Allochthonous and vagrant ichthyofauna in Hellenic marine waters

Maria Corsini-Foka and Panos S. Economidis

INTRODUCTION

Mediterranean is one of the most important close seas around world with a large shipping circulation and open but narrow communication with two oceans by Gibraltar strait (Atlantic) and by the man made Suez canal (Indian through Red Sea). It also has a free water exchange with Black Sea through Dardanelles, the Sea of Marmara and Bosporus, which are rather Mediterranean's annexed parts. All this frame of marine and brackish waters, convey a large variety of biota which enter continuisly in the Mediterranean and requently they qualified as "allochthonous", "exotic", "alien", "introduced" by man or "vagrant visitor". According to dependable ecological parameters they settled in Mediterranean for few or many years, temporarily or permanently, following their ecological requirements and the environmental short or long term oscillations, and establishing or not large or scarce populations. Therefore, Mediterranean is by far the major recipient of exotic species and vagrant visitors as macrophytes, invertebrates and fishes. Apart of the rather free energetic movement through the above passages, ships ballast and aquaculture are also important vectors of non-indigenous marine species appearing from time to time. Apparently Mediterranean presents a continue, since last glacier period, exchange of fauna with the Atlantic and the Black Sea, and during last about 150 years, when Suez canal was opened, the uniqueness of many Indo-Pacific species migrants through it. The rate especially of this last migration has increased in recent decades and has ecological and economical impacts basically in the Levantine basin.

THE MEDITERRANEAN ICHTHYOFAUNA

In a rather simplified scheme, which could also be adapted and used to the Hellenic seas, recent ichthyofauna of the Mediterranean is composed by four main groups of species: (1) The endemic as compacted by QUIGNARD & TOMASINI (2000), (2) The Atlantic, Boreal and Tropical (sensu TORTONESE, 1960, 1964), benthic, pelagic or shore dwelling species, errant as adult and larvae, or energetic swimming, rare visitor and new colonizer which are originated from NE Atlantic, as it has been confined and adopted for FNAM purposes (see WHITEHEAD *et al*., 1984-1986) and sometimes also amphi-Atlantic species (TORTONESE, 1967, 1970). Furthermore, these Atlanto-Mediterranean species occur or not in the Mediterranean according to environmental factors, many of which oscillate essentially by long or short terms climatic changes. Altogether form a fish fauna which should be called "autochthonous". Several such species having a rare, maybe periodical, appearance could be eventually named as vagrant" or "visitor" but not "alien" or "exotic", because in long terms the Mediterranean is inside of their native range and even present in limited concentration, many of them are in fact detected difficultly. Some other could also be called as "new colonizer", especially when their spreading is favoured by special circumstances as actually the Greenhouse Effect and tendency of change in temperature and current regime in NE Atlantic. (3) The introduced by man (sensu HUNTER & GIBBS, 2006), mainly for aquaculture or aquarium purposes which after escapement or careless releasing become free. This is a rather obscure phenomenon and actually there is no any or a few and elementary knowledge about its impact in the natural environment and genetic compatibility after mating with close related wild species and producing of hybrids. In the category of introduced should also be included various taxa releasing with the ballast water, many of which maybe are "exotic", and (4) The Lessepsian or Erythrean, of Red Sea origin migrant, which are real "exotic" or "alien" species which in several cases, when population explosion appeared, could

be characterized as real "invasive" (HUNTER & GIBBS, 2006), as use to be recently *Fistularia commersonii* in many areas of the Eastern Mediterranean.

In the following it should be analysing the last three groups of species of the above categories.

GREEK ALLOCHTHONOUS FISH SPECIES

Among a number of about 500 native marine fish species in the Hellenic waters 41 allochthonous species have been registered (Table 1). The seven of that species are not jet confirmed for various reasons, almost the entirety of which (six species) belong to the category of introduced for aquaculture and the presence in nature is based on unverified observation of free swimming specimen or undetermined samples, strongly suggesting of careless realising or escapement from related fish farms. From the rest of 34 species the majority of them (27 species plus one uncertain, i.e. 79.4%) are originated from Indo-Pacific ocean and Red Sea having penetrated via Suez Canal to the Mediterranean. Among the remaining seven species, four use to be originated from Atlantic ocean and thee, two sturgeons and one mullet, come from aquaculture either from stocking or escapement.

All these allochthonous species can be classified in three main groups according to their origin: (a) Atlantic, (b) Aquaculture and (c) Indopacific. The first group of species could eventually dropped easier in the indigenous Mediterranean species, according to the above expressed points (chapter: the Mediterranean Ichthyofauna), and according to the fact that more new records - after detailed and deeper investigations and true settlement followed by normal reproduction -, more strengthening of the Atlanto-Mediterranean character. The list of species of the second group expected be augmented gradually because the included species surely would became more and more as the number of aquaculture installations is accelerating in the Hellenic seas and in the neighbouring areas as well. Apparently, no serious precautions seems to be undertaken for avoiding of any escapement in the nature of farm stocks. The third group includes the majority of allochthonous species, which are real alien species in the Mediterranean as they have been penetrated in an area out of their original distribution. It is worthy to note that the majority of these species have a quite slow process of spreading and settlement, underlining their thermophylous and stenohalous, tropical or sub-tropical, character. In the Mediterranean such environmental conditions are current in the eastern basin, longwise of Asian coasts mainly. In the Aegean Sea close related situation is appearing in the SE corner around the Dodecanese continental plateau. There are evidences the contribution of the Indopacific alien species in the Aegean Sea fish species composition, and their population structure, is accelerated gradually, as many population of these species have already constracted fishable stocks, as long ago *Upeneus* and *Siganus* species in Dodecanese islands and more recently *Fistularia commersonii* (CORSINI *et al*., 2002; KALOGIROU *et al*., 2007), *Etrumeus teres* in Cyclades (KALLIANIOTIS & LEKKAS, 2005).

ATLANTIC VAGRANT AND NEW COLONIZER

As it is noted above, the vagrant or visitor and the new colonizer fish species of Atlantic origin are not easy to be enumerated because their flux is continued since more than at least 10000 years. Various attempts, however, have been undertaken for standardization the origin and for calculation of the number of Mediterranean fish species (see TORTONESE, 1938, 1963, 1970, 1975, 1982; QUIGNARD & TOMASINI, 2000 and related literature there). Furthermore, as search in various part of Mediterranean become more intensive, many new species has been registered each year, mainly in the western part of the sea, which is closest to the Atlantic. Eventually this could also be attributed to other reasons as a warming trend of the Mediterranean, an expansion of the maritime traffic, etc. (see GOLANI *et al*., 2002) or combination of all of these reasons and even more. There is a large discussion

relatively to the exact number (see QUIGNARD & TOMASINI, 2000) of Atlantic vagrant and new colonizer fish species. Recent estimation considered these species entered through the Gibraltar crossing into the Mediterranean more than 30 up to 2006 (GOLANI *et al*., 2002 updated to 2005 on-line; REINA-HERVÀS *et al*., 2004), reaching also the Aegean (ERYILMAZ *et al*., 2003; CORSINI *et al*., 2006) and the Adriatic sea as the recently recorded *Cyclopterus lumpus* (DULCIC & GOLANI, 2006). Some of them, particularly *Sphoeroides pachygaster*, *Seriola fasciata* and *Seriola carpenteri* have reached significant biomass (ANDALORO, 2001; ANDALORO *et al*., 2005).

Three such species of fish have been recorded from the Aegean: *Sphoeroides pachygaster*, well established in all the Mediterranean, *Enchelycore anatina* and *Seriola fasciata*, while the consideration of *Gaidropsarus granti* as a non-indigenous Atlantic colonizer is questionable (see Table 1). The occurrence of these species in the South Aegean waters may suggest that other new inhabitants of Atlantic origin already detected in the Western Mediterranean may be expected in the Levant, and consequently, in Greek waters.

The regular or rare appearance of "Atlantic" species in the Mediterranean is a more complicated phenomenon depending mainly on hydro-climatic long-term changes and short-term trophic relations among species. In a very preliminary and simplified approach, when North Atlantic waters become warmer, there is an access of temperate, even sub-tropical, species into Mediterranean. In contrary, when Atlantic waters become colder, northern species enter and colonize the Mediterranean. This play seems to have taken place repeatedly during the so-called Glacier Period dominating in the north Hemisphere of the planet during last more than one million year. The inter-glacier period favours the first movement while the glacier the second (see also QUIGNARD & TOMASINI, 2000). Actually, there is a rather clear range of these warm water or "thermophilous" and cold water or "psychrophilous" fish fauna in the Mediterranean, as the first is distributed in south mainly longwise of African and Asian coasts, while the second is restricted in European coasts, in some areas where cold water is dominating (North Adriatic, North Aegean, Black Sea, etc.), following the recent temperature and currents regime.

The active trophic movement concerns the errant large pelagic species as sharks, various tunids, tetrapterids, sword fish, etc. Several such species are season regular or rare vagrant visitors. In some other cases, as the sea lamprey (*Petromyzon marinus*), the parasitic mode of life oblige to move specimen faraway to their normal distribution. Therefore, the record of this last species in North Aegean sea (ECONOMIDIS *et al*., 1999), where there are not any spawning ground for permanent settlement, could be qualified as accidental and the species as "vagrant" and not as exotic or as alien, because the area belongs to its large range. A similar example would be given by any species of remoras, accompanying great marine animal, as the *Remilegia australis* (= *Remora australis*), signalled long ago in Greek waters (TORTONESE, 1946, 1947a), which, however, according to GOLANI *et al.* (2002) is very rare but it could consider as a Mediterranean resident.

In several other cases as the Atlantic muraenid *Enchelycore anatina,* the spreading from Atlantic to Mediterranean, where there are two records one of which in Elafonissos (Peloponnesus coasts) (GOLANI *et al*., 2002), could be explained by passive spreading of the leptocephali larvae and/or as ship ballast.

Table 1. List of allochthonous fishes in Hellenic waters. P: Proveniences (IP: Indo-Pacific, A: Atlantic, Aq: aquaculture). ES: Establishment success (E: Established, S: Stocking, C: Casual, Q: Questionable), FR: Region of first record. BP: Benthopelagic, P: pelagic, D: demersal, RA: reef associated, DW: deep waters, EP: epipelagic, TE: temperate, ST: subtropical, T: tropical, F: fish, BI: benthic invertebrates, I: invertebrates, C: crustaceans, Z: zooplankton, M: molluscs, GA: green algae, Ph: phytoplankton, P: plankton, O: omnivorous, H: herbivorous,

Fish	P	ES	FR	References*	World range**	Ecology**	Climate**	Food**
Acipenser güldenstädtii	Aq	S	Evros estuaries	[1]	Black and Caspian seas estuaries and rivers	BP, sandy and muddy	TE	F, BI
Acipenser stellatus ?	Aq	S? (1)	Evros estuaries	[1]	Black & Caspian seas drainage, native in Evros	BP, sandy and muddy	TE	F, BI
Acipenser sturio ?	Aq	S? (1)	Evros estuaries	[1]	European estuasries, native in Evros	BP, sandy and muddy	TE	F, BI
Alepes djedaba ?	IP	C (2)	Aegean Sea	[2]	Indo-Pacific, Red Sea, E. Africa	P, inshore	ST	C, F
Anguilla japonica ?	Aq	Q	Ionian Sea	Original	Pacific	D, estuaries	ST	F, C, insect
Apogon pharaonis	IP	E	Rhodes	[3]	Indo-Pacific. Red Sea, E. Africa coasts to Australia	D, nocturnal, rocky	T	Z
Atherinomorus lacunosus	IP	C	Rhodes	[4] [5]	Wide Indo-Pacific, Red Sea	RA, coastal, lagoons	ST	Z
Callionymus filamentosus	IP	C	Rhodes	[6]	Indo-Pacific, Red Sea	B, sandy and muddy	ST	BI
Enchelycore anatina	A	C	Elafonissos	[7]	Eastern Atlantic	D, pelagic eggs	ST	F, C
Etrumeus teres	IP	E	Rhodes, Cyclades	[6] [8]	Red Sea to E. Africa, Indian Ocean to Australia	P, inshore	ST	Z
Fistularia commersonii	IP	E	Rhodes	[9]	Wide Indo-Pacific, Central and South America	RA	T	F, C, M
Gaidropsarus granti	A	Q	Rhodes	[10]	Atlantic	DW	T	Palaemonid prawns
Hemiramphus far	IP	E	Rhodes	[11] [12] [13]	Wide Indo-Pacific, Red Sea	EP, inshore	ST	Z, GA, Ph
Huso huso	Aq	S	Evros estuaries	[1]	Black and Caspian seas drainage	BP	TE	F
Iniistius pavo	IP	C	Rhodes	[14]	Wide Indo-Pacific, Red Sea included, and E. Pacific	RA	T	M, C
Lagocephalus sceleratus	IP	E	Rhodes	[14]	Indo-Pacific	B (mainly), on sandy	T	BI
Lagocephalus spadiceus	IP	E	Samos	[15]	Wide Indo-Pacific, Red Sea	BP	ST	BI
Lagocephalus suezensis	IP	E	Rhodes	[6]	Red Sea endemic	B, sandy and muddy	TE	BI
Leiognathus klunzingeri	IP	E	Rhodes	[16]	Red Sea	D	T	BI
Liza carinata ?	Aq	Q	Amvrakikos	Original	Western Indian, Red Sea	Coastal and brackish water	T	BI, P
Liza haematocheila = Mugil soiuy	Aq	C	Thracian Sea	[17]	Far eastern Asia from Russia to China	Coastal, estuaries, freshwater	TE	O
Morone saxatilis ?	Aq	C	Ionian Sea	Original	Western Atlantic	Coastal waters, runs rivers	TE	F, BI
Pagrus major ?	Aq	C	?	Original	Northwest Pacific	D, oceanodromous	ST	BI
Parexocoetus mento	IP	E	Rhodes	[16]	Wide Indo-Pacific from Red Sea to Fiji	EP, inshore	T	Z
Pempheris vanicolensis	IP	E	Kastellorizon	[18]	Wide Indo-Pacific, Red Sea	Daytime in caves, night inshore pelagic	T	PC
Petroscirtes ancylodon	IP	C	Rhodes	[6]	Red Sea to Arabian Gulf	D, sandy shore	T	BI
Pteragogus pelycus	IP	E	Symi	[19]	Red Sea to E. Africa	D, coastal with sea grass	ST	BI
Sargocentron rubrum	IP	E	Rhodes	[20]	Indo-Pacific (E. Africa to Samoa and Japan)	Nocturnal, daytime in caves	ST	F, BI
Saurida undosquamis	IP	E	Naxos	[21]	Indo-Pacific to Australia and S. Japan	D, sandy or muddy	ST	F, C, BI
Seriola fasciata	A	C	Rhodes	[14]	Easterna and Western Atlantic	Young EP, adult BP	ST	F, M
Siganus luridus	IP	E	Tilos	[22]	Red Sea, E. Africa to Arabian Gulf	RA, rocky or hard with vegetation	ST	H
Siganus rivulatus	IP	E	Rhodes	[23]	Red Sea and Gulf of Aden	RA, sandy, with algae and seagrass	ST	H
Sphoeroides pachygaster	A	E	Rhodes	[24]	Atlantic, Indian oceans	D, muddy, sandy and rocky bottoms	ST	M
Sphyraena chrysotaenia (*pinguis*)	IP	E	Rhodes	[19]	Indo-Pacific to China and N. Australia	BP, coastal	ST	F, C
Sphyraena flavicauda (*obtusata*)	IP	C	Rhodes	[6]	Wide Indo-Pacific, Red Sea, E. Africa	EP, inshore	T	F, I
Stephanolepis diaspros	IP	E	Rhodes	[11] [12] [13]	Red Sea to the Arabian Gulf	D, rocky substrate with vegetation.	T	BI
Torquigener flavimaculosus	IP	C	Rhodes	[25]	Red Sea, Arabian Gulf, E. Africa, Seychelles	RA, shallow sandy shores with seagrass	T	BI
Tylerius spinosissimus	IP	C	Rhodes	[6]	Indo-West Pacific, Southeast Atlantic	DW	T	
Tylosyrus crocodilus	IP	C	Chalkidiki	[26]	Wide Indo-Pacific	EP, coastal	T	F
Upeneus moluccensis	IP	E	Rhodes	[27] [28]	Indo-Pacific	B, sandy or muddy	ST	BI, F
Upeneus pori	IP	C	Rhodes	[6]	Red Sea, Gulf of Oman	B, sandy and muddy	ST	BI

(1): As the species is considered as rare or extinct from its native range in Evros drainage, the new records maybe concern specimens from stocking (see KOUTRAKIS & ECONOMIDIS, 2006).

(2): The occurrence of *Alepes djedaba* in Greek waters is to be ascertained.

* [1] KOUTRAKIS & ECONOMIDIS, 2006; [2] BINI, 1960; [3] CORSINI *et a*l., 2004; [4] QUIGNARD & PRAS, 1986; [5] CORSINI, 2004, new data; [6] CORSINI *et al*., 2005; [7] GOLANI *et al*., 2002; [8] KALLIANIOTIS & LEKKAS, 2005; [9] CORSINI *et al*., 2002; [10] ZACHARIOU-MAMALINGA, 1999; [11] TORTONESE, 1946, [12] TORTONESE, 1947a [13] TORTONESE, 1947 b; [14] CORSINI *et al*., 2006; [15] ANANIADIS, 1952; [16] KOSSWIG, 1950; [17] KOUTRAKIS & ECONOMIDIS, 2000; [18] PAPACONSTANTINOU & CARAGITSOU, 1987; [19] CORSINI & ECONOMIDIS, 1999; [20] LASKARIDIS, 1948a; [21] ONDRIAS, 1971; [22] KAVALLAKIS, 1968; [23] BRUNELLI & BINI, 1934; [24] ZACHARIOU-MAMALINGA & CORSINI, 1994; [25] MARIES, 2006, pers. comm..; [26] SINIS, 2005; [27] SERBETIS, 1947; [28] LASKARIDIS, 1948b.

** Based on: GOLANI *et al*., 2002 upadate to 2005 on-line; FROESE & PAULY, 2006

SHIP BALLAST AND AQUACULTURE INTRODUCED

There is not any documented record that some exotic fish species are introduced in the Hellenic seas by ship ballast. But, on the other hand, uncontrolled and/or collapsed aquacultures are responsible for releasing of specimens in the nature of their reared stocks. In the Greek seas have already being observed such cases. One of them maybe is concerning of some mullet specimen, apparently *Liza carinata*, captured in several western Greece estuaries (unpubl. data). Such a species or so, was introduced long ago as fry from Egypt to some fish farm near Arta (river Arachthos estuary in Amvrakikos gulf), which collapsed after. The species, should also considered as lessepsian migrant, because it has been recorded in the Eastern Mediterranean (see GOLANI *et al*., 2002). However, its establishment seems to be problematic. Obviously around European estuaries and in Greek too, among captured growing European eel (*Anguilla anguilla*) there also are some specimens of the largely used in fish farms elvers of Japanese eel (*Anguilla japonica*) or other exotic eel species, escaping from eel farms. Another case concerns the American striped bass (?) (*Morone saxatilis*) which is observed to swim near the estuaries of the stream Lessini, flowing directly to Ionian sea (unpubl. data). Very recent records concerning several sturgeons species as *Acipenser güldenständi*, *Huso huso* or various rearing hybrids, and eventually *Acipenser sturio*, captured in Thracian Sea, near Evros estuaries or in the river itself, strongly suggest that they come from releasing of fry or escapement from hatcheries and/or fish culture, lying in river Evros catchenent in Bulgaria and/or in Turkey, because there is not any such installation in Greek part of the river. In fact, regarding Bulgaria this information is true as it has been verified recently by Dr. Angel Tchekov from Plovdiv University who informed one of us (PSE) that such an installation is existing near Plovdiv on river Evros bank (see also KOUTRAKIS & ECONOMIDIS, 2006). Therefore, some previous record of *Acipenser stellatus* (ECONOMIDIS *et al*., 2000) maybe have the same origin. Furthermore, there is unverified information that exotic fish species (for instance *Pagrus major*) or even fry of native Mediterranean fish, as *Dicentrarchus labrax* and *Sparus auratus*, eventually other species too, originated from faraway areas (i.e. Spain), are used largely in marine fish farms in Greece. Consequently, very often these different genetic stocks are released or escape as fry or adults individuals in the nature, mixed with short terms native stocks. But there is an absolutely confirmed record of the Indopacific native mullet, *Liza haematocheila* (*Mugil soiuy*), which was reared in Black sea cage fish farms. After early 90's many of these farms have been collapsed and carelessly deliberated many alive specimens in the nature which were errant in Azov and Black Sea (STARUSHENKO & KAZANSKY, 1996) and soon after entered in the Mediterranean. In the Aegean Sea the species has already been signalled in the gulf of Smyrna (KAYA *et al*., 1998) and in the Thracian Sea (KOUTRAKIS & ECONOMIDIS, 2000) (see also HARRISON, 2004). Actually, it forms fished population in various Thracian lagoons and it is appearing frequently in the fish market in North Greece (unpubl. data).

LESSEPSIAN ALIEN

Lessepsian migration and fish. The movement of various marine organisms from Red Sea to Mediterranean via Suez canal was named by POR (1969) "Lessepsian migration" and used after widely by same author (POR, 1978, 1990) and many other as well; very often it also called "Erythrean migration". According to GALIL & ZENETOS (2002), the Eastern Mediterranean, open to the Atlantic, Pontic and Erythrean biota, is particularly prone to invasions. Concerning fish, the Lessepsian species in the Mediterranean are real alien species because they belong to another ecological status (thermophilous) and to a different bio-geographical zone (Indopacific), and Mediterranean is out of their native distribution.

It is important to be comprehensible the point - of rather technical origin -, that the

recent years intensive researches discover more species which however eventually were there apparently in low density and so escaping from the sampling (CORSINI & ECONOMIDIS, 1999). The immigration of such alien species is far from cease after approaching a standard level, since practically the flux of invaders results to be continuous (STREFTARIS *et al*., 2005). Therefore, the dynamics of invasions and extension of the distribution of alien species obviously need a continue up-date or a monitoring procedure (see also GOLANI *et al*., 2004; ZENETOS *et al*., 2005; PANCUCCI-PAPADOPOULOU *et al*., 2005a, b).

Establishment. According to the more recent inventories the Lessepsian fish migrants in Mediterranean are one Elasmobranchii species and 67 Teleostei species (GOLANI *et al*., 2002 updated to 2005 on-line; GOKOGLU *et al*., 2003; CORSINI *et al*., 2005; AKYOL *et al*., 2005 CORSINI *et al*., 2006; BILECENOGLU & KAYA, 2006; ÇINAR *et al*., 2006). These species, once arrive at the Mediterranean sea through the Suez Canal, they are moving either westwards to the African coasts - although rarely because of Nile estuaries freshwater barrier - , or usually to eastwards first and then northwards, following mainly the Asiatic continental shelf. They normally establish, fast or slow, dense or scarce population, in the Levantine Sea where they have been influence or even modify essentially the composition and the implementation of local marine ecosystems. The common way for further colonization of the Mediterranean is mainly by using the South coast of Turkey and its norrow continental shelf. Besides, the water masses around the Dodecanese Islands, form the most important gates for entering and establishing in the Aegean Sea and the main pathway of spreading within the Mediterranean (PANCUCCI-PAPADOPOULOU *et al*., 2005b) (**see window: The Dodecanese refuge**) (Fig. 1). Among the total number of 67 Lessepsian immigrant fishes in the Mediterranean, 28 species result to have entered Greek waters (Table 1). More two, *Scomberomorus commerson* (in Gokova Bay, according to BUHAN *et al*., 1997) and *Sillago sihama* (in Datça peninsula, according to BILECENOGLU, 2004) have been reported from the SE Aegean Sea, along the Turkish coasts. Older records of Lessepsian fish in Hellenic waters until 1990 amounted in a number of thirteen species (see PAPACONSTANTINOU, 1987, 1990; see also References in Table 1). Among them it can be mentioned the follow: *Siganus rivulatus, Hemiramphus far, Stephanolepis diaspros*, *Upeneus moluccensis*, *Sargocentron rubrum*, *Lagocephalus spadiceus*. An evident increase of records has been observed in the last decade, when more than 15 other such species added. Alltogether they represent about the 41% of the Erythrean teleosts colonizers, counted today for all Mediterranean. Similar picture presents the Erythrean crustaceans, which suddenly revealed in the SE Aegean in the past decade and, according to GALIL & KEVREKIDIS (2002), it may be due to the more extensive inflow of the Asia Minor Current in the area.

CORSINI & ECONOMIDIS (1999) mention that several Lessepsian species were signalled in Dodecanese almost simultaneously as on the coasts of Israel. Such are the cases of *Siganus rivulatus*, *Upeneus moluccensis*, *Sargocentron rubrum*, *Pteragogus pelycus* and *Fistularia commersonii*. In contrary, as for example the cases of *Sphyraena chrysotaenia* (*pinguis*), *Apogon pharaonis*, *Etrumeus teres* and some others, the advancing along the Anatolian coasts was gradual and the immigrants reached this area after a relatively long time process of spreading, depending on biotic and abiotic factors (GOLANI, 1998a; CORSINI & ECONOMIDIS, 1999; CORSINI *et al*., 2002, 2004, 2005) (Table 1) (Fig. 2). There is a direct relation among the environmental conditions and the speed of spreading and adaptation of the new settler. In fact, species have to face combined unfavourable ecological conditions (water temperature, substratum, currents, trophic conditions etc.) when follow the narrow continental shelf of the South Anatolian as the main way for westward spreading, as the majority of such species are rather coastal. Consequently, once they reach the continental shelf of the Dodecanese islands, they usually remain there permanently (Dodecanese refuge), frequently

some of them forming important exploited populations (see below).

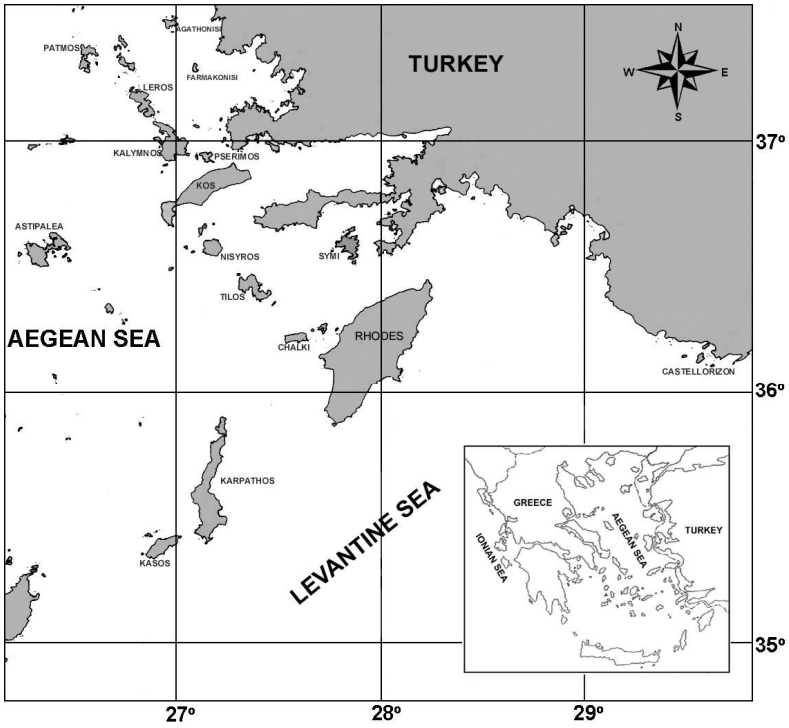

Fig. 1. The Dodecanese islands and the Greek Seas.

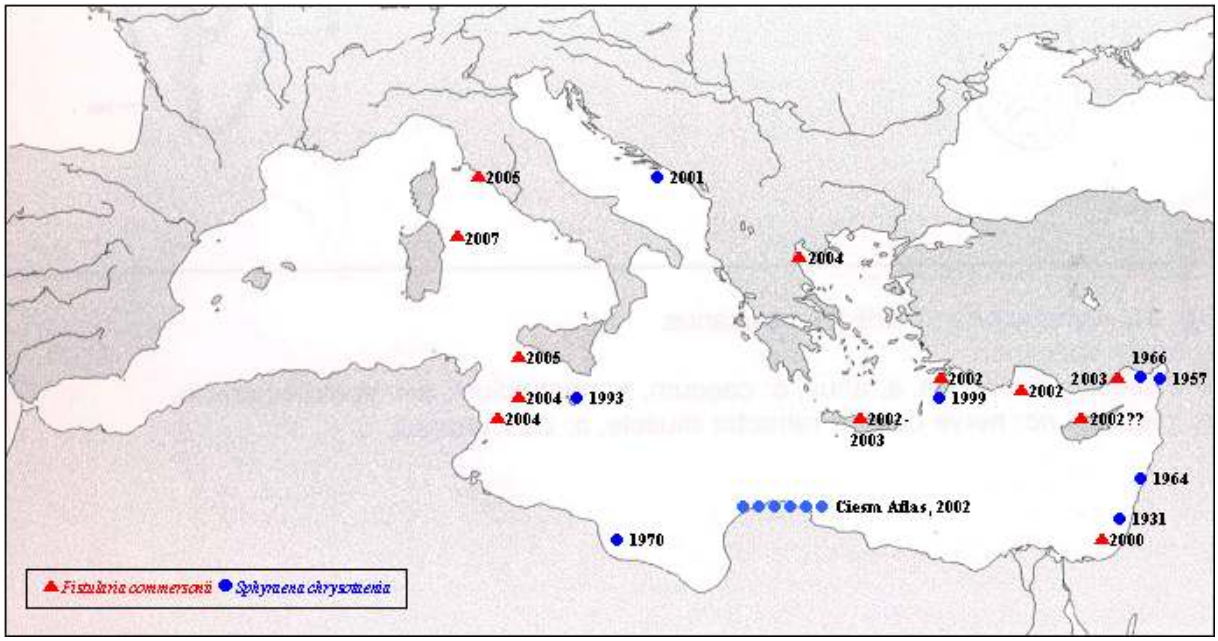

Fig. 2. Chronicle of the establishment and spreading of *Fistularia commersonii* and *Sphyraena chrysotaenia* along the Mediterranean coasts.

On the other hand, a large number of Lessepsian migrant, being well distributed in the

Levant, has not been recorded in the SE Aegean Sea. This different trend would be owed to many biotic and/or abiotic factors as for example the temperature regime and the thermal tolerance of the colonizing species, the food availability, the competition with indigenous species, the local pathogens and the suitable substrate (GOLANI, 1998a). Furthermore, the extension of the spawning season, the aggressive behaviour of the new species, their food preferences, could also be added. Free niches already existing or created by over-fishing of local species may be also occupied by the colonizers. All these, as many other factors, need a more accurate survey for obtaining a complete view of the real situation.

In comparison, along the Turkish territorial waters of Aegean and East Mediterranean, have been recorded 38 species teleosts of Red Sea origin (GOLANI *et al*., 2002, updated to 2005 on-line; BILECENOGLU *et al*., 2002; ÇINAR *et al*., 2005, 2006; BILECENOGLU & KAYA, 2006), representing the 57% of the total reported in the Mediterranean. A number of 25 species found in Hellenic waters result in common.

It is obvious that several fish species already detected and established along the Levantine Turkish coasts are to be expected also in the Hellenic waters. These especially are: *Dussumieria elopsoides*, *Herklotsichthys punctatus*, *Pelates quadrilineatus*, *Sillago sihama*, *Oxyurichthys petersi*, *Scomberomorus commerson*, *Cynoglossus sinusarabici*.

Window

The Dodecanese refuge

The Dodecanese continental shelf and passages among islands is considered as important gates and an ideal settlement of Lessepsian immigrants entering the Aegean waters. According to MASSETI (2002), "due to their geographical location, most of the islands of the Dodecanese fall within the biogeographical and paleogeographical range of Anatolia, to which they were joined by land-bridges at various different times duribg the Pleiostecene glacial episodes". The coastal zone of the marine area around Rhodes especially, is characterized by a sub-tropical open-sea environment and it is influenced essentially by the neighboring Levantine basin, since the island is hug by the warm Asia Minor current through the strait of Rhodes at north and the straits of Kassos and Karpathos at south (PANCUCCI-PAPADOPOULOU *et al*., 1999) (Fig. 1). Therefore it offers suitable environmental conditions for the establishment of thermophylous organisms, as are the Lessepsian emigrant. The evolution of the Eastern Mediterranean Transient (EMT) (THEOCHARIS & LASCARATOS, 2000) and other factors, mainly vacant niches, provides ulterior favorable conditions, for the maintenance and spread of Erythrean species, when entering in the the area and supports the understanding of the increase of Red Sea exotic recorded here in the last years (GALIL & KEVREKIDIS, 2002; CORSINI *et al*., 2005). Therefore, the biogeographic classification of the marine area around Rhodes into the "Lessepsian province" of the Mediterranean, proposed by Por (1990), is well sustained.

Nevertheless, the fish fauna in South Aegean Sea, including Dodecanese continental shelf is mainly of Atlantic-Mediterranean origin, but with a higher percentage of thermophylous species. This is especially obvious when it compared with the northern parts of the Mediterranean, including the North Aegean Sea, as it has been underlined long ago by TORTONESE (1947b). Recent unpublished data on the benthic-pelagic fishery resources in the South Aegean Sea confirm this fact, as they show that the major part of thermophilous species, comprehending also the Lessepsian fishes, occurs in the Dodecanese region rather than in Cyclades. Furthermore, the last years observed higher occurrence in coastal fishery of true thermophilous species, as *Lobotes surinamensis*, *Alectis alexandrinus* and *Mycteroperca rubra* (unpubl. data), which were previously considered rare in this area (see TORTONESE 1946, 1947a), may be explained by the global warming of the seas as discussed for the Mediterranean by BIANCHI & MORRI (2003) and AZZURRO (2006) and support the general trend for Erythrean species.

Regarding the other marine biota, there is a similar scheme as the majority of non-indigenous of them, listed from Hellenic waters, has been recorded in the South-East Aegean Sea, particularly at Rhodes and the other Dodecanese Islands' continental shelf. About the 90% of these biota are consisting by Indo-Pacific migrant species (PANCUCCI-PAPADOPOULOU *et al*., 2005a).

Spreading. Lessepsian migrant species once reaching the Dodecanese continental shelf (SE Aegean) seems to have difficulties for further spreading to the rest of the Aegean Sea, mainly in north, or to continue ranging to all Mediterranean. Actually, among the above 28 Lessepsian fish species (Table 1), only eight of them have been recorded northern than the Dodecanese plateau (Greek and Turkish coastal waters), three before the last decade and other four during the last seven years (Table 2). The record of *Tylosurus crocodilus* in Chalkidiki-Thermaikos Gulf (SINIS, 2005) need a special mention because this is a first record for all Mediterranean and the passive transport by ship ballast should not be excluded. Moreover, spreading to the south, central or to the western Greek territorial waters of the Aegean and the Ionian seas seems to have same low success, as only ten species followed these roads (Table 2).

Table 2. Spreading of Lessepsian fishes in Greek waters out of the Dodecanese continental shelf.

Species	North Aegean	South-Central Aegean	Ionian Sea	References*
Etrumeus teres		+		[1] [2]
Fistularia commersonii	+	+		[3] [4] [5]
Lagocepalus sceleratus	+	+		[6] [2]
Lagocephalus spadiceus	+			[7]
Leiognathus klunzingeri	+	+		[8] [9] [3]
Parexocoetus mento		+	+	[3]
Pempheris vanicolensis		+		[5]
Saurida undosquamis		+	+	[10] [3] [11]
Siganus luridus	+	+	+	[3] [12] [5]
Siganus rivulatus	+	+	+	[13] [3] [5]
Stephanolepis diaspros		+	+	[3] [14]
Tylosurus crocodilus	+			[15]
Upeneus moluccensis	+		+	[16] [17] [3]

* [1] KALLIANIOTIS & LEKKAS, 2005; [2] Crete, unpubl. data; [3] GOLANI *et al*., 2002 updated to 2005 on-line; [4] Chalkidiki, KARACHLÈ *et al*., 2004; [5] Crete, TINGILIS *et al*., 2003; [6] BILECENOGLU *et al*., 2006; [7] Samos, ANANIADIS, 1952; [8] KOSSWIG, 1950; [9] PAPACONSTANTINOU & TORTONESE, 1980; 10] ONDRIAS, 1971; [11] Crete, TSIMENIDIS *et al*., 1991; [12] TORCU & MATER, 2000; [13] GELDIAY, 1969; [14] Crete, ECONOMIDIS & BAUCHOT, 1976; [15] Thermaikos, SINIS, 2005; [16] KAYA *et al*., 1999; [17] Patraikos, KASPIRIS, 1976.

This statement shows that some abiotic (water temperature, salinity, currents regime, size of continental shelf, etc.) and/or biotic factors (food quality and quantity, spawning facilities, etc.) are impeding the spreading of Erythrean fish. In general, the species with a wide distribution area (see Table 1) are noticeably eurythermous as they are either true temperate species or they can colonize quite easier them, the water temperature not prohibiting their spreading, i.e. temperature is not a strictly isolating factor. The above mentioned species which have spread out of the Dodecanese "refuge", are dropping to this category, as the majority of them are merely eurythermous.

Although the Cretan continental shelf is lying a south of Aegean Sea in a rather warm water zone, the colonization by Lessepsian migrants presents some interesting particularities. Since these species are regarded as thermophylous, it is expected to be settled more easier in Cretan coastal waters. However, unfavourable factors obviously seems to be interdiction for their massive establishing there as only eight fish species were recorded, two before 2002, *Stephanolepis diaspros* and *Saurida undosquamis*, and other six in the last four years: *Siganus luridus* and *Fistularia commersonii*, *Siganus rivulatus* and *Pempheris vanicolensis* and recently, *Lagocephalus scleratus* and *Etrumeus teres* (Table 2). Eventually, these new records are the result of the recent more intensive local investigations, but still the number of species

is low. This paradox could be attributed to the fact that although Cretan continental shelf is accessible to Lessepsian migrants by the Kasos-Karpathos immerged corridor, its colonization show a rather slow process, mainly because it is very narrow and delimited by exceptionally deep waters which isolate coastal zone of Crete.

Several of the Erythrean fishes are not jet relegated in the Levant Basin, since at least nine of them, already established in the eastern Mediterranean, both along the Asiatic and African coasts as well as the Greek seas, have expanded their populations westward. According to GOLANI *et al*. (2002, 2004), in some cases they have reached the Central Mediterranean as *Siganus luridus*, *Siganus rivulatus*, *Stephanolepis diaspros*. *Siganus luridus* enlarged its distribution to southern coasts of Sicily (AZZURRO & ANDALORO, 2004) and the northern coasts of Sicily in the Thyrrenian sea (CASTRIOTA & ANDALORO, 2005), as also *Stephanolepis diaspros*, which reached Palermo coasts (CATALANO & ZAVA, 1993), *Sphyraena chrysotaenia* (*pinguis*) has been reported from Malta (LANFRANCO, 1993), *Parexocoetus mento* and *Fistularia commersonii* from Tunisia (BEN SOUSSI *et al*., 2004), the last species also from south Sicily (AZZURRO *et al*., 2004), SW shore of Sicily (MILAZZO *et al*., in press) and Central Thyrrenian waters (MICARELLI *et al*., in press; PAIS *et al*., 2007). Some Lessepsian fish are furthrmore colonizing the coasts of the Adriatic Sea, as *Siganus rivulatus*, *Stephanolepis diaspros, Sphyraena chrysotaenia* (*pinguis*), *Saurida undosquamis Parexocoetus mento*, *Leiognathus klunzingeri* and *Hemiramphus far* (DULČIĆ *et al*., 2003).

In conclusion, the estimation is that the westward spreading of Lessepsian species would be continued slowly, even accelerate if the trend of water warming shall be sustaining. A rearrangement of the population structure is already appearing in eastern basin and this fact could be the new factor for fishery management.

Habitat. Most Erythrean invertebrates alien occupy at present the Mediterranean littoral and infralittoral zones to a depth of 50m approximately, and are hardly found in deeper waters (GALIL & ZENETOS, 2002). This is also true for the Lessepsian fish species, which are in majority coastal species dwelling in rather shallow sandy or muddy habitats (GOLANI, 1993) or rocky shores, often covered by sea grass.

At Rhodes and other Dodecanese coastal areas the majority of Erythrean fish collected by trawlers at depths ranging up to 50m, more frequently on sandy-muddy bottom, covered by well-developed Chlorophyceae beds (*Caulerpa prolifera* and *Caulerpa racemosa*) and Phanerogames praries, mainly *Posidonia oceanica* and also *Halophila stipulacea* (CORSINI & ECONOMIDIS, 1999; CORSINI *et al*., 2005, 2006). Other species are encountered on sandy-rocky bottom, as *Pempheris vanicolensis*, *Sargocentron rubrum* and schools of juvenile *Shyraena chrysotaenia* or on very shallow sandy areas, as *Iniistius pavo*. On the other hand, as assessed by CORSINI *et a*l. (2005), *Tylerius spinosissimus* was collected at a depth which is lower than those in tropical waters, but deeper than the usual for Lessepsian migrant fish in the SE Aegean Sea. This statement probably shows that there may be several unexplored niches in the region, suitable to the new colonizers. The first finding of this young pufferfish in Rhodes, far from the Suez Canal, eventually indicates that a certain population of the species is already established in the eastern Mediterranean, especially in closer to Suez Canal areas, and spreading follows quite unusual ways, as observed in the case of *Tetrosomus gibbosus* (SPANIER & GOREN, 1988). However, it is not to be undervalued the possibility that other vectors (ship ballast, aquaculture or aquaria purposes transport), different from the natural pathway, may be involved in the introduction of this Indo-Pacific spiny blaasop *Tylerius spinosissimus*, as observed for other taxa in the Hellenic waters (PANCUCCI-PAPADOPOULOU *et al*., 2006).

Abundance and interactions. The abundance of some Lessepsian migrant fishes has assumed economical importance in the south-eastern Levant and Anatolian fishery (GUCU *et al*., 1994; TORCU & MATER, 2000; GOLANI *et al*., 2002; ÇICEK & ASVAR, 2003; HARMELIN-VIVIEN *et al*., 2005), while other Erythtrean invaders are considered as economic burden by GOREN & GALIL (2005).

Lessepsian fish all over coastal waters of Dodecanese continental shelf corresponds generally to species that have previously established there a population, large enough to be detectable and catchable (CORSINI *et al*., 2005). This is confirmed by the fact that various such species are normally present, more or less abundant, in fishery activities from their first recording in the region until today (CORSINI *et al*., 2004). Among the established species listed in Table 1, the majority are caught regularly, but they can not be considered abundant, which are namely: *Hemiramphus far*, *Stephanolepis diaspros*, *Upeneus moluccensis*, *Sargocentron rubrum*, *Saurida undosquamis*, *Atherinomorus lacunosus*, *Pempheris vanicolensis*, *Pteragogus pelycus* and *Apogon pharaonis*. On the contrary, some other species, established successfully, are common and acquired a commercial importance, i.e. *Siganus luridus*, *S. rivulatus* and *Sphyraena chrysotaenia* (*pinguis*), the last normally confused with the two indigenous species *S. sphyhraena* and *S. viridensis* coexisting in the same coastal area (CORSINI & ECONOMIDIS, 1999), and also with the new Erythrean colonizer *S. flavicauda* (*obtusata*) (Fig. 3). The quickly increasing population of the recent colonizer *Etrumeus teres* is already contributing to enrich fishery resources in Dodecanese (CORSINI-FOKA, unpubl. data) and in Cyclades Islands (KALLIANIOTIS & LEKKAS, 2005), as also has been observed in Israel, Cyprus and Turkish Mediterranean waters (GOLANI *et al*., 2002, ÇICEK & AVSAR, 2003).

Fig. 3. The alien *Sphyraena flavicauda (obtusata)* (above) and the indigenous *Sphyraena viridensis* (below), caught in the same trawl (Trianda Bay, NW Rhodes, 18 December 2006).

Local indigenous fishes, especially the small size and fry, are subjected to a remarkable predation pressure. This fact presents the other side of the coin, maybe suggesting that several invaders and native species are implicating in competition. Consequently, the impact brought to the local fished populations by Lessepsian migrants seems to be serious and accelerated in some cases. Thus a more detailed approach on this matter is needed.

An eventual, even very probable, permanent establishment of a large population of the Erythrean species in the area, and consequently how harmful would be for the native fish, is related to their reproductive success. In several cases such a successful breeding in combination with food availability and other favour environmental factors very often lead to a population explosion. Such a case of population explosion was observed in the area during the 40's for *Upeneus moluccensis* (LASKARIDIS, 1948a), followed by an incomprehensible

dramatic fall short after, so that nowadays this species is rather rare in the area (CORSINI & ECONOMIDIS, 1999).

Several Erythrean invaders apparently have found vacant ecological niches and obviously did not develop any remarkable competition with local native species. Thus, *Siganus luridus* and *S. rivulatus* established well in all the Levant basin first and them elsewhere due to the presence of few herbivorous competitors or abundant available food. Furthermore, *Upeneus moluccensis* is present but it does not prevail on *Mullus barbatus*. Also, *Apogon pharaonis* is regularly caught in trawl nets as well as its indigenous counterpart *Apogon imberbis*, while *Pteragogus pelycus* occurs with other same size labrid species (for example *Symphodus* sp., *Coris julis*, *Thalassoma pavo*). Schools of Sphyraenidae are caught, both belonging to the indigenous species *Sphyraena sphyraena* and *S. viridensis* but also to the Lessepsian *S. chrysotaenia* (*pinguis*) *and S. flavicauda* (*obtusata*) (see above). *Saurida undosquamis* is very rare compared with *Synodus saurus*. On the other hand, no local fish species disappeared in Rhodes marine area as assessed for the rest of the Eastern Mediterranean (GOLANI, 1998b).

Fistularia invasion. In terms of impact, the recent invader blue cornetfish, *Fistularia commersonii*, caught normally by trawl-nets up to 50-60m of depth, has developed important population and it is considered at the moment one of the more invasive species (PANCUCCI-PAPADOPOULOU *et al.*, 2005b). This species presents a very fast expansion along the coasts of the Levantine basin (GOLANI, 2000; CORSINI *et al*., 2002) and recently up to the north Aegean Sea (Chalkidiki peninsula), to the northern coasts of Crete and westward to the Central Mediterranean and Thyrrenian Sea (GOLANI *et al*., 2002 updated to 2005 on-line; References in Table 2; ICES, 2006; PAIS *et al*., 2007) (Fig. 2). The phenomenon is alarming because this fish reproduces and grows very rapidly, reaching a remarkably large size (Fig. 4). Since its first appearance in 2001 in Rhodes marine area, blue cornetfish actually occurs at a number of 5 to 20 specimens occasionally in a catch of any trawl nets operation, mainly at 20-25 m depth.

Fig. 4. A large specimen of *Fistularia commersonii* (the man is 1.8m height), caught along the SE Rhodes coasts, 16 m depth, December 2005 (Photo by Th. Froumis).

Additionally, the species presents an extreme feeding activity and it exercises a clear aggressive when in schools. As a free swimming carnivorous fish is merely dwelling over reefs and sea-grass beds. As it has no any or a few commercial value, it is subsisting in a very low fishing pressure, being a rather "by catch" fish than a target. Consequently, it is free to

form large populations which affects seriously, economical and ecological important native species not only in the limited area of SE Aegean Sea, but in all occupied new habitats, as the South Aegean Sea (unpublished data). It mainly feeds on fry and several exploited populations of economically valuable native fish, namely *Spicara smaris*, *Mullus* sp. and *Boops boops* (CORSINI *et al*., 2002; KALOGIROU *et al*., 2007). Anatomical features of mouth and feeding behaviour observed in nature and food items found in stomach content reveal that *Fistularia commersonii* should not be ranked in the highest trophic levels. Various size individuals of the species could be seen rather as an easy prey-fish for any energetic predator, if it welcomes and/or appreciates them.

Inventorying Lessepsian migrants. Lessepsian alien fish species occurring in Greek waters belong to 20 families. The incoming of non-indigenous species have added seven families to the Hellenic ichthyofauna: Siganidae, Hemiramphidae, Fistularidae, Holocentridae, Leiognathidae, Pempheridae, Monacanthidae, while other aliens increased the species number of five already well-represented families (ECONOMIDIS, 1973; WHITEHEAD *et al*., 1986; BAUCHOT, 1987; PAPAKONSTANTINOU, 1988) (Fig. 5). The remaining aliens increased the species number in families represented by one or two species, with the exception concerning the family Tetraodontidae, which needs particular attention. Until 1994, only the autochthonous *Lagocephalus lagocephalus*, the Lessepsian *Lagocephalus spadiceus* and *Sphoeroides pachygaster* from the Atlantic were known in the area. A rapid increase of records in the last two years added four more Indo-Pacific tetraodontid species: *Tylerius spinosissimus*, *Lagocephalus suezensis*, *Lagocephalus sceleratus* and *Torquigener flavimaculosus* (Table 1). Among these last alien tetraodontids colonizers, the population of the large sized *L. sceleratus* (Fig 6), which is not marketable because may be a source for food poisining, is increasing rapidly (AKYOL *et al*., 2005; GOLANI & LEVY, 2005; CORSINI *et al*., 2006; BILECENOGLU *et al*., 2006) and this fact is sustained also by very recent unpublished data which show the presence of large number of juveniles in trawling activities along the coasts of Rhodes island.

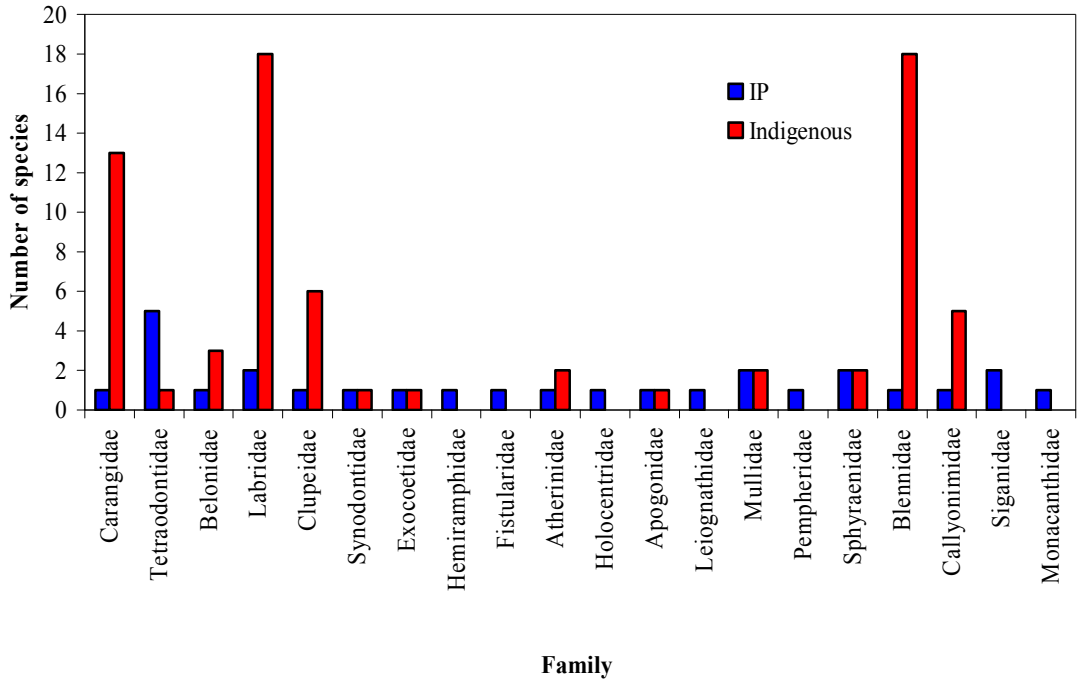

Fig. 5. Number of Lessepsian fish species and families added to the Hellenic ichthyofauna.

Fig. 6. A specimen of *Lagocephalus sceleratus* from Rhodes coastal area (SL 376 mm).

The presence of other Lessepsian species may be ascertained only through a comprehensive and regular study of the resources along the coasts, including also habitats fished infrequently, where a species of low density may go undetected, while it is a regular inhabitant (GOLANI *et al*., 2002), or habitats not exploited because their resources are considered of minimal or zero commercial value or unreachable by usual fishing methods due to bottom irregularity, but which may be important as nursery grounds and biodiversity reservoirs.

Taking into account obviously the increased interest of the scientific community for the Lessepsian colonization, a higher rate of invasion of the Levantine coasts by tropical fish species and their successful acclimatization is evident, confirming that "the littoral and infralittoral biota of the Levantine Sea is undergoing a profound change due to the influx of Erythrean invaders" (GALIL & ZENETOS, 2002), giving furthermore support to the indication of a tropicalization of the area. In long terms this phenomenon increases little by little the complexity of the entire eastern Mediterranean ecosystem, and it most probably leads to a new equilibrium, which would be characterising by a higher productivity and stability.

References

AKYOL, O., ÜNAL, V., CEYHAN, T. & BILECENOGLU, M., 2005. First confirmed record of *Lagocephalus sceleratus* (Gmelin, 1789) in the Mediterranean Sea. *Journal of Fish Biology*, 66: 1183-1186.

ANANIADIS, C., 1952. On the appearance of the fish *Tetrodon spadiceus* (Rich.) in Greek seas. *Praktika of Hellenic Hydrobiological Institute*, 6 (1): 73-74.

ANDALORO, F., 2001. La tropicalizzazione del Mediterraneo. p. 52-54. In: *La biodiversità nella regione biogeografica mediterranea.* Versione integrata del contributo dell'ANPA al rapporto dell'EEA sulla biodiversità in Europa. Rome, A.N.P.A., Stato dell'Ambiente 4/2001.

ANDALORO, F., FALAUTANO, M., SINOPOLI, M., PASSARELLI, F. M., PIPITONE, C., ADDIS, P., CAU, A. & CASTRIOTA, L., 2005. The lesser amberjack *Seriola fasciata* (Perciformes: Carangidae) in the Mediterranean: A recent colonist? *Cybium*, 29 (2): 141-145.

AZZURRO, E., 2006. *Cambiamento della diversità ittica in Mediterraneo: casi di studio*. Tesi di Dottorato di Ricerca in Biologia ed Ecologia marina, Università Politecnica delle Marche, Dipart. di Scienze del Mare, 238 p.

AZZURRO, E. & ANDALORO, F., 2004. A new settled population of the lessepsian migrant *Siganus luridus* (Pisces: Siganidae) in Linosa Island- Sicily Strait. *J. Mar. Biol. Ass. U. K.,* 84: 819-821.

AZZURRO, E., PIZZICORI, F. & ANDALORO, F., 2004. First record of *Fistularia commersonii* (Fistularidae) from the Central Mediterranean. *Cybium*, 28: 72-74.

BAUCHOT, M.-L., 1987. Poissons osseux. p. 891-1422. In: *Fiches FAO d'identification des espèces pour les besoins de la pêches. (Révision 1). Méditerranée et Mer Noire. Zone de pêche 37. Vol. 2: Vertébrés*, edited by W. Fischer, M.-L. Bauchot. and M. Schneider, Rome, FAO.

BEN SOUSSI, J., ZAOUALI, J., BRADAI, M. N. & QUIGNARD, J. P., 2004. Lessepsian migrant fishes off the coast of Tunisia. First record of *Fistularia commersonii* (Osteichthyes, Fistularidae) and *Parexocoetus mento* (Osteichthyes, Exocoetidae). *Vie et Milieu*, 54 (4): 247-248.

BEN SOUSSI, J., GOLANI, D., MEJRI, H. & CAPAPÉ, C., 2005. On the occurrence of *Cheilopogon furcatus* in the Mediterranean Sea. *J. Fish Biol.*, 67: 1144-1149.

BIANCHI, C. N. & MORRI, C., 2003. Global Sea warming and tropicalization" of the Mediterranean Sea: biogeographic and ecological aspects. *Biogeographia*, 24: 319-328.

BILECENOGLU, M., 2004. Occurrence of the lessepsian migrant fish, *Sillago sihama* (Forsskål, 17775) (Osteichthyes: Sillaginidae) from the Aegean Sea. *Israel Journal of Zoology*, 50: 420-421.

BILECENOGLU, M., & KAYA, M., 2006. A new alien fish in the Mediterranean Sea – *Platax teira* (Forsskel, 1775) (Osteichthyes: Ephippidae). *Aquatic Invasions*, 1 (2): 80-83.BILECENOGLU, M., TASKAVAK, E., MATER, S. & KAYA, M., 2002. Checklist of the marine fishes of Turkey. *Zootaxa*, 113: 1-194.

BILECENOGLU, M., KAYA, M. & AKALIN, S., 2006. Range expansion of silverstripe blaasop, *Lagocephalus sceleratus* (Gmelin, 1789), to the northern Aegean Sea. *Aquatic Invasions*, 1 (4): 289-291.

BINI, G., 1960. *Catalogue of the names of fishes of commercial importance in the Mediterranean*. FAO, Rome, 250 p.

BRUNELLI, G. & BINI, G., 1934. Sulla immigrazione di una specie di "Teuthis" del Mar Rosso al Mar Egeo. *Atti della Reale Accademia dei Lincei*, 19: 255-260.

BUHAN, E., YILMAZ, H., MORKAN, Y., BÜKE, Y. & YÜKSEK, A., 1997. A new catch potential for Güllük bay and Gökova bay *Scomberomorus commerson* (Lacépède, 1980) (Pisces-Teleostei). *Mediterranean Fisheries Congress, Izmir*, 9-11 April 1997, 7 p. (Turkish with English abstract).

CASTRIOTA, L. & ANDALORO, F. 2005. First record of the lessepsian fish *Siganus luridus* (Osteichthyes: Siganidae) in the Tyrrhenian Sea. JMBA2 – *Biodiversity Records*, Published online.

CATALANO, E. & ZAVA, B., 1993. Sulla presenza di *Stephanolepis diaspros* Fraser Brunner. *Doriana, suppl. degli Annali del Museo Civico di Stor. Naturale "G. Doria"*, 4 (181): 1-4.

CORSINI, M. & ECONOMIDIS, P. S., 1999. Distribution extension of two Lessepsian migrants found in the marine area of the island of Rhodes (Aegean Sea, Greece). *Cybium,* 23 (2): 195-199.

CORSINI, M., KONDILATOS, G. & ECONOMIDIS, P.S., 2002. Lessepsian migrant *Fistularia commersonii* from the Rhodes marine area. *Journal of Fish Biology*, 60 (4): 1061-1062.

CORSINI M., MARGIES, P., KONDILATOS, G. & ECONOMIDIS, P. S., 2005. Lessepsian migration in Aegean Sea: *Tylerius spinosissimus* (Pisces, Tetraodontidae) new for the Mediterranean, and six more fish records from Rhodes. *Cybium,* 29 (4): 347-354.

CORSINI M., MARGIES, P., KONDILATOS, G. & ECONOMIDIS, P. S., 2006. Three new exotic fish records from the SE Aegean Greek waters. *Scientia Marina*, 70 (2): 325-329.

CORSINI FOKA, M., KONDYLATOS, G. & ECONOMIDIS, P. S., 2004. Occurrence of the lessepsian species *Portunus pelagicus* (Crustacea) and *Apogon pharaonis* (Pisces) in the marine area of Rhodes Island. *Mediterranean Marine Science,* 5 (1): 5-17.

ÇICEK E. & AVSAR, D., 2003. Monthly distribution and abundance of Lessepsian fishes off Karatas (Northeastern Mediterranean) throughout 2002-2003 fishing season. *International Symposium of Fisheries and Zoology*. Abstract. www.istanbul.edu.tr

ÇINAR, M. E., BILECENOGLU, M., ÖZTÜRK, B., KATAGAN, T. & AYSEL, V., 2005. Alien species on the coasts of Turkey. *Mediterranean Marine Science*, 6/2: 119-146.

ÇINAR, M. E., BILECENOGLU, M., ÖZTÜRK, B. & CAN, A., 2006. New records of alien species on the Levantine coast of Turkey. *Aquatic Invasions*, 1 (2): 84-90.

DULČIC, J. & GOLANI, D., 2006. First record of *Cyclopterus lumpus* L., 1758 (Osteichthyes: Cyclopteridae) in Mediterranean Sea. *Journal of Fish Biology*, 69: 300-303.

DULČIĆ, J., PALLAORO, A., & LIPEJ, L., 2003: Lessepsian fish migrants reported in the *eastern Adriatic Sea: an annotated list*. *Ann. Istrian Mediterr. Stud. Ser. Hist. Nat.*, 13: 137–144.

ECONOMIDIS, P. S., 1973. Catalogue des poissons de la Grèce. *Hellenic Oceanology and Limnology*, 11: 421-598 (in Greek).

ECONOMIDIS, P. S. & BAUCHOT, M.-L., 1976. Sur une collection de poissons des mers helléniques (mers Egée et Ionienne) déposée au Muséum National d'Histoire Naturelle. *Bulletin du Muséum National d''Histoire Naturelle*, Paris, 3e sér., n° 392, Zoologie, 274: 871-903.

ECONOMIDIS, P. S., KALLIANIOTIS, A. & PSALTOPOULOU, H., 1999. Sea Lamprey, *Petromyzon marinus* (Cyclostomata, Petromyzontidae), in the eastern Mediterranean-two records from the Aegean Sea (Greece). *Journal of Fish Biology*, 55: 1114-1118.

ECONOMIDIS, P. S., KOUTRAKIS, E. TH. & BOBORI, D. C., 2000. Distribution and conservation of *Acipenser sturio* and related species in the Greek waters. *Boletin Instituto Espanol de Oceanografia*, 16(1-4): 81-88.

ERYILMAZ, L., ÖZULUG, M. & MERIÇ, N., 2003. The Smooth Pufferfish, *Sphoeroides pachygaster* (Müller and Troschel, 1848) (Teleostei: Tetraodontidae), new to the Northern Aegean Sea. *Zoology in the Middle East*, 28: 125-126.

FROESE, R. AND PAULY, D. (Eds.), 2006. FishBase. World Wide Web electronic publication. www.fishbase.org, version (12/2006).

GALIL, B. S. & KEVREKIDIS, K., 2002. Exotic decapods and a stomatopod off Rhodes Island (Greece) and the eastern Mediterranean Transient. *Crustaceana*, 75: 925-930.

GALIL, B. S. & ZENETOS, A., 2002. A Sea change-Exotics in the Eastern Mediterranean Sea. p. 325-336. In: *Invasive Aquatic Species of Europe. Distribution, Impacts and Management*, edited by E. Leppäkoski, Gollasch S. and S. Olenin. Netherlands: Kluwer Academic publishers. www.biomareweb.org

GELDIAY, R., 1969. The fishes of the Izmir Bay and the possibility of their invasions. Ege Universitesi fe Fak. Genel. Zooloji Kursusu, Izmir, p. 135.

GOKOGLU, M., BODUR, T. & KAYA, Y., 2003. First record of the bonnerfish (*Heniochus intermedius* Steindachner, 1893) from the Mediterranean Sea. *Israel Journal fo Zoology*, 49: 324-325.

GOLANI, D., 1993. The sandy shore of the Red Sea-launching pad for Lessepsian (Suez Canal) migrant fish colonizers of the eastern Mediterranean. *Journal of Biogeography*, 20: 579-585.

GOLANI, D., 1998a. Distribution of Lessepsian migrant fish in the Mediterranean. *Italian Journal of Zoology,* 65, Suppl.: 95-99.

GOLANI, D., 1998b. Impact of Red Sea Fish Migrants through the Suez Canal on the Aquatic Environment of the Eastern Mediterranean. *Bull. Yale School Forest. Environ . Stud.,* 103: 375-387.

GOLANI, D., 2000. First record of the Bluespotted cornetfish from the Mediterranean Sea.

Journal of Fish Biology, 56: 1545-1547.
GOLANI, D. & LEVY, Y., 2005. New records and rare occurrences of fish species from the Mediterranean coast of Israel. *Zoology in the Middle East*, 36: 27-32.
GOLANI, D., ORSI-RELINI, D., L., MASSUTI, E. & QUIGNARD, J.- P., 2002. CIESM Atlas of Exotic species in the Mediterranean. Vol. 1. Fishes (Briand F., ed.), Monaco, CIESM Publishers. p. 256.
GOLANI, D., ORSI-RELINI, L., MASSUTÌ, E. & QUIGNARD, J.- P., 2004. Dynamics of fish invasions in the Mediterranean: update of the CIESM Fish Atlas. *Rapport Commission International Mer Méditerranée,* 37: 367.
GOLANI, D., ORSI-RELINI, L., MASSUTÌ, E. & QUIGNARD, J.- P., 2002 updated to 2005. CIESM Atlas of Exotic fishes in the Mediterranean. http://www.ciesm.org/atlas/, visited in December 2006.
GOREN, M. & GALIL, B. S., 2005. A review of changes in the fish assemblages of Levantine inland and marine ecosystems following the introduction of non-native fishes. *Journal of Applied Ichthyology,* 21: 364-370.
GUCU, A. C., BINGEL, F., AVSAR, D. & UYSAL, N., 1994. Distribution and occurrence of Red Sea fish at the Turkish Mediterranean coast-northern Cilician Basin. *Acta Adriatica,* 34: 103-113.
HARMELIN-VIVIEN, M., BITAR, G., HARMELIN, J.-G. & MONESTIEZ, P., 2005. The littoral fish community of the Lebanese rocky coast (eastern Mediterranean Sea) with emphasis on Red Sea immigrants. *Biological Invasions,* 7: 625-637.
HARRISON, I., 2004. *Liza haematocheila* (Temminck and Schlegel, 1845). Addentum to vol. 8, part I, Mugilidae. In: *The Freshwater Fishes of Europe*, edited by P. J. Miller, vol. 8/II. Gobiidae 2, pp. 469-471.
HUNTER, M. L. & GIBBS, P., 2006. Fundamentals of Conservation Biology. Blackwell publishing, p. 516.
ICES, 2006. Working Group on Introductions and Transfers of Marine Organisms (WGITMO), 16–17 March 2006, Oostende, Belgium. ICES CM 2006/ACME:05. p.334.
KALLIANIOTIS, A. & LEKKAS, V., 2005. First documented report on the Lessepsian migrant *Etrumeus teres* De Kay, 1842 (Pisces: Clupeidae) in Greek Seas. *Journal of Biological Research*, 4: 225-229.
KALOGIROU S., CORSINI, M., KONDILATOS, G. & WENNHAGE, H., 2007. Diet of the invasive piscivor *Fistularia commersonii* in a recently colonized area of the eastern Mediterranean. *Biological Invasions*, in press.
KARACHLÉ, P. K., TRIANTAPHYLLIDIS, C. & STERGIOU, K. I.. 2004. *Fistularia commersonii* Rüppell, 1838 a lessepsian sprinter. *Acta Ichthyologica et Piscatoria,* 34 (1): 103-108.
KASPIRIS, P., 1976. New fish records from the Greek part of the Ionian Sea. *Revue des Travaux de l' Institut des Pêches Maritimes*, 40: 627-628.
KAVALLAKIS, G., 1968. *Siganus luridus* and *Siganus rivulatus* in the Dodecanese Islands. *Aliia*, 248: 307-308 (In Greek).KAYA, M., MATER, S. & KORKUT, A.Y., 1998. A new grey mullet species "*Mugil so-iuy* Basilewsky" (Teleostei: Mugilidae) from the Aegean coast of Turkey. *Turkish Journal of Zoology*, 22 (4): 303-306.
KAYA, M., BENLI, H. A., KATAGAN, T. & OZAYDIN, O., 1999. Age, growth, sex-ratio, spawning season and food of golden banded goatfish, *Upeneus moluccensis* Bleeker (1855) from the Mediterranean and south Aegean coasts of Turkey. *Fisheries Research*, 41: 317-328.
KOSSWIG, C., 1950. Erythräische Fische im Mittelmeer und an der Grenze der Agäis. *Syllegomena Biologica*. Festschrift Kleinschmidt, p. 203-212. Leipzig Akademie Verlag.
KOUTRAKIS, E. T. & ECONOMIDIS, P. S., 2000. First record in the Mediterranean (north

Aegean Sea, Greece) of the Pacific mullet *Mugil soiuy* Basilewsky, 1855 (Mugilidae). *Cybium*, 24 (3): 299-302.

KOUTRAKIS E. T. & ECONOMIDIS, P. S., 2006. Did sturgeons return to river Evros?. *Alieftika Nea*, 306: 68-83 (December, 2006) (in Greek).

LANFRANCO, G. G., 1993. The fishes around Malta (Central Mediterranean). Progress Press Co., Malta, p. 132

LASKARIDIS, K., 1948a. *Holocentrum rubrum* (Forsk) and *Lagocephalus lagocephalus* (L.), two newly reported members of the Greek fishfauna (Dodecanesian islands). *Praktika Hellenic Hydrobiological Institute*, 2 (1): 127-129.

LASKARIDIS, K., 1948b. Contribution to the biology of the fish *Mulloides auriflamma* (Forsk.). *Praktika Hellenic Hydrobiological Institute,* 2 (1): 103-118.

MASSETI, M., 2002. A glimpse of paleontology. p. 35-40. In: Island of Deer. Natural history of the fallow deer of Rhodes and the vertebrates of the Dodecanese (Greece), edited by M. Masseti M. City of Rhodes, Environment Organization.

MICARELLI, P., BARLETTANI, M. & CECCARELLI, R., in press. Note sul ritrovamento di un esemplare di *Fistularia commersonii* (Fistularidae, Pisces) nelle acque del Tirreno centrale., Trieste, 9–13 May 2005.

MILAZZO, A., BARRACO, B., BELTRAME, A.M., CANNIZZARO, L., PULEO, M., RIZZO, P., SALVO, G. & VITALE, S., in press. Catturata *Fistularia commersonii* (Fistularidae) (Rüppel, 1835) nelle acque costiere di Selinunte. *Atti Congresso Società Italiana Biologia Marina*, Trieste, 9–13 may 2005.

ONDRIAS, I. C., 1971. A list of the fresh and sea water fishes of Greece. *Hellenic Oceanology and Limnology*, 10: 23-96.

PAIS, A., MERELLA, P., FOLLESA, M. C. & GARIPPA, G., 2007. Westward range expansion of the Lessepsian migrant *Fistularia commersonii* (Fistulariidae) in the Mediterranean Sea, with notes on its parasites *Journal of Fish Biology* ,70 (1): 269-277.

PANCUCCI-PAPADOPOULOU M. A., SIMBOURA, A., ZENETOS, A., THESSALOU-LEGAKI, M. & NICOLAIDOU, A., 1999. Benthic invertebrate communities of NW Rodos (Rhodes) Island (SE Aegean Sea) as related to hydrological regime and geographical location. *Israel Journal of Zoology,* 45: 371-393.

PANCUCCI-PAPADOPOULOU, M. A., KEVREKIDIS, K., CORSINI-FOKA, M. & SIMBOURA, N., 2005a. Changes in species: invasion of exotic species. p. 336-342. In: *State of the Hellenic Marine Environment,* edited by E. Papathanassiou and A. Zenetos, Athens, HCMR Publications.

PANCUCCI-PAPADOPOULOU, M. A., ZENETOS, A., CORSINI-FOKA, M., & POLITOU, CH., 2005b. Update of marine alien species in Hellenic waters. *Mediterranean Marine Science*, 6/2: 147-158

PANCUCCI-PAPADOPOULOU, M. A., ZENETOS, A. & CORSINI-FOKA, M., 2006. Aliens in Hellenic Seas: emphasis on introductions in ports. Communication presented at ICES/IOC/IMO Working Group on ballast and other ship vectors. Oostende, Belgium, 13-15 March, 2006.

PAPACONSTANTINOU, C., 1987. Distribution of the Lessepsian fish migrants in the Aegean Sea. *Biologia Gallo-Hellenica*, 13: 15-20

PAPACONSTANTINOU, C., 1990. The spreading of Lessepsian fish migrant into the Aegean Sea (Greece). *Sci. Mar.,* 54 (4): 313-316.

PAPACONSTANTINOU, C. & CARAGITSOU, E., 1987. The first occurrence of the lessepsian fish immigrant *Pempheris vanicolensis* in territorial Greek waters. *Thalassographica*, 9 (2): 78-79.

PAPACONSTANTINOU C. & TORTONESE, E., 1980. On a collection of fishes from the

Thermaikos Gulf (N-E Greece). *Thalassiographica,* 3 (2): 15-42.
PAPAKONSTANTINOU K., 1988. Check-List of Marine Fishes of Greece. FAUNA GRAECIAE IV, National Center for Marine Research, Hellenic Zoological Society, Athens, p. 257.
POR, F. D., 1969. The Canuellidae (Copepoda, Harpacticoida) in the waters around the Sinai Peninsula and the problem of "Lessepsian" migration of this family. *Israel Journal of Zoology*, 18: 169-178.
POR, F. D., 1978. Lessepsian migration. The influx of Red Sea biota into the Mediterranean by way of the Suez Canal. Springer-Verlag Berlin Heidelberg New York, pp. 229.
POR, F. D., 1990. Lessepsian migration. An appraisal and new data. *Bulletin de l'Institut océanographique,* Monaco, No special 7: 1-10.
QUIGNARD, J. P. & PRAS, A., 1986. Atherinidae. p. 1207-1210. In*: Fishes of the North-eastern Atlantic and the Mediterranean,* edited by P. J. P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nielsen and E. Tortonese. Vol. 3. Paris, UNESCO.
QUIGNARD, J. P. & TOMASINI, J. A., 2000. Mediterranean fish biodiversity. *Biologia Marina Mediterranea*, 7(3): 1-66.
REINA-HERVÁS, J. A., GARCÌA RASO, J. E. & MANJÓN-CABEZA, M. E., 2004. First record of *Sphoeroides spengleri* (Osteichthyes: Tetraodontidae) in the Mediterranean Sea. *Journal of the Marine Biological Association U. K.*, 84: 1089-1090.
SERBETIS, CH., 1947. The appearance of a new fish (*Mulloides flavolineatus*) in the Mediterranean Sea at Dodecanese area. *Praktika Academy Athens*, 22: 209.
SINIS, A. I., 2005. First record of *Tylosurus crocodilus* (Péron & Lesueur 1821) (Pisces: Belonidae) in the Mediterranean (North Aegean Sea, Greece). *Journal of Biological Research*, 4: 221-224.
SPANIER, E. & GOREN, M., 1988. An Indo-Pacific trunkfish *Tetrosomus gibbosus* (Linnaeus): first record of the family Ostracionidae in the Mediterranean. *Journal of Fish Biology*, 32: 797-798.
STARUSHENKO L. I. & KAZANSKY, A. B., 1996. Introduction of mullet haarder (*Mugil so-iuy* Basilewsky) into the Black Sea and the sea of Azov. *Studies and Reviews, General Fisheries Council for the Mediterranean.* No 67. Rome, FAO. p. 29.
STREFTARIS, N., ZENETOS, A. & PAPATHANASSIOU, E., 2005. Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas. *Oceanography and Marine Biology: An Annual Review*, 43: 419-453.
THEOCHARIS, A. & LASCARATOS, A., 2000. Possible causes, origin, evolution and some consequences of the Eastern Mediterranean Transient during the period 1987-1999. *CIESM Workshop Series*, 10: 41-44.
TINGILIS, G., ANEZAKI, A., VALLA, E., LYMBERAKIS, P., KAPATANGAKIS, A., BIYIAKIS, S. & KAOURI, S., 2003. First records of Lessepsian fishfauna migrants from the Crete marine area. *Proceedings of the 11th Hellenic Ichthyologists Symposium*, Preveza, 10-13 April 2003, 47-50.
TORCU, H. & MATER, S., 2000. Lessepsian fishes spreading along the coasts of the Mediterranean and the Southern Aegean Sea of Turkey. *Turkish Journal of Zoology*, 24: 139-148.
TORTONESE, E., 1938. L' ittiofauna mediterranea in rapporto alla zoogeografia. *Boll. Mus. Zool. Anat. Comp. Torino*, 46: 1-35.
TORTONESE, E., 1946. On some fishes from the Eastern Mediterranean (Island of Rhodes). *Ann. Mag. Nat. Hist*., 13: 710-715.
TORTONESE, E., 1947a. Biological investigations in the Aegean Sea. *Nature*, 159: 887-888.
TORTONESE, E., 1947b. Ricerche zoologiche nell'isola di Rodi (Mar Egeo). Pesci. *Bolletino di Pesca Piscicul. Idrobiol.*, 23 (2): 143-192.

TORTONESE, E., 1960. General characters of the Mediterranean Fish fauna. *Idrobiologi BV* (1-2): 43-50.

TORTONESE, E., 1963. Elenco riveduto dei Leptocardi, Ciclostomi, Pesci Cartilaginei e Ossei dei Mar Mediterraneo. *Ann. Mus. St. nat. Genova*, 74: 156-185.

TORTONESE, E., 1964. The main biogeographical features and problems of the Mediterranean fish fauna. *Copeia*, 1964: 98-107.

TORTONESE, E., 1967. Citeva note comparative privind pestii din Mediterrana ci din Marea Neagra. *Bul. Inst. Cerc. pisc.,* 26(4): 37-55.

TORTONESE, E., 1970. Osteichthyes (Pesci Ossei). Parte prima. In: *Fauna d'Italia*. Bologna, Ed. Calderini, p. 565.

TORTONESE, E., 1975. Osteichthyes (Parte seconda). In: *Fauna d'Italia*. Bologna, Ed. Calderini. p. 636.

TORTONESE, E., 1982. I pesci a distribuzione circumtropicale presenti nel Mediterraneo. *Memorie Biologia Marina e Oceanografia*, 12: 191-203.

TSIMENIDIS, N., TSERPES, G., MACHIAS A. & KALLIANIOTIS, A., 1991. Distribution of fishes on the Cretan shelf. *Journal of Fish Biology*, 39: 661-672.

WHITEHEAD, P.J.P., BAUCHOT, M.-L., HUREAU, J.-C., NIELSEN, J. AND TORTONESE, E. (Eds.), 1984-1986. Fishes of the North-eastern Atlantic and the Mediterranean (FNAM) Vol. I, II, III, UNESCO, 1473 pp.

ZACHARIOU-MAMALINGA, E., 1999. The occurrence of the Atlantic fish *Gaidropsarus granti* in the Mediterranean Sea (South-eastern Aegean Sea, Dodecanese, Greece, Eastern Mediterranean). *Annales Musei Goulandris*, 10: 261-266.

ZACHARIOU-MAMALINGA, H. & CORSINI M., 1994. The occurrence of the fish *Sphoeroides pachygaster* in the south-eastern Aegean Sea (Greece). *Annales Musei Goulandris*, 9: 479-483.

ZENETOS, A. ÇINAR, M.E., PANCUCCI-PAPDOPOULOU, M. A., HARMELIN, J. G., FURNARI, G., ANDALORO, F., BELLOU, N., STREFTARIS, N. & ZIBROWIUS, H., 2005. Annotated list of marine alien species in the Mediterranean with records of the worst invasive species. *Mediterranean Marine Science,* 6/2: 63-118.