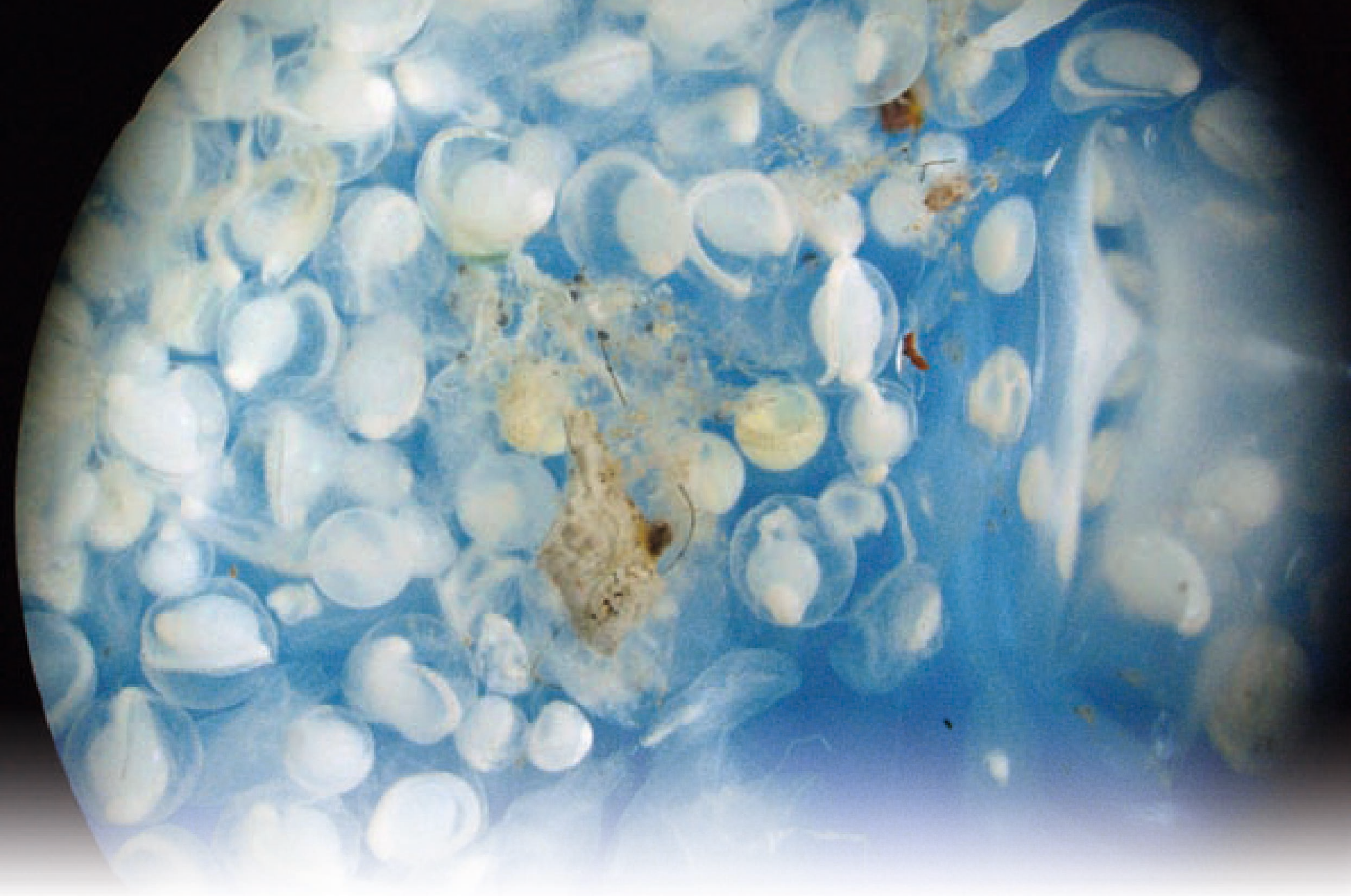


Bluefin Tuna Larval Survey

OCEANA

2008 Oceana-MarViva Mediterranean Project

MarViva

Bluefin Tuna Larval Survey

2008 Oceana-MarViva Mediterranean Project

Index

Executive Summary

The Oceana-MarViva project represented a new effort in the Mediterranean in defense of the North Atlantic bluefin tuna (*Thunnus thynnus*) (BFT), one of the most important commercial species living in the Mediterranean Sea[1]. According to the last stock assessments carried out by the Standing Committee on Research and Statistics (SCRS) of the International Commission for the Conservation of Atlantic Tunas (ICCAT), the bluefin tuna stock in the East Atlantic is still in critical condition. Furthermore, the Mediterranean Sea constitutes a hot spot because, while important spawning grounds are located here, this sea also constitutes the main fishing grounds for the industrial fleet of purse seiners that catches BFT during the critical spawning season.

Over the last decade (1996-2008), bluefin tuna fisheries have become highly profitable due to an increased demand from the Japanese sushi-sashimi market in the 1980s. This market buys up catches for raw consumption in Japan and other Asian countries[2]. As a result, fishing pressure on East Atlantic bluefin tuna stock has increased, causing severe stock depletion and a dramatic reduction in the Spawning Stock Biomass (SSB) according to the last stock assessment, raising serious concern over the survival of this resource[3;4]. Overexploited bluefin tuna stocks are being pushed toward collapse due to the fact that this highly valued fish is easily caught in the Mediterranean and also because of the lack or absence of control measures in the area in addition to the well-organized and coordinated fleet of pirate fishing vessels. Pressure has recently increased due to the rapid growth of commercial tuna fat-

The Marviva Med sailing in the south of Formentera, Balearic Islands, Spain. Marviva Med Mediterranean Expedition. June 2008. © OCEANA/ Keith Ellenbogen

tening and farming activities and the increase in fleet capacity, mainly represented by purse seiners, responsible for 60-80% of the bluefin tuna catch in the Mediterranean.

Knowledge concerning reproduction is extremely important for the management of the species, particularly its conservation. Accurate assessment of reproductive parameters such as age at maturity, fecundity, spawning frequency and spawning sites is essential for understanding population dynamics and managing tuna fisheries and associated species[5]. Although considerable progress has been made in understanding reproduction and quantifying the reproductive potential of local bluefin tuna populations in the Mediterranean Sea, many questions still remain unanswered.

The 2008 Oceana-MarViva bluefin tuna campaign in the Mediterranean Sea aimed to identify Essential Fish Habitats (EFH) to protect bluefin tuna spawning grounds and to promote the conservation of these sensitive habitats in the region. This could be achieved by creating a network of Marine Protected Areas (MPAs) free from fishing interference, particularly during the very critical spawning season, and ensuring sustainable tuna fishery activities. Larval accumulation and retention areas may have important implications in the design of these marine reserves and Essential Fish Habitats.

In order to identify the location and extent of Essential Fish Habitat in the Mediterranean, baseline information must be collected concerning the distribution and abundance of the critical life history stages of the overexploited bluefin tuna and associated species. Therefore, larval sampling surveys throughout the main spawning areas are required in order to assess the relative larval contribution of each area and to protect these essential fish habitats and spawning areas from fishing activities, in order to increase the Spawning Stock Biomass.

This report presents the preliminary results of the first-ever larval survey carried out by NGOs. The summer 2008 Oceana-MarViva campaign focused on providing further evidence of active spawning sites for bluefin tuna and other associated species. Larval samples were taken in some of the most relevant bluefin tuna spawning areas in the Mediterranean Sea, including southwest Malta, the southern Tyrrhenian Sea and the Aegean Sea, onboard the research vessel Marviva-Med, from 15 July to 11 August. Ichthyoplankton samples from 52 stations were taken using a bongo 90 net for surface plankton tows. The species found included the larvae of several tunas and tuna-like species such as bluefin tuna, albacore, frigate tuna and skipjack tuna, as well as swordfish larvae.

Scalloped ribbonfish larva (Zu cristatus) © OCEANA/ Patricia Lastra

Introduction:
the northern bluefin tuna

Bluefin tuna habitat

Bluefin tuna live mainly in the pelagic ecosystem throughout the North Atlantic and its adjacent seas, primarily the Mediterranean Sea. Geographically, it is widely distributed throughout the North Atlantic Ocean and can be found from Ecuador to Norway, and from the Black Sea to Mexico[6;7]. Unlike other tuna species, it is the only one that lives permanently in the temperate Atlantic waters. It was assumed that bluefin tuna preferentially occupy the surface and sub-surface waters of the coastal and open-sea areas, but archival tagging and ultrasonic telemetry have shown that bluefin tuna frequently dive to depths of 500 m to 1,000 m[8;9].

Like other tuna species and sharks, the Atlantic bluefin tuna is a pelagic predator that must continuously swim in order to ventilate, generating enough heat to maintain its vital organs (i.e. muscles, eyes, brain) and elevate its body temperature above that of the water. The complex structure of its circulatory system allows it to minimize heat loss. Thanks to this endothermic capacity, it can sustain cold (3°C) and warm water temperatures (up to 30° C) while maintaining a stable internal body temperature. This specialized circulation system is particularly well developed in bluefin tuna[10], making it a warm-blooded fish and fast swimmer (72.5 kilometers/hour), contributing to its extensive capacity for migration.

Migration

Electronic tagging studies have shown that the bluefin tuna is a highly migratory species with two types of migration occurring during its lifespan: a trophic migration to seek food and a reproductive migration to spawn[11;12]. The Atlantic bluefin tuna population is managed as two stocks separated by the 45°W meridian (SCRS, 1976): a smaller western Atlantic population that spawns in the Gulf of Mexico and a larger eastern stock distributed in the East Atlantic, the Mediterranean Sea and, in the past, the Black Sea, using the Mediterranean Sea as a spawning ground. Furthermore, bluefin tuna seem to display homing behavior and spawning site fidelity in both the Mediterranean Sea and the Gulf of Mexico, which constitute the two main spawning areas clearly identified[13;14]. This implies that adults and juveniles from both populations feed together, particularly off the east coast of North America and in the mid-Atlantic. When the spawning season begins, adults always return to the waters in which they were born. Thus, adults born in the Gulf of Mexico migrate to this area to spawn in spring (April-May), whereas adults born in the Mediterranean Sea return to the western and central areas, depending on climate and oceanographic conditions, when they reach maturity to spawn in late spring (June-July).

Bluefin tuna (*Thunnus thynnus*)

The *natal homing* mechanism has been proposed as a possible explanation for this behavior. This mechanism imprints specific environmental factors in early life stages and has been further developed within the meta-population concept by Fromentin & Powers (2005) as follows: *bluefin tuna would be considered as a collection of local populations, distributed in distinct and patchy suitable habitats and displaying their own dynamics but with a degree of demographic influence from other local populations through dispersal*[15]. It can be inferred from this statement that the effects of exploitation and the population's potential to recover from overfishing depend on ecological processes.

It may also be possible that the maintenance of such a life strategy is, in part, the result of an evolutionary process in relation to the spatial heterogeneity of environmental forces. In other words, Atlantic bluefin tuna would only maintain reproduction in confined Mediterranean regions in June (and secondarily in the Gulf of Mexico in May[6]), because the other areas where it is widely distributed (i.e. most of the North Atlantic and adjacent seas) would not favor this in respect to their variance in time and frequency domains[16]. Fromentin & Powers (2005) considered that the traditional unit stock cannot explain the complex bluefin tuna population structure and proposed the *contingent hypothesis*[17], purporting that divergent energy allocation during early life stages can cause divergent migration or habitat uses.

Adult fish that have been tagged with tracking sensors showed trans-Pacific migrations: some eastward, and some westward. Nevertheless, bluefin tuna population structure remains poorly understood and needs to be further investigated[4].

Maturity, reproduction and growth

Atlantic bluefin tuna is a slow-growing and long-lived species. Although progress has been made in explaining the reproductive biology of this species, more research needs to be carried out due to its complex behavior. SCRS reports (2008) have shown that bluefin tuna matures at age 4-5 in the East Atlantic and Mediterranean (length at maturity approximately 110-120 cm; 30-35 kg), whereas specimens in the West Atlantic population reach sexual maturity at approximately age 8 (length at maturity 200 cm; 150 kg)[6;4]. According to a recent study[18], 50% maturity has been established at age 4 for the eastern population, while maturity is believed to start as late as age 6 in the western stock.

Differences in age-at-maturity between the eastern and western populations in the North Atlantic might support the discrete population hypothesis (i.e. two stocks), however this still remains unknown given the apparently extensive and complex mixing movements identified across the east/west boundary in the Atlantic registered by archival tagging.

Hence, further investigation into bluefin tuna reproduction in both the West Atlantic and Mediterranean Sea is needed in order to clarify these and other discrepancies.

Based on tagging data, the longevity of the eastern bluefin tuna population has been estimated around 20 years[7], while longevity for the specimens from the western population has been estimated at 32 years based on radiocarbon traces (Neilson & Campana, in press).

All tuna species are oviparous and iteroparous[19]. A recent study has shown that bluefin tuna is a multiple batch spawner with asynchronous oocyte development (spawning frequency estimated at 1-2 days in the Mediterranean)[20]. Bluefin tuna relative batch fecundity would be similar to that of other *Thunnus* species. Based on archival tag data, Gunn & Block[21] stated that effective time spent in spawning grounds could be as short as two weeks with an average batch fecundity of 6.5 million eggs.

Like most fish, egg production appears to be age (or size)-dependent; thus a 5-year-old female can produce an average of five million eggs (of ~1 mm) per year while an older female of 15-20 years can carry up to 45 million eggs[22]. Spawning fertilization occurs directly in the water column and hatching occurs without parental care after an incubation period of 2 days. Another factor that must be taken into account to estimate the reproductive potential of bluefin tuna is whether adults spawn every year, as generally accepted, or every 2-3 years[23]. Experiments in captivity[24] raise questions about this assumption and suggest that spawning by an individual might occur only once every two or three years. Bluefin tuna adults can reach over 3 m in length, making them the largest of all tuna species and one of the largest teleosts. Adults weigh an average of 250 kg, but certain individuals can weigh up to 900 kg.

Bluefin tuna larvae

After spawning, bluefin tuna larvae (3-4 mm) are typically pelagic and can be found in surface waters throughout the Mediterranean Sea, with major concentrations occurring in areas where gyres and fronts are present, particularly in late summer. The larvae grow 1 mm per day up to a weight of 90 to 130 lbs. (40 to 80 kg), and separate into schools based on size. These schools often consist of multiple species, for example: albacore (*Thunnus alalunga*), yellowfin tuna (*Thunnus albacores*), bigeye tuna (*Thunnus obesus*), skipjack tuna (*Katsuwonus pelamis*), frigate tuna (*Auxis rochei*) and bonito (*Sarda sarda*). Bluefin tuna larvae are the only *Thunnus* species to have dorsal tail pigmentation (Alemany, pers. comm.), making them easier to distinguish from other species.

Bluefin tuna (*Thunnus thynnus*) larva.
© OCEANA/ Patricia Lastra

Bluefin tuna larvae are mostly present in surface waters with sea surface temperature (SST) ranging from 24-25 °C. Similarly, the SST regime is related to the nature of the water masses. Most bluefin tuna larvae are found in the mixing zones between the Atlantic and Mediterranean water masses. The intense circulation in this region produced by the meeting of water masses causes the formation of frontal structures and anti-cyclonic gyres that can play an important role in the early life stages of tuna larvae by concentrating food particles and assuring larval feeding requirements.

Feeding behavior

Bluefin tuna larvae appear to feed primarily on small zooplankton, mainly copepods and copepoda nauplii[25]. Juvenile and adult BFT are top predators and opportunistic feeders. Their diet can include several species of teleosts, invertebrates such as jellyfish and salps, and demersal and sessile species including octopus, crabs and sponges[26], although large differences have been noted within the study areas. In general, juveniles feed on crustaceans, fish and cephalopods, while adults primarily feed on fish such as herring (*Clupea arengus*), anchovy (*Engraulis encrasicolus*), sand lance (*Ammodytes* spp.), sardine (*Sardina pilchardus*), sprat (*Sprattus sprattus*), bluefish (*Pomatomus saltatrix*) and mackerel (*Scomber scombrus*)[27;28]. Typically, Atlantic bluefin tuna stomach contents are dominated by one or two prey-species, including Atlantic herring and sand lance in the West Atlantic[26] or anchovy in the East Atlantic and Mediterranean[26]. Small and large bluefin tuna display similar prey-size spectra. However, Chase[26] noted that the largest prey (those greater than 40 cm) were only consumed by giant bluefin tuna greater than 230 cm. Usually, it is postulated that adults do not feed during the spawning season, but this supposition remains poorly documented[29].

Bluefin tuna (*Thunnus thynnus*) in a tuna cage. Malta. Marviva Med Mediterranean Expedition. June 2008.

Particular spawning features required for bluefin tuna and associated species

Tuna and tuna-like species cannot be associated with the typical features of other fish habitats. Their habitat should be considered according to oceanographic features such as temperature range, salinity, fronts, oxygen levels, currents, shelf edges and a proper food chain.

All large pelagic species have floating eggs and free-swimming larvae that are distributed mainly by marine currents and sea fronts. Juveniles are mostly concentrated over the continental shelf in many Mediterranean areas although their presence and abundance is strictly linked to the availability of proper food in the same area and time.

• Temperature

Temperature influences fish life history at various stages (i.e. larval growth and mortality[30;31]), the timing of food availability for early ages[32], growth[33], maturity[34], timing of spawning[35] and egg viability[36]. In the case of tuna, temperature has been shown to play a key role in spawning activity for both tropical and temperate tunas (which spawn in warm water generally above 24°C)[7;19;37]. Temperature is also known to influence the production and distribution of plankton[38;39] and subsequently, the food resource for juvenile and adult BFT[6]. Thus, changes in temperature could also affect the spatial and temporal dynamics of Atlantic bluefin tuna.

• Ocean structures: anti-cyclonic gyres, fronts, currents... affecting the marine fish larvae

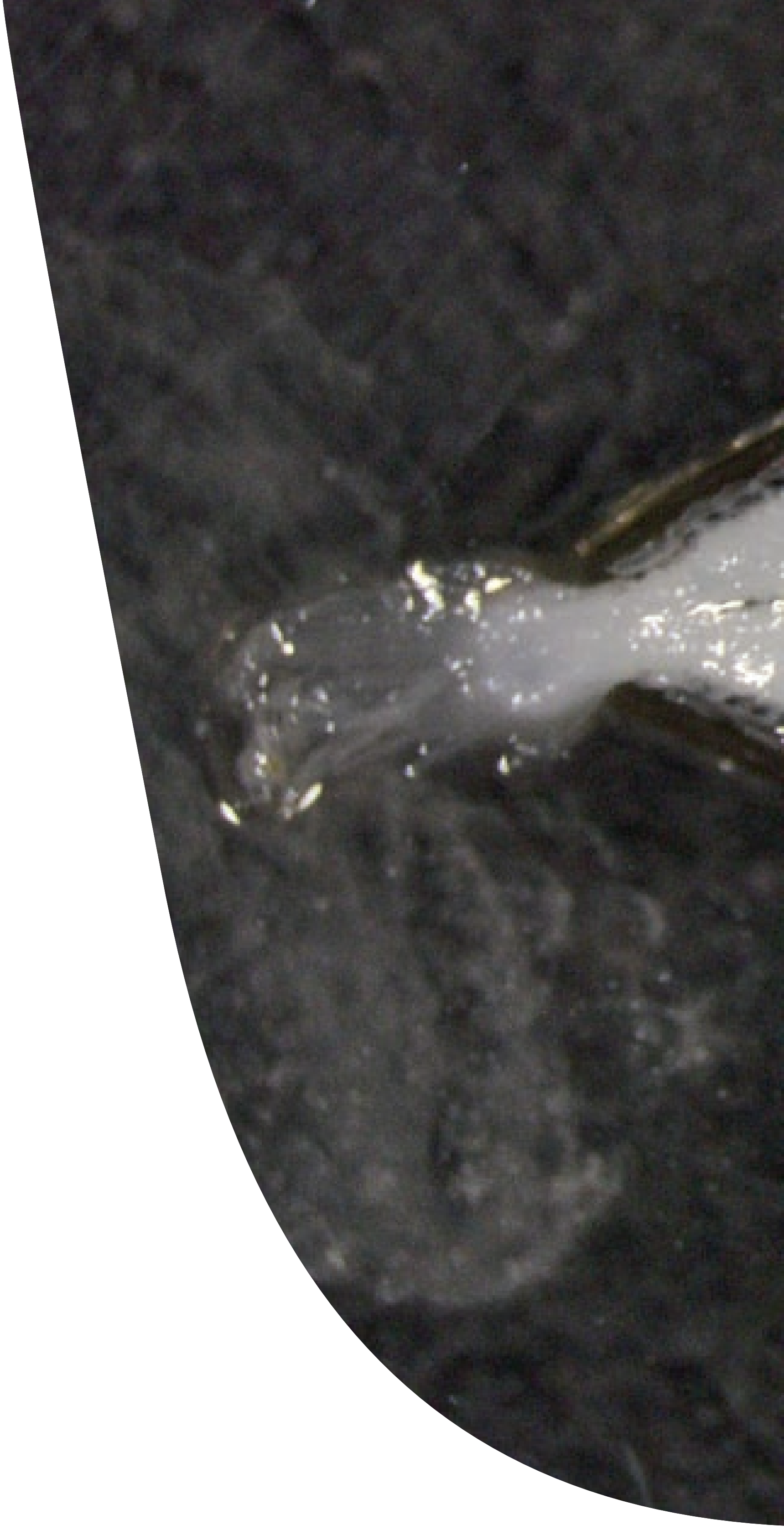
As noted above, in the North Atlantic Ocean, the bluefin tuna--probably one of the most threatened tuna species --is known to spawn in two areas: the Loop Current of the Gulf of Mexico and inside the Mediterranean Sea. The Mediterranean Sea is considered an oligotrophic sea, although there are coastal upwelling areas[40]. In contrast to popular beliefs, the spawning activity for bluefin tuna and associated species seems to be concentrated in areas of poor primary productivity such as the Balearic Islands and near island groups off Sicily, around Malta, etc. A common characteristic of these spawning areas appears to be the interaction of fairly strong currents with the obstructions represented by the islands to generate strong lateral frictional torques that can support the formation of mesoscale eddies and convergent fronts (García et al., in preparation).

It is known that most larvae are found in anti-cyclonic eddy structures where larval food organisms would tend to be concentrated in the convergent flow patterns. In addition, the size and swimming ability of large tuna might allow it to cross less suitable areas of the Mediterranean to insert larvae into particularly favorable environments, protecting them against potential predators or competitors with much weaker migration capacities and thus maximizing the probability of achieving a survival breakout.

• Salinity

Another factor to take into account is salinity, which is a clear indicator of the origin of water masses (Mediterranean waters contain more salt than Atlantic waters). When water masses with different densities mix, a density front is created. According to a study[41;42], it seems that denser Mediterranean waters are distributed in the north of the study area, while lighter Atlantic waters are located in the southern part, extending east of Ibiza to the southeast of Menorca, forming meanders, possibly due to bar clinic stability and the influence of bottom topography.

Nevertheless, bluefin tuna spawning strategy and recruitment success seems to be more complicated than what the usually postulated homing behavior approach implies, limited to small and permanent reproductive areas in the West Mediterranean and Gulf of Mexico. The degree of complexity of the bluefin tuna population structure on one hand and the potential impact of environmental changes on the spatial and temporal distribution of spawning areas on the other[43], are likely to shape and modify the reproductive strategy of bluefin tuna in both time and space.



Frigate tuna larva (*Auxis rochei*) © OCEANA/ Patricia Lastra

The Mediterranean Sea: historical spawning area for Atlantic bluefin tuna and associated species

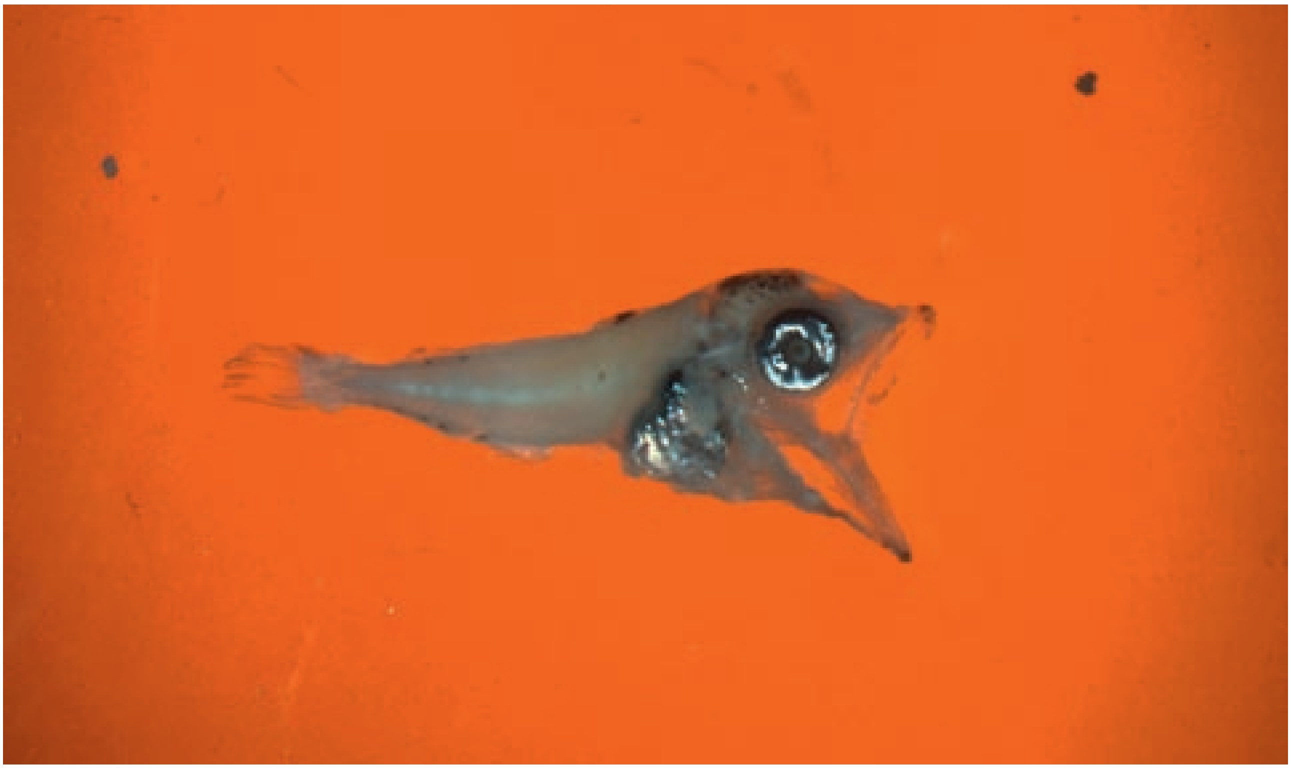
It is well known that the Mediterranean Sea constitutes an important spawning and fishing ground for Atlantic BFT. In fact, there is evidence of BFT fishing in the Mediterranean as far back as 7000 B.C.[44]. As a large pelagic fish species, bluefin tuna (*Thunnus thynnus* L.) is considered the most economically valuable species, especially in the Atlantic and Mediterranean Sea[11;45].

BFT spawns throughout the Mediterranean Sea during the months of May and August with spawning peaks, depending on climate and oceanographic conditions, during the months of June and July[1;20;46]. The western and central Mediterranean has been better documented in terms of spawning activity than the eastern Mediterranean sites where information about bluefin tuna reproductive biology is still scarce. There are three main spawning areas for Eastern Atlantic bluefin tuna: the Western and Central Mediterranean including waters around the Balearic Islands, waters around Malta Island and the South Tyrrhenian Sea. This has been supported by the presence of females with hydrated oocytes and post ovulary follicles or bluefin tuna larvae[20;46;47].

Since the 1960's, Italian trawlers reported diffused spawning activity in surface waters south of Malta, in the Strait of Sicily and in the southern Mediterranean, confirming biological data indicated by Libyan tuna traps. This large spawning area became more important than the traditional southern Tyrrhenian Sea in the middle of the 1990's, perhaps due to an intra-Mediterranean displacement of the tunas for unknown reasons. The Strait of Messina was typically a spawning area for bluefin tuna but spawning activity has recently declined compared to previous years[48].

In past centuries, spawning activities were reported in the Aegean Sea. More recently in the 1990's, bluefin tuna spawning activity was confirmed again in the eastern Mediterranean, in the Aegean Sea[49] and in the area around Cyprus[48;50]. As mentioned above, there is a lack of information regarding reproductive biology of bluefin tuna in the eastern Mediterranean Sea. Moreover, historical records point to seasonal migration from the Black Sea to the Bosphorus, but the fishery in the Black Sea ceased at the beginning of the 1960's, perhaps due to a displacement of bluefin tuna (and other species) caused by increasing pollution and the collapse of small pelagic fisheries, such as anchovy fisheries. This fact is also confirmed by some historical findings of eggs and larvae[51] and the presence of fish with ripe gonads[52].

Other spawning grounds, such as the Ibero-Morrocan embayment and the Black Sea, have also been mentioned in the past[6;53]. Picinetti & Picinetti-Manfrin[53] conducted egg and larvae surveys throughout the Mediterranean Sea between 1977 and 1988, concluding that bluefin tuna spawning locations were more widely distributed than usually accepted, extending into the eastern Mediterranean Sea. This has been confirmed by recent larvae sampling surveys conducted in this area which have shown the presence of bluefin tuna larvae in the Levantine Sea, expanding the widely accepted list of Mediterranean spawning sites (cited below) with the addition of two other spawning grounds in Levantine waters[50;54]. Moreover, the low quantity of eggs and larvae obtained during campaigns carried out in July-August[55;56] could be explained by early spawning occurring in the eastern Mediterranean[54]. These findings show that bluefin tuna spawning in the eastern Mediterranean can occur approximately one month earlier (May-June) than reported for other Mediterranean spawning sites in the western areas. The hypothesis made by Carlson and his colleagues (based on genetic analysis) states that bluefin tuna inhabiting the Levantine Mediterranean basin constitute a separate population that remains in this area all year round[57]. Moreover, it has been recorded that individuals tagged in the eastern Mediterranean Sea have been always recaptured within the Levantine basin[58].



Bluefin tuna larva from Capo Passero, Italy.

Nevertheless, important spatial changes in some of the most relevant spawning areas have been noticed in the last 10 years, particularly in the south Tyrrhenian and central Mediterranean. *The appearance and disappearance of important past fisheries further suggest that important changes in the spatial dynamics of bluefin tuna may also have resulted from interactions between biological factors, environmental variations and fishing activities*[4].

Understanding and quantifying the reproductive potential of local bluefin tuna populations in all of these geographic locations is of great importance in order to carry out research concerning population dynamics and management models for the species.

Other most relevant spawning areas

• The case of the Balearic Islands

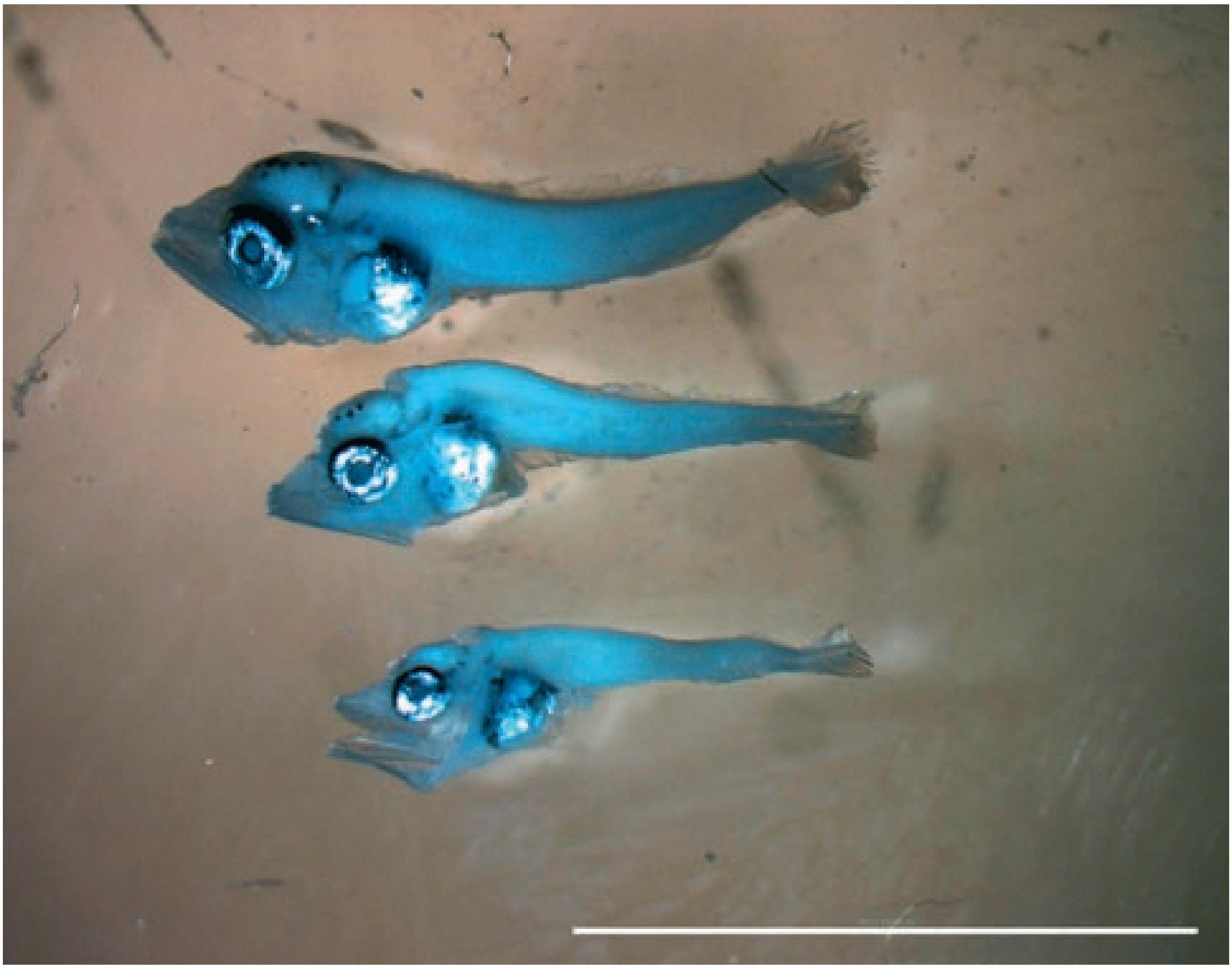
The most comprehensive study of bluefin tuna spawning conditions off the Balearic Islands has been carried out within the Instituto Español de Oceanografía (IEO) project, TUNIBAL (2001-2005), with a main objective of identifying the environmental factors that influence the reproductive strategies of adults and larval distribution in the waters surrounding the Balearic archipelago. The project was motivated by the fact that the bluefin tuna stock has suffered a considerable decline in the past two decades, induced by its high value in the Japanese market, leading to increased fishing effort in the Mediterranean targeting adult reproductive tuna. Due to the current state of bluefin tuna resources, ICCAT endorsed exploratory research sampling of larvae and spawning-size bluefin tuna in the Mediterranean[59].

Recent results of the yearly TUNIBAL larval surveys indicate that bluefin tuna spawning time strongly depends on certain environmental and hydrographic conditions[60]. From the hydrographic point of view, the Balearic region is considered a transition zone between two water masses, the Mediterranean Sea and the in-flowing Atlantic waters, which show differential physical, chemical and biological properties[61]. Therefore, this area is characterized by intense ageostrophic circulation of water masses[62;63;64] that generates important mesoscale features, such as fronts and gyres, which, as mentioned above, seem to play an important role in the spawning of bluefin tuna and other tuna and tuna-like species[41]. The waters surrounding the Balearic archipelago represent an ideal setting for the spawning of different tuna species. Recent studies indicate the presence of larvae from several tuna species including bluefin tuna (*Thunnus* *thynnus*), frigate tuna (*Auxis rochei*) and albacore (*Thunnus alalunga*), proving the suitability of environmental conditions for spawning in the Balearic Sea. Other related species were also identified including bonito (*Sarda sarda*), skipjack tuna (*Katsuwonus pelamis*) and Atlantic little tunny (*Euthynnus alletteratus*), further indicating the suitability of spawning habitats for tuna at different seasonal stages[60]. Moreover, in a recent survey conducted off the eastern coast of Mallorca, a large quantity of albacore larvae was caught, while bluefin tuna larvae appeared at lower densities because bluefin tuna spawning peaks earlier[65]. It is also worth highlighting that a considerable number of billfish larvae were captured, taking into account that only a few eggs and larvae of this species have been previously cited[66].

According to the recent report presented by WWF/Adena (2008) regarding the *Relevance of the Balearic Sea for the spawning of the bluefin tuna in the Mediterranean Sea*, from all of the larval studies carried out around the Balearic archipelago, it could be inferred that although Atlantic bluefin tuna probably spawns throughout the Mediterranean, with the exception of the north-western Mediterranean and the Adriatic Sea and also probably the Alboran Sea as Piccinetti & Piccinetti-Manfrin[67] suggested, waters around the Balearic Islands and Sicily are the most important spawning grounds for Atlantic bluefin and other tunas species, as larval densities in this area have always been among the highest recorded[68;69;70;71;72].

According to past surveys of bluefin tuna spawning habitats off the Balearic archipelago, there seems to be a positive co-relation between low salinity and a specific temperature range (23-25°C)[42;60], further demonstrating how spawning is affected by environmental conditions.

In fact, results of bluefin tuna larval research off the Balearic Islands indicate clear relationships between the temperature regime and hydrographic processes occurring in the area, due to the meeting of water masses of Atlantic and Mediterranean origin[60]. In contrast to tropical tuna, which spawn and feed throughout the tropical and subtropical oceans, bluefin tuna appear to reproduce within a small spatial and temporal window[7]. This could increase temporal variability and therefore lead to higher risks of recruitment failure. This hypothesis, however, presumes the existence of isolated populations and would not apply in the case of meta-populations. The identification of the major abiotic and biotic forces controlling bluefin tuna recruitment remains elusive, primarily due to limited direct observation. In general, bluefin tuna spawning takes place in warm waters above 24°C. The variation in timing could be due to differences in environmental cues or genetic variation. In the Mediterranean, spawning occurs at seawater temperatures of 21° to 25°C.



Albacore larvae (*Thunnus alalunga*)
© OCEANA/ Patricia Lastra

• The case of the Sicilian Channel

From environmental and oceanographic viewpoints, the Sicilian Channel is similar to the Balearic scenario in various ways. The principal hydrodynamic feature is the existence of the along-Channel, meandering current of Atlantic origin, called the Atlantic Ionian Stream (AIS)[73]. The AIS acts as an along shore transport mechanism of the early life stages of anchovy and other ichthyoplanktonic species towards the southeastern end of the island, off Cape Passero[74]. In this region, the AIS encircles a cyclonic vortex off Cape Passero, describing an anti-cyclonic meander in between and its meeting with the Ionian waters causes frontal systems in the southeastern region of the island[54]. The transport of fish eggs and larvae by the AIS towards the frontal structure may guarantee the feeding requirements of tuna larvae, since these form part of their diet at early life history stages[75,76].

An Italian larval survey[71;72] indicated that bluefin tuna larvae are mainly concentrated around Sicily (the Sicilian channel, southern Tyrrhenian and northern Ionian Seas), as well as south of the Balearic Islands.

• The case of the Tyrrhenian Sea

The Tyrrhenian Sea is considered a particular case because it is semi-enclosed between the islands of Corsica and Sardinia and the mainland (Italy), separated from the rest of the western basin by a channel of moderate depth.

Gyre-scale circulation

As with the other two cases shown above, in the northern and central Tyrrhenian Sea, the circulation is organized in a series of cyclonic and anti-cyclonic gyres determined by the wind effect[77]. According to a study by Colloca *et al.*[78], three main gyres were identified, all of them characterized by cold water inside, two cyclonic and one anti-cyclonic gyre. These gyres undergo significant seasonal changes, particularly the central anti-cyclonic gyre that spreads over most of the basin in spring and summer and nearly disappears in autumn and winter. Gyre activity is enhanced in autumn. During this season, a new gyre appears in the southeastern portion of the basin.

During the rest of the year, this region is characterized by very low dynamic activity. A cyclonic gyre is present all year round off the Bonifacio Strait with a frontal system separating the cold water from the much warmer water occurring in the rest of the basin. The current fluxes (except in winter) are mostly concentrated at the boundaries of the existing gyres. In winter, the current at the frontal region increases and there is a westward shift and intensification of associated upwelling. This is the only season in which a direct connection exists between the southern and northern opening of the Tyrrhenian Basin. During the other seasons, water transport is confined to the frontal regions of different gyres[71]. Due to the occurrence of the gyres, the northern part of the basin plays a crucial role in the general water mass budget in the Tyrrhenian Sea. The upwelling region shifts significantly westward during winter, involving the water layer up to 200 m (265 in summer). Moreover, the northern part of the basin is a privileged place for its concentration of the basin's chemical resources[79;80].

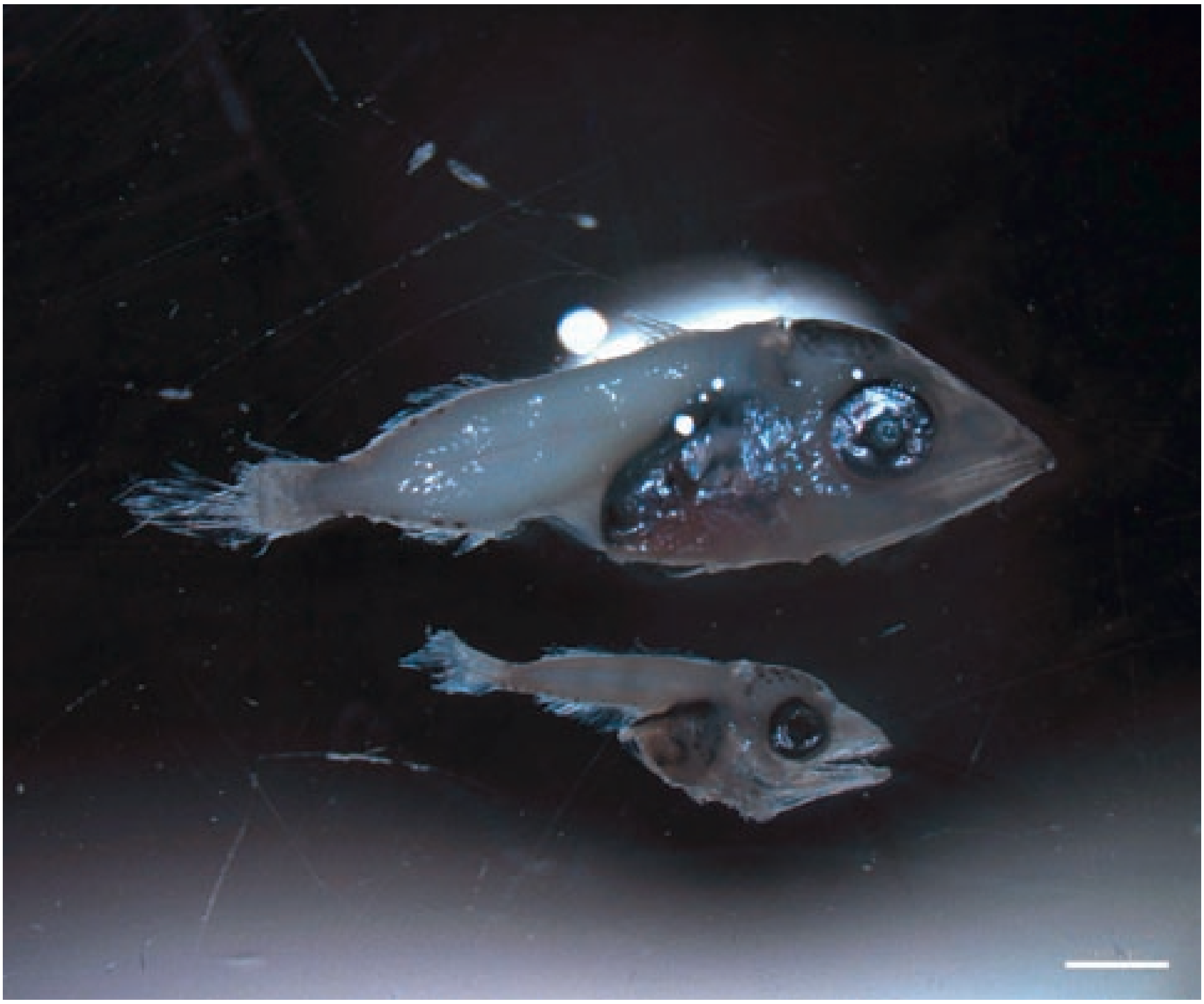
Larval surveys conducted by the IEO throughout the western Mediterranean[68;69] found the highest bluefin tuna larvae densities in the Tyrrhenian Sea. In 1994, under the auspices of ICCAT, tuna larvae surveys covering the entire Mediterranean Sea were conducted by the Japanese R/V

Shoyu Maru[47;70]. Bluefin tuna larvae were expected to be caught in larger quantities in the Tyrrhenian Sea, however maximum bluefin tuna larvae abundances were detected southeast of Sicily and in the Ionian Sea.

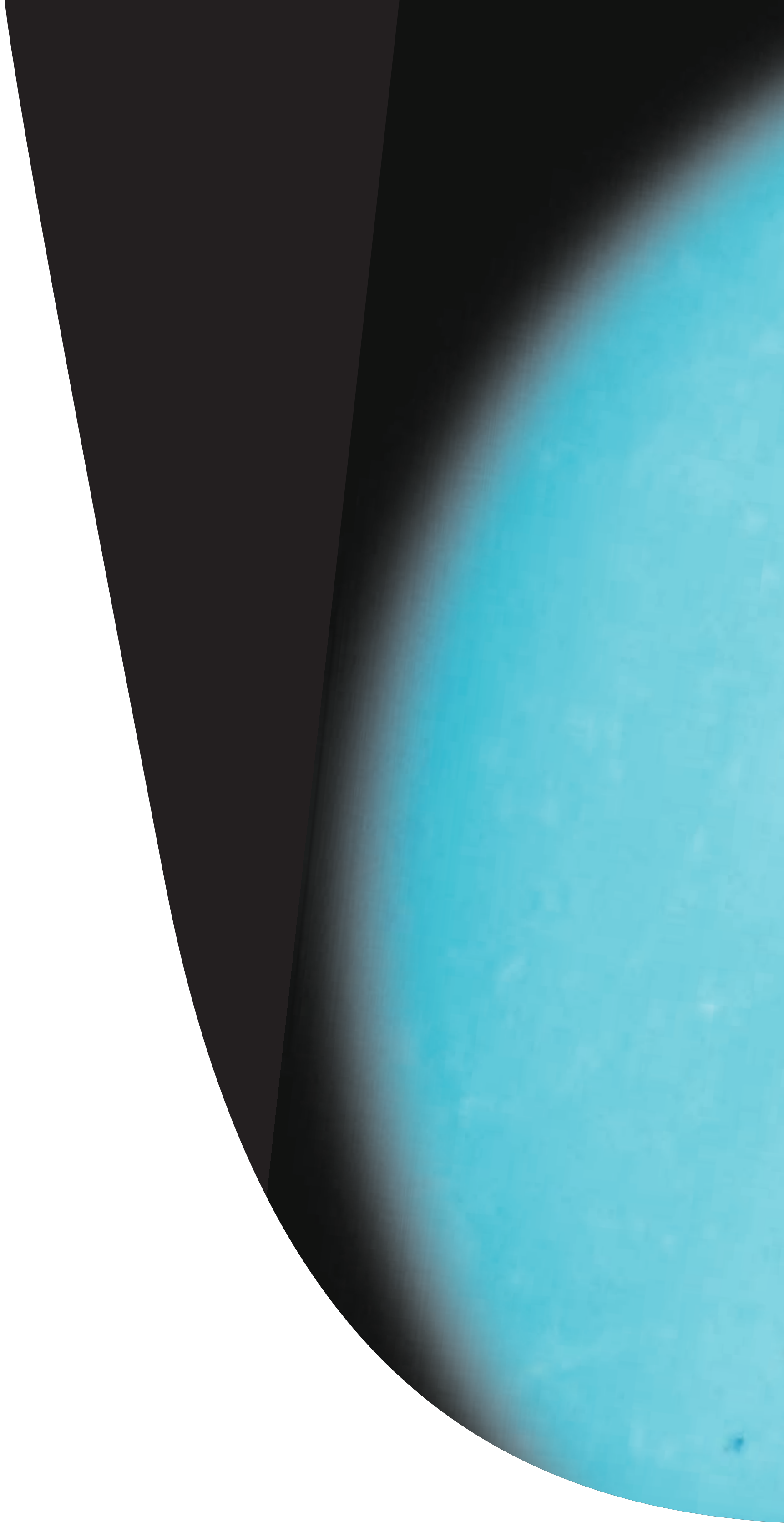
• The eastern Mediterranean Sea

Extensive research on the reproductive biology of bluefin tuna has been carried out in the Black Sea, Aegean Sea and in the Sea of Marmara. In fact, the presence of spawning areas in the eastern Mediterranean Sea has been supposed[81] but never demonstrated. Several larval studies have been conducted and a few larvae were found in some[47], while other studies were unsuccessful[67;70] Karakulak et al. carried out a larval study in the Levantine Sea showing the first evidence of a potential spawning area in the northern Levantine basin, assuring that spawning could occur about one month earlier than that reported for other Mediterranean spawning areas. A more recent study[54] had similar results supporting the area as a potential spawning ground.

The General Fisheries Commission for the Mediterranean (GFCM) and its Scientific Advisory Committee (SAC) advocate the need to implement an ecosystem-based approach to fishery resources, and to this end, it is fundamental to acquire information concerning spawning and nursery habitats. Moreover, efforts should be applied to identify and elucidate the key processes involved in open ocean ecosystems in which tuna spawning leads to an assessment of the potential top-down cascading effects that fishing pressure causes on apex predators and, inversely, the bottom-up effects on forage species. The achievement of this goal can, ultimately, lead to the understanding of ecosystem functioning, and thereby provide information for the development of ecosystem-based management strategies.



Frigate tuna larvae (*Auxis rochei*).



Seahorse (Hyppocampus sp.). © OCEANA/ Eduardo de Ana

The Oceana-MarViva campaign in the Mediterranean 2008

Executive summary

The Oceana team onboard the R/V *Marviva Med* was the first NGO team to carry out surveys on bluefin tuna ichthyoplankton. A bongo 90 net was used to collect larvae from tuna and other species in order to determine relative importance of different spawning areas in the central Mediterranean Sea. This report presents the preliminary results obtained from these larval surveys in terms of species present, relative abundance and the analysis of the influence of oceanographic conditions on larvae presence. The Oceana-Marviva campaign reports aim to provide essential data regarding bluefin tuna spawning activity. The reports also demonstrate the need to take action to protect these *Essential Fish Habitats* (EFH) and contributes to increasing the scientific knowledge available regarding bluefin tuna homing behavior and spawning site fidelity in the Mediterranean Sea (Note: further detail of *Essential Fish Habitats* proposed by Oceana can be found in the report "The use of EFH to guarantee long-term sustainability of Bluefin tuna fisheries and conservation in the Mediterranean Sea").

The Marviva Med expedition using the bongo net.
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In addition, during the five-month expedition of the 2008 Oceana-MarViva campaign in the Mediterranean, information was collected and the presence and activity of different (legal and illegal) fishing fleets was documented as they caught bluefin tuna in the Mediterranean, not complying with national legislation or international conventions, or carrying out destructive fishing activities which must be halted or strongly regulated. Thus, the R/V *Marviva Med* has been patrolling and documenting tuna fishing areas in the following locations: the Balearic Sea (mainly south of Formentera island), the Sicilian channel (mainly in the area around Pantelleria Island), the Malta channel (around Linosa and Lampedusa islands and south-west of Malta), the external limit to Libyan jurisdictional waters, international waters surrounding Algeria and Tunisia, and the southern Tyrrhenian Sea. Moreover, violations of the ICCAT and EU tuna recovery plan have been documented. All of the fishing activities documented during the 2008 Oceana-MarViva campaign have been extensively detailed and explained in a separate report. The present report only covers the part of the campaign concerning bluefin tuna larval sampling.

Bluefin tuna larval sampling

• Objectives

The overall objective of the Oceana-MarViva project in the Mediterranean is to end or significantly reduce illegal, indiscriminate and non-sustainable fishery practices in the Mediterranean Sea, and to promote the conservation of sensitive habitats in the region through the creation of *Essential Fish Habitats* in key spawning areas for bluefin tuna and other large pelagic species, free from destructive fishing interference while ensuring sustainable tuna fishery activity, particularly during the critical spawning season for this species.

In order to fill the gaps that currently exist regarding the relative importance of different spawning areas in the central Mediterranean and the distribution of bluefin tuna and its lifecycle, the Oceana-MarViva project uses the field data collection approach through larval surveys conducted in some of the most relevant spawning areas in the central Mediterranean Sea to assess each area's relative larval contribution and support the need to protect these spawning areas.

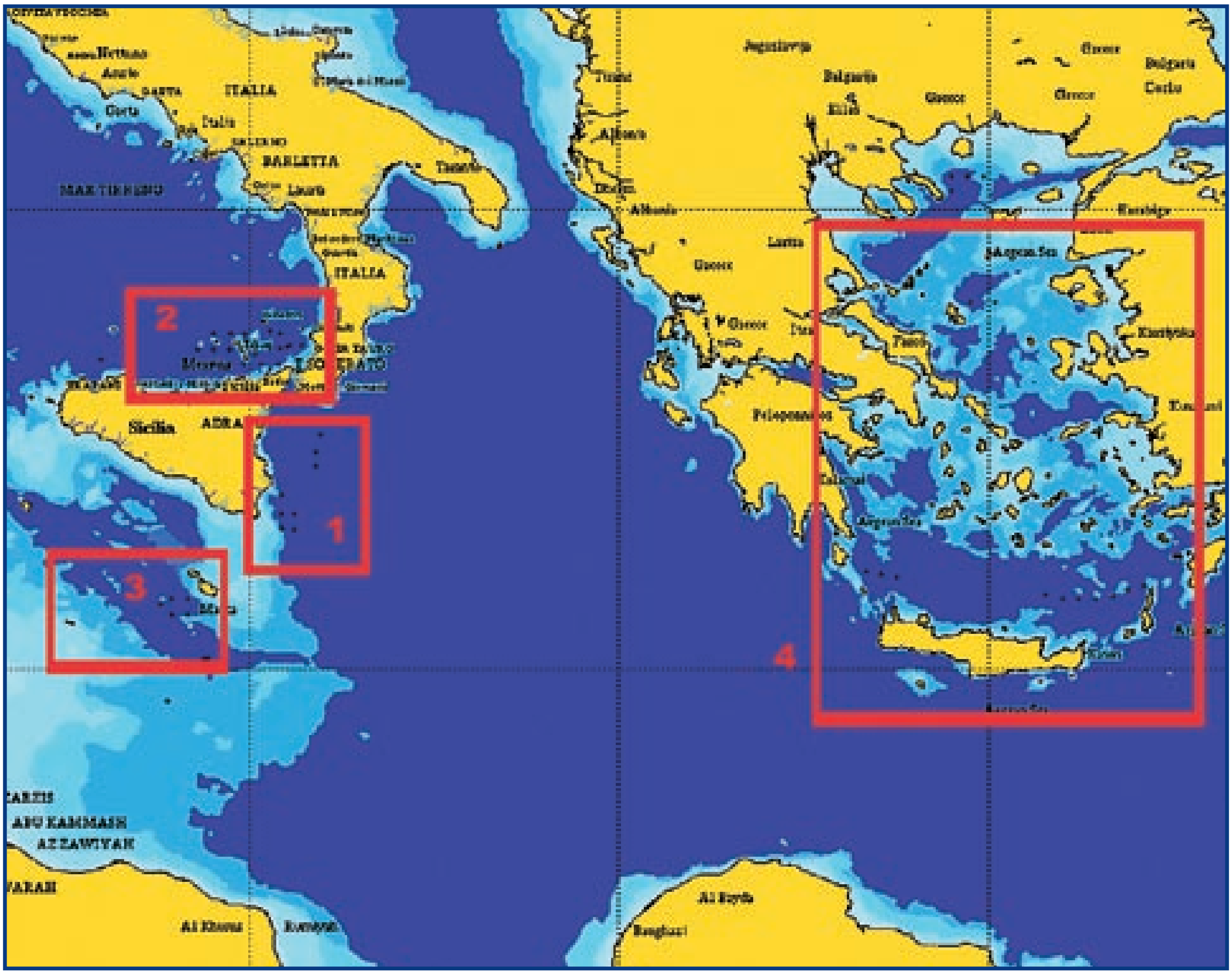
Results contained in this report correspond to an only preliminary analysis of the samples taken during the campaign.

• Material & methods

Study area

A larval survey was conducted from 15 July to 11 August 2008 on board the research vessel Marviva Med. A total of 53 stations were sampled in three of the most relevant spawning areas in the Mediterranean Sea: the southern Tyrrhenian Sea (around the Aeolian Islands), southwest of Malta Islands and the Aegean Sea (see Figure 1).

Figure 1: Map of the study area. The red squares represent the areas where the 53 surface plankton samples were taken during the different stages of the survey.



Larval sampling

One type of plankton gear was used to sample tuna larvae and associated species: a bongo 90 net with a quadrangular mouth opening equipped with 500 µm mesh for horizontal surface plankton tows, as shown in the photographs below (Fig. 2, 3).

Figure 2, 3: On the left, the bongo 90 net used for sampling; on the right, the 500 µm mesh-size net. © OCEANA/ Keith Ellenbogen

The plankton gear was equipped with a General Oceanics flowmeter to estimate the volume filtered (Figure 4).

Figure 4: General Oceanics flowmeters. © OCEANA/ Keith Ellenbogen

Moreover, sea surface temperatures (SST) and depth values were registered at each station using a *Minilog*. The net was towed at 2-2.5 knots at the surface for a constant duration of 10 minutes.

We pre-defined a 10x10-nautical-mile reference grid of stations, although the planned trajectory was often interrupted in order to take opportunistic samples.

Series from ichthyoplankton sampling on board the Marviva Med vessel with a bongo 90 net.
2008 Mediterranean expedition.

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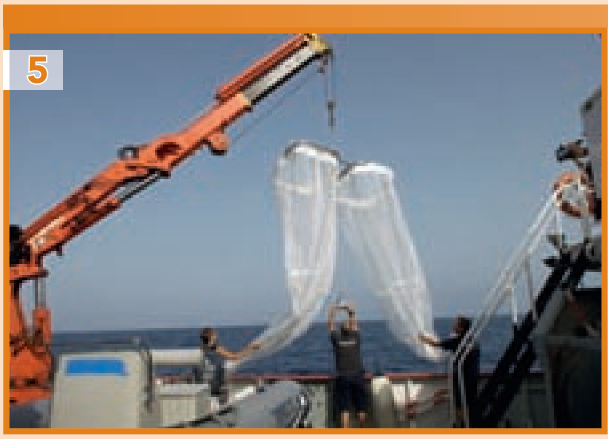

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Immediately after retrieval of the net, the cod ends were placed in buckets and the sample were stored in plastic containers with ethanol for subsequent examination under a microscope.

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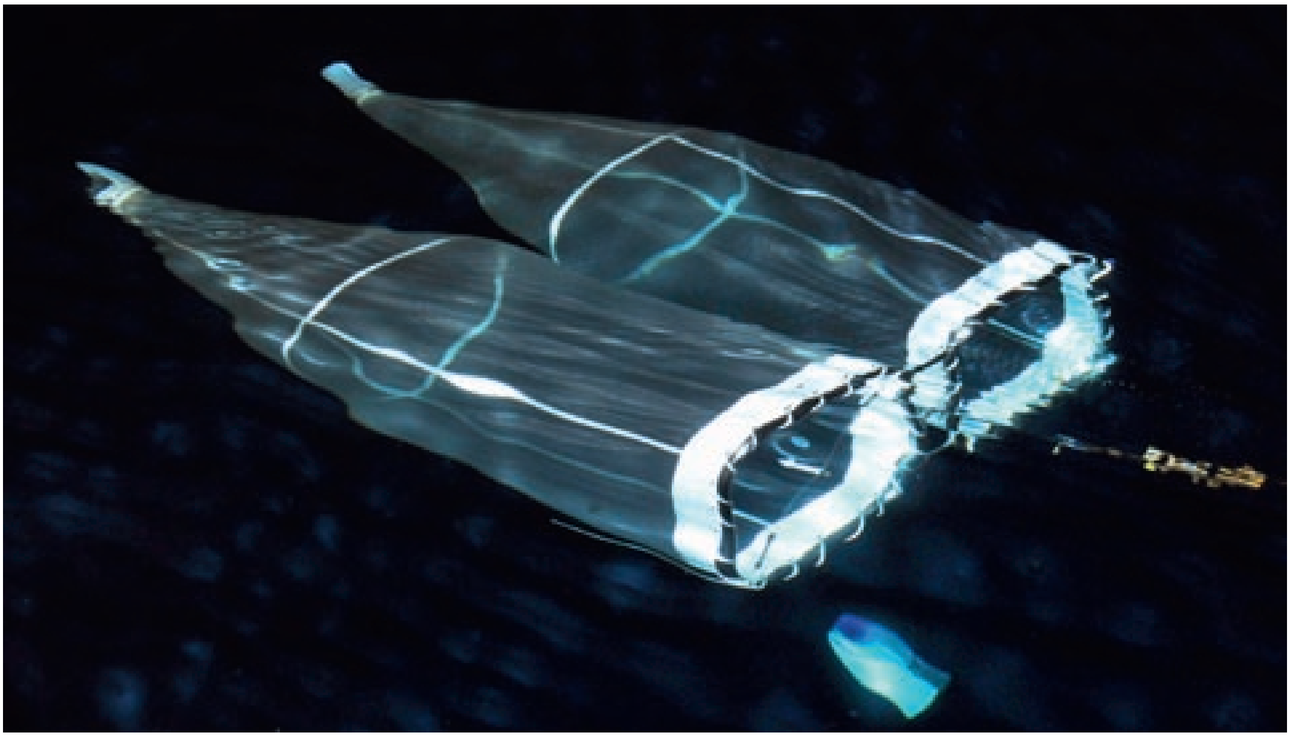
We also conducted larval sampling at night to observe any differences in terms of abundance and distribution of the bluefin tuna larvae pattern.



Icthyoplankton net taking samples at night.
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Bongo net being raised after night-time sampling
© OCEANA/ Carlos Minguell

At the end of the campaign, experts from the IEO in Palma de Mallorca analyzed the samples and provided Oceana with information regarding species present and relative abundance, and an analysis of the influence of oceanographic conditions on larva presence.

Other data recorded included sea state, intensity and direction of the wind, and the presence of purse seiners in the areas and any other fishing activity.

Fishing activity

Oceana also documented the presence and activity of different (legal and illegal) EU and non-EU fishing vessels mainly represented by purse-seiners and driftnetters catching bluefin tuna in the Mediterranean, in particular in the aggregation areas of the Balearic Islands and the south Tyrrhenian Sea. The activities of Greek, Turkish and Croatian purse seine fleets were also documented during the campaign. As mentioned above, further details concerning this part of the campaign are included in another report.

• Results

- Distribution of tuna larvae and associated species in each study area

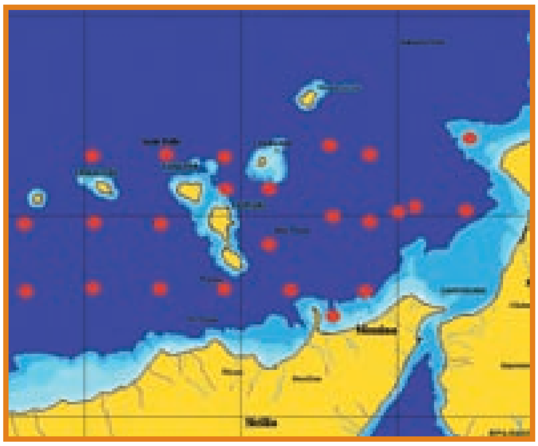
Samples from the stations with the highest concentrations of larvae from the four areas studied were examined under a microscope, and the results showed the presence of four tuna species larvae including Atlantic bluefin tuna (*Thunnus thynnus*), albacore (*Thunnus alalunga*), frigate tuna (*Auxis rochei*) and skipjack tuna (*Katsuwonus pelamis*). Remarkably, some stations showed the presence of swordfish (*Xiphias gladius*) larvae, confirming these areas are used as spawning grounds by a variety of large, commercial pelagic fish species of great importance in the Mediterranean Sea. Moreover, other small pelagic species were also identified such as European anchovy (*Engraulis encrasicolus*), round sardinella (*Sardinella aurita)* and Atlantic horse mackerel (*Trachurus trachurus)*. Special mention should be made of the presence of larvae of other interesting species from this pelagic survey including demersal species such as striped red mullet (*Mullus surmuletus*) and others, damselfish (*Chromis chromis*); scalloped ribbonfish (*Zu cristatus)*, parrot seaperch (*Callanthias ruber*), cardinal fish (*Apogon imberbis)* and paralarvae of cephalopods and palinurids.

Tables 1-4 below show all species identified (commercial and non-commercial) after microscope examination in each studied area (the two stations are combined).

Table 1: Capo Passero

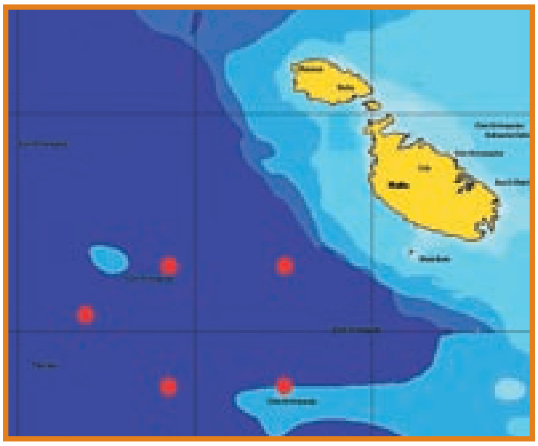
Species	N
Anthias anthias	3
Apogon imberbis	1
Auxis rochei	10
Ceratoscopelus maderensis	72
Chromis chromis	148
Coris julis	1
Cyclothone pygmaea	30
Cyclothones braueri	1
Engraulis encrasicholus	1
Hygophum sp.	9
Lampanyctus pusillus	72
Lestidiops jayakari	3
Lampris guttatus	1
Lestidiops jayakari	2
Luvarus imperialis	1
Mullus sp.	2
Myctophidae	1
Sardinella aurita	27
Sparidae	2
Serranus hepatica	1
Thunnus alalunga	33
Thunnus thynnus	72
Trachurus sp.	1
Zu cristatus	7
Xyrichthys novacula	7

Table 2: Aeolian Islands



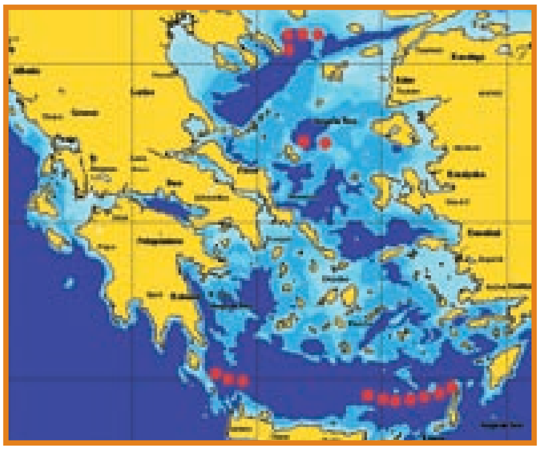
Species	N
Anthias anthias	1
Auxis rochei	59
Batophilus nigerrimus	1
Chromis chromis	4
Cyclothone pygmaea	57
Engraulis encrasicholus	1
Exocoetus heterurus	2
Lampanyctus pusillus	12
Lestidiops jayakari	1
Mullus barbatus	1
Mugilidae	1
Myctophum punctatum	4
Naucrates ductor	1
Sardinella aurita	36
Thunnus alalunga	22
Thunnus thynnus	10
Trachinus draco	2
Trachurus mediterraneus	2

Table 3: Malta



Species	N
Arnoglossus sp.	1
Auxis rochei	198
Caranx sp.	6
Ceratoscopelus maderensis	6
Chlorophthalmus agassizi	1
Dactilopterus volitans	1
Engraulis encrasicholus	2
Exocoetus heterurus	1
Katsuwonus pelamis	2
Hygophum sp.	1
Mullus barbatus	4
Thunnus alalunga	176
Uranoscopus scaber	1
Xiphias gladius	1
Xyrichthys novacula	1

Table 4: Aegean Sea



Species	N
Anthias anthias	1
Arnoglossus sp.	1
Auxis rochei	1
Bathylagidae	1
Buglossidium luteum	1
Caranx sp.	1
Ceratoscopelus maderensis	467
Chlorophthalmus agassizi	6
Chromis chromis	32
Cyclothone pygmaea	192
Engraulis encrasicholus	8
Epinephelus sp.	1
Holocentridae	5
Hygophum sp.	214
Lampanyctus pusillus	8
Lepidorhombus sp.	8
Lestidiops jayakari	1
Mugilidae	1
Sardinella aurita	1
Sparidae	14
Thunnus alalunga	23
Xiphias gladius	1

The results of the vertical distribution survey indicated that larvae concentrate in the surface and near-surface layers with higher concentrations at night.

- Tuna and tuna-like species found during the sampling

Atlantic Bluefin tuna (*Thunnus thynnus* L.)

- The Atlantic bluefin tuna is considered the largest scombriform (Order Perciformes; Subfamily Scombridae).
- Oviparous and iteroparous[82]. Spawning season in the Mediterranean Sea takes place from May to August with a peak in July[83].
- Larvae (3-4 mm) are typically pelagic and found in most of the Mediterranean Sea surface waters, with major concentrations occurring in areas where gyres and fronts are present.

Albacore (*Thunnus alalunga*)

- Pelagic species (Order Perciformes; Family Scombridae).
- Spawning usually takes place in late summer (from the end of June to the begining of September), with small yearly variation, due the influence of climate and oceanographic factors[84].

Frigate tuna (*Auxis rochei*)

- Pelagic species (order Perciformes; Family Scombridae) generally distributed throughout the Atlantic, Indian and Pacific Oceans, including the Mediterranean Sea[85].
- Eggs and larvae are pelagic.
- As all tuna species, they are oviparous and iteroparous[86]. Spawning activity peaks at the end of spring and throughout the summer[87].

Skipjack tuna (*Katsuwonus pelamis*)

- This species is an epipelagic Scombriform fish (Order Perciformes), living in the water column from the surface (0 m) to 300 m depth and occurring in waters ranging in temperature from 14.7°C to 30°C with a circumtropical distribution. Moreover, it is present along the oceanic coast of Europe and throughout the North Sea, and generally has been considered absent from the Mediterranean and Black Seas[88].
- The species spawns opportunistically all year long[89] and throughout the ocean in warm equatorial waters. Further away from the equator, the spawning season is limited to the warmer months[90]. Larvae and eggs are pelagic[86]. Despite being a commercial species targeted by several fisheries in the Mediterranean Sea[91], neither spawning activity nor spawning grounds have been identified in the Mediterranean Sea for this species.

Swordfish (*Xiphias gladius*)

- Pelagic species (Order Perciformes; Family Xiphiidae), with a cosmopolitan distribution in the Atlantic, Indian and Pacific Oceans: tropical and temperate and sometimes cold waters, including the Mediterranean Sea, the Sea of Marmara, the Black Sea, and the Sea of Azov.
- The species spawns in different areas of the Atlantic and the Mediterranean Sea[92]. Spawning takes place from the second half of May to July, with a peak in June to July, although in some years spawning was reported as late as April or up to the first week of September due to climate influence.

- Other species identified

Swallowtail seaperch (*Anthias anthias*)

- Reef-associated species (Order Perciformes; Family Serranidae). Generally living between 20 and 400 m depth. Distribution eastern Atlantic: Mediterranean and Portugal to Angola, including the Azores. Range reported to extend south to northern Namibia[93].
- Protogynous hermaphrodite species. Spawns between March and August[94] although others from June to September[95]. Oviparous with pelagic eggs.

Cardinal fish (*Apogon imberbis*)

- Reef-associated, non migratory species (Order Perciformes; Family Apogonidae). Living depth range 10-200 m.
- Spawning from June to September. Oral brooding by males[95]. Brood size of 4,000-6,000 eggs, and parental care lasts 5-7 days[96].

Scaldfish (*Arnoglossus* sp.)

- Demersal species (Order Pleuronectiformes; Family Bothidae), living between 60-75 m and 350 m depth in muddy bottoms.
- All species of the Genus *Arnoglosussus* found in the Mediterranean Sea spawn between April and August[97]. Despite being a demersal species, larvae have a pelagic stage[98].

Scaleless dragonfish (*Bathophilus nigerrimus*)

- Mesopelagic species (Order Stomiiformes; Family Stomiidae) generally living below 400 m depth.
- Since almost a century[99] ago, it has been known that larvae of this species have a pelagic stage. They can be found at depths less than 5 m in different larval samplings taken in the Atlantic[100].

Solenette (*Buglossidium luteum*)

- Demersal species (Order Pleuronectiformes; Family Soleidae) on sandy bottoms of the continental shelf and slope and generally found from the surface down to 300 m depth.
- It can reproduce from February up to August, being particularly active between May and June[101]. Larvae are often within the ichthyoplankton either in the Mediterranean[102] or the Atlantic[103].

Parrot sea perch (*Callanthias ruber*)

- Demersal species (Order Perciformes; Family Callanthiidae) found on rocks, muddy bottoms and submarine caves between 50 and 300 m depth.

- This species is oviparous, probably protogynous[104]. It is thought to spawn between December and January[105]. Its larvae have been found in larval samplings conducted during the summer in the Mediterranean Sea, particularly in the Aegean Sea[106], and between February and March in the Atlantic Sea in the Azores Islands[107].

Runner jack (*Caranx* sp.)

- Pelagic reef-associated species (order Perciformes; Family Carangidae), living from the surface down to 300 m depth.
- Oviparous with a spawning peak during the summer (between July and August[108]), although it can be earlier depending on the species.
- Eggs are pelagic.

Lanternfish (*Ceratoscopelus maderensis*)

- Bathypelagic species (Order Myctophiformes; Family Myctophidae). Generally living in deep waters at 2,000 m depth although they can appear at the surface at night[109]. Larvae and juveniles nyctoepipelagic at the surface.
- This species was often identified in several larval samplings in the Mediterranean Sea and the Atlantic[110].

Lanternfish larva (*Ceratoscopelus maderensis*).

Shortnose greeneye (*Chlorophthalmus agassizi*)

- Bathydemersal species (Order Aulopiformes; Family Chlorophthalmidae) generally living below 150 m depth down to 1,000-1,200 m.
- A hermaphroditic species[111]. Young are pelagic, living near the surface and larvae are planktonic[112].

Damselfish (*Chromis chromis*)

- Reef-associated species (Order Perciformes; Family Pomacentridae) living normally between 30-40 m depth. It is found near rocky reefs or above seagrass meadows.
- Spawns in the summer between late June and September[113], putting eggs inside caves where males take care of the offspring.

Rainbow wrasse (*Coris julis*)

- Reef-associated species (Order Perciformes; Family Labridae), living from the surface down to 100-150 m depth, mainly in rocky bottoms or above seagrass beds and kelp forests.
- Sexually mature at 1 year of age. Protogynous hermaphrodite species with reproduction from spring to summer[98]. Pelagic eggs[114].

Garrick (*Cyclothone braueri*)

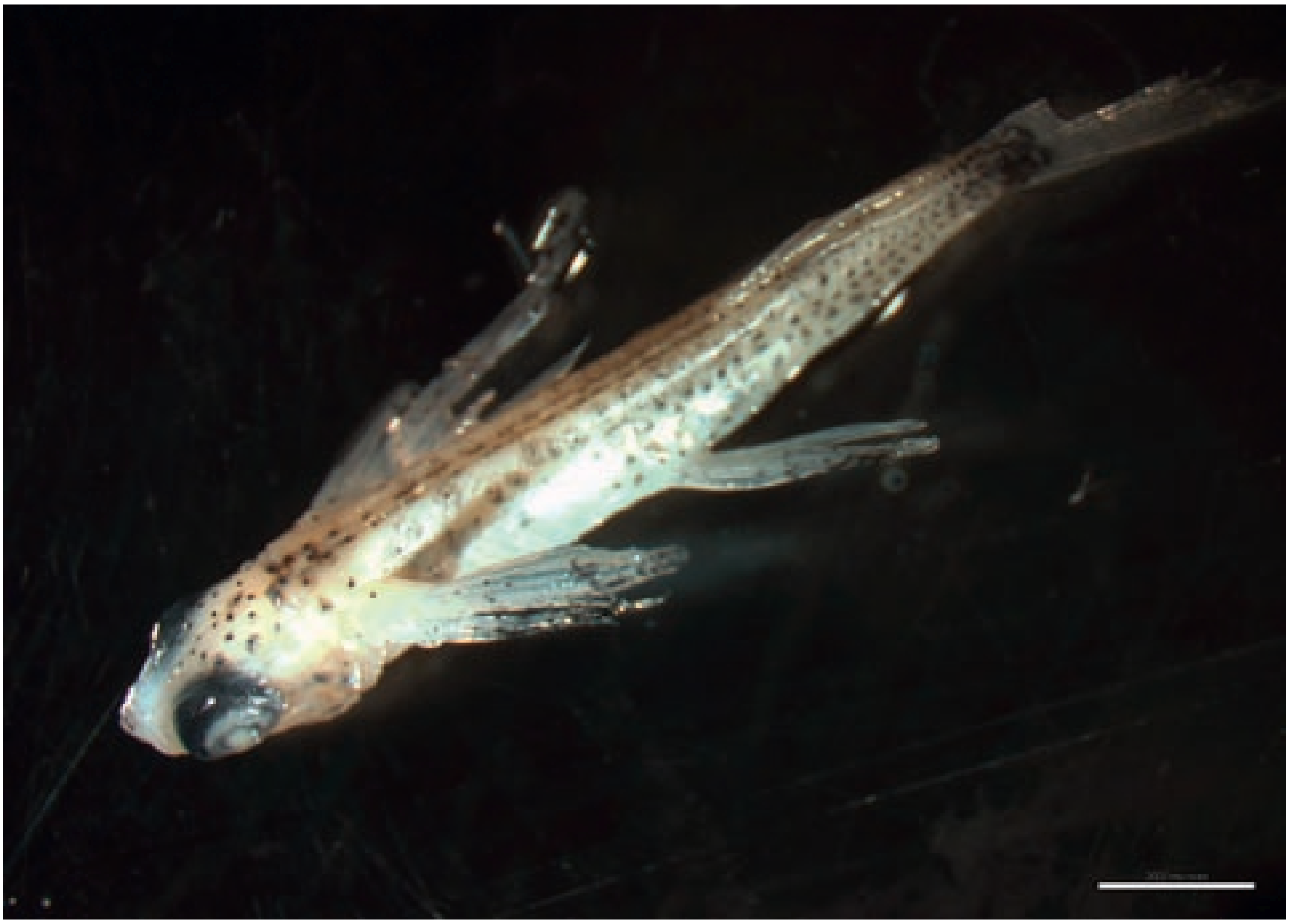
- Bathypelagic species (Order Stomiiformes; Family Gonostomatidae) appearing from 10 m down to 2,000 m depth[115].
- Sexually dimorphic with females larger than males. Extensive spawning season (from April to October[116]). Very little information is available for this species and it has been recently identified in the Aegean Sea[117].

Bristlemouth (*Cyclothone pygmaea*)

- Deep, meso to bathypelagic species (Order Stomiiformes; Family Gonostomatidae), inhabiting between 500 to more than 1,000 m depth.
- Wide spawning range between spring and autumn[117]. Presumed dioecious; spawns during spring to autumn[118]. Larvae appear close to the surface[119].

Flying gurnard (*Dactylopterus volitans*)

- Demersal, reef-associated species (Order Scorpaeniformes; Family Dactylopteridae), living in shallow waters above 100 m depth.
- Very little is known regarding reproduction. Mature females have been found in June and July[120]. Eggs and larvae are pelagic[121].



Flying gurnard (*Dactylopterus volitans*) found in the samples taken with the bongo net. © OCEANA/ Patricia Lastra

Anchovy (*Engraulis encrasicholus*)

- Small pelagic species (Order Clupeiformes; Family Engraulidae), generally appearing in big schools from 0 m to 400 m depth[122].
- Spawns from April to November with peaks usually in the warmest months[123] although it can be extended from spring up to autumn[124;125], depending on location and prey availability. Eggs float in the upper 50 m and hatch in 24-65 hours.

Grouper (*Epinephelus* sp.)

- Demersal species (Order Perciformes; Family Serranidae), generally associated with rocky bottoms; some species occur in deep water (to at least 525 m) but most are found in depths of 10 to 200 m[126].
- Synchronous hermaphrodite species that spawns in groups[127], with spawning peak during the summer[128].

Lanternfish (*Hygophum* sp.)

- Epipelagic to mesopelagic species (Order Myctophiformes; Family Myctophidae). Appears at greater depths during the day (i.e. 600 m), while migrating close to the surface at night[110].

- Oviparous, spawning in June and July, with planktonic eggs and larvae. Two common species in the Mediterranean Sea are *H. hygomii* y *H. benoiti*[129].

Pygmy lanternfish (*Lampanyctus pusillus*)

- Bathypelagic species (Order Myctophiformes; Family Myctophidae) found between 400 and 900 m depth although it migrates to 50 m depth at night[110].
- According to several studies, some spawn at the beginning of the year while others appear to spawn beginning in July[130].

Opah or Moonfish (*Lampris guttatus*)

- Bathypelagic, epipelagic and mesopelagic species[131] (Order Pleuronectiformes; Family Lampriformes). Oceanic and apparently solitary.
- Sexually dimorphic[132]. Probably spawns in spring[133]. Larvae are pelagic.

Megrim (*Lepidorhombus* sp.)

- Bathydemersal species (Order Pleuronectiformes; Family Scophthalmidae) associated with soft bottoms; depth range 100-700 m[134].
- Larvae are pelagic. *L. boscii* spawns in spring and the beginning of summer[136], although in the Mediterranean larvae appear at the beginning of spring[137]. *L. whiffiagonis* spawns at the beginning of winter[138].

Pacific barracudina (*Lestidiops jayakari*)

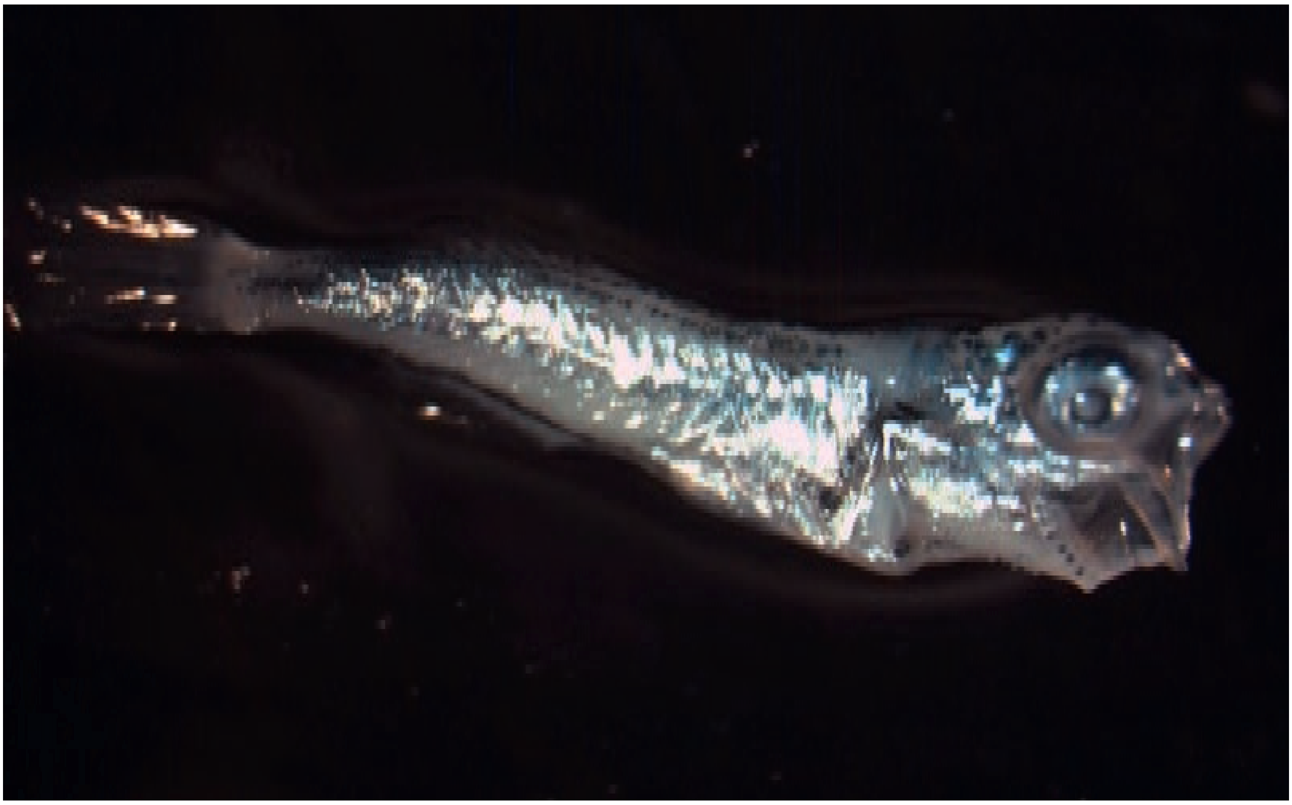
- Bathypelagic species (Order Aulopiformes; Family Paralepididae) found below 200 m depth[139].
- Larvae and juveniles are pelagic at the surface in the Mediterranean Sea[140].

Luvar (*Luvarus imperialis*)

- Pelagic species (Order Perciformes; Family Luvaridae).
- Spawning starts at the end of spring and during the summer[141].

Red mullet (*Mullus barbatus*)

- Demersal species (Order Perciformes; Family Mullidae) found on gravel, sand and muddy bottoms of the continental shelf. Depth range from 10-300 m.
- Reproduction from April to August[142]. Larvae and juveniles are very often part of plankton[143].



Red mullet (*Mullus barbatus*) larva.

Spotted lanternfish (*Myctophum punctatum*)

- Bathypelagic species (Order Myctophiformes; Family Myctophidae). Nyctoepipelagic at the surface and down to 125 m and found between 225-750 m during the day[144].
- Larvae found mainly in summer in the Mediterranean Sea and Atlantic Ocean[145].

Pilotfish (*Naucrates ductor*)

- Pelagic species (Order Perciformes; Family Carangidae).
- Larvae and eggs are pelagic[146]. It seems to have two spawning seasons: in summer and autumn[147]. In the Aegean Sea, larvae very often found from July to September[148].

Round sardinella (*Sardinella aurita*)

- Pelagic, reef-associated species (Order Clupeiformes; Family Clupeidae). Schools in coastal waters from inshore to the edge of the shelf. Highly migratory, often rising to surface at night and dispersing[149].
- Breeds perhaps throughout the year, but with distinct peaks. In some areas there are two main spawning periods depending on prey availability[150], with a peak in the summer in the Mediterranean Sea[150], although in the western part it often takes place in July and in the eastern part one month earlier, in June[151;152].

Brown comber (*Serranus hepatus*)

- Demersal species (Order Perciformes; Family Serranidae), living normally between 50 and 150 m depth in sandy and muddy sea bottoms[153].
- A synchronous hermaphrodite that spawns between March and September[154].

Greater weever (*Trachinus draco*)

- Demersal species (Order Perciformes; Family Trachinidae) living with a depth range from 1-150 m.
- Spawning takes place in May and September[98]. Eggs and larvae[155] are pelagic.

Mediterranean scad (*Trachurus mediterraneus*)

- Pelagic-demersal species (Order Perciformes; Family Carangidae)[156] associated with soft and sandy bottoms.
- Larvae and eggs are pelagic. It spawns between summer and winter and the start of autumn[157].

Atlantic stargazer (*Uranoscopus scaber*)

- Demersal species (Order Perciformes; Family Uranoscopidae) with a depth range from 15 m to 400 m, although eggs and larvae are pelagic[158].
- Studies in the Mediterranean Sea stated that this species can reproduce all year round[159].

Pearly razorfish (*Xyrichthys novacula*)

- Reef-associated species (Order Perciformes; Family Labridae), living from the surface to 60-70 m depth. Inhabits clear shallow areas with sandy bottoms, usually in the vicinity of seagrass beds and corals.
- Protogynous hermaphrodite species[160].

Scalloped ribbonfish (*Zu cristatus*)

- Bathypelagic species (Order Lampriformes; Family Trachipteridae)[161].
- Oviparous with planktonic eggs and larvae[162]. This species is very rare and little is known about it. Several recent larval samplings have found this species' eggs in the Atlantic[163] and for the first time in the Adriatic Sea[164] and Ligurian Sea[165].

Others

Apart from the species described above, samples from the Aegean Sea also included larvae from the Holocentridae family (squirrelfish). Currently, the only species known in the Mediterranean Sea is *Sargocentron rubrum*, which comes from the Red Sea into the Mediterranean Sea through the Suez Canal[166]. This species has a very short spawning season between July and August.

Larvae from the Bathylagidae family (deep-sea smelts) were also collected in this area. Despite a recorded presence of several species belonging to the same family in the Mediterranean Sea, such as *Dolicholagus longirostris, Bathylagus euryops* and *Melanolagus bericoides*, there is not much information currently available[167].

Other larvae identified belong to the mugilidae (mullets), sparidae (porgies, seabreams) and myctophidae (lanternfish) families, and the *Mullus* (red mullets), *Trachurus* (scads) and other genuses mentioned earlier in this report including *Arnoglossus, Epinephelus, Hygophum, Lepidorhombus* and *Caranx*.

- **Size frequency distribution of the three tuna species in each station studied**

Length-size measurements were taken for each individual larva found in order to assess the spawning activity in each area studied. Thus, four classes were established as follows: size-class I= larvae smaller than 2.5 mm length; size-class II: larvae 2.6<X>4.5; size-class III= larvae 4.6<X>6.5; size-class IV= larvae >6.6.

All of the graphs below show the size-frequency distribution of the three tuna species, Atlantic bluefin tuna (*Thunnus thynnus*), albacore (*Thunnus alalunga*) and frigate tuna (*Auxis rochei*), found in each study area. The presence of larvae less than 2.5 mm in length indicates that eggs have recently hatched, showing that these areas constitute active spawning areas.

Thus, in Capo Passero 6, the number of size class II tuna larva was highest for albacore tuna, indicating that this site is very important in spawning activity for this species (Fig. 5). While in Capo Passero 7, there was a higher concentration of size class II and III bluefin tuna larvae, confirming that this site is an active spawning area for this species (Fig. 6).

Figure 5: Size-class frequency distribution of tuna larvae in Capo Passero 6

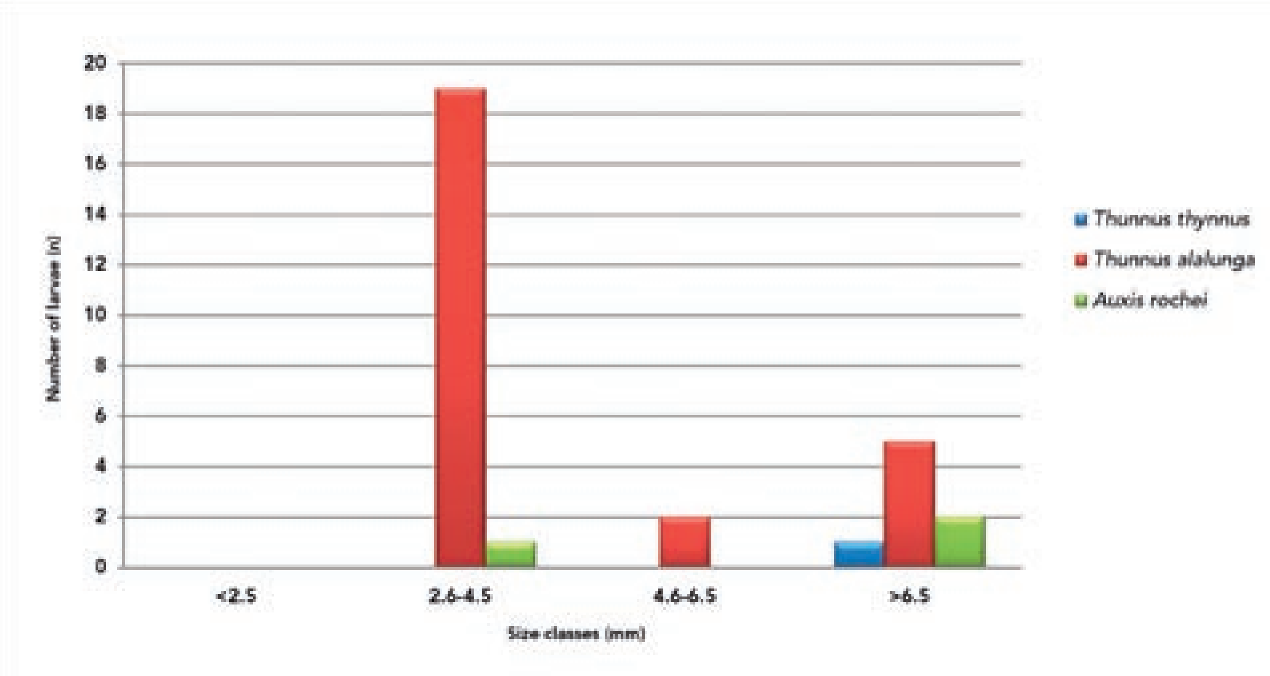
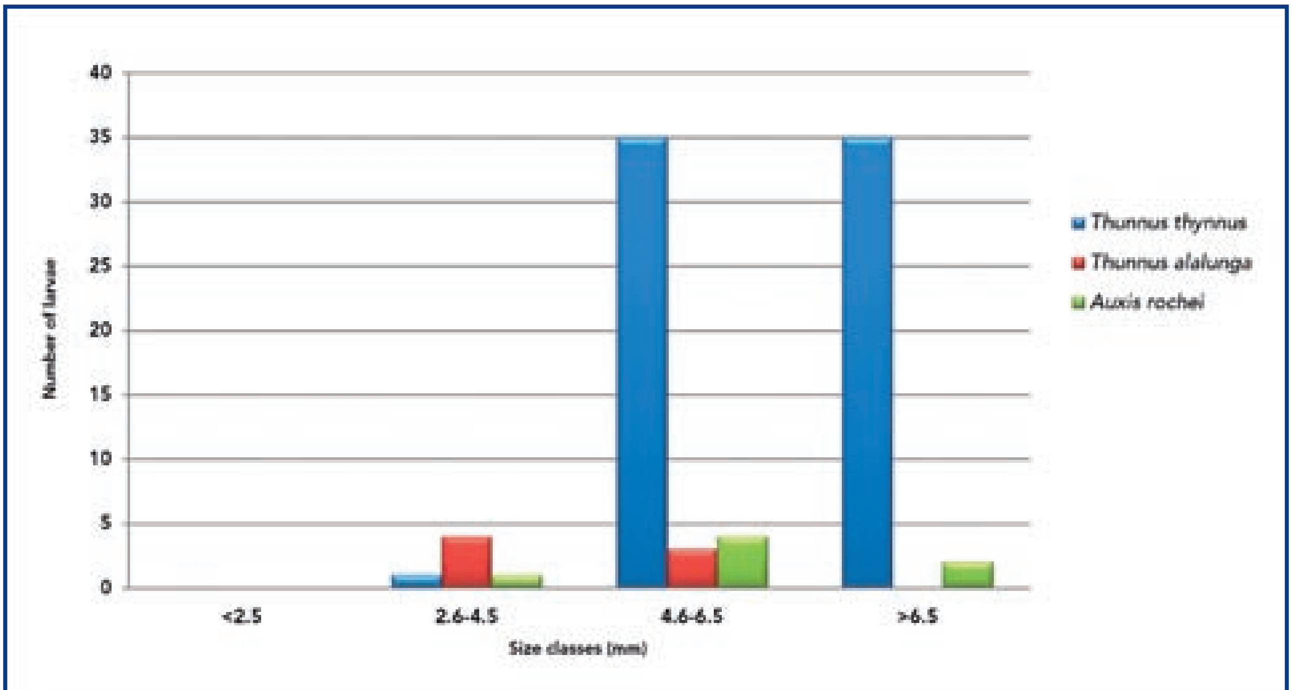


Figure 6: Size-class frequency distribution of tuna larvae in Capo Passero 7



Both Eolias 13 (Fig. 7) and Eolias 14 (Fig. 8) showed the highest frequency (around 400 and 20 larvae, respectively) of size class I albacore tuna larvae, which can be considered a good indicator of active spawning activity for the species. Remarkably, the presence of two other tuna species was also recorded: bluefin and frigate tuna of the smallest size classes.

Figure 7: Size class frequency distribution of tuna larvae in Eolias 13

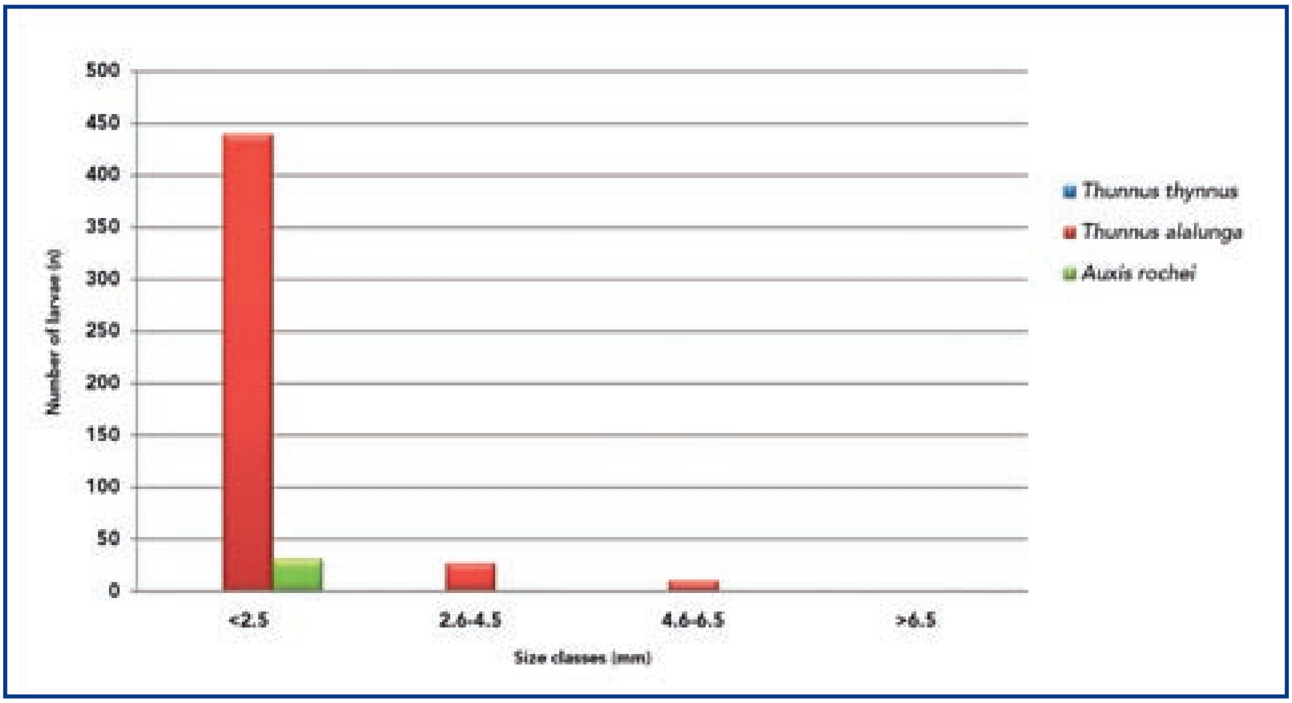
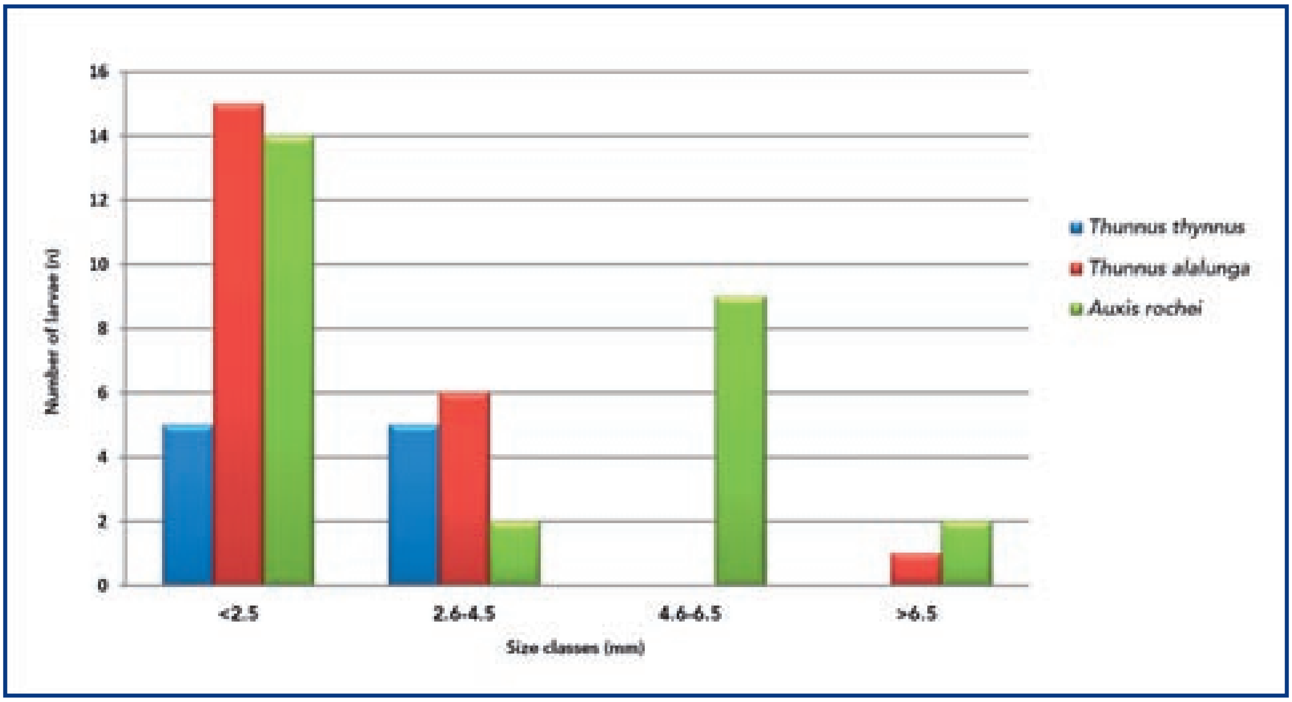


Figure 8: Size class frequency distribution of tuna larvae in Eolias 14



In Malta there was no presence of bluefin tuna larvae although there was a high concentration of size class II and III albacore and frigate tuna larva in both stations (Fig. 9 and Fig. 10), confirming again these areas as active spawning sites for these two species.

Figure 9: Size-class frequency distribution of tuna larvae in Malta 1

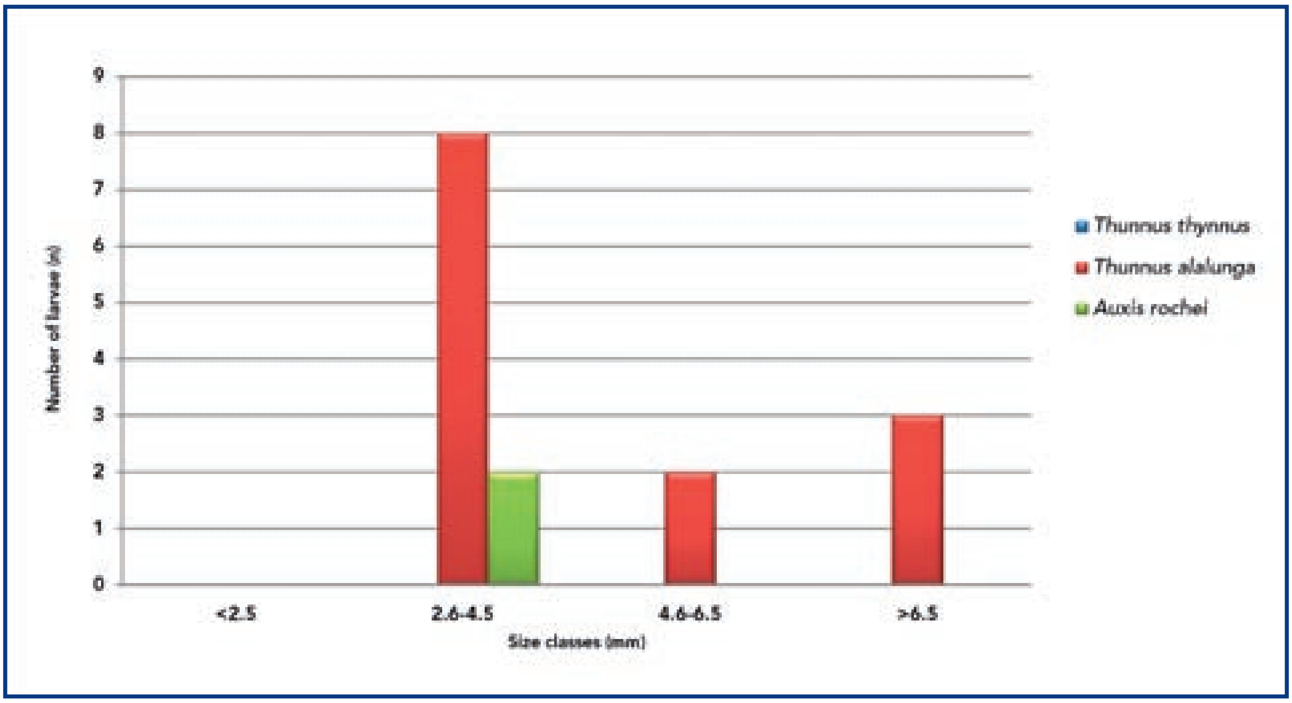
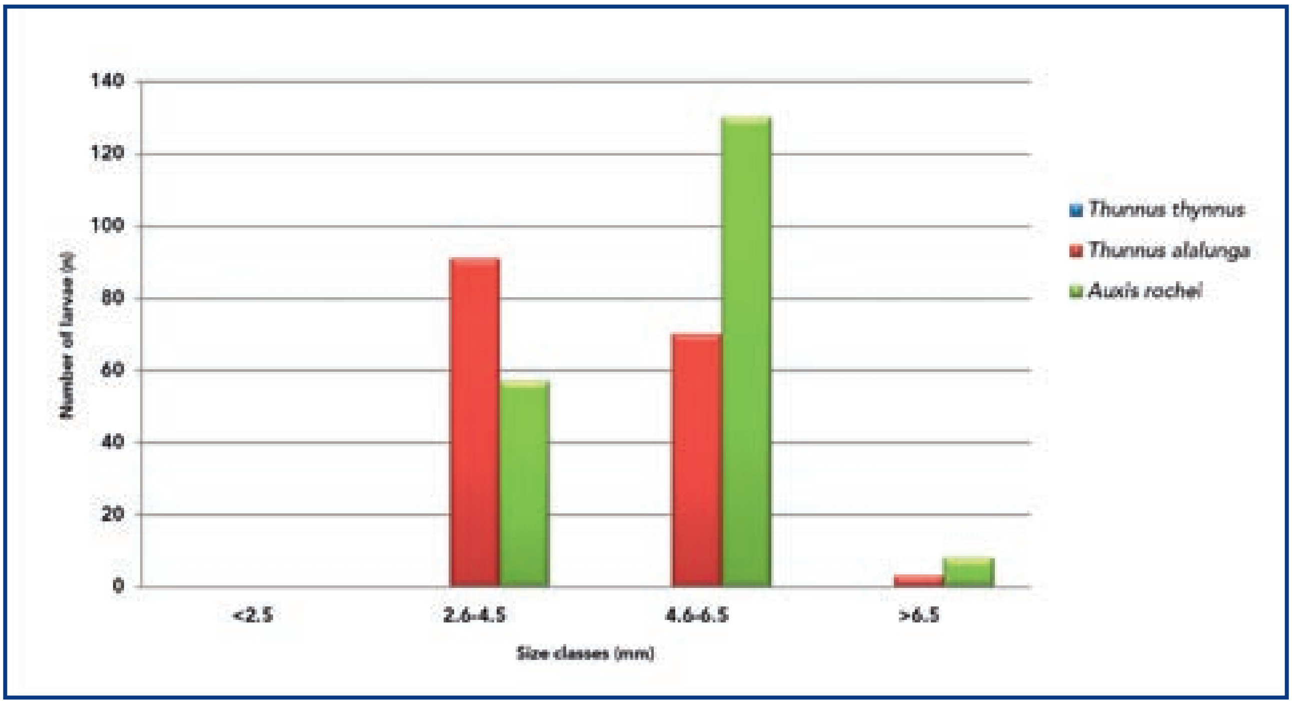


Figure 10: Size-class frequency distribution of tuna larvae in Malta 4



Finally, the most predominat species in the Aegean Sea was albacore, with the highest concentration from size class II larvae (Fig. 11 and Fig. 12).

Figure 11: Size class frequency distribution of tuna larvae in Aegean sea 9

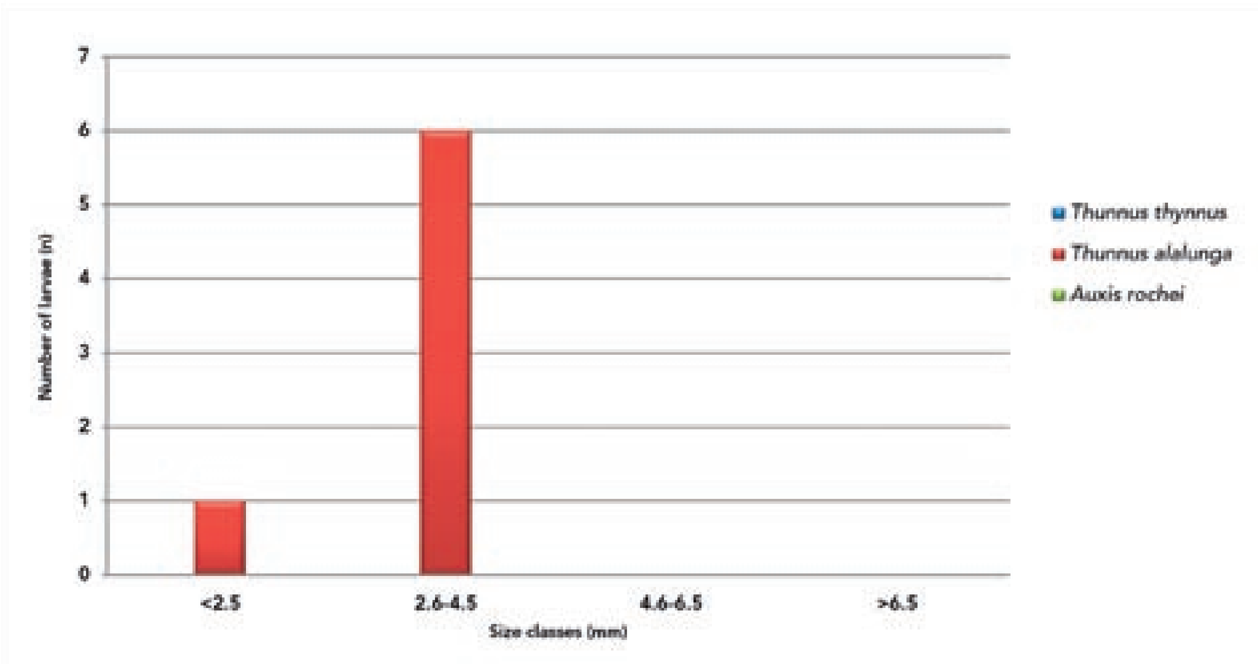


Figure 12: Size class frequency distribution of tuna larvae in Aegean sea 11

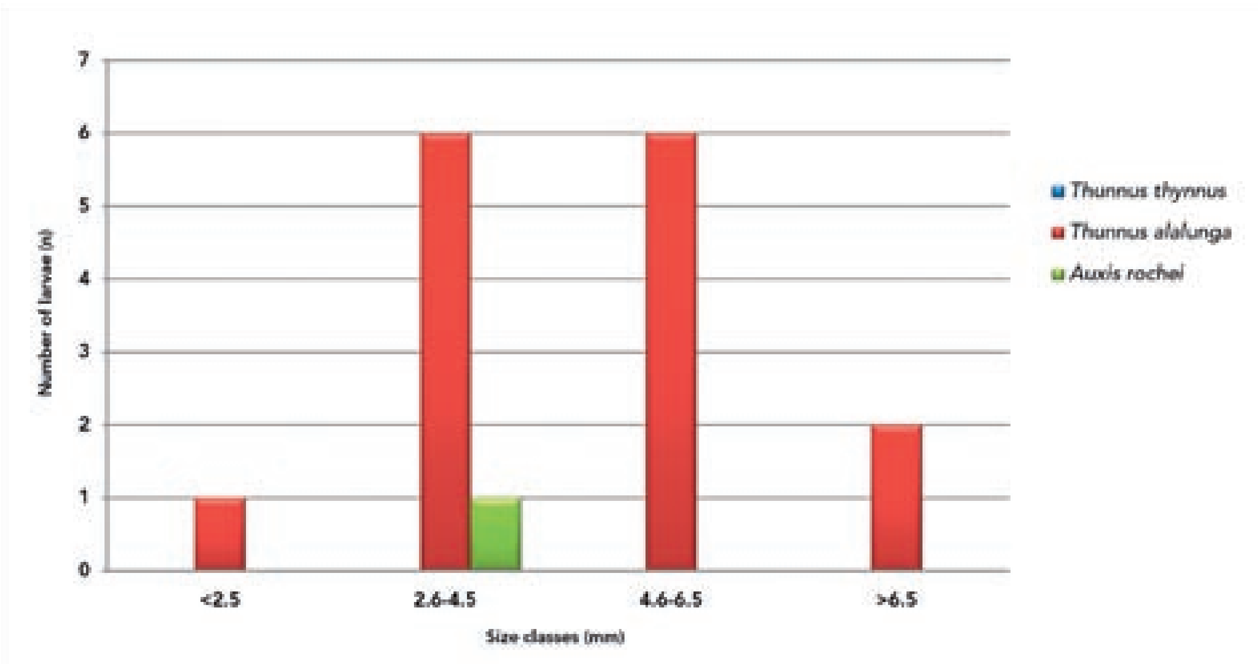


Table 5: Shows a summary of the three tuna species found in terms of number per station sampled

	Thunnus thynnus	*Thunnus alalunga*	*Auxis rochei*
Stations sampled (n)	3	8	7
Total larvae (n)	82	254	268
Larva/station	27.33	31.75	38.28

Table 6: Total larva (abundance m^3) by species in each station studied (larvae of tuna and tuna-like species are highlighted in blue)

Species	Capo Passero 6	Capo Passero 7	Malta 1
Anthias anthias	0.22	0.42	
Apogon imberbis		0.21	
Arnoglossus sp.			0.16
Auxis rochei	0.65	1.48	0.32
Bathylagidae			
Batophilus nigerrimus			
Buglossidium luteum			
Caranx sp.			0.16
Ceratoscopelus maderensis	15.83	27.16	0.96
Chlorophthalmus agassizi			0.16
Chromis chromis	1.94	27.16	
Coris julis		0.21	
Cyclothone pygmaea	4.74	1.48	
Cyclothone braueri	0.22		
Dactilopterus volitans			
Engraulis encrasicholus	0.22		0.32
Epinephelus sp.			
Exocoetus heterurus			
Holocentridae			
Hygophum sp.	1.94		0.16
Katsuwonus pelamis			
Lampanyctus pusillus	15.52		
Lampris guttatus		0.21	
Lepidorhombus sp.			
Lestidiops jayakari	0.65	0.42	
Luvarus imperialis		0.21	
Mugilidae			
Mullus barbatus			0.32
Mullus sp.	0.22	0.21	
Myctophidae	0.22		
Myctophum punctatum			
Naucrates ductor			
Sardinella aurita	0.22	5.23	
Sparidae		0.42	
Serranus hepatus		0.21	
Thunnus alalunga	5.61	1.48	2.72
Thunnus thynnus	0.22	14.28	
Trachinus draco			
Trachurus mediterraneus			
Trachurus sp.	0.22	0.21	
Uranoscopus scaber			0.16
Xiphias gladius			
Xyrichthys novacula		1.48	
Zu cristatus	1.58		

	Malta 4	Aegean Sea 9	Aegean Sea 11	Eolias 13	Eolias 14
			0.15		0.18
			0.15		
	28.44		0.15	5.58	4.85
			0.15		
					0.18
			0.15		
	0.73		0.15		
			71.29	3.88	
			0.92		
			4.89		0.72
			29.31	9.60	0.36
	0.15				
			1.22	0.17	
			0.15		
	0.15			0.35	
			0.76		
			32.67		
	0.29				
			1.22	0.35	1.80
			1.22		
			0.15	0.17	
		0.19			0.18
	0.29			0.17	
					0.72
					0.18
			0.15		6.48
			2.14		
	23.92	1.30	2.29	86.20	3.95
					1.80
					0.36
					0.36
				0.17	
	0.15		0.15		
	0.15				
				0.35	

Other campaign developments

The Marviva Med has been patrolling and documenting tuna fishing grounds in the following areas: the Balearic Sea (mainly south of Formentera Island), the Sicilian channel (mainly in the area around Pantelleria Island), the Malta channel (mainly around Linosa and Lampedusa islands and south-west of Malta), the external limit of Libyan jurisdictional waters, and the south Tyrrhenian Sea. We have identified and documented the activities of 59 industrial purse seiners from France, Italy, Spain, Greece, Turkey, Croatia, Libya, Morocco and Tunisia, as well as other vessels participating in bluefin tuna fishing activities in the Mediterranean.

Juan y Lucía and *Gepus* fishing with tuna cages. MarViva Med Mediterranean Expedition. Balearic islands, Spain. May 2008.

Illegal Italian driftnetters were documented south and west of Sardinia, in Tunisian waters, north of Malta and in the Tyrrhenian Sea (especially off Ponza Island, around the Aeolian archipelago, and north and east of Sicily). In most cases, driftnet fishing was being carried out in these areas, except Sardinia and Malta. Six of the vessels were suspected to have swordfish onboard when spotted and they were reported online to the Italian Coast Guard so that they could be intercepted upon their arrival at port.

Left to right: the Italian purse seiner *Luigi Padre*, the Turkish support vessel *Serter Ahmet 1* and the Libyan flagged *Abr Albihar 2*. Southwest of Malta. Marviva Med Mediterranean Expedition. June 2008.
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Turkish purse seiner *Denizer* and the support vessel *Serter Ahmet 1* operating with tuna cage. South of Malta. Marviva Med Mediterranean Expedition. June 2008.
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Bluefin tuna (Thunnus thynnus) in a tuna farm © OCEANA/ Keith Ellenbogen

Conclusions

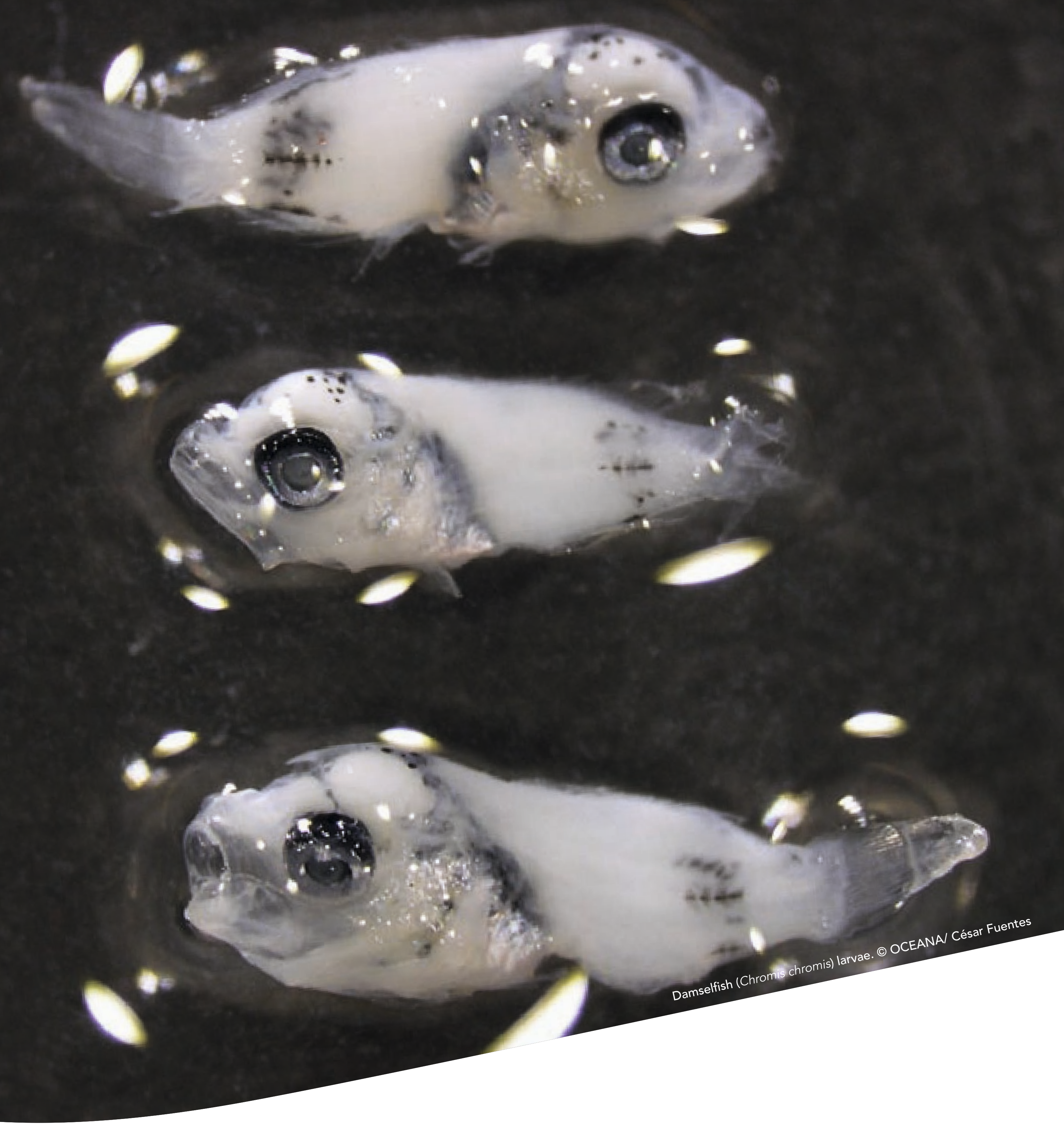
Despite the fact that larval surveys were conducted late in the spawning season, the results from the 2008 Oceana-MarViva campaign confirm the presence of larvae from three tuna species including bluefin, frigate and albacore. Furthermore, this confirms these areas as key spawning grounds for these large, commercial pelagic species of significant economic interest in the Mediterranean Sea. Additionally, the presence of other economically important species, such as swordfish larvae, further raises the importance of these areas. The results of the campaign prove just how important these spawning grounds are for these overexploited species. As such, these areas are in need of urgent protection in order to ensure the long-term sustainability of Mediterranean fishery resources.

Furthermore, the results of the campaign will contribute to the scientific knowledge available on the reproductive biology of certain tuna species for which information is lacking, such as skipjack tuna (*Katsuwonus pelamis*). In addition, the results will also shed light on the abundance and distribution of critical life stages and the larval contribution of these species in areas that require further research (e.g., the Aegean Sea), helping fill in some of the currently existing gaps.

The results included in this report are crucial in order to identify Essential Fish Habitats and protect spawners and/or juveniles of stocks that face the effects of overfishing and are at risk of collapse (i.e. bluefin tuna), thereby improving the current state of stocks.

Nevertheless, additional larval surveys should be carried out in upcoming years, particularly in the eastern Mediterranean Sea where there is a lack of information. These surveys will be used to assess relative larval contribution and monitor the main environmental parameters and oceanographic features that influence these primary life stages.

Pygmy lanternfish larvae (*Lampanyctus Pusillus*).
© OCEANA/ Patricia Lastra



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