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Fishes in Lagoons and Estuaries in the Mediterranean 2

Sedentary Fish

Mohamed Hichem Kara
Jean-Pierre Quignard

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Contents

Foreword

Lagoons, deltas and estuaries are by definition transition zones and represent a distinctive element of the Mediterranean shoreline. In days of old, people used to come here to catch an abundance of fish, and this coastal fishing – practiced behind the shoreline in the channels of the salt marshes and in the estuary mouths – was at that time more highly prized than fishing in the open sea. Nowadays, although lagoon fishing represents only a small fraction of annual fish catches in the Mediterranean, estuarine and lagoon habitats continue to play a major role, be it as nurseries or in supporting an often-intensive mariculture, such as in Egypt, Italy and Greece.

This academic publication, patiently compiled by two eminent ichthyologists who are familiar with both shores, covers in three volumes the ichthyofauna of 303 lagoons and estuaries in the Mediterranean region, from the coastline of the Alboran Sea to Anatolia. Volume 1 outlines the vast geographical, geomorphological, hydrological, physicochemical and also historic diversity of Mediterranean lagoons, a diversity that has led to marked differences in the biology, reproduction, genetics, feeding and behavior of lagoon fishes.

Further, the reader will find illustrated descriptions of 47 lagoon and estuarine species that have been studied, with a detailed discussion of systematics and of issues relating to biogeography, reproductive and feeding strategies, genetics and biodiversity. Throughout this work, a distinction is drawn between sedentary and migratory species – those that come and go each year between the lagoons where they find refuge, and the sea where they reproduce. However, the dividing line between these two worlds can sometimes be tenuous, and the authors introduce many central issues that remain unresolved, relating to, for instance, the genetic differentiation and adaptation (or preadaptation) between migratory and sedentary stocks, or the respective contributions made to the local fisheries by the lagoon nurseries and the marine shore area. The ichthyofauna of the studied sites is remarkably discrete: of the 249 species inventoried in 45 representative estuaries and lagoons, it will be noted that only 15 are found in 50% or more of the studied sites.

In the face of increasing anthropic pressures on the Mediterranean coast, already weakened by concrete urban development and its pathogenic wastes, by erosion, climate change, industrial and agricultural discharges into the sea, irresponsible mass tourism and the arrival of invasive Indo-Pacific species, the conservation and sustainable management of these areas and of lagoon fishing take on a certain urgency. The authors consider these topics at some length; their views are invaluable, drawn from their long experience in the field; I hope that many practitioners will find inspiration in them.

Because of the variety and expert knowledge of the themes covered, its extensive bibliography and illustrations, this work is sure to become indispensable to the technicians and managers involved in fisheries and Mediterranean aquaculture. On a wider level, it will interest the many students and researchers working in ichthyology.

Frédéric BRIAND
Director General
CIESM Mediterranean Science Commission

Preface

The conservation of the natural and economic heritage represented by Mediterranean lagoons and estuaries and the associated adjacent areas (wetlands, reed beds, sansouires and salt marshes) calls for an in-depth scientific knowledge of the past and present state and the functioning of these environments, and particularly of their plant and animal components. It is on this basis that appropriate management policies can be formulated.

Classed as transition zones between land and sea, these special ecosystems are matters of concern for both scientists and managers. The former group has accumulated significant knowledge of their abiotic characteristics and their functioning. They are now investigating the individuality of the resident populations, their interactions with the adjoining ecosystems and their future in the context of climate change. The latter group is seeking scientific and technical tools that will enable them to use these environments to their full potential, taking into account the increasing anthropic pressures.

In this book, divided into three stand-alone, complementary volumes, we have brought together scientific knowledge amassed over nearly two centuries on the fishes of the Mediterranean lagoons and estuaries. This summary has been compiled from documents published in local and international reviews and in general or specialized bioecological works on pure and applied ichthyology. We are, however, conscious that an entire fringe of works concerning lagoon and estuarine fishes has been omitted, this being the “gray literature” consisting of expert reports, academic projects and theses, etc.

The first volume, entitled *Diversity, Bioecology and Exploitation*, is a non-exhaustive approach to the characteristics of lagoons and estuaries, from a “geo-geographical”, hydrological and general bioecological viewpoint, and also looking at the ecophysiology and behavior of the fishes that live there. The general features of the exploitation and management of fish resources are also considered.

The second volume, *Sedentary Fish*, is devoted to the fishes that are so named because, being very euryvalent, they live out their entire lifecycle inside lagoons and estuaries. These fishes are not all specific to these environments; some have their counterparts in the sea or in fresh water.

The third volume, *Migratory Fishes*, is concerned with fishes that, after spending time in lagoons, are obliged to return to their native marine or river environment to complete their lifecycle (genesic migrations), the physicochemical conditions in lagoons and estuaries (temperature, salinity, turbidity, etc.) being incompatible with the water properties required for their reproduction. Strictly hydroclimatic events can also be at the origin of migratory journeys.

The data provided in volumes two and three of this book are at three taxonomic levels: family, genus and species. Those concerning family and genus are relatively brief and general, while those relating to species are exhaustive and very detailed for every aspect dealt with: systematics, genetics, phylogenesis, ecology, biology, behavior, etc.

This summary has been designed to permit rapid and comprehensive access to the body of scientific knowledge on lagoon and estuarine fishes and their sources. These data are indispensable in order to develop projects of research, infrastructure, management and conservation concerning these environments and their populations.

Mohamed Hichem KARA
Jean-Pierre QUIGNARD
November 2018

Introduction

Species whose entire lifecycle takes place in lagoons and estuaries are often called "sedentary fish". These fish show some peculiarities as much on a morpho-anatomical, genetic and bio-ecological level as in their behavior. Here, we will sketch the broad outlines of this guild's characteristics before giving detailed descriptions species by species.

Sedentary ichthyofauna in lagoons and estuaries, which differ depending on the geographical location of their habitat, are characterized by low species diversity (a total of 25 species, excluding Lessepsian species). This relative paucity of these species results from the values of several factors, including temperature (-2°C to +35°C) and salinity (0 to 70‰), which vary over space and time, so much so that lagoon waters are considered "extreme environments". As a result, only species that show some euryvalence have been able to adapt and establish themselves in these spaces.

Based on 97 lagoon fish surveys carried out in 45 lagoons, the most common species found are Atherinidae (80.4%), Syngnathidae (67%), Blenniidae and Gobiidae (62.8% each).

Overall, the best represented families include Gobiidae (at least 11 species) and Syngnathidae (at least ten species). These are followed by Cyprinodontidae (two species), Atherinidae (one or two species), Blenniidae (one species), Poeciliidae (one species), Labridae (one species) and Gasterosteidae (one species).

Disparity between environments

Some disparity is found between large, deep lagoons and laminar lagoons, with the latter having a relatively low species diversity. The geographical distribution of these species also shows some peculiarities. Iberian lagoons and estuaries are home to endemic species such as *Aphanius iberus* and *Valencia hispanica*; those in the Gulf of Lion are glacial relicts such as *Pomatoschistus microps*, *P. minutus* and perhaps *P. pictus*. The brackish waters along the Adriatic region possess *Knipowitschia panizzae*, *Padogobius* sp. and *Pomatoschistus canestrinii*. The lagoons of the eastern Mediterranean are enriched by Lessepsian immigrants. Furthermore, the lagoons of both Bardawil (Egypt) and El Bibane (Tunisia) contain Gobiidae (*Coryogobius (Monishia) ocheticus*, *Papillogobius melanobranchus*, *Silhouettea aegyptia*) and Atherinidae (*Atherinomorus forskalii* (*A. lacunosus*)). Finally, *Pomatoschistus tortonesei* is only present in Marsala (Sicily), Farwah (Libya) and six other Tunisian lagoons. We note that the most common species are *Atherina lagunae* (*boyeri*) (80.4%), *Syngnathus abaster* (67%), *Salaria pavo* and *Gobius niger* (62.8% each).

In a single geoclimatic sector, the diversity of sedentary fish in lagoons and estuaries is linked strongly to the history of navigation routes that link them to the sea; these may have been long term or temporary (graus, inlets, intermittent channels) and show dimensions (length, section, depth) that lead, via a “threshold effect” and “channel effect”, to the selection of species with “lagoon affinities” present on the shore. To these factors can be added the significance of the currents crossing the channel, lagoon and estuary inlets and the quality of the environment on arrival: surface and depth of the lagoon and nature and diversity of the habitat.

To interpret the current ichthyic lagoon landscape, in particular some of its specifics in terms of population, biogeographers and geneticists need to know the age of the lagoon. Indeed, at a given geographical point, this landscape can particularly differ depending on whether it is tectonic or indeed sedimentary in origin. In general, tectonic lagoons (e.g. Berre, Diane, Urbino) are older than sedimentary lagoons (the lagoons of Languedoc). Other events such as the Mediterranean Messinian crisis (about -5.5 Ma) should be considered, in which despite repeated phases of drying, long-term estuary systems were used as refuges by some small coastal sea fish. The last Würm glaciation and the Flanders marine transgression (10,000 to 17,000 years ago) may also have played a role in the distribution and diversification of laguno-estuarian fish, not to forget some more local hydrodynamic events. In the majority of cases, Mediterranean lagoons are relatively recent. Those of Venice and Tunis appeared at least 5,000 years ago, but others are more recent. For example, the lagoons of Languedoc (France), which are of potamothalassic origin, formed essentially from the 14th Century. They then underwent notable natural or anthropic fragmentation. From the end of the 20th Century, they could be considered “domesticated” and “frozen” in the coastal landscape.

The make-up of sedentary populations in lagoons and estuaries significantly varies in space and time. They can be locally wiped out by dystrophic, anoxic and toxic (H_2S, CH_4) crises; repopulation occurs via marine or river populations, sometimes from contiguous lagoons. In sedimentary lagoons, a rupture of the lido that isolates them from the sea following sea storms, or the overflow of fresh water following heavy precipitation, can upset the entire local lagoon ecosystem by a sudden influx of sea water, causing a serious run-off of lagoon bottoms and organisms. The duration of this marinization depends on the speed at which the lido is reconstructed and therefore on the arrival of sediment. However, it is often difficult to date the lagoon age of this populating process.

Similar morphologies and behaviors

Sedentary fish display shared morpho-anatomical traits: all of them are small (maximum 15 cm TL, in exceptional cases 20 cm) and display accentuated sexual dimorphism and dichromatism, except the Atherinidae. They have a short lifespan (from a few months to a maximum of 4–5 years), and their growth is so rapid that 80% of their maximum size is reached before sexual maturity. These fish are also remarkable in their reproductive behavior. In fact, the restrictive hydroclimatic conditions that we mentioned previously (temperature, salinity, anoxia, turbidity, etc.) tend to limit their reproductive success. The long reproductive period (sometimes 7 to 8 months) of these species and the “fragmentation of spawning” in females during this period enable them to overcome the negative effects of passing hydroclimatic crises. None of these fish produce planktonic oocytes (eggs). Females lay relatively fat oocytes (with a diameter equal to or greater than 1 mm), which focus on relatively developed “parental care”. From this point of view, we can recognize several guilds:

1) “attentive layers”, which limit the care given to the eggs (1 to 3 mm in diameter) by laying them in areas rich in vegetation (genera *Aphanius*, *Valencia*) or attaching them to upright algae and phanerogams (genera *Atherina*, *Atherinomorus*), before abandoning them. In both cases, the eggs are isolated from the bed, which is often sandy-muddy, or even muddy and putrid, and develop in waters rich in photosynthetic oxygen which helps in their development. The larvae hatch subplanktonically or planktonically;

2) those layers that practice “parental care” at least until the eggs hatch. In this case, we distinguish between species that practice:

- “external gestation” or nesting species (Gobiidae: *Gobius* sp. and *Pomatoschistus* sp.; Blenniidae: *Salaria pavo*; Labridae: *Symphodus cinerus*; Gasterosteidae: *Gasterosteus aculeatus*);

- “outer body gestation” (Syngnathidae: *Nerophis*);

- “internal gestation” or viviparity (Poeciliidae: *Gambusia holbrooki*; Syngnathidae: *Syngnathus* and *Hippocampus*).

One of the particularities shared by the majority of laguno-sedentary fish is to exert control over the management of their gametes and eggs. Thus, a female goby is able to distribute her mature oocytes over several nests depending on their appearance – size, general state, filling rate (nests without eggs, just like overcrowded nests, are not very attractive) – as well as on the appearance of the male owner. As a precaution, she “doesn’t put all her eggs in the same basket”. The same is true for the females of the genus *Syngnathus*. In fact, genetic studies have shown that a male’s incubator pocket may contain eggs from several females. In this case, it could be the male that limits, for one reason or another (e.g. undesired female), by interruption of coitus, the number of oocytes that a female can transmit to the male. In Poeciliidae, females are able to eliminate spermatozoids from unwanted couplings, especially when they are subject to sexual attacks. Males with nests are also able to increase or decrease the volume of their ejaculate depending on competition between sperm caused by the presence of mature males without nests (called sneakers). These sneakers seek to fertilize oocytes left by a female in the nest of a male owner. Moreover, in gobies and perhaps in blennies, the females fix their oocytes and the males fix their spermatoza to the walls of the nest “wrapped” in a mucus ribbon called a “sperm trail” (which prevents losses caused by dispersion of a current) and ensure that they are protected by guardian males; these factors control the fate of their spermatozoids and oocytes. The spermatozoids are gradually freed from this as the females spawn. Some losses are caused by dispersion in the intra-nest water current, as well as by spermatozoids that come into contact with oocytes fixed on the same wall. In addition, males can leave during spawning without damaging their reproductive success. These males can become egg-eaters with the aim of taking responsibility for the eggs in their nest and eliminating eggs that are not clean or wanted.

Evolution and adaptation

The geological isolation of lagoons from the sea, their broad geographical distribution and their environmental characteristics, which can sometimes be very restrictive, have made a remarkable differentiation between lagoon and sea and between different lagoons in the species that populate them. This phenotypic, or even genetic, differentiation is considered an adaptive response to these different environmental conditions. Isolation and confinement, which are often considered to be the determining factors in the emergence of these divergences, remain to be discussed. In fact, if Syngnathidae neonates from the genera *Hippocampus* and *Syngnathus* are non-planktonic juveniles, with the appearance and behavior of adults, those of Gobiidae, Blenniidae, Labridae, Cyprinodontidae and Syngnathidae *Nerophis ophidion* are planktonic larvae that may be easily drawn into the sea by exiting lagoon currents, just like those of marine populations which may be passively introduced into lagoons by incoming currents. A possible "passive" swirling between the sea and lagoons, and in turn between interlagoon populations, should be considered, even more than the anthropization of these environments, with the stabilization and recalibration (enlargement or deepening) of channels linking them to the sea and facilitating exchanges with them. Similarly, direct communications between lagoons have been created. This is the case, for example, in Languedoc (France) where the inlets of 12 lagoons open into a 60 km channel parallel to the coast linking the lagoons of Thau (Sète) to the Rhône. Built in the 18th and 19th Centuries, this channel partly re-established a situation dating from the 16th and 17th Centuries when an immense lagoon called "Petite mer de Pline" extended from the top of the Saint-Loup (Agde) to the Rhône (towards Aigues-Mortes) but which had been gradually fragmented.

Benefits and threats

Some sedentary species such as *Gobius niger*, *Atherina lagunae* and *Pomatoschistus microps* have been considered as bio-indicators of environmental quality. The first species is demersal and the second one is nektonic, with a relatively long lagoon lifespan (about 5 years); they are good at integrating environmental events such as those caused by pollutants. The third species, which is a glacial relict and short-lived (about one year), is a good potential indicator of thermal changes in the aquatic shore environment.

Laguno-sedentary fish are subject locally to small-scale fishing, the significance of which is difficult or even impossible to evaluate. According to the FAO's fishing statistics:

– Landings of Atherinidae (*Atherina lagunae*) in the Mediterranean amounted to 2,967 t in 1983, including: 2,395 t in Italy, 287 t in France (but, in 2006, the estimate was 160 t), 181 t in the former Yugoslavia and 536 t in Turkey (Fischer *et al*., 1987);

– For gobies, the estimate was 7,333 t, including 5,204 t in Italy.

The lagoon wrasse (*Symphodus staitii*) had been subject to relatively substantial fishing in deep lagoons until the 1970s, but it is currently very rarely seen in deposits and scarcely found in markets any longer;

– Syngnathidae, especially seahorses, are subject to local harvesting to meet the tourist demand;

– The blenny (*Salaria pavo*), the mosquito fish (*Gambusia holbrooki*) and cyprinodons (*Aphanius* sp.) are not eaten. Aphanius fasciatus are poisonous (Penso, 1953); however, they can serve, along with *Atherina lagunae*, as food for *Sepia officinalis* (Anonymous, 1980).

– Although sedentary species have no significant commercial use, they are the basis for the wealth of fishing in lagoons, as forage fish for migratory ichthyophagous species with a high market value, such as the sea bass *Dicentrarchus labrax*.

Several lagoon–estuary species are endangered. According to the red lists of Mediterranean fish species (Smith and Darwall, 2006; Abdul-Malak *et al*., 2011), one species is in critical danger of extinction (*Pomatoschistus microps*), three are in danger (*Aphanius iberus*, *Pomatoschistus tortonesei* and *Syngnathus taenionotus*) and five are almost endangered (*Hippocampus hippocampus*, *H. guttulatus*, *Syngnathus tenuirostris*, *S. acus* and *S. typhle*).

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1

Atherinidae Risso, 1827

Vernacular names: *mirlotu*, *xugla* (ES)[1]; *athérines* (FR); silversides, sand smelt (GB); *aterinidi*, *latterini* (IT).

Etymology: from the Greek *atherina*, meaning fish, perhaps derived from *atés* (vertebral spine).

Brief description: small fish, with a total length generally less than 20 cm (except for *Odontesthes bonariensis*, Atherinopsinae: TL_{max} 72 cm). Oblong body, laterally compressed. Small superior, terminal mouth, moderately protractile jaws with very small teeth (except in *Chirostoma* sp.). Two well-separated dorsal fins: the first D1 with six to ten flexible spiny rays and the second D2 being longer, displaying one spiny ray followed by segmented rays. An anal fin with one spiny ray followed by segmented rays. Lobed caudal fin. Well-developed pectoral fins situated part-way up the body. Pelvic fins in the abdominal position with a spiny ray and segmented rays. Cycloid scales. Lateral line not marked by pores, including at least 50 scales (more than 50 in *Labidestes* sp. *Menidiinae*). Closed air bladder. Short digestive tract without pyloric ceca. Vertebrae: 31 to 60. Generally brown-silver color with a longitudinal band clearly silvered on the flanks, becoming brown or blackish in alcohol or formalin.

Biogeography: Atherinidae, Europe and America; Atherinopsinae, temperate waters in the west of North and South America; Menidiinae, Tropical Atlantic and Pacific America.

Habitat and bio-ecology: nektonic to nektobenthic fish in temperate to tropical regions. Some species of marine origin in this family tend to occupy freshwater successfully, naturally or following human intervention (transplantation). Currently, Atherinidae are present in the sea (littoral), hypersaline to brackish lagoons, freshwater estuaries, continental lakes and water courses, as well as on very varied riverbeds (sandy to muddy surroundings, hard and

1 Throughout the book, the abbreviations refer to each country as follows: ES, Spain; FR, France; GB, Great Britain; IT, Italy; TN, Tunisia.

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bare or vegetated with plants or algae). Carnivorous species (from zooplanktivores to benthivores), gonochoric, ovuliparous with relatively low fertility.

Systematics and phylogeny: the Atherinidae family is not monophyletic. Some authors have identified two very distinct “groups”, one from the New World (Atherinopsinae, Menidiinae) and the other from the Old World (Atherinoninae, Atherininae). The number of subfamilies recognized varies from six, according to White (1985), to four, according to Nelson (1994) and Chernoff (1986).

Biodiversity: if we allow the four subfamilies retained by Nelson (1994), the wealth of this family can be evaluated around 25 genera and 165 species. Three genera are present in the Mediterranean: *Atherina* (six species), *Atherinomorus* (one Lessepsian species) and *Odontesthes* (one species originating from America).

Paleontology: fossils have been found in some terrains from the lower European Eocene (*Rhamphognatus* sp.).

Originality: Tortonese (1985) drew researchers’ attention to the benefit of research, both fundamental and applied, on Atherinidae. Sexuality can be governed by abiotic factors such as temperature for *Menidia* sp. (America). Spawning is directly related to the “moon-tide” system among *Leuresthes* sp. (America).

1.1. *Atherina* Linnæus, 1758

Type: *Atherina hepsetus* Linnæus, 1758, Syst. Nat., Ed. X: 315.

Synonym: *Hepsetia* Bonaparte, 1836, sometimes considered a sub-genus of *Atherina*.

Etymology: *atherina*, from the Greek *aterina*, meaning “fish” (Aristotle), perhaps derived from *atés* (vertebral spine). *Hepsetus, hepsetia*, from the Greek *epsétos, hepsétos* (to cook).

Brief description: scaly body and head, except at the interorbital level. Preoperculum without any “notch”. Initial dorsal fin with 6 to 11 non-segmented, flexible rays. Second dorsal fin and anal fin facing one another and of the same length.

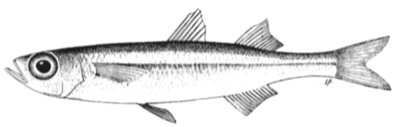
Biogeography: genus typically belonging to the temperate Mediterranean-Atlantic region.

Habitat and bio-ecology: nektobenthic, coastal, carnivorous, euryhaline fish, eggs fixed to a support, most often algae and phanerogams, by filaments.

Biodiversity: six species in the Mediterranean: four seawater, one Mediterranean brackish water and one Mediterranean freshwater species.

Systematics and phylogeny: two sub-genera are sometimes allowed, *Hepsetia* and *Atherina* (Miller, 2003), and six species. Using three mitochondrial and two nuclear markers among 318 specimens in the *A. boyeri* complex from the Atlantic, the Mediterranean and the Black Sea, Francisco *et al*. (2011) confirmed that the genus Atherina is monophyletic and highlighted two non-tropical clades, one South African (*A. breviceps*) and the other Atlantic-Mediterranean (*Atherina hepsetus, A. presbyter, A. boyeri* complex).

1.1.1. Atherina (Hepsetia) lagunae *Trabelsi* et al., *2002*



1.1.1.1. *Nomenclature*

Synonyms: *Atherina lagunae* belonging to the *Atherina boyeri* complex whose main synonyms are: *Atherina sarda* Valenciennes, Cuvier and Valenciennes, 1835 (Sardinia); *Atherina lacustris* Bonaparte, 1836 (Italy), doubtful synonym; *Atherina pontica* Eichwald, 1836 (Black Sea), doubtful synonym; *Atherina riqueti* Roule, 1902 (canal du Midi, France), *Atherina bonapartii* Boulanger, 1907 (Nile, Egypt), *Atherina (Hepsetia) boyeri*: various authors.

Vernacular names: *moixonet, pejerrey* (ES); *athérine, cabassoun, joël, siouclet* (FR); Boyer's sand smelt (GB); *Latterino capoccione*, *atherina* (IT); *gumus* (TN).

Etymology: *Atherina* is the name given to this fish by Aristotle, perhaps derived from the Greek *atès* (fish bone); *boyeri* was derived from the name of Guillaume Boyer, a naturalist and mathematician, born in Nice (France); *lagunae* was derived from the word lagoon.

Systematics issues: in their geographical distribution, Atherinidae of the *A. boyeri* complex display a mosaic of semi-isolated or isolated (continental) populations, each with their own morphological (meristic and metric), ecobiological and behavioral characteristics, depending on the constraints of the environments occupied (Kiener and Spillmann, 1969 and 1972; Bamber and Henderson, 1988;

Henderson *et al.*, 1988; Mistri, 1990; Trabelsi *et al.*, 2009). According to some authors, *Atherina boyeri* is a complex composed of new species that are in the process of emerging (Henderson and Bamber, 1987). According to Bamber and Henderson (1988) and Trabelsi *et al.* (2002a, 2002b, 2003), some populations of individuals have already reached the speciation “threshold”.

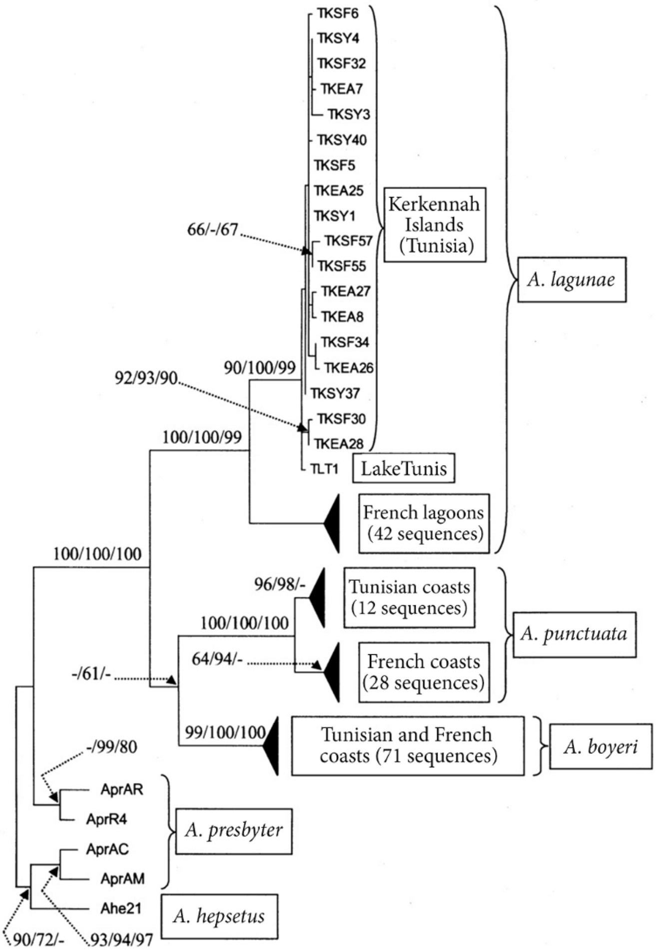


Figure 1.1. *Phylogenetic tree of the* Atherina boyeri *complex*–Atherina lagunae–Atherina punctata *(according to Trabelsi et al., 2009)*

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