

PREFACE

In this book, the authors present current research in the study of fish ecology and marine ecosystems. Topics discussed include the metabolic rate of marine fish in early life and its relationship to their ecological status; antioxidant defense in marine fish; teleostean fish and the genomic content; the genetic structure of the masu salmon; the catadromous freshwater eel and the taxonomic representations of marine fish from archaeological assemblages in the Beagle Channel, Argentina.

Chapter 1 - Metabolic rate of different species varies as a consequences of both exogenous (temperature, salinity, oxygen consumption, pressure, feeding, pollution, etc.) and endogenous factors (animal size, growth, age, behavior, activity, physiological status and biochemical composition). Lipids area major energy source during fish early development, especially neutral lipids accumulated in yolk sac. Quantity of early life stages, larvae hatching and their survival depend on the energy generation, because energy is needed for synthesis of various substances, morphogenesis, successful growth and development. All these biological processes result in either heat generation or heat consumption. Direct microcalorimetry plays an important role for study these thermal activities because it is nondestructive and non-invasive to the animal. The goals of the present work were (i) to study the changes in lipid composition during the early life of some Black Sea fish species, (ii) to monitor the trends of heat production in embryos and hatching larvae using microcalorimetry and (iii) to evaluate the toxic effects of some organic substances – environmental pollutants on metabolic rate of fish early developmental stages. The heat dissipation of fish eggs and larvae was measured with a multi channel heat conduction type micro calorimeter (The Thermometric 2277 Thermal Activity Monitor, TAM, LKB, Sweden). Lipid composition fluctuations related with fish embryo genesis were shown. The level of triglycerides was decreased while the content of free fatty acids was elevated. Heat production of developing fish was increased during development and the high values were detected in hatching larvae. The obtained results demonstrated that metabolic rate correlated with the lipid content and reflected the peculiarities of fish early development stages depending of their ecology. The impact of different chemical stressors (pesticides, PCB, environmental pollution) modified metabolic rate of developing embryos and larvae associated with the disturbance of the processes of energy generation and utilization. The responses of fish early developmental stages on the complex of a biotic and anthropogenic factors associated with their ecological status are discussed.

Chapter 2 - The aerobic life is associated with the production of the potentially harmful components free radicals which damage many of biological molecules, membranes and cell components. So-called "oxygen paradox" means that the aerobic organisms including fish which cannot exist without oxygen are nevertheless inherently at risk due to oxidative stress. During the evolution process the defense mechanisms and complex of responses on oxidative stress were provided. They include special adaptive antioxidant enzymes and low molecular weight scavengers (vitamins, carotenoids, SH-compounds, and etc.). This complex protect organism against free radical production. At present increase of anthropogenic pollution of environment results negative biological effects in living organisms in all levels of their biological organization. Two consequences of environmental contamination might be noted: 1. xenobiotics cause the increase of oxyradical flux in the environment and result the deleterious in living organisms and 2. they induce the lipid peroxidation processes and the change of the prooxidant-antioxidant balance in the organisms which stimulate the pathologies, damage of immune system and premature senility and death.

Like all aerobic organisms, fish are very sensitive to oxidative stress and they have developed antioxidant defense. The study describes the various adaptation mechanisms and responses of marine fish (in the case of Black Sea especially) associated with oxidative stress. The results demonstrated that fish antioxidant status correlates with their phylogenetic position, trophic strategies, feeding behavior, variables of ecological conditions, swimming activity, belonging to the different ecological group (benthic, suprabenthic, suprabenthic-pelagic, and pelagic), seasonal fluctuations and some other environmental factors. The findings could be applied as for the solution of the problems of conservation ecology regarding pollution (especially in the case of Black Sea), but also for marine monitoring and fishery development.

Chapter 3 - The nature of the forces driving the genomic GC content of both prokaryotes and eukaryotes is matter of debate. Latest results favor selection as the main factor shaping base composition in bacteria. In vertebrates the subject is still under discussion.

Focusing on teleostean fish, the mass specific routine metabolic rate temperature-corrected using the Boltzmann's factor (MR) and base composition of genomes (GC%) were re-examined and related with their major habitats: polar, temperate, sub-tropical, tropical and deep-water. Fish of the polar habitat showed the highest MR. The MR of temperate fish was significantly higher than that of tropical one, which showed the lowest average value. Regarding GC%, polar and temperate fish both showed significantly higher values than both sub-tropical and tropical fish. Plotting MR and GC% a significant correlation was found between the two variables.

Different methylation levels characterized the genomes of fish living in different habitats. More precisely, the amount 5-methylcytosine (5mC) decreases from polar to tropical fish. Considering the positive correlation between CpG and GC%, as well as the temperature dependence of the 5mC deamination process, low genomic GC% in fish living in warm habitats could be the result of a CpG shortage.

The frequencies of CpG as well as that of the derivative doublets, that is TpA and CpA, were checked in the intronic sequences of the available teleostean genomes completely sequenced, namely *D. rerio*, *O. latipes*, *G. aculeatus*, *T. nigroviridis* and *T. rubripes*. The analysis of doublets further supported a link between environment, metabolic adaptation and genome base composition.

In this frame, also taking into account that MR turned out to be not significantly different between fish living in tropical and deep-water habitats, the authors suggest that the level of environmental O₂ content (dictated by the Henry's law) could be a source of variability that directly affects MR adaptation and hence the base composition of fish genomes.

Neutral and selective hypotheses, proposed to explain the base composition evolution at the genome level, namely mutational bias, biased gene conversion (BGC), DNA breakpoints distribution, thermal stability and metabolic rate, were discussed in the light of current data. Negative (purifying) selection is proposed for the genome variation of teleostean fish among habitats.

Chapter 4 - Salmonid species have the potential to make a population genetic structure due to their homing behavior. However, the extent of genetic structuring would vary considerably because precision of homing varies within and among species. In addition to homing, several biotic and/or abiotic factors would also influence genetic structuring. A description of the genetic structure at various spatial scales and an understanding of the extent of genetic structuring could facilitate the identification of factors that affect genetic structuring. The knowledge of such factors is a fundamental requirement for the accurate inference of population dynamics, evolutionary processes, and conservation decisions. The authors focus on the factors that influence population genetic structuring and briefly describe the genetic structure of masu salmon (*Oncorhynchus masou*) populations at both regional and micro geographic scales. By analyzing mitochondrial DNA and microsatellite DNA variations, they found that masu salmon exhibit hierarchical genetic structuring and genetic differentiations not only at the regional scale but also at the microgeographic scale. These observations indicate that masu salmon would have the potential to make a population genetic structure at the microgeographic scale due to precise homing. Furthermore, it is also suggested that genetic structuring would be affected by several factors, such as refugia during glacial periods, ocean current, and dispersal patterns of each individual and the effects of such factors may vary depending on the intended geographic scale. However, such intrinsic genetic structuring faces the danger of being eroded by anthropogenic effects, including habitat degradation, habitat fragmentation, and artificial release of hatchery-reared fish. In fact, the negative impact of damming would hold true for masu salmon. The authors' results indicate the possibility that the indigenous genetic structure that has been created over many years would be lost by human activities during short periods.

Chapter 5 - The freshwater eel of the genus *Anguilla*, being catadromous, migrate between fresh water growth habitats and offshore spawning areas. However, a number of recent studies found that the temperate species *Anguilla anguilla*, *A. rostrata*, *A. japonica*, *A. australis* and *A. dieffenbachia* have never migrated into fresh water, spending their entire life in the ocean. Furthermore, those studies found an intermediate type between marine and freshwater residents, which appear to frequently move between different environments during their growth phase. The discovery of marine and brackish water residents suggests that anguillid eels do not all have to be catadromous and it calls into question the generalized classification of diadromous fish. However, there has been little available information concerning migration in tropical eels. In *A. marmorata*, showed three fluctuation patterns; (1) freshwater residence, (2) continuous residence in brackish water, and (3) residence in fresh water after recruitment, while returning to brackish water. Such migratory histories were found in other tropical eels, *A. bicolor bicolor* and *A. bicolor pacifica*. The *A. bicolor bicolor*, collected in a coastal lagoon of Indonesia, showed two patterns of habitat use, (1) constantly

living in either brackish or sea waters with no fresh water life, and (2) habitat shift from fresh water to brackish or sea waters. The wide range of environmental habitat use indicated that migratory behavior of the tropical eel was facultative among fresh, brackish and marine waters during their growth phases after recruitment to the coastal areas. Further, the migratory behaviors of tropical eels appear to differ in each habitat in response to inter- and intra-specific competition. The results suggest that tropical eels have a flexible pattern of migration, with an ability to adapt to various habitats and salinities. This flexible habitat use was the same as that of temperate eels. Thus, the migrations of anguillid eels into fresh water is clearly not an obligatory behavior.

Chapter 6 - Native fish fauna of tropical semiarid freshwater ecosystems in Brazil are key representatives of the Neotropical region. Ichthyofauna of this region comprises of the orders Characiformes, Perciformes, Siluriformes and Synbranchiformes, besides invasive and exotic species. The population increase and the continued demand for quality fish generate the need for aquaculture as an alternative means of increasing fish production. Consequently, anthropic factors ranging from deforestation, construction of reservoirs on small rivers, introduction of invasive fish species to non-sustainable fish culture practice, can generate negative impacts on native species. Within these anthropic factors, proliferation of invasive and exotic fish species in the freshwater ecosystems has been deemed as a threat to the integrity of native species. However, the extent to which these factors can interfere and modify semiarid freshwater ecosystems remains an open question. This chapter focuses on how anthropic factors directly impact on the native fish species in semiarid freshwater ecosystems. Conversions of vegetation rich rural lands to urban areas degrade streams by qualitatively altering the composition, structure and function of their aquatic ecosystems. Construction of reservoirs can undoubtedly alter the natural hydrological regime of water bodies located downstream, and adversely impact on the migratory fish of this region. Introduction of exotic and carnivorous fish species from other hydrographical basins has significantly mediated to the decline of the native fish species, due to their competitive ability to thrive in semiarid aquatic ecosystems. Deforestation degrades riverine habitats and reduces ecological diversity of fish, besides causing pluvial shifts. Tropical semiarid Brazil is characterized with infrequent spells of rain interspersed with prolonged dry season. In tropics, rainfall is the main environmental driver that modulates the timing of fish spawning period. Changes in these environmental constraints present them with new challenges to survival and reproductive success. Since freshwater fish is important as a source of protein and provides sustained revenue, declining fish populations can have far reaching socioeconomic impacts which are compelling reasons for proper management. Strict regulations on introductions of fish species and restrictions on release of pollutants to aquatic ecosystems would reverse ecosystem degradation, improve water quality and conserve fish diversity.

Chapter 7 - This chapter analyses the taxonomic representations of marine fish from eight archaeological assemblages of the Beagle Channel. This study provides information about fish taxonomic distribution and ecological conditions in this region since 6400 to 500 radiocarbon years BP. Species corresponding to Nototheniidae family are represented throughout the archaeological sequence, in particular *Paranotothenia magellanica* and species attributable to *Patagonotothen* gender. Other fish of intertidal or shallow waters, as *Austrolycus depressiceps*, *Cottoperca gobio*, *Sprattus fueguensis*, etc., are also presented in the archaeological record. Among deep-sea species, *Macruronus magellanicus* is widely represented in the archaeofaunal assemblages. Nevertheless, the data also indicate that many

species of deep waters (*Merluccius* sp. and *Thyrstites atun*) frequently consumed by hunter-gatherers are not common today in the marine ecosystem of the Beagle Channel. Comparisons of these data with modern ecological surveys indicate that both environmental stability at coastal waters and changes of the distributions of deep-sea species have occurred. This last result provides a new insight regarding the influence of modern human activities and the scope of overfishing in the uttermost part of the world.

Chapter 8 - Shads (Clupeidae: subfamily Alosinae) are a cosmopolitan group of fishes that exploit a wide range of habitats throughout the world, occurring in lakes, rivers, and seas. They are valuable ecological and economical resources. Species are able to adapt to estuarine, lentic and/or lotic habitats and present large plasticity in reproductive features, e.g. there is evidence of hybridization between allis shad *Alosa alosa* and twaite shad *A. fallax*. On the other hand, shads constitute important recreational and commercial fishes, e.g. American shad *A. sapidissima* in North America, allis shad in Europe or Indian shad *Tenualosa ilisha* in the Indo-Pak subcontinent and the Persian Gulf region. Most of these alosines are anadromous (a few landlocked populations have been found in Portugal, Ireland, Eastern Europe or Northern India), some species migrating several hundred kilometers upriver to spawn (e.g. 800 km in the case of allis shad or as much as 1200 km in the case of Indian shad), and others exhibiting a pronounced homing behavior similar to that of migratory salmonids (e.g. allis shad). Adults are usually fished during the upriver movements towards spawning grounds but catches have been declining worldwide during the last 20 to 30 years, mostly due to anthropogenic activity, e.g. damming of rivers, overfishing (the predictability of migrations has rendered them vulnerable to overharvest) and deterioration of habitats by industrial and agricultural pollution.

Environmental conditions in the freshwater/brackish water reaches of rivers during the embryo-larval period are thought to play an important role in the future of populations, purposely determining the recruitment variability that is characteristic of the alosines. Moreover, the successful domestication of shads, American shad in USA and Reeves shad *T. reevesii* in China, and use as broodstock for restoration programs largely depends on understanding the biology of eggs, larvae and juveniles. Notwithstanding, the early life-history stages have been relatively poorly studied in European, Middle Eastern or African shads as opposed to North American species. A decade ago, two international conferences held in Bordeaux (France), in 1999, and in Baltimore (USA), in 2001, assembled the knowledge on world shads, namely their biology. Since then, relevant work on early life-history stages of shads worldwide has been carried out. Herein, the author compiles, updates and integrates these recent contributions on the biology and ecology of egg, larval and juvenile stages of shads, and prospects future work.

Chapter 9 - Heat shock proteins are highly homologous chaperone proteins, present in all cells playing key roles in limiting the consequences of protein damage and facilitating its recovery. There are accumulating data about the involvement of HSPs in chaperoning function. However, the task of HSPs with regard to its participation in cell survival processes still remains undeciphered in response to stress stimuli in natural conditions. The objective of this review is to interpret the role of HSPs in stress tolerance and cell survival mechanisms in fish exposed to pollutant stress in natural field conditions. HSPs inhibit apoptosis by down regulating apoptotic events like apoptosome formation, release of apoptogenic factors and ASK1-mediated JNK1/2 signaling etc. On the other hand, HSP also favors survival by promoting the activities of pro survival kinases like ERK1/2 and Akt. Generally,

the overall balance between the signaling pathways of survival and death determine the fate of the cell. HSPs modulate multiple events within the signaling pathways in stressed fish thereby helping them to sustain survival.