

**SHAD 2001:**  
*A Conference on the Status and  
Conservation of Shads Worldwide*

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**Abstracts for Plenary Talks**

*(in alphabetical order)*

## Genetic Research and Conservation of European shads, *Alosa alosa* and *Alosa fallax*

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Since the development of molecular techniques and the recognition of the potential usefulness of polymorphic genetic markers several issues of conservation relevance can be addressed including spatial and temporal aspects of species evolution and population structure. Thus, genetic information is critical because successful management depends on the correct delimitation of species units, populations or stocks and analysis of their evolutive patterns.

European shads, *Alosa alosa* and *Alosa fallax*, are two close anadromous fish that have been studied by using different kind of genetic markers, to clarify aspects such as interspecific genetic differentiation, hybridization and introgression, population structure and definition of stocks or genetic changes in landlocked populations. Results based on the analysis of 8 polymorphic protein markers, from a total of 29 screened loci, in several populations of both species covering a significant part of their geographic range of distribution, show that although no diagnostic loci were found allis and twaite shads could be considered two separate species (45% of total genetic variation is due to differences between species) but still at an early stage of divergence. This could explain the occurrence of extensive hybridization in some basins where both species are sympatric and where man-mediated environmental disturbances cause overlapping of spawning sites. Several lines of evidence indicate that hybrid fish can reproduce and both protein and mtDNA markers confirms the existence of recent introgression.

Within *A. fallax* three groups of populations are clearly defined, one formed by French Mediterranean and Morocco populations, other by Portuguese southern populations and a third one including Atlantic populations from north Portugal and France. These results do not support the subspecific status of *A. fallax rhodanensis*. Although this population structure could be explained in part by an isolation by distance model, other factors such as the occurrence in sympatry of *A. alosa* and introgression seems to be relevant for the observed pattern of differentiation. Subgrouping of *A. alosa* populations are also apparent although not so evident as for *A. fallax* due to their low level of protein genetic variation. The inclusion of new highly polymorphic markers, such as microsatellites, in the genetic population analysis of this species will certainly clarify this question. Preliminary data based on such microsatellite markers, together with protein loci, indicate that landlocked populations of allis shad are less variable and diverged, by processes of time dependend genetic drift or "bottleneck" effects, from original anadromous populations.

These results are discussed in the prespective of their relevance for the conservation and management of European shad populations.

**Biology, Status and Conservation of the Anadromous Twaite Shad,  
*Alosa fallax fallax* (Lacépède, 1803)**

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Twaite shad have been reported from Iceland to Morocco and as far east as the Baltic Sea; they are coastal in habit occurring at depths from 10 to 110m. Twaite shad mature from 2 to 9 years old with females mainly at 4 and 5 years and males a year earlier. Absolute fecundity ranges from 25,942 to 675,000 eggs and relative fecundity from 42,540 to 302,358 egg kg<sup>-1</sup>. All populations are iteroparous, having a high proportion of repeat spawners.

The spawning migration into the estuary begins between February (southern populations) and May (northern populations), extends for three months and is temperature dependent. Spawning occurs in fresh water, is mainly nocturnal though has been reported during daylight and occurs over substrate ranging from mud to sandy-gravel at depths of 0.15m to 8m. Eggs (1.7 – 4.5mm) successfully develop between 15°C and 25°C. Incubation takes 72 to 120h depending on temperature. Larvae measure 4.25 to 9.2mm at hatching. 0+ fish migrate seaward during the autumn / winter, in the surface layers of the water column.

The adults do not feed in fresh water. Juveniles consume mainly *Uniramia* in fresh water and zooplankton in the estuary. At sea Mysidacea and fish dominate. The fastest growing populations were in the Nyamunas and in the Loire and Charente. Little difference in growth exists between other populations from the Sebou to the Severn. Populations at the northern limit of their range are regulated mainly by density independent factors.

Genetic differences exist between populations. Conservation strategies are being developed as a result of European legislation.

## The Allis shad (*Alosa alosa* Linné, 1758): Biology, Ecology, Range and Status of Populations

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The Allis shad belongs to *Alosa*; no subspecies has been identified. It is morphologically distinct from the twaite shad *Alosa fallax fallax*, with which it coexists in sympatry; however hybridization between the two species does occur.

Allis shad populations are mainly anadromous but some landlocked populations have arisen as a result of dam construction. All anadromous populations have common biological characteristics: the migration (December-June) and the reproduction (April-July) occur only when the water temperature is above 11 °C and 15 °C respectively; age of adults ranges from 3 and 8 years old; females grow faster and mature later than males; their spawning behaviour is similar and populations are semelparous. A latitudinal gradient in biological characteristics exists with southern populations migrating upstream earlier and growing faster.

Historically, the range of the species extended along the eastern Atlantic coasts from Norway to southward to Morocco and into the western Mediterranean sea. Today, the range is restricted to the Atlantic coasts of France and Portugal. There have been no successful transplantation carried out. Recently, restoration and conservation programmes have been instigated, these included the installation of fish passes and the conservation of spawning areas. To date there has been no stocking programme as artificial culture has not proved reliable.

Allis shad is fished commercially using traditional fishing methods. The catch in the region is from 600 to 900  $\text{t}^{-1}$  mainly from the Gironde-Garonne-Dordogne basin (France).

To conserve and enhance allis shad further research is needed on juvenile stage in fresh water, the degree of homing, the marine phase and their population dynamics.

## **Biology, Fisheries and Status of Tropical Shads (*Tenualosa*) in Southeast Asia**

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Five species of tropical shads (Clupeidae: *Tenualosa* species) (Terubuk in Indonesia, Terubok in Malaysia, Hilsa in Indian sub-continent, Pba Mak Pang in the Mekong) live in the estuaries and coastal waters of tropical Asia. The most widespread and well-studied species is *T. ilisha*, which is found from north Sumatra in the east to Kuwait in the west, and is the basis of important fisheries in Bangladesh, India, Burma, Pakistan and Kuwait. The closely related *T. reevesii* occurs intermittently along the South China coast and far up the Yangtze, Pearl and Qiantang rivers and *T. thibaudeaui*, which only lives in the lower and middle Mekong system, is believed to be close to extinction. Once widespread, *Tenualosa toli* is now found only in the estuaries and adjacent coastal areas of Sarawak (north coast of Borneo) while *T. macrura*, lives in the coastal waters of Sumatra and Borneo. *Tenualosa* species exhibit several life history strategies; for example, *T. ilisha* and *T. reevesii* are gonochoristic, whereas *T. toli* and *T. macrura* are protandrous hermaphrodites. Habitat preferences, movement patterns and maximum age also vary between species. All *Tenualosa* are subject to heavy fishing pressure and have suffered major declines. Although *T. toli* and *T. macrura* have great cultural significance in Sarawak and Sumatra respectively, both are still commercially fished for their eggs, which command very high prices.

## **Sensitivity of American Shad to Changes in Fishing Mortality**

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The American shad, *Alosa sapidissima*, is an anadromous species which occurs along the Atlantic coast from southern Labrador to northern Florida. Many of the spawning runs along the Atlantic coast have been subjected to in river commercial and recreational fisheries of varying magnitude; total landings have declined steadily since 1980 (ASMFC 1998), and commercial landings in the northeast US have been declining since the 1960s. A number of factors have been identified as possible causes for the decline in landings, including overfishing, an increase in predation by striped bass, changes in abiotic conditions, and a drop in commercial fishing effort. Overall, the Atlantic coast stocks are considered to be fully exploited and well below their historic levels of abundance. We examine the sensitivity of the reproductive potential of the Atlantic coast stocks, expressed as eggs per recruit, to changes in fishing mortality. Our analysis indicates that southern stocks of American shad along the Atlantic coast are less sensitive to changes in fishing mortality than northern stocks. We also find that American shad are general less sensitive than other shad species, as well as other fish species occupying the same range along the Atlantic coast. The Atlantic States Marine Fisheries Commission (ASMFC), through its participating states, has undertaken a vigorous campaign to restore shad stocks by improving habitat and fish passage, stocking, and inter-basin transfers. We conclude that the ASMFC strategy will yield much stronger dividends than a strategy of stock restoration solely through reduction in fishing mortality.

## **African shads, with Emphasis on *Ethmalosa fimbriata***

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Four shad species are found in Africa: *Alosa fallax* and *A. alosa* whose populations in North Africa can be regarded as relics; *Ethmalosa fimbriata*, an abundant tropical West African species and *Hilsa kelee*, present in East Africa and all the Indian Ocean.

*Ethmalosa* has been the most studied species. A precedent review of the status of the species (Charles-Dominique 1982) is summarized and updated. *Ethmalosa* inhabits mainly shallow estuaries and lagoons open to the sea, and sometimes the coastal sea nearby. Possible diadromy is discussed. The distribution of the juveniles, young adults and old adults show different patterns, the older having more affinities with the sea. Migrations from brackish waters upstream have been reported in certain areas. The resilience is discussed from recent fish communities studies, emphasizing the adaptability of the species and its place in the trophic web.

*Ethmalosa* is exploited since old times and carries cultural value for the coastal people of West Africa. The catches are marketed cured in the coastal zone, sometimes far from the fishing areas. It is a locally important, low price and much appreciated food fish.

The fisheries are intensive and developing (150,000 mt/yr at the moment) although almost entirely artisanal; some reliable fisheries data do exist by places. Main threats to the *Ethmalosa* populations by overfishing and worsening of the environment are discussed.

*Hilsa kelee* is much less documented. A comparison with *Ethmalosa* is nevertheless attempted, on the basis of available information.

Charles-Dominique, E., 1982.- Synopsis of biological data on *Ethmalosa fimbriata* S. Bowdich, 1825. *Revue d'Hydrobiologie Tropicale*, 15 (4):373-397. (in french)

## **Ecosystem-Level Effects Of Dams Resulting From Losses Of Diadromous Fishes And Other Organisms**

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Humans have been damming rivers for millenia, and our more ambitious efforts over the past century have arguably altered river ecosystems more extensively than any other anthropogenic activity. Some effects of dams on riverine biota are well known, and include curtailment of species migrations and community shifts towards species tolerant of the altered habitats. Diadromous species have been widely eliminated from upstream portions of their freshwater ranges by dams that hinder passage. Although the habitat of diadromous and other riverine species is often maintained in the lower, undammed reaches of a river system, remnant populations often suffer reduced abundance as a result of dam-altered flow and habitat regimes. Ecosystem-level consequences of faunal depletion caused by dams are only beginning to be appreciated. The loss of one species can lead to the loss of another, as in the case of freshwater mussels isolated from their migratory fish hosts. Depletion of amphidromous shrimps above dams in tropical streams, such as those draining Caribbean islands, can significantly affect the quality and quantity of benthic organic matter and affect ecosystem processes such as detrital processing. Similarly, depletion of migratory fishes may alter stream algal and insect communities. The loss of fish-delivered marine derived nutrients, as quantified in streams made inaccessible to diadromous salmonid populations, can lower stream productivity at multiple trophic levels. Greater ecological focus on effects of dams on ecosystem processes, as mediated by faunal change, would improve our ability to assess the costs and benefits of future river management strategies.

## **Biology and Status of the Hickory Shad, *Alosa mediocris***

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The hickory shad is one of four anadromous clupeid fishes native to the Atlantic slope of North America. Historically, hickory shad contributed significantly to important commercial fisheries, especially in Chesapeake Bay tributaries and southeastern rivers. Like its larger and more celebrated congener, the American shad, many stocks of hickory shad declined dramatically throughout the 20th Century. In fact, as recently as the early 1990's hickory shad were considered almost extirpated from some coastal rivers, including the James River, Virginia. However, research monitoring has documented an apparent recovery by hickory shad in several Chesapeake Bay tributaries since 1998, but the mechanisms of this apparent recovery are unclear. In contrast to American shad, hickory shad have not been the focus of substantial research and restoration initiatives, and as a result the biology of this species is poorly understood. Based on comparative analysis of selected population characteristics, including age structure and reproductive biology, for hickory shad and its sympatric congeners, this paper will evaluate the relatively dramatic, and wholly unexpected, recovery of hickory shad in Virginia coastal rivers and attempt to apply that knowledge to restoration efforts for other anadromous clupeid fishes.

## **Culture and Transplant of Alosines in North America**

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North American populations of the alosines have been severely impacted by construction of dams, habitat alteration, pollution and overfishing. Successful restoration of depleted populations has occurred through transplanting of sexually mature, pre-spawn adults or stocking of cultured larvae or juveniles. Transplanting of fertilized eggs has been attempted with little success. Reproducing populations of *Alosa aestivalis*, *Alosa pseudoharengus*, and *Alosa sapidissima* have been established in many locations in Eastern North America by transplanting pre-spawn adults.

Major efforts to culture alosines for restoration purposes have centered on *A. sapidissima* with less effort directed toward *A. aestivalis*, *A. mediocris*, and *A. pseudoharengus*. Culture of alosines has historically relied upon strip-spawning eggs from running ripe adults, collected on the spawning grounds. Fertilized eggs for culture can also be obtained by natural spawning in a tank environment, with or without the use of hormone injections. The most challenging aspects of working with members of this group include: their sensitivity to handling and stress in all life stages; the adhesive nature of the eggs of some species; and, for some species, an inability to provide ample forage, small enough to be utilized by first-feeding larvae.

## **Riverine Passage for Shads at Dams**

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After mainstem river damming during the Industrial Revolution blocked shad spawning migrations in most large North American rivers, there was a long period before a successful fishway for American shad was constructed. The two fish lifts built at Holyoke Dam on the Connecticut River (first one built in 1957) were the first successful fishways that were designed to pass shads. In 1992, they passed 700,000 American shad and more than one million total anadromous fish. Due to the success of this design, application of this technology spread during the latter 20<sup>th</sup> Century and fish lifts for shads were constructed on other North American rivers and in Europe. Shads also use technical fishways (particularly, those of short length) such as pool and weir, vertical slot, and Denil types. However, success is highly variable and depends on creating acceptable environmental conditions in the fishway for the non-jumping shads. Passage is likely affected by many physical factors, i.e., illumination, water velocity, bubbles, slope, and structural configuration. Shads do not use submerged orifices of pool-and-weir fishways and they pass during daylight hours with fallback of many fish at night in long fishways. At the Turners Falls Fishway (Modified Ice Harbor type) on the Connecticut River, the longest technical fishway used by shad in North America, passage is poor. Energetics does not limit passage success at this site, instead fish behavioral response to the fishway environment prevents most individuals from passing. Shads ascending technical fishways are delayed by complex turbulent hydraulic conditions and passage performance can be improved by providing more linear flows. Because all adult shad do not die after spawning, some adults passed upstream of dams and their progeny need protection from turbines and passage when they move seaward. During the 1980s and 1990s, the behavioral response of migrants to physical stimuli (particularly, light and sound) was evaluated with the hope of developing guidance systems. Performance of behavioral guidance systems for migrant shads has been variable, and to date, only physical barriers, such as bar rack and louver arrays, are effective in guiding shads at dams under a wide range of river conditions. Effective bypass systems for shads that employ a physical static barrier to guide migrants to a surface spill or a bypass pipe, have been constructed at many dams in North America and Europe.

## **American Shad in its Native Range**

**Karin Limburg**

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Anadromous American shad (*Alosa sapidissima* Wilson) ranges from the St. Lawrence River in Canada to the St. Johns River, Florida. Once the major commercially fished species in the U.S., catches went from a high of nearly 230,000 metric tons (1896) through a series of cascading declines to the present-day levels in the hundreds of metric tons. The declines were attributed to overfishing, habitat loss, and pollution over the past 170 years. Despite the success of fishways, modern major spawning rivers have lost approximately 4,000 km of habitat due to dams.

American shad exhibits biological variation along its geographic range. This variation includes growth rates (counter gradient), fecundity, and degree of iteroparity. Good information exists on adult migration trends, migration physiology, and on young-of-year ecology. Whereas many aspects of American shad biology have been well studied in certain systems, complete population profiles from its entire range, including accurate population size estimates, are lacking. This paper synthesizes available data and points out the gaps in information that would aid in restoration and management of this valuable species.

## **River Herring Invasions of Inland Waters**

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Presented by D.B. MacNeill - dbm4@cornell.edu

The Erie Barge Canal is believed to be the invasion route to Lake Ontario used by alewives, *Alosa pseudoharengus*, in the 1860s, and blueback herring, *Alosa aestivalis*, in the mid-1990s. Although in the marine environment, both species are partially segregated in a spatial and temporal context, competitive interactions are more likely in Lake Ontario should blueback herring become established, because of depressed zooplankton production and abundance in the system. A literature review is presented, drawing on comparisons of known feeding habits, and feeding behaviors for these species. Results of a preliminary study of the functional morphology of branchial arch structures are presented. Predicted prey retention efficiencies of similar-sized alewife and blueback herring, based on a cumulative gill raker spacing model, suggests that alewives may retain smaller prey with higher efficiency than blueback herring.

## **Shads and Diadromy– Getting the Big Picture**

**Robert M. McDowall**

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Amongst fishes of the family Clupeidae (which includes the shads), around 29 species are diadromous, most of them anadromous, though one is amphidromous and two are catadromous. The origin and evolution of diadromy in shads remains largely unexamined, and it is not known whether it has evolved once, or more often.

The implications of diadromy for shad evolution biogeography, distribution, diversity and ecology are diverse, and include the following:

1. Diadromy suppresses divergence and diversity through facilitation of gene flow between populations that are otherwise isolated in separate river systems;
2. This gene flow is hindered, and so divergence and diversity are inhibited, however, when diadromous shads are able to undertake accurate homing to natal habitats;
3. Diadromy facilitates dispersal and the acquisition of broad geographical ranges, as even where there is some homing, straying is likely;
4. Diadromy enables species to be amongst the first that invade newly available habitats (as with glacial retreats both historically and contemporaneously), and also facilitates restoration of fish populations to habitats following short-term perturbation;
5. Diadromy appears, in general, to hinder human translocation of species to novel areas, probably as a result of highly evolved navigational powers that relate to solar or geomagnetic guidance mechanisms – though the only instance in which a shad translocation has been attempted, it was successful, and the species has continued to spread.
6. Diadromous migrations pose special problems for conservation, in relation to their need for upstream and downstream access during their life cycles;
7. There is latitudinal variation in the frequency of diadromy, with anadromous fishes tending to be more common at higher latitudes, but explanations of this variation that point to parallel gradients in marine productivity seem more elegant than real – and are, at best, a partial explanation;
8. Diadromy has a significant and distinctive role in stream fish community assembly, and gradients of upstream-downstream diversity in strongly diadromous fish communities, that superficially appear to conform to the River Continuum Concept, have an altogether different explanation;
9. Diadromy has implications for the application of Indices of Biological Integrity, to the extent that without the acquisition of extensive datasets of local origin, and the elaboration of models of distribution, IBIs are largely inapplicable to fish communities that include a significant proportion of diadromous fishes.

**Distribution, Life History, and Status of the Alabama Shad (*Alosa alabamae*) and Skipjack Herring (*A. chrysochloris*) in Gulf of Mexico Drainages**  
**Maurice F. Mettee and Patrick E. O'Neil**

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Two *Alosa* species occur in rivers that drain into the Gulf of Mexico. *Alosa alabamae*, an anadromous species, is a seasonal inhabitant of large rivers from the Mississippi River eastward to the Suwannee River, Florida. Adults generally enter fresh water from late February to March, spawn from March to early June depending on upstream migration distance, and move downstream to salt water from August to October. Young-of-the-year Alabama shad spend their first three to five months in fresh water before moving downstream. *Alosa chrysochloris* occurs in freshwater rivers, reservoirs, and larger streams from the Colorado River, Texas, eastward to the Apalachicola River, Florida; a few scattered records exist from smaller coastal drainages. Adults aggregate and spawn in tail waters below dams and other swift water areas. A review of existing literature supplemented with recent communication from fisheries biologists suggest that high-lift navigation and hydroelectric dams have blocked upstream spawning migrations of *Alosa alabamae*, resulting in a significant decline in inland observations over the last 40 to 50 years. Two views exist concerning the current status of *Alosa chrysochloris*. Some biologists reported dams adversely affected the distribution and abundance of *A. chrysochloris* in the upper Mississippi River basin. In other states, low turbidity conditions above newly constructed reservoirs apparently increased *A. chrysochloris* abundance.

## Shads of Eastern Europe

**Ion Navodaru**

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Three species belonging to *Alosa* genera are known in North-Western part of Black Sea, including Sea of Azov: Pontic shad, *Alosa pontica* Echwald 1838, Caspian shad, *Alosa caspia* Eichwald 1838, and Black sea shad, *Alosa maeotica* Grimm 1901. Many regional subspecies or populations are quoted along the time, migrating in Danube, Dniester, Dnieper and Don rivers. Pontic shad, the greatest population of shads from Eastern Europe, migrates for spawning upstream 500 km in Danube River at the end of March, at 3-5°C. The peak of migration is in April-May at 9-18 °C and end in July-August at 22-25°C. Pelagic eggs and larva drift seawards in 0-0.5 m upper layer of river water. First summer fry feed in brackish water in front of Danube Delta and leave shoreline in autumn. Adult stock lives in deep sea (50-100m), feeding on fish. Species longevity is 5-7 years with maturity at 3-4 years. Most of shads die after spawning migration, but less than 10% spawn repeatedly. The other two species spawn in brackish water of deltas and lagoon lakes. Pontic shad fishery is the most important, followed by that of Caspian shad while Black Sea shad fishery collapsed. Fishing pressure and pollution are the main threats for Pontic shad (there is no dam in breeding areal). Spawning habitat for Caspian shad and Black sea shad have drastically decreased. Closed season and area in the river, are core regulations for shad species conservation. Species behavior, spawning and recruitment, year class strength, and estimation of population dynamics are yet open research and management issues.

## Monitoring Shad Fisheries

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The strength of the annual spawning run in semelparous populations of *Alosa* is set by prior levels of juvenile production, survival of immature fish at sea, and age at maturity of each immature cohort. For iteroparous populations, survival of repeat spawners is an additional parameter. Each reproductive mode requires a different quantitative model to forecast run size and a different fisheries monitoring program to assure protection of the stocks. Indexes of juvenile production require validation but there are few examples. New methods to estimate age at maturity have been developed for iteroparous populations but this parameter is difficult to obtain for semelparous stocks. Estimating survival of immature fish at sea is problematic. As a result, models that predict run strength may not be feasible, especially in semelparous populations. Semelparous stocks are especially vulnerable to over-fishing if there is a strong spawner-recruit relationship. For these stocks, annual assessment of run strength may be required before setting harvest levels for that year. Current status of stocks and targets for restoration can be determined by comparison to appropriate historical data. In-river tagging of mature fish before they enter the fishery allows estimation of fishing mortality and population size if reporting rate and harvest are known, but tagging may alter migratory behavior. Change-in-ratio (CIR) methods allow assessment of exploitation in gender-specific fisheries; index-removal (IR) methods are more generally applied but have an additional assumption. Both require sampling the pre- and post-spawning migration and determination of reproductive maturity stage. Partial semelparity (some but not all virgins die on the spawning grounds due to the physiological stress of spawning) may confound CIR and IR results. Management and monitoring considerations become more complex in the case of mixed-stock fisheries.

# **American Shad in the Columbia River Basin: Current Knowledge, Management, and Information Needs**

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American shad (*Alosa sapidissima*), which are native to eastern North America, were introduced into the Sacramento River (California) in 1871, migrated north along the Pacific coast, and became well established in the Columbia River by 1885. The number of adult American shad passing Bonneville Dam on the lower Columbia River has increased dramatically in the last 60 years, from an average of 16,700 adults between 1938-1957 to over 2 million adults per year during the last decade. American shad migrate up the Columbia and Snake rivers at least 695 km during May through July, spawn in the mainstem rivers, and juvenile shad are abundant during late summer and fall throughout the lower Columbia River and the estuary. Although specific data are unavailable to answer many questions, American shad are likely influencing nutrient levels, the abundance and composition of the zooplankton community, and food webs in this large river system. Juvenile shad may be competing with some stocks of juvenile salmonids, especially fall chinook salmon in the lower river and estuary. Juvenile shad are supplementing the diet of top predators in the system, contributing up to 80% of the diet of northern pikeminnow (*Ptychocheilus oregonensis*) in late summer and fall. We review the current management of adult shad, potential impacts on adult salmonid migration, and future management options. Finally, we discuss some needed research on American shad necessary to identify their direct and indirect effects in the Columbia River system.

## **River Herrings (*Alosa aestivalis*, *A. pseudoharengus*) in their Native Ranges**

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We approached the issue of long term population trends in these species by examining data sets available for the southern (North Carolina and Virginia), central (Delaware to Connecticut), and northern (Maritime Provinces) parts of the Atlantic coast. Commercial landings of adult river herring in the southern part of their range have declined rapidly since the early 1970s. Young-of-year (YOY) abundance indices show that recent recruitment has been below average for both species and that year to year fluctuations in these indices are significantly correlated between species within drainages. Correlations between drainages were low, however.

In the central Atlantic region, blueback herring (*A. aestivalis*) are one or two orders of magnitude more abundant than alewives (*A. pseudoharengus*). We have no data on adult alewife population trends but numbers of adult blueback herring passed over the first dam on the Connecticut River have sharply declined in the last 20 years. YOY abundance indices have also declined in Connecticut River blueback herring but we have no data for alewives in this system. YOY abundance indices are significantly correlated between the Delaware and Hudson Rivers for both species, however long term trends in these indices indicated a stable population or slight declines over the last 15 years.

Alewives are more abundant than blueback herring in the Maritime Provinces and alewives are more heavily exploited than blueback herring. Alewives are mostly age-5 or younger and there is a low percentage of repeat spawners in the most heavily exploited fisheries. Recent catches in most of the fisheries have declined and are below their long term means.

## **A Case History: American Shad Restoration on the Susquehanna River**

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Stocks of anadromous American shad (*Alosa sapidissima*) and river herring (*A. aestivalis* and *A. pseudoharengus*) are being restored to the Susquehanna River in Maryland, Pennsylvania and New York. This river once supported extensive shad fisheries which were lost with construction of four large hydroelectric dams in the lower 90 km during 1904-1931. Fish re-introduction and project evaluation activities have been undertaken over a three-decade period by numerous state, federal, and utility company partners. These included the culture and release of over 150 million marked larval and fingerling shad, and trap and transport of over 200,000 pre-spawned adults to suitable spawning waters above blockages. The shad population returning to the lowermost dam on the Susquehanna grew from only a few hundred to over 150,000 fish in the past 16 years. Survival of out-migrating juvenile shad through hydroelectric turbines has been evaluated and, where necessary, improved with project operational changes during peak movement periods. Settlement agreements with each of the utility companies led to construction of large capacity fish elevators and ladders at the four lower river dams during 1991-2000. As a result, over 750 km of historic spawning habitat for anadromous fishes has been reopened for the first time in almost a century.

## **An Introduction to the Alosines**

**John Waldman**

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Alosinae is a subfamily of Clupeidae. The most recent review (by Grande 1985) placed it among four other subfamilies, including Pellonulinae (freshwater “double-armored” herrings), Dussumierinae (round herrings), Dorosomatinae (gizzard shads), and Clupeinae (sea herrings). However, the phylogenetic relationships among the subfamilies remains unknown. Alosinae is composed of about 19 species among seven genera: *Alosa*, *Brevoortia*, *Ethmalosa*, *Ethmidium*, *Gudusia*, *Hilsa*, and *Tenualosa*. The genus is defined by a notched upper jaw into which the lower jaw articulates. Alosines range to about 60 cm in length but are more typically 20 – 30 cm. They have an almost worldwide distribution, occurring in lakes, rivers, and seas. Many are diadromous, but principally anadromous. Limited genetic research to date has elucidated phylogenetic relationships within *Alosa*, and has shown stock structure and evidence of natal homing for *Alosa sapidissima*. The anadromous alosines show a high degree of plasticity and intrageneric niche differentiation. Intra-specific variation is also notable and consistent with adaptation to varying habitats. Landlocking and dwarfing of anadromous alosines may occur but the proclivity to do so varies with species. The anadromous alosines are important recreational and commercial fishes. They support numerous culturally-unique “festivals,” due in part to the highly predictable nature of their spawning runs. However, the same predictability has rendered them vulnerable to overharvest; abundances have also declined because of habitat alteration, chiefly the construction of dams that reduce or eliminate spawning habitat.

# **Induction of Spawning in Fishes: Physiological and Biotechnological Approaches**

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As captive broodstock, hatchery and restoration programs have intensified during the last three decades, it has become increasingly obvious that modern seed production facilities must gain complete control over the reproductive cycle of the target fish and produce fertilized eggs on demand. The early spawning induction technologies used pituitary extracts or mammalian gonadotropins. With the determination that most fish held in captivity fail to spawn due to a lack of gonadotropin (LH) release from the pituitary, research and development efforts focused on the use of gonadotropin-releasing hormones (GnRHs). Analogs of GnRH were designed which are resistant to enzymatic degradation, have a higher affinity to the GnRH receptor and are potent stimulators of LH release and ovulation. These analogs were incorporated into a range of sustained-release delivery systems that have been optimized for the induction and synchronization of final oocyte maturation (FOM), ovulation, spermiation and spawning in multiple fish species. This GnRH-based technology has also been successfully applied to American shad seed production and restoration programs. The discovery that the brains of most fish species contain 3 forms of GnRH, and information about their relative roles in the regulation of reproduction, is now being used to tailor more physiologically-compatible GnRH spawning induction therapies. The cloning of the genes and cDNAs coding the multiple GnRH forms and their receptors, and our current understanding of the regulation of GnRH synthesis and release, is shedding new light on the nature of the hormonal failure responsible for the absence of FOM, ovulation and spawning in many farmed fish, and will lead to the development of novel biotechnological strategies for their induction.