrain, SSR, S. Biol. Moria* pp. 52-66.

Nikolski, G. V. (1963). *The ecology of fishes.* 352 pp. London and New York: Academic Press.

Nilsson, N. A. (1975). Skyddsvarda fiskar. *Sveriges Natur Arsbok* **66,** 141-150.

Nobre, A., Afreixo, J. and Macedo, J. (1915). *A Ria de Aveiro, Relatório oficial do regulamento da Ria de 28 de Dezembro de 1912.* Lisboa. Imprensa nacional.

Nobre, A. (1932). *Peixes de água doce de Portugal.* Seperata do Boletim **13 (2),** Ministerio da Agricultura.

Nobre, A. (1935). *Fauna marinha de Portugal I. Vertebrados (Mamiferos, Répteis e Peixes).* Porto:

Noël, S. B. J. (1815). *Histoire générale des pêches anciennes et modernes dans les mers et les fleuves des deau continents.* 428 pp. Paris: Imprimerie royale.

Nolte, W. (1976). *Die Küstenfischerei in Niedersachsen.* Kommissionsverlag Gött. Tagebl./Göttingen.

Novello, R. and Oppi, E. (1985). Biologia e pesca dell'Agone nel lago di Garda. In: *Il Garda, l'Ambiente, l'Uomo: Prima Miscellanea. Centro studi per ilterritorio benacense.* pp. 21-34. Verona:La Grafica di Lavagno.

Nybelin, O. (1922). Anatomisch - systematischen. Studien ueber Pseudophyllidien. *Göteborgs Kungliga Vetenskaps- och Vitterhets-Samhalle Handlingar Bihang* **26,** 169-211.

O'Grady, K. T. (1988). *EIFAC National report for the United Kingdom for Inter sessional period January 1986 - December 1987.* EIFAC occaisional paper **20,** European Inland Fisheries Advisory Committee.

O'Hara, K. (1976). *An ecological study of fishes, with particular reference to freshwater species, in the Welsh Dee at Chester.* Ph.D. Liverpool: University of Liverpool.

O'Maoileidigh, N. O., Cawdery, S., Bracken, J. J. and Ferguson, A. (1988). Morphometric, meristic character and electrophoretic analysis of two Irish populations of twaite shad, *Alosa fallax* (Lacépède). *Journal of Fish Biology* **32,** 355-366.

O'Maoileidigh, N. (1990). *A Study of fish populations in the Killarney Lakes.* Ph. D. Thesis National University of Ireland, University College Dublin.

O'Riordan, C. E. (1965). *A catalogue of the collection of Irish fishes in the National Museum of Ireland.* Stationery Office. Dublin.

Oesmann, S. (1994). *Nahrung und Wachstum clupeider Fische in der Unterelbe.* 95pp. Diploma. Institut für Hydrobiologie und Fischereiwissenschaft, Hamburg.

Oesmann, S. and Thiel, R. (2001). Feeding of juvenile twaite shad (*Alosa fallax* Lacépède, 1803) in the Elbe estuary. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 785-800.

Ogerien, F. (1863). Histoire naturelle du Jura et des départements voisins III Zoologie vivante. (Masson, ed.), 558 pp. Paris:

Olivier, E. (1882). *Faune de Doubs ou catalogue raisonné des animaux sauvages observés jusqu'à ce jour dans ce département.* 67 pp. Besançon.

Ombredane, D. and Baglinière, J.-L. (1992). Les écailles et leurs utilisations en écologie halieutique. In: *Tissus durs et âge individuel des vertébrés. [Hard tissues and individual age of vertebrates]. Colloque national, Bondy, France, 4-6 Mars 1991.* (Baglinière J.L, Castanet, J., Conand F. and Meunier, F. J. eds.), pp. 151-192. Paris:ORSTOM - INRA.

Omori, M. and Ikeda, T. (1984). Sampling. In: *Methods in Marine Zooplankton Ecology*. pp. 20-55. Chichester:Wiley and Sons.

Oppi, E. (1974). Note sulla fauna ittica del Garda e studio sul regime alimentare dell'Alosa. In: *Quaderni I.R.S.A.* **18**, pp. 241-261. Roma:

Oppi, E. and Novello, R. (1986). *Ulteriori osservazioni sulla biologia e pesca dell'agone (Alosa fallax lacustris) nel Lago di Garda.* 18 pp. Verona. Federazione Italiana Pesca Sportiva.

Oppi, E. and Novello, R. (1989). Ulteriori osservazioni sulla biologia e pesca dell'agone (*Alosa fallax lacustris*) nel Lago di Garda. *Ricerche sui pesca del Lago di Garda. Cooperativa fra pescatori.* pp.189-202.

Osório, B. (1912). Pescas e peixes. Uma nota relativa à pesca e aos peixes da Ria de Aveiro. *Biol. Soc. Geogr. Lisboa* **30,** 216-224; 264-271.

Owen, G. (1892). *The description of Pembrokshire.* Chas J Clark, 4 Lincoln's Inn Field, London.

Paepke, H. J. (1981a). Die gegenwärtige Situation der Süsswasserfischfauna in der DDR. *Archiv Naturschutz Landschaftsforsch* **21,** 113-130.

Paepke, H. J. (1981b). Anthropogene Einwirkung auf die Süsswasserfischfauna der DDR und Möglichkeiten des Artenschutzes. *Archiv Naturschutz Landschaftsforsch* **21,** 241 258.

Paleari, M. A., Soncini, G., Beretta, G., Grimaldi, P. and Tava, A. (1993). Microbiology and chemical composition of a typical product from *Alosa fallax lacustris*. *Journal of Applied Ichthyology* **9,** 222-229.

Panagiotopoulos, P. (1916a). Poissons anadromes. *Bulletin Station Hydrbiologique Marine Grecque* **1,** 449-455.

Panagiotopoulos, P. (1916b). Catalogues des poissons d'eau douce. *In: Rapport concernant la Station Hydrobiologique.* pp. 575-576.

Paolucci, C. (1918). I prodotti della pesca sul mercato di Cagliari. *Riv. Pesca e Idrobiol.* **9,** 81.

Paolucci, C. (1918). Note sulle condizioni fische e biologiche dell'alto Cixerre e del Flumendosa. *Ann. Idrobiol. e Pesca*

Paris, P. (1935). Les captures du Pêcheur dans nos eaux douces. *Bulletin scientifique de Burgogne* **5,**

Parnell, R. (1837). Fishes of the Firth of Forth. *Memoirs of the Wernerian National History Society* **7,** 329-332.

Parsley, M. J., Palmer, D. E. and Burkhardt, R. W. (1989). Variation in Capture Efficiency of a Beach Seine for Small Fishes. *North American Journal of Fisheries Management* **9,** 239-244.

Pattée, E. (1988). Fish and their environment in large European river ecosystems: The Rhône. *Sciences de l' eau* **7,** 35-74.

Pavesi, P. (1884). Brani biologici di due celebri pesci nostrali di acque dolci. *Rendiconti Reale Ist. Lomb. Sci. Lett.* **17,** 271-278.

Pavesi, P. (1896). La distribuzione dei pesci in Lombardia. *Soc. Lomb. Pesca Aquicol., Pavia.* **10,** 1 - 40.

Pavlov, P. I. (1964). Present condition of the reserves of commercial fishes of the lower Dnieper and the Dnieper-Bug Liman and thei protection. *Izd-vo VINITI, Kiev* 298 pp.

Pavlovic, M. and Pantic, V. (1973). Nucleus preopticus and nucleus lateralis tuberis in teleostea *Alburnus albidus* and *Alosa fallax* in various stages of the sexual cycle. *Arkiv bioloskih nauka* **25,** 9-16.

Pavlovic, M. and Pantic, V. (1975). The adenohypophysis in the teleostea *Alburnus albidus* and *Alosa fallax* i n different phases of the sexual cycle. *Acta Veterinaria (Beograd)* **25,** 163-178.

Pavlovic, M. (1976). Hypothalamus and pituitary gland of fishes during migration and changes of water salinity. *Rev. Trav. Inst. Pêches marit.* **40,** 705-706.

Pecorini, M. G. (1959). Larve di cestodi nei copepodi del Lago Maggiore. *Memorie dell' Instituto Italiano di Idrobiologia Dott. Marco de Marchi* **11,** 213-238.

Peczalska, A. (1973). Parposz, *Alosa fallax* (Lacépède, 1800) - ryba malo znana. [*Alosa fallax* (Lacépède, 1800), a little known fish.]. *Przeglad Zoologiczny* **17,** 195-200.

Pellegrin, J. (1921). Les poissons des eaux douces de l' Afrique du Nord Francaise: Maroc, Algerie, Tunisie, Sahare. *Mem. Soc. Sci Nat. Phys. Maroc* **1,** 216.

Pennant, T. (1777). *British Zoology.* Chester:

Pennant, T. (1810). *Tours in Wales.* **3**, London: Wilkie and Robinson.

Perceva-Ostroumova, T. A. (1963). Lieux et conditions de reproduction des Clupeidés du genre Alosa dans le Nord de la Mer Caspienne en 1934-1937. *Trudy Inst.Okeanol.* **62,** 28-48.

Pereira, A., Sousa, C., Alexandrino, P. and Ferrand, N. (1992). Polimorfismo genético da desaminase da adenosina (ADA, E.C. 3.5.4.4.) em populaçoee de sável (*Alosa alosa* L.) e savelha (*Alosa fallax* Lacépède). *Journadas de Genética Luso-Espanholas* **XXVII,**

Pereira, A., Alexandrino, P. and Rocha, J. (1995). Estudo electroforético das esterases 9es; E.c. 3.1.1.-) de sável (Alosa alosa L.) et savelha (Alosa fallax Lacépède). *Journadas de Genética Luso-Espanholas* **XXX,**

Pereira, A. (1995). *Caraterizaçao genética e bioquimica de esterases e peptidases de sável, Alosa alosa e savelha A.fallax.* Dissertaçao de Mestrado em Ecologia Aplicada. Porto.

Perkins, E. J. (1986). The marine flora and fauna of the Solway Firth area. *Dumfies and Galloway Natural History and Antiquarian Society* **45,** 15-43.

Perrier, R. (1964). *La faune de la France illustrée Ib - Vers et Némathelminthes.* 179 pp. Paris: Librairie Delagrave.

Persat, H. and Keith, P. (2002). Proposals for the reassessment of threatened status of freshwater fishes in France. In: *Freshwater Fish Conservation: Options for the Future.* (Collares-Pereira, M. J., Coelho, M. M. and I. G. Cowx, I. G. ed.), pp. 346-359. Oxford:Fishing News Books.

Pethon, P. (1979). Sjeldne saltvannsdfisker fra sydostnorske farvann i årene 1970-78. [Rare marine fishes from south eastern Norwegian waters in the years 1970-78]. *Fauna (Blindern)* **32,** 145-151.

Petit. (1979). Migration des alosas dans le bas -Rhône; dispositif de franchissement des obstacles et possibilité de reproduction au niveau de l' aménagement de Beaucaire. *DAA, Ecole Nationale Supérior d' Agronomie de Rennes.*

Petroli, J. C., Zaugg, C. and Zaugg, B. (1991). *Aktionsprogramm "Rhein", Rückkehr der Langdistanz-Wanderfische in den Rhein.* IKSR-Projekt Nr. 6 Schweizerischer Beitrage, Literaturstudium; 142s.

Petter, A. J. and Maillard, C. (1987). Ascarides de poissons de Mediterranee occidentale [Ascarids of fishes from western Mediterranean sea]. *Bulletin du Museum national d'Histoire naturelle (France). 4e serie. Section A. Zoologie, biologie, et ecologie animales.* **9,** 773-798.

Petter, A. J. and Cabaret, J. (1995). Ascaridoid nematodes of teleostean fishes from the eastern North Atlantic and seas of the north of Europe. *Parasite* **2,** 217-230.

Péguin, F. (1997). *Caractérisation des sites de frayères de la grande alose entre Agen et la centrale de Golfech.* 63 pp + annexes. Tours. Mémoire IUT de Tours.

Pérez-Bote, J. L., Da Silva, E., Moran, R., Cidoncha, P. and Lopez, M. (2000). *Distribution of allis shad Alosa alosa (Linnaeus, 1758) in the middle Guadiana River basin (SW Iberian Peninsula).* Freshwater Fish Conservation: Options for the Future. Algarve, Portugal. Abstracts

Philippart, J.-C. and Vranken, M. (1981). Pour la conservation de notre faune ichtyologique. *Bulletin des Réserves Naturelles et Ornithologiques de Belgique* **28,** 41-50.

Philippart, J. C. and Vranken, M. (1982). *Les poissons d'eaux douce menaces au region wallone.* Leige. Universite Liege, Ministere des Affaires Wallones.

Philippart, J.-C. and Vranken, M. (1983a). *Protégeons nos poissons. Collection "Animaux menacés en Wallonie".* 206 pp. Gembloux: Duculot.

Philippart, J. C. and Vranken, M. (1983b). Atlas du poissons de Wallonie. Distribution, écologie-éthologie, pêche conservation. *Cahier d'éthologie appliquée* **3 (1-2),** 51-54.

Philippart, J. C. (1985). Histoire des salmonidés migrateurs - saumon de l'Atlantique et truite de mer - dans la Meuse. In: *Compte rendu du Colloque Réintroduction du Saumon Atlantique dans le Bassin de la Meuse. Namur, 28 mars 1985.* pp.5-47. Service de la Pêche de la Région Wallone.

Philippart, J. C. (1987). *Histoire de l'extinction et problématique de la restauration des salmonidés migrateurs.* La Restauration des Rivières à Saumons. Actes du Colloque Franco - Québecois sur la Restauration des Rivières à Saumons. pp.125-137. Bergerac France. INRA, Paris.

Philippart, J. C. (1988). Le restauration des populations de poisson: le programme "barbeau" et la projet "saumon". *Actes Colloque de Namur (Belique) 3 -4 November 1987* pp. 107-121.

Philippart, J. C., Gillet, A. and Micha, J.-C. (1988). Fish and their environment in large European river ecosystems: The River Meuse. *Sciences de L'eau* **7,** 115-154.

Philippart, C. J. M., Lindeboom, H. J., Meer, J. v. d., Veer, H. W. d. and Witte, J. I. J. (1996). Long-term fluctuations in fish recruit abundance in the western Wadden Sea in relation to variation in the marine environment. *International Council for the Exploration of the Sea Journal of Marine Science* **53,** 1120-1129.

Pickett, G. D., Brown, M., Harley, B. and Dunn, M. R. (2002). *Surveying fish populations in the Solent and adjacent harbours using the CEFAS bass trawl.* Science Series Technical Report **118,** 16 pp. Lowestoft. Centre for Environmental Fisheries and Aquaculture Science.

Pina, T., Coelho, M. L., Esteves, E. and Andrade, J. P. (1999). *Fecundity of Twaite Shad, (Alosa fallax fallax) from the upper estuary of Rivers Mira and Guadiana (Portugal).* Environment, development and growth of fishes. University of St Andrews, Scotland. Abstract

Pina, T. A. S. (2000). *Aspectos da reprodução de savelha, Alosa fallax fallax (Lacépède, 1803), nos rios Mira e Guadiana.* 85 pp. + anexos. Tese de Mestre. Coimbra: Universidade de Coimbra.

Pinon, M. P. (1998). *Migration et caractérisation biologique de l'alose du Rhône (Alosa fallax rhodanensis, Roule 1924). Suivi des pêcheries (1996-1998) et essai d'estimation du stock franchissant le barrage de Vallabrègues. Campagne d'études 1998.* **1998 N^{o} 3/7,** 42 pp + annexes. Laboratoire Ecologie Aquatique INRA Rennes, Laboratoire halieutique ENSA Rennes. Association Migrateurs Rhône-Méditerranée.

Pirie, S. F. (1975). Scottish records of rare fishes, 1973. *Ann.Biol., Cons. Perm. Int. Explor. Mer* **30,** 208.

Pirola, M. E. (1930). L'Agone, fécondation et incubation artificielles. *Bulletin Français de Pisciculture* **22,** 225-230.

Piton, J. (1997). *Inventaire des populations d'aloses sur les côtes Bretonnes et de Basse-Normandie.* M.Sc. INRA écologie Aquatique Rennes.

Poitrineau, A. (1985). La Loire, les peuples du fleuve. (Horvath, ed.), 151-163.

Poizat, G., Chauvelon, P., Rosecchi, E. and Crivelli, A. J. (1999). Passage de poissons du Rhône par les pompes d'irrigation de Camargue: Premiers résultats. *Bulletin Français de la Pêche et de la Pisciculture* **352,** 31-43.

Poll, M. (1947). Poissons marins. In: *Faune de Belgique*. 452 pp. Bruxelles:Musée Royal D' Histoire Naturelle de Belgique, Bruxelles.

Poll, M., Teugels, G. G., Whitehead, P. J. P. (1984). Clupeidae. In: *Check-list of the freshwater fishes of Africa (CLOFFA).* 1, (Daget, J., Gosse, J. P. and Thys van den Audenaerde, D. F. E., eds.), pp.41-55. Paris and Tervuren:Musee royale de l'Afrique Centrale and Office de la Recherche Scientifique et Technique Outre-Mer.

Pollini, C. (1816). *Viaggio al lago di Garda e al monte Baldo.* pp. 1-152. Verona: Mainardi.

Pombo, L. and Rebelo, J. E. (2000). Ria de Aveiro ictiofauna: diversity in space and time. *Revista Biol. (Lisboa).* **18,** 69-81.

Pombo, L., Elliott, M. and Rebelo, J. E. (2002). Changes in the fish fauna of the Ria de Aveiro estuaine lagoon (Portugal) during the twentieth century. *Journal of Fish Biology.* **61 (Supplement A),** 167-181.

Pomfret, J. R., Elliott, M., O'Reilly, M. G. and Phillips, S. (1991). Spatial and temporal patterns in the fish communities in two UK North Sea estuaries. In: *Estuaries and Coasts: Spatial and temporal intercomparisons.* (Elliott, M. and Ducrotoy, J. –P. eds.), pp. 277-284. H. Fredensborg:Olsen & Olsen.

Pomini, F. P. (1937). Osservazioni sull'itiofauna delle acque dolci del Veneto e indagini riguardanti la pesca. *Boll. Pesca Piscic. Idrobiol.* **13,** 1-53.

Pomini, F. P. (1937a). Osservazioni sull'itiofauna del Veneto e indagini riguardanti la pesca. *Boll. Pesca Piscic. Idrobiol.* **13,** 262 - 312.

Poplin, R. (1952). Le peuplemont des eaux de l'Yonne moyenne. *Bull. Fr. Piscic.* **164,** 109-114.

Porcher, J. P. (1992). *Poissons migrateurs: Contrat "Retour aux sources", propositions d'action.* 169 pp. Conseil Supérieur de la Pêche, Ministère de l'Environnement.

Porcher, J. P. (1993). *Actions enterproses pour sauver les poissons migrateurs.* Pour un retour des poissons migrateurs: Adour-Charente-Dordogne-Garonne. pp.95-99. Hotel-Dieu, Toulouse. Agence de 'eau Adour-Garonne, CSP, CNRS.

Porumb, I. I. (1968). Contribution à l'étude de la biologie des aloses du littoral roumain de la mer Noire; particulièrement de leur nourriture. *Rev. Roum. Biol (Zool)* **13,** 447-452.

Potter, I. C., Claridge, P. N. and Warwick, R. M. (1986). Consistency of seasonal changes in an estuarine fish assemblage. *Marine Ecology Progress Series* **32,** 217-228.

Potter, I. C., Bird, D. J., Claridge, P. N., Clarke, K. R., Hyndes, G. A. and Newton, L. C. (2001). Fish fauna of the Severn Estuary. Are there long-term changes in abundance D. and species composition and are the recruitment patterns of the main marine species correlated? *Journal of Experimental Marine Biology and Ecology* **258,** 15-37.

Potts, G. W. and Swaby, S. E. (1991). *The British (non-bird) vertebrates Red Data Book: Marine fishes. Annex B of the final report to the Nature Conservancy Council.* **HF 3.03.417,** 37 pp. Peterborough. Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1993). *Marine and estuarine fishes of Wales. The development of the British Marine Fishes Database and monitoring programme for Wales.* Countryside Council for Wales.

Potts, G. W. and Swaby, S. E. (1993). *Marine fishes on the EC Habitats and Species Drective.* Confidential report to the JNCC. Peterborough. Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1993a). *Review of the status of estuarine fishes.* English Nature Research Report by the Marine Biological Association **34,** Peterborough. English Nature.

Potts, G. W. and Swaby, S. E. (1995). Fish: other species. Region 5. North-east England: Berwick-upon-Tweed to Filey Bay. (Barne, J. H., Robson, C. F. Kaznowska, S. S., Davidson, N. C. and Doody, J. P. eds.), Peterborough: Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1995). Fish: other species. Region 6. Eastern England: Flamborough Head to Great Yarmouth. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. and Davidson, N. C. eds.), Peterborough:Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1995). Fish: other species. Region 12. Wales: Margam to Little Orme. (Barne, J. H., Robson, C. F., Kaznowska, S. S. and Doody, J. P., eds.), pp. 113-115. Peterborough:Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1995). Fish: other species. Region 13. Northern Irish Sea Colwyn Bay to Stranraer, including the Isle of Man. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. and Davidson, N. C. eds.), Peterborough:Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1996). Fish: other species. Region 3. North-east Scotland: Cape Wrath to St. Cyrus. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. and Davidson, N. C. eds.), Peterborough:Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1996). Fish: other species. Region 9. Southern England: Hayling Island to Lyme Davidson. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. and Davidson, N. C. eds..), Peterborough:Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1996). Fish: other species. Region 10. South-west England: Seaton to the Roseland Peninsula. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P., Davidson, N. C. and Buck, A. L. eds.,), Peterborough:Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1996). Fish: other species. Region 11. The Western Approaches: Falmouth Bay to Kenfig. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P., Davidson, N. C. and Buck, A. L. eds.), Peterborough:Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1997). Fish: other species. Region 14. South-west Scotland: Ballantrae to Mull. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P., Davidson, N. C. and Buck, A. L. eds.), Peterborough:Joint Nature Conservation Committee.

Potts, G. W. and Swaby, S. E. (1997). Fish: other species. Region 15 & 16. North-west Scotland: The Western Isles and west Highland. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P., Davidson, N. C. and Buck, A. L. eds.), Peterborough:Joint Nature Conservation Committee.

Pouchet, G. and Biétrix, E. (1889a). Sur l'oeuf et les premiers développements de l'Alose. *C. R. Acad. Sci. Paris* **99,** 951-953.

Pouchet, G. and Biétrix, E. (1889b). Sur le développement de l'alose et de la Feinte. *Journ. Anat. Phys. Paris* **25,** 628-639.

Povz, M. and Sket, B. (1990). *Nase sladkovodne ribe.* Ljubljana: Mladinska knjiga.

Povz, M. (1996). The Red Data List of the freshwater lampreys (Cyclostomata) and fish (Pisces) of Slovenia. In: *Conservation of Endangered Freshwater Fish In Europe*. (Kirchofer, A. and Hefti, D. eds.), pp. 63-86. Basel:Birkhäuser Verlag.

Pravotorov, B. I. (1979). Some data on the biology of juvenile shad Alosa caspia nordmanni Antipa from the lower reaches of Dnieper and the Dnieper-Bug Liman. *In: Fish Farming Urozhai Press, Kiev* **28,** 82-87.

Prodanov, K. and Kolarov, P. (1983). On the problem of the rational exploitation of fish populations. *Izv.-Inst.-Ribn.-Resour.,-Varna-Izv.-Inst.-Rybn.-Resur.,-Varna ProcINST.-FISH.,-VARNA* **20,** 47-70.

Protasova, E. N. (1977). *Essentiel of Cestodology. VIII - Botriocephali - Taenia – Helminthes of Fishes.* **VIII**, 298 pp. Moscow:

Prouzet, P. (1988). *Rapport sur la campagne de pêche exercée par les marins pêcheurs dans l'estuaire de l'Adour en 1987.* IFREMER / DRV, RH/INRA St-Pée.

Prouzet, P. and Martinet, J. P. (1989). Las peche estuarienne sur L'Adour; Bilan de l'annee 1988. [The fishery in the Adour Estuary in 1988]. *Equinoxe* 23-32.

Prouzet, P., Martinet, J. P. and Casaubon, J. (1989). *Rapport sur la pêche des marins pêcheurs dans l'estuaire de l'Adour en 1988.* IFREMER / DRV, RH / INRA St-Pée.

Prouzet, P., Martinet, J. P., Luro, C. and Cuende, F. X. (1990). *Rapport sur la pêche des marins pêcheurs dans l'estuaire de l'Adour en 1989.* . IFREMER DRV / RH / INRA St-Pée.

Prouzet, P., Martinet, J. P., Luro, C. and Cuende, F. X. (1991). *Rapport sur la pêche des marins pêcheurs dans l'estuaire de l'Adour en 1990.* . IFREMER DRV / RH / INRA St-Pée.

Prouzet, P., Martinet, J. P. and Luro, C. (1992). *Rapport sur la pêche des marins pêcheurs dans l'estuaire de l'Adour en 1991.* 25 pp. INRA-IFREMER.

Prouzet, P. (1993). *Rapport sur la pêche des marins pêcheurs dans l'estuaire de l'Adour en 1992.* IFREMER / DRV, RH/INRA St-Pée.

Prouzet, P., Martinet, J. P., Luro, C. and Cuende, F. X. (1994). *Rapport sur la pêche des marins pêcheurs dans l'estuaire de l'Adour en 1993.* 20 pp. INRA-IFREMER.

Prouzet, P., Martinet, J. P. and Badia, J. (1994a). Caractérisation biologique et variation des captures de la grande alose (*Alosa alosa*) par unité d'effort sur le fleuve Adour (Pyrénées-atlantiques, France). [Biological characteristics and catch variation of allis shad (*Alosa alosa*) from commercial catches in the Adour River (Pyrenees atlantiques, France)]. *Aquatic Living Resources* **7,** 1-10.

Prouzet, P., Martinet, J. P. and Cuendec, F. X. (1994b). Les pêches professionnelles dans les estuaires de la Loire et de l'Adour. *Rep. Océans* **6,** 31-78.

Prouzet, P., Martinet, J. P. and Cuende, F. X. (1994c). La pêche estuariennes du bassin de l'Adour. In: *Les pêche prefessionnelle des poissons migrateurs dans les estuaires de la Loire et de l'Adour.* **6**, pp.33-71. Repères Océan, IFRENER, INRA, ENSAT.

Punt, A. (1941). Recherches sur quelques Nématodes Parasites de Poissons de la Mer du Nord. *Mémoires de musée Royal D'Histoire Naturelle de Belgique* **98,** 110.

Pushbarnehk, E. B. (1987). Characteristic features of the spawning part of a population of the Caspian shad *Alosa caspia caspia* off the Dagestan coast in 1980-1984. *Journal of Ichthyology* **27,** 593-597.

Pustelnik, G. (1978). Etude préliminaire sur la biologie de l’alose dans la Basse Dordogne. *CSP Toulouse.* 17 pp.

Pustelnik, G. (1978). Etude préliminaire sur la biologie de l'alose du Rhône.Pêche et difficultés croissantes de ses migrations. *Bull. Fr. Pisc.* **263,** 50-76.

Pustelnik, G. (1987). *Les résultats de la campagne 1986 de piégeage et de capture dans la passe à poissons de Bergerac.* 10 pp. Toulouse. Rap. Cons. Sup. Pêche, Dél. Rég. Midi-Pyrénées-Aquitaine.

Puyo, C. and Venel, A. (1987). Contribution d'un modèle réduit physique aux études d'ingénierie de l'ascenseur à poissons de Golfech.[A scale model contributing to the engineering studies of the Golfech fish lift]. *La Houille Blanche* **1/2** 81-87.

Quatrefages, A. (1849). Les animreng.ux utiles. 1 - Le hareng. *Revue des deux mondes* **1,** 22-54.

Quero, J. C. (1984). *Les poissons de mer des pêches françaises.* 394 pp. Grancher.

Quero, J. C., Dardignac, J. and Vayne, J. J. (1989). *Les poissons de Golfe de Gascogne.* 229 pp. Istitute Français de Recherche pour l'Exploitation de la Mer.

Quéro, J.-C. (1980). *Les poissons de mer des pêches françaises.* 394 pp. Grancher.

Quigley, D. T. G. and Flannery, K. (1996). Endangered freshwater fish in Ireland. In: *Conservation of Endangered Freshwater Fish in Europe*. (KirchhoferA. and Hefti, D. eds.), pp. 27-34. Basel (Switzerland):Birkhäuser Verlag.

Quigley, D. G. (1996). Status and conservation of euryhaline fish in Irish waters. *Aquatic Conservation : Marine and freshwater ecosystems* **6,** 313-318.

Quignard, J.P. (1962). Contribution à la faune ichthyologique sétoise. *Naturalia Monspeliensia* **3,**

Quignard, J. P. and Kartas, F. (1976). Les aloses feintes *Alosa fallax (Lacepede, 1803)* de l' atlantique nord-est et de la méditerranée occidentale, caractères numériques. *Revue des Travaux de l'Institut des Pêches Maritimes.* **40,** 721-723.

Quignard, J. P. (1977). Le Rhône et quelque problèmes concernant ses poissons, ou histoire naturelle de ce fleuve [The River Rhone and some problems of its fish or the non-natural history of this river]. *Les Cahiers du Gard rhodanien, Collect. Parme (Art Sci.)* **1,** 22 pp.

Quignard, J. P. and Kartas, F. (1977). Les aloses feintes *Alosa fallax* (Lacépède 1803). Poissons Clupéiformes de l' Atlantique nord-est et de la Méditerranée. Étude des caractères numériques. [The shads *Alosa fallax* (Lacépède 1803) clupeiform fishes from the northeastern Atlantic and Mediterranean. A study of numerical characters]. *Bulletin de Muséum National D'Histoire Naturelle 3e série Zoologie 350.* **501,** 1241-1256.

Quignard, J. P. (1978). Le Rhône et quelques problèmes concernent ses poissons ou histoire naturelle de ce fleuve. *La Sabranenque, Bagnols-sur-Cèse* 23 pp.

Quignard, J. P. and Zaouli, J. (1980). Les lagunes périméditerranéennes. Bibliographie ichtyologique annotée. Première partie: les étangs français de Canet à Thau. *Bull. Off. Natn. Pêch., Tunisie* **4,** 293-360.

Quignard, J. P. and Zaouli, J. (1981). Les lagunes périméditerranéennes. Bibliographie ichtyologique annotée. Deuxième partie: b) les étangs français d'Ingril à Porto-Vecio. *Bull. Off. Natn. Pêch., Tunisie* **5,** 41-96.

Quignard, J. P. and Douchement, C. (1991). *Alosa fallax killarnensis* (Regan, 1916). In: *The freshwater fishes of Europe. Volume 2. Clupeidae, Anguillidae.* 2, (Hoestlandt, H. ed.), pp. 254-256. Wiesbaden:Aula-Verlag.

Quignard, J. P. and Douchement, C. (1991a). *Alosa alosa* (Linnaeus, 1758). In: *The freshwater fishes of Europe. Volume 2. Clupeidae, Anguillidae.* 2(Hoestlandt, H. ed.), pp. 89-126. Wiesbaden:Aula-Verlag.

Quignard, J. P. and Douchement, C. (1991b). *Alosa fallax fallax* (Lacepède, 1803). In: *The freshwater fishes of Europe. Volume 2. Clupeidae, Anguillidae.* 2, (Hoestlandt, H. ed.), pp.225-253. Wiesbaden:Aula-Verlag.

Quignard, J. P. and Douchement, C. (1991c). *Alosa fallax rhodanensis* (Roule, 1924). In: *The freshwater fishes of Europe. Volume 2. Clupeidae, Anguillidae.* 2, (Hoestlandt, H. ed.), pp.274-288. Wiesbaden:Aula-Verlag.

Quignard, J. P. and Douchement, C. (1991d). *Alosa fallax nilotica* (Geoffrey Saint-Hilaire, 1808). In: *The freshwater fishes of Europe. Volume 2. Clupeidae, Anguillidae.* 2, (Hoestlandt, H. ed.), pp. 265-273. Wiesbaden:Aula-Verlag.

Quignard, J. P. and Douchement, C. (1991e). *Alosa fallax* (Lacepède, 1803). In: *The freshwater fishes of Europe. Volume 2. Clupeidae, Anguillidae.* 2 (Hoestlandt, H. ed.), pp. 211-212. Wiesbaden:Aula-Verlag.

Quignard, J. P. and Douchement, C. (1991f). *Alosa fallax lacustris* (Fatio, 1890). In: *The freshwater fishes of Europe. Volume 2. Clupeidae, Anguillidae.* 2, (Hoestlandt, H. ed.), pp. 257-264. Wiesbaden:Aula-Verlag.

R.N.D.E., C.S.P. and S.F.F. (1994). *Cinq examples d'évolutions de populations piscicoles.*

Raat, A. J. P. (2001). Ecological rehabilitation of the Dutch part of the River Rhine with special attention to the fish. *Regulated Rivers: Research & Management.* **17,** 131-144.

Rae, B. B. and Wilson, E. (1952). Rare and exotic fishes recorded in Scotland during 1951. *The Scottish Naturalist* **64,** 102-111.

Rae, B. B. and Wilson, E. (1953). Rare and exotic fishes recorded in Scotland during 1952. *The Scottish Naturalist* **65,** 141-153.

Rae, B. B. and Wilson, E. (1954). Rare and exotic fishes caught in Scotland during 1953. *the Scottish Naturalist* **66,** 170-185.

Rae, B. B. and Wilson, E. (1956a). Rare and exotic fishes recorded in Scotland during 1954. *The Scottish Naturalist* **68,** 23-38.

Rae, B. B. and Wilson, E. (1956b). Rare and exotic fishes recorded in Scotland during 1955. *The Scottish Naturalist* **68,** 92-108.

Rae, B. B. and Wilson, E. (1961). Rare and exotic fishes recorded in Scotland during 1956. *The Scottish Naturalist* **70,** 22-33.

Rae, B. B. and Lamont, J. M. (1961). Rare and exotic fish recorded in Scotland during 1957. *The Scottish Naturalist* **70,** 34-42.

Rae, B. B. and Lamont, J. M. (1962a). Rare and exotic fishes recorded in Scotland during 1959. *The Scottish Naturalist* **70,** 111-119.

Rae, B. B. and Lamont, J. M. (1962b). Rare and exotic fishes recorded in Scotland during 1958. *The Scottish Naturalist* **70,** 102-110.

Rae, B. B. and Lamont, J. M. (1963). Rare and exotic fishes recorded in Scotland during 1960. *The Scottish Naturalist* **71,** 29-36.

Rae, B. B. and Lamont, J. M. (1964). Rare and exotic fishes recorded in Scotland in 1961. *The Scottish Naturalist* **71,** 39-46.

Rae, B. B. and Pirie, S. F. (1969). Scottish records of rare fishes, 1968. *Annls. Biol. Copenh.* **25,** 257.

Rafinesque-Schmaltz, C. S. (1820). Ichthyologia Ohiensis. *Western Review Misc. Mag.* **2,** 1-170.

Raibaut, A., Hassine, O. K. B. and Maamouri, K. (1971). Copepodes parasites des poissons de Tunisie. *Bull. Inst.Océanogr. Pêche Salammbô* **2,** 169-197.

Rajad, M. (1977). *Les aloses du Maroc. Répartition et pêche, contribution à leur étude systématique et biologique.* Dip. Etud. Appr. Techn. Prod. Anim. Toulouse:

Rakaj, N. and Flloko, A. (1995). Conservation status of freshwater fish of Albania. *Biological Conservation* **72,** 195-199.

Rakaj, N. (1995). *Iktiofauna e Shqiperise.* 700 pp. Tirana, Albania: Shtepia Botuese "Libri Universitar".

Rakaj, N. and Crivelli, A. J. (2001). Occurrence of agone *Alosa agone* in Lake Shkodra, Albania in sympatry with the twaite shad *Alosa fallax nilotica. Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 1067-1073.

Rameye, L., Keiner, A., Spillmann, C. P. and Biousse, J. (1976). Aspects de la biologie de l'Alose du Rhône - Pêche et difficultés croissantes de ses migrations. [Biological considerations on *Alosa* in the Rhone river. Fisheries and increasing difficulties for its migrations.]. *Bulletin Francais de Pisciculture* **263,** 50-76.

Ramos, M. A. (1977). Reproducao artificial de *Alosa alosa* L. *Repositorio de Trabalhos do Laboratorio Nacional de Investigacao Veterinaria.* **IX,** 41-45.

Randall, J. (1882). *The Severn Valley.* Madeley.

Raveret-Wattel, C. (1907). *La pisciculture.* 2, 508 pp. Paris: Klinchsieck.

Ray, J. (1851). *Rapport sur la pêche fluviale dans le départment de l'Aube.* Soc. agri. sci. Arts et Belles Lettres de l'Aube. 38 pp.

Rebelo, J. E. (1992). The icthyofauna and abiotic hydrological environment of the Ria de Aveiro, Portugal. *Estuaries* **15,** 403-415.

Redeke, H. C. (1939). Über den bastard Clupea *Alosa finta* Hoek. *Archives Neerlandaise de Zoologie* **3,** 148-158.

Regalla, F. A. F. (1888). *Relatório sobre a pesca no rio Minho em 1884.* 22 pp Ministério da marinha e Ultramar.

Regan, C. T. (1911). *The freshwater fishes of the British Isles.* pp. 131-137. London: Methuen and Co Ltd,.

Regan, C. T. (1912). The twaite shad in Killarney lakes. *Irish Naturalist* **21,** 63.

Regan, T. (1916). The British fishes of sub-family Clupeidae and related species in other seas. *The Annals and Magazine of Natural History* **18,** 1-19.

Regan, C. T. (1917). A revision of the clupeoid fishes of the genera *Pomolobus, Brevoortia* and *Dorosoma* and their allies. *Ann. Mag. Nat. Hist.* **19,** 297-316.

Regan, C. T. (1917). *Guide to the British Fresh-Water Fishes.* 40 pp. William Clowes & Sons.

Repecka, R. (1999). *Biology and resources of the main commercial fish species in the Lithuanian part of the Curonian Lagoon.* Proceedings of Symposium on Freshwater Fish and the Herring (*Clupea harengus*) Populations in the Coastal Lagoons - Environment and Fisheries. pp.185-195. Sea Fisheries Institute, Gdynia (Poland).

Reshetnikov, Y. S., Bogutskaya, N. G., Vasil'eva, E. D., Dorofeeva, E. A., Naseka, A. M., Popova, O. A., Savvaitova, K. A., Sideleva, V. G. and Sokolov, L. I. (1997). An annotated check-list of the freshwater fishes of Russia. *J. Ichthyology* **37,** 687-736.
Ribeiro, S. (1971). Importancia económica e social da pesca nas áquas interiores. *I Simpásio nacional sobre poluicao des áquas interiores* **1,** 25-34.

Ridewood, W. G. (1904). On the cranial osteology of the Clupeoid fishes. *Proceedings of the Zoological Society London* **II,** 448-493.

Riebs, R. (1995). Mitt. Vorsitzender der Fischerzunft Auenheim.

Riedel, W. (1894a). Zur Frage der Maifisch-Erbrütung. *Allgem. Fischerei-Zeitung* **XIX,** 18-21.

Riedel, W. (1894b). Zur Frage der Maifisch-Erbrütung. *Allgem. Fischerei-Zeitung* **XIX,** 59-60.

Riethe, P. (1991). *Das Buch von den Fischen.* 150 pp. Sazlburg: Otto Müller Verlag.

Risso, A. (1826). *Histoire naturelle des principales productions de l'Europe méridionale.* 3, Paris: Levrault.

Rizzotti, M. and Gioppato, F. (1997). Hemoglobin ontogeny of *Alosa fallax* (Teleostei, Clupeiformes): Comparison between a marine anadromous population and a landlocked one. *Animal Biology* **6,** 13-18.

Rizzotti, M. and Giopatto, F. (1999). Fish haemoglobins: the order Clupeiformes. *Reviews in Fish Biology and Fisheries* **9,** 71-89.

Robbins, J. (1962). The Shad; the shad arrive to play, feed and breed. *Anglers World.* **November 1962,** 9 - 10.

Roberts, R. (1979). *Pathologie du poissons.* 317 pp. Ed. Maloine.

Rochard, E. (1985). *Suivi des captures et traitements statistiques dans le cadre de la dynamique des population des espèces migratrices.* 16 pp. Bordeaux. DEA, Université Bordeaux.

Rochard, E. and Castelnaud, G. (1986). *Étude de suivi halieutique de l'estuaire de la Gironde 1985. 2^{e} partie: évaluation de la production et calculs de CPUE. Campagne 1984.* 82 pp. Bordeaux. CEMAGREF Bordeaux.

Rochard, E. (1992). *Mise au point d'une méthode de suivi de l'abondance des amphihalins dans le système fluvio-estuarien de la Gironde, application à l'étude écobiologique de l'esturgeon Acipenser Sturio. [Set up of a method to survey the abundance of amphihaline fish in the river estuary system of the Gironde, application to the ecological study of the sturgeon Acipenser sturio.].* 315 pp. Thèse Doctorale de l'Université de Rennes I. Rennes: Université de Rennes I.*[Set up of a method to survey the abundance of amphihaline fish in the river estuary system of the Gironde, application to the ecological study of the sturgeon Acipenser sturio.].* pp. 315. Thèse Doctorale de l'Université de Rennes I. Rennes: Université de Rennes I.

Rochard, E. (2001). Migration anadrome estuarienne des géniteurs de grande alose *Alosa alosa*, allure du phénomène et influence du rythme des marées. [Anadromous Estuarine migration of adult allis shad *Alosa alosa*, shape of the phenomenon and influence of the tidal cycle.]. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 853-867.

Rodrigues, H. d. O., Carvalho Varela, M. and Rodrigues e Rigoletto, S. S. (1972). Alguns trematódeos digenéticos de peixes do Oceano Altlanico - Costa Continental Portuguésa Costa Continental de Africa [Some digenic trematodes of fish from the Atlantic Ocean – the continental Portugese coast and the continental African coast]. *Atlas da Sociedade De Biologia do Rio De Janeiro* **15,** 87-93.

Roguet, M. (1993). *Bilan du programme de restauration des poissons migrateurs dans le basssin Adour-Garonne.* Pour un retour des poissons migrateurs: Adour-Charente-Dordogne-Garonne. pp. 100-109. Hotel-Dieu, Toulouse. Agence de 'eau Adour-Garonne, CSP, CNRS.

Roguet, M. (1994). *Results of the migratory fish restoration program in the Adour-Garonne basin. 1975-1993.* Pour un Retour Des Poissons Migrateurs [Migratory Fish Restoration] Papers of the National Symposium. Pp.100-109. Toulouse France. Actes Du Colloque. Agence de l' Eau Adour Garonne.

Rohrmann, F. (1909). *Die Fische des Neckars bei Heidelberg.* Ludwigshafen:

Romer, A. S. (1966). *Vertebrate paleontology.* University of Chicago Press.

Rondelet, G. (1558). *Histoire entière des poissons. 1^re^ partie.* 418 pp. Lyon: Macébonhome.

Rosoiu, N., Serban, M., Panait, M. and Stoica, S. (1983). Characterization of antihyaluronidasic activity from marine organisms. *Cercet.-Mar.-Rech.-Mar.* **16,**.

Roth, J. (1988). *Die Fischbeseidlung des nördlichen Oberrheins und des Mittelrheins im Jahre 1986.* Diplomarbeit 147 S. TH Darmstadt.

Roth, S. (1997). Ever the Twaite Shad meet. *Water Bulletin* **774,** 7.

Roule, C. (1920). La croissance de l' alose feinte d' après les écailles. *C. R. Soc. Biol. Paris* **83,** 1542- 1544.

Roule, L. (1920a). Les espèces d'aloses du bassin de la Seine. *Bull. Mus. Hist. Nat. Paris* **26,** 610-611.

Roule, L. (1922). *Les poissons migrateurs et leur pêche.* 175 pp. Paris: Flammarion.

Roule, L. (1922a). La migration reproductrice et la protandrie de l'alose feinte (*Alosa finta* L.). *Ann. Sci. nat. (Zool) Paris Ser.* **5,** 61-76.

Roule, L. (1923). Notes sur les Aloses de la Loire et de L' Aquitaine. *Bull. Soc. Cent. Aquaculture Pêche* **30,** 14-22.

Roule, L. (1924a). Les aloses des eaux douces de la France. *Bull. Soc. Zool. France* **49,** 265-266.

Roule, L. (1924b). *Paralosa (Nilotica) rhodanensis.* Faune et Flore Méditerranéene. *Comm. Intern. Explor. Scient. Mediterr* 1.

Roule, L. (1924c). Le thermotropisme dans la migration de l'alose. *Comptes Rendues 48ème session Association Française Avancement des Sciences* 954-957.

Roule, L. (1925). *Les poissons des eaux douces de la France.* 228 pp. Paris: Presses Universitaires de France.

Roule, L. (1929). *Les poissons et le monde vivant des eaux. Voyages et migrations.* **3**, Paris: Delgrave.

Roule, L. (1933). *Fishes, their journeys and migrations.* London: G Routledge and Sons Ltd.

Roule, L. (1945). La thermophilie des aloses. In: *Les poissons*. III, pp.161-179. Paris:

Roure, F. (1997). *Étude des zones potentielles de frai sur la Cèze. Campagne d'études 1996.* **1996 N^o 4/8,** 38 pp + annexes. ATOUT Environment. Association Migrateurs Rhône-Méditerranée.

Roure, F., Velez, M. and Garridot, S. (1997). *Le retour des aloses sur la Cèze: suivi de la frayère de substitution du Port de l'Ardoise, Laudun (30). Campagne d'études 1997.* **1997 N^o 3/6,** 38 pp + annexes. ATOUT Environment. Association Migrateurs Rhône Méditerranée.

Roure, F. and Sabatier, G. (1998). *Le retour des aloses sur la Cèze: suivi de l'efficacité de la passe à poissons de Codolet et des frayères potentielles en aval de Chusclan. Campagne d'études 1998.* **1998 N^o 2/7,** 34 pp + annexes. ATOUT Environment. Association Migrateurs Rhône-Méditerranée.

Ruchon, Menella, J. Y. and Tabardel, M. (1994). *Reproductibilité du franchissement par les aloses des écluses de navigation sur le Bas-Rhône. Plan Migrateurs Rhône Méditerranée.* 47 pp. Association Migrateurs Rhône-Méditerranée.

Russell, F. S. (1976). *The Eggs and Planktonic Stages of British Marine Fishes.* London: Academic Press.

Saat, T., Jarvekujg, R., Eschbaum, R. and Tambets, J. (2002). The status of threatened freshwater fishes in Estonia. In: *Conservationn of freshwater fishes: options for the future.* (Collares-Pereira, M. J.,Coelho, M. M. and Cowx, I. G. eds.), pp. 34-44. Oxford:Fishing News Books.

Sabatié, M. R. (1990). Croissance linéaire de l' alose vraie, *Alosa alosa* Linné 1758 (Clupeidae) dans l'oued Sebou (Façade Nord - Atlantique du Maroc) [Linear growth of *Alosa alosa* Linné, 1758 (Clupeidae) in the River Sebou (North Atlantic coast of Morocco)]. *Cybium* **14,** 131-142.

Sabatié, M. R. (1993). *Recherches sur l'écologie et la biologie des aloses du Maroc (Alosa alosa Linné, 1758 et Alosa fallax Lacépède, 1803). Exploitation et taxinomie des populations atlantiques; bioécologie des aloses de l'oued Sebou. [Ecological and biological researches on shad in Marocco (Alosa alosa Linné, 1758 et Alosa fallax Lacépède, 1803), fishing and taxonomy of Atlantic populations, bioecology of shad in Sebou River].* 326 pp. + annexes. Thèse de Doctorat. Brest: Université de Bretagne Occidentale en Océanologie Biologique.

Sabatié, M. R., Alexandrino, P. and Baglinière, J. L. (1996). Comparison des caractéristiques biologiques de la grande alosa (*Alosa alosa*) dans l'oued Sebou (Façade Nord-Atlantique du Maroc) et dans le Fleuve Lima (Portugal). [Comparison of biological characteristics of allis shad (Alosa alosa) in wani Sebou (north-east Atlantic coast of Morrocco) and in Lima river (Portugal).]. *Cybium* **20,** 59-73.

Sabatié, M. R., Boisneau, P. and Alexandrino, P. (2000). Variabilité morphologique. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations.* (Baglinière, J. L. and Elie, P. eds.), pp. 137-178. Paris:INRA-CEMAGREF.

Sabatié, M. R. and Baglinière, J. L. (2001). Quelques traits biolécologiques des aloses du Maroc; un patrimoine culturel et socio-économique récemment disparu. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 903-917.

Sabatié, M. R., Baglinière, J. L. and Boisneau, P. (2002). Shad of the Northeastern Atlantic and the Western Mediterranean (*A. alosa* L., 1758 and *A. fallax* Lac., 1803) : Biology, Ecology and Harvesting. In: *Fisheries and aquaculture: aquatic living resource.* (EOLSS, ed.), UNESCO.

Saemundsson, B. (1949). *Zoology of Iceland . IV Marine Pisces.*

Salmon Fisheries Commission. (1861). *Report of the Commissioners appointed to inquireinto Salmon Fisheries (England and Wales); together with the minutes of evidence.* HMSO London.

Salviani, I. (1554). *Aquatilium Animalium Historiae.* 256 pp. Roma:

Sammicheli, M. (1998). Italy pays homage to the Ombrone River shad. *Shad Journal* **3,** 6-7.

Sauriau, P., G. , Marchand, J. and Goinard, N. (1996). *Estuaire de la Loire: rapports de synthese de l'APEEL: 1984-1994. Volume 3: Ressources vivantes.* 67 pp. Nantes (France). Association pour la protection de l'environnement de l'estuaire de la Loire.

Scharff, R. F. (1894). The allis shad (Clupea alosa L) in the Erne. *The Irish Naturalist* **3,** 224.

Scharff, R. F. (1900). Attempted Introduction of the American Shad into Irish Waters. *Irish Naturalist* **9,** 185.

Schäfer, M. (1844). *Moselfauna.* 1, 339 pp. Wirbelthiere – Trier.

Schäfer, J. (1931). Die Fischerei im Kehler Gebeit. *Badische Heimat* **18,** 105-114.

Scheffel, H.-J. (1988). *Untersuchungen zum jungfischaufkommen in der bremer unterweser [Investigations on the occurrence of young fishes in the lower River Weser at Bremen].* 205 pp. Bremen.

Scheffel, H.-J. and Schirmer, M. (1991). Larvae and juveniles of freshwater and euryhaline fishes in the tidal River Weser at Bremen, FRG. *Verdhandlungen der Internationalen Vereinigung fur Theoretische und Angewandte Limnologie* **24(4),** 2446 2450.

Schinz, H. (1837). Fauna Helvitica. *Newe Denkschr. d. Allg. Schweig. ges.* **158,**

Schnakenbeck, W. (1928). Die Nordseefischerei. In: *Handbuch d. Seefischerei Nordeuropas*. V, (Lübbert, H. and Ehrenbaum, E. eds.), 229 pp. Stuttgart:Schweizerbart'sche Verlagsbuchhandlung.

Schnakenbeck, W. (1931). Clupeiformes - Clupeidae. In: *Faune ichthyologique de l'Atlantique nord*. (Joubin, L. ed.), Copenhagen:

Schwolert, H. (1891). Berichte über die küntsliche Zucht des Maifisches der Elbe. *Circulare des D.F.V.* **30,** 164-166.

Scopoli, I. A. (1786-1788). *Deliciae florae et faunae insubricae seu novae, aut minus cognitae species plantarum et animalium quas in Insubria Austriaca tam spontaneas, quam exoticas vidit. Descripsit et aeri incidi curavit Ioannes Antonius Scopoli.* 1, 1: viii + 85 pp., 25 pls.; 2: 115 pp., 25 pls.; 3: 87 pp., 25 pls. Ticino: Monasterius S. Salvatoris.

Scott, T. (1901). Notes on some parasites of fishes. *Annual Report of the Fisheries Board of Scotland.* **19,** 120-153.

Scott, A. (1906). Faunistic notes. *Transactions of the Biological Society Liverpool* **20,** 47 57.

Scott, T. and Scott, A. (1913). *The British parasitic Copepoda 1 - Copedoda parasitic on fishes.* 1, pp. 1-257. London: Ray Society.

Scotti, L. (1897). La distriuzione dei pesci d'acqua dolce in Italia. *Giorn. Ital. Pesca Acqicolt.* **11,** 170-179.

Seaby, R. and Henderson, P. (1994). *Fish and Crustacean Captures at Hinkley Point Nuclear Power Station April 1993 to March 1994.* Consultancy Report **FCR 092/94,** Fawley aquatic research laboratories Ltd.

Seaby, R. and Henderson, P. (1995). *Fish and Crustacean Captures at Hinkley Point Nuclear Power Station, April 1994 to March 1995.* Consultancy Report **FCR 151/95,** Fawley Aquatic Research Laboratories Ltd.

Seeley, H. G. (1886). *The freshwater fishes of Europe.* Chapter VII, pp. 256-265.

Selys Longchamps, E. d. (1887). Révision des poissons d'eau douce de la faune belge. *Bull. Acad. roy. Belgique* **(3) XIV,** 80 pp.

Sertier, M., Elie, P. and Rochard, E. (1990). *Etude de suivi halieutique de l'estuaire de la Gironde 1989.* 230 pp. Bordeaux. CEMAGREF Div. ALA Bordeaux / EDF.

Serventi, M., Vitali, R. and Gandolfi, G. (1990). Biologia e biometria dei riproduttori di alosa, *Alosa fallax* (Lacépède) in migrazione nel delta del Po [Reproductive biology and biometry of the twaite shad, *Alosa fallax* (Lacépède), migrating in the Po Delta]. *Rivista di Idrobiologia* **29,** 469-475.

Service, R. (1892). Freshwater fishes of the Solway area. *Annals of Scottish Natural History* 18-25.

Severn Fishery District. (1869-1965). *Annual Reports.*

Severn River Authority. (1966-1979). *Annual Reports.*

Severn Tidal Power Group. (1989). Ecological studies, landscape and nature conservation. ETSU-TID 4060-P4. 54pp. Harwell: Severn Tidal Power Group/Central Electricity Generating Board/ Department of Energy.

Sey, O. (1968). Parasitic helminths occurring in Adriatic fishes. Part 1 (Flukes). *Acta Adriatica* **13,** 3-15.

Sey, O. (1970). Parasitic helminths occurring in Adriatic fishes. Part III (Nematodes, Acanthocephala). *Acta Adriatica* **13,** 3-16.

Shaw, K. S. (1977). *The freshwater fish and fisheries of Wales Vol I and II.* M. Sc. Thesis. University of Wales Institute of Science and Technology.

Shubina, L. I. and Rychagova, T. L. (1981). Dynamics of fat and water metabolism in Caspian shad, *Alosa caspia caspia* , in relation to its biological peculiarities. *Journal of Ichthyology* **21,** 123-127.

Siebold, C. T. E. (1863). *Die Susserwasserfische von Mitteleuropa.* 238 pp. Leipzig:

Sim, G. (1903). *The vertebrate fauna of the "Dee" Aberdeen.*

Sindermann, C. J. (1970). *Principal diseases of Marine fish and shellfish.* 369 pp. Academic press New York and London.

Sinis, A. I. (1981). *L'autoécologie de l'espèce endémique Alosa (Caspialosa) macedonica (Vinciguerra) (Pisces: Clupeidae) du Lac Volvi.* Thessaloniki.

Sinis, A. I. and Kattoulas, M. E. (1986). Population structure of *Alosa macedonica* (Vinciguerra, 1921) (Pisces: Clupeidae) in Lake Volvi (Macedonia, Greece). *Cybium* **10,** 91-101.

Sinis, A. J. and Economidis, P. S. (1987). Age and growth of *Alosa macedonica* (Pisces: Clupeidae), of the Lake Volvi (Macedonia, Greece). *Vestnik ceskoslovenske Spolecnosti zoologike.* **51,** 43-57.

Skora, K. S. (1996). Protected fish species from the Polish zone of the Baltic Sea. *Zoologica Poloniae* **41,** 79-86.

Slater, F. (1988). *The Nature of Central Wales.* Buckingham: Barracuda Books Ltd.

Smitt, F. A. (1895). A history of Scandinavian fishes. 2, pp. 567-1240.

Smyth, J. (1639). Lives of the Berkeleys in the county of Gloucester. (-. Sir John Maclean, ed.), Gloucester:

SNPRCN. (1991). Peixes dulciaquicolas e migradores. In: *Livro Vermelho dos Vertebrados de Portugal*. 2, (Servico Nacional de Parques, Reservas e Concervacao da Natureza, ed.), 55 pp. Lisbon:Secretaria de Estado do Ambiente.

SNPRCN. (1992). *Livro vermelho dos vertebrados de Portugal.* **II. Peixes dulciaquicolas e migradores,** Secretaria de Estado do Ambiente e Defensa do Consumidor.

Soljan, T. (1948). Ribe. In: *Fauna i flora Jadrana.* 1, (Hrvatske, ed.), 437 pp. Zagreb:

Soljan, T. (1963). *Fishes of the Adriatic.* 247 pp. Belgrade: NOLIT Publishing House.

Soljan, T. (1975). *I Pesci dell'Adriatico.* 523 pp. Verona: Arnoldo Mondatori Editore.

Solomon, D. (1988). *Fish and Fisheries in the Bristol Channel and Severn Estuary. Conservation aspects - Fish.* **SBPP/DJS/3.7(ii)d3,** Severn Barrage Development Project. Harwell: Energy Technical Support Unit. 11pp.

Solomon, D. (1988). *Aspects of the behaviour of migratory fish.* **SBPP/DJS/3.7(ii)d2,** Severn Barrage Development Project. Harwell: Energy Technical Support Unit. 46 pp.

Sostoa, A. and Sostoa, F. J. (1979). Notas sobre la ictiofauna continental del Delta del Ebro (NE de la Peninsula Iberica). *Miscellania zoologica.* **5**, 178-179.

Sostoa, A. and Sostoa, F. J. (1985). The fish community of the Ebro delta (Northeast Spain): a model of Mediterranean estuarine ecosystem. In: *Fish community ecology in estuaries and coastal lagoons: towards an ecosystem intergration.* (Yanex-Arancibia, ed.), pp. 654-694. Mexico:UNAM Press Mexico.

Sostoa, A. and Lobon-Cervia, J. (1989). Fish and fisheries of the River Ebro: actual State and recent history. In: *Historical changes of large alluvial rivers: western Europe.* (Petts, G. E., Möller, H., Roux, A.L., eds.), pp. 233-247. Chichester:John Wiley & Sons Ltd.

Sostoa, A. and coll., i. (1990). *Historia natural dels païpos catalans. 11. Peixos. Enciclopèdia Catalana.* 11, 169 pp. Barcelona: Fundacio Enciclopèdia Catalana.

Sourdot, M. (1988). Un pêcheur, ses pêches et sa rivière. *Pêche Poissons* **520,** 60-62.

Spano, B. (1956). Pisciculture in Sardegna. *Boll.Interessi. Sardi*

Spano, B. (1956). La pesca fluvio-lacuale in Sardegna. *Boll. Soc. Geogr. Ital.*

Spiess, H. J. (1986). Erfassung und Kartierung der Fische und Rundmaeuler in der DDR. [Registration and mapping of freshwater fish and lampern of German Democratic Republic.]. *Z. Binnenfisch. Ddr* **33,** 130-136.

Spillman, C. J. (1959). Rectification de la nomenclature de deux poissons: L'Alose feinte et L'Able de Stymphale. *Bull. Mus. Hist. nat.* **31,** 85-87.

Spillman, C. J. (1961). *Faune de France. 65: Poissons d'eaux douce.* 65, 303 pp. Paris: Fédération Française des Sociétés Naturelles, P. Lechevalier.

Sposny, W. (1975). *Die Fischfauna des Rheins.* Diplomarbeit. Mainz.

Sproston, N. G. (1946). A synopsis of the monogenetic trematodes. *Transactions of the Zoological Society, London* **25,** 185-600.

Stein, R. A., Mecom, J. O. and Ivanovic, B. (1981). Commercial exploitation of fish stocks in Lake Skadar, 1947-1976. In: *The Biota and Limnology of Lake Skadar*. (Karaman, G.S. and Beeton, A.M.eds.), pp. 343-354. Titograd, Montenegro:

Steinbach, P., Gueneau, P., Autuoro, A. and Broussard, D. (1986). Radio-pistage de grandes aloses adultes en Loire. [Radio-tracking of Atlantic shads in the river Loire]. *Bulletin Français de la Pêche et de la Pisciculture* **302,** 106-117.

Steindachner, F. (1866a). Ichthyologischer bericht über eine nach Spanien und Portugal unternomene Reise. I. Überdie Fische des Tajo (portug. Tejo), Duero (portug. Douro), Miño (portug. Minho), deren Nebenflüssen und dem Jucar bei Cuenca. *Sitzungsb. Akad. Wiss. Wien.* **54,** 1-27.

Steindachner, F. (1866b). *Allgemeine Bemerkungen über die Süsswasswerfischce Spaniens und Portugal und Revision der einzelnen Atren.* 1-15 pp. Wien.: Selbstverlag des Verfassers.

Steinmann, P. (1923). *Die Bedingungen der Fischerei im Hochrhein. Mit besonderer Berücksichtigung der durch die Kraftwerke geschaffenen Veränderungen.* pp. 1-85. Aarau: H.R.Sauerländer & Co.

Steopoe, I. and Teodor Escu-Leonte, R. (1960). Contributions a la connaisance de la structure de la gonade mûre de *Alosa pontica* Eichus, et des derrier stades de son développment. *Bul. Inst. Cercet. Pisc. Roman* **19,** 70-77.

Sterner, E. (1918). Die niederelbische Küstenfischerei. II. Die Fischereiarten. 5. Der Maifischfang. *Der Fischerbote* **10,** 13-16.

Stuxberg, A. (1895). *Sveriges och Norges Fiskar.* Göteborg: Wettergren & Kerber.

Supino, F. (1908). Note biologiche sugli Agoni (*Alosa finta var. lacustris*). *Riv. Mens. Pesca, Milano* **X,**

Supino, F. (1916). *I Pesci d'acqua dolce D'Italia.* pp. 60-61. Milano:

Sushkina, A. P. (1940). (The food of the larvae of the anadromous shads in the Volga River) In Russian. *Trans, USSR Inst. Mar. Fish. Oceanogr.* **14,** 147-210.

Suster, M. (1989). Contributo allo studio delle sostanze nutrienti dei pesci del Benaco. *G. Zippel, Trentp* 3-12.

Svardson, G. (1961). *Rödingen.* In: Fishes. pp. 25-38.

Svetovidov, A. N. (1952). Clupeidae (Seldevye (Clupeidae)). In: *Fauna of USSR, Fishes.*II, (Izdat, ed.), pp. 1-331. Akad. Nauk SSSR (Traduit par Israel, Program. Sci. Translation, Jerusalem 1963).

Svetovidov, A. N. (1963). Systematic report on anadromous clupeids of the genera *Alosa, Caspialosa* and *Pomobolus* in Europe and North America. *Zool. Zh. AN U.S.S.R.* **42,** 1523-1538.

Svetovidov, A. N. (1964). Systematics of the North American Clupeoid fishes for the genera *Alosa, Caspialosa* and *Pomolobus. Copeia* **196,** 118-130.

Svetovidov, A. N. (1964). *Handbook of the fauna of the USSR, fishes of the Black Sea.* 550 pp. Moscow: Izdatel'stvo Nauka.

Svetovidov, A. N. (1966). *Alosa fallax* (Lacépède, 1803) proposed preservation as the name for the Twaite Shad (Pisces). *Bull. Zool. Nomencl.* **23,** 52-54.

Svetovidov, A. N. (1973). Clupeidea. In: *Check List of the Fishes of the North-eastern Atlantic and of the Mediterranean.* 1, (Hureau, J. C. and Monod, T. eds.), pp. 99-109. Paris:UNESCO.

Swaby, S. E. and Potts, G. W. (1990). Rare British marine fishes - identification and conservation. *Journal of Fish Biology* **37 (Suppl. A),** 133-143.

Swaby, S. E. and Potts, G. W. (1997). Fish: other species. Region 4. South-east Scotland: Montrose to Eyemouth. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. and Buck, A. L. eds.), Peterborough:Joint Nature Conservation Committee.

Swaby, S. E. and Potts, G. W. (1997). Fish: other species. Region 1. Shetland. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. and Buck, A. L. eds.), Peterborough:Joint Nature Conservation Committee.

Swaby, S. E. and Potts, G. W. (1997). Fish: other species. Region 17. Northern Ireland. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. Davidson, N. C. and Buck, A. L. eds.), Peterborough:Joint Nature Conservation Committee.

Swaby, S. E. and Potts, G. W. (in prep.(a)). Fish: other species. Region 7. South-east England: Lowestoft to Dungeness Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. and Buck, A. L. eds.), Peterborough:Joint Nature Conservation Committee.

Swaby, S. E. and Potts, G. W. (in prep.(b)). Fish: other species. Region 8. Sussex: Rye Bay to Chichester Harbour. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. and Buck, A. L. eds.), Peterborough:Joint Nature Conservation Committee.

Swaby, S. E. and Potts, G. W. (in press). Fish: other species. Region 2. Orkney. (Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P. and Buck, A. L. eds.), Peterborough:Joint Nature Conservation Committee.

Sweetman, K. E., Maitland, P. S. and Lyle, A. A. (1996). Scottish natural heritage and fish conservation in Scotland. In: *Conservation of Endangered Freshwater Fish in Europe*. (Kirchhofer, A. and Hefti, D.eds.), pp. 23-26. Basel, Boston, Berlin:Birkhäuser Verlag.

Symonds, F. J. (1908). Fishes. In: *The Victoria history of the counties of England – Herefordshire*. (Page, W. ed.),

Tabardel, M., Menella, J. Y. and Gendre, L. (1995). *Suivi de la dévalaison des alosons À Aauveterre. Prospection de sites d'échantillonnage sur le Grand Rhône et le Petit Rhône. Campagne d'études 1994.* **1994 N^{0} 4/5,** 44 pp. Association Migrateurs Rhône Méditerranée.

Taddei, A., Calvario, E., Sarrocco, S. and Pietromarchi, A. (1999). Indagine faunistica sui pesci del bacino idrografico del Lago di Bolsena IItalia centrale). *Quaderni ETP* **28,** 203-208.

Tanner, H. (1987). *75 Jahre Fischereiverband Baselland 1912-1987.* Liestal.

Taverny, C. and Elie, P. (1988). *Mortalités engendrées par l' industrie et la pêche. Le cas des juveniles d' Alosa alosa et d' Alosa fallax dans l' estuaire de la Gironde en 1986.* 51 pp. Bordeaux. Rapport CEMAGREF , Bordeax, ALA.

Taverny, C. and Elie, P. (1988). *Les aloses (Alosa alosa L.1758 et Alosa fallax lac. 1803) dans le système fluvio-estuarien Gironde-Garonne-Dordogne. Essais de relativisation des activités anthropiques sur les alosons dans l'estuaire de la Gironde.* 50pp.CEMAGREF de Bordeaux Div. ALA/Min. Environnement SRETIE EGPN/CSP./EDF.

Taverny, C. (1990). *An attempt to estimate Alosa alosa and Alosa fallax juvenile mortality caused by three types of human activity in the Gironde Estuary, 1985-1986.* Management of Freshwater Fisheries. Proceedings of a Symposium organised by the European Inland Fisheries Advisory Commission. pp. 215-229. Göteborg, Sweden. 31 May - 3 June 1988. Pudoc, Wageningen.

Taverny, C. and Elie, P. (1990). *Les aloses du système estuairien Gironde-Garonne Dordogne. Mortalité engendrée par l'industrie et la pêche dans le cas des juvéniles d'Alosa alosa et d'Alosa fallax de 1985 - 1988. [Shad in the estuarine system of the Gironde-Garonne-Dordogne. Mortalities generated by industry and fishing on Alosa alosa and Alosa fallax juveniles 1985-1988.].* Série Alose No. 3 **Rapport final.,** 206 pp +44 annexes. CEMAGREF de Bordeaux Div. ALA.

Taverny, C. (1991). *Contribution à la connaissance de la dynamique des populations d'aloses (Alosa alosa L. et Alosa fallax Lacépède), dans le système fluvio-estuarien de la Gironde: pêche, biologie et écologie. Étude particulière de la dévalaison et de l'impact des activités humaines.* 451 p. + Annexes. Thèse de Doctorat de l'Université. Bordeaux: Université de Bordeaux 1/ CEMAGREF Bordeaux.

Taverny, C. (1991a). *Pêche, biologie, écologie des Aloses dans le Système Gironde Garonne-Dordogne (Fishing, biology, ecology of shads in the system of Gironde, Garonne-Dordogne).* **4**, 392 pp. Bordeaux: CEMAGREF.

Taverny, C., Belaud, A., Elie, P. and Sabatié, M. R. (2000a). Influence des activités humaines. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations*. (Baglinière, J. L. and Elie, P. eds.), pp.227-248. Paris:INRA-CEMAGREF.

Taverny, C., Cassou-Leins, J. J., Cassou-Leins, F. and Elie, P. (2000b). De l'oeuf à l'adulte en mer. In: *Les aloses (Alosa alosa et Alosa fallax spp.). Écobiologie et variabilité des populations.* (Baglinière, J. L. and Elie, P. eds.), pp. 93-124. Paris: INRA CEMAGREF.

Taverny, C. and Elie, P. (2001a). Répartition spatio-temporelle de la grande alose *Alosa alosa* (Linné, 1766) et de l'alose feinte *Alosa fallax* (Lacépède, 1803) dans le Golfe de Gascogne. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 803-821.

Taverny, C. and Elie, P. (2001b). Régime alimentaire de la grande alose *Alosa alosa* (Linné, 1766) et de l'alose feinte *Alosa fallax* (Lacépède, 1803) dans le Golfe de Gascogne. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 837-852.

Tendeiro, J. and Valdez, V. (1955). Helmintologie ictiológica I. Alguns helmintes do sável *Alosa alosa (*L.) das águas portuguesas. Descricáo de uma nova espécie *Mazocraes vilelai* n. sp. (Trematoda Monogenea). *Boletim Cultural da Guiné Portuguesa* **10,** 49-80.

Tendron, G. and Roguet, M. (1989). Aspects techniques et économiques de la politique de restauration des grands migrateurs. *Courrier de la Nature* **122,** 27-36.

Tendron, G. (1994). *The agreements for fish migrations in the Adour-Garonne Basin (France, S.W.).* Migratory Fish Restoration. Papers of the National SymposiumPour un retour des poissons migrateurs. Actes du Colloque. pp.166-168. Toulouse France. Agence de l' Eau Adour Garonne,.

Thiel, R., Sepúlveda, A., Kafemann, R. and Nellen, W. (1995). Environmental factors as forces structuring the fish community of the Elbe Estuary. *Journal of Fish Biology* **46,** 47-69.

Thiel, R., Mehner, T., Köpcke, B. and Kafemann, R. (1996). Diet niche relationships among early life stages of fish in German estuaries. *Marine and Freshwater Research* **47,** 123-136.

Thiel, R., Sepúlveda, A. and Oesmann, S. (1996a). Occurence and distribution of twaite shad (*Alosa fallax* Lacépède) in the lower Elbe river, Germany. In: *Conservation of endangered freshwater fish in Europe*. (Kirchhofer, A. and Hefti, D. eds.), pp.157-170. Basel (Switzerland):Birkhäuser Verlag.

Thiel, R., Winkler, H. M. and Urho, L. (1996b). Zur veränderung der fischfauna. In: *Warnsignale aus der Ostsee.* (Lozan, J. R., Lampe, R., Matthäus W. *et. al.*, ed.), pp.171 178. Berlin:Blackwell Wissenschafts-Verlag.

Thiel, R., Nellen, W., Sepulveda, A., Oesmann, S., Tebbe, K. and Drenkelfort, T. (1997). Spatial gradients of food consumption and production of dominant fish species in the Elbe Estuary, Germany. *ICES-CM-1997* **S:4,** 23 pp.

Thiel, R. (2001). Spatial gradients of food consumption and production of juvenile fish in the lower River Elbe. *Archiv fur Hydrobiologie. Supplementband.* **135,** 441-462.

Thiel, R. and Potter, I. (2001). The ichthyofaunal composition of the Elbe estuary: an analysis in space and time. *Marine Biology* **138,** 603-616.

Thome, H. (1957). Salve Mosella. *De Letzeburger Sportfescher.* Mosel Sondernummer**,** 5-8.

Tkanchenko, V. A. and Parchuk, G. K. (1984). Feeding of young-of-the-year commercial
fishes in Sasykski Reservoir and Kiliskaya Delta of the Danube. *Hydrobiol-J* **6**, .

Tocko, M. (1959). Alosa fallax nilotica (Geoffroy) dans le Lac Ohrid. *Rec. Trav. Sta. Hydrobiol. Ohrid.* **7,** 1-3.

Tocko, M. and Jovanovic, R. (1959). *Alosa fallax nilotica* in Lake Ohrid. *Zbornikna rabotie, Ohrid* **7,** 1-12.

Tomasi, G. (1963). *I laghi del Trentino.* pp. 1-329. Roverto: Manfrini.

Tortonese, E. (1951). Intorno ai Clupeidi della ittiofauna italiana. On the Italian Clupeids). *Boll. Pesca Piscic. Idrobiol* **6,** 134-137.

Tortonese, E. (1970). *Fauna D'Italia, Osteichthyes (Pesci ossei).* **10**, 565 pp. Bologna: Calderini.

Tourenq, J. N. and Dauba, F. (1978). Transformation de la faune des poissons dans la rivière Lot. *Annls. Limnol.* **14,** 133-138.
Trahms, O. K. (1954). Der Rhein: Abwasserkanal oder Fischgewässer. *Mitt. Rhein. Ver. Denkmalpflege und Heimatschutz* **3/4,** 1-8.

Travade, F. (1982). *Ascenseur à poissons. Critères de conception. Applications au barrage de Golfech.* **H/E31-82-48.** 36 pp**,** EDF Direction des Etudes et Recherches. Département Environnement Aquatique et Atmosphérique.

Travade, F., Bomassi, P., Bach, J. M., Brugel, C., Steinbach, P., Luquet, J. F. and Pustelnik, G. (1989). Use of radiotracking in France for recent studies concerning the EDF fishways program. *Hydroécologie appliquee.* **1-2,** 33-51.

Travade, F. (1990). *Monitoring techniques for fish passes recently used in France.* International Symposium on Fishways. pp.119-126. Gifu, Japan.

Travade, F., Larinier, M., Trivellato, D. and Dartiguelongue, J. (1992). Conception d'un ascenseur à poissons adapté à l'alose (*Alosa alosa*) sur un grand cours d'eau: l'ascenseur de Golfech sur la Garonne. [Design of a fish lift adapted for shad (*Alosa alosa*) on a large watercourse: the fish lift at Golfech on the River Garonne]. *Hydroécologie Appliquée.* **4,** 91-119.

Travade, F. and Larinier, M. (1992). Les techniques de contrôles des passes à poissons. *Bulletin Français de la Pêche et de la Pisciculture* **326-327,** 151-164.

Travade, F. and Larinier, M. (1992a). La migration de dévalaison: problèmes et dispositifs. *Bulletin Français de la Pêche et de la Pisciculture* **326-327,** 165-176.

Travade, F., Larinier, M., Boyer-Bernard, S. and Dartiguelongue, J. (1996). Feedback on four fishpass installations recently built on two rivers in southwest France. *International Counc. for the Exploration of the Sea. Anadromous Catadromous Fish Restoration Progect.* **ICES-CM-1996/T:14,** 16 pp.

Travade, F., Larinier, M., Boyer-Bernard, S. and Dartiguelongue, J. (1998). Performance of four fish pass installations recently built on two rivers in south-west France. In: *Fish migration and fish bypasses*. (Jungwirth, M. Schmutz, S. and Weiss, S. eds.), pp.146-170. Oxford:Fishing News Books-Blackwell Science Ltd.

Travade, F. and Larinier, M. (2002). Monitoring techniques for fishways. *Bulletin Français de la Pêche et de la Pisciculture* **364 Supplément,** 166-180.

Travade, F. and Larinier, M. (2002a). Fish locks and fish lifts. *Bulletin Français de la Pêche et de la Pisciculture* **364 Supplément,** 102-118.

Trewavas, E. (1938). The Killarney shad or "Goreen" *Alosa fallax killarnensis* (Regan,1916). *Proceedings of the Linnaeen Society, London* **150,** 110-112.

Troschel, F. H. (1852). *Alausa vulgaris* und *finta*, verscheidene Arten. *Archiv fur Naturgeschicte gegründet von Weigmann* **I,** 228.

Trouilhet, J. F. (1989). *Étude d'un dispositif de reconnaissance de signature acoustique de la fraie des aloses.* 34 pp. Toulouse. LAMI Toulouse-Comité de Gestion de la Réserve Naturelle de la frayère d'alose d'Agen.

Trouilhet, J. F. (1992). *Étude d'un dispositif de reconnaissance automatique de signature acoustique.* 113 pp. Toulouse: Institut National Polytechnique.

Tseeb, Y. Y., Sergeev, A. I. and Grigor'ev, B. F. (1971). Zooplankton of the Dnieper-Bug liman and lower Dnieper under the conditions of regulated flow. In: The Dnieper-Bug Liman. *Vid-vo AN UkrSSR, Kiev* pp.202-228.

Turan, C. and Basusta, N. (2001). Comparison of morphometric characters of twaite shad

(*Alosa fallax nilotica*, Geoffroy Saint-Hilaire, 1808) among three areas in Turkish seas. *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 1027-1035.
Turnpenny, A. W. H. and Utting, N. J. (1987). *The seasonal incidence of fish species at the cooling water intake of Sizewell power station.* **TPRD/L/3131/R87,** Central Electricity Generating Board (Central electricity research laboratories).

Turnpenny, A. W. H., Davies, M. H., Fleming, J. M. and Davies, J. K. (1992). Experimental studies relating to the passage of fish and shrimps through tidal power turbines. 116 pp.Harwell: AEA Technology, National Power PLC.

Turnpenny, A. W. H., Thatcher, K. P., Wood, R. and Loeffelman, P. H. (1993). *Experiments on the use of sound as a fish deterrent.* **ETSUT0400171REP,** 79 pp. Harwell: Energy Technology Support Unit.

Twomey, E. (1958). A specimen of shad *Alosa fallax killarnensis* from Lough Leane, Killarney. *Irish Nauralists Journal* **3,** 270.

Twomey, E. (1967). *Alosa finta*, (Cuvier) Twaite Shad and *Alosa alosa*, (L.) Allis Shad. In: *Notes on some Irish estuarine and inshore fishes*. No. 3, (BrackenJ. and Kennedy, M. eds.), Dublin:The Stationery Office, Department of Agriculture and Fisheries, Fisheries Division.

Ubelaker, J. E., Kazic, D., Mayberry, L. and Cankovic, M. (1981). Parasitism of fishes and other vertebrates of Lake Skaddar. In: *The Biota and Limnology of Lake Skaddar.* (Karaman, G. S. and Beeton, A. M. eds.), pp. 356-383. Titograd.

Ulltang, O. (1977). *Methods of measuring stock abundance other than by the use of commercial catch and effort data.* Fish Technology Paper **176**, 21 pp.

Ulutuerk, T. (1987). Goekceada cevresinin balik faunasi ve cevre fon radyoaktivitesi. [Fish fauna, back-ground radioactivity of the Goekceada marine environment.]. *Su Urunleri Dergisi [Journal of Aquatic Products]* **1,** 95-119.

Utrilla, C. G., Garcia-Gonzalez, D., Baldo, F., Arribas, C. and Fernadez-Delgado, C. (2000). *Recent records and conservation status of the twaite shad Alosa fallax fallax (Lacépède, 1803) in the Guadalquivir estuary (SW Spain).* Freshwater Fish Conservation: Options for the Future. Algarve, Portugal. Abstract.

Valenciennes, A. (1847). *Histoire naturelle des poissons.* 21, 536 pp. Paris: Levrault.

Valente, A. C. N. (1990). *Trout populations in the Lima Basin, North Portugal.* Management of Freshwater Fisheries. Proceedings of a Symposium organised by the European Inland Fisheries Advisory Commission.(van Densen, W.L.T., Steinmetz, B. and Hughes, R.H. eds.) pp. 437-446. Göteborg, Sweden. 31 May - 3 June 1988. Pudoc, Wageningen.

Vallot, J.-N. (1837). *Ichthyologie français ou Histoire naturelle des Poissons d'eau douce de la France.* Dijon.

van Beneden, P. J. (1858). Memoire sur les vers intestinaux. *Extrait supplement de comptes rendus des séances de l'Academie de Sciences.* **2,** 1-376.

Van Cleef. (1923). *Rapport betreffende het ingestelde onderzoek naar den achteruitgang van den elfstand en de middelen tot verbetering.* 's-Gravenhage.

Van den Broek, W. L. F. (1977). *Aspects of the biology of fish populations from the Medway Estuary, based on Power Station intake sampling, with special reference to parasitism and pollution.* Ph.D. University of London, London.

Van den Broek, W. L. F. (1979). A seasonal survey of fish populations in the lower Medway estuary, Kent, based on power station screen samples. *Estuarine and Coastal Marine Science* **9,** 1-15.

Van-Urk, G. (1984). Lower Rhine-Meuse. In: *Ecology of European Rivers*. (Whitton, B. A. eds.), pp. 437-467. Oxford:Blackwell Scientific Publications.

Vandelannote, A. and Coeck, J. (1998). Rode lijst ven de inheemse en ingeburgerde zoet en brakwatervissen en van de rondbekken in Vlaanderen. In: *Atlas van de Vlaamse beek- en riviervissen.* (Verheyen, R. F. ed.), pp. 259-264.

Vasil'eva. (1996). On Divergence of Shads of Genus *Alosa* from the Azov Sea; Craniological Findings. *Journal of Ichthyology* **36,** 139-145.

Vasil'yev, V. P. (1980). Chromosome numbers in fish-like vertebrates and fish. *Journal of Ichthyology* **20,** 1-38.

Vasnetsov, V. V. (1953). Developmental stages of Teleosts. Essays on general problems of ichthyology. *Moscow Izd-vo AN SSSR* pp. 207-217.

Verhey, C. J. (1961). De vissen en de visvangst. In: *De Biesbosch, land ven het levende water. (The fish and fisheries)*. (Verhey, C. J. ed.), pp. 139-164.

Verneaux, J. (1971). Faune dulcaquicole de Franche-comté. Le bassin du Doubs (Massif du Jura). In: *Zoologie, Physiologie & Biologie animale.* **7**, 3-18. Besançon:l'Université de Besançon.

Véron, V. (1999). *Les populations de grande Alose (Alosa alosa, l.) et d'Alose feinte (Alosa fallax Lacépède) des petits fleuves français du littoral Manche Atlantique.* 81 pp. Diploma d'Agromnomique Approfondie Halieutique. Rennes: ENSAR Laboratoire Halieutique and INRA, Rennes.

Véron, V., Sabatié, M. R., Baglinière, J. L. and Alexandrino, P. (2001). Première caractérisation morphologique, biologique et génétique des populations de grande alose

(*Alosa alosa*) et d' alose feinte (*Alosa fallax* spp.) de la Charente (France). *Bulletin Français de la Pêche et de la Pisciculture* **362/363,** 1037-1057.

Vialle, M. (1987). Les passes à aloses: expérience de la CNR [Ladders for alosa: CNR's experience]. *La Houille Blanche* **1/2,** 59-64.

Vibert, R. and Lagler, K. (1961). *Pêches continentales. Biologie et aménagement.*. 720 pp. Paris:

Vickerman, D. (1993). Native species of fish show decline. *Western Mail.* Tuesday 16th February.

Vickers, K. U. (1959). Unusual fish from North-east Irish coast. *Irish Naturalists Journal* **13,** 22.

Vilcinskas, A. (1993). *Einheimische Süßsswasserfische: Allen Arten: Merkmale, Verbreitung, Lebensweise.* 207 pp. Augsburg, Germany: Naturbuch Verlag.

Vincent, P. (1889). La propagation artificielle de l'alose. *Bull. Agric. France* 7.

Vincent, P. J. B. (1894). Notes sur l'alose. *Revue Maritime et Coloniale* **124,** 445-451.

Vincent, P. J. B. (1894a). Notes sur l'alose. *Revue Maritime et Coloniale* **122,** 667-681.

Vincent, P. J. B. (1894b). Notes sur l'alose. *Revue Maritime et Coloniale* **123,** 193-205.

Vincent, P. J. B. (1894c). Notes sur l'alose. *Revue Maritime et Coloniale* **123,** 445-451.

Vinciguerra, D. (1921). Descrizione di tre nuove specie di pesci delle acque dolci di Grecia. *Annali del Museo Civico di Storia Naturale di Genova. Series 3a* **9,** 322-331.

Viney, M. (1996). Time to catch on to fish struggling for survival. *The Irish times.*

Virbickas, J. (1986). *Lietuvos žuvys.* 17 pp. Vilnius: Mokslas.

Virbickas, J. and *et. al.* (1992). *Lietuvos retosios žuvys.* Vilnius: Akademija.

Vitali, R. and Braghieri, L. (1981). Structural and dynamic characteristics of the fish community of the middle stream of Po River at Caorso (Piacenza, Italy). *Riv.-Idrobiol* **20,** 269-299.

Vitali, R., Pesaro, M. and Gandolfi, G. (1983). *La migrazione dell' alosa, Alosa fallax nilotica attraverso il delta del Po.* Atti 5 Congr Associazione Italiane di Oceanologia e Limnologia. pp. 727-736.

Vivier, P. (1976). La pollution est-elle toujours désastreuse pour la pêche? *L'eau pure, protection de la nature* **38,** Vladimirov, V. I. (1955). Conditions of fish reproduction in the lower Dnieper and Kakhovsk Reservoir. *Izd-vo AN UkrSSR Kiev* 148 pp.

Vladimirov, V. I., Sukhoyvan, P. G. and Bugai, K. S. (1963). Reproduction of fishes under the conditions of regulated river stream (in the example of Dnieper). *Izd-vo AN UkrSSR, Kiev* 394 pp.

Vogel, O. E. (1903). *Die seuche unter den agoni des Lago di Lugano (colibacillosis Alosae fintae).* Facultät de Universtät Bern.

Volta, G. S. (1828). Descrizioni del lago di Garda e dei suoi contorni con osservazioni di

Storia Naturale e di Belle Arti. In: *La Virgiliana*. pp.1-57. Mantova:

Von Brandt, A. (1972). *Fish Catching methods of the world.* 240 pp. London: Fishing News (Books) Ltd.

Von Dem Borne, M. (1883). *Die Fischerei-Verhältnisse des Deutschen Reiches, Österreich-Ungarns, der Schweiz und Luxemburgs.* Berlin: Hofdruckerei W. Moeser.

Von Wunder, W. (1975). Röntgenanalysen verkürtzer fisch wirbelsaülen (A) Kabeljau (*Gadus morrhua* L) und (B) (*Alosa alosa* L) (Rontgen-ray analysis of shortened back bones in fishes (A) Cod (*Gadus morrhua* L) and (B) Allis shad (*Alosa alosa* L)). *Arch.Hydrobiol.* **75,** 366-401.

Vukovic, T. (1961). Populations of twaite shad *Alosa fallax nilotica* from River Neretva and Lake Skadar. *Gadisnjak Bioloskog Institute Univerzitete U Sarajevu* **15,** 26-34.

Vukovic, T. (1961a). Populacije i mrescenje *Alosa fallax nilotica* (Geoffroy) u Vodama Neretva i Skadarskogjezera. *Gadisnjak Bioloskog Institute Univerzitete U Sarajevu* **14,** 85-178.

Vukovic, T. and Ivanovic, B. (1971). *Slatkovodne ribe Jugoslavie. [Freshwater fishes of Yugoslavia.].* 263 pp. Sarajevo: Zemaljski Musej, Bosne i Hercegovine.

Walker, C. E. (1905). Fishes. In: *The victoria history of the County of Sussex*. (Page, W. ed.),

Walsh, G. and Fitzgerald, G. J. (1984). Analyses et commentaires - Biais inhérents à l'analyse de l'alimentation des poissons - Cas de trois d'épinoche (Gasterosteidae). *Nat. Can. (Rev. Ecol. Syst)* **111,** 193-202.

Warfel, H. E. and Olsen, Y. H. (1947). Vertebral counts and the problem of races in the Atlantic shad. *Copeia* **1947,** 177-183.

Waters, B. (1947). *Severn Tide.* London: J.M.Dent and Sons Ltd.

Waters, I. (1952). About Chepstow. *Newport and Monmouthshire Branch of the Historical Association and Chepstow Society.*

Waterstraat, A. (1986). Aktuelle aufgaben zum schutz gefährdeter rundmäuler unf fische in Mecklenburg in auswertung der artenschutzbestimmung von 1984. *Naturschutzarbeit in Mecklenburg* **29,** 87-92.

Watier, C. (1918). La pêche de l'alose au Maroc. *Ann. Univ. de Grenoble* **29,** 5-27.
Waugh, A. (1996). Way of the World; Shad Abuse. *Daily Telegraph.* December 21, 1996. pp.19.

Weber, M. (1876). Überdie Nahrung der *Alausa vulgaris* und die Spermatophore von *Temora velox* Lilj. *Arch. Naturgesch.* **XLII,** 169-178.

Weber, M. (1987). *The by-catch of the Glasseel fishery in the Rio Minho (Iberian Westcoast).* Report to working Group **Eel Working Group,** European Inland Fishery Advisory Commission (EIFAC- FAO).

Weibel, U. (1991). Neue Ergebnisse zur Fischfauna des nördlichen Oberrheins – ermittelt am Rechengut von Kraftwerken. *Fischökologie* **5,** 43-68.

Wells, L. A. (1958-1960). *The observer's book of sea fishes.* 160 pp. London: F.Warne & Co Ltd.

Wells, A. L. (1961). *The Observer Book of Freshwater Fishes.* London: Frederick Warne & Co.

Went, A. E. J. (1946). Irish freshwater fish. *The Salmon and Trout Magazine* **118,** 9 pp.

Went, A. E. J. (1949). Giraldus Cambrensis' notes on Irish fish. *The Irish Naturalists' Journal* **9,** 221-224.

Went, A. E. (1953). The status of the shads, *Alosa finta* and *Alosa alosa* Cuvier, in Irish waters. *The Irish Naturalist Journal* **11,** 8-11.

Went, A. E. J. (1957). *List of Irish Fishes.* 31 pp. Dublin: Department of Lands, Fisheries Division.

Went, A. E. J. (1958). Reflections on the "List of Irish fishes (1957)". *The Irish Naturalists' Journal* **12,** 255-258.

Went, A. E. J. (1959). Rare fishes taken in Irish waters in 1958. *The Irish Naturalists' Journal* **13,** 2 .

Went, A. E. J. (1960-1961). Fisheries of the Munster Blackwater. *Journal of the Royal Society of Antiquities of Ireland* **XCL,** 24-27.

Went, A. E. J. (1963). *The shad.* pp.15. Peterborough: E. M. Art and Publishing Limited, Peterborough.

Went, A. E. J. (1963). The shad in Irish Waters. *Fishing.* **4, March 15,** 15.

Went, A. E. J. and Kennedy, M. (1969). *List of Irish Fishes.* Government Stationery Office, Dublin.

Went, A. E. J. (1974). Some interesting fishes taken from Irish waters. *The Irish Naturalists' Journal* **18,** 58-65.

Went, A. E. J. and Kennedy, M. (1976). List of Irish Fishes. 3, Stationary Office, Dublin:

Western Mail Reporter. (1987). Rare species join queue for the law's protection. *Western Mail.* 5th January.

Wharfe, J. R., Wilson, S. R. and Dines, R. A. (1984). Observations on the fish population of an East coast estuary. *Marine Pollution Bulletin* **15,** 133-136.

Wheatley, H. (1853). Remarks on the Icthyology of Herefordshire. *Transactions of the Woolhope Naturalists Field Club* 62-78.

Wheeler, A. (1958). The fishes of the London area. *The London Naturalist* **37,** 80-101.

Wheeler, A. (1969a). *The fishes of the British Isles and North West Europe.* 613 pp. London: McMillan.

Wheeler, A. (1969b). Fish life and pollution in the lower Thames: a review and preliminary report. *Biological Conservation* **2,** 25-30.

Wheeler, A. and Blacker, R. W. (1972). Rare and little-known fishes in British seas in 1968 and 1969. *Journal of Fisheries Biology* **4,** 141-170.

Wheeler, A., Blacker, R. W. and Pirie, S. F. (1975). Rare and little known fishes in British seas in 1970 and 1971. *Journal of Fish Biology* **7,** 183-201.

Wheeler, A. (1977). The origin and distribution of the freshwater fishes of the British Isles. *Journal of Biogeography* **4,** 1-24.

Wheeler, A. (1978a). *Key to the fishes of Northern Europe.* 380 pp. London: Frederick Warne.

Wheeler, A. (1978b). Twaite and Allis Shad. *The Marshall Cavendish Fishermans's Handbook.* **51,** 1414 - 1421.

Wheeler, A. (1979). *The Tidal Thames: The history of a river and its fishes.* 223 pp. London: Routledge and Kegan Paul.

Wheeler, A. (1985). The Linnaean fish collection in the Linnaean Society of London. *Zool. L. Linn. Soc.* **84,** 1-76.

Wheeler, A. (1992). A list of the common and scientific names of fishes of the British Isles. *Journal of Fish Biology* **41,** 1-37.

Whelan, K. (1989). *The Angler in Ireland.* Dublin: Country House.

Whilde, A. (1993). *Threatened mammals, birds amphibians and fish in Ireland : Irish Red Data Book 2: Vertebrates.* pp. 145-168. Belfast: Her Majestys Stationery Office.

Whitchell, C. A. and Strugnall, W. B. (1892). *The fauna and flora of Gloucestershire.* Russell street, Stroud: George H. James.

Whitehead, P. J. P. (1967). The Clupeoid Fishes described by Lacépède, Cuvier and Valeciennes. *Bull. Mus. Nat. Hist. Zool.* pp. 1-180.

Whitehead, P. J. P. (1984). Families Clupeidae, Engraulidae. In: *Fishes of the Northeastern Atlantic and Mediterranean.* 1, (Whitehead, P. J. P., Bauchot, M. L., Hureau, J. C., Nielsen, J. and Tortonese, E. eds.), pp.268-283. Paris:UNESCO.

Whitehead, P. J. P. (1985). FAO Species Catalogue 7: Clupeoid fishes of the world (Suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part 1: *Chirocentridae, Clupeidae* and *Pristigacteridae. FAO Fisheries Synopsis (125)* **7,** 1-303.

Whitehead, P. J. P. and Bauchot, M.-L. (1985). Catalogue critique des types de Poissons du Museum national d'Histoire naturelle. (Suite). Ordre des Clupeiformes (Familles des Clupeidae, Engraulididae et Denticipitidae). *Bull. Mus. Natl. Hist. Nat. Sect. A Zool. Biol.*
Ecol. Anim. **4,** 1-77.

Whitehead, P. J. P. and Blaxter, J. H. S. (1989). Swimbladder form in clupeoid fishes. *Zoological Journal of the Linnean Society.* **97,** 299-372.

Whitehead, P. J. P. (1990). Clupeidae. In: *Check-list of the fishes of the eastern tropical Atlantic .* 3, (Quéro, J.-C., Hureau, J. –C., Karrer, C., Post, A., and Saldanha, L. eds.), pp.
208-227. Paris:UNESCO.

Wiecaszek, B., Krzykawski, S. and Skóra, K. (1999). *Fishes of genus Alosa Linck at Polish coast of Baltic Sea in the recent years.* 16th Baltic Marine Biologists Symposium. Klaipeda University, Klaipeda, Lithuania.

Wiecaszek, B. and Krzykawski, S. (1999). Majowe sledzie znow plywaja w Baltyku. *Rybotowstwo Morskie* **3,** 29-30.

Wiktor, J. (1989). Fish farming in Polish Baltic waters and its role in preserving the stocks of valuable species. *Biuletyn Morskiego Instytutu Rybackiego, Gdynia/Bulletin of the Sea Fisheries Institute, Gdynia* **20,** 50-54.

Wilkens, H. and Köhler, A. (1977). Die Fischfauna der unteren und mittleren Elbe: die genutzten Arten, 1950-1975. *Abhandllungen und Verhandlungen des naturwissenschaftlichen Vereins zu Hamburg* **20,** 185-222.

Wilkins, N. P. and Iles, T. D. (1966). Haemaglobin polymorphism and its ontogeny in herring (*Clupea harengus*) and sprat (*Sprattus sprattus*). *Comp. Biochem. Physiol.* **17,** 1141-1158.

Willem, V. (1921). La saumon du Rhin et de la Meuse. Les déversements d'alevins effectués par le gouvernement hollandais pendant les dernières années. *Pêche et Pisciculture* **32,** 41-45.

Willem, V. (1923). La disparition de l'alose dans les eaux Hollandaises (résumé d'une étude de Van Cleef, 1923). *Pêche et Pisciculture* **34,** 153-180.

Willemse, J. J. (1968). Helminth and sporozoan parasites of fishes in the Netherlands. *Bulletin Zoologisch Museum University of Amsterdam* **1,** 83-87.

Willis Bund, J. (1901). Fishes. In: *The Victoria History of the Counties of England Worcestershire*. II, (Arthur Doubleday, H. ed.), 131 pp.

Winfield, J. I., Fletcher, J. M. and Cragg-Hine, D. (1994). *Status of Rare Fish. A Literature Review of Freshwater Fish in the UK.* R & D Report **18,** 58 pp. Bristol: National Rivers Authority.

Winkler, H. M. (1991). Changes of structure and stock in exploited fish communities in estuaries of the southern Baltic coast. *Internationale Revue der gesamten Hydrobiologie* **76,** 413-422.

Winkler, H. M., Skora, K., Repecka, R., Ploks, M., Neelov, A., Urho, L., Gushin, A. and
Jespersen, H. (2000). Checklist and status of fish species in the Baltic Sea. *ICES CM2000/Mini* **11,** 15 pp.

Winkler, H. M., Skora, K., Rimantas, R. and Lauri, U. (2000). Historical and recent status
of allis shad (*Alosa alosa*) and twaite shad (*Alosa fallax*) in the Baltic Sea. Unpublished. Poster paper presented at First International Conference on European shads – Bordeaux May 2000 .

Witte, J. Y. and Zijlstra, J. J. (1979). The species of fish occurring in the Wadden Sea. In:
Fish and Fisheris of the Wadden Sea. (Dankers, N., Wolff, W. L. and Zijlstra, J. J. eds.), Rotterdam:Balkema.

Wittmack, L. (1875). *Beiträge zur Fischerei-Statistik des Deutchen Reichs sowie eines*

Theiles von Osterreich-Ungarn und der Schweiz. pp. 1-252. Berlin: W. Moeser, Hofbuchdruckerei.

Wozniewski, M., Lojko, J. and Buras, P. (1999). Minelo 30 lat wloclawsskiej przeplawki.
Kommunikaty Rybackie **6,** 23-25.

Wunder, W. (1975). Roentgenanalysen verkuerzter Fischwirbelsaeulen A. Kabeljau (Gadus morrhua L.) und B. Maifisch (Alosa alosa L.). X-Ray Analysis of Shortened Backbones in Fishes: A . Cod (*Gadus Morhua* L.) and B. Allis Shad(*Alosa Alosa* L.), (In German). *Archiv fur Hydrobiologie.* **75,** 366-401.

Yamaguti, S. (1968). *Systema helminthum. IV. Monogena and Aspidocotylea.* 699 pp. New York: J. Wiley.

Yamaguti, S. (1971). *Synopsis of Digenetic Trematodes of Vertebrates. Part 1.* 1074 pp. Tokyo: Keigaku.
Yang, J. (1982). The dominant fish fauna in the North Sea and its determination. *Journal*
of Fish Biology **20,** 635-643.

Yarrell, W. (1836). *A History of British Fishes.* London: John Van Voorst.

Yarrell, W. (1841). *A History of British Fishes.* 611 pp. London: Bentley.

Zakharyan, G. B. and Teruni, N. V. (1979). The Influence of Light-Assisted Fishing of the "Kilka" of the Genus *Clupeonella* on Stocks of the Caspian Shad of the Genus *Alosa* (Family Clupeidae). *Journal of Ichthycology* **19,** 129-132.

Zarfdjian, M. H., Vranovsky, M. and Economidis, P. S. (1990). The planktonic invertebrates of Lake Volvi (Macedonia, Greece). *Int.-Rev.-Gesamt.-Hydrobiol* **75,** 403 412.

Zarfdjian, M.-E., Economidis, P. S. and Sinis, A. I. (1995). *Large zooplankton predation by fish in Lake Volvi (Macedonia, Greece).* Proceedings of The 1st World Fisheries Congress. Theme/Condition of the Worlds Aquatic Habitats. pp. 267-278.

Ziggiotti, A. (1927). Studio morfologico sul cranio dell'Agone e della Cheppia. *Riv. Natura.* **18,** 81.

Zijlstra, J. J. (1979). The function of the Wadden Sea for members of its fish fauna. In: *Fish and Fisheris of the Wadden Sea.* (Dankers, N., Wolff, W. L. and Zijlstra, J. J. eds.), 20-25. Rotterdam:Balkema.

Zompolas, G. (1939). Contributo allo studio dell'alimentazione dei pesci *Clupea finta* Cuv. *Bollett. Pesca. Piscicolt. e Idrobiol.* **15,** 708-714.

Zschokke, F. (1931). Die Tierwelt. In: *Der Rhein, sein Lebensraum, sein Schicksal.* (Haushofer, K. ed.), pp. 221-254. Berlin:Vowinckel-Verlag.

Zylberblat, M., Solente, B., Le Hy, J. B. and Renoult, R. (1991). Rapport de synthèse. Schéma de vocation piscicole de fleuve Rhône. *Ministère de l' Environnement. Délégation de Bassin Rhône Méditerranée Corse, Service de la Navigation Rhône Saône*

Zylberblat, M. and Mennella, J.-Y. (1996). Upstream passage of migratory fish through navigation locks. In: *Ecohydraulics*. **B**, (Leclerc, M., Capra, H., Valentin, S., Bourdreault, A. and Côté, Y. eds.), pp. 829-841. Quebec:INRS-Eau.

APPENDIX 1. Sites that have been designated as Special Areas for Conservation (SAC) or Sites of Community Interest (SCI) under the Habitats Directive for Alosa alosa.

Type: A = Designated SPA (Special Protected Area) not related to other Natura 2000 site; B = Eligible SCI not related to another Natura 2000 site; C = Area of eligible SCI is same as designated SPA; D = SPA touches another Natura 2000 site; E = Eligible touchess another Natura 200 site; F = SPA containing eligible SCI; G = Eligible SCI within designated SPA; H = Designated SPA contains an eligible SCI; I = Eligible SCI contains a designated SPA; J = SPA overlaps an eligible SCI; K = Eligible SCI overlaps a SPA.

Global: A = site originally selected for shad (excellent representative); B = site originally selected for shad (good representative); C = site not primarily for shad (significant representative); D = non-significant shad presence

Country	Type	Site Code	Site Name	Specimen Number	Specimen	Global
Germany	C	DE0916303	Ntp s-h Wattenmeer u. Angrenzender Küstenstreifen	1102	*Alosa alosa*	A
Denmark	I	DK00CY163	Ringkøbing fjord og Nymindestrømmen	1102	**ALOSA ALOSA**	A
Denmark	K	DK00FX122	Ålborg Bugt, Randers fjord og Mariager fjord	1102	*Alosa alosa*	C
England		UK0013111	Plymouth Sound and Estuaries	1102	*Alosa alosa*	C
England & Wales		UK0012642	River Wye	1102	*Alosa alosa*	C
Wales		UK0013010	River Tywi	1102	*Alosa alosa*	C
Wales		UK0020020	Carmarthen Bay and Estuaries	1102	*Alosa alosa*	D

Wales		UK0013116	Pembrokeshire Marine	1102	*Alosa alosa*	C
Wales		Uk0013007	River Usk	1102	*Alosa alosa*	C
France	B	FR2400565	Vallee de la Loire de Mosnes a Tavers	1102	*Alosa alosa*	B
France	B	FR2400528	Vallee de la Loire de Tavers a Belleville-sur-Loire	1102	*Alosa alosa*	A
France	B	FR2600968	Bec d'Allier	1102	*Alosa alosa*	A
France	B	FR2600967	Vallee de la Loire entre Devay et Digoin	1102	*Alosa alosa*	A
France	B	FR2600966	Vallee de la Loire entre Imphy et Decize	1102	*Alosa alosa*	B
France	B	FR2600964	Val de Loire de Iguerande a Digoin	1102	*Alosa alosa*	A
France	B	FR4201797	Le secteur alluvial Rhin - Ried - Bruch	1102	*Alosa alosa*	
France	B	FR5200629	Vallee de la Loire des Ponts-de-Ce a Montsoreau	1102	*Alosa alosa*	C
France	B	FR5200630	Basses vallees Angevines et aval de la riviere Mayenne	1102	*Alosa alosa*	B
France	B	FR7200662	Vallee de la Dronne de Brantome a sa confluence avec l'Isle	1102	*Alosa alosa*	A
France	B	FR7300952	Gorges de l'Aveyron, causses proches et vallee de la Vere	1102	*Alosa alosa*	
France	B	FR8201689	Forets alluviales, riviere et gorges de l'Eygues	1102	*Alosa alosa*	C
France	B	FR8301020	Vallee alluviale de la Loire	1102	*Alosa alosa*	C

France	B	FR9101405	Le Petit Rhône	1102	*Alosa alosa*	B
France	B	FR9101436	Cours inferieur de l'Aude	1102	*Alosa alosa*	
France	B	FR5200622	Vallee de la Loire de Nantes au Ponts-de-Ce et zones adjacentes	1102	*Alosa alosa*	B
France	B	FR9301589	La basse durance et ses ripisylves, de Cadarache a la confluence du Rhône	1102	*Alosa alosa*	C
France	B	FR9301571	Riviere et gorges du Loup	1102	*Alosa alosa*	C
France	B	FR9301590	Le Rhône, de Donzere-Mondragon a la Mediterrannee	1102	*Alosa alosa*	B
France	B	FR7200661	Vallee de l'Isle de Perigueux a sa confluence avec la Dordogne	1102	*Alosa alosa*	A
France	B	FR2400548	La Loire de Candes Saint Martin a Mosnes	1102	*Alosa alosa*	A
France	B	FR2400536	Vallee de la Creuse et affluents	1102	*Alosa alosa*	C
France	B	FR7300889	Vallee de l'Adour	1102	*Alosa alosa*	B
France	B	FR7301822	Garonne, Ariege, Hers, Salat, Pique et Neste	1102	*Alosa alosa*	
France	B	FR8201657	Vallee moyenne de l'Ardeche et ses affluents	1102	*Alosa alosa*	C
France	E	FR5400430	Vallee de la Charente (basse vallée)	1102	*Alosa alosa*	B
France	E	FR7200660	La Dordogne	1102	*Alosa alosa*	A

France	E	FR7200700	La Garonne	1102	*Alosa alosa*	A
France	E	FR7300898	Vallee de la Dordogne quercynoise	1102	*Alosa alosa*	B
France	E	FR8301016	Vallee de l'Allier sud	1102	*Alosa alosa*	C
France	E	FR8301032	Zones alluviales de la confluence Dore-Allier	1102	*Alosa alosa*	C
France	E	FR8301038	Val d'Allier pont du chateau/Jumeaux-Alagnon	1102	*Alosa alosa*	C
France	E	FR7200668	La Vezere	1102	*Alosa alosa*	A
France	E	FR7200677	Estuaire de la Gironde	1102	*Alosa alosa*	A
France	E	FR7200724	L'Adour	1102	*Alosa alosa*	A
France	E	FR5400469	Pertuis Charentais	1102	*Alosa alosa*	B
France	E	FR5400472	Vallee de la Charente (moyenne vallée) et Seugne et Coran	1102	*Alosa alosa*	B
France	I	FR8301015	Vallee de l'Allier nord	1102	*Alosa alosa*	
France	I	FR9301592	Delta de Camargue	1102	*Alosa alosa*	B
France	K	FR2300121	Estuaire de la Seine	1102	*Alosa alosa*	A
France	K	FR2300122	Marais Vernier et basse vallee de la Risle	1102	*Alosa alosa*	
France	K	FR2500088	Marais du Cotentin et du Bessin - baie des Veys	1102	*Alosa alosa*	A
France	K	FR2600969	Val d'Allier	1102	*Alosa alosa*	A

France	K	FR5200621	Estuaire de la Loire	1102	*Alosa alosa*	C
France	K	FR5200659	Marais Poitevin et baie de l'Aiguillon	1102	*Alosa alosa*	C
France	K	FR5300010	Cote de Trestel a la Baie de Paimpol, estuaires du Jaudy et du Trieux, Archipel de Brehat	1102	*Alosa alosa*	C
France	K	FR2400522	Vallee de la Loire de Neuvy au bec d'Allier	1102	*Alosa alosa*	A
France	K	FR2500077	Baie du Mont Saint-Michel	1102	*Alosa alosa*	B
France	K	FR5400446	Marais Poitevin	1102	*Alosa alosa*	B
Portugal	B	PTCON0039	Serra d'Arga	1102	*Alosa alosa*	B
Portugal	E	PTCON0032	Rio Guadiana/Juromenha	1102	*Alosa alosa*	B
Portugal	E	PTCON0020	Rio Lima	1102	*Alosa alosa*	C
Portugal	I	PTCON0013	Ria Formosa/Castro Marim	1102	*Alosa alosa*	C
Portugal	K	PTCON0009	Estuário do Tejo	1102	*Alosa alosa*	C
Portugal	K	PTCON0036	Guadiana	1102	*Alosa alosa*	B
Portugal	K	PTCON0019	Rio Minho	1102	*Alosa alosa*	B
Spain	B	ES5140010	Ribera de l'Ebre a Flix-Illes de l'Ebre	1102	*Alosa alosa*	B
Spain	B	ES1140001	Sistema fluvial ulla - deza	1102	*Alosa alosa*	B
Spain	B	ES1200025	Río Navia	1102	*Alosa alosa*	C

Spain	B	ES2200014	Río Bidasoa	1102	*Alosa alosa*	C
Spain	C	ES0000024	Parque nacional de Doñana	1102	*Alosa alosa*	
Spain	C	ES0000051	Sierra de Aracena y Picos de Aroche	1102	*Alosa alosa*	C
Spain	E	ES4310026	Rio Guadiana Alto - Zujar	1102	*Alosa alosa*	B
Spain	E	ES4310027	Rio Guadiana Internacional	1102	*Alosa alosa*	B
Spain	E	ES6150008	Doñana	1102	*Alosa alosa*	
Spain	E	ES6150010	Andevalo occidental	1102	*Alosa alosa*	C
Spain	E	ES6150014	Marismas y riberas del Tinto	1102	*Alosa alosa*	
Spain	E	ES6150018	Rio Guadiana y ribera de Chanza	1102	*Alosa alosa*	C
Spain	E	ES6150019	Bajo Guadalquivir	1102	*Alosa alosa*	
Spain	E	ES6170016	Valle del rio del Genal	1102	*Alosa alosa*	
Spain	E	ES1300011	Rio Ason	1102	*Alosa alosa*	C
Spain	E	ES1140007	Baixo Miño	1102	*Alosa alosa*	B
Spain	E	ES1200023	Río Eo (asturias)	1102	*Alosa alosa*	B
Spain	E	ES2120006	Aiako Harria	1102	*Alosa alosa*	B
Spain	E	ES2120015	Terrazas y marismas del Bidasoa	1102	*Alosa alosa*	B
Spain	G	ES1300007	Marismas de Santoña , Victoria y Joyel	1102	*Alosa alosa*	C

Spain	G	ES1200016	Ría del Eo	1102	*Alosa alosa*	B
Spain	I	ES5140013	Delta de l'Ebre	1102	*Alosa alosa*	C
Spain	I	ES1140004	Complexo ons - o grove	1102	*Alosa alosa*	B
Spain	K	ES1120002	Río Eo	1102	*Alosa alosa*	B

APPENDIX 2. Sites that have been designated as Special Areas for Conservation (SAC) or Sites of Community Interest (SCI) under the Habitats Directive for Alosa fallax spp.

Type: A = Designated SPA (Special Protected Area) not related to other Natura 2000 site; B = Eligible SCI not related to another Natura 2000 site; C = Area of eligible SCI is same as designated SPA; D = SPA touches another Natura 2000 site; E = Eligible touchess another Natura 200 site; F = SPA containing eligible SCI; G = Eligible SCI within designated SPA; H = Designated SPA contains an eligible SCI; I = Eligible SCI contains a designated SPA; J = SPA overlaps an eligible SCI; K = Eligible SCI overlaps a SPA.

Global: A = site originally selected for shad (excellent representative); B = site originally selected for shad (good representative); C = site not primarily for shad (significant representative); D = non-significant shad presence.

Country	Type	Site Code	Site Name	Specimen Number	Specimen	Global
Germany	B	DE2526302	Komplex NSG Heuckenlock Und NSG Schweenssand	1103	*Alosa fallax*	C
Germany	B	DE2527303	Borghorster Elblandschaft	1103	*Alosa fallax*	C
Germany	B	DE2627301	Komplex NSG Zollenspieker Und NSG Kiebitzbrack	1103	*Alosa fallax*	C
Germany	C	DE0916303	NTP S-H Wattenmeer U. Angrenzender Küstenstreifen	1103	*Alosa fallax*	A
Germany	C	DE2016301	Nationalpark Hamburgisches Wattenmeer	1103	*Alosa fallax*	B
Germany	E	DE2222301	Unterelbe Bei Glückstadt	1103	*Alosa fallax*	B
Germany	I	DE2424302	Komplex NSG Neßsand Und LSG Mühlenberger	1103	*Alosa fallax*	A

			Loch			
Germany	K	DE2119301	Unterelbe	1103	*Alosa fallax*	B
Germany	K	DE2323303	Schleswig-Holsteinisches Elbästuar	1103	*Alosa fallax*	B
Denmark	C	DK00EX026	**Dråby Vig**	1103	*Alosa fallax*	B
Denmark	C	DK00CY040	Venø, Venø Sund	1103	*Alosa fallax*	A
Denmark	G	DK009X182	Vidå, Rudbøl Sø Og Magisterkogen	1103	*Alosa fallax*	
Denmark	I	DK00CX160	Nissum Fjord	1103	*Alosa fallax*	C
Denmark	I	DK00CY163	Ringkøbing Fjord Og Nymindestrømmen	1103	*Alosa fallax*	C
Denmark	I	DK00EY133	Agger Tange, Nissum Bredning, Skibsted Fjord Og Agerø	1103	*Alosa fallax*	B
Denmark	K	DK00FX122	Ålborg Bugt, Randers Fjord Og Mariager Fjord	1102	*Alosa alosa*	C
Denmark	K	DK00AY176	Vadehavet Med Ribe Å, Tved Å Og Varde Å Vest For Varde	1103	*Alosa fallax*	A
Denmark	K	DK00FX122	Ålborg Bugt, Randers Fjord Og Mariager Fjord	1103	*Alosa fallax*	C
Netherlands	C	NL1000021	Volkerakmeer	1103	*Alosa fallax*	C
Netherlands	E	NL1000015	Haringvliet	1103	*Alosa fallax*	B
Netherlands	E	NL4000017	Voordelta	1103	*Alosa fallax*	B
England &		UK0012642	River Wye	1103	*Alosa fallax*	

Wales						
Wales		UK0013010	River Tywi	1103	*Alosa fallax*	
Wales		UK0020020	Carmarthen Bay and Estuaries	1103	*Alosa fallax*	
Wales		UK0013116	Pembrokeshire Marine	1103	*Alosa fallax*	
Wales		UK0013007	River Usk	1103	*Alosa fallax*	
Eire	B	IE0002137	Lower River Suir	1103	*Alosa fallax*	B
Eire	B	IE0002162	River Barrow And River Nore	1103	*Alosa fallax*	A
Eire	E	IE0000781	Slaney River Valley	1103	*Alosa fallax*	B
Eire	I	IE0002170	Blackwater River (Cork/Waterford)	1103	*Alosa fallax*	B
Eire	K	IE0000365	Killarney National Park, Macgillycuddy's Reeks And Caragh River Catchment	1103	*Alosa fallax*	A
France	B	FR2400565	Vallee De La Loire De Mosnes A Tavers	1103	*Alosa fallax*	C
France	B	FR2400528	Vallee De La Loire De Tavers A Belleville-Sur-Loire	1103	*Alosa fallax*	A
France	B	FR2600966	Vallee De La Loire Entre Imphy Et Decize	1103	*Alosa fallax*	A
France	B	FR2600968	Bec D'allier	1103	*Alosa fallax*	A
France	B	FR4201797	Le Secteur Alluvial Rhin - Ried - Bruch	1103	*Alosa fallax*	C
France	B	FR5200629	Vallee De La Loire Des Ponts-De-Ce A Montsoreau	1103	*Alosa fallax*	C

France	B	FR5200630	Basses Vallees Angevines Et Aval De La Riviere Mayenne	1103	*Alosa fallax*	B
France	B	FR8201677	Milieux Alluviaux Du Rhone Aval	1103	*Alosa fallax*	C
France	B	FR8201689	Forets Alluviales, Riviere Et Gorges De L'eygues	1103	*Alosa fallax*	C
France	B	FR9101405	Le Petit Rhone	1103	*Alosa fallax*	B
France	B	FR9101436	Cours Inferieur De L'aude	1103	*Alosa fallax*	
France	B	FR9400572	Mucchiatana	1103	*Alosa fallax*	
France	B	FR5200622	Vallee De La Loire De Nantes Au Ponts-De-Ce Et Zones Adjacentes	1103	*Alosa fallax*	C
France	B	FR9301589	La Basse Durance Et Ses Ripisylves, De Cadarache A La Confluence Du Rhone	1103	*Alosa fallax*	B
France	B	FR9301627	Embouchure De L'argens - Marais De Frejus - Etangs De Villepey	1103	*Alosa fallax*	B
France	B	FR9301590	Le Rhone, De Donzere-Mondragon A La Mediterrannee	1103	*Alosa fallax*	A
France	B	FR9301608	Mont Caume - Mont Faron - Foret Domaniale Des Morieres	1103	*Alosa fallax*	B
France	B	FR7200661	Vallee De L'isle De Perigueux A Sa Confluence Avec La Dordogne	1103	*Alosa fallax*	A
France	B	FR2400548	La Loire De Candes Saint Martin A Mosnes	1103	*Alosa fallax*	B

France	E	FR5400432	Marais De Seudre	1103	*Alosa fallax*	B
France	E	FR7200660	La Dordogne	1103	*Alosa fallax*	B
France	E	FR7200700	La Garonne	1103	*Alosa fallax*	B
France	E	FR7200677	Estuaire De La Gironde	1103	*Alosa fallax*	A
France	E	FR7200724	L'adour	1103	*Alosa fallax*	B
France	E	FR5400469	Pertuis Charentais	1103	*Alosa fallax*	B
France	I	FR8201654	Basse Ardeche Urgonienne	1103	*Alosa fallax*	B
France	I	FR9101395	Le Gardon Et Ses Gorges	1103	*Alosa fallax*	B
France	I	FR9301592	Delta De Camargue	1103	*Alosa fallax*	B
France	K	FR2300121	Estuaire De La Seine	1103	*Alosa fallax*	A
France	K	FR2300122	Marais Vernier Et Basse Vallee De La Risle	1103	*Alosa fallax*	B
France	K	FR2500088	Marais Du Cotentin Et Du Bessin - Baie Des Veys	1103	*Alosa fallax*	A
France	K	FR5200621	Estuaire De La Loire	1103	*Alosa fallax*	C
France	K	FR5200659	Marais Poitevin Et Baie De L'aiguillon	1103	*Alosa fallax*	C
France	K	FR2400522	Vallee De La Loire De Neuvy Au Bec D'allier	1103	*Alosa fallax*	A
France	K	FR2500077	Baie Du Mont Saint-Michel	1103	*Alosa fallax*	B
France	K	FR5400446	Marais Poitevin	1103	*Alosa fallax*	B

France	K	FR2600965	Vallee De La Loire Entre Fourchambault Et Neuvy-Sur-Loire	1103	*Alosa fallax*	A
Portugal	B	PTCON0039	Serra D'arga	1103	*Alosa fallax*	C
Portugal	E	PTCON0020	Rio Lima	1103	*Alosa fallax*	C
Portugal	I	PTCON0011	Estuário Do Sado	1103	*Alosa fallax*	C
Portugal	K	PTCON0009	Estuário Do Tejo	1103	*Alosa fallax*	C
Portugal	K	PTCON0036	Guadiana	1103	*Alosa fallax*	B
Portugal	K	PTCON0019	Rio Minho	1103	*Alosa fallax*	B
Spain	B	ES5140010	Ribera De l'Ebre A Flix-Illes De l'Ebre	1103	*Alosa fallax*	B
Spain	B	ES1140001	Sistema Fluvial Ulla - Deza	1103	*Alosa fallax*	B
Spain	C	ES0000024	Parque Nacional De Doñana	1103	*Alosa fallax*	C
Spain	E	ES4310026	Rio Guadiana Alto - Zujar	1103	*Alosa fallax*	B
Spain	E	ES4310027	Rio Guadiana Internacional	1103	*Alosa fallax*	B
Spain	E	ES6150008	Doñana	1103	*Alosa fallax*	C
Spain	E	ES6150014	Marismas Y Riberas Del Tinto	1103	*Alosa fallax*	
Spain	E	ES6150019	Bajo Guadalquivir	1103	*Alosa fallax*	C
Spain	E	ES6170016	Valle Del Rio Del Genal	1103	*Alosa fallax*	

Spain	E	ES1140007	Baixo Miño	1103	*Alosa fallax*	B
Spain	I	ES5140013	Delta De l'Ebre	1103	*Alosa fallax*	C
Spain	I	ES1140004	Complexo Ons - O Grove	1103	*Alosa fallax*	B
Italy	B	IT1315720	Fiume Roia	1103	*Alosa fallax*	C
Italy	B	IT3210018	Basso Garda	1103	*Alosa fallax*	B
Italy	B	IT3320036	Anse Del Fiume Stella	1103	*Alosa fallax*	
Italy	B	IT6010035	Fiume Mignone (Basso Corso)	1103	*Alosa fallax*	B
Italy	B	IT6040025	Fiume Garigliano (Tratto Terminale)	1103	*Alosa fallax*	B
Italy	B	IT7140107	Lecceta Litoranea Di Torino Di Sangro E Foce Fiume Sangro	1103	*Alosa fallax*	B
Italy	C	IT2040022	Lago Di Mezzola E Pian Di Spagna	1103	*Alosa fallax*	C
Italy	C	IT3320037	Laguna Di Marano E Grado	1103	*Alosa fallax*	
Italy	C	IT3330005	Foce Dell' Isonzo - Isola Della Cona	1103	*Alosa fallax*	
Italy	C	IT4010001	Isola De Pinedo	1103	*Alosa fallax*	B
Italy	C	IT4010009	Fiume Po Dalla Foce Del Fiume Trebbia Alla Lanca Di Mezzano	1103	*Alosa fallax*	B
Italy	C	IT4020002	Fiume Taro Da Fornovo Di Taro All'autostrada Del Sole	1103	*Alosa fallax*	A

Italy	C	IT4060003	Vene Di Bellocchio, Sacca Di Bellocchio, Foce Del Fiume Reno,...	1103	*Alosa fallax*	B
Italy	C	IT4060004	Valle Bertuzzi, Valle Porticino-Cannevie'	1103	*Alosa fallax*	B
Italy	C	IT4060005	Sacca Di Goro, Po Di Goro, Valle Dindona, Foce Del Po Di Volano	1103	*Alosa fallax*	B
Italy	C	IT4060008	Bonifica Del Mezzano	1103	*Alosa fallax*	B
Italy	C	IT4060011	Garzaia Dello Zuccherificio Di Codigoro	1103	*Alosa fallax*	A
Italy	C	IT4060013	Po Da Golena Bianca A Isola Bianca	1103	*Alosa fallax*	A
Italy	E	IT1343502	Parco Della Magra - Vara	1103	*Alosa fallax*	B
Italy	E	IT6010020	Fiume Marta (Alto Corso)	1103	*Alosa fallax*	B
Italy	E	IT8010003	Basso Corso Del Fiume Volturno	1103	*Alosa fallax*	A
Italy	E	IT8010007	Foce Del Fiume Garigliano	1103	*Alosa fallax*	B
Italy	E	IT8010008	Foce Del Fiume Volturno	1103	*Alosa fallax*	A
Italy	E	IT8050007	Basso Corso Del Fiume Bussento	1103	*Alosa fallax*	A
Italy	E	IT8050012	Fiume Alento	1103	*Alosa fallax*	B
Italy	E	IT8050015	Foce Del Fiume Sele	1103	*Alosa fallax*	A
Italy	G	IT6010017	Sistema Fluviale Fiora - Olpeta	1103	*Alosa fallax*	B
Greece	B	GR1260002	Ekvoles Potamou Strymona	1103	*Alosa fallax*	B

Greece	C	GR1110001	Delta Evrou	1103	*Alosa fallax*	B
Greece	C	GR2310001	Delta Acheloou, Limnothalassa Mesolongiou-Aitolikou, Ekvoles Evinou Kai Nisoi Echinades	1103	*Alosa fallax*	C
Greece	I	GR1130009	Limnes & Limnothalasses Tis Thrakis-Evryteri Periochi	1103	*Alosa fallax*	B
Greece	I	GR1150010	Delta Nestou & Limnothalasses Keramotis-Evryteri Periochi	1103	*Alosa fallax*	B