EastMed TECHNICAL DOCUMENTS 04

REPORT OF THE TECHNICAL MEETING ON THE LESSEPSIAN MIGRATION AND ITS IMPACT ON EASTERN MEDITERRANEAN FISHERY

NICOSIA, CYPRUS 7 - 9 DECEMBER 2010

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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NICOSIA, CYPRUS

7 - 9 DECEMBER 2010

Hellenic Ministry of Foreign Affairs

Hellenic Ministry of Rural Development and Food

ITALIAN MINISTRY OF AGRICULTURE, FOOD AND FORESTRY POLICIES

GCP/INT/041/EC – GRE – ITA

Athens (Greece), 7-9 December 2010

The conclusions and recommendations given in this and in other documents in the *Scientific and Institutional Cooperation to Support Responsible Fisheries in the Eastern Mediterranean* series are those considered appropriate at the time of preparation. They may be modified in the light of further knowledge gained in subsequent stages of the Project. The designations employed and the presentation of material in this publication do not imply the expression of any opinion on the part of FAO or donors concerning the legal status of any country, territory, city or area, or concerning the determination of its frontiers or boundaries.

Preface

The Project “Scientific and Institutional Cooperation to Support Responsible Fisheries in the Eastern Mediterranean- EastMed is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by Greece, Italy and EC.

The Eastern Mediterranean countries have for long lacked a cooperation framework as created for other areas of the Mediterranean, namely the FAO sub-regional projects AdriaMed, MedSudMed, CopeMed II and ArtFiMed. This fact leaded for some countries to be sidelined, where international and regional cooperation for fishery research and management is concerned. Following the very encouraging experience of technical and institutional assistance provided to countries by the other FAO sub-regional Projects,

EastMed

was born to establish multidisciplinary expertise necessary to formulate appropriate management measures under the FAO Code of Conduct for Responsible Fisheries and the principles of the Ecosystem Approach to Fisheries (EAF to ensure rational, responsible and participative fisheries management

The project’s **longer-term objective** aims at contributing to the sustainable management of marine fisheries in the Eastern Mediterranean, and thereby at supporting national economies and protecting the livelihoods of those involved in the fisheries sector.

The project’s **immediate objective** aims at supporting and improving the capacity of national fishery departments to increase their scientific and technical information base for fisheries management and to develop coordinated and participative fisheries management plans in the Eastern Mediterranean sub-region.

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This document is the final version of the Report of the Sub-Regional Technical meeting on the Lessepsian migration and its impact on Eastern Mediterranean fishery, organized by the FAO-EastMed Project (Scientific and Institutional Cooperation to Support Responsible Fisheries in the Eastern Mediterranean) in Nicosia (Cyprus), 7-9 December 2010.

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ABSTRACT

The sub-regional technical meeting on the lessepsian migration and its impact on Eastern Mediterranean fisheries was held in Nicosia, Cyprus from the 7th to 9th of December 2010. Experts from Cyprus, Egypt, Gaza Strip and West Bank, Greece, Italy, Lebanon and Turkey attended the meeting. After the opening of the meeting two general presentations were given concerning the "tropicalisation" effect and the oceanography of the Eastern Mediterranean. Information regarding lessepsian species and their influence on local fisheries were also given by the representatives of each country. The participants discussed future research ideas on lessepsian species especially with respect to fisheries. The problem of *Lagocephalus sceleratus* was highly discussed since this species is causing considerable damage to fisher`s static nets and longlines in all the countries in the project area. The participants mentioned that some lessepsian species such as *Siganus* spp. and *Saurida undosquamis,* among others were successfully introduced into the local markets and in some cases of high commercial value. The marketing and commercialisation of lessepsian species was seen as of high priority. Educating the local public was also important since for example *Lagocephalus* spp. is a toxic species and there is a high risk of death if people consume individuals of this species. A network of experts on lessepsian species was established, which would have the responsibility to promote the issue of lessepsian species in the Mediterranean and develop a database on lessepsian species. The network will also assist the Coordination Committee through the focal points to propose solutions to avoid the harmful effects of lessepsian species on the Eastern Mediterranean fisheries. Most of the issues described in this report are at the moment relevant to the Eastern Mediterranean which however, in the near future will surely increase in importance in the other parts of the Mediterranean.

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Opening of the Meeting and election of the Chairman

The EastMed Technical Meeting on the Lessepsian migration and its impact on Eastern Mediterranean Fishery took place in a conference room of the Hotel Cleopatra in Nicosia, Cyprus from the 7th-9th of December 2010. Local arrangements were made by the Department of Fisheries and Marine Research, of the Ministry of Agriculture, Natural Resources and Environment of the Republic of Cyprus.

Thirty one scientists from six countries currently participating in the EastMed Project and the FAO-EastMed staff attended this technical meeting. The list of participants is given in Annex I of this report.

Mrs Egli Pantelaki, General Director of the Ministry of Agriculture, Natural Resources and Environment, opened the meeting, welcoming the participants to Cyprus. She thanked the FAO-EastMed for the organization of this meeting with respect to an important issue for Fisheries in the Eastern Mediterranean including Cyprus. She emphasized the importance of fishery research for the sustainable management of fisheries resources within the context of the ecosystem approach to Fisheries.

Mr Loizos Loizidis, Director of the Department of Fisheries and Marine Research, also thanked the organization of this meeting in Cyprus, emphasizing the urgency of helping the fishers and protect mainly the artisanal fisheries from the negative impacts of harmful Lessepsian migrants particularly that of *Lagocephalus sceleratus*. He mentioned the serious damages in the fishing gears, the loss in the catch caused by *L. sceleratus* and the replacement of commercially important species in the catches, reducing significantly fishers income.

Mrs Konstantina Karlou-Riga, Coordinator of the EastMed Project, presented the scope and objectives of the project. She recalled the reasons for organizing this meeting, referring to the particular need to address negative effects of some invasive Lessepsian species on fisheries and ecosystems of the eastern Mediterranean. Then she presented the agenda and the Terms of Reference of the Sub-regional technical meeting on “the Lessepsian migration and its impact on Eastern Mediterranean fishery” (Annex II).

The agenda was adopted without any changes and is attached as Annex III.

The meeting appointed Mr Panagiotis Economidis as Chairman and Mr Mark Dimech, Mrs Eugenia Lefkaditou, Mr Guizeppe Scarcella as rapporteurs.

After the appointment of the rapporteurs all the participants introduced themselves to the meeting.

Overview on the Lessepsian migration phenomenon and the most invasive species

Two key presentations dealt with general aspects of the geological history of the Mediterranean Sea, the characteristics of the Mediterranean biogeography before and after the construction of the Suez Canal, the immigration of non-indigenous warm-water/tropical species of Indo-Pacific origin, so-called “lessepsian species”, with the circulation of water masses and the recent changes particularly in the hydrological properties of the Eastern Mediterranean waters. The relevant working documents are included in this report in Annex VI, whereas the main points presented and discussed are described below.

Tropicalization of Eastern Mediterranean (presented by Mrs Corsini-Foka)

The “tropicalization” of the Mediterranean, particularly evident in its eastern basin, is mainly due to the increased occurrence of non-indigenous warm-water/tropical species of Indo-Pacific origin observed in the last decades. This should be also combined with the climatic changes and the rising of the seawater temperature. Today, the 82% of alien biota introduced into the Eastern Mediterranean, are of Indo-Pacific origin, mainly of Indian Ocean and Red Sea derivation, because this basin is close to the Red Sea and connected to it via the Suez Canal, while the Atlantic influx is limited due to great distance of the main way of connection, i.e. the Gibraltar strait.

The origin of the recent native Mediterranean biota before the human-made Suez Canal connection with the Red Sea was related with the geological history of the Mediterranean Sea. The profound socio-economical changes produced along the Mediterranean coasts after the Suez Canal construction, have greatly contributed to the bio-communities changes in the marine environment.

The role of the Suez Canal is essential to the bio-geographic phenomenon of the Lessepsian migration, mainly by promoting the multivalent taxa which show plasticity in adaptation, being able to survive along the rough Canal conditions and to enter into the Mediterranean. According to literature, the main obstacles that a Lessepsian species has to overcome in the Canal are its shallowness and narrowness, its high salinity, the lack of rocky substrate that could serve as refuge and the pollution from maritime activity. After incoming, the further successful settlement and spreading of Erythrean biota, which in some cases result in population explosion-invasion, depend on suitable abiotic (high temperature, high salinity, prevalent counter-clockwise surface current) and biotic conditions in the new area (food availability, free niches to be occupied or niches poorly appreciated by natives, suitable density of genitors, proper habitats and conditions for successful reproduction, limited interspecific and intraspecific competition, low or vanishing parasites and diseases) and also on the intrinsic characteristics of the incoming Erythrean population (like favorable genetic fitness, initial number of individuals). Generally, once a Lessepsian migrant has arrived into the Levantine basin and established a sustainable population, there are no significant physical barriers preventing their further dispersal along the Mediterranean coasts..

As concerns the distinction between invader and colonizer Erythrean species, it is evidenced by the ability of invader species to exploit local indigenous resources faster than native species and to form rapidly large populations which spread at the shallow coastal habitats (see the recent cases of *Fistularia commersonii* and *Lagocephalus sceleratus*). Regarding fishery, invasive species have a true immediate and negative impact. However, the distinction between invaders and colonizers is still questionable as often all the Erythtrean alien species are considered invasive, because the slow or rapid integration of these tropical species in the eastern Mediterranean bio-communities is dramatically changing or has already changed the native biotic complex toward a new biotic complex.

The intensification of the phenomenon of warm-water species introduction and settlement favored by global warming and by the continuous increase of human activities, is constantly introducing factors of disturbances in the bio-community equilibrium. This situation makes urgent the need for more systematic and synthetic studies on abiotic conditions and on the composition, structure and functioning of the biotic complex, based on international monitoring and a center of survey.

Variability of the circulation and water properties in the Eastern Mediterranean in the context of the "climatic change": An overview (presented by Mr. Alexander Theocharis)

The Mediterranean is classified as an oligotrophic concentration basin with high-density water production. This process is effective in exchanging properties between the atmosphere and sea-surface and the euphotic zone and the abyssal depths.

The Mediterranean is affected by the westerly flow during the whole year. Moreover, it is exposed to larger scale systems as the South Asian Monsoon (SAM) in summer, the Siberian High Pressure System in winter, the North Atlantic Oscillation (NAO) and the El Niño Southern Oscillation (ENSO).

The eastern Mediterranean multi-scaled circulation is dominated by strong currents and jets as well as by cyclonic/anti-cyclonic eddies and gyres. The circulation is forced by water exchanges through various straits and channels, wind stress, and buoyancy at the surface due to freshwater and heat fluxes. The resulting vertical thermohaline structure comprises the Atlantic water, the Levantine surface water and the Black Sea water at the sea upper layers, the Levantine and Cretan Intermediate Water and the Deep and Bottom Waters masses

The Eastern Mediterranean Transient (EMT), which is an abrupt shift of the deep water formation site from the Adriatic to the Aegean Sea was a major event, unique in the oceanography of the Mediterranean since the beginning of the 20th century and evolved in early 90s. The EMT has gradually decayed since 1995, but the Eastern Mediterranean has not returned to its previous equilibrium. Significant changes in the circulation and the thermohaline structure occurred in the entire Mediterranean.

The Mediterranean Sea is not in a steady state and is potentially very sensitive to changes in atmospheric forcing. In long-term (1910-2000) temperature and salinity show an increasing trend in the intermediate and deep layers, while in the surface layer there is a great variability. However during the last 23 years sea surface warming in the Eastern Mediterranean has been shown to be a fact and follows the warming of the Northern Hemisphere. Comparison of oceanic and atmospheric temperatures revealed periods with agreement and disagreement between them due to both the influence of the atmospheric circulation, as well as other mechanisms, as the ocean circulation and local wind fields explaining the differing thermal behavior of the atmosphere and the ocean.

Discussion

The discussion after the presentations was focused on the role of prevailing currents in the Eastern Mediterranean which favored the expansion of Lessepsian species. The currents contributed either by transferring the planktonic stages and/or by forming favorable environmental conditions for the survival, growth and reproduction of immigrating Indo-Pacific species. It was further discussed the link between the differentiation of the biotic assemblages and the circulation of the water-masses, particularly that of the mesoscale eddies, like for example the Rhodos cyclone and the neighbouring Ierapetra anticyclone. The effects of global warming and the significant change of hydrological conditions in the eastern Mediterranean were also discussed, and the participants highlighted the importance monitoring environmental parameters to better understand the migration mechanisms and pathways of lessepsian species.

General information on the lessepsian species expansion and monitoring.

The meeting was then followed by presentations on lessepsian species from scientists of the Eastern Mediterranean countries. Several discussions arose after each presentation. The following are abstracts of the presentations:

Status, Trend and Monitoring of Lessepsian Species in the North-eastern Mediterranean Sea (presented by Mr. Cemal Turan, Turkey)

Lessepsian species and their roles in the benthic and pelagic ecosystems are increasingly becoming a subject of study in many countries. The impacts of lessepsian species on their new environment include restructuring established food webs, competition with native organisms for food and space and altering the gene pool when the invading organisms reproduce with native species, altering evolutionary processes and causing dramatic changes in native populations. So far, sixty five indo-Pacific fish species has migrated to the Mediterranean Sea. In Turkish coast of Mediterranean Sea, catch composition of fisheries has been changed and the lessepsian species comprise the majority. According to size of populations, three types of introduced species by Suez Chanel can be distinguished in Turkish waters: Rare species, species having established stable populations, very common and abundant migrant species. On the other hand, there are harmful effects of the lessepsian species. These can be categorised as: (a) health problem (poisoning, pain) for fishermen, swimmers, divers, tourism, (b) net damages, (c) mesh clogging, (d) fouling and (e) extra labour for fishermen. There are three types of consequences of introduction of lessepsian immigrants in Turkey: ecological consequences, economical consequences, economical and ecological consequences. Management actions for the lessepsian species could include appropriate legislation to prevent species introduction, increase the knowledge of the biology of aliens and indigenous species as well as the invasion mechanisms, biological methods such as introduction of predators, target vectors of invasion, good knowledge on the fauna of Suez Chanel and Red Sea and cooperation between the countries concerned. The control of lessepsian migrant is difficult because there are no physical border between the Red Sea and Mediterranean. Therefore stopping lessepsian species from the Suez Chanel does not seem to be possible. However, slowing down of the lessepsian species passage to the Mediterranean Sea should be urgently studied. A warning system is needed for harmful species to mitigate negative impacts to the fishermen, fish farming and human health. A special alarm system and data base can be executed mainly for the venomous fish and other species like jelly fish and others. For example, the CIESM has initiated International JellyWatch Programme for monitoring jellyfish blooms along Mediterranean coasts.

Past and present of fish fauna in the NE Levant Sea and factor facilitating the colonization by lessepsian fishes (presented by Mr. Ali Cemal Gucu, Turkey)

Occurrence of lessepsian fishes in the bottom trawl surveys carried out in 1980's and 2000's were compared. Surprisingly the percentages of lessepsian fishes in the total catch (fish only) were significantly higher in 1980's (40-50%) almost twice the percentage in 2000's (20-30%). Yet, a slight decrease in the occurrence of lessepsian fish was noted as the last 5 years were considered. However the number of lessepsian fish species observed in the catch are much larger in the recent surveys as compared to 1980's and the number is keep increasing with a rate of 1.7 species per year. The comparison of these results with a neighbouring Fisheries Restricted Area represented a similar rate of increase in the number of lessepsian fish species (1.2 lessepsian fish/year) despite significantly reduced fishing pressure in the FRA. The percentage of lessepsian fishes in the total fish biomass, however, has increased remarkably within the FRA, possibly indicating that the Lessepsian fishes show faster recovery rate than the native species when a stress factor over the ecosystem is removed or at least reduced.

On the other hand, the pelagic trawl surveys conducted on the same area showed that lessepsian small pelagic fishes were not as successful as the demersal fishes. Their involvement was around 5-7% of the total small pelagic catch. This is probably due to successful adaptive feeding and spawning strategies of the dominant native small pelagic fish, *Sardinella aurita* agreeing well with the eutrophic and subtropical nature of the area. Yet, in contrary to its demersal counterparts, *S. aurita* is a thermophilic species. This feature enhances its resilience against intruders.

The nature of the Lessepsian migration "problem" and its effect to the Hellenic Fisheries (presented by Ms Eugenia Lefkaditou, Greece)

The migration of marine species from the Red Sea to the Mediterranean Sea was enabled by the opening of Suez Canal in 1869 and facilitated by the continuous dredging of the canal and the construction of the Aswan High Dam, which resulted into the gradual removal of salinity barriers due to the hyperaline waters of the Bitter Lakes and the periodical Nile river dilution. Furthermore, rising of Mediterranean sea-water temperature due to the global warming, favours northward expansion of thermophilic species including migrants of Indo-Pacific origin by providing them with a distinct advantage in interspecific interactions with the native Mediterranean species of cold water affinity. The evaluation of the Lessepsian migration effects on native species populations is even more complex, as these latter apart from stress due to their physiological constraints, also undergo pressure due to overfishing and coastal habitat destruction.

In the Hellenic Seas, the Lessepsian migrants caught by fishing gears include 28 fish, 11 crustacean and 1 cephalopod species (Annex V) according to up-to-date information derived by the Ellenic Network on Aquatic Invasive Species (ELNAIS). However, most of them have been scarcely recorded only to the southeastern Aegean Sea and at depths lower than 100 m. According to the data kept in the Fisheries Data Base of the Institute of Marine Biological

Resources (HCMR), which were systematically collected, through experimental trawl surveys, surveys using observers on board commercial vessels and landing inventories at fishing ports all over the country, only nine Lessepsian fish species, *Etrumeus teres, Fistularia commersoni, Lagocephalus sceleratus, Pteragogus pelycus, Siganus luridus, Siganus rivulatus*, and *Upeneus molucensis*, and *Upeneus pori*, might be considered as rather regularly occurring in the catches of at least one fishing gear in the southernmost areas of Hellenic territorial waters, whereas only *Siganus* sp. are reported as landed in Rhodes and Crete islands. The major part of Lessepsian fish caught by boat seine, static nets, bottom trawl and purse-seine, are discarded due to the small quantities obtained and the generally small size of caught individuals. In conclusion, effects of Lessepsian migration have a local character and are restricted in specific coastal fisheries mainly in SE Aegean. The systematic and continuous monitoring of the Lessepsian species catches (landed and discarded) by the different fishing gears, parallel to the monitoring of environmental parameters particularly in inshore waters, is necessary to improve our understanding of these species population dynamics and the existing linkages with environmental variability.

Lessepsian fish species of Cyprus (presented by Mr. Nikolas Michailidis)

A total of 133 alien species have been recorded so far in Cyprus (30 fish, 44 molluscs, 19 polychaetes, 15 phytobenthic species, 12 crustaceans and 13 species from other taxa). Of these, 109 are Lessepsian (105 of Indo-Pacific origin, 4 cosmopolitan or circumtropical). A total of 27 Lessepsian fish species (all of Indo-Pacific or Red Sea origin) were recorded:

- 4 invasive (*Siganus luridus, Siganus rivulatus, Lagocephalus sceleratus, Fistularia commersonii*)
- 19 established (*Atherinomorus lacunosus, Stephanolepis diaspros, Saurida undosquamis, Saurida undosquamis, Sargocentron rubrum, Alepes djedaba, Alepes djedaba, Hemiramphus far, Sphyraena chrysotaenia, Upeneus moluccensis, Dussumieria elopsoides, Pempheris vanicolensis, Pempheris vanicolensis, Etrumeus teres, Parexocoetus mento, Upeneus pori, Lagocephalus spadiceus, Lagocephalus spadiceus, Scomberomorus commerson*)
- 3 casual (*Herklotsichthys punctatus, Sillago sihama, Scarus ghobban*)
- 1 questionable (*Himantura uarnak*)
- there is also 1 cephalopod species - *Sepioteuthis lessoniana* (established).

Palestine (presented by Mr. Abdalnasser Madi, Palestine)

The General Directorate of fisheries identified several lessepsian species which are found in the Palestinian fishing area in the coast of Gaza. The fish statistics in Palestine includes the amount of the caught from the lessepsian species. The universities or any research institutions do not have the resources to follow up research on lessepsian species. The close proximity of the Gaza Strip to the Suez canal gives the area an advantage in conducting research and studies on lessepsian species and its effect on the fisheries.

Lebanon (presented by Samir Majdalani and Dahej El Mokdad, Lebanon)

Lessepsian Migration was reported in Lebanon for many decades and it happened for many reasons such as changes in water temperature and a decrease of the nutritional resources. However many lessepsian species are reported in Lebanon after the opening of the Egyptian-Suez Canal. Most species are important for our fisheries like *Siganus* spp., *Mullus* spp., *Scomberomorus commerson* unlike others like puffer fish (*Lagocephalus sceleratus*) which are harmful to both fishermen and consumers. They are attacking other species and at the same time are damaging the fishing nets. In addition, they are poisonous and harmed many people. Since this fish is dangerous, so mitigation measures are urgently needed to decrease its harmful effects. In our opinion, the problem can be resolved by using stronger nets and by learning the technique of removing the poison from their body for the nutritional purposes.

Is the Lessepsian province in expansion? (presented by M. Corsini-Foka, Greece)

Mrs M. Corsini-Foka reported the main factors contributing to the increased number of alien species of Indo-Pacific origin introductions observed in the last decades in the Mediterranean, underlying that the Erythrean invasion is no more limited to the Eastern basin, but it is showing a significant expansion northwards and westwards of its geographic limits, previously assumed to be east of Sicily, South of the Aegean and Adriatic Seas, the well-known "Lessepsian Province".

She mentioned that along the Hellenic waters of the Aegean and Ionian Seas, an increasing trend of alien species was observed since the decade 1980-1990, culminating in the present one. Multiple factors support this increasing trend, global warming and tropicalization scenario included. The Dodecanese Islands belong to the “Lessepsian Province” and they are considered as a hot-spot area for the spread of alien species to the European Mediterranean coasts. In this area occurs the 45% of the alien species recorded in Hellenic waters and the 82% of these alien species signaled from Dodecanese (76 species) has been introduced via the Suez Canal.

Mrs Corsini-Foka assessed that alien fishes of Red Sea-Indo-Pacific origin represent the best example in revealing the expansion of the Lessepsian Province boundaries northwards and westwards into the Aegean waters. She listed 30 Indo-Pacific fish species recorded in the southeastern Aegean waters and described their up to date distribution in this sea, underlying that only very recently some of these species entered into the North Aegean and are trying to establish there.

She reported recent qualitative and quantitative results obtained in Dodecanese coastal fishery, asserting that only five Lessepsian fish species show a local commercial importance, while the major part are discarded, in particular *Fistularia commersonii* and the toxic *Lagocephalus sceleratus*, both widely distributed and abundant. She gave also some information on Lessepsian invertebrates present in the area.

She discussed the socio-economic and ecological impact of introduced Erythrean species on native biotic communities and also the serious danger for public health of the highly toxic *L. sceleratus*, suggesting furthermore the promotion of various coordinated actions to better understand and face the problem.

Summary Data from countries on Lessepsian Species

At the end of this session Mrs E. Lefkaditou presented the information and data received from the participants before the meeting for the compilation of an Excel Template (sent on behalf of the organizing committee of the meeting) relevant to Lessepsian species first records by geographic area, frequency of occurrence and CPUE data of Lessepsian species by fishing gear and relevant literature.

Due to the scarcity of published information on recent data on Lessepsian fisheries, the group proposed to include in the Report of the Technical Meeting a single Table including indicative information on the Lessepsian species recorded and the fishing gears catching these species in substantial quantities by country/GSA/geographic region (Annex V).

Information on the status of knowledge on key lessepsian species biology, ecology and impact on fisheries

There were only two but interesting presentations in this session, concerning the biology of *Lagocephalus sceleratus* in Cyprus waters and the contribution of Lessepsian species in the fish assemblages at *Posidonia oceanica* meadows and sandy coastal habitats around Rhodos island.(Greece). The abstract of the presentations are provided below.

Study on *Lagocephalus sceleratus* in Cyprus (presented by Mr.Nikolas Michailidis)

The Department of Fisheries and Marine Research of Cyprus collected data on *L. sceleratus* for a period of 8 months in the years 2009 and 2010, in order to attain information on the species and the problems it is causing to the marine environment and the fisheries of Cyprus. Some preliminary results from the analysis of the data are the following:

- Almost isometric growth (same for males and females)
- Seasonalized V. Bertalanffy growth equation (L_{inf}.= 82 cm TL, K = 0.5 yr-1, C=1)
- One spawning season, mainly in June.
- First reproduction at 2 years of age (~ 45 cm TL)
- Main distribution areas: South-East coast of Cyprus (warmer in summer)
- Highly adaptive in feeding behavior (also cannibalistic)
- No effect of bottom type, wind and current conditions or moon phase to the catchability of the fish
- Possible reasons of success: fast growth, early reproduction, high adaptation, especially on feeding habits, no fishing pressure, absence of predators or competitors, high intelligence.
- Possible solutions to the problem: fishing pressure on big individuals before they reproduce, exportation to countries where it has a high price in the market

Moreover Mr. Marios Josephides from DFMR added some information on the possible markets in the far east where the species can be exported after a formal agreement with the EC, considering that according to the current European Union legislative requirements (Regulation 853/2004/EC; Regulation 854/2004/EC), poisonous fish of the family Tetraodontidae and products derived from them must not be placed on the European markets.

Unfortunately Japanese legislation does not allow importation of such species, as well as South Korea. Instead a positive feedback was provided by Chinese market, although there is still not a clear response.

The presentation was followed by a discussion of the group on the feeding habits of the species, growth characteristic, new possible way of consume (e.g. no toxic specimens) and possible gears to avoid the unwanted catch of the species.

Non-indigenous fish species in the food web of *Posidonia oceanica* meadows and sandy habitats from an area of the eastern Mediterranean (presented by Mr. Stefanos Kalogirou)

In *Posidonia oceanica* beds and on sandy bottoms 10 and five species, respectively, were non-indigenous fish of Indo-Pacific origin. The proportional contribution of non-indigenous species individuals on *P. oceanica* beds was similar to that of sandy bottoms (16.5 *vs.* 17 %) but in terms of biomass it was approximately two times higher over sandy bottoms (30 %) compared to *P. oceanica* beds (17 %), indicating that low diverse systems may be more prone to introductions than species-rich communities. On the contrary, a wider food spectrum seemed to be a beneficial trait for the establishment of non-indigenous species in species-rich communities. Quantitative sampling in combination with classification of fish species into six major feeding guilds revealed the role of non-indigenous species in the food web of *Posidonia oceanica* and sandy habitats in an area of the eastern Mediterranean. The two habitats had similar guilds, but the biomass contribution of non-indigenous species varied within each guild, indicating different degrees of impacts on the available resources. This study showed that non-indigenous fish species inhabiting the coastal systems studied significantly contributed to the differences in biomass between habitats. Feeding guild classification helped to demonstrate that the success of fish species introductions was species-dependent.

General Discussion

Future research themes on lessepsian species were discussed especially with respect to fisheries. Ideas were proposed in order to find a commercial market for the species, with the possibility to review and/or develop cooking recipes for such species and distribute them to the general public. *Lagocephalus sceleratus* was highly discussed since at the moment it has become very abundant in the project area with no commercial applications. One possible option that was raised during the meeting was to find alternatives to utilise *L. sceleratus* such as to export *L. sceleratus* to countries where these species are consumed for example Korea, China and Japan. Participants from Cyprus mentioned that they had already tried to contact foreign entities to market *L. sceleratus*, however only China showed an interest in the product with discussions still in progress. Other suggestions were put forward to start research to determine if *L. sceleratus* could be utilized to extract its toxin since the toxin has commercial applications.

Lagocephalus sceleratus has been also discussed with respect to the damage it is causing to fisher`s static nets and longlines in all the countries in the project area. Apparently *L. sceleratus* is eating the fish caught in the fishing gears and in doing so causing a lot of damage to the gears. The group recognized that research should be devoted to solve this problem and suggestions were raised if for example a stronger material to construct the nets could be used which would make the nets more resistant.

The participants mentioned that some lessepsian species such as *Siganus* spp. and *Fistularia commensoni* were successfully introduced into the local markets and are being seen as a positive effect of lessepsian species on the fishery. However in the Greek part of Aegean Sea *F. commensoni* has not been commercialized yet as fishers are discarding this species. The group discussed that it would be useful to start a market strategy to introduce this species in the fish markets and it`s consumption in the Aegean Sea.

The coastal fishery for *Siganus* spp. has been recognized as being commercially important over the whole project area and the need to monitor this fishery was discussed. The participants suggested that catch and effort statistics should be collected for this *Siganus* spp. and possibly consider also biological parameters such as length, weight, sex and maturity and any other data important for the management of the fishery.

Apart from *Siganus* spp. the group also recognized the importance of gathering catch and effort statistics on all the lessepsian migrants encountered in fish markets and that these species should be routinely monitored together with the other native commercial species.

The importance of monitoring lessepsian species in Egypt was highlighted since this is the first country in which lessepsian migrants occur. The focal point for Egypt described that at the moment a pilot study on the collection of fisheries data is being implemented in Egypt with the support of the EASTMED project. The coordinator of the project described that as a part of that pilot study, training courses on the collection of catch and effort and biological data were conducted in November 2010 to the Egyptian authorities responsible for fisheries. During the period of the pilot study, data and information are being gathered on commercial species among which three commercially important lessepsian species are also included.

Educating the local public on the danger that brings the consumption of some lessepsian species was discussed by the group as a high priority since for example *Lagocephalus sceleratus* has already caused death to humans.

Establishment of a network of experts

The participants agreed to set up a network of experts on lessepsian species to continue research of lessepsian species in the project area and to direct to the Coordination Committee through the focal points, proposals to avoid the harmful effect of lessepsian species on the fishery. The group elected Ms. Eugenia Lefkaditou from the Institute of Marine Biological Resources of the Hellenic Center of Marine Research (HCMR) of Greece as Chairperson and Mr. Cemal Turan from the Mustafa Kemal University Fisheries Faculty of Turkey as Vice-Chair of the group. The terms of reference can be found in Annex IV.

The group started the discussion on issues related on lessepsian species in the eastern Mediterranean. The discussion was fuelled by the presentations and studies presented during the meeting. The working documents of the meeting can be found at the end of this report in Annex VI

Recommendations on Future Research

The group recognized the importance to concentrate its effort on two categories of lessepsian species

a) Species of interest for human consumption, including: *Siganus* spp., *Saurida undosquamis*, *Sphyraena chrysotaenia*, *Fistularia commensoni*, *Etrumeus teres, Sepioteutis lessoniana, Marsupenaeus japonicus, Portunus segnis*

AND

b) Harmful species: *Lagocephalus* spp., *Plotosus lineatus* (fish), *Rhopilema nomadica* (jellyfish), *Teredo navalis* (gastropod)

The group agreed that further research is required on the following themes:

1) Increase the knowledge on the biology of indigenous and lessepsian species, in the project area as well as the invasion mechanisms. Specific topics which could be considered include:

- Monitoring of *Siganus* spp. fishery, which is an important coastal fishery for the countries in the project area, to collect catch, effort and biological data (e.g. length, weight, sex, maturity, etc).
- Comparative study on biology of lessepsian species of fishery concern (e.g. *Lagocephalus* spp.) between the project area and the Red Sea.
- Investigation of factors that determine why some lessepsian species and not others have exploded in the project area.
- Gather information on the existing knowledge of fauna of Suez Canal and Red Sea through some other RFMOs or projects in the Red Sea.
- Studies on the connectivity of the populations of lessepsian species using genetic analysis, however this activity may be considered in the future since the populations have been recently established or new alien species.

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2) Increase the knowledge on the changes in the physical environment and its effect on the introduction, expansion and invasion mechanisms of lessepsian species and correlation of these these changes to their biological properties.

3) Gather data on records and landings on lessepsian species in countries where no information exists.

4) Standardize as much as possible the methodologies used to collect data on lessepsian species in the project area.

5) Agree on a common terminology for alien species and any associated definitions by the EastMed project area and possibly to propose an updated terminology to GFCM.

6) Determine the impact of the fishery on the lessepsian species, with classical stock assessment methodology. This can be done with case studies from the project area where data is available for example:

- *Etrumeus teres* small pelagic fishery in southern part of turkey
- Elongated herring purse seine fishery south of turkey
- *Saurida undosquamis*, (Lizard fish) trawl fishery in the South of Turkey

7) Determine the impact of all the lessepsian biota on the fishery and its associated ecosystems.

8) Develop a database on studies on lessepsian species and the legislation in force on lessepsian species in the Mediterranean.

9) Develop methods to adapt the fishery to the introduction of lessepsian species including the market demand. Several ideas were discussed on this important research topic including:

- Consider pilot studies on selective gears (e.g. traps) to catch native target species and avoid dangerous lessepsian species such as *Lagocephalus* spp. and jelly fish
- Suggest methods on ways to use the unwanted lessepsian species caught by fishers e.g. *Lagocephalus* spp., jellyfish, e.g. for food, fish meal, extraction of toxin, exportation.
- Studies on improving the net design to prevent the harmful effects of *Lagocephalus* spp.
- Gather information on fishing gears catching lessepsian species in countries outside the project area where these species are native.
- Market and promote the consumption of lessepsian species which are consumed in some countries but not in others.
- Determine if biological control of harmful lessepsian species is a possible solution.
- Research on how to reduce the vectors of invasion (e.g. ballast waters, aquaculture).

Adoption of the workshop report and closure of the meeting

The Workshop Report was adopted on Friday, 9th December 2010.

ANNEXES

Annex I List of participants

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Annex II Terms of Reference

EastMed Sub-regional Technical meeting on the Lessepsian migration and its impact on eastern Mediterranean fishery

During the Inception Meeting of the FAO EastMed Project, the organization of a technical meeting on alien marine organisms in the eastern Mediterranean, known as Lessepsian species, was decided for the 1st year of the project.

The Terms of Reference for this meeting are the following:

- Overview on the Lessepsian migration phenomenon and the most invasive species

  Invited experts will present an overview on the "Status, trend and monitoring of Lessepsian migrant species in the Mediterranean Sea", as well as, on "the historical events and environmental conditions favoring Lessepsian species expanding in the Mediterranean"

- General information on the Lessepsian species expansion and monitoring

  Experts from the region will bring information on the Lessepsian species recorded in the different areas. Harmful/venomous species will be distinguished from edible/commercial ones. Methods to overcome existing problems will be discussed

- Information on the status of knowledge on key Lessepsian species' biology, ecology and impact on fisheries

  The experts will present all available information on the biology of key Lessepsian species, including data on size composition, abundance and role in local fish assemblages. Fisheries data in terms of Lessepsian species contribution in catch composition by fishing gear and time series on native species catches affected by the phenomenon will be also presented.

- Establishment of a network of experts, to facilitate a coordinated international research effort in order to better evaluate and understand the impact of Lessepsian species on fisheries. The ToR of the network will be drafted among the participants

- Prepare an adequate report of the meeting.

Annex III Agenda

Sub-regional Technical meeting on the Lessepsian migration and its impact on eastern Mediterranean fishery
Cleopatra Hotel, 8 FLORINIS STR. , 1065 NICOSIA, TEL. +357 22 844000, FAX. + 357 22 844222, Nicosia, Cyprus, 7-9 December 2010

Day 1, 9:30 am
1. Opening of the meeting

2. Adoption of the agenda and arrangements of the meeting – Election of a chairman and designation of rapporteurs

3. Objectives of the meeting
a. Presentation of the Terms of Reference of the meeting

4. Overview on the Lessepsian migration phenomenon and the most invasive species
a. Invited experts will present an overview on the "Status, trend and monitoring of Lessepsian migrant species in the Mediterranean Sea", as well as, on "the historical events and environmental conditions favoring Lessepsian species expanding in the Mediterranean"

11:00 Coffee break
11:30 am

5. General information on the Lessepsian species expansion and monitoring
a. Experts from the region will bring information on the Lessepsian species recorded in the different areas. Harmful/venomous species will be distinguished from edible/commercial ones. Data on changes of environmental factors if available, as well as existing databases and monitoring programs, will be discussed
b. Methods to overcome existing problems will be discussed

13:00 Lunch break
14:00

5. General information on the Lessepsian species expansion and monitoring (continued)

6. Information on the status of knowledge on key Lessepsian species biology, ecology and impact on fisheries
a. *The experts will present all available information on the biology of key Lessepsian species, including data on size composition, abundance and role in local fish assemblages. Fisheries data in terms of Lessepsian species contribution in catch composition by fishing gear and time series on native species catches affected by the phenomenon will be also presented.*

15:30 Coffee break
16:00

6. Information on the status of knowledge on key Lessepsian species biology, ecology and impact on fisheries (continued)

Day 2, 9:30 am

7. Presentations relevant to the Lessepsian migration

a. Any other works relevant to the Lessepsian migration will be presented

8. Discussion to be developed

a. *How to access Lessepsian species impact on fisheries*

b. *How to minimize bias made by external factors (climate change, overfishing, other alien species, anthropogenic impact…)*

c. *Methods to overcome problems caused*

11:00 Coffee break

11:30

8. Discussion to be developed (continued)

9. Establishment of a network of experts

a. *Establishment of a network of experts, to facilitate a coordinated international research effort in order to better evaluate and understand the impact of Lessepsian species on fisheries. The ToR of the network will be drafted among the participants*

13:00 Lunch break

14:00
Network of experts (continued)

15:30 Coffee break

16:00

Day 3, 9:30 am

11. Any other matters

12. Approval of minutes and adoption of the report

13. Closure of the meeting

Annex IV Terms of Reference for the Network of experts

Terms of Reference for the Network of experts on the effect of Lessepsian species on Fisheries of the Eastern Mediterranean

1) To standardize as much as possible the methodologies used to collect data on lessepsians in the project area.

2) To promote the issue of lessepsian species in the Mediterranean

3) To develop a common terminology for alien species and any associated definitions and propose an updated terminology to GFCM.

4) To develop a database on studies on lessepsian species and the legislation in force on lessepsians in the Mediterranean.

5) To develop and suggest methods to adapt the fishery to the introduction of lessepsian species in the Mediterranean.

Network of experts on the effect of Lessepsian species on Fisheries of the Eastern Mediterranean

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Annex V List of Lessepsian species caught by fishing gears

List of Lessepsian species caught by fishing gears in the Mediterranean Sea
and indicative data on the species expansion and capture by fisheries
in different geographic divisions of the EastMed Project area,
as provided by the Network of experts

Fishing Gear	Symbols
Boat seine	BS
Purse seine	PS
Bottom trawl	BT
Long lines	LL
Nets	N
Gill Nets	GN
Trammel Nets	TN
Pots-Traps	PT
Hand-line	HL
Recorded species	Y

Species name	Category	Egypt GSA 26 S Levantine	Palestine GSA 27 E Levantine	Lebanon GSA 27 E Levantine	Cyprus GSA 25 NE Levant
Alepes djedaba	fish	PS	PS,BT,GN	Y	Y
Apogon fasciatus	fish				
Apogon pharaonis [1]	fish	BT, BS		Y	Y
Apogon queketti	fish			Y	
Apogon smithi	fish			Y	
Atherinomorus lacunosus [2]	fish	Y		Y	Y
Bregmaceros atlanticus	fish				
Callionymus filamentosus	fish	BT		Y	
Champsodon vorax	fish			Y	
Crenidens crenidens	fish	BT			
Cyclichthys spilostylus	fish				
Cynoglossus sinusarabici	fish	Y		Y	
Decapterus russelli	fish			Y	
Dussumieria elopsoides [3]	fish	PS		Y	Y
Epinephelus coioides	fish				
Epinephelus malabaricus	fish				
Equulites klunzingeri [4]	fish	BT		Y	Y
Etrumeus teres	fish	Y		Y	Y
Fistularia commersonii	fish		BT	Y	Y
Hemiramphus far	fish	PS		Y	Y
Heniochus intermedium	fish			Y	
Herklotsichthys punctatus	fish	Y		Y	Y
Himantura uarnak	fish	Y	GN,BT	Y	Y
Hippocampus fuscus	fish			Y	
Hyporhamphus affinis	fish				
Iniistius pavo	fish				
Lagocephalus sceleratus ● ▲	fish			Y	Y
Lagocephalus spadiceus ●	fish	Y		Y	Y
Lagocephalus suezensis ●	fish	Y		Y	Y
Liza carinata	fish	Y		Y	
Monotaxis grandoculis	fish				
Muraenesox cinereus	fish			Y	
Nemipterus randalli	fish			Y	
Oxyurichthys papuensis [5]	fish	BS		Y	
Papilloculiceps longiceps	fish				
Parexocoetus mento	fish	Y		Y	Y
Parupeneus forsskali	fish				

Species name	Category	Egypt GSA 26 S Levantine	Palestine GSA 27 E Levantine	Lebanon GSA 27 E Levantine	Cyprus GSA 25 NE Levant
Pelates quadrilineatus	fish	Y		Y	
Pempheris vanicolensis	fish			Y	Y
Petroscirtes ancylodon	fish				
Platax teira	fish				
Platycephalus indicus	fish	Y		Y	
Plotosus lineatus ●	fish			Y	
Pomacanthus maculosus	fish			Y	
Pomadasys stridens	fish	Y		Y	
Priacanthus Sagittarius	fish				
Pteragogus pelycus	fish			Y	Y
Pterois miles	fish				
Rachycentron canadum	fish				
Rastrelliger kanagurta	fish				
Rhabdosargus haffara	fish			Y	
Rhynchoconger trewavasae	fish				
Sargocentron rubrum [6]	fish	Y	BT,GN	Y	Y
Saurida undosquamis	fish	BT	BT,GN	Y	Y
Scarus ghobban	fish			Y	Y
Scomberomorus commerson	fish	PS	BT,PS,LL,GN	Y	Y
Siganus javus	fish				
Siganus luridus	fish	Y	GN,BT,PS	Y	Y
Siganus rivulatus	fish	Y	GN,BT,PS	Y	Y
Silhouetta aegyptia	fish	Y			
Sillago sihama	fish	Y		Y	Y
Sorsogona prionota	fish				
Sphyraena chrysotaenia	fish	BT	GN,PS	Y	Y
Sphyraena flavicauda	fish	Y			
Sprateloides delicatulus	fish				
Stephanolepis diaspros	fish	BT	LL,BT	Y	Y
Terapon jarbua	fish				
Terapon puta	fish	BT, PS		Y	
Terapon theraps	fish				
Tetrosomus gibbosus	fish				
Torquigener flavimaculosus	fish				
Trachurus indicus	fish				
Tylerius spinosissimus	fish			Y	
Tylosurus choram	fish	PS		Y	
Upeneus moluccensis	fish	Y	BT,GN	Y	Y
Upeneus pori [7]	fish	Y	BT,GN	Y	Y
Vanderhorstia mertensi	fish				

Species name	Category	Egypt GSA 26 S Levantine	Palestine GSA 27 E Levantine	Lebanon GSA 27 E Levantine	Cyprus GSA 25 NE Levant
Sepioteuthis lessoniana	squid				Y
Octopus aegina	octopus				
Strombus persicus	gastropod			Y	Y
Erugosquilla massavensis	mantis squilla	Y		Y	
Marsupenaeus japonicus	shrimp	Y		Y	
Metapenaeopsis aegypta	shrimp	Y		Y	
Metapenaeopsis mogiensis	shrimp				
Metapenaeus monoceros	shrimp	Y	BT,TN	Y	
Metapenaeus stebbingi	shrimp	Y	BT,TN	Y	
Trachysalambria palaestinensis [8]	shrimp	Y			
Charybdis hellerii	crab	Y		Y	
Charybdis longicollis	crab	Y		Y	
Eurycarcinus integrifrons	crab				
Gonioinfradens paucidentatus	crab				
Ixa monodi	crab			Y	
Leucosia signata	crab	Y		Y	
Myra subgranulata	Crab	Y		Y	
Portunus segnis [9]	crab	Y	BT,TN	Y	
Diadema setosum ●	urchin			Y	
Ropilema nomadica ▲ ●	jellyfish			Y	
Macrorhynchia philippina ●	hydroid			Y	
Synaptula resiprocans ▲	holothurian			Y	
Serpulids polychaetes ▲	polychaete				

● Venomous, ▲ Harmful for fisheries or aquaculture

[1] Synonym to Apogon nigripinnis according to Gon & Randall (2003)

[2] Synonym to Pranesus pinquis (Lacepède, 1803) and Atherina forskali (Rׂóppell, 1838)

[3] Synonym to Leiognathus klunzingeri (Steindachner, 1898)

[4] According to the revision of Clupeidae systematics in Whitehead (1985) lessepsian immigrant, previously reported as Dussumieria acuta was assigned to D. elopsoides.

[5] Synonym to Oxyurichthys petersii

[6] Synonym to Holocentrus rubber

[7] In some cases misidentified as *Upeneus asymmetricus* according to Torcu & Mater (2000)

[8] In some cases identified as Trachysalambria curvirostris

[9] According to the recent revision of the systematics of the *Portunus pelagicus* species complex (Lai et al., 2010), lessepsian migrant was assigned to *Portunus segnis*

Species in shaded lines have not yet been recorded in countries participating in the EastMed Project.

Species name	Category	Turkey		Greece	
		GSA 24	GSA 22	GSA 24	GSA 23
		Levant	Aegean	Megisti Isl.	Crete Isl.
Alepes djedaba	fish	PS			
Apogon fasciatus	fish	PS, BT			
Apogon pharaonis [1]	fish	BT		Y	
Apogon queketti	fish	BT			
Apogon smithi	fish	BT			
Atherinomorus lacunosus [2]	fish	BT	BT		
Bregmaceros atlanticus	fish	BT	BT		
Callionymus filamentosus	fish	BT			BT
Champsodon vorax	fish				
Crenidens crenidens	fish				
Cyclichthys spilostylus	fish				
Cynoglossus sinusarabici	fish	BT			
Decapterus russelli	fish	PS			
Dussumieria elopsoides	fish	PS			
Epinephelus coioides	fish				
Epinephelus malabaricus	fish				
Equulites klunzingeri [3]	fish	BT			
Etrumeus teres	fish	PS	PS		BT, PS
Fistularia commersonii	fish	BT,PS,GN	BT,PS,GN	Y	N
Hemiramphus far	fish	TN,GN,PS,BT	TN,GN,PS,BT		
Heniochus intermedium	fish	TN,GN			
Herklotsichthys punctatus	fish	PS			
Himantura uarnak	fish	BT			
Hippocampus fuscus	fish	BT			
Hyporhamphus affinis	fish				
Iniistius pavo	fish				
Lagocephalus sceleratus ● ▲	fish	GN,BT,PS	GN,BT,PS		BS,LL,HL,BT,N
Lagocephalus spadiceus ●	fish	BT, GN,PS	GN,BT,PS		
Lagocephalus suezensis ●	fish	GN,BT,PS	GN,BT,PS		
Liza carinata	fish	GN, BT			
Monotaxis grandoculis	fish	Y			
Muraenesox cinereus	fish				
Nemipterus randalli	fish	GN,BT			
Oxyurichthys papuensis	fish	BT			
Papilloculiceps longiceps	fish				
Parexocoetus mento	fish	PS	N		Y
Parupeneus forsskali	fish	GN			

Species name	Category	Turkey		Greece	
		GSA 24	GSA 22	GSA 24	GSA 23
		Levant	Aegean	Megisti Isl.	Crete Isl.
Pelates quadrilineatus	fish	BT,GN			
Pempheris vanicolensis	fish	GN, BT	BT	TN	Y
Petroscirtes ancylodon	fish	BT	BT	Y	
Platax teira	fish		TN		
Platycephalus indicus	fish				
Plotosus lineatus ●	fish				
Pomacanthus maculosus	fish				
Pomadasys stridens	fish	BT, GN,TN			
Priacanthus sagittarius	fish				
Pteragogus pelycus	fish	BT, GN,TN	GN,TN		Y
Pterois miles	fish				
Rachycentron canadum	fish				
Rastrelliger kanagurta	fish				
Rhabdosargus haffara	fish				
Rhynchoconger trewavasae	fish				
Sargocentron rubrum[4]	fish	GN,TN	GN,TN	TN, LL	Y
Saurida undosquamis	fish	BT, GN,TN	BT, GN,TN		Y
Scarus ghobban	fish				
Scomberomorus commerson	fish	GN,TN, PS	BT,GN,TN		
Siganus javus	fish				
Siganus luridus	fish	BT, GN,TN	BT,GN,TN	TN	TN
Siganus rivulatus	fish	BT, GN,TN	BT, GN,TN	TN	TN
Silhouetta aegyptia	fish				
Sillago sihama	fish	BT			
Sorsogona prionota	fish				
Sphyraena chrysotaenia	fish	BT, GN,TN,PS	GN,TN,PS,BT		
Sphyraena flavicauda	fish	BT, PS			
Sprateloides delicatulus	fish				
Stephanolepis diaspros	fish	BT	N,BT		BT, N, BS
Terapon jarbua	fish				
Terapon puta	fish				
Terapon theraps	fish				
Tetrosomus gibbosus	fish				
Torquigener flavimaculosus	fish	BT	BT	Y	BS
Trachurus indicus	fish	PS			
Tylerius spinosissimus	fish	BT			
Tylosurus choram	fish				
Upeneus moluccensis	fish	BT,PS, GN	BT,PS, GN		BT
Upeneus pori	fish	BT,PS, GN			Y
Vanderhorstia mertensi	fish	BT			

Species name	Category	Turkey GSA 24 Levant	Turkey GSA 22 Aegean	Greece GSA 24 Megisti Isl.	Greece GSA 23 Crete Isl.
Sepioteuthis lessoniana	squid	BT		Y	
Octopus aegina	octopus	BT	Y		
Strombus persicus	gastropod	Y			
Erugosquilla massavensis	mantis squilla	GN,TN,BT	Y		
Marsupenaeus japonicus	shrimp	BT,GN	Y		
Metapenaeopsis aegypta	shrimp		Y		
Metapenaeopsis mogiensis	shrimp	BT,GN	Y		
Metapenaeus monoceros	shrimp	BT,GN	Y		
Metapenaeus stebbingi	shrimp	BT,GN	Y		
Trachysalambria palaestinensis[5]	shrimp	TN,BT	Y		
Charybdis hellerii	crab	GN,TN,BT	Y	Y	
Charybdis longicollis	crab	BT,GN	Y		
Eurycarcinus integrifrons	crab	BT,GN			
Gonioinfradens paucidentatus	crab				
Ixa monodi	crab	GN,BT	Y		
Leucosia signata	crab				
Myra subgranulata	Crab				
Portunus segnis[6]	crab	GN,TN,BT	Y		
Diadema setosum ●	urchin	N			
Ropilema nomadica ▲ ●	jellyfish	Y			
Macrorhynchia philippina ●	hydroid	Y			
Synaptula resiprocans ▲	holothurian	Y			
Serpulids polychaetes ▲	polychaete	Y			

Species name	Category	Greece GSA 22(a) SE Aegean (N<38°, E<26°) & Rhodes Isl.	Greece GSA 22(b) SW Aegean (N<38o, E>26o)	Greece GSA 22(c) N Aegean (N>38°)	Greece GSA 20 E Ionian	Italy GSA 19 W Ionian
Alepes djedaba	fish	Y				
Apogon fasciatus	fish					
Apogon pharaonis [1]	fish	Y				
Apogon queketti	fish					
Apogon smithi	fish					
Atherinomorus lacunosus [2]	fish	Y				
Bregmaceros atlanticus	fish					
Callionymus filamentosus	fish	BS	BT			
Champsodon vorax	fish					
Crenidens crenidens	fish					
Cyclichthys spilostylus	fish					
Cynoglossus sinusarabici	fish					
Decapterus russelli	fish					
Dussumieria elopsoides	fish					
Epinephelus coioides	fish					
Epinephelus malabaricus	fish					
Equulites klunzingeri [3]	fish	Y	Y			
Etrumeus teres	fish	PS, BS	PS			
Fistularia commersonii	fish	BS, TN	BS	BS	Y	Y
Hemiramphus far	fish	Y				
Heniochus intermedium	fish					
Herklotsichthys punctatus	fish					
Himantura uarnak	fish					
Hippocampus fuscus	fish					
Hyporhamphus affinis	fish					
Iniistius pavo	fish	BS, TN, LL				
Lagocephalus sceleratus ● ▲	fish	BS, TN, LL, HL	BS, LL, HL, BT, N	Y	Y	
Lagocephalus spadiceus ●	fish	BS			BT	
Lagocephalus suezensis ●	fish	BS				
Liza carinata	fish					
Monotaxis grandoculis	fish					
Muraenesox cinereus	fish					
Nemipterus randalli	fish					
Oxyurichthys papuensis	fish					
Papilloculiceps longiceps	fish					
Parexocoetus mento	fish	Y	Y		Y	
Parupeneus forsskali	fish					

Species name	Category	Greece GSA 22(a) SE Aegean (N<38^o, E<26^o) & Rhodes Isl.	GSA 22(b) SW Aegean (N<38o, E>26o)	GSA 22(c) N Aegean (N>38^o)	GSA 20 E Ionian	Italy GSA 19 W Ionian
Pelates quadrilineatus	fish					
Pempheris vanicolensis	fish	Y				
Petroscirtes ancylodon	fish	BS				
Platax teira	fish					
Platycephalus indicus	fish					Y
Plotosus lineatus ●	fish					
Pomacanthus maculosus	fish					
Pomadasys stridens	Fish					
Priacanthus sagittarius	fish					
Pteragogus pelycus	fish	BS, TN	BS			
Pterois miles	fish					
Rachycentron canadum	fish					
Rastrelliger kanagurta	fish					
Rhabdosargus haffara	fish					
Rhynchoconger trewavasae	fish					
Sargocentron rubrum[4]	fish	BS, TN				
Saurida undosquamis	fish	Y	Y		Y	Y
Scarus ghobban	fish					
Scomberomorus commerson	fish	BS		Y		
Siganus javus	fish					
Siganus luridus	fish	BS, N, TN, HL	BS, N		BS, N	
Siganus rivulatus	fish	BS, N, BT, TN, HL	BT		BS, N	
Silhouetta aegyptia	fish					
Sillago sihama	fish					
Sorsogona prionota	fish					
Sphyraena chrysotaenia	fish	BS				
Sphyraena flavicauda	fish	BS				
Sprateloides delicatulus	fish					
Stephanolepis diaspros	fish	BS, TN	BS, N, BT, PS	BS	BT	Y
Terapon jarbua	fish					
Terapon puta	fish					
Terapon theraps	fish					
Tetrosomus gibbosus	fish					
Torquigener flavimaculosus	fish	BS				
Trachurus indicus	fish					
Tylerius spinosissimus	fish	BS				
Tylosurus choram	fish					
Upeneus moluccensis	fish	BT, BS	BT		Y	
Upeneus pori	fish	BS				
Vanderhorstia mertensi	fish					

Species name		Category	Greece				Italy
			GSA 22 (a) SE Aegean ($N<38^o$, $E<26^o$) & Rhodes Isl.	**GSA 22(b)** SW Aegean (N<38o, E>26o)	**GSA 22(c)** N Aegean ($N>38^o$)	**GSA 20** E Ionian	**GSA 19** W Ionian
Sepioteuthis lessoniana		squid	Y				
Octopus aegina		octopus					
Strombus persicus		gastropod	Y				
Erugosquilla massavensis		mantis squilla					
Marsupenaeus japonicus		shrimp	Y				Y
Metapenaeopsis aegypta		shrimp	BT				
Metapenaeopsis mogiensis		shrimp	Y				
Metapenaeus monoceros		shrimp	Y				
Metapenaeus stebbingi		shrimp					
Trachysalambria palaestinensis[5]		shrimp					
Charybdis hellerii		crab	Y				
Charybdis longicollis		crab	TN				
Eurycarcinus integrifrons		crab	Y				
Gonioinfradens paucidentatus		crab					
Ixa monodi		crab	PT				
Leucosia signata		crab	TN				
Myra subgranulata		Crab	TN				
Portunus segnis[6]		crab	TN				
Diadema setosum	●	urchin	TN				
Ropilema nomadica	▲ ●	jellyfish					
Macrorhynchia philippina	●	hydroid					
Synaptula resiprocans	▲	holothurian					
Serpulids polychaetes	▲	polychaete					

Annex VI Working papers presented during the meeting

EastMed

Sub-regional Technical meeting on the Lessepsian migration and its impact on eastern Mediterranean fishery

Nicosia, 7-9 December 2010

Variability of the circulation and water properties in the Eastern Mediterranean in the context of the climatic change: An overview

Alexander Theocharis
Athens-Greece

Abstract

The Mediterranean Sea is a semi-enclosed, deep (average depth 1.45 km, max. depth 5.5 km), oligotrophic, concentration basin with high density water production. It communicates to the west with the Atlantic Ocean, to the Northeast with the Black Sea and to the southeast with the Red Sea. It is composed by two major interacting sub-basins, the western and eastern Mediterranean. The Mediterranean region is a climate transition area, tightly related to the global climate variability. Within the last two decades, more and more scientific evidences are indicating that environmental changes are occurring at all scales with profound impacts on among others the Mediterranean basins and coasts. Because the European climate (including the Mediterranean) is under the influence of both subtropical and arctic regimes, the evolution of the physical parameters (i.e. temperature, salinity) in response to global warming is adjusting to the regional climate and circulation.

The prevailing multi-scaled circulation of the eastern Mediterranean Basin is dominated by strong currents and jets, as well as, by cyclonic/anti-cyclonic eddies and gyres. The eastern Mediterranean Sea has undergone major changes in circulation and water properties during the last 23 years; it is not yet in a steady state and is potentially very sensitive to changes in atmospheric forcing. Sea-surface warming follows the warming of the Northern Hemisphere. It is necessary to continuously monitor the environmental parameters for better understanding of Lessepsian migration mechanisms and pathways.

Geography, Topography and Climatic conditions

The Mediterranean Sea (area: 2.26 x 10^6 km^2, volume 3.2 x 10^6 km^3, average depth 1.45 km, max. depth 5.5 km) is an elongated, semi-enclosed, marginal almost isolated midlatitude (30-45^{o}N) basin bounded by the European, North-African and west Asian coasts (Fig. 1). It communicates with the Atlantic Ocean through the narrow (15km) and shallow (~250m) Strait of Gibraltar. It is composed by two major interacting sub-basins, the western and eastern Mediterranean, connected by the Straits of Sicily with sill depth ~1000m. In each sub-basin there exist a number of smaller basins and seas; the Alboran, the Balearic, the Ligurian and Tyrrhenian in the west and the Ionian, Levantine, Adriatic and Aegean in the east. To the northeast the Mediterranean communicates with the Black Sea through the Strait of Dardanelles (61km long, 1,2-6.0 km wide and 82 m max depth) that joins the Aegean and Marmara Seas. Finally, to the southeast it communicates with the Red Sea through the long and narrow Suez Canal (total length 190km, max width 160-200m and depth 11.6m). The deepest region of the Mediterranean is found in the eastern Ionian (Vavilov Deep, 5520m) and along the Hellenic Trench to the south of the Cretan Arc area (max depth at the Rhodes abyssal basin, 4500m).

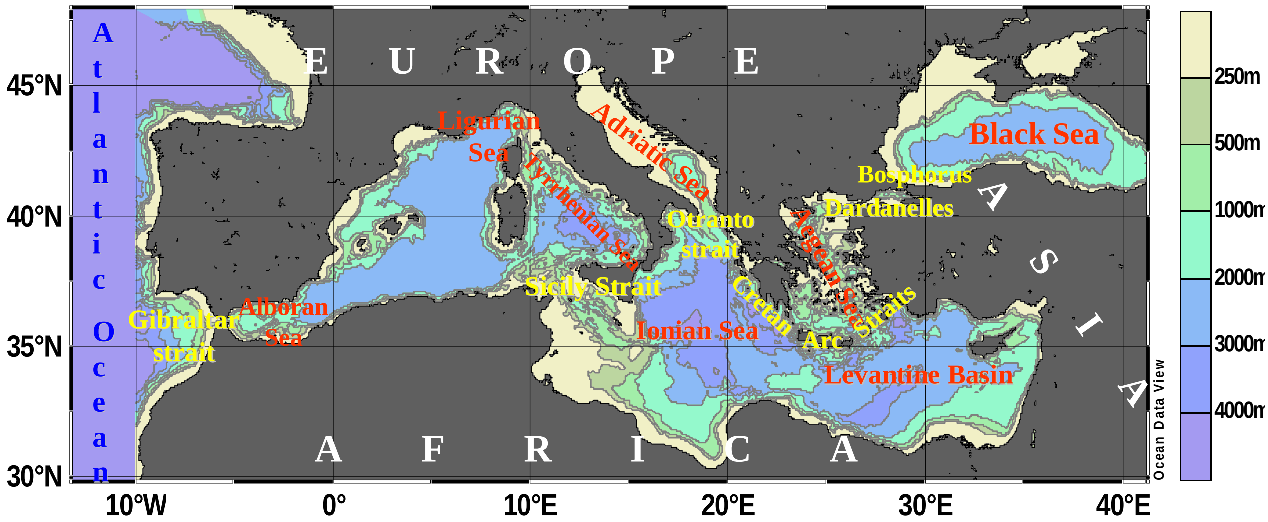


Figure 1. The Mediterranean Sea

The Mediterranean region and the surrounding lands are influenced by some of the most relevant mechanisms acting upon the global climate system (Xoplaki et al., 2003). It marks a transitional zone between the deserts of North Africa and the central and northern Europe tightly related to the global climate variability with intense scale-interaction processes. It is not only under the influence of tropical phenomena, such as ENSO and tropical monsoons, but also under strong control of mid and high latitude meteorological systems (e.g. NAO). Current research has not yet reached conclusive results on these teleconnection mechanisms. It is affected by the westerly flow during the whole year and also exposed to larger scale atmospheric systems, as the South Asian Monsoon (SAM) in summer, the Siberian High Pressure System in winter, the North Atlantic Oscillation (NAO) and the El-Niño Southern Oscillation (ENSO) (Corte-Real et al., 1995; Hurrell, 1995; Maheras et al., 1999).

The Mediterranean Circulation and its variability.

The Mediterranean develops its own circulation regime, which is decoupled from the Atlantic, while many processes that are fundamental to the general circulation of the World Ocean also occur within the Mediterranean, either identically or analogously (Robinson et al., 2001). Therefore, as a “regional” sea and a “miniature” ocean (Bethoux *et al.*, 1999), the Mediterranean has undergone both global and regional changes.

The Mediterranean is classified as a concentration basin, where evaporation exceeds precipitation and river runoff, with high-density water production. It receives light, low salinity waters from the Atlantic Ocean through Gibraltar and into the east Mediterranean through Sicily Strait at the surface layers and exports dense and saline waters by underwater currents. It also receives fresh waters, but to a lesser extent, from the Black Sea at the surface layers. This type of circulation is called “lagoonal”. Therefore, equilibrium is reached by which the salinity remains constant. The water transport through the Suez Canal is considered negligible.

In the largest scales of interest, i.e. interannual and basin-wide scales, the circulation of the Mediterranean is determined by its exchanges of water and heat with the atmosphere through the sea surface and the water and salt with the adjacent seas through the various Straits and channels. The thermohaline circulation of the Mediterranean, which reflects the largest scale motion, is forced by the buoyancy exchanges and is driven by its negative heat and freshwater budgets.

Therefore, in general, two kinds of thermohaline cells result. The first, the upper open conveyor belt, is consisted by (i) the non-return flow of low salinity Atlantic Water (AW), entering from the Gibraltar Strait, to the easternmost end of the Levantine Basin in the upper 150-200m and (ii) the formation and westward spreading of the warm and saline (S~39.00-39.1 at the source area) Levantine Intermediate Water (LIW), at depths 200-400m, to the Gibraltar, where it enters the Atlantic Ocean. Secondly, there exist internal thermohaline cells or closed conveyor belts in each of the Mediterranean sub-basins driven by deep water formation processes (Theocharis et al., 1998) (Fig. 2).

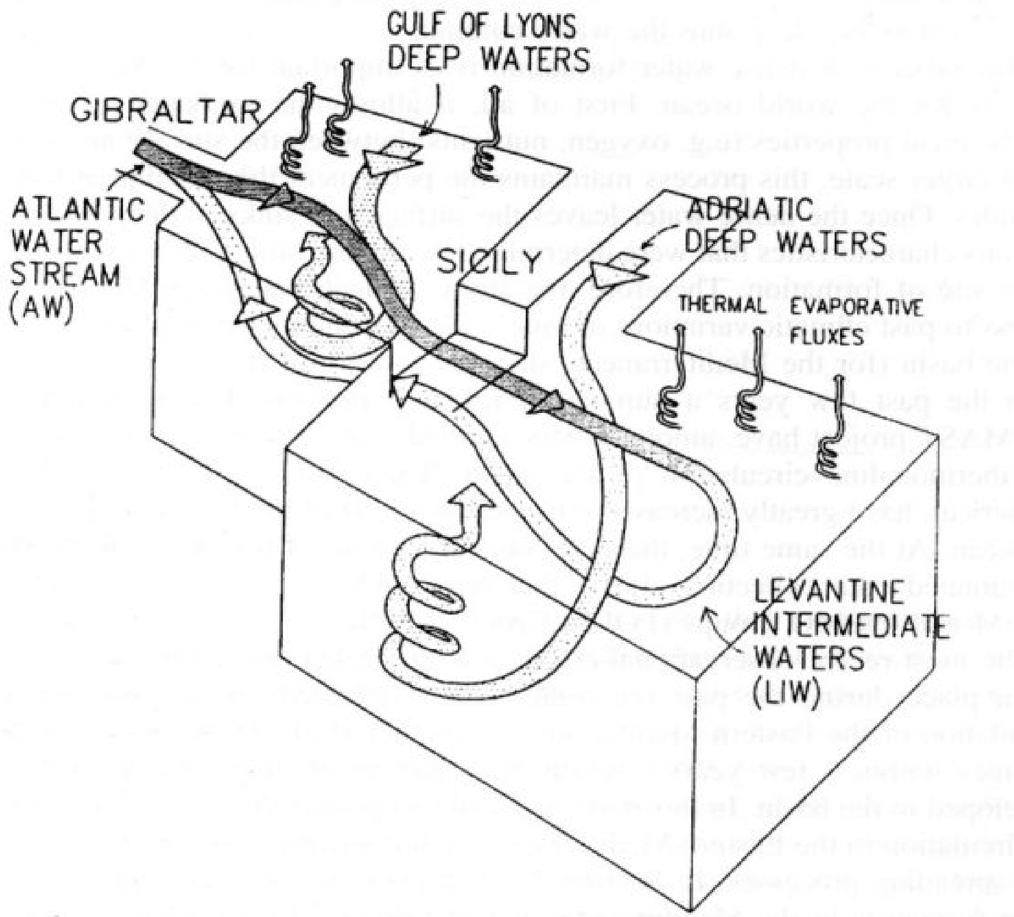


Fig. 2. Schematic representation of the thermohaline circulation in the Mediterranean Sea.

The resulting vertical thermohaline structure in the Eastern Mediterranean comprises (i) the Atlantic Water (AW), the Levantine Surface Water (LSW) and the Black Sea Water (BSW) at the sea upper layers, (ii) the Levantine and Cretan Intermediate Waters (LIW and CIW) and (iii) the Deep and Bottom Water masses (EMDW). The LSW is formed during the warm period of the year in the Levantine Basin and spreads westwards entering the Aegean through the eastern Cretan Arc Straits. The eastwards flowing AW that enters from the Gibraltar gains salt and heat by mixing along its route. LIW is considered the most important component of the large scale circulation and dynamics because it spreads throughout most of the Basin, including the Adriatic and Aegean, and affects the background stratification at these major areas of deep water formation. Another loop of the upper layers connects the Mediterranean with the Black Sea. In the latter case, the Aegean Sea acts as an intermediate machine that modifies the received LIW and exports it to the Black Sea via the Marmara Sea.

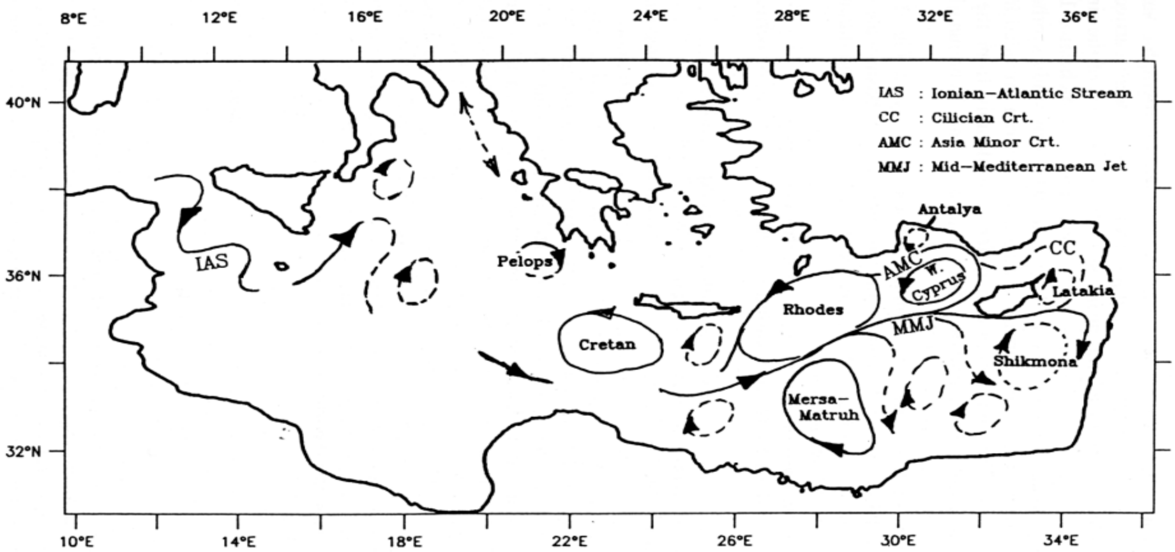


Figure 3 Circulation pattern of the Eastern Mediterranean as inferred from the multinational research program POEM 1985-1987 (POEM group, 1992)

The first attempt to construct a general circulation map of the entire Mediterranean was made by Nielsen (1912). Several basic circulation features were well represented; the AW stream as a rim current along the African coasts, the branching and turning to the north within the Western Basin and in the Eastern Basin turning along the south coasts of Asia Minor then entering the Aegean through the east Cretan Arc Straits. Also, the BSW route is well represented. Another feature is the subsurface flow that represents the LIW and CIW westward route.

Later Ovchinnikov et al., 1966 used great amount of data and produced a rather more detailed “composite” circulation map showing the general, but also the mesoscale features. However these patterns differ in some extent from the relatively recent 1985-90 circulation revealed from the POEM program.

The new picture of the general circulation in the eastern Mediterranean Sea, which emerged during the past twenty five years from the data, collected and analyzed in the frame of multinational and international research programs (POEM, EU programs, etc), is more complex, and composed of three predominant and interacting spatial scales: the basin scale, including the thermohaline (vertical/circulation), the sub-basin scale, and the mesoscale.

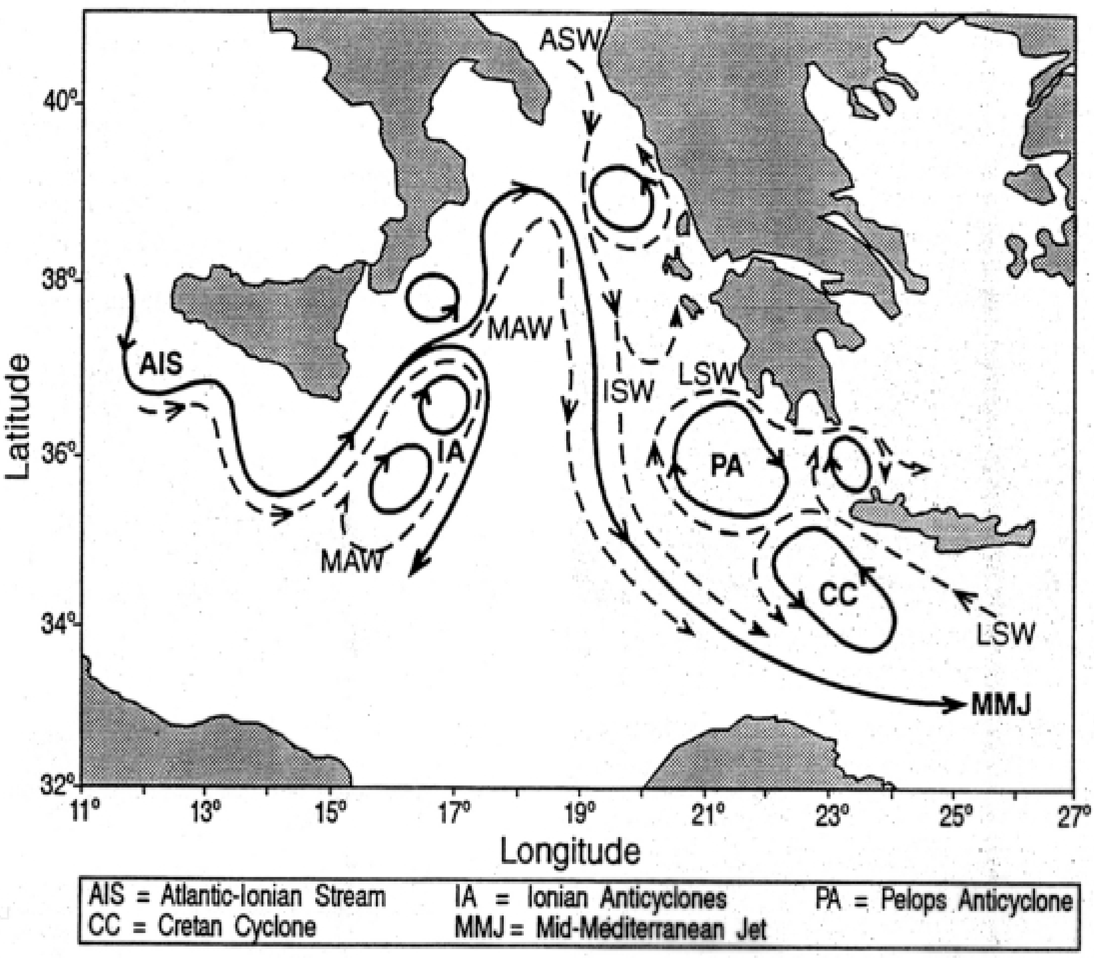


Figure 4 Circulation pattern (surface) of the Ionian Sea as inferred from the multinational research program POEM 1985-1987 (Malanotte-Rizzoli et al., 1999)

Complexity and scales arise from the multiple driving forces, from strong topographic and coastal influences, and from internal dynamical processes. The multi-scaled circulation of the eastern Mediterranean Basin is dominated by strong currents and jets, as well as, by cyclonic and anti-cyclonic eddies and gyres (Figs 3,4,5). Composite circulation patterns in the Aegean and the surrounding sea areas as inferred from in situ measurements in the period 1994-1998, show that the sub-basin and mesoscale nature of circulation dominates (Fig. 6). The main persistent circulation features in the Eastern Mediterranean are the following: (i) the Mid-Mediterranean Jet that meandering eastwards along the African coasts carries the AW from the Western Basin to the easternmost Levantine, branches of which bring considerable amounts of AW into the northern Ionian, (ii) the Asia Minor Current that flowing westwards along the southern coasts of Turkey carries warm and high saline Levantine Waters from the east Levantine to the west Levantine, branching along its route, thus transporting heat and salt into the Aegean through the eastern Cretan Arc Straits (mainly through the Rhodes Strait), (iii) the large Rhodes cyclonic gyre to the southeast of Rhodes that is the main location of the LIW formation, bringing deeper cooler, less saline and nutrients richer waters to the surface, and finally (iv) the several anticyclonic gyres and eddies (Ionian Anticyclones in the western part, the Pelops gyre to the west-southwest of Peloponnesus, the Ierapetra Anticyclone to the southeast of Crete, the Mersa-Matruh gyre in the central Levantine and the complex of Shikmona and Cyprus anticyclones in the eastern Levantine. All the circulation features present both temporal and spatial variability.

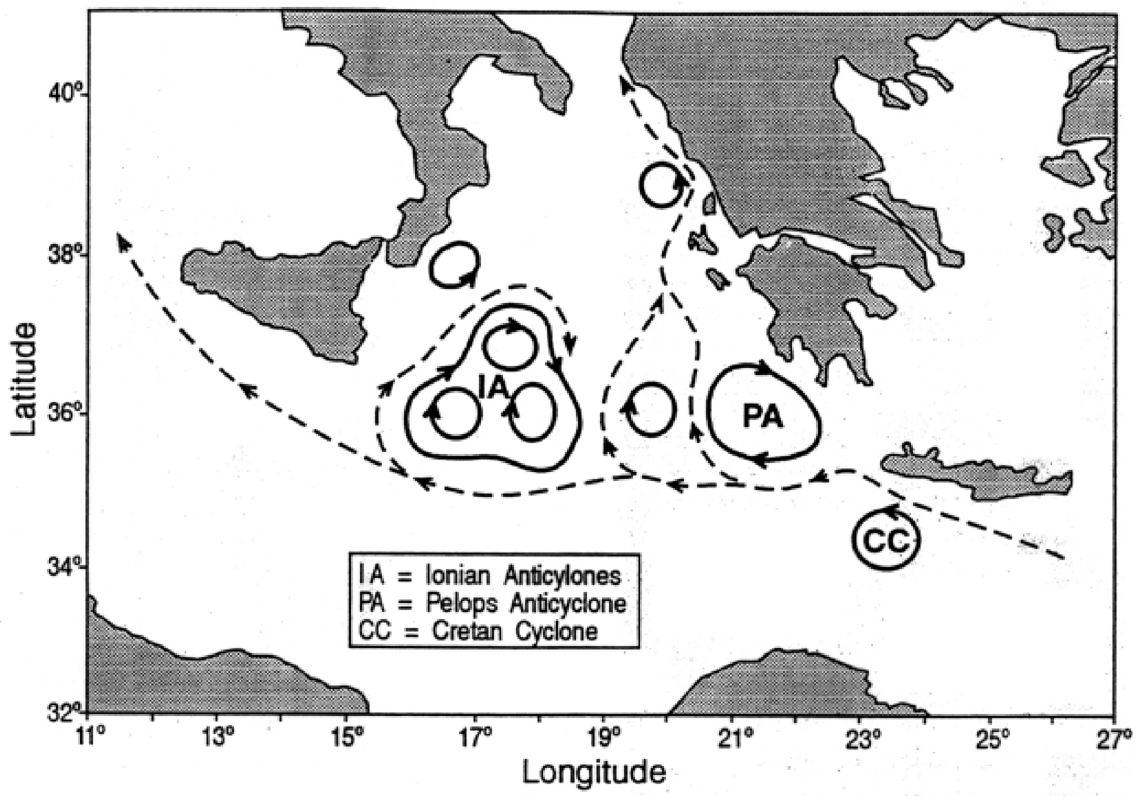


Figure 5 Mediterranean general circulation pattern at intermediate depths, (Malanotte-Rizzoli et al., 1999)

The eastern Mediterranean is classified as an oligotrophic basin. The high density water production which implies vertical processes is effective in exchanging properties (Temperature, Salinity, Oxygen, Nutrients, etc) between the atmosphere and sea-surface and on the other hand between the euphotic zone and the abyssal depths. Therefore, the intermediate and deep layers of the Mediterranean Sea are renewed (oxygenation) through water mass formation processes that take place in winter at selected regions under favourable meteorological and oceanic conditions. Additionally, nutrient enrichment of the upper layers occurs at the same time.

Recent changes in the Eastern Mediterranean

In the last decades Earth's climate experiences rather long term changes, especially accelerated by human activities. The Mediterranean Sea has undergone major changes in circulation and water properties during the last 23 years; it was believed especially in the first half of the 20^{th} century and until the early results of the multinational POEM project (Physical Oceanography of the eastern Mediterranean) in the '80s (Özsoy et al., 1989; POEM group, 1992, Robinson et al., 1991; Theocharis et al., 1993; Malanotte-Rizzoli et al., 1997) the Mediterranean Sea was more-or-less in steady state. Small deviations from that steady state were revealed when the first trends in deep-water temperature and salinity were found (Lacombe et al., 1985; Charnock, 1989; Bethoux et al., 1990).

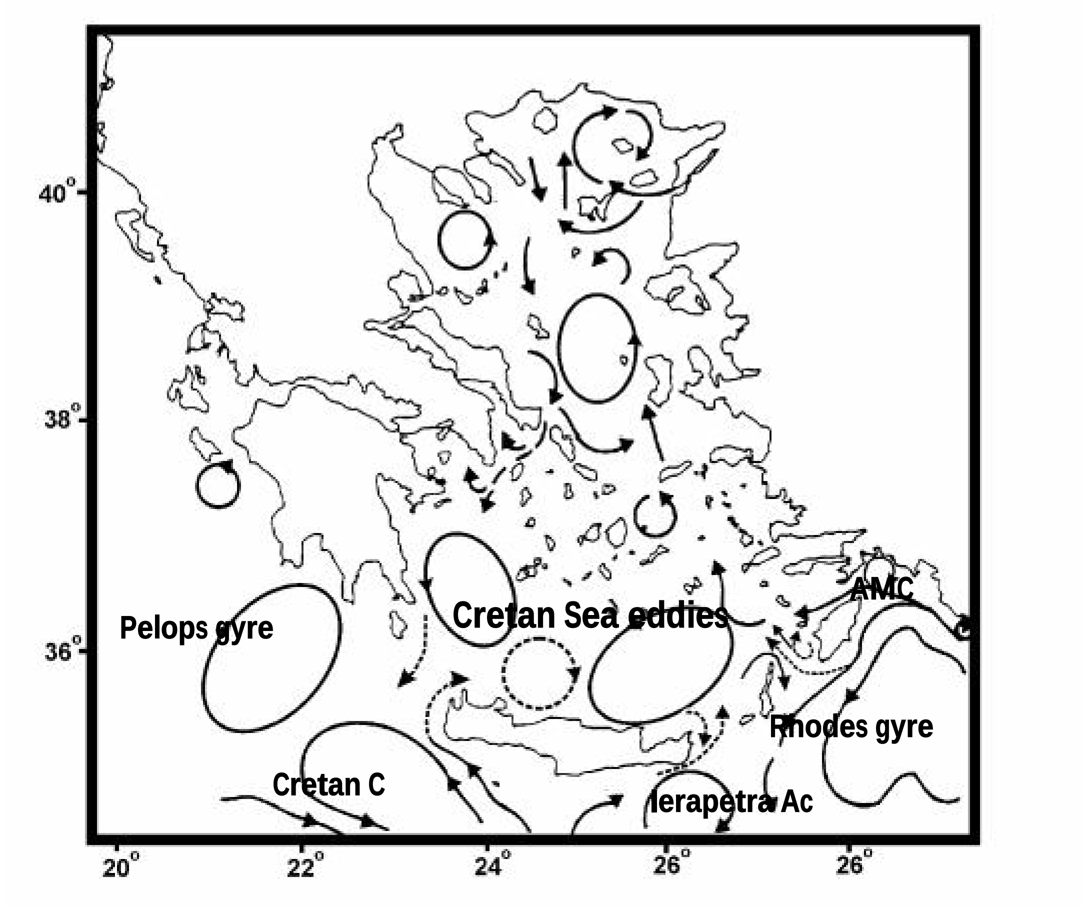


Figure 6. Composite circulation pattern in the Aegean and the surrounding sea areas (1994-1998) (From Lykousis et al., 2001)

More specifically, a major event, unique in the oceanography of the Mediterranean since the beginning of the 20th century, evolved within the last 23 years and was called the "Eastern Mediterranean Transient" (EMT). The engine of the conveyor belt in the Eastern Mediterranean was up to 1987 the convective cell of the Southern Adriatic, while in late 80s-early 90s the active convection region has shifted to the Aegean (Fig. 7). The new source has become more effective since the estimated production rate of dense waters was more than three times than the old one (1Sv instead of 0.3Sv). It affected the entire hydrological and dynamical structure of the Eastern Mediterranean. The signal of this change has passed the Sicily Strait and has been felt in the western Basin. The event has gradually decayed since 1995 indicating its transitional nature. However, the Mediterranean has not yet reached its previous equilibrium. Such a major change has not been observed in oceanography during the period that scientific measurements are taken. Of course such changes did occur in the far past during geological temporal scales.

As part of the steady-state concept, the major source of the deep waters of the Eastern Mediterranean since the beginning of observations (1908) has been considered to be the Adriatic Sea (Pollack, 1951). The Aegean Sea has also been reported as a sporadic secondary source of dense waters. However, the amounts produced have never been enough to drastically influence the thermohaline structure of the eastern Mediterranean. In more details, during late 80s-early 90s, abrupt significant consecutive changes, such as increase in salinity (1987-1992) and drop in temperature (1992-1994), caused continuous increase of density and massive deep water formation in the south Aegean and outflow through the Cretan Arc Straits (Fig. 8). The so called Cretan Deep Water (CDW) that filled the entire south Aegean

Sea was warmer, saltier and denser water than the water produced up to that time by the "Adriatic engine". This event altered the thermohaline circulation of the entire eastern Mediterranean with consequences also in the distribution of other environmental parameters. This abrupt change has been mainly attributed to important meteorological anomalies (extended reduced rainfalls and drought, change in wind patterns, exceptionally consecutive cold winters) in the eastern Mediterranean at large and especially in the Aegean (Fig. 9) and to changes of circulation patterns (routes of the AW and LIW) and to the reduced Black Sea Water outflow through the Dardanelles into the Aegean (Theocharis et al., 1999a). The relationship between the heat loss and large scale atmospheric patterns (e.g. NAO) is also investigated. These episodic hydrological changes have been superimposed to the long-term trends observed in the Mediterranean (Boscolo and Bryden 2001). It is worth to mention that palaeoceanographic information has certified the large sensitivity of the Aegean Sea to climatic variability.

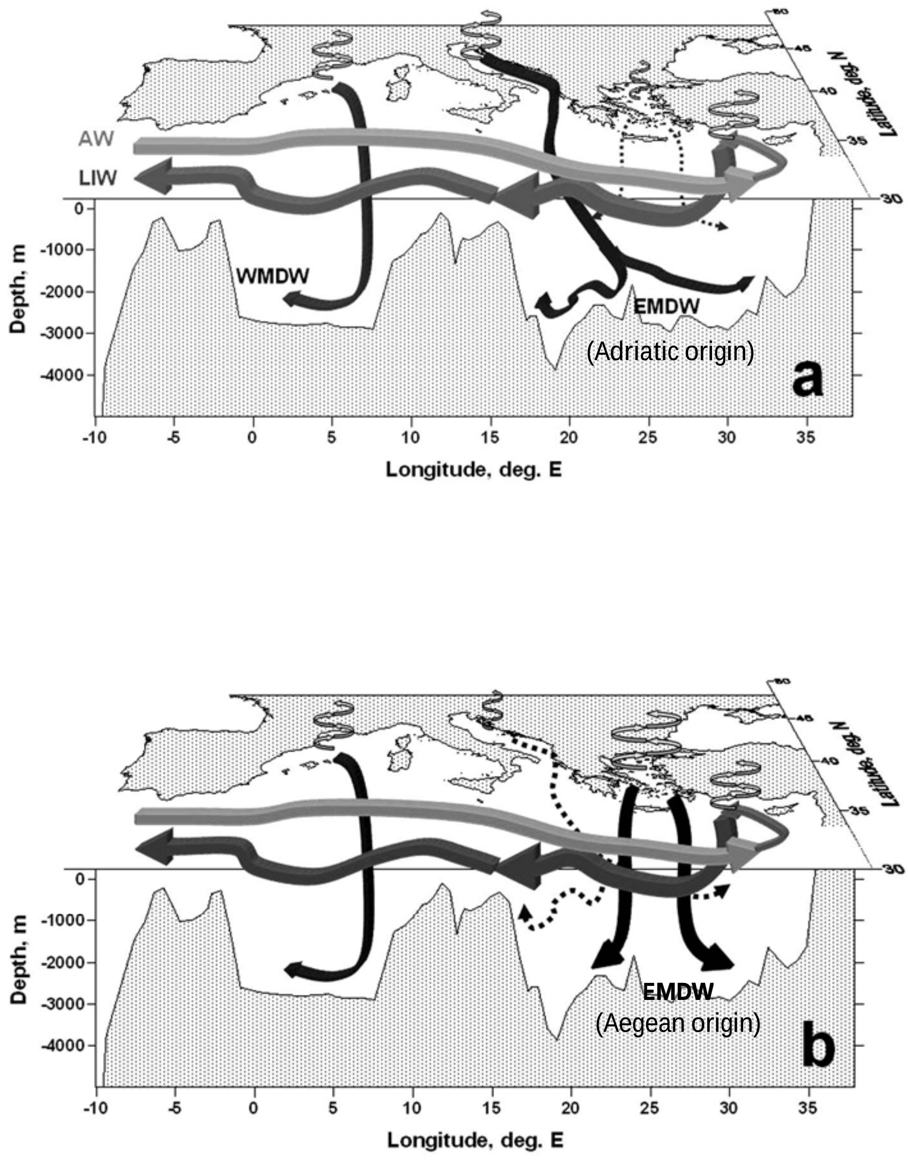


Figure 7. Pre-EMT (a) and Post-EMT (b) T/H circulation patterns (From Tsimplis et al., 2006).

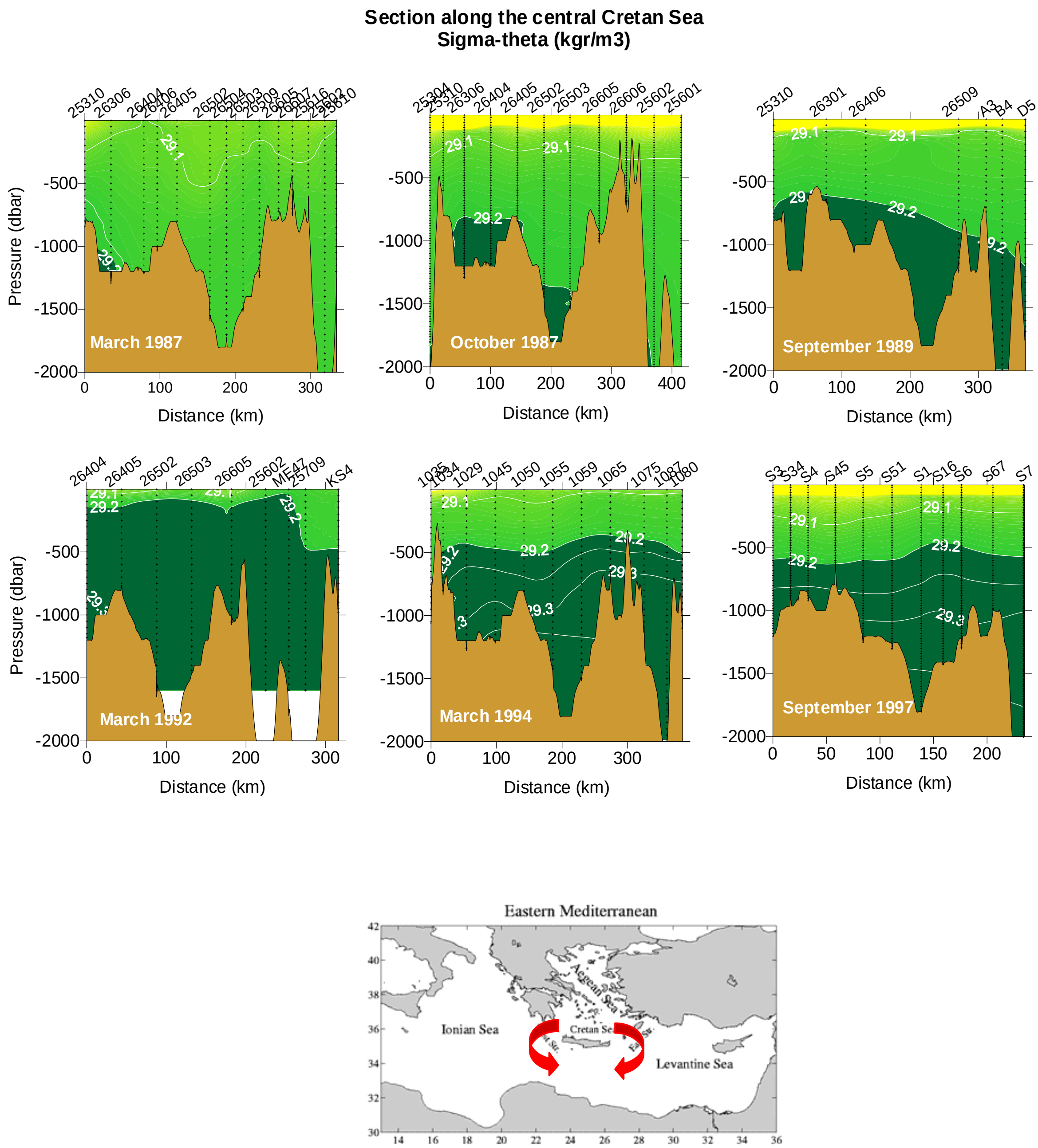
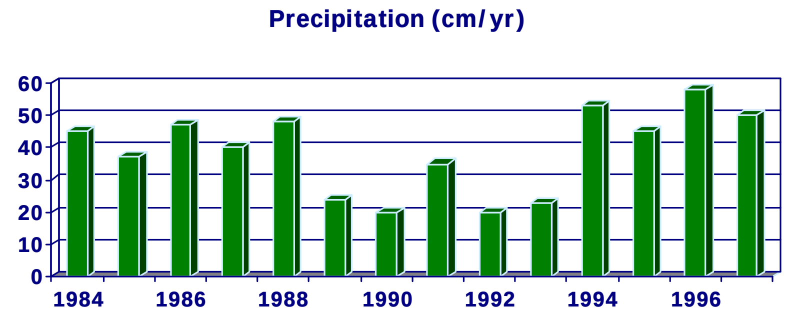


Figure 8. Intense Dense Water Formation in the Aegean Sea (From Theocharis et al., 1999)

This hyper-salinity event was caused mainly to the salt transport increase, into the Aegean from the eastern Cretan Arc Straits, by a power of 1-4 times from 1987 to 1994, intensification of the Asia Minor Current AMC, due to a significant precipitation decrease (drought) over the entire eastern Mediterranean area (Theocharis et al., 1999). The effect of atmospheric forcing was also intensified by the long-term salinity increase due to runoff control of major rivers (i.e. Nile) (Bethoux et al., 1990). The second EMT period (1992-93) is also characterised by anomalously cold winter temperatures (Fig. 9), which are a key parameter triggering the intense water mass formation process in the Mediterranean, and the revealed variability of the produced intermediate and deep waters, affected the thermohaline circulation of the entire Mediterranean Basin.



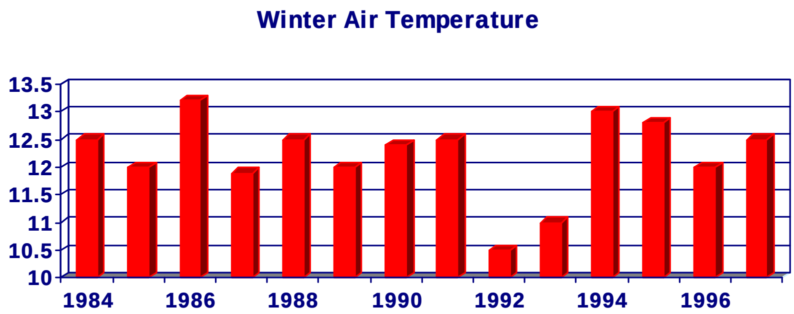


Figure 9. Annual distribution of Precipitation showing the extended dry period 1989-1993 (upper panel) and Annual distribution of winter air temperature showing the exceptionally cold winters 1992-1993 (lower panel) in the Aegean Sea.

Additionally, during the EMT period, a new intermediate water mass was generated in the Cretan Sea, in the South Aegean Sea, namely Cretan Intermediate Water (CIW), with similar to LIW characteristics, that replaced the LIW within the western region of the Eastern Mediterranean (Ionian Sea), the latter being blocked and recirculating within the Levantine Basin (Fig. 10) (Malanotte-Rizzoli et al., 1999). This water mass rich in salt fed the Adriatic during the following years, thus strongly supporting the reactivation of the previous long-term dominance of the Adriatic (Theocharis and Lascaratos, 2004).

The CDW being of particularly high density (29.3 kg/m3) sank into the near-bottom layers forming an extended dome –like volume of very dense water first in the central part, uplifting the older deep waters several hundred meters (Fig. 11). This process brought (i) oxygen in the deep and bottom layers thus renewed the deep and bottom waters and (ii) nutrients in shallower layers up to the euphotic zone. Moreover, this uplifting that occurred during the early stages of the EMT (1991-95) has caused dilution of waters about 30% in the LIW horizons (Roether et al., 1998), while CIW has formed a large tongue in the eastern Ionian (Malanotte-Rizzoli et al., 1999) and at a later stage there was a replacement of the LIW by the new warmer and more saline CIW (Manca, 2002).

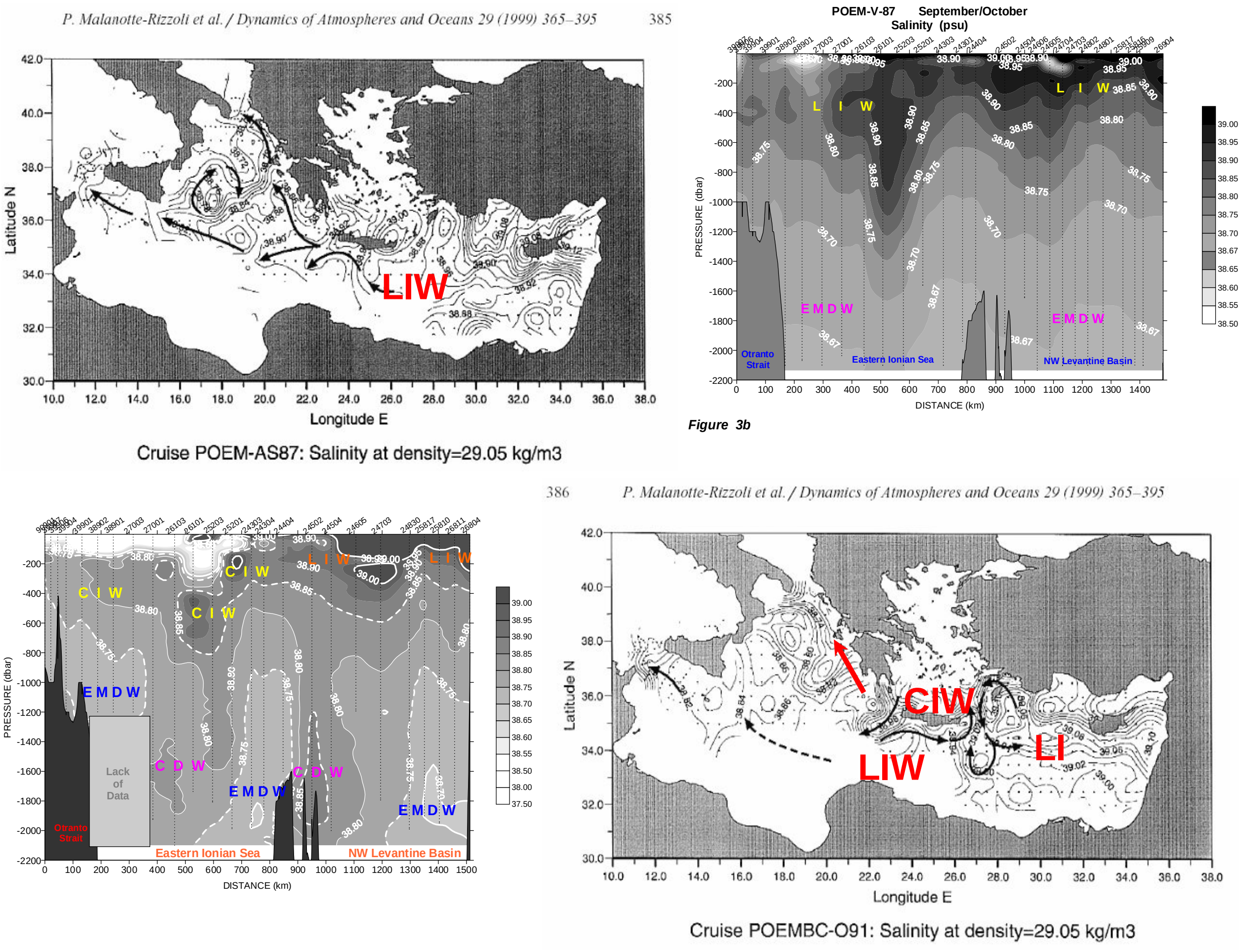


Figure 10. Horizontal maps (LIW and CIW routes in 1987 and 1991) taken from Rizzoli et al., 1999 and Vertical salinity Sections taken from Theocharis and Kontoyiannis, 1999.

The intrusion of old Mediterranean waters into the Cretan Sea greatly influenced the exchange between the Aegean and the adjacent basins. This water, namely Transitional Mediterranean Water (TMW) has formed a distinct layer in the South Aegean Sea (200-600m) during the first stages of EMT (Fig. 12), strongly affecting the stratification of the water column and the vertical distribution of the environmental parameters.

No seasonal changes in the circulation pattern of the South Aegean Sea have been observed after the EMT event. The circulation remained stable from 1994 up to now (Theocharis et al., 1999b). On the contrary, in the Ionian Sea two reversals of the general circulation pattern have been identified (from cyclonic to anticyclonic during the EMT first stage (Malanotte-Rizzoli et al., 1997, 1999), and again to cyclonic after the decay of the EMT (Theocharis et al., 2002), approximately in 1998. In long term, temperature and salinity in the Ionian Sea show some trends mostly in the intermediate and deep waters, while the surface waters present great variability (CIESM, 2002).

The recent analyses of the existing long data series indicate that the Mediterranean Sea is not yet in a steady state and is potentially very sensitive to changes in atmospheric forcing. In long-term (1910-2000) temperature and salinity clearly show an increasing trend in the intermediate and deep layers, while in the surface layer there is a large variability. However, among others, sea surface warming (1985-2006) has been shown to be a fact and follows the warming of the Northern Hemisphere (Raitsos et al., 2010). The temperature in the upper layer of the Mediterranean Sea has been increasing at an average (±SD) rate of 0.03 ±

0.008°C yr–1 for the western basin and 0.05 ± 0.009°C yr–1 for the eastern basin. The increases in temperature are not constant throughout the year but occur primarily during May, June and July. Maximum increases of 0.16°C yr–1 are found in June in the Tyrrhenian, Ligurian and Adriatic Seas and close to the African coast. The Aegean Sea shows maximum change in sea surface temperature during August (Nykjaer, 2009).

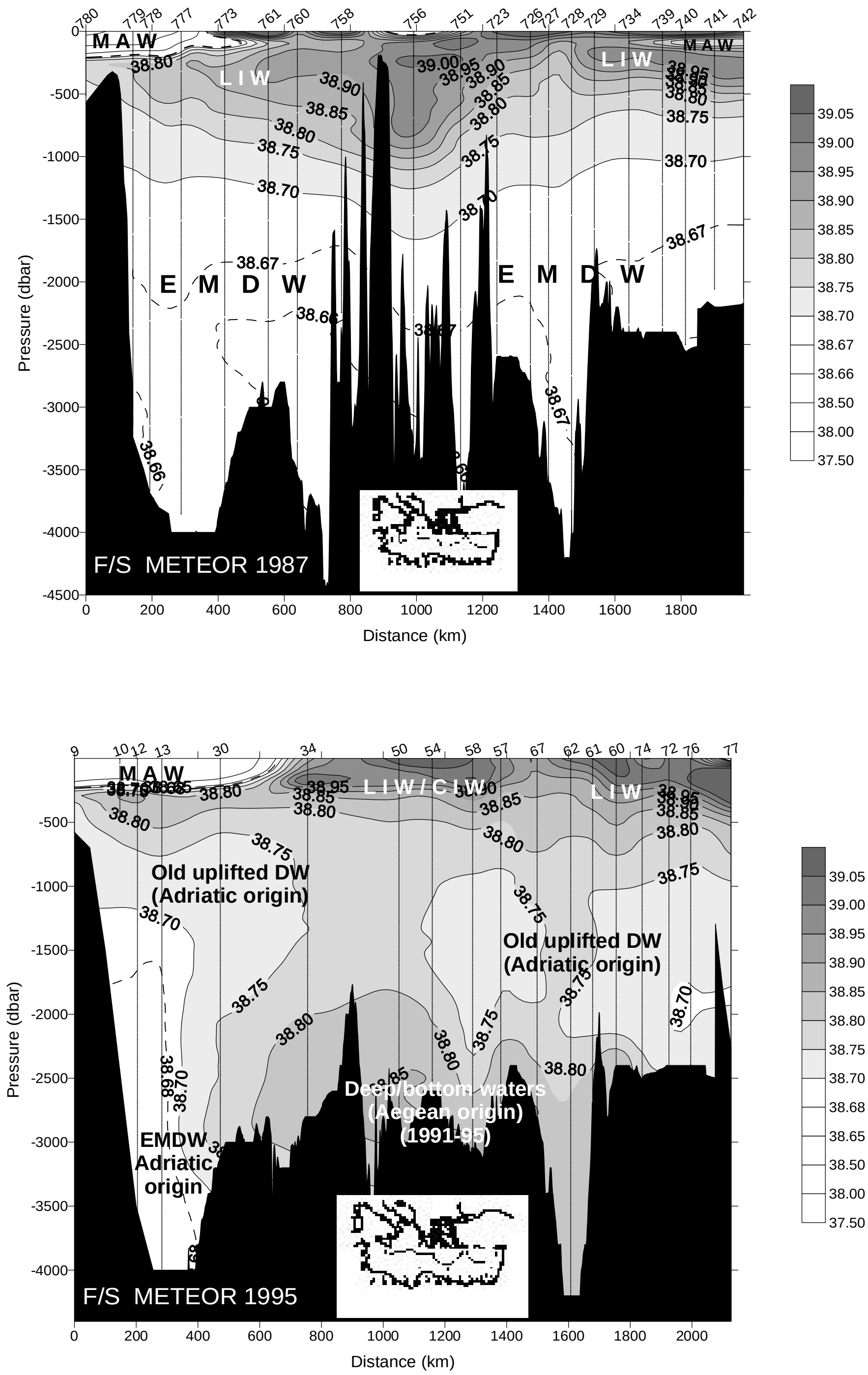


Figure 11. The change in the vertical hydrological structure in the Eastern Mediterranean 1987-1995 (From Robinson, Theocharis et al., 2001)

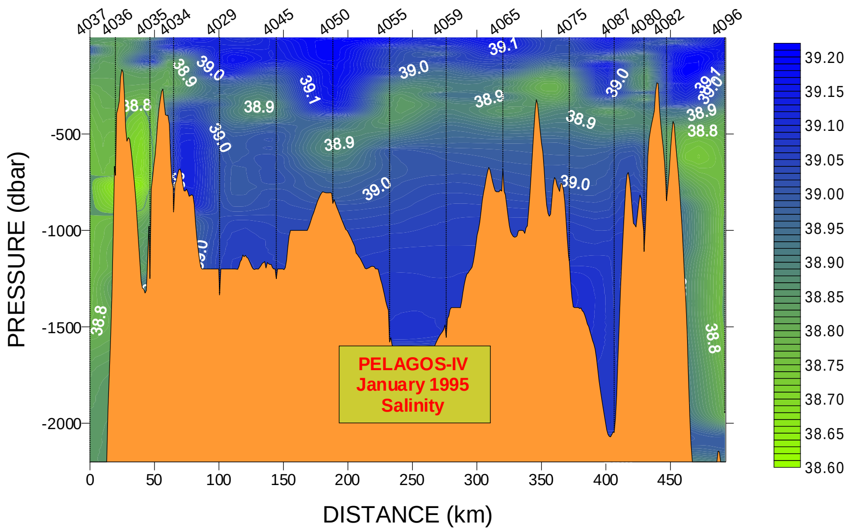


Figure 12. W-E Salinity section showing the TMW layer in the Cretan Sea. (from Theocharis et al., 1999)

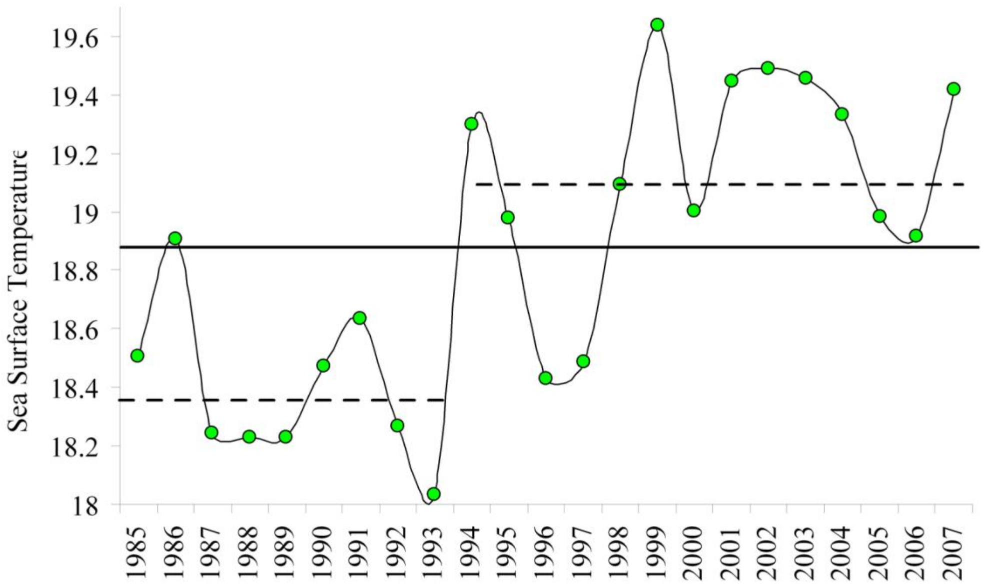


Figure 13. Temperature annual mean in the Aegean Sea (From Raitsos et al., 2010)

Raitsos et al. 2010, examined whether there was evidence of warming in the eastern part of the Mediterranean Sea and more specifically in the Aegean Sea, and how this could be linked to large-scale change in temperature using North Hemisphere Temperature (NHT) anomalies. The 23 year time-series showed that there was a pronounced change during the last decade with evidence for a stepwise increase in 1994. It can be clearly seen that after this year the annual SST mean remains above the overall mean, whereas the opposite occurred before 1994 (Fig. 13). The same time series of regional SST for the Aegean and eastern Ionian Seas revealed a pronounced change in temperature also around 1998. However, regionally within the Aegean Sea, the differences of the mean SST being much larger, can reach 2.5 ºC. The most prominent alterations occurred during the summer months and particularly in August (1.2 ºC difference between the two decades) (Fig. 14), along with smaller changes during the winter months. These changes are also evident in the surrounding areas such as Levantine and Ionian Seas.

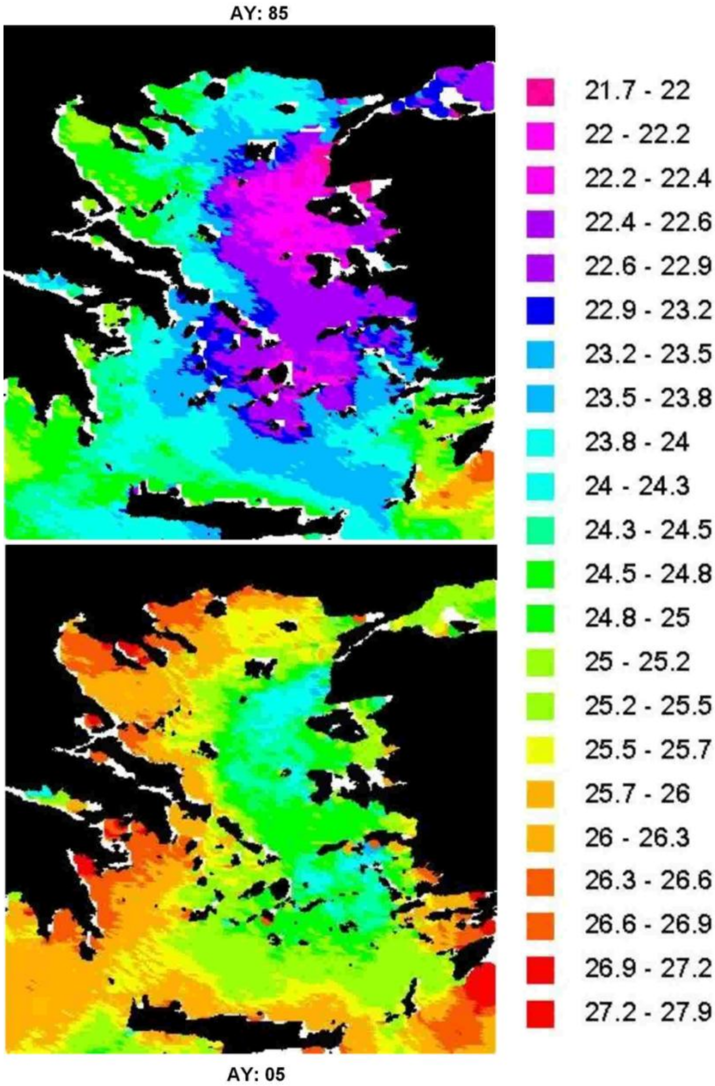


Figure 14. Sea Surface Temperature in the Aegean in August 1985 (upper) and August 2005 (lower) (From Raitsos et al. 2010).

The increase in regional temperature paralleled changes observed in NHT anomalies. Both large-scale and regional temperature changes were significantly positively correlated at an annual and at a monthly scale. The mean annual SST of the pre-shift (1985–1997) was 18.5^{0}C, whereas the mean of the post-shift period (. 1998) was 19.3^{0}C (0.8^{0}C increase). Long-term changes in monthly NHT anomalies revealed that the temperature shift located at the end of the 1990s was the most intense change that occurred in the last 158 yr. Therefore the warming of the sea surface layer in the Eastern Mediterranean is not a regional event but it is considered in the frame of the global warming.

Comparison of oceanic and atmospheric temperatures leads to the identification of periods with agreement and disagreement between the atmosphere and the ocean (Xoplaki et al., 2009). A study in the Adriatic Sea, taken as a test area, revealed influence of the atmospheric circulation, as well as other possible mechanisms, such as the oceanic circulation, explaining the differing thermal behavior of the atmosphere and the ocean. Therefore, periods with agreement of the behavior of the atmospheric and oceanic temperatures can be distinguished, as well as periods with absolute disagreement, either warmer atmosphere with cooler ocean or higher oceanic temperatures and lower atmospheric temperature. Periods of warm (cold) atmosphere and ocean are connected with westerly (northerly) flow, increased frequency of low pressure systems (high pressure, blocking high), while during the periods that the ocean and the atmosphere present different signs of temperature anomalies, other factors than the Sea Level Pressure define the thermal oceanic conditions as oceanic circulation and local wind fields.

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EastMed

Sub-regional Technical meeting on the Lessepsian migration and its impact on eastern Mediterranean fishery

Nicosia, 7-9 December 2010

Is the Lessepsian Province in expansion? The Aegean Sea experience

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Abstract

Lessepsian fish species constitute the best example in revealing the expansion of the Lessepsian Province boundaries. The spreading northwards and westwards of Lessepsian fishes introduced into the Aegean waters is discussed. Recent data acquired in fishery studies carried out in the southeastern Aegean waters are reported. Future plans are also suggested.

Introduction

Increase in Indo-Pacific-Red Sea alien species' introductions has been observed during the last three decades in the Eastern Mediterranean. The lowering of the salinity in the Suez Canal seems to play an important role in this ongoing process in the Eastern Mediterranean area, accompanied by the deepening and widening of the Canal, the increase of shipping, fisheries overexploitation and other factors. It seems however that the "amplification" of the immigration is strongly sustained by the climate changes and the rise in water temperature of the whole Mediterranean (Bianchi, 2007; Por, 2010). According to Galil (2006), the Erythrean invasion is not limited to the Eastern Mediterranean, but is showing a significant expansion northwards and westwards of its geographic limits, previously assumed to be east of Sicily, South of the Aegean and Adriatic Seas, the well-known "Lessepsian Province" (Por, 1990).

Recognizing the need for collaboration in research and management of aquatic alien species at both national and international level, a network of experts was established in 2007 at the Hellenic Centre for Marine Research-Greece (Zenetos et al., 2009a). To date, the Hellenic network for Aquatic alien species (ELNAIS: http://elnais.ath.hcmr.gr/) includes 42 experts from 11 research centres/Universities across the country. ELNAIS is an open information system providing on line the state of the art in aquatic alien species in Greece. ELNAIS, though without any financial support, is continually updated thanks to the input and the enthusiasm of a small group of experts, with the aim to provide a powerful tool to scientists and stakeholders.

The Aegean Sea invasion

Along the Hellenic waters of the Aegean and Ionian Seas, 202 alien species have been recorded by the end of 2009 (ICES/IOC/IMO, 2010), but their number is increasing day by day, an increasing trend that started in the decade 1980-1990, continues in the following decade and culminates in the present decade. The Dodecanese Islands belong to the above mentioned "Lessepsian Province" and they are considered as a hot-spot area for the spread of alien species to the European Mediterranean coasts. In this area occurs the 45% (95) of the alien species recorded in Hellenic waters. The 82% of these alien species signaled from Dodecanese (76 species) has been introduced via the Suez Canal. It is interesting to note that, although the ecological quality status of Rhodes waters (located at the southeastern corner of Dodecanese) is high according to the Water Frame Directive 2000/60/EC, the Biopollution Level (BPL) assessment proposed by Olenin et al. (2007) results strong for the island (Pancucci-Papadopoulou et al., 2009). The increasing rate of invasion in Greece may be due to a multiplicity of interactions (Zenetos et al., 2009b), such as intensive research into marine biota and increased anthropogenic activities over the last decades (e.g. aquaculture, international trade and tourism favour the unintentional introduction of aliens). In addition, global warming and the tropicalization scenario (Occhipinti-Ambrogi, 2007) cannot be ruled out as contributing factors enhancing the opportunities for introduced aliens to establish viable populations. Thus, although water warming cannot explain totally the aliens' success, it may accelerate the northward expansion and biomass increase of thermophilic species, including non-indigenous tropical and subtropical species. The pronounced increase in marine aliens observed in Greek waters has paralleled a substantial warming initiated at the beginning of the 1980s and accelerating at the end of the 1990s (Raitsos et al., 2010). This correlation was also ascertained in the SE Aegean: the remarkable increase in alien species' introductions observed during the last three decades has paralleled the observed warming of the area, which is creating more favourable conditions for the establishment of exotic species (Pancucci-Papadopoulou *et al.*, 2009; Pancucci-Papadopoulou & Corsini-Foka, 2010).

The Aegean taken in its whole is a temperate sea: coastal seawater temperature at surface ranges from 12^{o}C-17^{o}C (winter) to 20^{o}C-30^{o}C (summer), while salinity ranges between 35-39.4 PSU. Around Rhodes coastal seawater temperature at surface ranges from 16.4^{o}C-17.4^{o}C (winter) to 23.8^{o}C-28.2^{o}C (summer), while salinity ranges between 39-39.4 PSU (Corsini-Foka, 2010), values indicating the subtropical character of the region.

Due to the complexity and variety of morphological features, bathymetry, hydrological and hydrodynamic features (Papathanassiou and Zenetos, 2005), the Aegean offers a unique opportunity for monitoring the spreading of tropical colonizers in various environmental conditions. Lessepsian migrant species, once arrived the SE Aegean Sea, Dodecanese and/or Asia Minor continental shelf, generally revealed difficulties spreading to the rest of the Aegean Sea, especially in the north, or continuing their expansion westward and southward (Papaconstantinou, 1990; Corsini-Foka and Economidis, 2007).

Among the Lessepsian species, fishes are undoubtedly premonitory and constitute the best example in revealing the expansion of the Lessepsian Province boundaries northwards and westwards into the Aegean waters. This is probably due to their longer life cycle compared to invertebrates, higher mobility and the ability of colonizing and settling. In the SE Aegean, 30 ascertained Lessepsian fish species have been recorded (14 before 1990, the remaining up today), the 80% well established (Corsini-Foka, 2010; Bilecenoglu, 2010) (Table 1). They approximately constitute the 41% of total Indo-Pacific fish introduced into the Mediterranean (Golani, 2010; Bariche 2010a, b), the 7% of the Aegean ichthyofauna and about the 10% of the local known ichthyofauna. Fourteen of the above 30 Lessepsian fishes are listed among the 100 Worst Invasive Alien Species of the Mediterranean (Streftaris and Zenetos, 2006). Half of the Lessepsian fishes introduced into the Aegean Sea inhabits subtropical waters in their native range, the rest tropical waters, most feed on fishes and/or invertebrates, few species on zooplankton and only two, the siganids *Siganus luridus* and *S. rivulatus*, are herbivorous, the major part have planktonic propagules and reproduce during summer, some from spring to autumn (Golani et al., 2002, 2006; Froese and Pauly, 2010). They dwell mainly at depths up to 50 m (with some exceptions), on various types of bottoms: sandy, sandy-muddy covered by well-developed vegetation, sandy-rocky, rocky. Methods of captures could be trawling, boat seining, purse seining, set nets, fishing lines.

Table 1. Alien fish species of Indo-Pacific origin in the southeastern Aegean waters.

Introduced up to 1990	***Introduced from 1991***
Siganus rivulatus Forsskål, 1775	*Pteragogus pelycus* Randall, 1981
Leiognathus klunzingeri (Steindachner, 1898)	*Sphyraena chrysotaenia* Klunzinger, 1884
Parexocoetus mento (Valenciennes, 1847)	*Fistularia commersonii* (Rüppell, 1838)
Hemiramphus far (Forsskål, 1775)	*Tylerius spinosissimus* (Regan, 1908)
Stephanolepis diaspros Fraser-Brunner, 1940	*Upeneus pori* Ben-Tuvia and Golani, 1989
Upeneus moluccensis (Bleeker, 1855)	*Callionymus filamentosus* Valenciennes, 1837
Sargocentron rubrum (Forsskål, 1775)	*Sphyraena flavicauda* Rüppell, 1838
Lagocephalus spadiceus (Richardson, 1845)	*Etrumeus teres* De Kay, 1842
Alepes djedaba (Forsskål, 1775)	*Lagocephalus suezensis* Clark and Gohar, 1853
Siganus luridus (Rüppell, 1828)	*Petroscirtes ancylodon* Rüppell, 1835
Saurida undosquamis (Richardson, 1848)	*Iniistius pavo* (Valenciennes, 1840)
Apogon pharaonis Bellotti, 1874	*Lagocephalus sceleratus* (Gmelin, 1789)
Pempheris vanicolensis Cuvier, 1831	*Torquigener flavimaculosus* Hardy and Randall, 1983
Atherinomorus lacunosus (Forster, 1801)	*Scomberomorus commerson* (Lacepède, 1800)
	Sillago sihama (Forsskål, 1775)
	Oxyurichthys petersi (Klunzinger, 1871)

Contrarily to the past, now also the Central-Western and Southern Aegean waters are able to sustain populations of Lessepsian fish species, as 12 and 11 species having respectively reached these areas (Corsini-Foka, 2010; Katsavenakis et al., 2009; Tzomos et al., 2010; ELNAIS, 2010). Recent data are suggesting that the zoogeographical separation (from Eubea Island to Chios-Izmir) between the North Aegean-cold water fauna and the Central-South, warm water fauna is changing position, shifting northwards: four of the early introduced Lessepsian species (*Siganus rivulatus*, *Stephanolepis diaspros*, *Lagocephalus spadiceus*, *Hemiramphus far*) and three other recently introduced (*Etrumeus teres*, *Fistularia commersonii*, *Lagocephalus sceleratus*) have been signaled along the NE Aegean coasts having overcome the winter isotherm of 15^{o}C, while *Fistularia commersoni* and *Lagocephalus sceleratus* occur also in the cold NW Aegean waters (over the isotherm of 14^{o}C) (Golani et al., 2007; Tuncer et al., 2008; Corsini-Foka, 2010; Lefkaditou et al., 2010; Yarmaz et al., 2010; Akça and Bilecenoglu, 2010) (Fig. 1).

As already discussed for fish invasions in the Mediterranean (Mavruk and Avsar, 2008; Golani, 2010), the success of Lessepsian fishes in colonizing the Aegean coasts could be attributed to a combination of factors, like a particular ability of adaptation to the new ecosystem, overcoming environmental impediments like temperature, salinity, currents, the ability to occupy available and diversified niches, life history strategies, food habits and feeding strategy, anti-predator adaptations, schooling, limited competition and predation. The evolution of the EMT (Eastern Mediterranean Transient) (Rilov and Galil, 2009) and the increase of the Aegean sea water temperature (Theocharis, 2008) could have furthermore contributed to the enhancement of their introduction, establishment and spreading, favouring the dispersion of their planktonic eggs and larvae (see Ben Rais-Lasram et al., 2008).

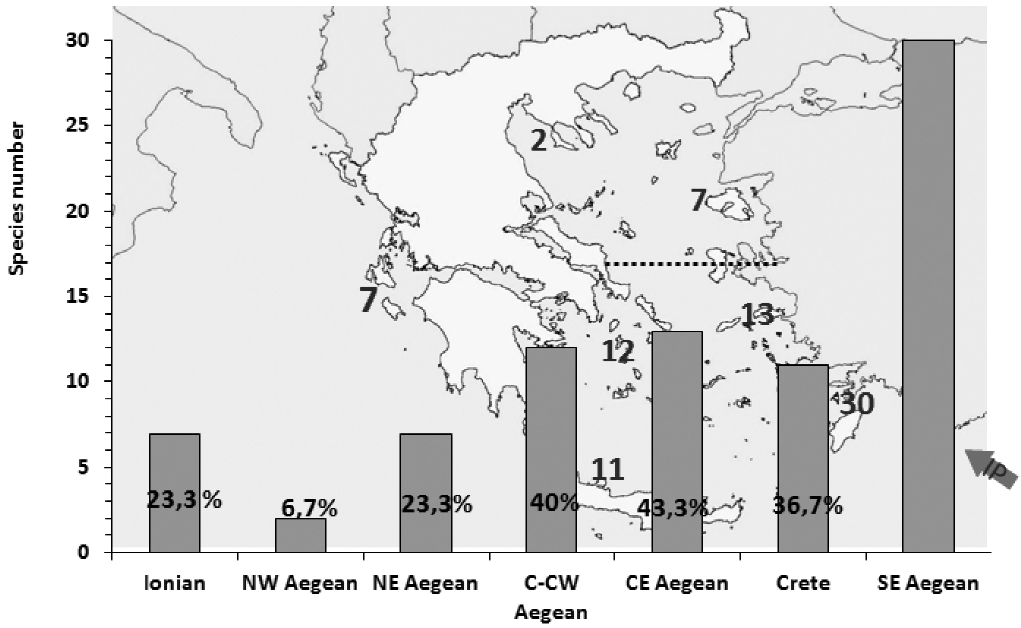

Fig. 1. Distribution of alien fish of Indo-Pacific origin in the Aegean waters.

Lessepsian species in Aegean coastal fishery

Concerning Hellenic waters, quantitative data on the abundance of Lessepsian species and their importance in the fishery of the SE Aegean were limited to siganids (Peristeraki et al., 2006), while studies on this matter and on the role of non indigenous species in ecosystem functioning started very recently (Kalogirou et al., 2010a, b).

Although 30 species have been recorded in the area (Corsini-Foka, 2010), Lessepsian fish commonly caught in fishery activities along the southern Dodecanese islands belong to 16 species, of which 10 may have a commercial importance (Golani et al., 2002 updated 2008), but in practice, only *Siganus rivulatus*, *Siganus luridus*, *Sphyraena chrysotaenia*, *Etrumeus teres* and *Scomberomorus commerson* are more or less exploited in the area, depending on the method used, the habitat, the abundance, and the season.

Preliminary results obtained from 20 experimental boat seining hauls performed between 2008-2009 on various bottoms in the SE Aegean (5-35 m of depth) showed the occurrence of 10 Lessepsian fish species: *Fistularia commersoni*, *Lagocephalus sceleratus*, *Lagocephalus suezensis*, *Pteragogus pelycus*, *Siganus luridus*, *Siganus rivulatus*, *Sphyraena chrysotaenia*, *Stephanolepis diaspros*, *Upeneus moluccensis* and *Upeneus pori*. The above Lessepsian fish species constituted the 13.5% of total ichthyofauna diversity captured (74 species), the 7.8% of total density (total number of specimens= 50200) and 7.3% of total biomass (total weight= 379 Kg). The native *Spicara smaris* and *Boops boops* predominated in terms of density (74%) and biomass (58%). Among the Lessepsian fishes, *Siganus rivulatus*, *Sphyraena chrysotaenia*, *Fistularia commersonii* and *Pteragogus pelycus* predominated in terms of density, *Lagocephalus sceleratus*, *Sphyraena chrysotaenia*, *Siganus rivulatus* and *Fistularia commersonii* in terms of biomass, while *Fistularia commersonii*, *Siganus rivulatus*, *Pteragogus pelycus*, *Lagocephalus sceleratus* and *Siganus luridus* showed the higher frequency of occurrence in the hauls (Corsini-Foka and Pancucci-Papadopoulou, 2010) (Table 2). Considering single hauls, and depending on the habitat and other factors, Lessepsian fish could reach the 25-30% of the total fish diversity. Although in terms of total biomass, the percentage of Lessepsians could seem low compared with data from other countries of the Levantine Basin (Golani, 2010), the contribute of Lessepsian fish in single hauls often reaches the 30% of biomass: in some cases the 20% of total biomass was constituted by *Lagocephalus sceleratus*, in other cases, the 30% was represented by *Fistularia commersonii*. Using trammel-nets, the results could reach more impressive results, with Lessepsians representing sometimes more than the 80% of total biomass (*Siganus luridus* 47%, *Lagocephalus sceleratus* 26%, *Fistularia commersonii* 11%, native 16%).

Table 2. Data on Lessespian fish caught in 20 boat seining hauls carried out in the south-eastern Aegean Sea (2008-2009).

Species	Frequency of occurrence (%)	Number of individuals/haul	Weight (kg/haul)
Fistularia commersonii	85	11.3	0.147
Lagocephalus sceleratus	50	6.5	0.429
Lagocephalus suezensis	15	0.3	0.008
Pteragogus pelycus	60	6.8	0.032
Siganus luridus	50	4.3	0.102
Siganus rivulatus	65	100.8	0.188
Sphyraena chrysotaenia	20	62.7	0.353
Stephanolepis diaspros	30	2.1	0.122
Upeneus moluccensis	5	0.1	0.000
Upeneus pori	15	0.3	0.001

Sphyraena chrysotaenia is regularly confused with native sphyraenids (*S. viridensis* and *S. sphyraena*) and with the less common non native *S. flavicauda*. This happens also with native e non native mullids, regularly confused: although in the Dodecanese area the biomass of *Upeneus moluccensis* and *Upeneus pori* results irrelevant compared with the native *Mullus barbatus* and *Mullus surmuletus*, the population of the recently introduced *U. pori* is clearly increasing. The mackerel *S. commerson* is the last one recorded Lessepsian fish in Hellenic waters: fishermen usually confuse it with similar native scombrid species, but quantitative data on its abundance are not still available. Also the abundance of *Etrumeus teres* in the SE Aegean Sea is not known, although frequently caught, while data from the Cyclades and Crete are given in Kallianiotis and Lekkas (2005) and Kasapidis et al. (2007).

As mentioned above, up to date, the Lessepsian species *Fistularia commersonii* and *Lagocephalus sceleratus* continue to be widely distributed and abundant: the first is not appreciated and discarded, while the landing of the second is forbidden due to its toxicity and potential danger for human health (Katikou et al., 2009). It is evident that at the depths and habitats invaded by these Lessepsian fishes, young specimens of *Fistularia commersonii* could be prey items for other fishes, while adults of the blue cornetfish probably are not preyed and could furthermore compete with other native piscivorous species. Probably absent seem to be *Lagocephalus sceleratus* predators and competitors.

Among the Lessepsian invertebrates occurring in the Hellenic waters of the SE Aegean Sea (ELNAIS, 2010), few species, the crustaceans *Marsupenaeus japonicus*, *Portunus segnis* (previously assigned to *Portunus pelagicus*, see Lai et al., 2010), *Erugosquilla massavensis*, the gasteropod *Strombus persicus* and the recent introduced and established cephalopod *Sepioteuthis lessoniana* present some commercial importance. No quantitative data are available for the above invertebrates, except for *S. persicus*, abundantly distributed on all sandy bottoms and rocks covered by vegetation and locally commercialized. The bigfin reef squid *S. lessoniana* is already common around Rhodes (weight up to 1.4Kg) and sold, usually confused with native squids, while *Portunus segnis*, although frequent in nets, is not marked.

Biological data

According to Kalogirou et al. (2007) *Fistularia commersonii* is a piscivorous fish: it feeds on commercially important species belonging to Centracanthidae, Sparidae and Mullidae and on a large number of gobiids. Under analysis are the feeding habits of other recent invaders. Qualitative observations on the diet of *L. sceleratus* show that it feeds mainly on cephalopods decapods and octopods (*Sepia officinalis*, *Octopus vulgaris*) and also on crabs, shrimps, gasteropods and benthic fishes. Similarly, *Lagocephalus suezensis* feeds on decapod crustaceans, cephalopods, bivalves and gasteropods, echinoderms and small benthic fishes (Corsini-Foka and Pancucci-Papadopoulou, 2010). Preliminary results on the maturity of *L. sceleratus* suggest that the species reproduces during summer months (Corsini-Foka, 2010; Peristeraki et al., 2010) similarly to the Gulf of Suez population (Sabrah et al., 2006). Length-weight relationships of various Lessepsian fish collected in Rhodes area (2008-2009) are under study (preliminary results are given in Table 3) and comparison with measurements obtained from other eastern Mediterranean populations.

Table 3. Length-weight relationship parameters in Lessepsian fish species and statistical data.

	***TW*= a · *SL* ^{b}**				***SL***		***TW***	
Species	**N**	**a**	**b**	**r**	**Avg±SD**	**min-max**	**Avg±SD**	**min-max**
Fistularia commersonii	210	0.0001	3.4768	0.9970	43.53±20.94	11.10-87.30	104.10±130.85	0.47-628.20
Lagocephalus sceleratus	73	0.0197	2.9660	0.9978	22.52±13.31	5.88-58.00	470.21±831.39	4.33-4100.00
Lagocephalus suezensis	24	0.0281	2.8499	0.9861	13.48±2.41	9.92-19.30	50.29±26.45	20.50-114.90
Pteragogus pelycus	40	0.0189	3.1910	0.9916	5.32±3.22	3.22-8.78	4.87±0.79	0.79-17.67
Siganus luridus	49	0.0237	3.0399	0.9907	10.64±3.51	4.52-18.60	41.60±34.71	2.16-160.24
Siganus rivulatus	74	0.0155	3.0828	0.9529	7.32±1.97	4.70-20.00	10.27±24.22	1.96-210.67
Stephanolepis diaspros	16	0.0942	2.5522	0.9913	12.28±3.25	8.00-19.00	64.86±47.02	19.63-174.29
Upeneus pori	14	0.0225	2.8854	0.9866	7.53±1.61	5.90-12.00	8.52±6.03	3.62-26.57

Legend. N: number of specimens, TW: total weight (g), SL: standard length (cm), Avg: average, SD: standard deviation, Min: minimum, Max: maximum.

Conclusions

Aliens are integrant part of the marine communities mainly along the coasts of the eastern Mediterranean, Aegean Sea included. Along the crucial area of SE Aegean coasts in particular, they significantly contribute to the total diversity and are well represented at all levels, from plankton to benthos and nekton. In the SE Aegean, Lessepsian fishes are at least the 10% of the local ichthyofauna diversity, well established and inserted in the trophic web of the coastal waters. In the last years, environmental conditions, in particular the observed increase of the seawater temperatures and the widening of the summer period, appear more suitable than in past not only for Indo-Pacific alien income, but also for their quick establishment and further spreading, more similar to an invasion wave than to a colonization process. Indeed, numerous of the recent entries became common or abundant in a brief time, showing high ability to adaptation to the new environment, not only because they are able to produce large populations but also because they expand westwards and northwards their target area. If the number of species in the eastern Mediterranean is increasing due to the continue addition of new aliens, the sudden production of large populations of new inhabitants could seriously threat the equilibrium of native communities.

The herbivorous Lessepsian Siganids are established and exploited in the area since decades, while the native herbivorous *Sarpa salpa* is now not common in fishery.

Many species have negative socio-economic effect on the area: they have not commercial value (e.g. *F. commersonii* and *L. sceleratus*) and their large populations are mainly sustained by intensive feeding on native fish like *Spicara smaris*, *Boops boops* and Mullids, and invertebrate stocks like cephalopods (*Sepia officinalis, Octopus vulgaris*) locally exploited and economically important in fisheries. Lessepsians feed also on large quantities of benthic invertebrates and fish and macrophytes, fundamental members of the intricate marine food web although not commercially important. Unknown and unforeseeable are the potential ecological effects on the structure, composition and functioning of native communities. A negative economic effect is also greatly increasing, due to the effort required to clean fishing gear by abundant and unwanted species like *L. sceleratus* and *L. suezensis*. Moreover, the serious danger for public health of the highly toxic *L. sceleratus* prohibits its landing and leads to the loss of large biomasses.

Future plans

In order to better understand and face the problem, it is necessary to fill the existing gaps in our knowledge, promoting coordinated actions, such as:

- Systematic monitoring of fish landings with the aim to quantify the local resources and the abundance of Lessepsian species in fishery.
- Ecosystems functioning study. A common project performed by all countries involved in the invasion phenomenon which could allow the comparison of the results and the achievement of a global view on the impact of Lessespian immigrants on coastal marine resources along stations of the eastern Mediterranean coasts..
- Monitoring of benthic assemblages on sand and rocky bottoms is also necessary due to their ecological importance and participation to the food web.
- Collection of oceanographic data in all involved area with the aim to monitoring changing trends of environmental conditions.
- Exchange and dissemination of knowledge, environmental education programs at primary and secondary school levels through cooperation with professional fishermen associations.

For the achievement of above plans at international level, we propose the creation of an International Center for the Study of Alien Species introduction in the Mediterranean (ICASM) in Rhodes, which will provides a new institutional focus for education (undergraduate and postgraduate programs) and international research (collaboration, visiting researchers) on both Global Changes and Alien Species spreading. Moreover, it will provide a major opportunity for all involved sectors (governments, international agencies, nongovernmental organizations, industry, and scientific groups) to address policy issues affecting the Mediterranean at global, regional, and national levels and to make progress in advancing global strategic issues, including technology, resources and biodiversity conservation.

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Sub-regional Technical meeting on the Lessepsian migration and its impact on eastern Mediterranean fishery

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The effect of Lessepsian immigrants to the Hellenic Fisheries

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Abstract

In the Hellenic Seas, the Lessepsian migrants caught by fishing gears include 28 fish, 11 crustacean and 1 cephalopod species, according to up-to-date information derived by the Ellenic Network on Aquatic Invasive Species (ELNAIS). However, analysis of data kept in the Fisheries Data Base of the Institute of Marine Biological Resources (HCMR), which are collected systematically through experimental trawl surveys, surveys using observers on board commercial vessels, and landing inventories at fishing ports all over the country, suggested that most of those species are scarcely recorded, limited to the southeastern Aegean Sea and at depths shallower than 100 m. Only nine Lessepsian fish species, namely *Etrumeus teres, Fistularia commersoni, Lagocephalus sceleratus, Pteragogus pelycus, Siganus luridus, Siganus rivulatus, Stephanolepis diaspros, Upeneus molucensis* and *Upeneus pori*, might be considered as rather regularly occurring in the catches of at least one fishing gear in the southernmost areas of Hellenic territorial waters, whereas only *Siganus* sp. are reported among landings. In fact, the major part of Lessepsian fish caught by boat seine, static nets, bottom trawl and purse-seine, are discarded either due to their low/no commercial value, or due to the small quantities obtained and the generally small size of caught individuals in cases when there is a certain commercial interest for a specific species. Effects of Lessepsian migration on fisheries in Hellenic waters have a local character and are restricted in specific coastal fisheries mainly in SE Aegean. The systematic and continuous monitoring of the Lessepsian species catches (landed and discarded) by the different fishing gears, parallel to the monitoring of environmental parameters particularly in inshore waters, is necessary to improve our understanding of these species population dynamics and the existing linkages with environmental variability.

Introduction

The appearance of Lessepsian species in the caches of fishing gears used in the Hellenic Seas has started in 1930, when *Lagocephalus spadiceus* was caught by trawl northwest off Samos island (Ananiadis, 1952). *Siganus rivulatus* was the second fish immigrant from the Red Sea, found in Rhodes island in 1932 (Brunelli & Bini, 1934), the abundance of which however was noticed in coastal waters of the southern Aegean Sea between 1942-1944 (Papaconstantinou, 1990), i.e. during the second World War when Greece was found under

German Possession, fact that explains the common name “germanos” that it shares with the sympatric species *Siganus luridus*.

In the first review of Lessepsian fishes from the Hellenic waters by Papaconstantinou (1987), 11 fish species have been reported from the Aegean Sea, among which only *S. luridus* occurring also in the eastern Ionian. In the recent most reviews by Zenetos *et al.* (2009, 2011) are included 28 fish, 11 crustacean and 1 cephalopod species of Indo-Pacific origin, caught by fishing gears (as listed in ANNEX V). The majority of these species has been scarcely recorded, and is mainly distributed in the southeastern Aegean Sea. Particularly in relation to fish species, 12 have been collected in the southwestern Aegean (E>26^{o}), 4 northern to 38 ^{o} N and 9 in the eastern Ionian Sea, according to the records mapped by the Ellenic Network on Aquatic Invasive Species (ELNAIS, Dec. 2010 update).

The Lessepsian migrants, due to the scarcity of their records, until the early 2000s attracted little interest even between marine biologists and relative references were included in faunistic studies reporting new findings and alien species inventories. Since 2005, when the poisonous for human consumption *Lagocephalus scheleratus* appeared in the Aegean Sea (Kasapides *et al.*, 2007), “alien” species invasion in the Hellenic Seas has become subject of public discussion and efforts for alien species monitoring have increased. Thereafter, the first Panhellenic meeting for the “Invasion of aquatic aliens species in the eastern Mediterranean” has been organized (Anonymous, 2007), the ELNAIS website has been created and held by the Hellenic Centre for Marine Research since 2008, whereas studies on biology and ecology of some common Lessepsian fishes have been included in current marine research (Kalogirou *et al.*, 2006; 2007; 2010; Bardamaskos & Megalofonou, 2008; Peristeraki *et al.*, 2010). However analyses in relation to the Lessepsian migrants contribution in fisheries catches are still very limited. Some preliminary results concerning the spatial variation of lessepsian species catches by boat seine have been recently reported (Lefkaditou & Petrakis 2010; Lefkaditou *et al.*, 2010), whereas scanty information on *E. terres* catches by purse seine in Cyclades (Kallianiotis & Lekkas, 2005) and *S. luridus* catches by trammel-nets in Crete and Dodecanese islands (Tingilis *et al.*, 2003; Peristeraki *et al.*, 2006) has been published.

In the present document, the presentation of Lessepsian species frequency of occurrence in the catches of different fishing gears is provided along with the data on the CPUE and the size range of individuals caught, based on outputs from the Fisheries Data Base of the Institute of Marine Biological Resources (IMBR-HCMR) and using additional data published in scientific journals and Technical Reports of the Greek Research Institutes.

Materials and Methods

The Fisheries Data Base of the IMBR-HCMR is including data collected systematically through: a) regional experimental bottom trawl surveys carried out since 1983, b) the national experimental bottom trawl surveys following the common standardized sampling protocols of the International bottom trawl survey in the Mediterranean (MEDITS), carried out since 1994, c) surveys for small pelagic fishes based on acoustic and ichthyoplankton methods, d) surveys using observers on board commercial vessels using different fishing gears, carried out on a national level e) the national monitoring of fishing activity taking place at fishing ports all over the country since 2003, in the frame of the EU data collection Regulation (DCR).

Table I. Regional and National Surveys of IMBR-HCMR considered for the present study.

Programme Title	Studied Area/s - Subdivisions	**Duration**	Sampling periodicity	Fishing Gear/s
Development possibilities of coastal fisheries in the region of Kastellorizo island (Dodecanese)	Region of Kastellorizo isl. (NW Levant Sea)	1985-1986	seasonal	Trammel nets Long lines
Development of the Greek fisheries – Assessment of the demersal fisheries resources of commercial interest in the S. Aegean Sea	Cyclades and Dodecanese regions	1995-1996	seasonal (2 years)	Bottom Trawl
International bottom trawl survey in the Mediterranean (MEDITS-GR)	E. Ionian Sea Argosaronikos region S. Aegean Sea N. Aegean Sea	1994-2000	annual	MEDITS Bottom Trawl
National Fisheries Data Collection Program-Bottom Trawl Survey (MEDITS)		2001 2003-2006 2008	annual	MEDITS Bottom Trawl
Estimates of discards in Hellenic commercial fisheries	South Aegean Sea East Ionian Sea	1995-1997	seasonal (2 years)	Bottom Trawl
Analysis of trawls' discard operation in the central and eastern Mediterranean sea (DISCARDS)	South Aegean Sea East Ionian Sea	1998-2000	seasonal (2 years)	Bottom Trawl
National Fisheries Data Collection Program-Surveys on Board of Commercial Vessels (DISCARDS)	N. Aegean Sea E. Ionian Sea	2001	Seasonal*	Bottom Trawl*
National Fisheries Data Collection Program-Surveys on Board of Commercial Vessels (DISCARDS)	North Aegean Sea South Aegean Sea East Ionian Sea	2003-2006 2008	seasonal	Bottom Trawl* Purse Seine Static Nets Long Lines
National Fisheries Data Collection Program-Monitoring of Fishing Effort and Landings	30 monitoring stations, over Greece (Fig 1)	2003-2008	monthly	Bottom Trawl* Purse Seine Boat Seine Static Nets Long Lines Other hooks Traps
Evaluation of the Consequences of the Prohibition of the Beach Seine Fishery in Greece	Pagasitikos Gulf Cyclades islands Zakynthos isl.(Ionian)	2000-2001		Boat Seine
Evaluation of the impact of boat-seine fishery on fish stocks	11 coastal areas of Aegean and eastern Ionian Seas	2008-2009	monthly (6 months)	Boat Seine
Study of the fisheries viability of the Argolic Gulf	Argolic Gulf (southwestern Aegean)	2007-2008	monthly (5 months)	Bottom Trawl Boat Seine, Nets, Long lines
Study on sustainable exploitation of fishery resources in Messara	Messara region (south Crete)			Bottom trawl

*Due to the fishing ban for trawling from 1/6 to30/9 in the Hellenic Seas, only 3 seasons were considered by year for surveys on board of commercial trawlers.

Particularly for the present analyses, queries including data on Lessepsian species records (number and total weight of individuals caught, total length measurements), as well as data concerning the hauls carried out down to 100m depth (date, duration, longitude, latitude, bottom depth, shooting time), have been performed for the surveys listed in Table I.

Furthermore additional information about the recorded Lessepsian fish species during experimental trawl surveys conducted from 1988 to 1995 on the Cretan shelf (Kallianiotis *et al.*, 2000; Anonymous, 2008) by the Institute of Marine Biology of Crete (IMBC, currently joint with ex-NCMR to HCMR) were also considered.

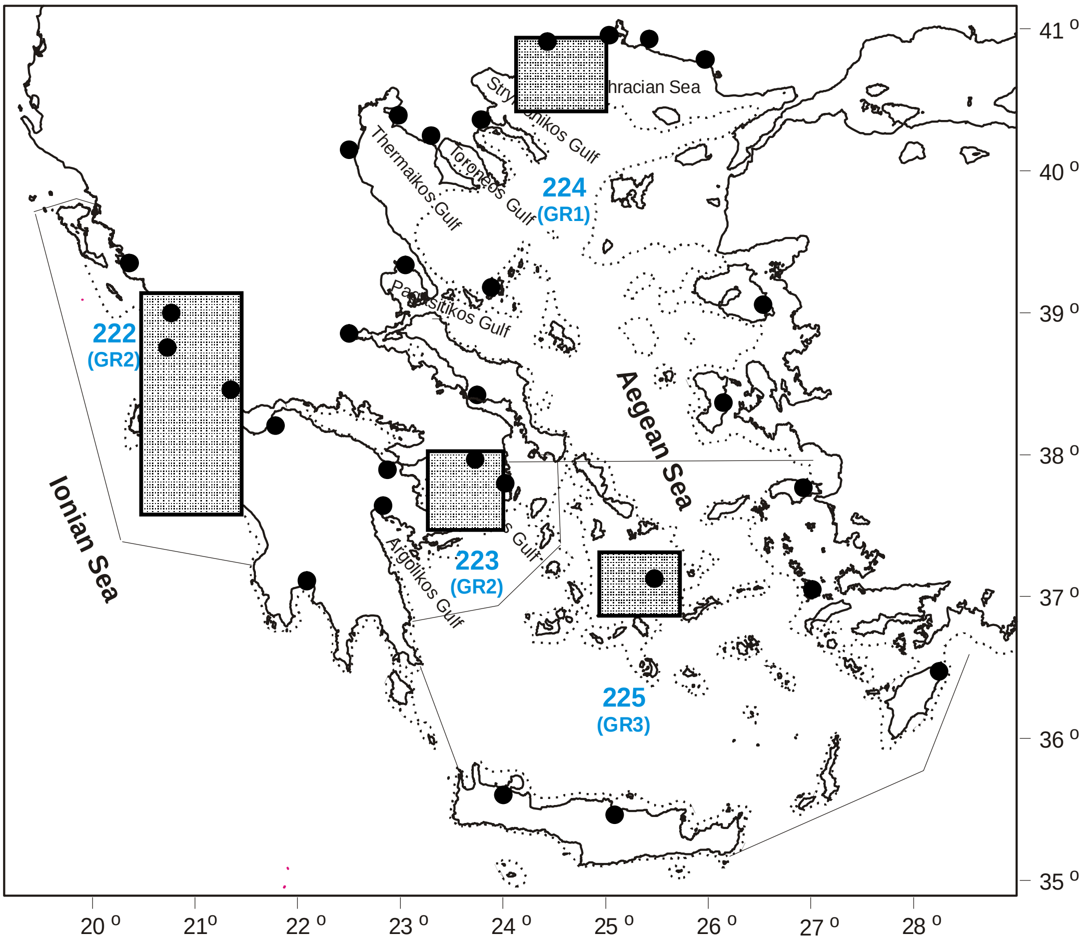

Figure 1. Map showing the Hellenic Seas sub-divisions considered for the MEDITS surveys (222, 223, 224, 225), the areas considered for surveys onboard of vessels fishing with static nets (marked roughly with shaded parallelograms) and the main ports (black circles) considered for the monitoring of fishing effort and landings

The frequency of occurrence (F.O.) of each Lessepsian species in the caches recorded during surveys of experimental trawling and on board of commercial fishing vessels (Table I) is presented as the ratio of the number of hauls/trips in which the species occurred to the total number of hauls/trips carried out at depths lower than 100 m, by survey (annual/seasonal) and fishing gear, considering 3 geographic divisions, eastern Ionian, northern Aegean (N>38^o) and southern Aegean Sea (N<38^o). The mean CPUE was expressed respectively as number of individuals (N), and as kilograms (kg) per haul or fishing trip for the different fishing gears, considering all registered hauls conducted till the depth of 100 m.

In the case of boat seine, fishing areas surveyed in 2008-2009, were grouped in 5 geographic divisions, eastern (E) Ionian (Zakynthos and Lefkada islands), middle-western (MW) Aegean (Saronikos and Evoikos Gulfs), northeastern (NE) Aegean (Lesvos and Chios islands), south-western (SW) Aegean (Cyclades islands, Argolikos and Lakonikos Gulfs) and south-eastern (SE) Aegean (Kos island), in which F.O and average CPUE of Lessepsian species were estimated bimonthly. In the Corinthiakos Gulf, a semi-enclosed deep-water basin of the Ionian Sea, no Lessepsian species was found despite the systematic sampling during the study period.

The monitoring of fishing effort and landings of the Greek Fishing fleet, carried out in the framework of the National Fisheries Data Collection Program (2003-2008) was based upon information collected on a monthly basis at thirty (30) prefectures, including 209 landing ports distributed at prefecture in the whole country. The data analysis was made for two geographical subdivisions of the Greek territorial waters, Ionian Sea (GSA 20) and Aegean Sea (GSA 22), as foreseen in the Framework of the Data Collection Regulations (EC 1543/2000; 1639/2001). The fleet in each GSA, was stratified by type of fishing gear (Table I) and category of fishing vessel's size (overall length of vessel: <12m, 12-24m, 24-40m).

Results

Geographic, bathymetric and size range of Lessepsian species

Ten Lessepsian fish species, *Etrumeus teres, Fistularia commersoni, Lagocephalus sceleratus, Lagocephalus spadiceus, Pteragogus pelycus, Siganus luridus, Siganus rivulatus, Stephanolepis diaspros, Upeneus molucensis* and *Upeneus pori* have been recorded within catches by different fishing gears in the southern Aegean Sea, only four of them (*L. spadiceus, S. luridus, S. rivulatus, S. diaspros*), in the eastern Ionian Sea, while *Sargocentron rubrum* has been reported only from trammel-net and long-line catches off Megisti island (NE Levant Sea). In the Northern Aegean only two Lessepsian fish species, *F. commersoni* and *S. diaspros*, were recently reported from boat seine catches (Table VI).

Table II. Depth range and total body length (TL) of the nine Lessepsian species more frequently registered from fishing gear catches in the Hellenic Seas

Species	Depth range (m)	Total Length range (cm)
Etrumeus teres	6 - 62	8.3 - 28.0
Fistularia commersonii	3 – 9	13.7 – 89.6
Lagocephalus sceleratus	1- 52	7.1 - 61.3
Pteragogus pelycus	3 – 9	3.2 – 10.0
Siganus luridus	2 – 60	3.3 – 27.0
Siganus rivulatus	3 – 55	4.5 – 29.0
Stephanolepis diaspros	1.5 – 114	3.7 - 64.9
Upeneus moluccensis	32 - 96	10.6 -11.7
Upeneus pori	30 - 55	6.1 – 16.3

Records of Lessepsian species are limited at depths lower than 100 m (Table II), except one record of *S. diaspros* at 114 m and the first record of *L. spadiceus* at 146 m (Ananiadis, 1952).

Bottom trawl catches

During experimental bottom trawl surveys carried out seasonally in different areas of the northern Aegean and the Ionian Seas in the decade 1983-1993 (Politou et al., 2007), Lessepsian species were absent from catches. Earliest records concern *Stephanolepis diaspros* found on the Cretan shelf during experimental trawling in 1989-91, which was also recorded along with *U*peneus molucensis from bottom trawl sampling at Cyclades-Dodecanisa islands in 1995-1996 (Table III). Records from the most recent bottom trawl surveys in the gulf of Messara include both species of the genus *Siganus* and new findings of *U. pori* on south Cretan shelf.

Table III. Lessepsian species seasonal frequency of occurrence (F.O.) and Catch Per Unit Effort (CPUE) at depths lowers than 100m, during bottom trawl regional surveys carried out by IMBC and IMBR-HCMR.

Geographic Area	Year	Season	Species	F.O.	Mean CPUE	
					N/hour	kg/hour
Cretan shelf	1988	summer	*Stephanolepis diaspros*	2/31	5.2	0.480
	1988	winter	*none*	0/25	-	-
	1989	spring	*Stephanolepis diaspros*	3/33	6.4	0.305
	1989	summer	*Stephanolepis diaspros*	2/33	2.5	0.143
	1989	winter	*Stephanolepis diaspros*	2/38	3.2	0.081
	1990	spring	*Stephanolepis diaspros*	2/29	2.5	0.094
	1990	summer	*none*	0/12	-	-
	1990	winter	*Stephanolepis diaspros*	1/12	6.0	0.054
	1991	spring	*Stephanolepis diaspros*	1/8	2.4	0.180
Messara Gulf (south Crete)	2007	summer	*none*	0/5	-	-
	2007	autumn	*Siganus luridus*	1/5	4.8	0.039
	2008	winter	*Siganus rivulatus*	2/5	13.4	0.102
			Stephanolepis diaspros	1/6	1.9	0.038
			Upeneus pori	2/7	5.0	0.095
Cyclades & Dodecanese	1995	autumn	*Stephanolepis diaspros*	1/18	27.0	-
			Upeneus moluccensis	1/18	4.0	0.070
	1995	winter	*Stephanolepis diaspros*	1/5	3.0	-
	1996	spring	*Upeneus moluccensis*	2/18	4.5	0.157
	1996	autumn	*none*	0/16	-	-

During the MEDITS experimental bottom trawl surveys carried out in early summer from 1994 to 2008, five Lessepsian species were only recorded in the southern Aegean Sea (including the Argosaronikos region) as shown in Table IV. Their findings were very scarce, not appearing, for none of these species, in more than 1 haul per annual survey, except from *S. diaspros* in 2008.

The presence of Lessepsian species, among commercial catches registered on board of trawlers was very scarce. *S. rivulatus* (5 individuals, total weight: 50 g) and *S. diaspros* (75 individuals, total weight: 750 g) have been reported in two hauls carried out during winter 2004 in the southern Aegean, while *L. spadiceus* (8 individuals, total weight: 4 kg) and *S. diaspros* (1 individual, total weight: 3.6 kg) were identified among catches from the Ionian sea in spring 2005 and autumn 2006 respectively.

Table IV. Lessepsian species recorded in experimental trawl catches, during MEDITS surveys 1994-2008.

Year *	Species	F.O.	Total number of individuals	Mean Individual Weight (g)	Depth (m)
1994	*Stephanolepis diaspros*	1/13	1	160	29
2003	*Siganus rivulatus*	1/19	3	67	28-32
	Stephanolepis diaspros	1/19	1	1000	28
2004	*Siganus rivulatus*	1/16	1	170	30-34
2005	*Etrumeus teres*	1/18	403	6.2	59-61
	Stephanolepis diaspros	1/18	1	35	25-26
2006	*Stephanolepis diaspros*	1/18	4	100	29-31
	Upeneus moluccensis	1/18	1	25	62-68
2008	*Stephanolepis diaspros*	2/18	4	105	43-53
	Upeneus pori	1/18	3	22	30

* none Lessepsian species was recorded during the MEDITS surveys in the years 1995-2001. MEDITS survey was not carried out in 2001 and 2007 in the Hellenic Seas.

Purse seine catches

Among commercial catches registered on board of Purse seiners, *Etrumeus teres* and *Stephanolepis diaspros*, were the only Lessepsians species that were recorded respectively at one and two hauls carried out in 2005, in the southern Aegean Sea.

Static nets catches

Surveys on board of inshore fisheries vessels recording catches with static nets, in the framework of the National Fisheries Data Collection Program 2003-2008, were carried out in the Ionian, the north and the south Aegean, focusing particularly in the geographic areas shown in Figure 1. *Stefanolepis diaspros* and the two species of the genus *Siganus* have been recorded in static nets catches in the southern Aegean and the eastern Ionian, since 2004, during spring, summer and autumn (Table V). Caught specimens of the three species were over 12 cm in total length and were frequently landed. Catches per vessel-trip never exceeded 1 kg for any of the Lessepsian species collected by static nets.

During experimental fishing with trammel nets near Megisti island (NW Levant Sea-GSA 24), carried out by NCMR in 1985-1986, *S. luridus, S. rivulatus* and *S. rubrum* were caught¸ the latter of which had been also fished by long-lines (Papaconstantinou *et al.*, 1988). *S. luridus* was among the most abundant species, representing the 11.3% of the collected individuals, ranging between 14cm and 27 cm in total length (TL).

During a recent survey on fisheries in the Argolic Gulf, a few specimens of *S. diaspros* (7.5-19 cm in TL) collected by trammel nets (16-18 mm and 28-34 mm mesh size) were the only Lessepsian species recorded (Kapiris, 2008).

Table V. Lessepsian species seasonal participation in landed (L) and discarded (D) catches of static nets from the southern Aegean and the Ionian Sea, monitored in the Framework of National Fisheries Data Collection Programm (2003-2008). (F.O.= Frequency of Occurrence; CPUE = Catch Per Unit Effort).

Area	Year	Season	Species	F. O.	Mean CPUE (N/trip)	Mean CPUE (kg/trip)	Mean Individual Weight (g)
South Aegean	2003	summer	none	0/8			
		autumn	none	0/6			
	2004	summer	*Stephanolepis diaspros*	2/10	0.3	0.013	42 L
		autumn	*Stephanolepis diaspros*	1/10	0.1	0.002	20 D
		winter	*Stephanolepis diaspros*	1/16	0.1	0.006	45 L
	2005	spring	*Siganus luridus*	1/12	0.1	0.033	400 D
		summer	*Siganus luridus*	2/12	0.3	0.051	203 L
		autumn	*Stephanolepis diaspros*	2/13	0.5	0.024	52 D
	2006	spring	none	0/11			
		summer	none	0/13			
		winter	none	0/6			
	2008	summer	*Stephanolepis diaspros*	2/15	0.4	0.059	148 L
		winter	none	0/12			
Eastern Ionian	2003	summer	none	0/8			
		autumn	none	0/8			
	2004	summer	none	0/11			
		autumn	*Siganus luridus*	1/10	0.9	0.094	104 L
		winter	none	0/12			
	2005	spring	*Siganus luridus*	1/6	0.3	0.039	117 D
		summer	*Siganus luridus*	1/12	0.1	0.011	160 L
		autumn	none	0/8			
	2006	spring	none	0/7			
		summer	*Siganus rivulatus*	1/10	0.3	0.051	171 L
		winter	none	0/7			
	2008	summer	*Siganus luridus*	1/9	0.1	0.031	278 D
		winter	none	0/4			

Table VI. Lessepsian species contribution in the boat seine catches by geographic area during the fishing period October 2008-March 2009. (F.O.= Frequency of Occurrence; CPUE = Catch Per Unit Effort).

Area	Months	Species	F.O. (%)	CPUE		Mean weight (g)
				N/haul	kg/haul	
E Ionian	Oct-Nov	*Siganus luridus*	3/33 (24.2)	2.6	0.012	5
		Siganus rivulatus	2/33 (6.1)	0.4	0.001	2
	Dec-Jan	none	0/10			
	Feb-Mar	none	0/6			
NE Aegean	Oct-Nov	none	0.4			
	Dec-Jan	*Fistularia commersonii*	1/14	0.1	0.001	5
		Stephanolepis diaspros	1/14	0.1	0.001	20
	Feb-Mar	none	0/18			
MW Aegean	Oct-Nov	*Lagocephalus sceleratus*	2/23	0.3	0.012	45
		Pteragogus pelycus	1/23	0.1	0.001	10
		Siganus luridus	3/23	2.0	0.036	17
		Siganus rivulatus	4/23	0.2	0.004	21
		Stephanolepis diaspros	14/23	1.2	0.059	50
	Dec-Jan	*Lagocephalus sceleratus*	2/17	0.2	0.013	55
		Pteragogus pelycus	2/17)	0.7	0.003	4
		Stephanolepis diaspros	11/17	3.7	0.212	57
	Feb-Mar	none	0/4			
SW Aegean	Oct-Nov	*Fistularia commersonii*	7/36	0.3	0.004	15
		Lagocephalus sceleratus	4/36	0.8	0.026	33
		Siganus luridus	16/36	1.2	0.014	12
		Siganus rivulatus	1/36	0.1	0.003	30
		Stephanolepis diaspros	18/36	1.6	0.090	55
	Dec-Jan	*Fistularia commersonii*	5/26	0.2	0.007	29
		Lagocephalus sceleratus	2/26	0.9	0.036	39
		Siganus luridus	5/26	0.5	0.004	7
		Stephanolepis diaspros	15/26	1.7	0.144	83
	Feb-Mar	*Fistularia commersonii*	1/27	0.1	0.000	5
		Lagocephalus sceleratus	1/27	0.0	0.001	30
		Pteragogus pelycus	10/27	0.8	0.003	4
		Siganus luridus	6/27	0.4	0.007	16
		Siganus rivulatus	2/27	0.1	0.000	5
		Stephanolepis diaspros	10/27	0.7	0.067	101
SE Aegean	Dec-Jan	*Etrumeus terres*	1/1	6.0	0.150	25
		Fistularia commersonii	1/1	1.0	0.015	15
		Pteragogus pelycus	1/1	9.0	0.028	3
		Siganus luridus	1/1	8.0	0.080	10
		Siganus rivulatus	1/1	316.7	1.900	6
	Feb-Mar	*Fistularia commersonii*	2/2	13.5	0.460	34
		Pteragogus pelycus	2/2	6.2	0.025	4
		Siganus luridus	2/2	157.3	1.985	13
		Siganus rivulatus	2/2	699.4	3.525	5

Boat seine catches

Boat-seine catches composition, at Zakynthos isl. (SE Ionian), Pagasitikos gulf (NW Aegean) and Cyclades islands (SW Aegean) in 2000, suggested that Lessepsian fish species were only represented by *S. diaspros* fished in Cyclades (Petrakis *et al.*, 2001).

However, during a most recent study of beach seine catches, conducted in 2008-2009, seven Lessepsian fish species, *E. teres, F. commersoni, L. sceleratus, P. pelycus, S. luridus, S. rivulatus* and *S. diaspros*, have been identified (Table VI). The two species of *Siganus* were the only Lessepsian species recorded in the Ionian Sea during autumn, while they were also among the most frequently Lessepsians caught in the Aegean Sea. *S. diaspros*, occurred in more than 50% of boat-seine hauls in the western Aegean, appearing also in NE Aegean waters, but was absent from the catches in Kos island (SE Aegean). In February-March the Lessepsian species were less frequently caught in the SW Aegean and absent from catches in the northern most sampled fishing grounds (Table VI). Apart from a few large specimens (TL>15cm) of *S. diaspros*, Lessepsian fishes were discarded. Even in cases like those of *S. luridus* and *S. rivulatus*, that reached a maximum of 170 and 1174 ind/haul respectively, catches were discarded due to the small size of the collected individuals (TL<14 cm). On the other hand, specimens of the long-bodied *Fistularia commersoni*, which reached a maximum size of 52 cm TL, were discarded because the species does not present any commercial interest, and the same is true for the small-sized species *P. pelycus* (TL_{max}=15 cm).

Lessepsian species landings

Reports of Lessepsian species landings by the commercial fishing fleet, appeared after 2004 in GSA 22 (Table VII) The main regions where these reports appear are the Dodecanese prefecture and particularly the Rhodes Island, as well as the prefectures of Chania and Heraklion in Crete island. *Siganus luridus* and *Siganus rivulatus* are the two species reported under the single common name “germanos”, among landings of small scale fishery boats fishing with trammel nets.

According to local reporters *Upeneus molucensis* participates in trawler’s landings in the Dodecanese islands, mixed with other species of Mullidae.

Table VII. Estimated annual landings Siganus sp. in the Aegean Sea.

Year	Vessel length class	Landings (kg)	Error
2004	<12 m	9.079,43	52,57%
2006	<12 m	6.718,23	29,02%
2006	12-24 m	114,39	56,58%
2007	<12 m	62.755,56	13,20%
2008	<12 m	6.661,55	27,57%

Discussion

Despite the scarcity of Lessepsian species records in fishery surveys, a relative increase in the frequency of occurrence is noted for some of these species, indicating the progressive acceleration of their spreading in the Hellenic Seas in recent years. The latter is in accordance with other findings suggesting an increasing rate of new Erythrean biota entry in Hellenic waters (Pancucci-Papadopoulou *et al.*, 2005; Peristeraki *et al.*, 2006; Corsini-Foka & Economidis, 2007; Zenetos *et al.*, 2009). In addition to sea warming, other factors such as salinity increase and oceanographic forcing, have been considered to favour the expansion of alien species of warm water affinity like Lessepsians (Raitsos *et al.*, 2010).

However, Lessepsian migration up to now has minor effects on Hellenic commercial fisheries, that concern mainly certain local coastal fisheries particularly in the SE Aegean Sea. The major part of Lessepsian fish caught by professional fishermen, are discarded either due to their low/no commercial value, or due to the small quantities obtained and the generally small size of caught individuals, in cases when there is a certain local market demand for a specific species.

Among the most frequently reported species, there are some of those considered as the earliest migrants to the Aegean Sea, such as S. *diaspros*, *S. luridus* and *S. rivulatus* (Zenetos *et al.*, 2009), that are generally caught in larger number of individuals per unit of effort and are occasionally landed depending on the size of individuals caught and the total daily catch. On the contrary, fast expanding Lessepsians like *F. commersoni* and *L. sceleratus* that have entered into the eastern Mediterranean during the last decade, and present a wide distribution in the Aegean Sea (Karachle *et al.*, 2004, Galil, 2006; Peristeraki *et al.*, 2006), they are usually caught in low numbers. The number of individuals caught per unit of fishing effort, might also depend on the aggregating behaviour displayed by some of the Lessepsian fish species like *E. terres* and the siganids (FISH BASE).

The exceptionally numerous records of *L. sceleratus* during the last 4 years should not be overestimated, as they are mainly due to the large publicity given and the particular interest expressed by the social and scientific institutions because of the potential risk of this species for human consumption. Several catches of *L. sceleratus* have been recorded from trammel-net fisheries around Crete island (Peristeraki *el al.*, 2006), but due to the lack of systematic surveys on board of inshore fishing vessels in this area, no further analysis on the contribution of the specific species, as well as that of other Lessepsians to daily catches was possible.

Analysis of boat-seine catches during the fishing period Oct. 2008-March 2009, in the framework of specific surveys onboard professional vessels operating over a wide area of the Aegean and the Ionian Seas (Anonymous 2009), showed a substantial northward extension of the previously known spreading out of *S. diaspros* and the small-sized *P. pelycus* (Lefkaditou *et al.*, 2010). Boat-seine survey findings have also contributed in obtaining a more clear idea of the spatio-temporal variation of Lessepsian species occurrence in coastal fishing grounds. The percentage of hauls, where Lessepsian migrants appeared, was considerably higher (>60%) in the southern Aegean Sea, reaching the 100% of hauls realized around Kos island (SE Aegean) (Lefkaditou *et al.*, 2010). However Lessepsian fish species, were generally not exceeding 1% (0.2 kg/haul) of boat-seine catches in terms of weight, except from those in the southeastern Aegean where they composed 2,3% of catches (Lefkaditou & Petrakis, 2010).

Recent studies of the Hydrobiological Station of Rhodes, based mainly on boat seine catches around Rhodes Island, have revealed the importance of Lessepsian species to the local coastal fish assemblages and hence to the catches in the area (Kalogirou *et al.*, 2010; Corsini-Foka *et al.*, 2011). In addition, the occurrence of four more Lessepsian fish species, *Lagocephalus suezensis*, *Sphyraena chrysotaenia*, *Upeneus molucensis* and *Upeneus pori*, has been reported in boat seine catches around Rhodos island (Kalogirou *el al*., 2010; Corsini *el al*. 2011). The absence of these species, as well as that of *L. sceleratus* and *S. diaspros,* from boat seine catches in Kos island (SE Aegean) might be due to the low number of hauls conducted in this area (Table VI), although it should be pointed out that only *U. molucensis* among the four above-mentioned species has been ever recorded northern to Rhodes Island (ELNAIS).

The factors controlling expansion of Lessepsians in the Aegean and the Ionian Seas are evidently related to the physiological properties of each species, as well as to the biological characteristics and the essential habitat for the different life stages, which have not yet been sufficiently understood. The foreseen scheme for the collection of metier-related variables for 2011-2013, in application of the EC Regulation 199/2008, will be based on the concurrent sampling of catches on-board fishing vessels, and of commercial landings, at 12 major areas ensuring a better coverage of inshore fishing activities over the whole country and hence shedding further light on catches of Lessepsian species in Hellenic territorial waters. Furthermore, a more comprehensive study of both environmental processes and life history of species (including Lessepsian migrants) distributed in the eastern Mediterranean is needed, in order to improve our understanding of their population dynamics and the links with environmental variability.

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Sub-regional Technical meeting on the Lessepsian migration and its impact on eastern Mediterranean fishery

Nicosia, 7-9 December 2010

Study on the lessepsian migrant *Lagocephalus sceleratus* in Cyprus

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Abstract

A study on the lessepsian migrant *Lagocephalus sceleratus* in the coastal waters of Cyprus was conducted during the years 2009 and 2010. Here the main results and conclusions concerning its growth, reproduction, feeding, preferable environmental and meteorological conditions, spatial distribution in the study area and possible reasons of its success are presented and discussed.

Introduction

Lagocephalus sceleratus (Gmelin, 1789) is a member of the Tetraodontidae family (Class: Actinopterygii, Order: Tetraodontiformes), which includes 19 genera and 121 species (Froese & Pauly, 2010). It is one of the largest members of its family, reaching 110 cm in standard length and 7 kg in weight (Smith, 1965; Masuda *et al.*, 1984; Smith & Heemstra, 1986; Froese & Pauly, 2010). *L. sceleratus* has a widespread distribution throughout the tropical Indian and Pacific Oceans, from Japan, Australia and Hong Kong in the east to Mozambique and southern African shores, as well as the Red Sea (Dor, 1984; Smith & Heemstra, 1986; Ni & Kwon, 1999; Akyol *et al*., 2005; Froese & Pauly, 2010).

L. sceleratus was first recorded in the Mediterranean Sea in February 2003 in Gökova Bay, Turkey (Akyol *et al*., 2005). In September 2004 the species was recorded in Antalya Bay, Turkey (Bilecenoglu *et al*., 2006), in November 2004 in Jaffa, Israel (Golani & Levy, 2005), in September 2005 in Rhodes island, Greece (Corsini *et al*., 2006), in December 2005 in Crete, Greece (Kasapidis *et al*., 2007) and in April 2006 in Izmir Bay, Turkey (Bilecenoglu *et al*., 2006). The first official record from Cyprus was in 2006 (DFMR, 2006; Katsanevakis *et al*. 2009), although the species was well known much earlier.

L. sceleratus is characterized as an invasive species and included in the list of the 100 "worst invasives" in the Mediterranean (Streftaris & Zenetos, 2006; Katsanevakis *et al*., 2009). In Cyprus *L. sceleratus* has a significant negative impact on the artisanal fisheries, since it often damages both the fishing gear and the catch of the fishermen with its powerful jaws. In some areas, many fishermen have even altered their fishing methods (gear, depths, time of the day, etc.) in order to avoid interaction with this species (Katsanevakis *et al*., 2009). According to unpublished statistics of the Department of Fisheries and Marine Research of Cyprus, in 2009 and 2010, *L. sceleratus* represented around 4% in weight of the total artisanal catch of Cyprus. *L. sceleratus* also has a potential risk to humans, since it contains tetrodotoxin, which may cause poisoning and even death (Bentur *et al.,* 2008; Katikou *et al.,* 2009; Katsanevakis *et al*., 2009).

This study is a first attempt to study the biological and ecological characteristics of *L. sceleratus* in the coastal waters of Cyprus, as well as to define the possible reasons for its establishment success in the area.

Materials and Methods

L. sceleratus fishing data were collected from the artisanal fisheries of Cyprus during the period October 2009 to December 2009 and May 2010 to October 2010 (8 months in total). For each fishing trip, fishing data including the date, fishing area (Fig. 1), depth, bottom type, fishing gear (type, size, quantity), fishing hours and duration, as well as the total number and weight of *L. sceleratus* specimens caught, were collected. For the same period, environmental data were also collected, including wind and current conditions (on a scale 1 to 3), the moon phase, as well as sea surface temperatures - SST (°C) (from unpublished data of the Department of Fisheries and Marine Research, Cyprus).

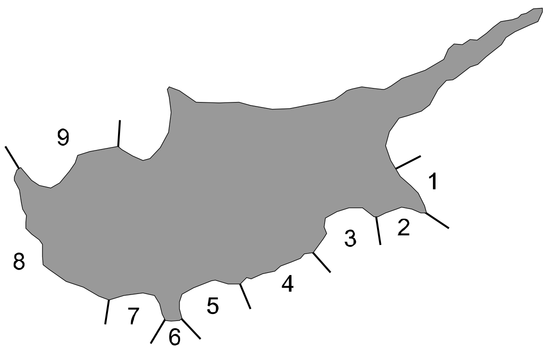

Fig. 1. Map of Cyprus with fishing areas under study (1 – 9).

By applying a random selection of trips and specimens per area, 50 specimens per week from each area (where possible) were examined for the collection of biological data. These data included total length (mm), weight (g), sex, maturity stage (Nikolsky scale 1-6), weight of the gonads (g), content of stomach (on a taxon level) and fullness of stomach (on a scale 1 to 3).

All data where then analyzed for the determination of biological and ecological characteristics of *L. sceleratus* including size and growth (size range, length distributions, length-weight relationships, Von Bertalanffy growth equation), reproduction (spawning season, mean length at sexual maturity, sex ratio), feeding (food type, feeding intensity), ecology (preferable temperature, depth, bottom type, wind and current conditions, moon phase) and distribution in the study area (preferable areas, spawning grounds).

Results

During the 8-month period, 2,250 trips were recorded, at which a total of 61,228 *L. sceleratus* individuals were captured, weighing around 30 tons. Approximately 80% of all fish were caught in fishing areas 1 to 4, which only represent around 37% of the total coastline of the study area (Fig. 2). Together with *L. sceleratus*, 5 *Lagocephalus spadiceus*, 216 *Lagocephalus suezensis* and 7 *Torquigener flavimaculosus* specimens were also recorded. This is the first record of *Torquigener flavimaculosus* in Cyprus waters.

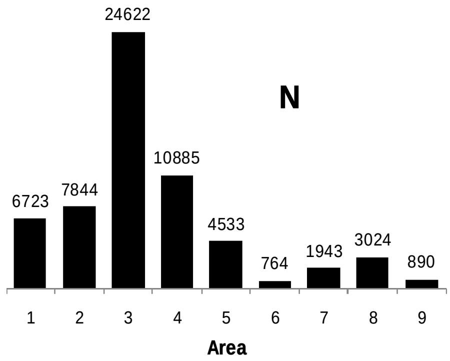

Fig. 2. Total number of *L. sceleratus* individuals caught in each fishing area.

More than 10% of the total number of *L. sceleratus* individuals (6,656) was examined for the collection of biological data.

The total length of the examined specimens ranged from 60 to 770 mm (Fig. 3) and their weight from 3 to 5,600 g. Individuals larger than 690 mm in total length were all females, with the exception of one male.

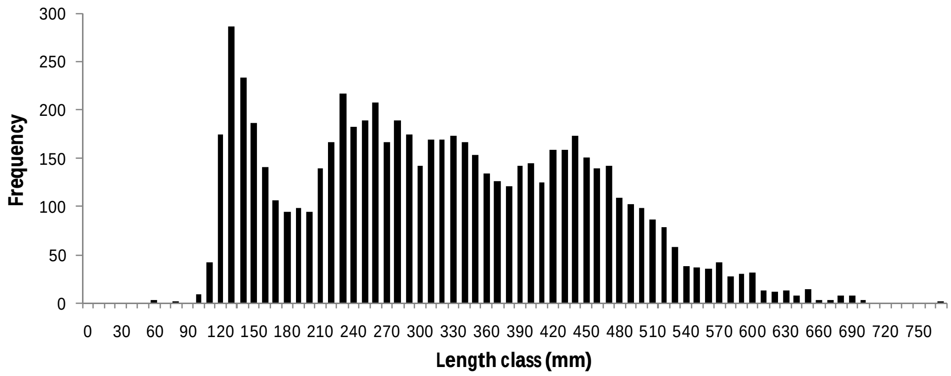

Fig. 3. Length frequencies of *L. sceleratus* specimens examined during the months May to December.

The length–weight relationship (W in g and TL in cm) for both sexes together was found to be $W=0.0106\ TL^{3.018}$, indicating a slightly positive allometric growth (Fig. 4). A slight difference was found in the L-W relationship between females ($W=0.0105\ TL^{3.0255}$) and males ($W=0.0111\ TL^{3.0037}$), which can be attributed to the difference in gonad weight, especially during the spawning season.

Growth based on length frequencies was best described by the seasonalized Von Bertalanffy growth equation, where L_{∞}=820 mm TL, K=0.5 yr^{-1} and C=1, indicating strong seasonal oscillations, with higher growth rate in warm months and lower in cold months (Fig. 5). Separation of normal distributions using Bhattacharya's method was difficult to apply because of the absence of data for 4 months, the absence of the very small classes due to gear selectivity and also the high growth rate right after spawning, in the same age class, which affected the theoretical normality of the distribution. Nevertheless, at least 3 age classes (0+, 1+, 2+) were present in the catches.

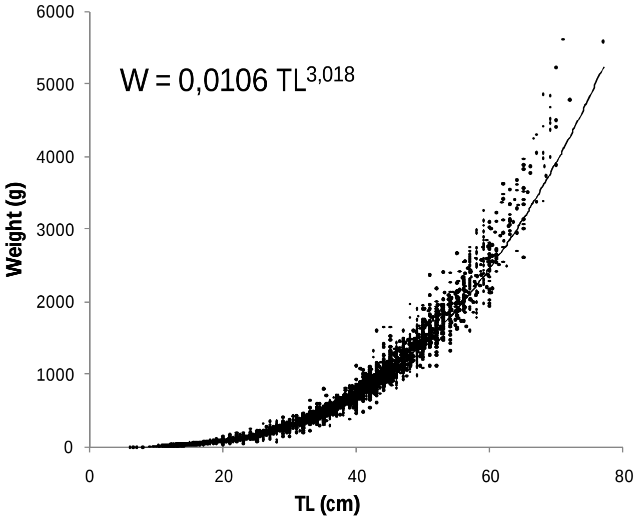

Fig. 4. Length-weight relationship for *L. sceleratus* (both sexes).

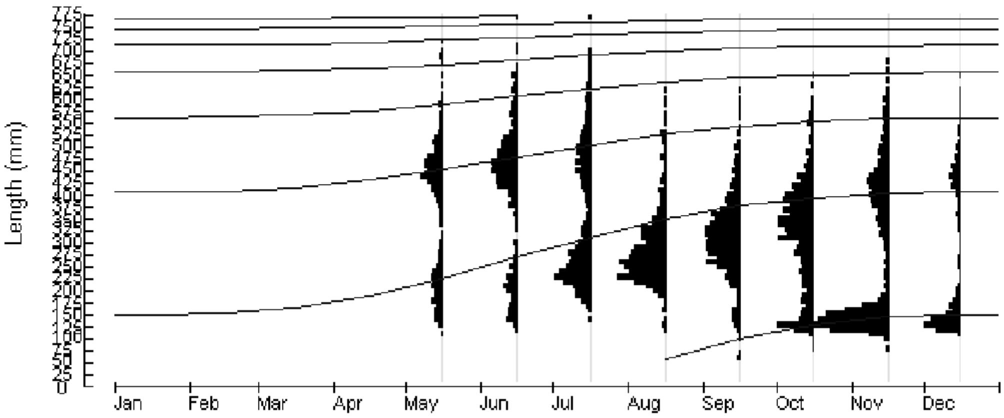

Fig. 5. Seasonalized Von Bertalanffy growth curves for *L. sceleratus* in relation to monthly length frequencies.

The monthly mean values of the gonadosomatic index (GSI) for the months May to December (Fig. 6) showed that spawning of *L. sceleratus* in Cyprus takes place mainly in June and July. This was also clear by the rapid decrease in the number of individuals at Nikolsky stage 5, especially from June to July, which is an indication that most mature individuals had already spawned (Fig. 7).

The mean length at sexual maturity (L_m), which is the length at which 50% of all fish have gonads in an advanced stage of development (stages 3-6 in the Nikolsky scale), was around 200 mm TL for both sexes (Fig. 8). The average size of spawners (individuals at stage 5 in June and July) was approximately 52 cm TL (Fig. 9) and 1600 g in weight. These results indicated that the first reproduction generally takes place when fish are at the end of age 1 (~ 2 years old).

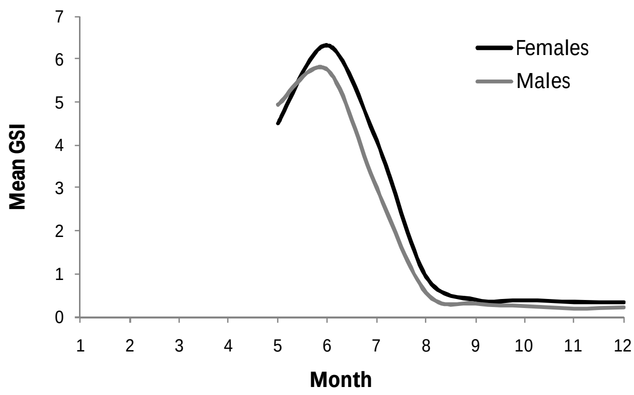

Fig. 6. Monthly mean GSI values of female and male *L. sceleratus* for the months May to December.

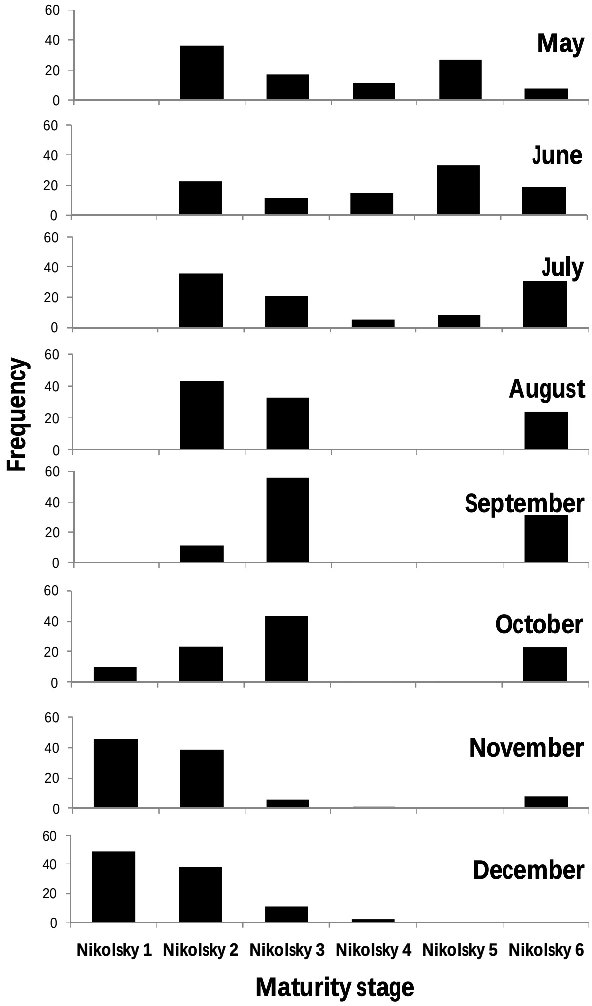

Fig. 7. Monthly frequencies of *L. sceleratus* individuals from each Nikolsky maturity stage (1-6).

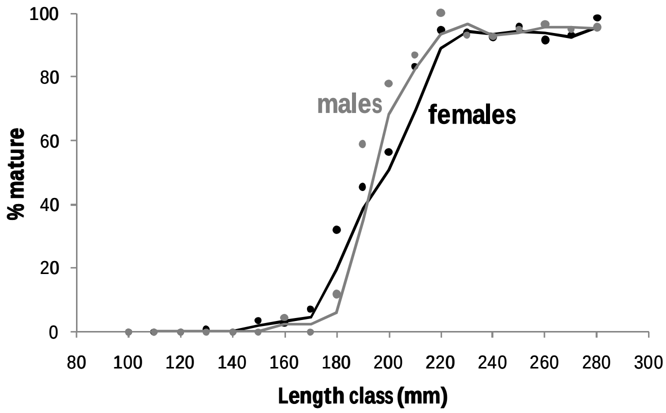

Fig. 8. Percentage of male and female mature *L. sceleratus* individuals, per length class.

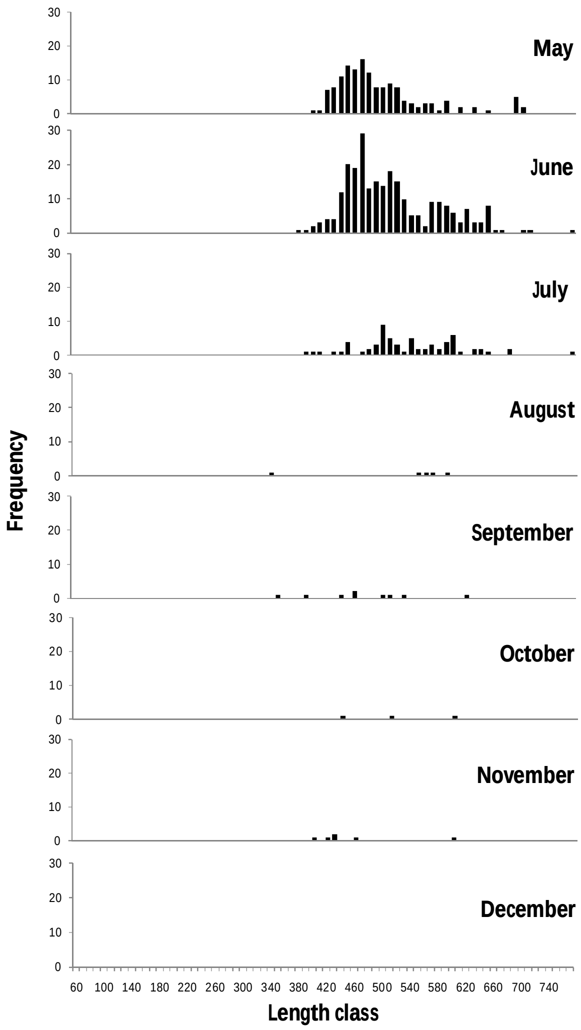

Fig. 9. Monthly length frequencies of *L. sceleratus* specimens at maturity stage 5 for the months May to December.

The proportion of males to females (sex ratio) was not found to change significantly according to length class (P=0.1) (Fig. 10) or month (P=0.29) (Fig. 11).

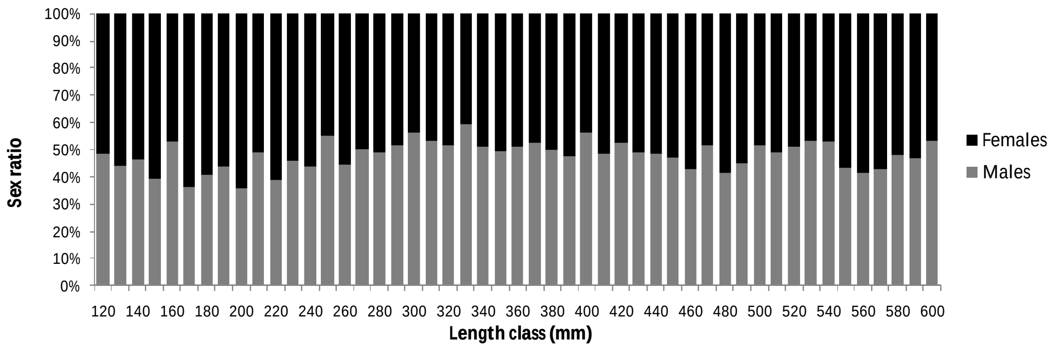

Fig. 10. Sex ratios of *L. sceleratus* for each length class (small and big classes are not included due to small number of specimens).

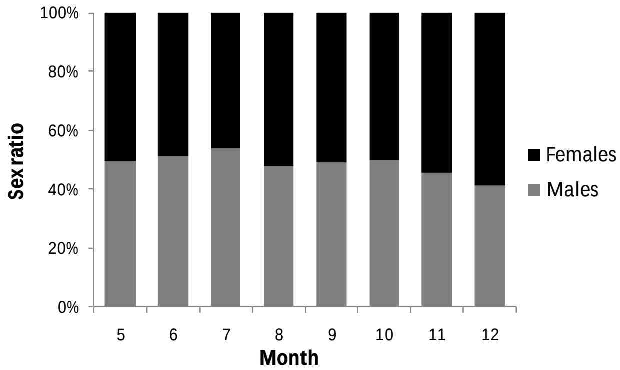

Fig. 11. Monthly sex ratios of *L. sceleratus* for the months May to December.

The food items found in *L. sceleratus* stomachs included fish (including its own species) in 27% of all fish examined, crustaceans (7.3%), cephalopods (4.5%) and echinoderms (0.2%). Pieces of marine plants, items most probably used as bait (animal flesh and bones, potatoes etc.), as well as pieces of fishing net (8.4%) and hooks (0.2%) were also found. The percentages of each food type found in the stomachs of *L. sceleratus*, with and without net are shown in Fig. 12.

All length classes seemed to feed with all three main types of prey (Fig. 13). Feeding intensity in terms of percentage of empty stomachs was found to be quite stable during the year, at around a mean of 60% (±5%) of all specimens examined (Fig. 14).

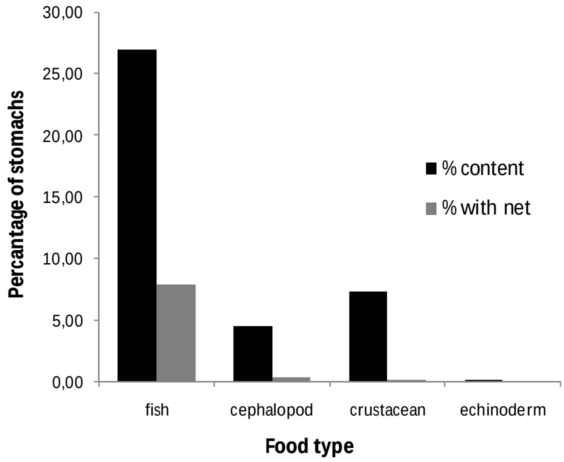

Fig. 12. Percentage of each food type of *L. sceleratus*, with and without net.

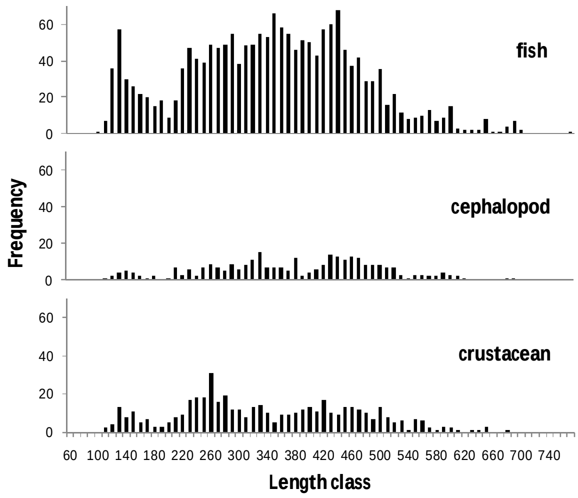

Fig. 13. Length frequencies of *L. sceleratus* by food type.

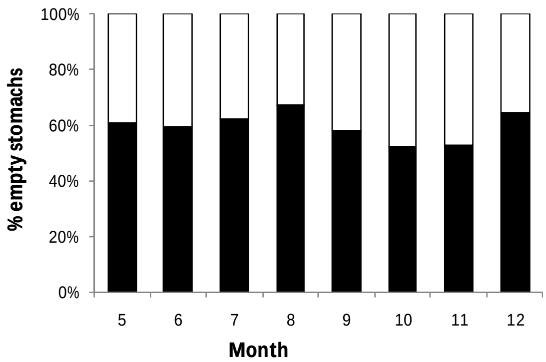

Fig. 14. Monthly percentages of empty stomachs (black) for *L. sceleratus* for the months May to December.

All fish were caught between 2 and 120 m of depth, whereas about 90% of the fish were caught between 10 and 40 m of depth (Fig. 15).

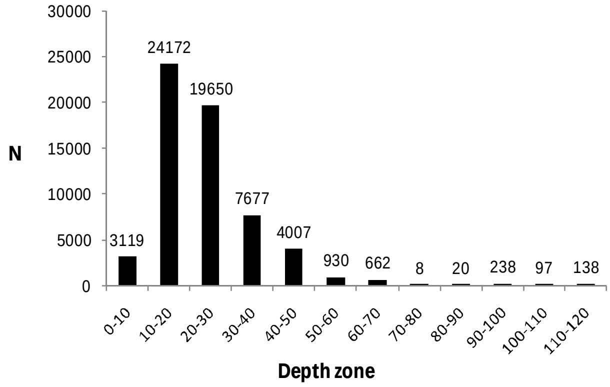

Fig. 15. Number of *L. sceleratus* individuals caught at each depth zone.

The bottom type did not seem to affect the catchability of *L. sceleratus* since the percentage of the number of fish caught over each bottom type (weighted by number of trips) resembled the composition of the study area. The same applied for the wind and current conditions (Fig. 16).

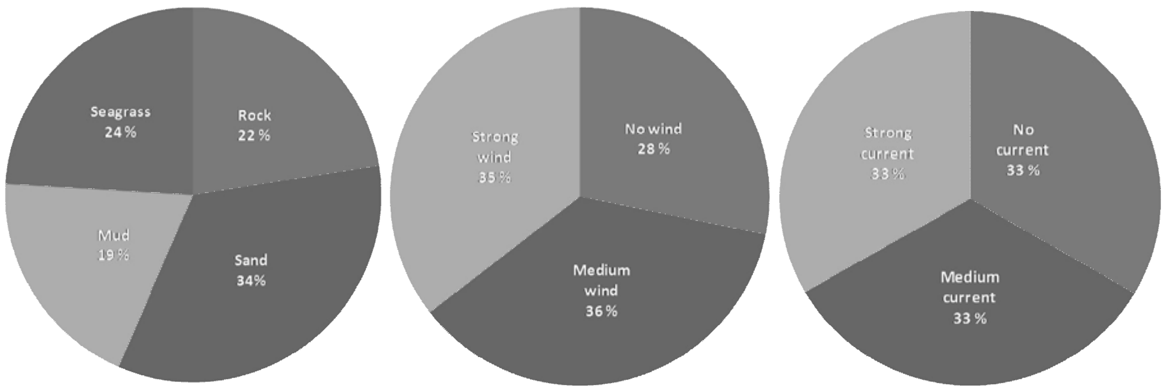

Fig. 16. Percentage of *L. sceleratus* individuals (weighted by number of trips) caught over different bottom types (left) and different wind (middle) and sea current (right) conditions.

The average number of fish caught per fishing trip did not seem to change significantly according to the moon fullness (luminosity). Nevertheless there seemed to be a slight increase in the numbers of fish caught per trip close to full moon (Fig. 17).

The length distributions of *L. sceleratus* in fishing areas 1 to 9 (Fig. 18) revealed a spatial separation of different length classes. Big individuals were more abundant in areas 2 and 3, especially during the spawning season (possibly spawners) (Fig 19). In addition, more than 75% of the individuals at maturity stage 5 were caught in areas 1, 2 and 3 (Fig. 20), suggesting the existence of possible spawning grounds of *L. sceleratus* in these areas.

The monthly mean SST of areas 1, 2 and 3 was found to be at least 3 ºC higher compared to the rest of the areas during the warm months of the year, when reproduction takes place (Fig. 21). The peak of the spawning season was found to coincide with a mean SST of around 25°C.

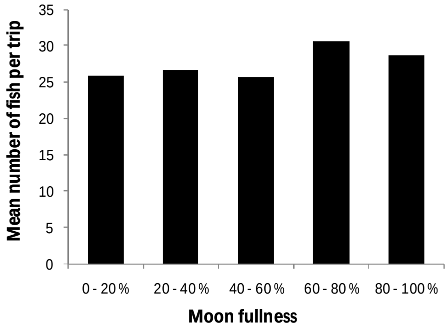

Fig. 17. Average number of *L. sceleratus* individuals caught at each fishing trip, in relation to the moon fullness.

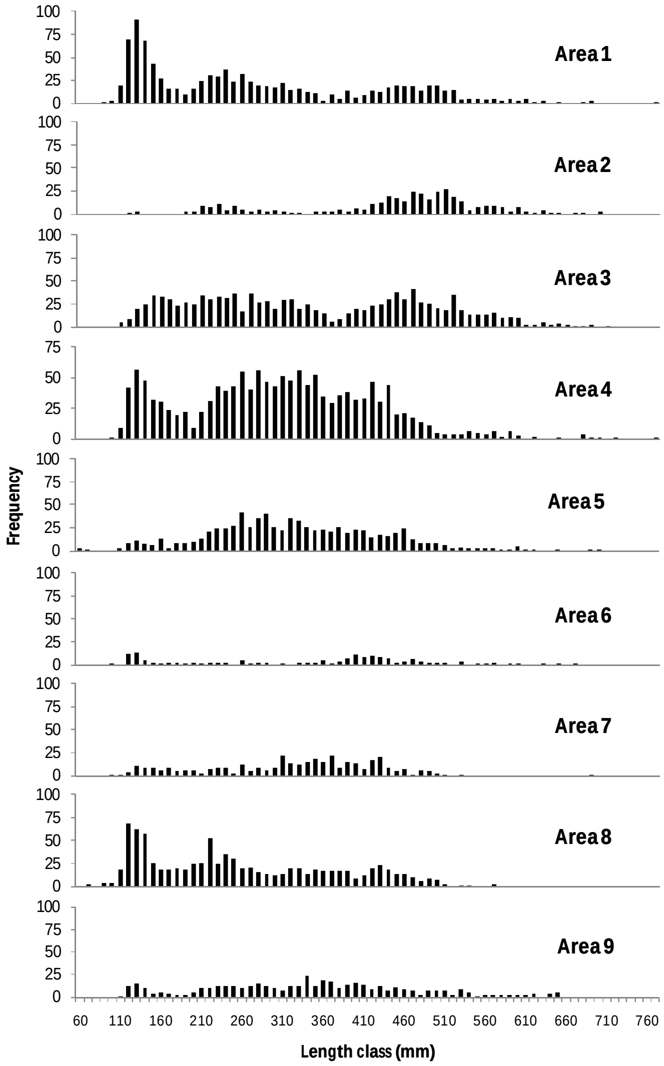

Fig. 18. Length frequencies of *L. sceleratus* in fishing areas 1 to 9 for the months May to December.

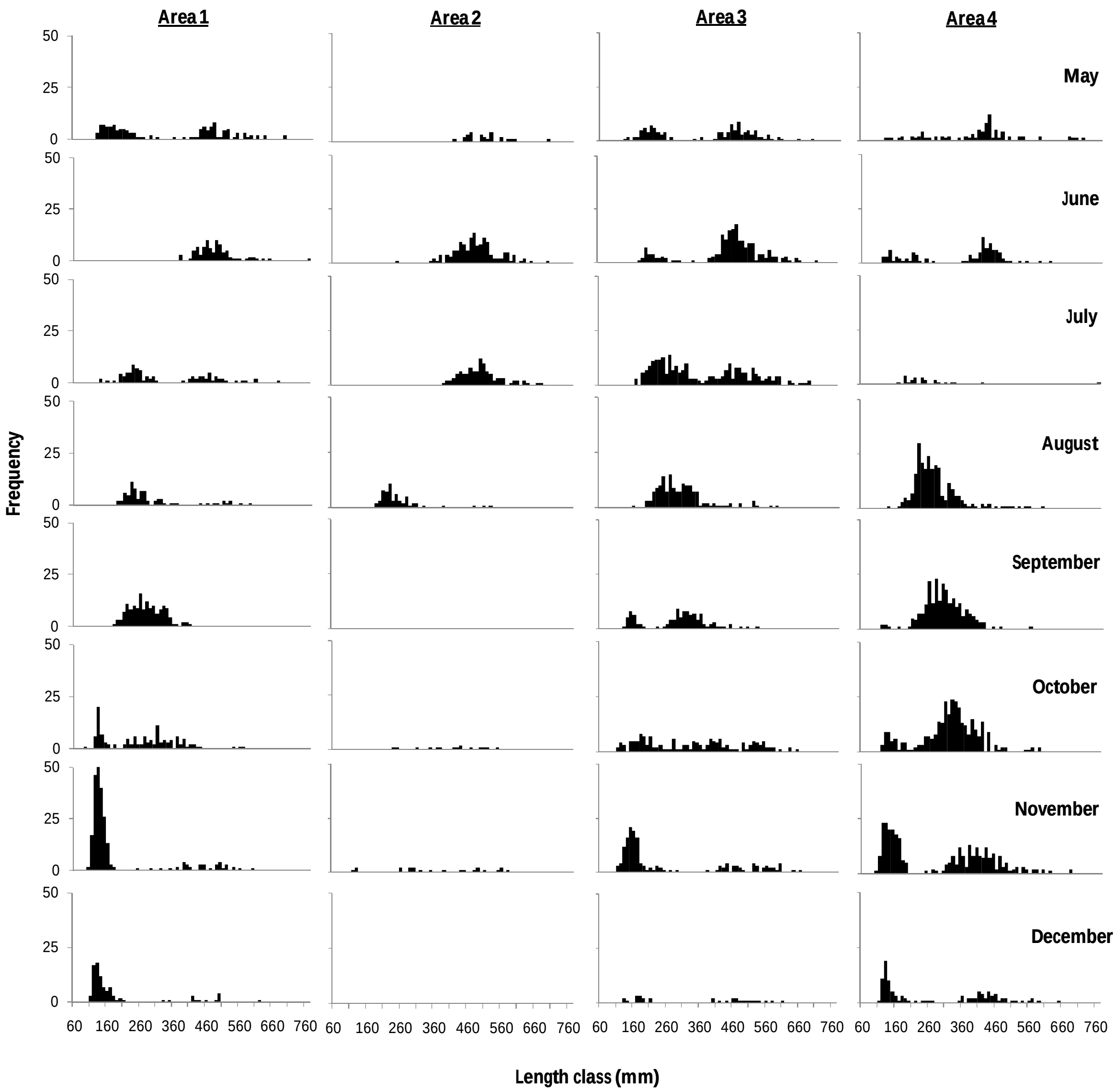

Fig. 19. Monthly length frequencies of *L. sceleratus* in fishing areas 1 to 4 for the months May to December.

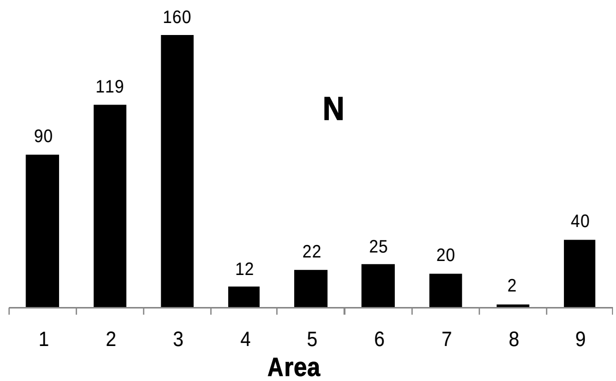

Fig. 20. Total number of *L. sceleratus* individuals at maturity stage 5 caught at each fishing area.

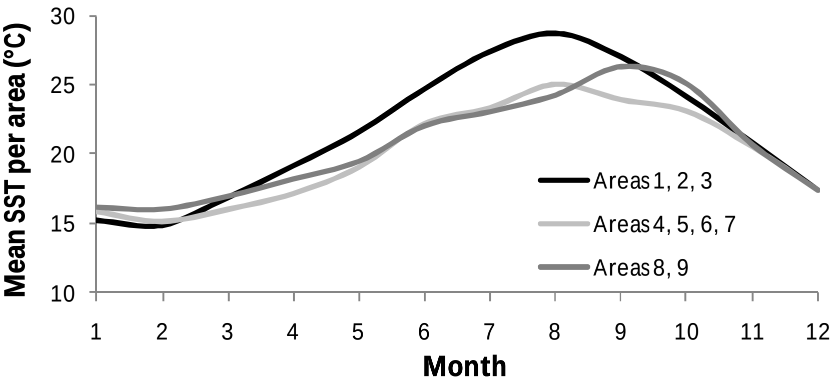

Fig. 21. Monthly mean SST of the areas 1-3, 4-7 and 8-9.

Discussion

The ongoing arrival of lessepsian species in the Mediterranean Sea has altered in many cases the community structure along many coastal areas of the Levantine Basin (Galil, 2007). In Cyprus, lessepsian fish species represented up to 10% in weight of the annual artisanal landings in the last years (DFMR, unpublished data). Along with the first record of *Torquigener flavimaculosus* in Cyprus waters reported in this work, there are now officially 28 lessepsian fish species in Cyprus (Ioannou *et al.*, 2010) and possibly many more not yet recorded.

L. sceleratus has become a dominant species in many parts of Cyprus, like in many other coastal areas of the Levantine basin, during the last years. The reasons for its success over other species in this new environment can be attributed to several factors. According to the present work, *L. sceleratus* is a fast growing species, capable of reproducing at only 2 years of age (Fig. 5). This combined with the fact that in Cyprus *L. sceleratus* is not a target species for the fisheries and up to now has no known predators or competitors in the area, gave this species an advantage over other species to expand and settle freely in all suitable environments.

The relatively high percentage of stomachs including both fish and pieces of net (Fig. 12), could suggest that *L. sceleratus* often preys on fast swimming fish when they are already entangled in nets (energy efficient) or even that it makes use of the nets for hunting fish, a possible indication of high intelligence compared to other species. In any case *L. sceleratus* seems to be greatly adaptable in its feeding behavior, which is also supported by the fact that it preys on all types of food at all ages (Fig. 13) and also the stable feeding intensity in all seasons (Fig. 14).

The fact that external factors like the bottom type and the wind and current conditions did not affect the catchability of the species (Fig. 16) shows its great tolerance to environmental variations. Nevertheless, 3 factors seemed to affect more or less the catchability of fish: SST, depth and the moon phase.

The fact that approximately 80% of all fish were caught in fishing areas 1 to 4 (Fig. 2), combined with the fact that fishing effort was similar in all fishing areas, suggests that there is a higher abundance of the species in these 4 areas in relation to the rest 5. In addition, most of the spawning activity was found to take place in areas 1, 2 and 3 (Fig. 20), suggesting the existence of possible spawning grounds of *L. sceleratus* in these areas. The preference of *L. sceleratus* for these areas could be explained by their higher monthly mean SST, especially during the warm months of the year (Fig. 21), which are apparently important for the well being of tropical species like *L. sceleratus* (Froese & Pauly, 2010). The fact that most specimens were caught in shallow (warmer) waters may also be related to the tropical nature of *L. sceleratus*.

The slight increase in the numbers of fish caught per trip close to full moon (Fig. 17) seems to agree with reports from fishermen that the species is more active during the day and at nights with full moon. If this is the case, it may indicate that this species mostly depends on its sight, rather than other senses, to hunt.

The social and economic effects of the presence of *L. sceleratus* to the fisheries, as well as its impact on the ecosystem are very difficult to assess. For example, according to DFMR unpublished data and reports from the artisanal fishermen, there seems to be an effect of the increasing *L. sceleratus* population, at least since 2006, on the cephalopod populations in Cyprus (Fig. 22). If this is the case, then many commercial species that feed on these cephalopods are indirectly affected by the presence of *L. sceleratus*, and this in its turn affects the catches and the income of artisanal fishermen. It has been foreseen that the impact of alien species like *L. sceleratus* on fisheries and the ecosystem will intensify in the future in more Mediterranean countries and especially in the Levantine basin (Katsanevakis *et al.*, 2009).

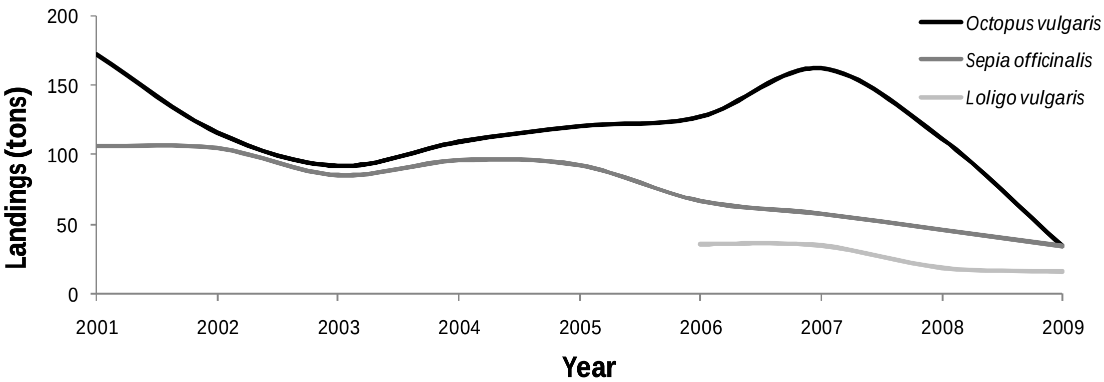

Fig. 22. Annual landings of *Octopus vulgaris, Sepia officinalis* and *Loligo vulgaris* in Cyprus for the years 2001 to 2009.

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Past and present of fish fauna in the NE Levant Sea and factor facilitating the colonization by Lessepsian fishes

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Abstract
Occurrence of Lessepsian fishes in the bottom trawl surveys carried out in 1980's and 2000's were compared. Surprisingly the percentages of Lessepsian fishes in the total catch (fish only) were significantly higher in 1980's (40-50%) almost twice the percentage in 2000's (20-30%). Yet, a slight decrease in the occurrence of Lessepsian fish was noted as the last 5 years were considered. However the number of Lessepsian fish species observed in the catch are much larger in the recent surveys as compared to 1980's and the number is keep increasing with a rate of 1.7 species per year. The comparison of these results with a neighbouring Fisheries Restricted Area (FRA) represented a similar rate of increase in the number of Lessepsian fish species (1.2 Lessepsian fish/year) despite significantly reduced fishing pressure in the FRA. The percentage of Lessepsian fishes in the total fish biomass, however, has increased remarkably within the FRA, possibly indicating that the Lessepsian fishes show faster recovery rate than the native species when a stress factor over the ecosystem is removed or at least reduced.

On the other hand, the pelagic trawl surveys conducted on the same area showed that Lessepsian small pelagic fishes were not as successful as the demersal fishes. Their involvement was around 5-7% of the total small pelagic catch. This is probably due to successful adaptive feeding and spawning strategies of the dominant native small pelagic fish, *Sardinella aurita* agreeing well with the eutrophic and subtropical nature of the area. Yet, in contrary to its demersal counterparts, *S. aurita* is a thermophilic species. This feature enhances its resilience against intruders.

Introduction
Demersal stocks in the NE Levant Sea have been exploited since 1940 when there were only two demersal trawlers in the region (Aasen and Akyuz, 1956). Later, in the 1950s, when the number of trawlers reached 14, a drop in the CPUE drew the attention of the local authorities and a fisheries survey was carried out in the Gulf of Iskenderun (Aasen and Akyuz, 1956; Akyuz, 1957). The survey revealed the first symptoms of over-fishing, but the fishing fleet kept growing. The increase in the number of boats further intensified after the mid 1980s (Figure 1).

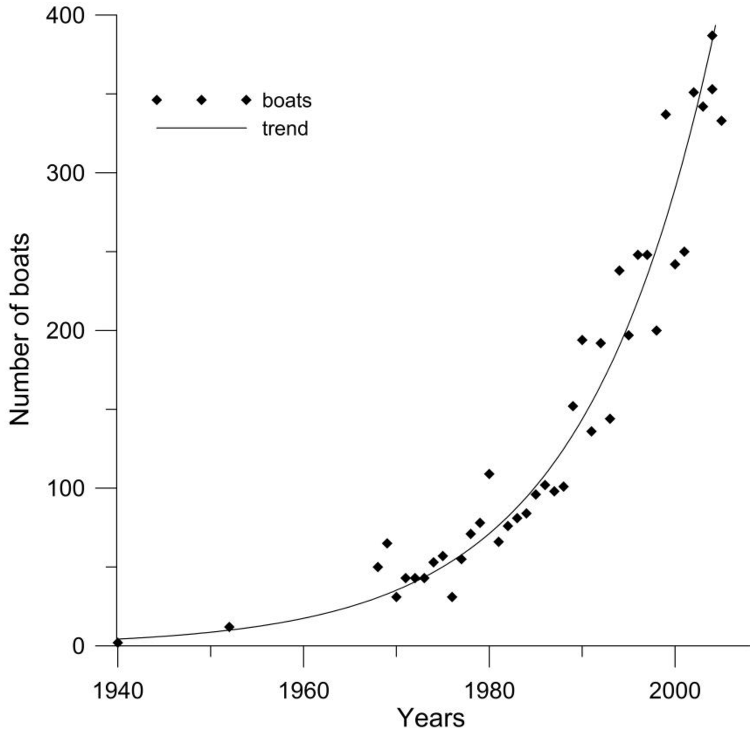

Figure 1. Development of the trawl fleet in the NE Levant Sea (Gucu and Bingel, in press).

At the same years, researchers noted occurrence of Lessepsian in the catch at a commercial scale (Akyuz, 1957). Almost after 20 years Gücü et al. (1994) evaluated the spatial distribution of lessepsian demersal species, and reported occurrence of 20 Lessepsian species in the area. The number of Lessepsian fishes kept increasing and their numbers has reached to 52 as of 2010. The list of species appeared in the literature is given in Table 1.

Table 1. List of Lessepsian fishes reported in North Levant Sea (GSA 24)

Species	**Record**	**Reference**	**Species**	**Record**	**Reference**
Liza carinata	1956	Kosswig, 1956	*Fistularia commersonii*	2002	Bilecenoglu et al. 2002
Cynoglossus sinusarabici	1957	Akyuz, 1957	*Himantura uarnak*	2002	Bilecenoglu et al. 2002
Parexocoetus mento	1966	Ben-Tuvia, 1966	*Oxyurichthys petersi*	2002	Bilecenoglu et al. 2002
Herklotsichthys punctatus	1984	Whitehead et al. 1984	*Sphyraena flavicauda*	2002	Bilecenoglu et al. 2002a
Sillago sihama	1994	Gücü et al. 1994	*Lagocephalus suezensis*	2002	Bilecenoglu et al. 2002a
Pempheris vanicolensis	1994	Gücü et al. 1994	*Platycephalus indicus*	2002	Bilecenoglu et al. 2002
Apogon nigripinnis	1994	Gücü et al. 1994	*Tylosurus choram*	2002	Bilecenoglu et al. 2002
Callionymus filamentosus	1994	Gücü et al. 1994	*Hyporhamphus affinis*	2002	Bilecenoglu et al. 2002
Dussumieria elopsoides	1994	Gücü et al. 1994	*Crenidens crenidens*	2002	Bilecenoglu et al. 2002
Hemiramphus far	1994	Gücü et al. 1994	*Rastrelliger kanagurta*	2002	Bilecenoglu et al. 2002
Sargocentron rubrum	1994	Gücü et al. 1994	*Pomadasys stridens*	2002	Bilecenoglu et al. 2002
Lagocephalus spadiceus	1994	Gücü et al. 1994	*Heniochus intermedium*	2003	Gökoglu et al. 2003
Pelates quadrilineatus	1994	Gücü et al. 1994	*Bregmaceros atlanticus*	2004	Yilmaz et al. 2004
Pranesus pinquis	1994	Gücü et al. 1994	*Hippocampus fuscus*	2004	Gokoglu et al. 2004
Saurida undosquamis	1994	Gücü et al. 1994	*Lagocephalus sceleratus*	2005	Akyol et al. 2005
Scomberomorus commerson	1994	Gücü et al. 1994	*Torquigener flavimaculosus*	2005	Bilecenoglu 2005
Alepes djeddaba	1994	Gücü et al. 1994	*Platax teira*	2006	Bilecen & Kaya, 2006
Siganus luridus	1994	Gücü et al. 1994	*Apogon quaqetti*	2006	Eryilmaz & Dalyan, 2006
Siganus rivulatus	1994	Gücü et al. 1994	*Monotaxis grandoculis*	2007	Bilecenoglu, 2007
Sphyraena chrysotaenia	1994	Gücü et al. 1994	*Vanderhorstia mertensi*	2008	Bilecenoglu et al. 2008
Stefanolepis diaspros	1994	Gücü et al. 1994	*Nemipterus randalli*	2008	Bilecenoglu & Russell, 2008
Upeneus pori	1994	Gücü et al. 1994	*Champsodon nudivittis* (?)	2009	Çiçek & Bilecenoglu. 2009
Upeneus moluccensis	1994	Gücü et al. 1994	*Apogon smithi*	2009	Goren et al. 2009
Leiognathus klunzingeri	1995	Gücü et al. 1994	*Decapterus russelli*	2010	Sakinan & Ak Orek, 2011
Etrumeus teres	1997	Basusta et al. 1997	*Apogon fasciatus*	2010	Turan et al. in press
Pteragogus pelycus	2000	Taskavak et al.1999			
Petroscirtes ancylodon	2000	Taskavak et al., 2000			

In this study, we evaluated and compared the situation in 1980's and at present with respect to Lessepsian fish occurrence based on survey data collected by METU-IMS. We also tried to link the success of Lessepsian fishes with the fishing pressure.

Material and Methods

In this study, results of 6 different fisheries projects carried out at different years were used. The trawl survey data were collected by R/V Lamas of METU-IMS. In all surveys the same local design of trawl net (locally called the Ottoman) was used; the trawling duration was kept constant at 30 min and the same sampling protocol was applied throughout the study; the samples were sorted out to the species level; each species was weighed separately; the number of individuals was counted and measured.

The surveys were conducted for two different purposes: to evaluate monthly and annual variations and the spatial distribution of the fish stocks. The number of trawl surveys and number of stations covered in each survey are presented in Table 2. Monthly surveys were initiated in 1980 in three sub-regions that were selected based on the intensity of commercial trawling activities taking place in the area. Four trawl hauls covering different depth ranges (0–15, 15–30, 30–50; >50 m) were carried out in each region. In 1981, the number of sub-regions was increased to seven to cover the entire fishing area range of the fishing fleet. Between 1983 and 1984, three basin-wide surveys were conducted. The autumn surveys were carried out with the onset of the fishing season and the spring survey began after the closure of the season. In the basin-wide survey a total of 180 trawl hauls were carried out (60 trawl stations in each survey). However, only 168 of them were used. The rest were disregarded due to problems that occurred during the trawling operation, such as net damage. The exact geographic coordinates of the trawl stations are available only for surveys carried out after 1983. The sampling area of the surveys conducted before 1983 is shown by a circle in Figure 2.

Table 2. Summary of trawl survey datasets used in the study

Date	Period	# of Stations	Area Coverage
May 1980 – May 1981	Monthly	12 stations	see Figure 2
May 1981 – Nov. 1982	Monthly	16 stations	see Figure 2
Oct. 1983 - Oct. 1984	Seasonal	168 stations	see Figure 2
Oct. 1999 – Oct. 2010	Seasonal	96 stations	see Figure 4
May 2007 – Oct. 2010	Monthly	3 stations	see Figure 2
Apr. 2009 – Oct. 2010	Seasonal	varying	see Figure 6

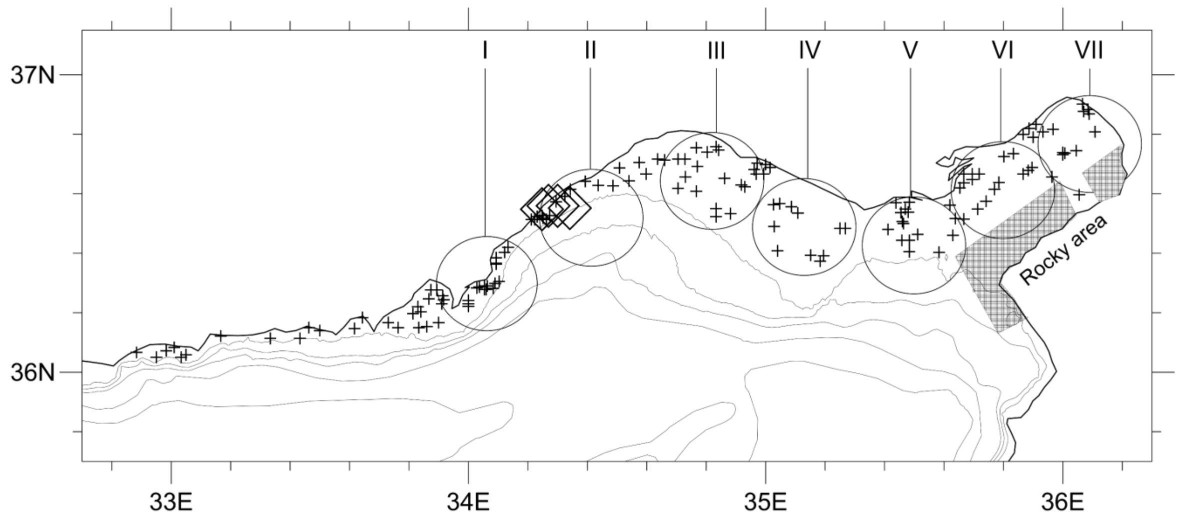

Figure 2. Study area and the position of trawl stations; circles are the subregions where trawl sampling between 1980-1982 were conducted; “+” signs are the stations sampled between 1983-1984; “◊” represents stations sampled between 2007-2010.

In 1999, the area shown in Figure 3 has been designated as fisheries restricted area, in which all types of industrial scale fishery was banned all year round. With the onset of the enforcement, a stock monitoring program has been initiated. The demersal trawl stations selected inside and at the outer periphery of the FRA are depicted in Figure 4. The monitoring surveys were carried out by Lamas-1 and exactly the same protocol given above was applied.

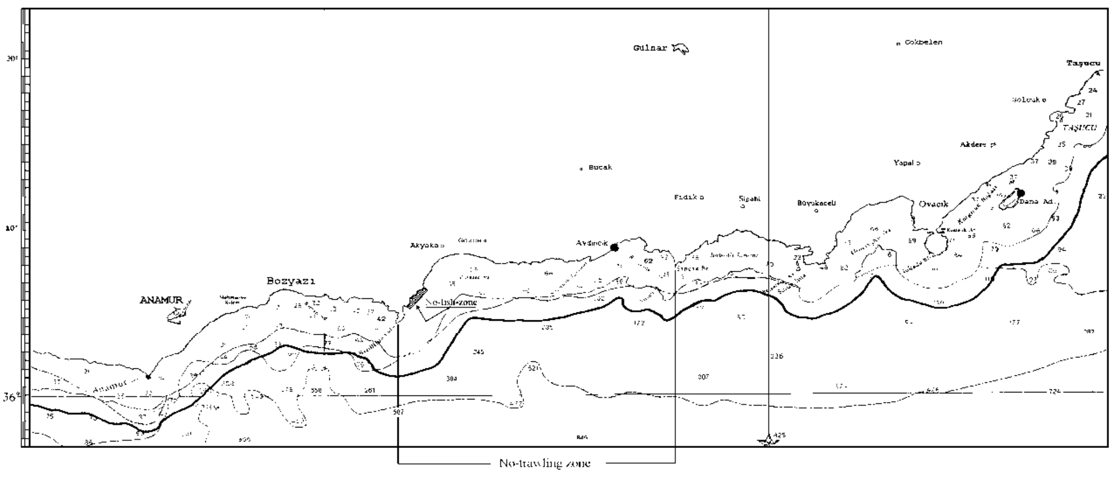

Figure 3. The FRA; the bold line is the 3 miles trawl exclusion zone applied before the designation, greyed areas are the fishing grounds

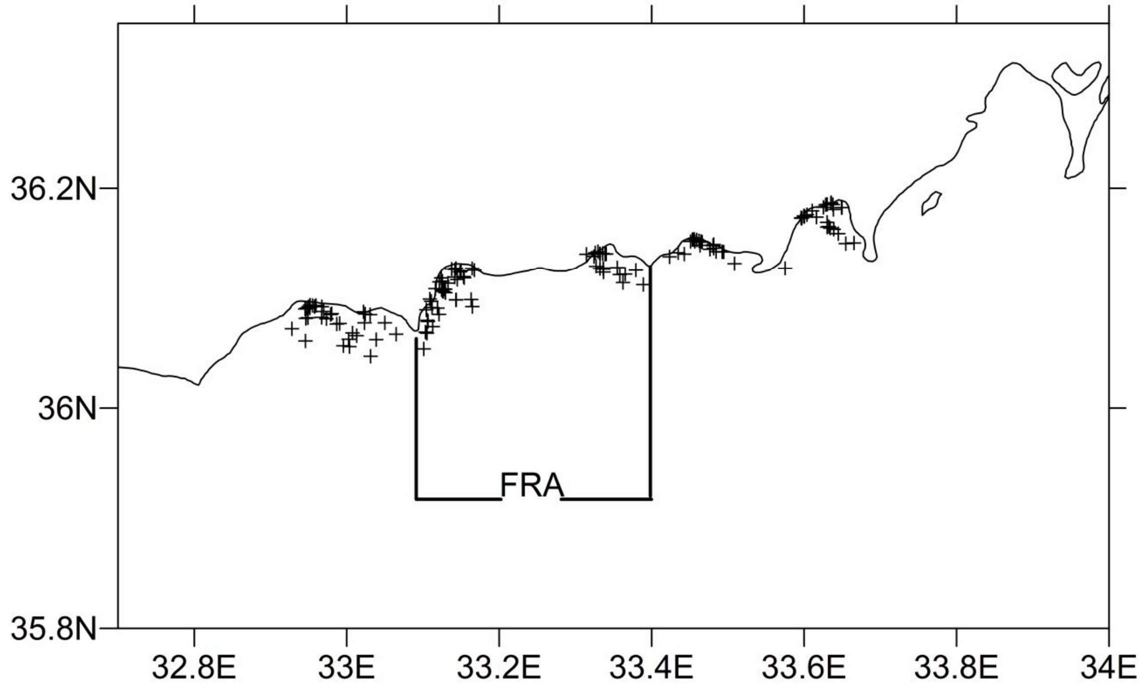

Figure 4. Demersal trawl stations sampled in and around the FRA.

Between May 2007 and October 2010, a series of monthly demersal trawl surveys was conducted; within region II presented in Figure 2. In this time series the same depth ranges sampled in 1980s were re-sampled. Additionally, 2 more depth ranges 150 and 200 m were sampled in order to cover the entire bathymetric extend of the continental shelf

The results of the acoustic surveys were used to assess the distribution and abundance of small pelagics in the NE Levant. The area shown in figure 5 was surveyed twice yearly since 2009. In addition to the acoustic transect, mid-water trawling was conducted to sample to schools acoustically detected. Ground trusting sampling was carried out randomly in the area where small pelagic schools are concentrated (Figure 6).

Community structure of the lessepsians were analysed using cluster analysis which was applied to log transformed data formed using the Bray-Curtis similarity index coupled with group average linkage.

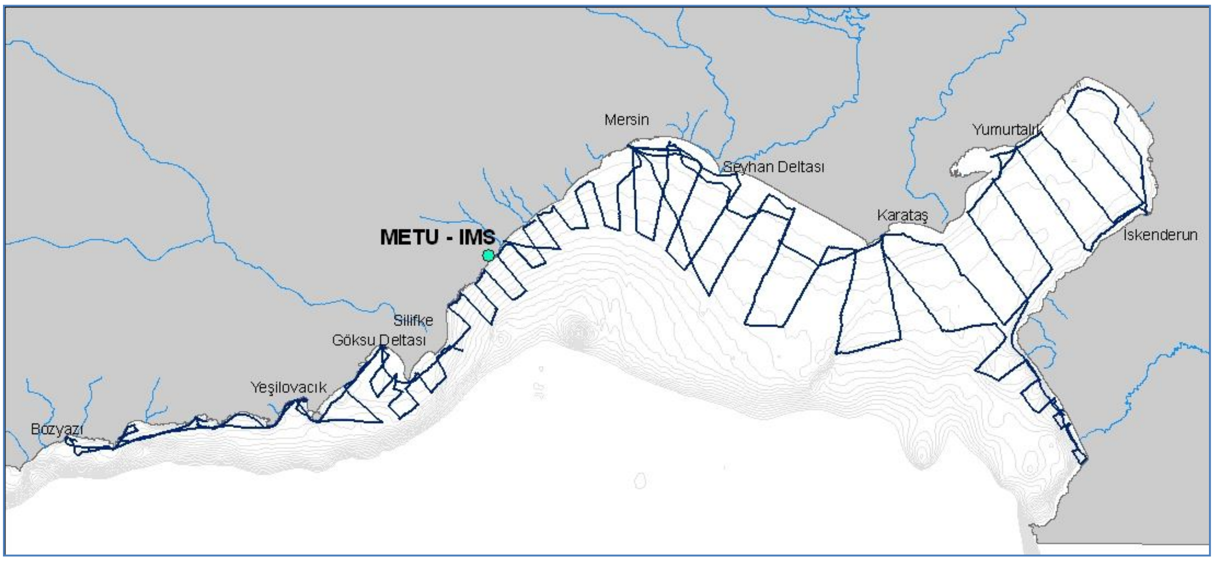

Figure 5. Cruise tracks followed during the fisheries acoustic surveys

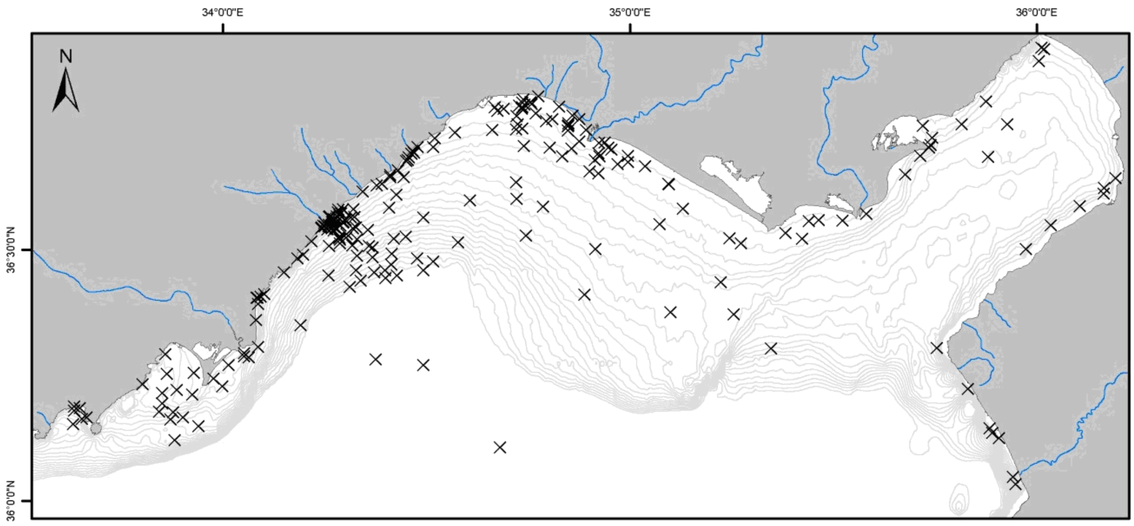

Figure 6. Position of the mid-water trawl stations sampled during the acoustic surveys

Finally, regional landing statistics were taken from the Turkish Institute of Statistics (Anonymous, 2007)

Results

Although several Lessepsian species has long been exploited on commercial scale, not all of them are recorded separately in the Turkish landing statistics. Brushtooth lizardfish (*Saurida undosquamis*) and stripped goat fish (*Upeneus moluccensis*) are among few which are reported in the statistics. Their landings from south coast of Turkey depicted in Figure 7. The figure shows a steady increase in the total landings until 1993; however contribution of Lessepsian species to this increase was not significant as can be seen from the percentage of Lessepsians in the catch. With respect to their contribution the data suggests two different phases; the high occurrence until 1986 and an immediate drop after that year.

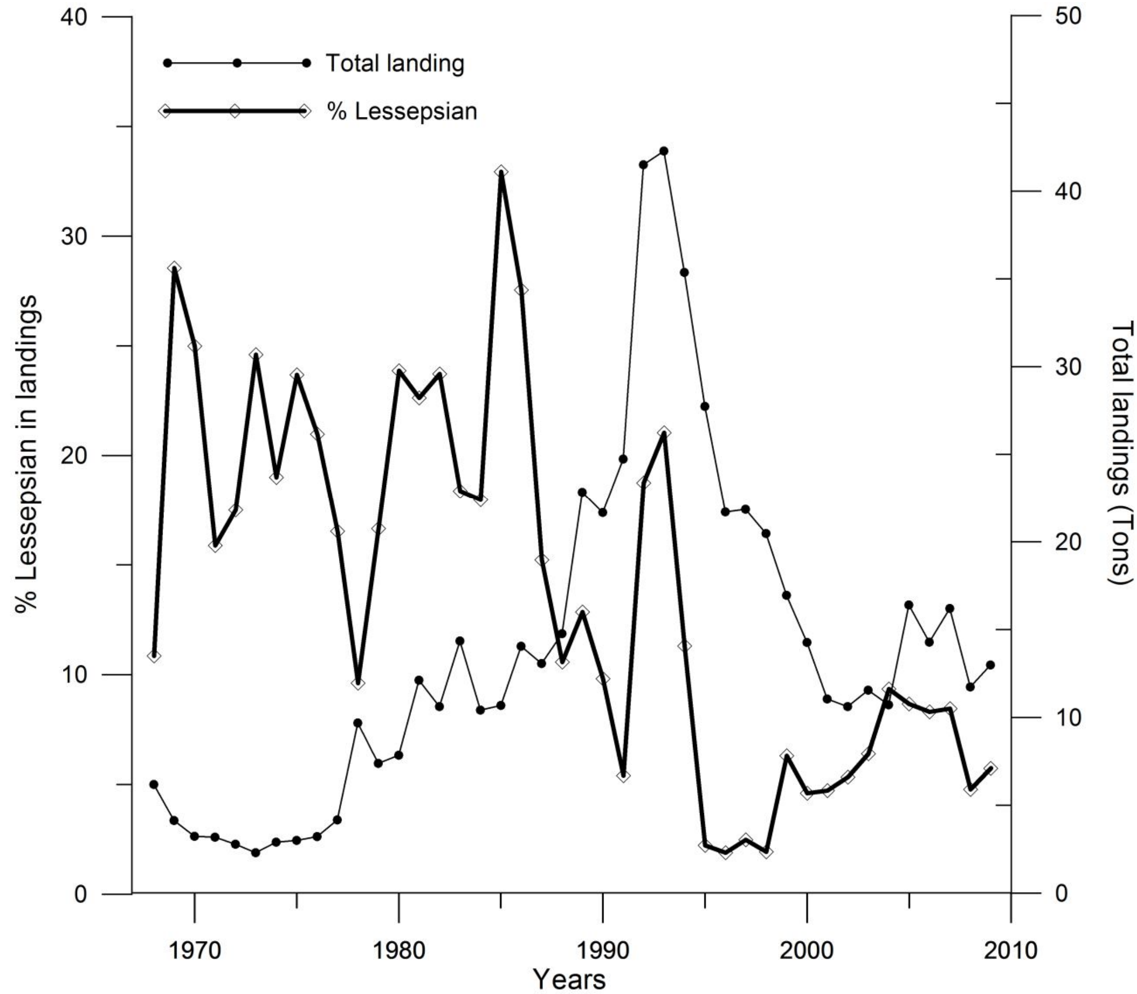

Figure 7. Total fish landings from the south coast of Turkey (GSA 24) and the percentage of *Saurida undosquamis* and *Upeneus moluccensis* in the catch.

The same pattern was also observed in the results of surveys carried out at the same area. The contribution of the Lessepsians within the fish catch was around 40% in 1980s (Table 3). The first two species having the highest weight in the catch were Lessepsian species; *Saurida undosquamis* (23%) and *Leiognathus klunzingeri* (14%). Within the top 90% fraction of the catch only three lessepsian fish were observed.

Two new species, *Stephanolepis diaspros* and *Upeneus pori* attained to greater quantities and placed within the first 90% fractions of the catch in 1983 and 1984, respectively (Table 4). The species composition remained quite the same except gradual disappearance of *Trigla lucerna*. Spatial distribution of Lessepsian fishes both, in percent weights and in percent of Lessepsian fish species with the total number of fish species caught are given in Figure 8 and Figure 9. In general both weights and number of Lessepsian fishes are very low at stations deeper than 60 meters. There are also longitudinal differences; percentages are high in the Gulf of Iskenderun, the easternmost part of the study area; low in the Bay of Mersin, central part; high around Goksu river; and very low in the westernmost section of the region (Figure 8).

Table 3. Composition of fish accounting for 90% of the fish fauna over the continental shelf between 1980 and 1982 (* are the lessepsian fishes).

Species	**%**
*Saurida undosquamis**	22.6
*Leiognathus klunzingeri**	13.6
Mullus barbatus	10.5
Dasyatis pastinaca	5.8
Trigla lucerna	5.4
Arnoglossus laterna	4.4
*Upeneus moluccensis**	4.1
Rhinobathus annularis	3.4
Solea solea	3.3
Myliobathis Aquila	3.1
Merluccius merluccius	2.6
Pteroplatea altavela	2.1
Pagellus erythrinus	1.7
Citharus linguatula	1.7
Argyrosomus regium	1.4
Mustellus vulgaris.	1.4
Raja miraletus	1.2
Gobius niger.	1.2
Lessepsian total	**40.3**

Table 4. Composition of fish accounting for 90% of the fish fauna over the continental shelf between 1983 and 1984.

Fall 1983 (32%)		**Spring 1984 (24%)**		**Fall 1984 (47%)**	
*Saurida undosquamis**	18.0	*Saurida undosquamis**	14.1	*Leiognathus klunzingeri**	20.9
Mullus barbatus	15.2	*Mullus barbatus*	13.9	*Saurida undosquamis**	18.3
*Leiognathus klunzingeri**	9.4	*Dasyatis pastinaca*	13.7	*Mullus barbatus*	9.4
Boops boops	6.7	*Raja miraletus*	5.5	*Myliobathis aquila*	5.7
Dasyatis pastinaca	4.9	*Pagellus erythrinus*	5.4	*Pagellus erythrinus*	4.1
Pagellus erythrinus	4.5	*Lepidotrigla cavillone*	4.6	*Citharus linguatula*	3.7
Citharus linguatula	4.5	*Spicara flexiosa*	3.3	*Upeneus moluccensis**	3.2
Trigla lucerna	3.3	*Trigla lucerna*	2.9	*Sparus aurata*	2.5
*Stephanolepis diaspros**	2.9	*Arnoglossus laterna*	2.9	*Raja miraletus*	2.5
Rhinobathus annularis	2.8	*Citharus linguatula*	2.8	*Merluccius merluccius*	2.4
Lepidotrigla cavillone	2.3	*Pagrus pagrus*	2.6	*Diplodus sargus*	2.1
Arnoglossus laterna	2.2	*Leiognathus klunzingeri**	2.3	*Stephanolepis ocheticus**	2.1
Pagellus acarne	1.9	*Bothus podas*	2.0	*Lepidotrigla cavillone*	1.8
Spicara flexiosa	1.4	*Upeneus moluccensis**	1.8	*Mustelus mustelus*	1.7
Uranoscopus scaber	1.4	*Stephanolepis ocheticus**	1.5	*Arnoglossus laterna*	1.7
Raja miraletus	1.3	*Uranoscopus scaber*	1.3	*Argyrosomus regium*	1.5
Myliobathis aquila	1.2	*Merluccius merluccius*	1.3	*Uranoscopus scaber*	1.2
Pagrus pagrus	1.1	*Solea solea*	1.2	*Spicara flexiosa*	1.0
Bothus podas	1.1	*Squatina squatina*	1.1	*Bothus podas*	0.9
Solea solea	1.0	*Trigla lineata*	1.0	*Upeneus pori**	0.9
*Upeneus moluccensis**	1.0	*Diplodus vulgaris*	0.9	*Ephinephelus aeneus*	0.8
Ephinephelus aeneus	1.0	*Argyrosomus regium*	0.9	*Trigla lucerna*	0.8
		Dentex dentex	0.8		
		Sparus aurata	0.8		
		Diplodus annularis	0.8		

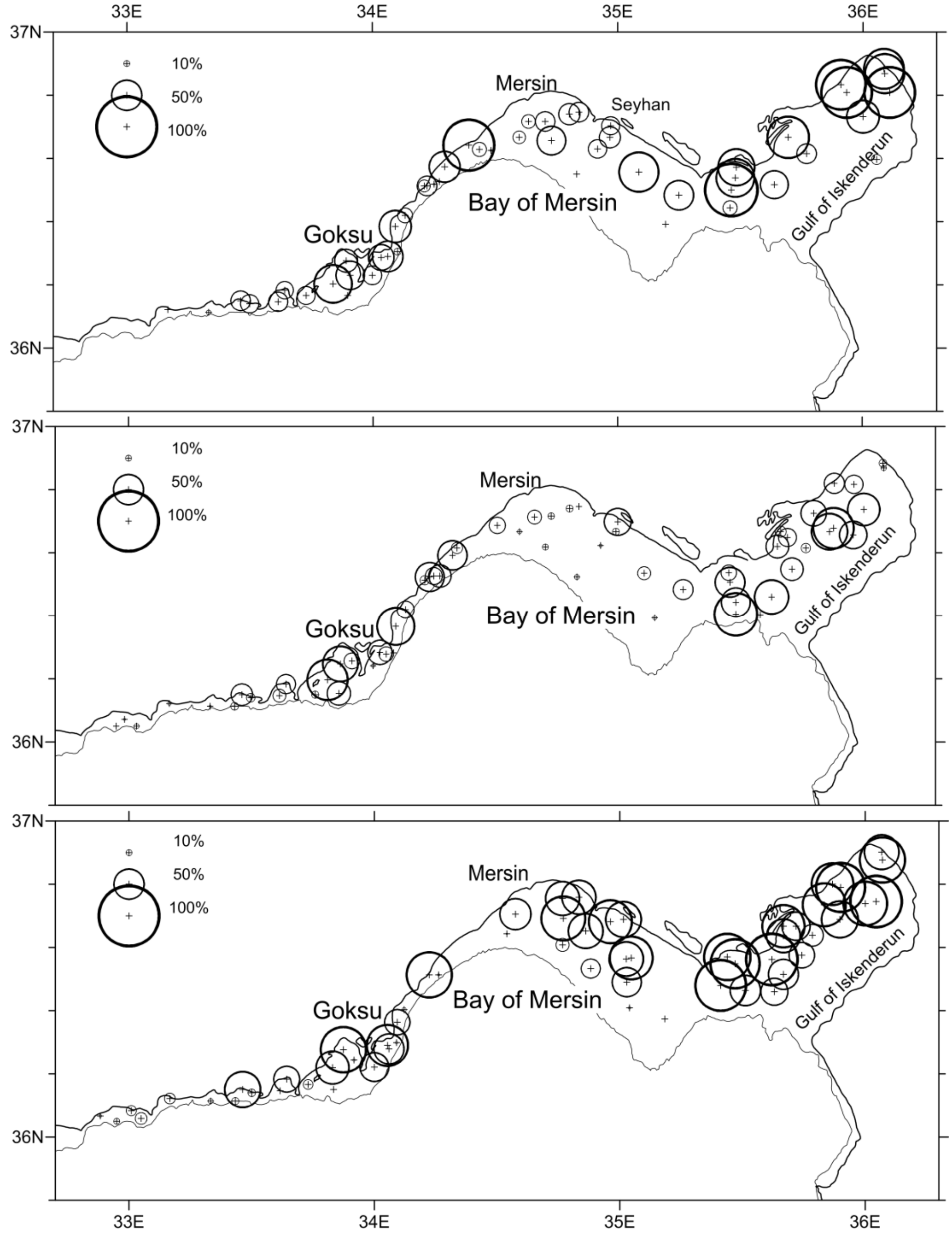

Figure 8. Percent of Lessepsian fish in weights in the total catch in fall 1983 (top), spring 1984 (middle) and fall 1984 (bottom).

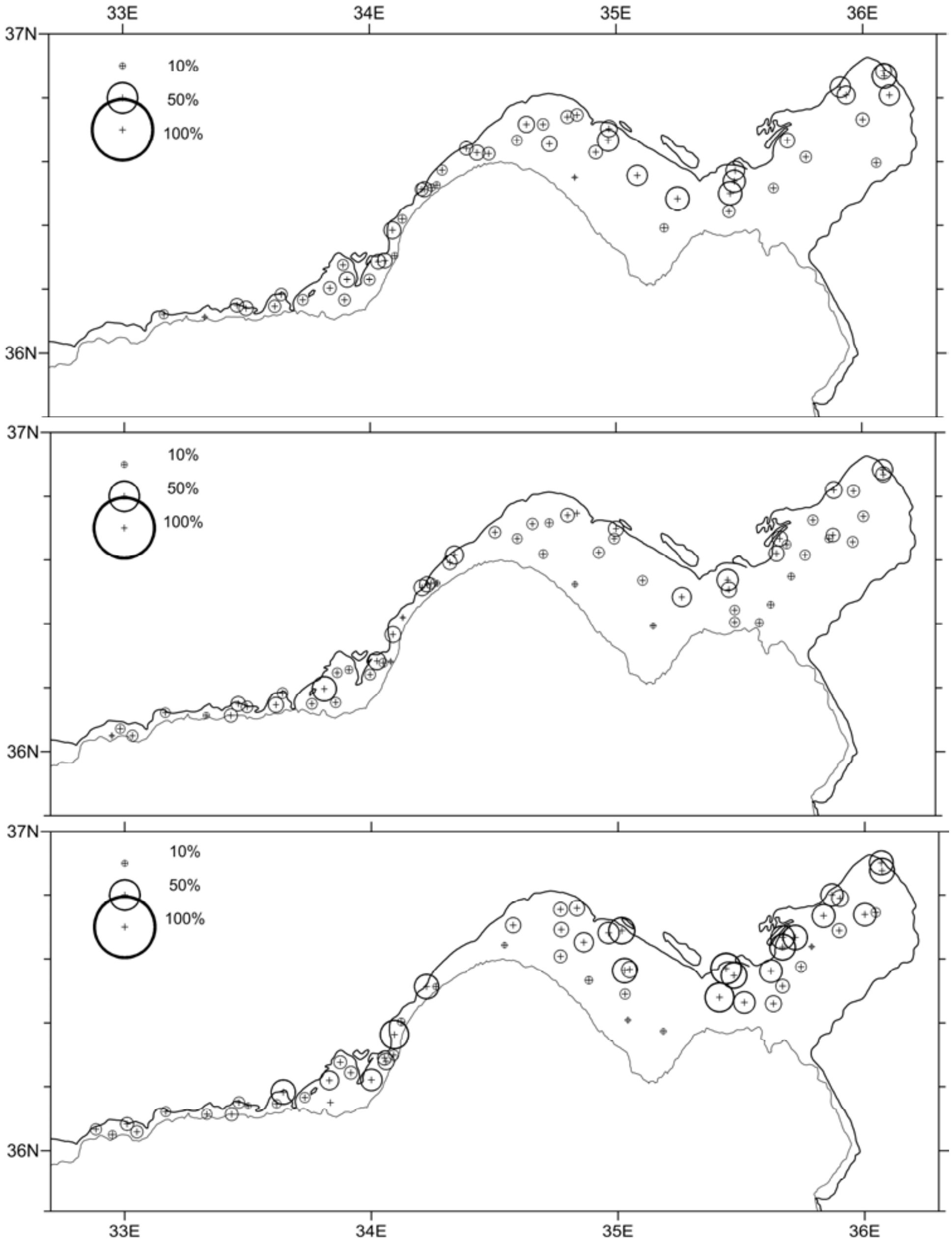

Figure 9. Percent of Lessepsian species in the total number of fish species caught in fall 1983 (top), spring 1984 (middle) and fall 1984 (bottom).

The results of the cluster analysis of the species composition of the Lessepsian species at the stations are given in Figure 10 where three clusters may be noticed. The group of stations clustered within the right hand side of the dendrogram are the ones located on the infralittoral zone covering the depth strata down to 30 meters. The most abundant species within this group is *Leiognathus klunzingeri*. As can be seen from the size of the diamonds on the figure, this group has great percentages within the catch. The second cluster in the middle of the dendrogram are those of the stations located within the lower part of the circalittoral zone (30-50m) of the same region covered by the previous group. This group were also represented by high percentages in the catch indicating that infra- and circalittoral zones are under the significant level of Lessepsian occurrence, however the species assemblages observed in the area display different composition. The last cluster on the left hand side, are the stations represent the area under very low Lessepsian occurrence. This group was observed either at deeper parts or on the western most side of the study area.

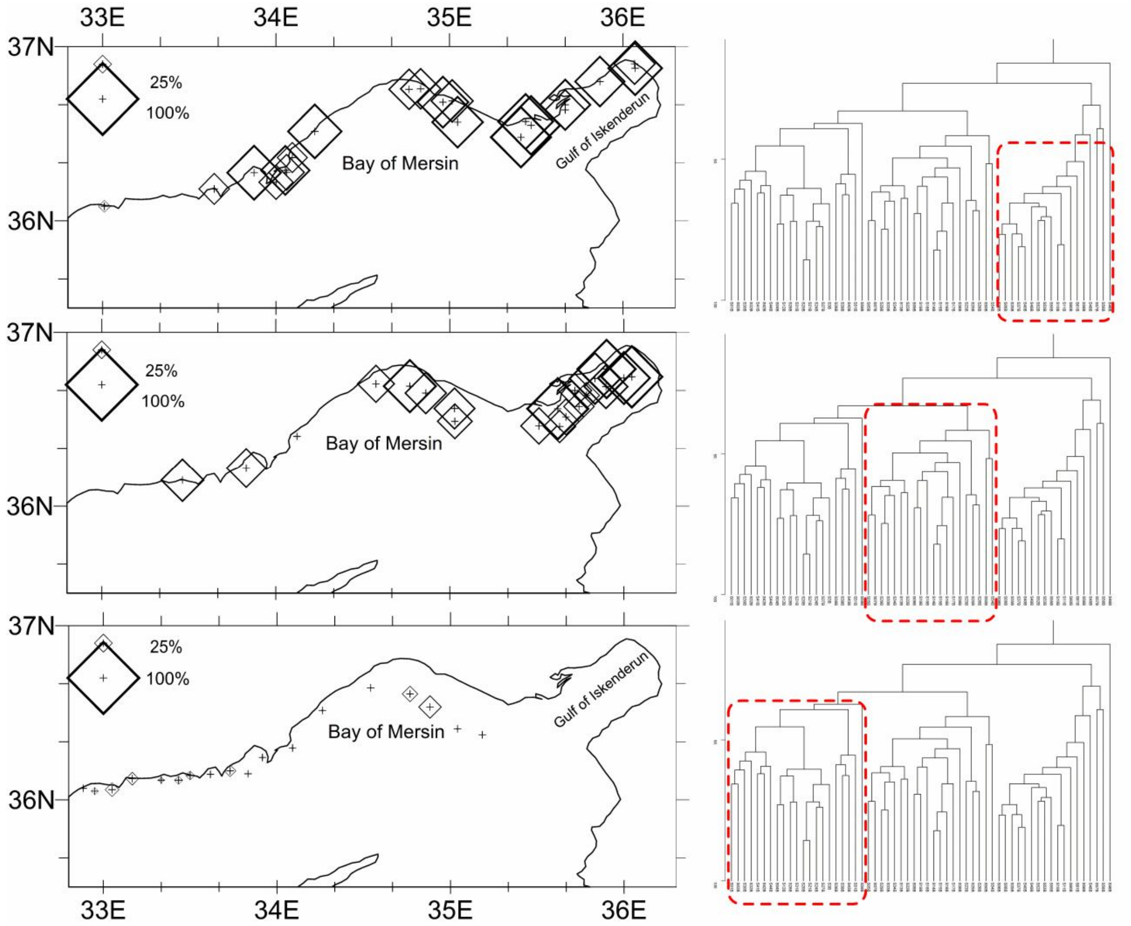

Figure 10. Results of cluster analysis and the position of the station located within the same clusters.

The survey carried out in the fishery restricted area showed that even in the areas exposed to very low level of fishing pressure, Lessepsian occurrence is high (Figure 11). During the twelve years of monitoring, the number of Lessepsian fishes entering to the FRA followed an almost steadily increasing trend (r = 0.95) with a rate of 1.2 new species added to the fish fauna in the FRA.

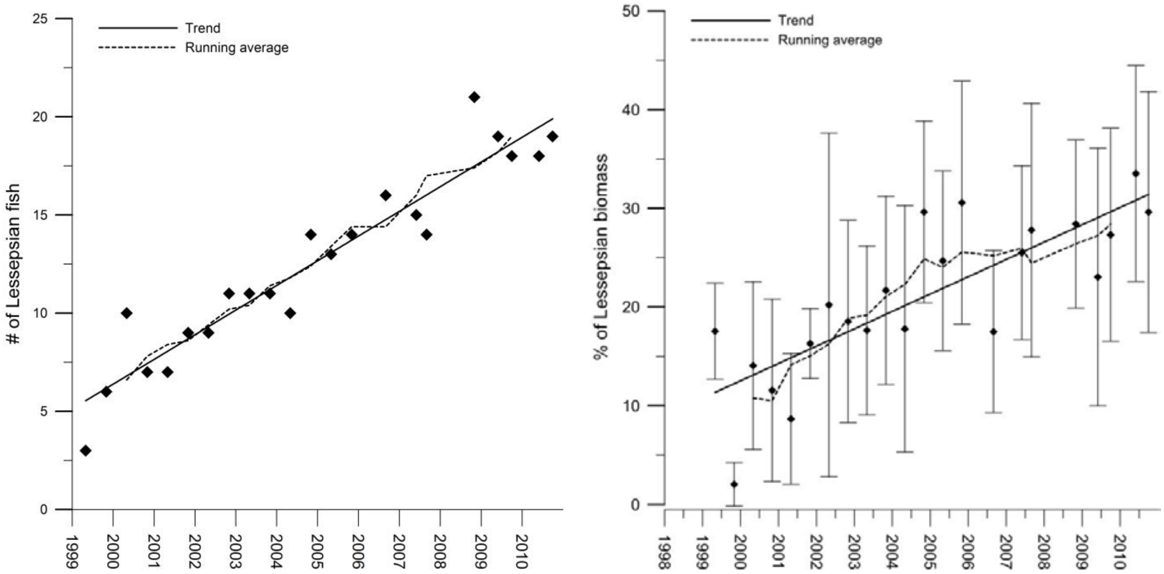

Figure 11. Number of Lessepsian fish species (left) and their percentages in the catch (right) sampled in the trawl surveys carried out in the FRA

The percentage of Lessepsian fishes in the fish biomass in the FRA represented a similar increasing trend (Figure 11). If the percentage of the Lessepsian fishes increases with the same trend, it may be speculated that in the next 50 years the fish fauna of FRA will be composed solely of Lessepsian species leaving no room for native ones.

In a neighbouring area, where fishing is permitted, entry rate of new Lessepsian fish is slightly higher (1.7 sp / year; r = 0.73) than those observed in the FRA (Figure 12). The percentage of Lessepsian fishes in the total biomass was averaged around 25, a value quite identical to the one observed in the FRA. However in contrary to the FRA, it has not changed over the last 4 years and even represented a slightly decreasing trend.

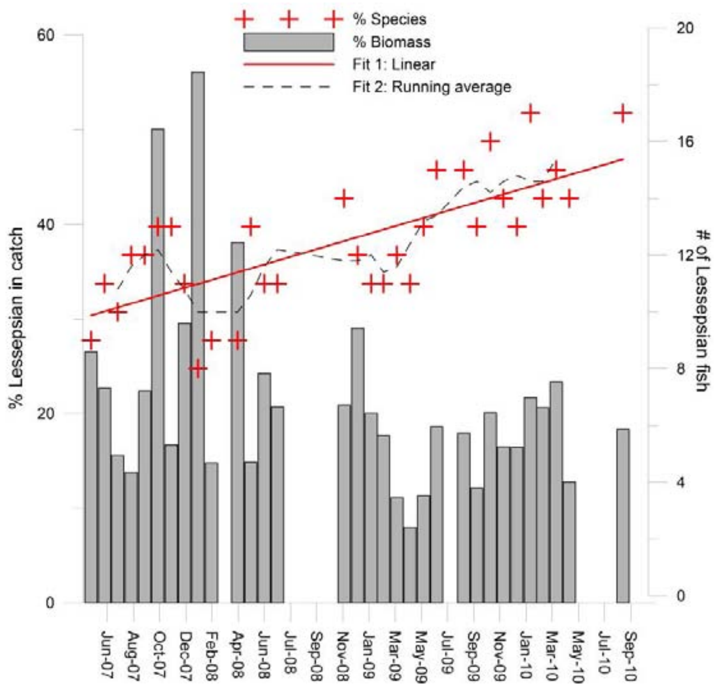

Figure 12. Number of Lessepsian fishes and their percentage in the fish biomass sampled in Mersin Bay.

There are significant changes in the species composition when the results of the surveys carried out between 1980 and 1982 are compared with the surveys of recent years. Number of fish species composing the 90% of the total catch has increased from 13 to 26. The most important species which occupied a quarter of the catch in 1980s, *S. undosquamis*, lost its significance. In return, a native species *M. barbatus* gained importance. Number of Lessepsian species in the main bulk of the catch has also increased from 3 to 7 species. Stripped goat fish, *U. moluccensis*, which, once, was in the first 5 most important fish in the area, was replaced by another Lessepsian mullid, *U. pori*.

The bathymetric distribution of Lessepsian fishes are depicted in Figure 13. Although there is a remarkable decrease in the biomass from 1980s to 2000s, the vertical pattern is quite the same. The highest quantities were found at shallow depths, and then declined rapidly below 50 meters. Below 100 meters depth the quantities are very low and no Lessepsian fish was observed below 200m.

Table 5. Comparison of fish accounting for top 90% of the fish fauna over the continental shelf between 1980s and 2000s.

1980-1982		**2007-2010**	
Saurida undosquamis	24.0	*Mullus barbatus*	19.8
Dasyatis pastinaca	12.5	*Leiognathus klunzingeri*	15.7
Leiognathus klunzingeri	11.5	*Pagellus acarne*	8.2
Mullus barbatus	9.5	*Bothus podas podas*	6.2
Upeneus moluccensis	6.5	*Pagellus erythrinus*	4.9
Arnoglossus laterna	4.4	*Dasyatis pastinaca*	4.4
Trigla lucerna	4.1	*Upeneus pori*	4.3
Citharus linguatula	3.8	*Trachurus trachurus*	3.5
Merluccius merluccius	3.4	*Saurida undosquamis*	2.9
Pagellus erythrinus	3.0	*Spicara flexuosa*	2.4
Solea solea	2.7	*Gymnura altevela*	2.0
Rhinobatos rhinobatos	2.4	*Boops boops*	1.9
Bothus podas	1.7	*Lagocephalus suiezensis*	1.8
Lessepsian total	42.0	*Lithognathus mormyrus*	1.4
		Raja clavata	1.3
		Upeneus moluccensis	1.1
		Raja radula	1.1
		Citharus linguatula	1.0
		Trachurus mediterraneus	1.0
		Arnoglossus laterna	1.0
		Rhinobatos rhinobatos	0.9
		Merluccius merluccius	0.7
		Callionymus filamentosus	0.6
		Serranus hepatus	0.6
		Argentina sphyraena	0.6
		Lagocephalus spadiceus	0.6
		Lessepsian total	27.0

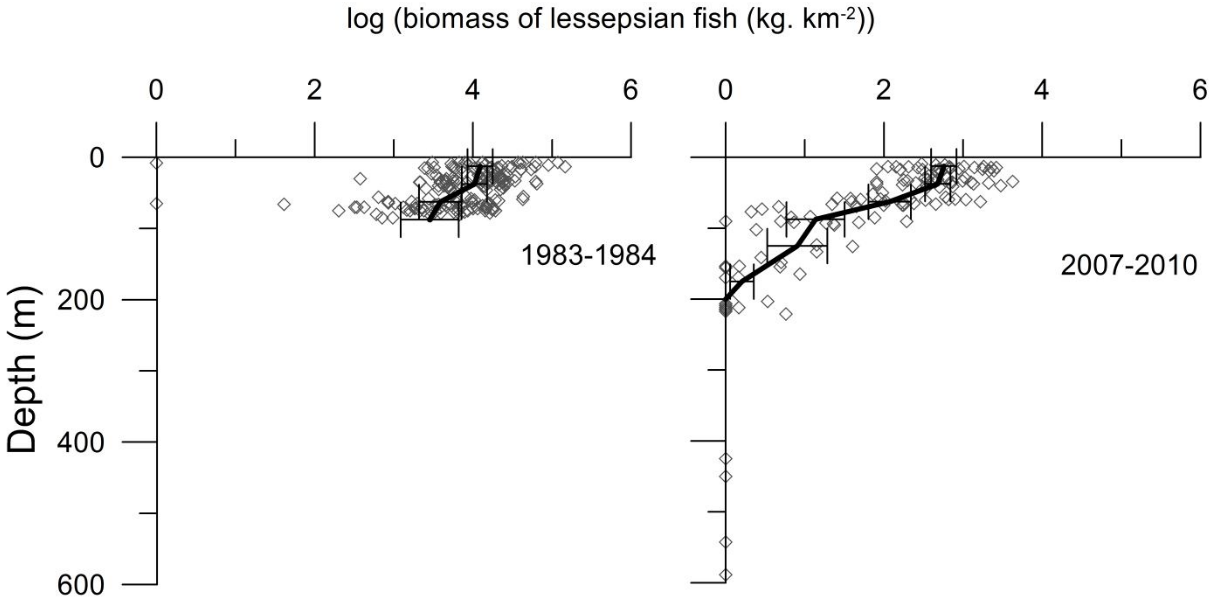

Figure 13. Bathymetric distribution of Lessepsian fishes at two different periods

Small pelagics

The list of major small pelagic fish species and their compositon in the catch (in weight and number) are given in Table 6. It seems that the small pelagic Lessepsian fishes are not yet as successful as their demersal counterparts. They formed 6.7% of the small pelagic abundance and 11.3% of the small pelagic fish biomass in the mid-water trawl samples in the north-eastern Levant Sea (Figure 6). Among them *Dussumieria elopsoides* has the largest place, both in abundance and biomass. This was followed by *Alepes djadaba*. It may worth noting that this species is particularly abundant in the Gulf of Iskenderun and attained to higher abundance and biomass values in the years when the Lessepsian jellyfish *Rhopilema nomadica* outburst.

Table 6. The species composition of the samples collected using mid-water trawl in the NE Levant Sea

Abundance		***Biomass***	
Engraulis encrasicolus	43.4	*Sardinella aurita*	40.9
Sardinella aurita	30.0	*Trachurus mediterraneus*	16.9
Trachurus mediterraneus	10.5	*Engraulis encrasicolus*	13.2
Sardina pilchardus	6.5	*Sardina pilchardus*	10.3
Sardinella madarensis	1.1	*Sardinella madarensis*	2.5
Scomber japonicus	0.6	*Caranx rhonchus*	1.0
Trachurus trachurus	0.4	*Trachurus trachurus*	0.9
Trachurus picturatus	0.3	*Scomber japonicus*	0.8
Caranx rhonchus	0.3	*Caranx crysos*	0.7
Caranx crysos	0.1	*Alectis alexandrinus*	0.6
Alectis alexandrinus	0.1	*Pomatomus saltatrix*	0.4
Pomatomus saltatrix	0.1<	*Trachurus picturatus*	0.4
Dussumieria elopsoides	5.2	*Dussumieria elopsoides*	8.0
Alepes djedaba	0.8	*Alepes djedaba*	2.5
Etrumeus teres	0.6	*Etrumeus teres*	0.6
Decapterus russelli	0.1	*Decapterus russelli*	0.2
Herklotsichthys punctatus	0.1	*Herklotsichthys punctatus*	0.1<

The relative distribution of the school forming small pelagic fishes in the NE Levant sea is presented in Figure 14. The highest concentration of small pelagic fishes was observed in front of Mersin city. The acoustic surveys and midwater trawl samples showed that *Sardinella aurita* is always and by far dominant species in this particular area.

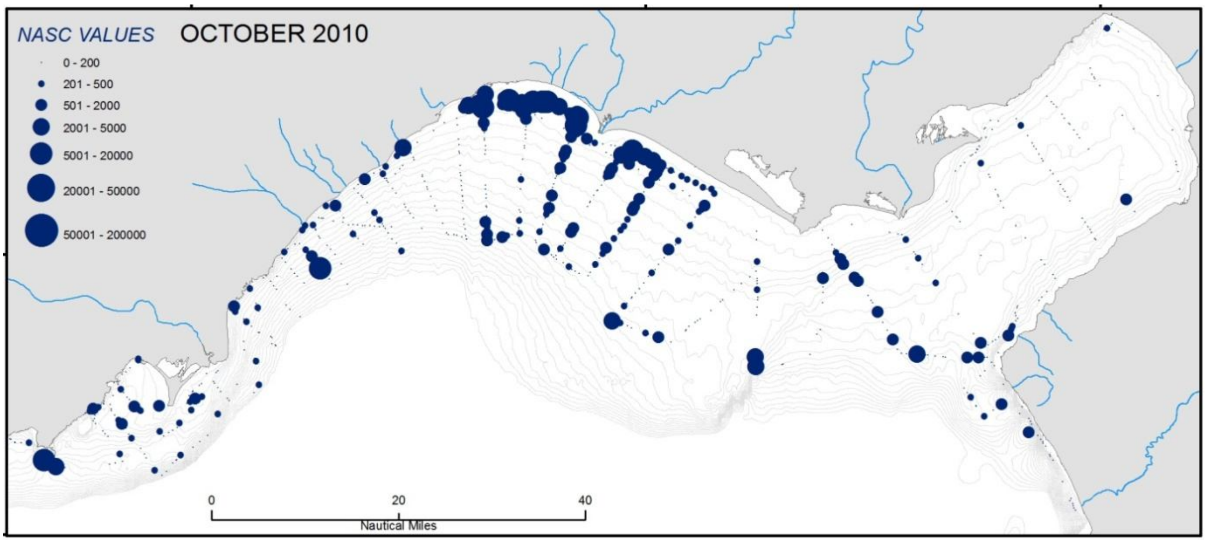

Figure 14. Relative distribution of school forming small pelagic fishes in the NE Levant Sea.

Discussion

Evaluation of fishing pressure (Figure 1) and the percentage of Lessepsian fishes in the landings (Figure 7) showed an unexpected pattern. Lessepsian fishes have been exploited in the study area since early 1950s and their reported share in the total landings was quite stable around 20% until 1980s. With the development of the fishing fleet after 1980s, the percentage of Lessepsian in the landings reduced remarkably. Until the end of the 1980s the fishing fleet in the area was composed of coastal shrimp trawlers that were equipped and licensed to catch highly commercial, native and Lessepsian penaeids in the shallow coastal waters. Following the anchovy crises in 1989 in the Black Sea, a substantial proportion of the northern fishing fleet moved to the southern seas (Gucu, 2002). Following the entry of the relatively larger and more powerful boats of the Black Sea fleet, the fishing grounds in the NE Levant Sea expanded towards deeper waters; hence the catch composition diversified and several new species appeared in the landings in greater quantities (Figure 7). On the other hand, as the bathymetric distribution of the Lessepsian fishes gradually reduces towards deeper waters, the changes in the structure and expansion in the range of the fishing fleet seems to have little influence on the quantity of Lessepsian fishes observed in the total landings.

The period when the landings peaked for several years, is the period when remarkable climatic changes was observed (Gucu and Bingel, in press). Following three successive cold years between 1991 and 1993, the mean annual air temperature has increased remarkably (Figure 15). There have been noticeable increases in the landings of cold favouring fishes, such as *Merluccius merluccius* and *Sardina pilchardus* during the cold years (Gucu and Bingel, in press) and they immediately disappeared during the warmer period. A similar event linking abundance of a lessepsian fish and temperature was reported in the 1950s on the Israeli coast. The sudden increase in the populations of Lessepsian Brushtooth lizardfish was attributed to the exceptionally warm winter of 1954–55, when the sea temperature rose by 1.0–1.5 °C (Ben Yami, 1955; cf. Goren and Galil, 2005).

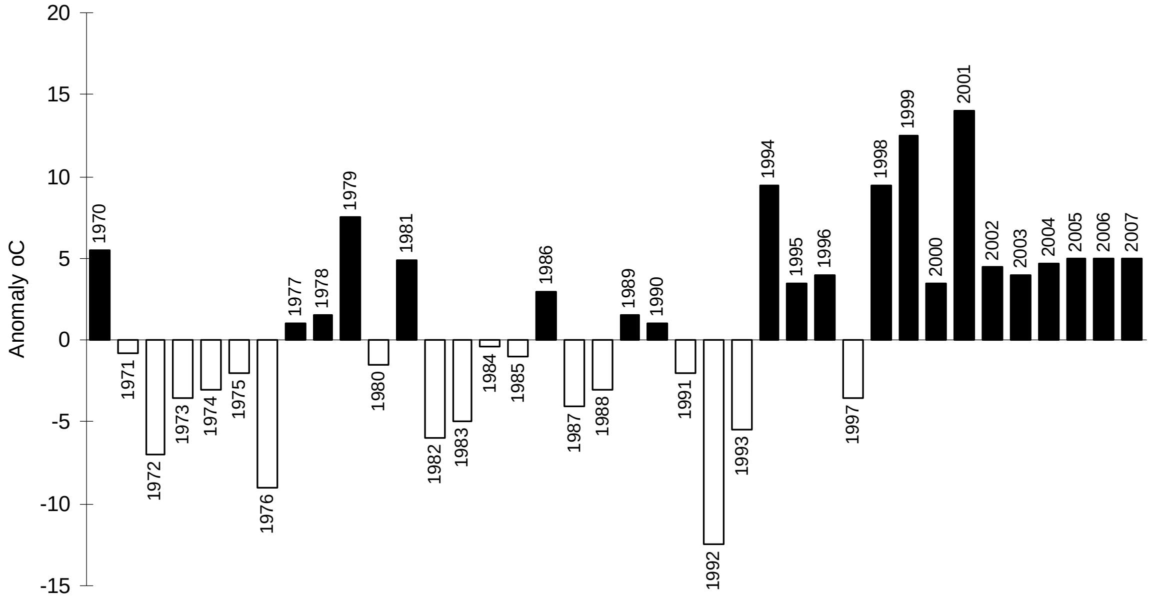

Figure 15. Mean temperature anomalies in Turkey (taken from Turkish Meteorological Works).

The same pattern was also observed in the results of fisheries surveys. In 1980's Lessepsian fishes observed in the bottom trawl samples accounted for almost half of the catch (Table 3 and Table 4). In a similar survey carried out 30 years later at the same location the share of Lessepsian in the catch dropped to a quarter despite increase in the number of fishing boat operated in the area. Even during the same fishery survey, the percentage of lessepsians in some subareas was found lower compared to the rest. An example to such an event was observed in the Bay of Mersin (Figure 8). The Lessepsian occurrence on the east and the west of the bay was remarkably higher. When the fishing pressure over the study area was evaluated, Bay of Mersin hosted the highest number of trawler in 1980s due to its proximity to the largest fishing port of the region (Figure 16).

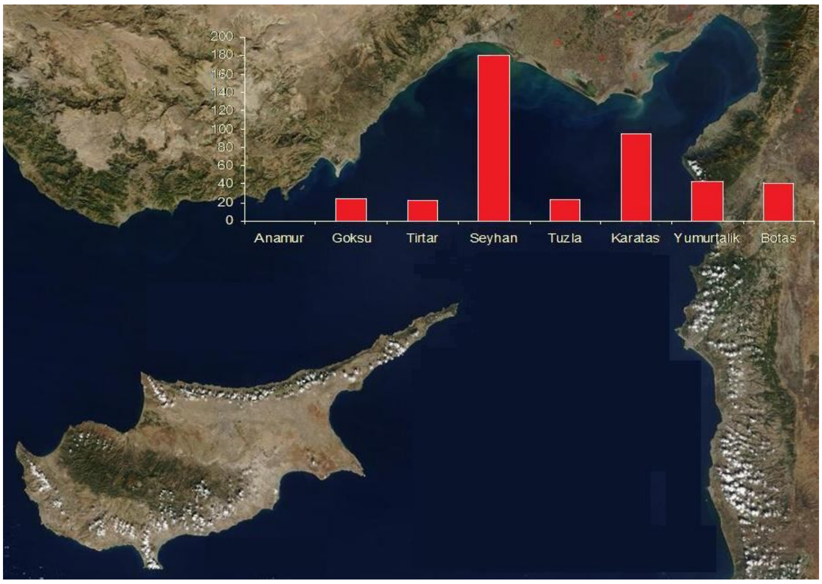

Figure 16. Number of trawl boat operating in the sub-regions (see also Figure 2)

In the FRA, where the fish stocks had been at the verge of a collapse before fishing pressure has been reduced in 1999, the Lessepsian fish invasion kept increasing and noticeably higher than a neighbouring area where fishing pressure is still very high (Figure 11 and Figure 12).

Some of the Lessepsian fishes, such as *L. klunzingeri* and *S. undosquamis* are opportunistic species with a high growth rate (Ismen, 2004, Ozutok and Avsar, 2004). They are either heterochronal spawners (El-Greisey, 2005; El-Halfawy et al., 2007) or spawn late (Ozutok and Avsar, 2003) compared to the native fishes. These traits might possibly help successful colonization of these species. However then, due to uncontrolled increase in the fishing effort they were over-fished along with the native fishes for several decades. Within these years some native fishes like *Trigla lucerna,* were not able to cope with the changes and disappeared. The fisheries regulation in the region bans trawling between May and September to protect the spawning stocks (Anon, 2008). Following this five months of fishery closure, stocks are heavily exploited before the winter. Therefore, in contrary to the long lived species or to the heterochronal species, fast growing, early maturing fishes such as *Mullus barbatus* benefited from the fishery ban during the spawning period; utilize the advantage of secured pre-recruitment period and increased their biomass no matter how high was the fishing pressure. Consequently, the fish fauna in the region seems to be altered and re-composed by the abruptly fluctuating fishing pressure over the ecosystem, which may be an example of “ecosystem overfishing” (Pauly et al. 1989). In the case of reduction of fishing pressure, it seems that native species are not able to respond quickly enough and opportunistic lessepsian species with their tropical traits possibly use the advantages and take over as it was observed in the FRA.

The results also show that Lessepsian invaders are successful in some areas and represented in low densities in some other (
Figure **8**). The depth is one of the crucial factors which determine the distribution of the Lessepsian species. In the past, the surveys were carried out within the 100 meters depth and biomass and abundance of Lessepsian fishes declined at depths deeper than 50 meters. In the recent surveys bathymetric range of the surveys has been increased

and it was observed that they were observed almost in every depth over the continental shelf; although there is still a remarkable density gradient around 80 meters. This depth is actually near to the lower edge of the thermocline. Beyond this limit lessepsian fishes were observed only during winter and spring when the entire water column is mixed up due to winter convective processes.

Another factor limiting the spread of Lessepsian fishes in 1980's were the occurrence of *Posidonia oceanica* meadows. The plant is a Mediterranean endemic and is found almost everywhere at shallow depths down to 30-50 meters. The one of the few exceptions is the Levant Sea (Gucu and Gucu, 2002a; Gucu and Gucu, 2002b). As can be seen from Figure 17 the areas with very low percentage of Lessepsian fish coincide with the eastern limit of *P. oceanica* in the Mediterranean. This figure shows that either sea grass itself, which forms mature habitats resilient to invasive pressures stops further spreading of the Lessepsian fishes; or the factor inhibiting the growth of the *P.oceanica* in the Levant Sea favours Lessepsian colonizers. Also, as can be seen from the comparison of species composition of Lessepsian fishes, western part displays species structure quite dissimilar to the rest of the study area in 1980s (Figure 10). The differences in the species assemblages of Lessepsian fishes have been verified in the recent surveys. Some striking examples for dissimilarities are the differences in the abundance of *Lagocephalus scelaratus* and *Lagocephalus suezensis* in the east and west of the study area. L. suezensis is very abundant in the east and *L. sceleratus* is more abundant on west where *P. oceanica* occurs.

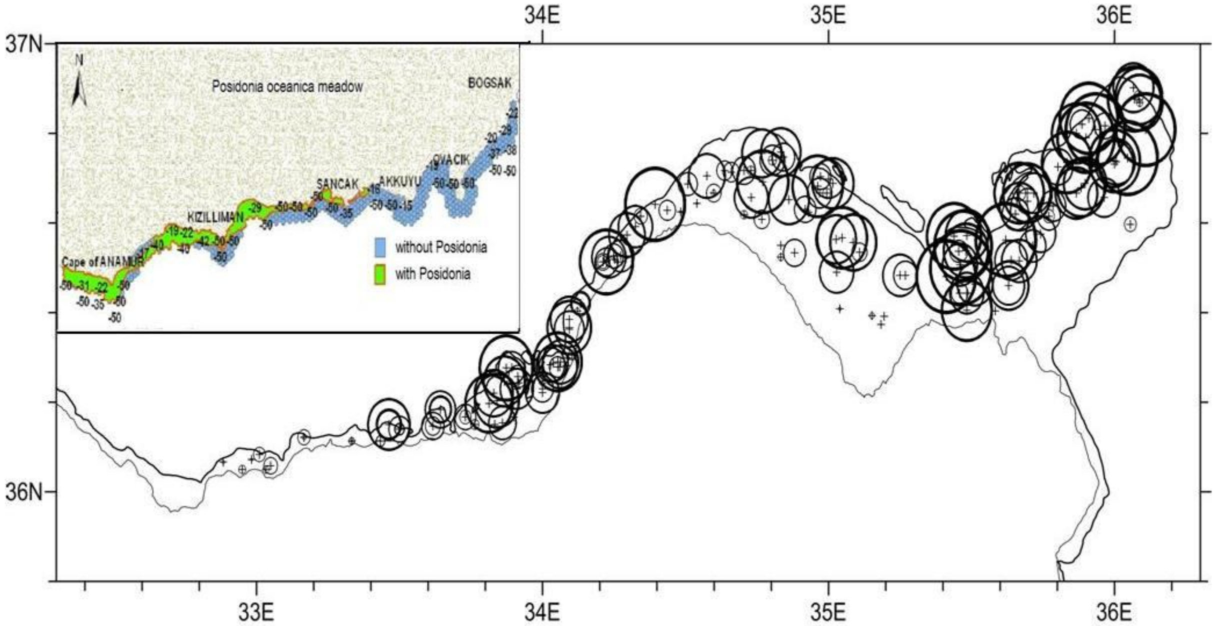

Figure 17. Percentage of Lessepsian fish in the total catch and the map of *Posidonia oceanica* distribution at its eastern limit in the Mediterranean.

In contrary to the successful colonization history of demersal fishes Lessepsian small pelagic fishes were represented with very low involvement in the mid-water trawl surveys. They formed around 5-7% of the total small pelagic catch. The small pelagic fish assemblage in the region is dominated by *Sardinella aurita* almost exclusively occupying the Bay of Mersin. The bay is characterised by eutrophic nature as oppose to extreme oligotrophy in the surrounding waters (Figure 18). As an extension of the hydrographical conditions in the NE Levant, eutrified waters are trapped in the bay and forms so called Surface Levantine Water; SLW. This peculiar water mass occupying the shallow basin, is significantly warmer than the rest of the basin (Bingel et al., 1993). The conditions in the SLW favour thermophilic small pelagic fish, *Sardinella aurita*. The adaptive feeding and spawning strategy of this fish agrees well with the eutrophic and subtropical nature of the area. This feature enhances its resilience against intruders.

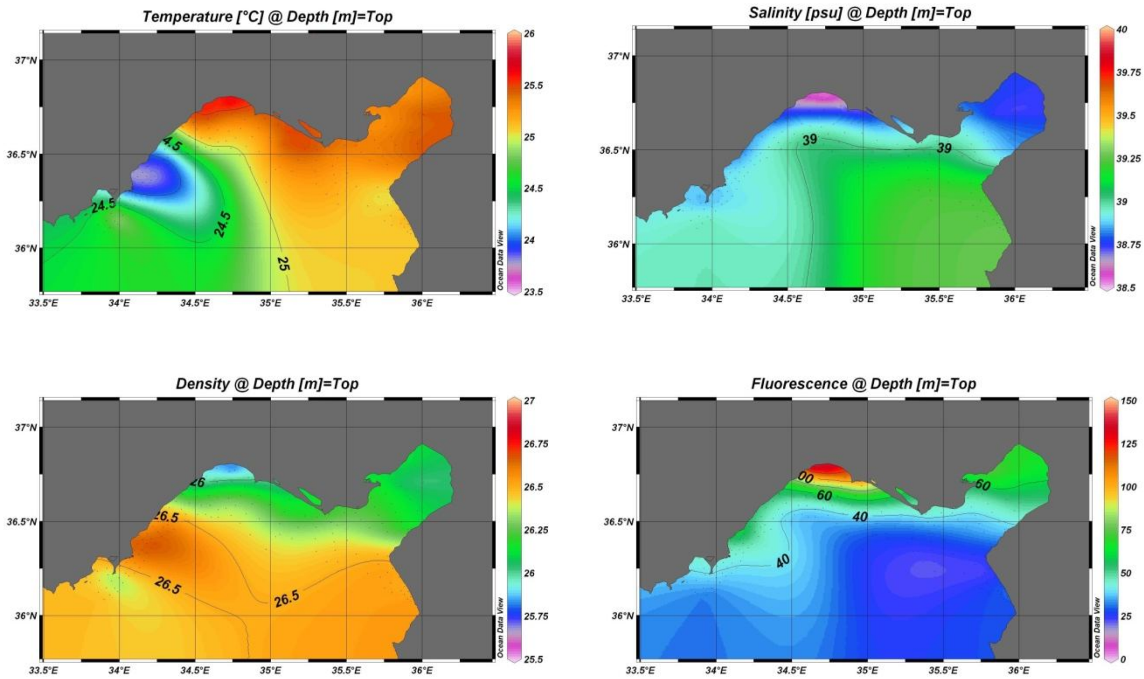

Figure 18. Surface temperature, salinity, density and fluorescence distribution in the NE Levants Sea (June 2010)

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EastMed

Sub-regional Technical meeting on the Lessepsian migration and its impact on eastern Mediterranean fishery

Nicosia, 7-9 December 2010

Status and Trend of Lessepsian Species in Marine Waters of Turkey

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Abstact

So far, 65 indo-Pacific fish species has migrated to the Mediterranean Sea. In Turkish coast of Mediterranean Sea, catch composition of fisheries has been changed and the lessepsian species comprise the majority. According to size of populations, three types of introduced species by Suez Chanel can be distinguished in Turkish waters: Rare species, species having established stable populations, very common and abundant migrant species. In addition to harmful effects of the lessepsian species the catch composition of fishery by trawling, purse seiner and gill nets have been changed in Turkish waters.

Introduction

Invasive species are a global problem adversely affecting biological diversity and a serious threat to conservation efforts (Box *et al.*, 2003). The negative effects of invasive species have initiated the social and scientific media to take some precautions against the dispersal of aliens among regions.

The opening of the Suez Canal in 1869 has had serious zoogeographic and ecological repercussions. The canal connects two major bodies of water, the Red Sea and the Mediterranean Sea, which differ both faunistically and hydrographically. The fauna of the Red Sea is of tropical Indo-Pacific origin. On the other hand, the Mediterranean Sea is mainly of temperate Atlantic origin. The Red sea and Mediterranean Sea were exposed to invasion of organisms from each other by opening of the Suez Canal. However, the great majority of migrational movement has been from the Red Sea to the Mediterranean Sea and termed as “lessepsian migration” (Por 1978). For the opposite direction minor migrations have been occurred and known as “anti-lessepsian migration” (Golani 1998). Lessepsian species and their roles in the benthic and pelagic ecosystems is increasingly becoming a subject of study in many countries. When lessepsian species are established and becoming abundant in their new niches they are getting invasive. Invasive species are introduced, abundant, dangerous for native species/communities, and harmful (ecologically/economically) (Boudouresque, 1999; Golen and Galil, 2005). The impacts of invasive species on their new environment can be listed as restructuring established food webs, competition with native organisms for food and space, altering the gene pool when the invading organisms reproduce with native species, altering evolutionary processes and causing dramatic changes in native populations, including extinctions, and importing new diseases (Mooney and Cleland, 2001; Frankham, 2005).

Distributions of aliens in the Mediterranean Sea

There are numerous vectors of dispersal of alien species which allow penetrating Mediterranean Sea. Dispersal vectors of alien species are the Suez Canal, Straits of Gibraltar, ballast waters of ships, fouling, aquarium activities, aquaculture and scientific purposes. The Suez Canal is the most important vector for aliens of the Mediterranean since lessepsian species constitute the majority of alien species in the Mediterranean Sea as shown in Figure 1.

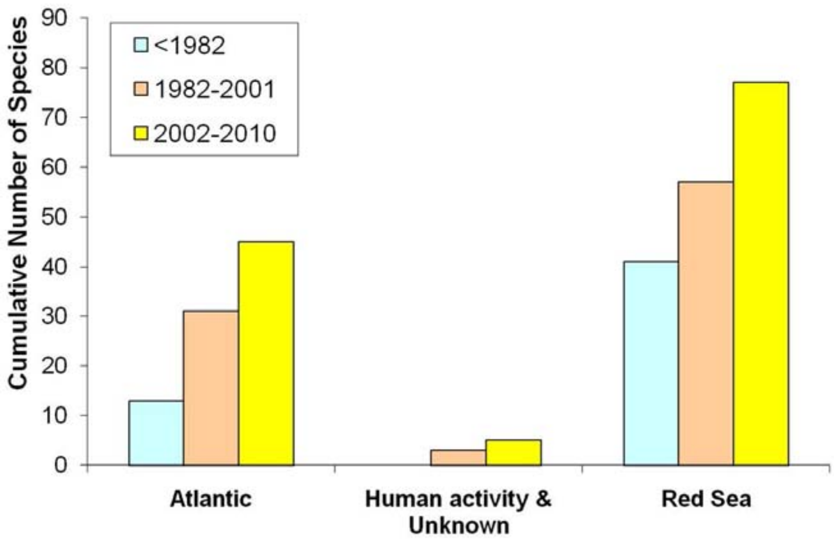

Figure 1. The Origin of Alien Species and Trend in the Mediterranean.

The composition of alien species in the Mediterranean Sea constitute molluscs (27.6 %), fish (21.6%), crustacea (20.7%), polichaeta (14%), bryzoans (5%), ascidians (3%), sponges (3%), and other animal groups (15.8%). The majority of aliens of Mediterranean Sea are composed of molluscs and fish.

The geographic distribution of alien fish species in the Mediterranean Sea is biased. The lessepsian species distribution is concentrated in the Levantine Basin, the eastern Mediterranean Sea. Atlantic species distribution is concentrated in the western Mediterranean Sea (Figure 2). The region trend of alien fish distribution in the Mediterranean Sea is highly increasing for the last decade (Figure 2).

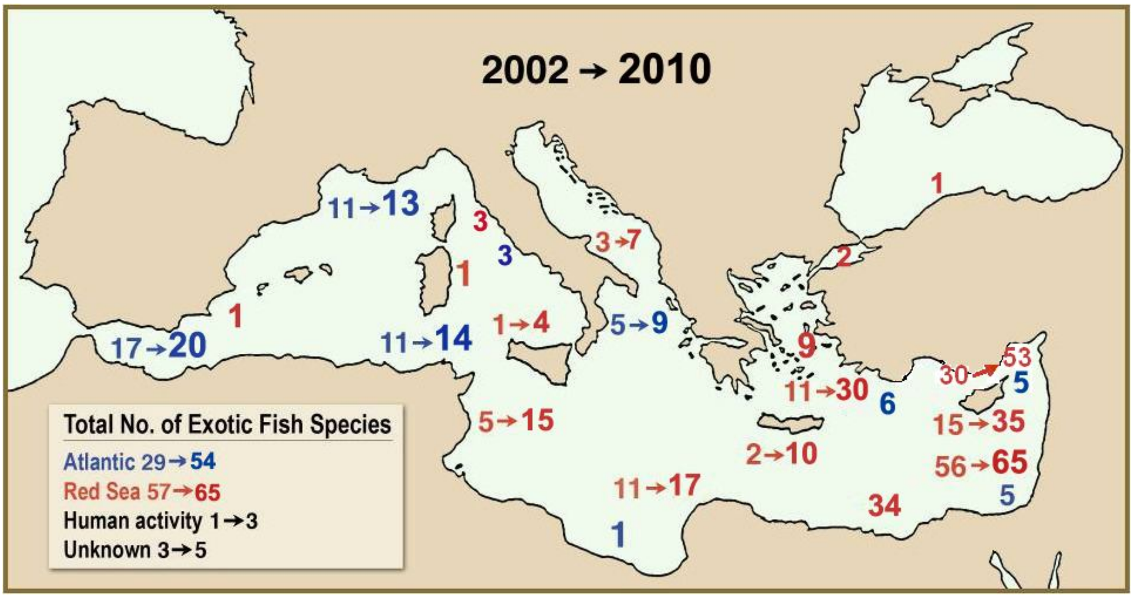

Figure 2. Alien fish species distribution and regional trends for the last decate in the Mediterranean Sea.

Lessepsian fish species in marine waters of Turkey

The Mediterranean Sea is currently becoming warmer. The temperature of the Mediterranean Sea has been rising in deep and surface waters for the last 30–40 years (Lasram and Mouillot, 2009). The successful introductions of indo-Pacific species from the Red Sea and Atlantic species from lower latitudes to the Mediterranean Sea is in correlation with the increasing temperature of the Mediterranean Sea (Lasram & Mouillot 2009). The number of lessepsian fish species in Turkish marine waters is increasing. The geographic distribution of lessepsian species is mainly located on the Mediterranean coast of Turkey (Figure 2). The increase in the number of lessepsian species can be related to the increasing water temperature of Mediterranean Sea as reported by Lasram and Mouillot (2009). In the Iskenderun Bay, northeastern Mediterranean, when the last 30 years sea temperature are investigated there is increasing trend as illustrated in Figure 3.

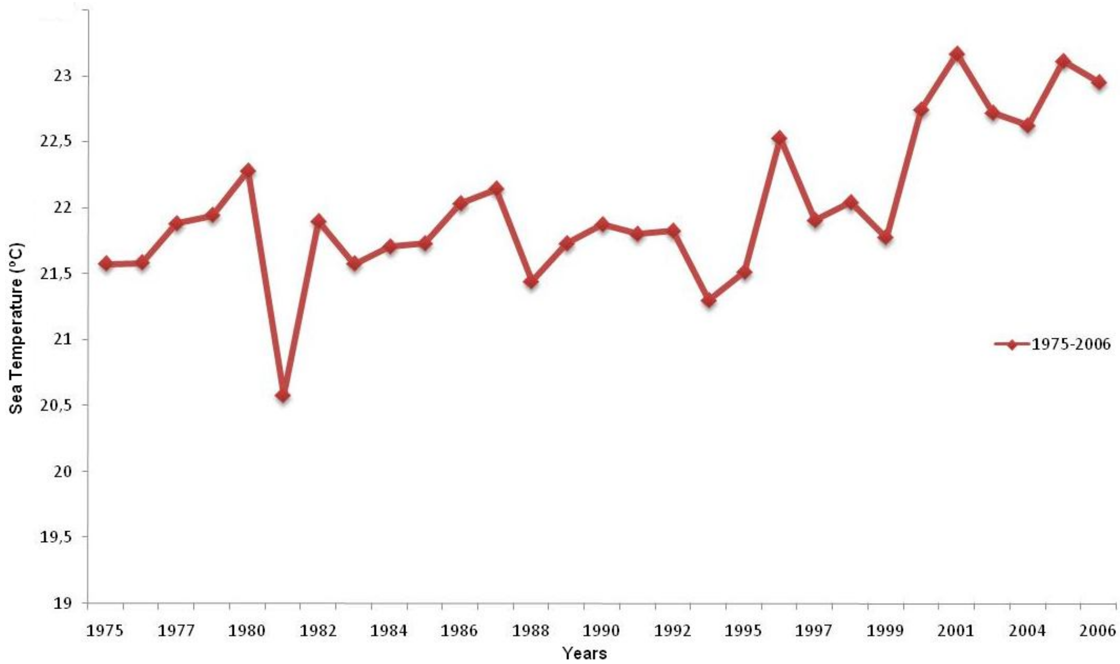

Figure 3. Sea temperature of the Iskenderun Bay between 1975-2006 years.

The increase in the number of lessepsian migrant species can be related to the increasing sea temperature level in Turkey. Recently two lessepsian species, *Apogon fasciatus* (Turan *et al.*, 2010) and *Tylerius spinosissimus* (Turan and Yaglioglu, 2011), have been reported from Turkish marine waters. Up to date there has been 53 lessepsian fish species in Turkish marine waters (Figure 4).

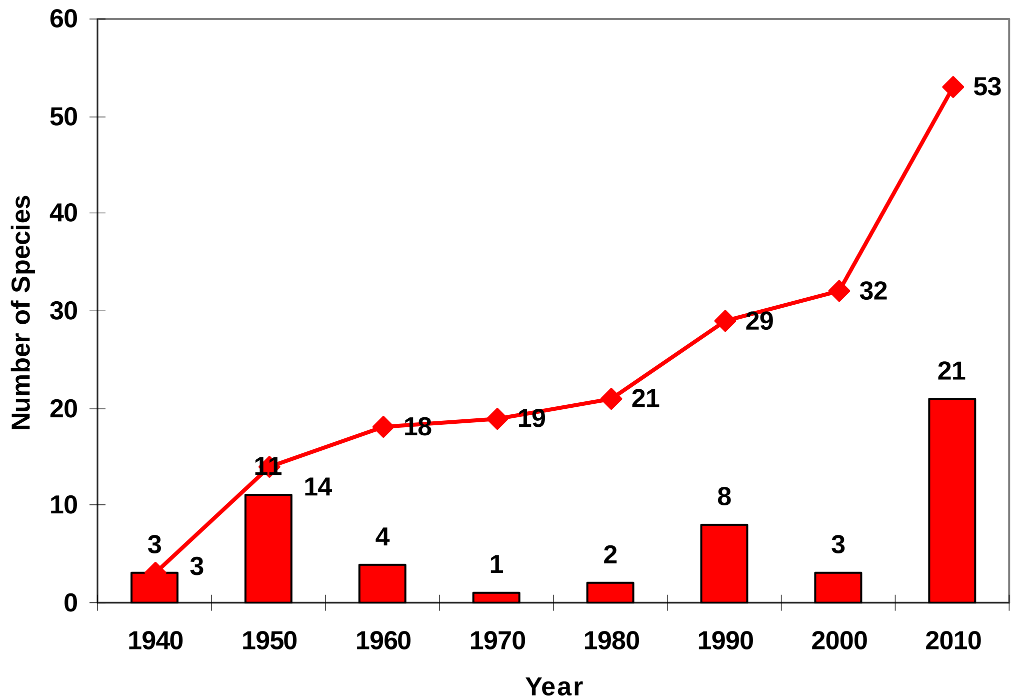

Figure 4. Trends of Lessepsian Fish Species in Marine Waters of Turkey for the last 7 decades.

When we look at the distribution of lessepsian species according to families the highest number of species assembled in the family Tetraodontidae (Figure 5).

Apogonidae family constitute second largest species number in Marine Waters of Turkey.

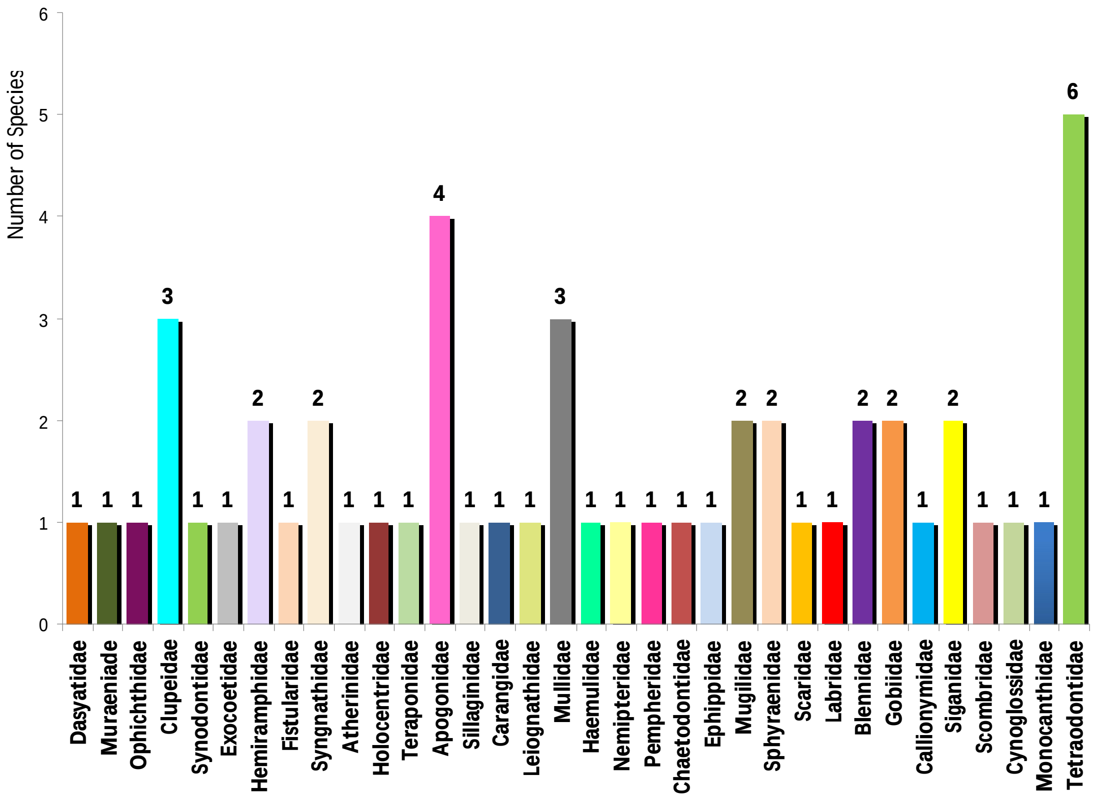

Figure 5. The distribution of lessepsian species according to families in marine waters of Turkey.

When we look at the number of fish species according to origin in marine waters of Turkey, 68% Atlanto-Mediterranean, 14% Mediterranean endemic, 13% cosmopolitan and 11% lessepsian species constitute Turkish Marine fish fauna. The Mediterranean coast of Turkey comprise 80% of the lessepsian migrant fish species of Turkey. The Aegean Sea comprises 15% of the lessepsian fish species (Figure 6).

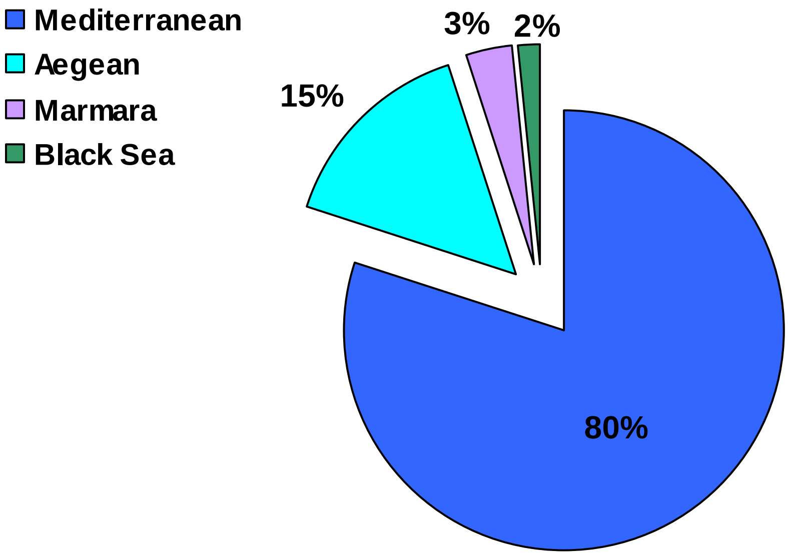

Figure 6. Percentage of composition of lessepsian species in marine waters of Turkey

In the Mediterranean coast of Turkey there are three main fishing ports, the Iskenderun, Mersin and Antalya Bays. Mainly four types of fishing have been used in these ports, trawling, purse seiner, gill net and long-lining. On the bases of these fishing methods generated by the project supported by the Ministry of Agriculture and Rural Affairs of Turkey (The Effects of Global Climate Change on Fish Populations in the Eastern Mediterranean Sea-TAGEM-09/AR-GE/11 coordinated by C.Turan) the distribution and abundance of the lessepsian species in these bays are different as given in Table 1.

The status of abundance of lessepsian migrants

In Turkish coast of Mediterranean Sea, according to size of populations, three types of introduced species by the Suez Channel can be distinguished. These types are (i) rare species (ii) species having established stable populations and (iii) very common and abundant migrant species (Table 1).

Parupeneus forsskali (Fourmanoir & Gueze,1976), *Pteragogus pelycus* (Randall, 1981), *Sphyraena obtusata* (Cuvier, 1829) are rarely occured lessepsian fish species in the Mediterranean coasts of Turkey (Table 1). *Dussumieria elopsoides* (Bleeker, 1849), *Etrumeus teres* (Dekay, 1842), *Herklotsichthys punctatus* (Ruppell, 1837), *Hemiramphus far* (Forsskal, 1775), *Liza carinata* (Valenciennes, 1836), *Upeneus moluccensis* (Bleeker, 1855), *Upeneus pori* (Ben-Tuvia & Golani, 1989), *Saurida undosquamis*, *Scomberomorus commerson* (Lacepede, 1800), *Sillago sihama* (Forsskal, 1775), *Sphyraena chrysotaenia* (Kluzinger, 1884) are species of having established stable populations. Migratory species (etc. *Champsodon nudivittis* (Ogilby, 1895), *Pomadasys stridens*'in (Forsskal, 1775), that are able to establish large communities in Turkish coasts. On the bases fishing methods generated by the ongoing TAGEM project the composition of lessepsian species for trawling and purse seiner fishery is 20% and 39% respectively in the eastern Mediterranean coast of Turkey.

Table 1. The list and distribution of lessepsian migrants in the Mediterranean coasts of Turkey. – indicate absence, + indicate occurrence. R, rare; A, abundant; E, established.

Family	Species	Antalya Bay	Mersin Bay	Iskenderun Bay	Establis hment
Carcharhinidae	*Carcharhinus altimus* (Springer, 1950)	-	-	+	R
Dasyatidae	*Himantura uarnak* (Forsskål, 1775)	-	+	+	R
Chirocentridae	*Chirocentrus dorab* (Forsskål, 1775)	-	+	-	R
Clupeidae	*Dussumieria elopsoides* Bleeker, 1849	+	+	+	E
	Etrumeus teres (DeKay, 1848)	+	+	+	E
	Herklotsichthys punctatus (Rüppell, 1837)	+	+	+	E
Muraenidae	*Enchelycore anatina* (Lowe, 1839)	+	+	-	R
Synodontidae	*Saurida undosquamis* (Richardson, 1848)	+	+	+	E
Bregmacerotidae	*Bregmaceros atlanticus* Goode and Bean, 1886	+	+	+	A
Exocoetidae	*Parexocoetus mento* (Valenciennes, 1846)	+	+	+	E
Hemiramphidae	*Hemiramphus far* (Forsskal, 1775)	+	+	+	E
Fistularidae	*Fistularia commersonii* (Rüppell, 1835)	+	+	+	E
Syngnathidae	*Hippocampus fuscus* Rüppell, 1838	+	-	-	R
	Syngnathus rostellatus Nilsson, 1855	+	-	-	R
Atherinidae	*Atherinomorus forskali* (Rüppell,1838)	-	-	+	R
Holocentridae	*Sargocentron rubrum* (Forsskal, 1775)	+	+	+	E
Teraponidae	*Pelates quadrilineatus* (Bloch, 1790)	-	+	+	E
Apogonidae	*Apogon pharaonis* Bellotti, 1874	+	+	+	E
	Apogon queketti Gilchrist, 1903	-	-	+	E
	Apogon smithi (Kotthaus, 1970)	+	+	+	E
	Apogon fasciatus (White, 1790)	-	-	+	E
Sillaginidae	*Sillago sihama* (Forsskal, 1775)	+	+	+	E
Carangidae	*Alepes djedaba* (Forsskal, 1775)	+	+	+	R
	Trachurus indicus Nekrasov, 1966	-	-	+	R
	Decapterus russelli (Rüppell,1830)	-	-	+	R
Lethrinidae	*Monotaxis grandoculis* (Forsskål, 1775)	+	-	-	R
Leiognathidae	*Equulites klunzingeri* (Steindachner, 1898)	+	+	+	E
Mullidae	*Upeneus moluccensis* (Bleeker, 1855)	+	+	+	E
	Upeneus pori Ben-Tuvia & Golani, 1989	+	+	+	E
	Parupeneus forsskali (Fourmanoir&Gueze,1976)	-	+	-	R
Champsodontidae	*Champsodon nudivittis* (Ogilby, 1895)	-	-	+	A
Haemulidae	*Pomadasys stridens* (Forsskål, 1775)	-	+	+	A
Nemipteridae	*Nemipterus randalli* Russell, 1986	+	+	+	E
Pempheridae	*Pempheris vanicolensis* Cuvier, 1831	+	+	+	E
Chaetodontidae	*Heniochus intermedius* Steindachner, 1893	+	-	-	R
Mugilidae	*Liza carinata* (Valenciennes, 1836)	-	+	+	E
Sphyraenidae	*Sphyraena pinguis* Günther, 1874	+	+	+	E
	Sphyraena obtusata Cuvier, 1829	+	-	-	R
Labridae	*Pteragogus pelycus* Randall, 1981	+	-	+	R
Blennidae	*Petroscirtes ancylodon* Rüppell, 1838	+	+	+	R
Gobiidae	*Oxyurichthys petersi* (Klunzinger, 1871)	+	+	+	E
	Vanderhorstia mertensi Klausewitz, 1974	+	+	+	A
	Trypauchen vagina (Bloch and Schneider, 1801)	-	-	+	R
Callionymidae	*Callionymus filamentosus* Valenciennes, 1837	-	+	+	E
Siganidae	*Siganus luridus* (Rüppell, 1828)	+	+	+	E
	Siganus rivulatus (Forsskal,1775)	+	+	+	E
Scombridae	*Scomberomorus commerson* (Lacepéde, 1800)	+	+	+	E
Cynoglossidae	*Cynoglossus sinusarabici* (Chabanaud, 1931)	-	+	+	E
Monocanthidae	*Stephanolepis diaspros* Fraser-Brunner, 1940	+	+	+	E
Tetraodontidae	*Lagocephalus sceleratus* (Gmelin, 1788)	+	+	+	E
	Lagocephalus spadiceus (Richardson, 1844)	+	+	+	E
	Lagocephalus suezensis Clark & Gohar, 1953	+	+	+	E
	Sphoeroides pachygaster (Müller and Troschel, 1848)	+	-	-	R
	Torquigener flavimaculosus Hardy & Randall, 1983	+	+	+	R
	Tylerius spinosissimus (Regan, 1908)	-	-	+	R

Negative effects of lessepsian species on fishery

Several lessepsian species cause some harmful effects which are health problems (poisoning, pain), net damages, mesh clogging, fouling and extra labor (Table 1). Fishermen are affected from this poisonous species. Puffer fish species tear gill nets and cut long lining hooks (Figure 7). Fire worms have very painful cilias and give pain and extra labor to fishermen during collection of fishes on the net. Jellyfish *Ropilema nomadica* covers sometime 80% of total catch of gill nets, trawls or purse seiners. Sometime fishermen leave the nets in the sea due to over loading of *R. nomadica*.

Table 3. Effect of lessepsian species on the fishing gears.

	Effects on					
		Fishing Gears				
Species	**Human**	**Gill net**	**Long lining**	**Trawling**	**Purse seining**	**Fish farming**
Tetraodontid species (Puffer fish)	+	+	+			
Ropilema nomadic (jellyfish)	+	+		+	+	
Callinectes sapidus (Decapods)		+	+			
Macrorhynchia philippina (Hydroid)	+	+				
Diadora setosum (Sea urchin)	+	+				
Synaptula resiprocens (Holothurian)		+				
Serpulids polycaetes (warms)		+				+
Hermodice carunculata (fire warm)	+	+				
Caulerpa taxifolia (Algae)		+				

Figure 7. Views on the effects of fire warm and puffer fish species on gill net and long lining.

Consequences of introduction of the lessepsian migrants in Turkey

Consequences of introduction of the lessepsian migrants in Turkey can be grouped as ecological, economical, economical and ecological. Ecological impact of lessepsian species on indigenous species are modification of ecological niches, modification of functioning of ecosystem and replacement of indigenous species. Economical consequences can be divided as possitive and negative. Arrival of lessepsian species (*Etrumeus teres, Herklotsichthys punctatus, Dussumieria elopsoides, Sauira undoscamis, Nemipterus rendalli*) which have economic interest in Turkish markets is a positive effect. Negative consequences is loss of indigenous species such as *Merluccius merluccius* with economic interest. Ecological and economical consequences are the replacement of economically important indigenous species with economically important lessepsian species. This can be exampled with *Siynodus saurus* and *Mullus surmuletus*. *Siynodus saurus* was an abundant and economically important Mediterranean species in Turkish waters and for the last ten years *Siynodus saurus* has been rarely seen in Turkish waters. *S. saurus* is probably replaced with *Saurida undosquamis* which is very abundant in Mediterranean coasts of Turkey and in great number in local markets of Turkey.

Management actions for the lessepsian species could be as appropriate legislation to prevent species introduction, increase the knowledge of the biology of aliens and indigenous species as well as the invasion mechanisms, biological methods such as introduction of predators, target vectors of invation, good knowledge on the fauna of Suez Chanel and Red Sea, cooperation between the countries concerned. On the other hand, the control of lessepsian migrant is difficult because there are no physical border between the Red Sea and Mediterranean. Therefore stopping the lessepsian species from the Suez Chanel is seems to be impossible. However, slowing down of the lessepsian species passage to the Mediterranean Sea should be urgently studied. A warning system is needed for harmful species to mitigate negative impacts to the fishermen, fish farming and human health. A special alarm system and data base can be executed mainly for the venomous fish and other species like jelly fish and others. For example, the CIESM has initiated International JellyWatch Programme for monitoring jellyfish blooms along Mediterranean coasts.

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Non-indigenous fish species in the food web of *Posidonia oceanica* meadows and sandy habitats from an area of the eastern Mediterranean

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ABSTRACT
Quantitative sampling in combination with classification of fish species into six major feeding guilds revealed the position and contribution of non-indigenous species (NIS) in the food web of *Posidonia oceanica* and sandy habitats in an area of the eastern Mediterranean. In *P. oceanica* beds and on sandy bottoms 10 and five species, respectively, were non-indigenous fish, some of them being true Indo-Pacifics and some being Red Sea endemics. The proportional contribution of NIS individuals on *P. oceanica* beds was lower than that of sandy bottoms (12.7 *vs.* 20.4 %) a pattern that also followed for biomass (23.4 *vs.* 13.6 %), indicating that low diverse systems may be more prone to introductions than species-rich communities. However, abilities in feeding on various taxa seemed to be a beneficial trait for the establishment of NIS in species-rich communities. The two habitats had similar fish feeding guilds, but the biomass contribution from non-indigenous species varied within each guild, indicating different degrees of impact on the available resources. This study showed that of the non-indigenous fish species in the coastal systems studied, only a few species contributed to the differences in biomass between habitats. Further, the feeding guild classification indicated that the success of fish species introductions was largely species-dependent by revealing that a wider food spectrum might be a beneficial trait during the establishment phase.

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INTRODUCTION

The Mediterranean Sea is considered to be one of the main hotspots of marine bioinvasions on earth and the rate of introductions appears only to increase (Rilov & Galil 2009). A recent review indicates that nearly 1000 species have already been introduced in the Mediterranean Sea, including species from the Red, the Black and the Atlantic Sea. The review estimates that the rate of introductions has been elevated to 1 species every 9 days (Zenetos 2010). Since the opening of the Suez Canal, 1869, the coastal ecosystems of the eastern Mediterranean Sea have been subjected to the establishment of non-indigenous species (NIS) of Indo-Pacific origin and Red Sea endemics (Golani 2010). Concerning fish, 80 species have already been reported in the eastern Mediterranean (Golani 2010). The fish fauna of the Mediterranean Sea that developed after the Messinian salinity crisis, 5.3 million years ago, was characterized by a mixture of temperate and subtropical species. The number of fish species in the western Mediterranean is considered to be higher than in the eastern Mediterranean (Quignard & Tomasini 2000), with a general decrease in number of species moving eastwards (Golani et al. 2006). New data for the eastern basin has demonstrated that the introduction of NIS through the Suez Canal has reduced the difference in species richness, increasing the divergence in fauna between the eastern and western Mediterranean, towards an Indo-Pacific and Atlantic fish fauna respectively (Massuti et al. 2010).

Most of the scientific work done in the Mediterranean Sea has so far mainly considered large scale spreading and establishment of NIS. The main vector of fish species introductions is through immigration via the shallow Suez Canal, explaining the dominance of coastal fish species among NIS. The rate of fish immigration has increased in recent decades and has ecological, as well as social and economical impacts. The coastal zone plays an important role for many fish species which may utilize the different shallow habitats during one or several parts of their life cycle (Pihl & Wennhage 2002). Shallow coastal habitats, such as seagrass meadows, provide food and shelter, and serve as high quality settlement and nursery habitats for many fish species (Wennhage & Pihl 2002). Such species-rich communities are believed to be resistant to incursions of NIS, according to the biotic resistance hypothesis (Levine & Adler 2004). Accordingly, the most truly explanation is that less-diverse communities (Leppäkoski & Olenin 2000) and/or stressed ecosystems (Occhipinti-Ambrogi & Savini 2003) are believed to be more prone to the introductions of NIS. This is due to the fact that these areas have few species and have simpler food-web interactions, thus providing empty niches for the establishment of NIS. Further, Ricciardi and Mottiar (2006) applies Darwin’s “pre-adaption hypothesis” in the context of invasion biology, i.e. to test whether the presence of closely related indigenous species could be used to predict the successful introduction of NIS, because it makes the NIS more likely to possess traits that pre-adapt them to their new environment. While taxonomic affiliation of invader’s to the local fish fauna will make species rich communities more prone to introductions, biotic resistance will make these systems less vulnerable.

Several factors have contributed to the increasing rate of reported introductions of NIS during the last decades. Increased scientific interest, gradual deepening of the Suez Canal, increased sea water temperature and gradual equalization of Red Sea salinity with Great Bitter Lakes are among the most important factors mentioned (Por 2010). Once a NIS is established in a large ecosystem such as the Mediterranean Sea, it is almost impossible to eradicate. The physiological abilities in combination with different life history traits and ecological interactions in the recipient community (e.g. competition for resources, habitat to settle, spawning grounds, grazing or predation, trophic cascading effects, or even, filling up empty niches) will determine the introduced species ability to adapt to the ecosystem that it arrives in. An obvious example of competitive exclusion/displacement of an indigenous species was the introduction of the two herbivorous fish species, *Siganus rivulatus* Forsskål and *Siganus luridus* Rüppell in the coastal zone of Lebanon in the eastern Mediterranean (Harmelin-Vivien et al. 2005). These two species out-competed the native herbivorous species *Sarpa salpa* (L.) and significantly reduced its abundance (Harmelin-Vivien et al. 2005, Azzurro et al. 2007a). Several non-indigenous fish species may have the ability to change the trophic food web by being highly dominant in a habitat or by competing for food resources with indigenous species. The impact of NIS on biodiversity is often referred as positive simply because more species increase species richness, however Wallentinus and Nyberg (2007) argues that the opposite effect may result from the so called biological pollution. This is due to the fact that some species become highly abundant or even pests altering the community structure and reducing biodiversity (Boudouresque & Verlaque 2002).

Given that many of the NIS invade and become highly abundant in shallow coastal areas of the eastern Mediterranean Sea, the study of their impact in the food web is highly important. The established species may already have affected the trophic interactions among species and altered ecosystem functioning. In this study we focused on two important coastal habitats, *Posidonia oceanica* meadows and sandy habitats. Through seasonal quantitative data from both habitats and by classifying species into feeding guilds we studied how non-indigenous fish species may interact and affect native predators, competitors and prey in the food web.

The aim of this study was to investigate the position and contribution of NIS in the food web of two common coastal habitats in an area of the eastern Mediterranean. Specifically, we test whether there is a significant higher proportion of non-indigenous fish species on sandy bottoms compared to *Posidonia oceanica* meadows. Additionally, we investigate seasonal variations in the proportion of NIS within and between the two habitats.

MATERIALS AND METHODS - STUDY AREA

As the largest island of the Dodecanese Archipelago, Rhodes is located in the straddle between the Levantine and the Aegean Sea. The coastal zone of Rhodes Island is categorized as sub-tropical open-sea, since it possesses a limited continental shelf. Rhodes is directly influenced by the neighbouring Levantine Basin, since the island is hugged by the warm-salty Asia Minor Current (AMC) (Pancucci Papadopoulou et al. 1999). Mean surface water temperature ranged between 16 and 18 °C in winter, between 21 and 23 °C in autumn and spring and reaching 28 °C in summer. Surface salinity varied from 39.3 in winter to 39.7 PSU in summer (Kalogirou et al. 2010). Surface water was separated from bottom water by a thermocline, formed in May and reaching maximum by mid August, at 35-40 meters in depth. The thermocline breaks up in mid November (Corsini-Foka 2010).

The investigation was carried out at four locations around Rhodes Island (Fig. 1). The shoreline is characterized by a mixture of rocky- and sediment bottom areas. Two of the selected locations (localities 1, 2; Fig. 1) were considered representative of *Posidonia oceanica* habitats around the coasts of Rhodes Island, while the other two locations (locations 3, 4; Fig.1) represented unvegetated sandy bottoms. West side of Rhodes Island is mainly characterized by Posidonia oceanica habitats while eastern part is characterized by clear sandy and rocky bottoms.

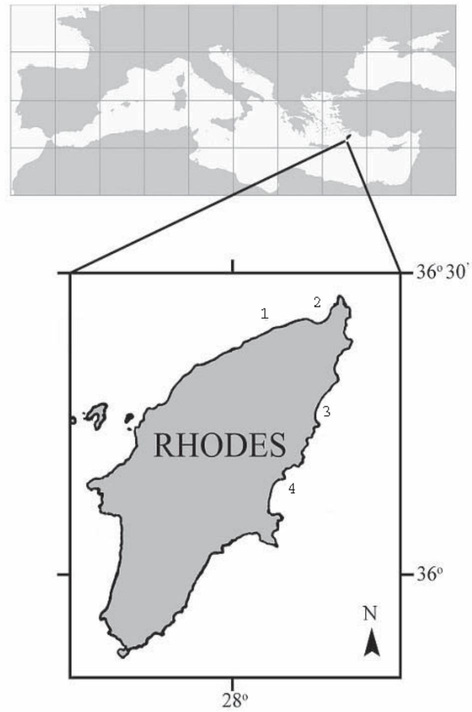

FIG. 1 Map of the investigated area with Posidonia oceanica meadows (1, 2) and sandy bottoms (3, 4).

SAMPLING

The Danish-seine method was used to sample the fish, from a local commercial fishing boat. The procedure is to set out the start warp with an anchor near the shore together with a buoy at 5m depth and while the boat forms a triangle set the net in parallel to the coastline, sampling the habitat from 5 to 35 m depth. The mesh size of the gear decreases from the outer end of the wing towards the centre with the sequence 500, 180, 32-34, 12, and 11 mm, with minimum mesh size of 5-8 mm in the codend. For further details see Kalogirou *et al.* (2010).

In order to study temporal and spatial variations in fish assemblages, daylight samples were undertaken at all localities on four occasions over the year to represent seasonal variations in water temperature. December 2008 represented autumn while March, May and August 2009 represented winter, spring and summer respectively. Three samples with the seine were randomly deployed on each location and sampling occasion, covering a total area of 0.12 km² (0·.04 km² per seining). All fishes were identified to species level immediately after capture following available literature (Whitehead et al. 1986, Golani et al. 2002, Golani et al. 2006), weighed in g and measured for total length, L_T. Two strictly zooplanktivorous species, being the dominant in the coastal system, *Spicara smaris* (L.) and *Spicara maena* (L.), were excluded from all the analysessince they have a patchy distribution and a low association to a specific habitat (Kalogirou et al. 2010). The two *Spicara* species were therefore not considered as relevant in order to describe the fish assemblage structures associated with the habitats under concern

A Bray-Curtis similarity matrix based on fish biomass was used to produce a non-metric Multi Dimensional Scaling ordination (MDS) (Clarke & Gorley 2006) in order to 2-D visualize differences in the fish assemblages between habitats and seasons. The biomass data had been log-transformed prior to analysis. A bubble-plot was superimposed on the MDS to show patterns in the proportions of non-indigenous species that could be attributed to habitat and season. The similarity matrix was also used to perform an ANOSIM in order to discriminate seasonal and habitat differences in the fish assemblages (Anderson 2001a, b, McArdle & Anderson 2001). In addition, a SIMPER analysis (Clarke & Gorley 2006) was performed to identify the species mainly responsible for similarities and differences in fish assemblage structure between habitats.

FEEDING GUILDS

The fish assemblage was divided into feeding guilds based on a review of the feeding habits of Mediterranean fish by Stergiou and Karpouzi (2002). For fish species not included in this review additional information was obtained from Bell & Harmelin-Vivien (1983) Whitehead et al. (1986), Cardinale et al. (1997) as well as local diet analyses (Kalogirou, unpublished). Primary information on the diet of each species was used to construct the following feeding guilds: herbivorous (H), zooplanktivorous (Z), invertebrate feeders (I), piscivorous (P), invertebrate and fish feeders (IF) and omnivorous (O). To be classified to the feeding guild H, Z, I and P, 90% of the diet had to belong to the respective food category. Further, to be classified as IF, invertebrates and fish together had to add up to 90 % of the total diet while when vegetation together with invertebrates and/or fish were among the food categories and contributed to 90 % of the total diet it was classified as O. The purpose of this classification was to reveal new interactions in the food web and give insights on the impact on food resources and potential competitors, following the introduction of non-indigenous fish species.

RESULTS

FISH SPECIES

Altogether, 85 species within 32 families were identified during this study. The two strictly zooplanktivorous species, *Spicara smaris* (L.) and *Spicara maena* (L.), excluded from the analysis together contributed with 168453 individuals and 465 kg. Seventy-nine species occurred in *Posidonia oceanica* beds and 25 were found on sandy bottoms, of which 19 species were common to both habitats (Table 1). In *P. oceanica* beds and on sandy bottoms 10 and five species, respectively, were non-indigenous fish. All NIS found on sandy bottoms were also found in *P. oceanica* beds. Non-indigenous species contributed 13 % of the species numbers in *P. oceanica* beds, and to 16 % of the species on sandy bottoms. Most of the non-indigenous fish species observed during this study were of Indo-Pacific origin while some area Red Sea endemics (Table 1).

Table 1. Species list of fish recorded in *Posidonia oceanica* beds and on sandy bottom areas on the coasts of Rhodes Island. Fish species are divided into feeding guilds based on Stergiou and Karpouzi (2002) accordingly: herbivorous, H; zooplanktivorous, ZP; invertebrate feeders, I; piscivorous, P; those feeding on invertebrates and fish, IF and omnivorous, O. Species was further divided into two groups depending on origin (IN: indigenous; NIS: non indigenous).

Family	Species	English name	Sandy	Posidonia	Feeding Guild	Origin
Apogonidae	*Apogon imberbis*	Cardinal fish		X	IF	IN
Atherinidae	*Atherina hepsetus*	Mediterranean sand smelt		X	I	IN
Balistidae	*Balistes capriscus*	Grey triggerfish		X	I	IN
Blenniidae	*Blennius ocellaris*	Butterfly blenny		X	I	IN
	Parablennius pilicornis	Ringneck blenny		X	I	IN
	Parablennius tentacularis	Tentacled blenny		X	I	IN
Bothidae	*Bothus podas*	Wide-eyed flounder	X	X	I	IN
Centracanthidae	*Spicara maena*	Blotched picarel	X	X	ZP	IN
	Spicara smaris	Picarel	X	X	ZP	IN
Carangidae	*Caranx crysos*	Blue runner	X		IF	IN
	Seriola dumerili	Greater amberjack	X	X	P	IN

	Trachurus mediterraneus	Mediterranean horse mackerel		X	IF	IN
	Trachurus trachurus	Atlantic horse mackerel		X	IF	IN
Clupeidae	*Sardina pilchardus*	European pilchard		X	O	IN
	Sardinella aurita	Round sardinella		X	O	IN
Dactylopteridae	*Dactylopterus volitans*	Flying gurnard	X		IF	IN
Dasyatidae	*Dasyatis pastinaca*	Common stingray		X	IF	IN
Fistularidae	*Fistularia commersonii*	Bluespotted cornetfish	X	X	P	NIS
Gobiidae	*Gobius cobitis*	Giant goby		X	O	IN
	Gobius couchi	Couch's goby		X	I	IN
	Gobius cruentatus	Red-mouthed goby		X	I	IN
	Gobius geniporus	Slender goby		X	I	IN
	Gobius paganellus	Rock goby		X	I	IN
Labridae	*Coris julis*	Mediterranean rainbow wrasse		X	I	IN
	Labrus merula	Brown wrasse		X	I	IN
	Pteragogus pelycus	Sideburn wrasse		X	I	NIS
	Symphodus cinereus	Grey wrasse		X	I	IN
	Symphodus doderleini			X	I	IN
	Symphodus mediterraneus	Axillary wrasse		X	I	IN
	Symphodus melanocercus	Blacktailed wrasse		X	I	IN
	Symphodus ocellatus			X	I	IN
	Symphodus roissali	Five-spotted wrasse		X	I	IN
	Symphodus rostratus			X	I	IN
	Symphodus tinca	East Atlantic peacock wrasse		X	I	IN
	Thalassoma pavo	Ornate wrasse		X	I	IN
	Xyrichthys novacula	Cleaver wrasse	X		I	IN
Monacanthidae	*Stephanolepis diaspros*	Reticulated leatherjacket	X	X	I	NIS
Mullidae	*Mullus barbatus*	Red mullet	X	X	I	IN
	Mullus surmuletus	Striped red mullet	X	X	IF	IN
	Upeneus pori	Por's goatfish	X	X	I	NIS
Muraenidae	*Muraena helena*	Mediterranean moray		X	IF	IN
Pomacentridae	*Chromis chromis*	Damselfish		X	I	IN
Scaridae	*Sparisoma cretense*	Parrotfish		X	O	IN
Sciaenidae	*Sciaena umbra*	Brown meager		X	IF	IN
Scorpaenidae	*Scorpaena maderensis*	Madeira rockfish		X	IF	IN
	Scorpaena porcus	Black scorpionfish		X	IF	IN
	Scorpaena scrofa	Largescaled scorpionfish		X	IF	IN
Serranidae	*Epinephelus marginatus*	Dusky grouper		X	IF	IN
	Serranus cabrilla	Comber		X	IF	IN
	Serranus hepatus	Brown comber		X	IF	IN
	Serranus scriba	Painted comber		X	IF	IN
Siganidae	*Siganus rivulatus*	Marbled spinefoot		X	H	NIS
	Siganus luridus	Dusky spinefoot		X	H	NIS
Soleidae	*Solea solea*	Common sole	X	X	I	IN
Sparidae	*Boops boops*	Bogue	X	X	O	IN
	Dentex dentex	Common dentex		X	IF	IN
	Diplodus annularis	Annular seabream		X	I	IN
	Diplodus puntazzo	Sharpsnout seabream		X	IF	IN
	Diplodus sargus sargus	White seabream		X	IF	IN
	Diplodus vulgaris	Common two-banded seabream		X	IF	IN
	Lithognathus mormyrus	Striped seabream	X		I	IN
	Oblada melanura	Saddled seabream		X	I	IN
	Pagellus acarne	Axillary seabream	X	X	IF	IN
	Pagellus erythrinus	Common Pandora	X	X	IF	IN
	Pagrus pagrus	Common seabream	X	X	IF	IN
	Sarpa salpa	Salema		X	H	IN
	Spondyliosoma cantharus	Black seabream		X	I	IN
Sphyraenidae	*Sphyraena chrysotaenia*	Yellowstripe barracuda		X	P	NIS
	Sphyraena flavicauda	Yellowtail barracuda		X	P	NIS
	Sphyraena sphyraena	Eurpoean barracuda		X	P	IN
	Sphyraena viridensis	Yellowmouth barracuda		X	P	IN

Syngnathidae	*Hippocampus guttulatus*	Long-snouted seahorse		X	I	IN
	Nerophis maculates			X	I	IN
	Syngnathus acus	Greater pipefish		X	I	IN
	Synganthus typhle	Broad-nosed pipefish		X	IF	IN
Synodontidae	*Synodus saurus*	Atlantic lizardfish	X	X	IF	IN
Tetraodontidae	*Lagocephalus sceleratus*	Silverstripe blaasop	X	X	IF	NIS
	Lagocephalus suezensis		X	X	IF	NIS
Trachinidae	*Trachinus araneus*	Spotted weever	X	X	IF	IN
	Trachinus draco	Greater weever	X	X	IF	IN
Trichiuridae	*Trichiurus lepturus*	Largehead hairtail	X		IF	IN
Triglidae	*Chelidonichthys lucerna*	Tub gurnard	X		IF	IN
	Trigla lyra	Piper gurnard		X	I	IN
	Trigloporus lastoviza	Streaked gurnard		X	I	IN
Zeidae	*Zeus faber*	John dory		X	IF	IN

ASSEMBLAGE STRUCTURE

The results showed that the fish assemblages (in terms of biomass) were mainly structured according to habitat, although a separation according to season was also obvious (ANOSIM; $p < 0.001$; Fig. 2). August was clearly separated from all the other seasons, a pattern that was consistent for both habitats (ANOSIM, $p < 0.01$, Fig. 2). The proportion of non-indigenous species clearly dominated in spring and autumn on sandy bottoms and in summer on *Posidonia* beds (Fig. 2).

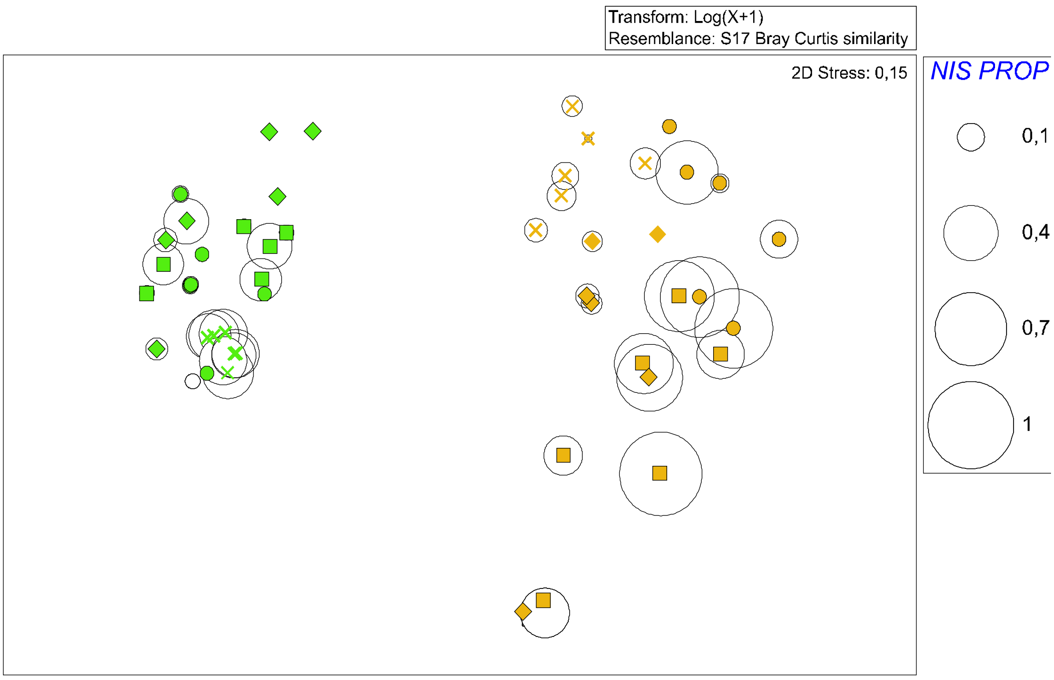

FIG. 2 Multidimensional scaling ordination of the fish assemblage structure in terms of biomass per habitat (*Posidonia oceanica* beds, ■; sandy bottoms, ■), and season (spring, ●; summer, ×; autumn, ■ and winter, ♦). The radius of each circle corresponds to the proportion of non-indigenous species per replicate

FEEDING GUILDS

The fish assemblage in *Posidonia oceanica* beds consisted of three herbivorous species (two NIS), one zooplanktivor (0 NIS), 35 invertebrate feeders (three NIS), six piscivors (three NIS), 28 invertebrate and fish feeders (two NIS) and four omnivors (0 NIS) (Table 1). The two non-indigenous species *Siganus rivulatus* and *Siganus luridus* made up more than 99 % of the herbivorous species both in terms of density and biomass (Fig. 3a), and the indigenous herbivorous species *Sarpa salpa* represented only a fraction (< 0.3 %) over *P. oceanica* beds. In terms of density, *S. rivulatus* and *S. luridus* represented 62.3 and 37.6 % of the individuals, respectively. Non-indigenous species were also dominating within the IF guild in *P. oceanica* beds (Fig. 3a). Among the 28 species in the IF feeding guild the NIS *Lagocephalus sceleratus* made up 63 % of the total biomass (Fig. 3a). Within the piscivorous feeding guild the three NIS, *Fistularia commersonii* Rüppell, *Sphyraena chrysotaenia* Klunzinger and *Sphyraena flavicauda,* contributed with 22 % in terms of biomass (Fig. 3a). Among the 35 invertebrate feeders found in *P. oceanica* meadows the three NIS *Pteragogus pelycus* Randall, *Stephanolepis diaspros* Fraser Brunner and *Upeneus pori* together made up 1 and 2 % in terms of biomass and density, respectively (Fig. 3a).

The fish assemblage on sandy bottoms consisted of seven invertebrate feeders (two NIS), two piscivorous (one NIS), 13 invertebrate and fish feeders (two NIS) and one omnivorous species (0 NIS) (Table 1, 6). On sandy bottoms, NIS were highly represented within the invertebrate and fish feeding guild, contributing with 59 % in terms of biomass (Fig. 3b). *Lagocephalus sceleratus* made up 56 % of the total biomass within this feeding guild. *Lagocephalus suezensis* made up 3 % of the total biomass within the same feeding guild (Fig. 2). Non-indigenous species were also highly represented within the piscivorous and invertebrates feeding guild, contributing with 26 and 19 % in terms of biomass, respectively (Fig. 3b). Out of the seven invertebrate feeders found over sandy bottoms, the two NIS *Stephanolepis diaspros* and *Upeneus pori* made up 8 and 19% in terms of density and biomass, respectively.

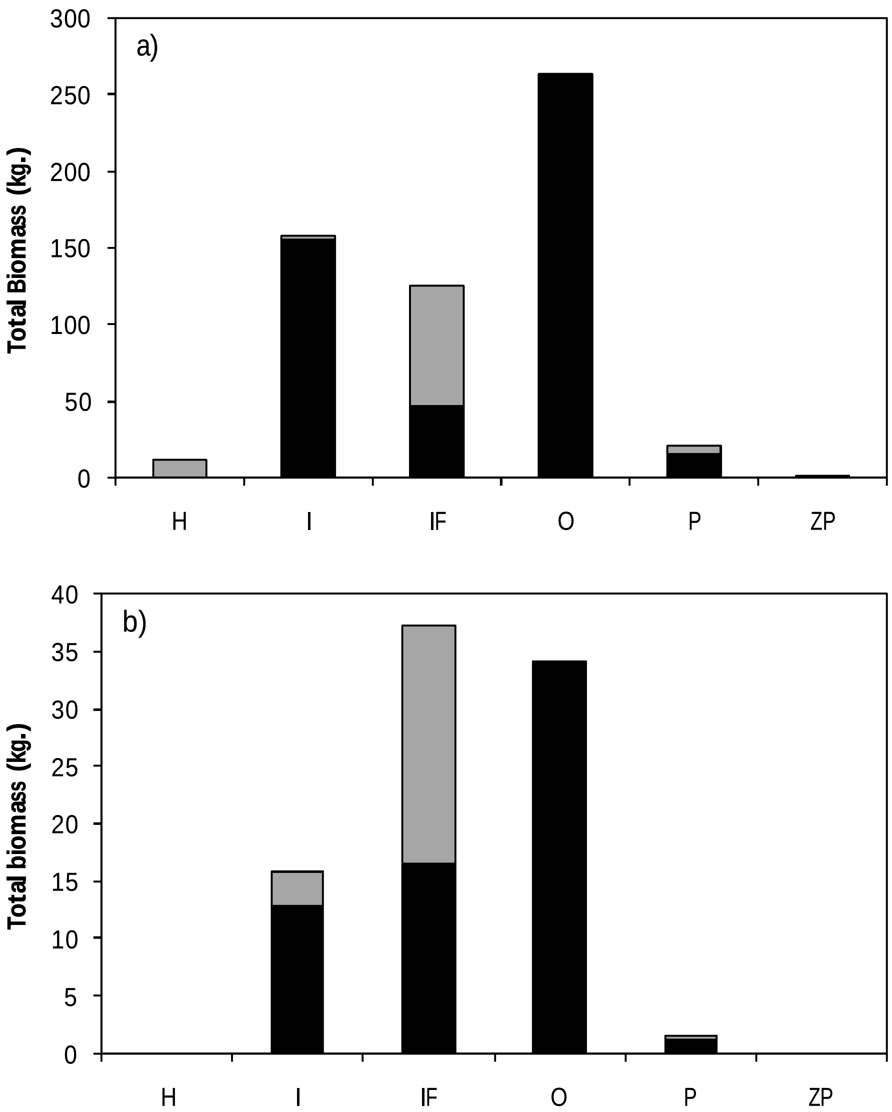

FIG. 3 Biomass per feeding guild (H: Herbivorous; I: invertebrate feeders; IF: invertebrate and fish feeders; O: omnivorous; P: piscivorous; ZP: zooplanktivorous) and origin (■: indigenous and □: non-indigenous species) among the fish assemblage in *Posidonia oceanica* beds (a) and on sandy bottoms (b)

DISCUSSION

This investigation was designed to study the fish assemblages associated with seagrass and sandy substratum, two dominating coastal habitats in the eastern Mediterranean. To our knowledge this is the first study in the eastern Mediterranean to quantitatively compare the density and biomass of fish species in the two habitats under the influence of NIS. The objective of this study was to assign fish species to a feeding guild, in order to investigate the contribution and position of non-indigenous species in the food-web contrasting the two habitats.

The proportion of non-indigenous fish species was 13% in *Posidonia oceanica* meadows and 16 % on sandy substrata. However, NIS made up a significantly higher proportion of fish biomass on sandy bottoms (23%) compared to *P. oceanica* meadows (13%). Both in terms of density and biomass, the highest contribution of NIS to the fish assemblage in *Posidonia oceanica* occurred during the summer, whereas during this season the contribution of NIS on sand was at the lowest. Instead, the highest contribution of NIS on sandy bottoms was encountered during spring and autumn and these seasons were significantly higher compared to the other two seasons.

The sampling method used in this study was a boat seine. This is an active gear, proved to be an effective fishing method in catching a large variety of fish species, a large size range of fish, and sampling *Posidonia oceanica* meadows and sandy bottoms similar efficiency (Kalogirou et al. 2010). The standard sampling area covered (0.04 km^2 per replica) was assumed to give reliable estimates of fish density, biomass and number of fish species. While records of NIS provides valuable information upon arrival of a species e.g. Papaconstantinou (1990), Corsini-Foka (2010), Corsini-Foka & Economides (2007), seasonal quantitative measurements and classification of fish species into feedings guilds allowed us to compare the abundance and biomass contribution of non-indigenous fish species in the fish assemblage between habitats. Density of fish species can seasonally vary due to migration of fish species between habitats, a common pattern found when studying fish assemblage structure of seagrass meadows. Several studies report that juveniles of many fish species are highly abundant over seagrass meadows during spring and summer, a pattern attributed to the nursery and refuge function provided by the canopies of the seagrass (Bell & Harmelin-Vivien 1982, Francour 1997, Guidetti 2000, Moranta et al. 2006, Deudero et al. 2008). Since a main objective of this study was to investigate the position and contribution of NIS in the food web of the two under study habitats, we mainly based our analyses on biomass of fish to better estimate the impact of non-indigenous species in the food web. Assessing possible rearrangements in the food web, attributed to the introduction of non-indigenous fish species will be an important step for future research on the impact of NIS.

The two dominating habitats investigated (*Posidonia oceanica* and sandy bottoms) within the coastal zone of Rhodes Island was found to harbour a highly diverse indigenous and non-indigenous fish fauna including at least 85 species, belonging to 32 families. Not surprisingly, all NIS recorded during this study were of Indo-Pacific origin, a fact that can be attributed to the presence of the man-made Suez Canal in the eastern Mediterranean. The fish fauna of the Mediterranean Sea, which developed after the Messinian salinity crisis, is characterized by a mixture of temperate and subtropical species revealing that westerly species have already colonized the eastern Mediterranean through natural migration. A species immigrating from the Red Sea to the Mediterranean must pass through substantial physical and ecological difficulties such as the shallowness and narrowness of the Suez Canal, its high salinity and its lack of rocky substrate (Golani 1998, Golani 2010). When succeeded, a species physiological demands must fall in similar abiotic conditions (temperature, salinity) to the source area. However, the high number of NIS in the eastern Mediterranean indicates that species which have succeeded to overcome the Suez Canal’s barriers have a good chance of becoming established and to spread to other areas (Golani 2010). Success to establish will also depend on appropriate food resources in the recipient community as well as competitive abilities and level of competition in the food web within habitats.

Four out of six feeding guilds found within *Posidonia oceanica* meadows were matched by similar feeding guilds on sandy bottoms, although both the relative and absolute contribution in biomass differed between habitats. The *P. oceanica* fish assemblage had all feeding guilds previously described, while sandy substrata lacked herbivores and zooplanktivores. The sandy bottom habitat was characterized mainly by infauna feeding fish, utilizing the various invertebrates found in this substratum.

Macrovegetation is the main difference between the two habitats and the habitat forming *P. oceanica* meadows can be hypothesised to support a higher number of species and guilds than the sand habitat. Most of the dominant invertebrate feeders were found to be highly associated to *P. oceanica* meadows suggesting high affinity to vegetation and associated benthic and epibenthic macrofauna. The contribution of non-indigenous invertebrate feeders in *P. oceanica* meadows (1 %) was lower than that in sandy habitats (19 %), suggesting that the low diverse system is more prone to the introduction of non-indigenous invertebrate feeders, due to lack of competition over the available resources of benthic and epibenthic macrofauna. On the contrary, the contribution of non-indigenous IF was found to be higher in the *P. oceanica* habitat (63 %) than on sandy bottoms (55 %), indicating that invasive species of more generalist feeding guilds, such as IF, may have greater success in becoming established in a highly diverse system. The zooplanktivorous species, excluded from the analysis, mainly rely on pelagic food items brought in with water currents to both habitats, explaining the lack of difference in affinity between the habitats. The only ZP species included in the analysis was *Sardina pilchardus* found to spend its juvenile stages in the *P. oceanica* beds. The contributions of non-indigenous piscivorous species were similar in both habitats (22 % in seagrass; 26 % on sand) and consisted primarily of *F. commersonii* and *S. chrysotaenia*. Native piscivores mainly rely on small-sized coastal zooplanktivorous species and species using the coastal habitats as a nursery ground, while also to a lesser extent on the juveniles of resident species (Golani 1993). This pattern holds for the non-indigenous piscivorous species *F. commersonii* (Kalogirou et al. 2007). The high prevalence of the blue-spotted cornetfish, *F. commersonii*, among the piscivores within both habitats studied clearly suggests that this invasive species now has become established in the area. Several studies have emphasized the impact of the non-indigenous rabbitfishes among herbivorous species in different coastal areas of the eastern Mediterranean and report the competitive exclusion of the indigenous *S. salpa*. (Bariche et al. 2004, Harmelin-Vivien et al. 2005, Azzurro et al. 2007b). Accordingly, in the present study, the two non-indigenous rabbitfishes made up more than 99 % among the herbivores in the *P. oceanica* habitat while *S. salpa* contributed only a very small fraction to this guild.

The spread and establishment of NIS is a major concern from a conservation perspective (Galil 2007). Given the ecological, social and economical costs of species introductions, understanding the environmental driving forces has become a major goal for ecologists and managers. In marine systems the introduction of NIS can have major effects on the structure and function of ecosystems (Grosholz 2002). The relationship between indigenous species richness and non-indigenous species ability to colonize new habitats, i.e. the community “invasibility” (Stachowicz & Byrnes 2006) is of main interest (Francour et al. 2010). This concept implies that highly diverse systems are difficult to invade while species-poor communities, or stressed ecosystems are more prone to introductions, attributed to a lack of biotic resistance (Occhipinti-Ambrogi & Savini 2003). The underlying theory is that high diverse assemblage of plants or animals utilizes its resources more efficient than less diverse communities. Through this mechanism, increased competition intensity makes it more difficult for new species to establish (Francour et al. 2010).

The significant higher proportion and invasion success of NIS over sandy bottoms might be attributed to lower level of competition for benthic food resources within this habitat. Many species uses *P. oceanica* meadows as a habitat to reproduce or feed, explaining the high proportions of NIS during summer. On the other hand, feeding guild classification revealed that species with a wide food spectrum were not affected by high level of fish diversity. This indicates a species-specific dependence, because NIS with a wide food spectrum did not follow the general hypothesis of biotic resistance. Additionally, non-indigenous species were represented in different amounts within the various feeding guilds and their feeding preferences could be represented in more than one feeding guild. For that reason, the impact on the local invertebrate and fish resources is higher than that described for each guild simply because invertebrates and fish are represented in more than one feeding guild.

In conclusions, NIS made up a larger proportion of the fish assemblage biomass on sandy bottoms compared to *Posidonia* meadows, supporting the hypothesis that more diverse systems are less prone to invasions. The function of *Posidonia oceanica* meadows as a habitat for reproduction and feeding for many fish species explain the high proportions of NIS in this habitat. However, success of establishment will also depend on appropriate food resources in the recipient community as well as competitive abilities and level of competition in the food web within habitats.

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