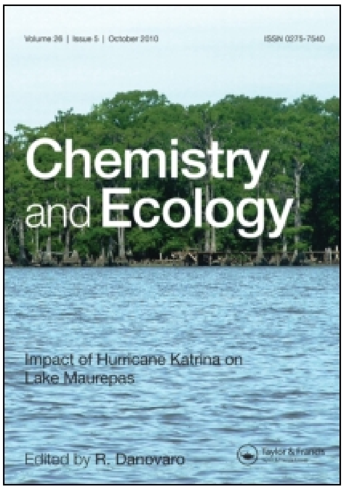

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

Large pelagic fish, swordfish, bluefin and small tunas, in the Ligurian Sea: biological characteristics and fishery trends

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Online publication date: 20 May 2010

To link to this Article: DOI: 10.1080/02757541003627696
URL: http://dx.doi.org/10.1080/02757541003627696

Chemistry and Ecology
Vol. 26, Supplement, June 2010, 341–357

Taylor & Francis
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(*Received 15 July 2009; final version received 14 December 2009*)

This article presents a review and summary of the data on large pelagic fish, collected over the period 1990–2007, thanks to national and European Community research programmes. Swordfish are present in the Ligurian Sea at all life history stages. Time series of longline fishing catch per unit effort (CPUE) values show a good exploitation status, possibly related to the dismission of past questionable fishing technics (e.g. 'spadare' nets). CPUE values were also negatively related to North Atlantic oscillation: climatic factors probably had synergic effects. Bluefin is present in the Ligurian Sea with mainly schools of young fish aged 1–4 years, which feed on small pelagic fish and on the Ligurian krill *Meganyctiphanes norvegica*. Recent limitations on catches have severely reduced local fishing activities. Following the dismission of purse seiners, artisanal hook-based fisheries should be maintained, regardless of the length of fish caught, as a way of monitoring stock status. The two most abundant species of small tuna, *Sarda sarda* and *Auxis rochei rochei*, are present in the Ligurian Sea at all life stages. In particular, *Auxis rochei rochei* is a commercially neglected species which, in terms of larval occurrence, is the most abundant in the Mediterranean. Physiomorphological and genetic studies have been recently carried out in order to improve forthcoming exploitation.

Keywords: Ligurian Sea; Pelagos Sanctuary; bluefin; swordfish; small tunas; biology exploitation

1. Introduction

Total Ligurian fishery landings represent only ∼2% of total Italian fishery production and large pelagic fish landings [1] are in line with this percentage (Table 1). However, total catches in the Ligurian Sea are far more relevant because they also include landings by French fleets and fleets from southern Italy.

Mediterranean small tunas (Table 2) are considered by the Food and Agriculture Organisation of the United Nations (FAO) [2] to be of great interest both in terms of the huge total catches (mainly obtained in Turkish waters) and because they include both native species that are not fully exploited, e.g. *Auxis rochei rochei* (Risso, 1810), and recent immigrant species, e.g. *Scomberomorus commerson* (Lacepede, 1800), which is becoming a fishery resource for several

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ISSN 0275-7540 print/ISSN 1029-0370 online

DOI: 10.1080/02757541003627696
http://www.informaworld.com

Table 1. National and Ligurian production of three large pelagic species from the IREPA statistics [1].

Species		2003	2004	2005	2006	2007	Total
Swordfish	No. Italian landings	8395	6953	7460	7626	6518	36952
	No. Ligurian landings	304	177	97	220	193	991
	% Ligurian landings	3.62	2.55	1.30	2.88	2.96	2.68
Bluefin tuna	No. Italian landings	4504	4067	4272	4292	4528	21663
	No. Ligurian landings	11	16	37	49	12	125
	% Ligurian landings	0.24	0.39	0.87	1.14	0.27	0.58
Atlantic bonito	No. Italian landings	2291	1188	1427	1544	1601	8051
	No. Ligurian landings	21	14	20	37	77	169
	% Ligurian landings	0.92	1.18	1.40	2.40	4.81	2.10

Table 2. Small tunas of the Mediterranean and Black Seas [2].

ICCAT Code	Species name	English	French	Spanish
BLT	*Auxis rochei rochei*	Bullet tuna	Bonitou	Melva
LTA	*Euthynnus alletteratus*	Little tuny	Thonine commune	Bacoreta
SKJ	*Katsuwonus pelamis*	Skipjack tuna	Listao	Listado
BOP	*Orcynopsis unicolor*	Plain bonito	Palomette	Tasarte
BON	*Sarda sarda*	Atlantic bonito	Bonite à dos rayè	Bonito del Atlàntico
COM	*Scomberomorus commerson*	Narrow-barred Spanish mackerel	Thazard rayè Indo-Pacifique	Carite estriado Indo-Pacifico

Mediterranean countries. Unfortunately, statistics for the Ligurian Sea [1] take into account only one species of small tuna, the Atlantic bonito *Sarda sarda* (Bloch, 1793) (Table 1).

Since 1990, the large pelagic fish of the Ligurian Sea have been studied by the Laboratory of Marine Biology and Animal Ecology of Genoa University under three-year programmes funded by the Ministero delle Politiche Agricole Alimentari e Forestali (MiPAAF). During the 1990s, these studies were also supported by European Community projects, in collaboration with the Instituto Español de Oceanografía (IEO), Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) and other large pelagic research teams. In recent years, research on tuna has also been sustained by the Ministero dell' Istruzione, dell' Università e della Ricerca (MIUR) within the framework of Progetti di Ricerca di Interesse Nazionale (PRIN) 2005–2007 and by regional and EU funds (National Programme of Data Collection Regulation (EC Reg. 1543/00); CAMPBIOL).

Large pelagic fishing mainly takes place in the western sector of the Ligurian Sea, which constitutes the core of the international Pelagos Sanctuary for Cetaceans, a Specially Protected Area of Mediterranean Importance (SPAMI) under the Barcelona Convention. The biological and hydrological characteristics of this offshore environment, which spans a water column of ∼2500 m, may easily represent the epitome of pelagic life in the Mediterranean [3].

This article is a summary of studies carried out on the fishery and biology of large pelagic fish (swordfish *Xiphias gladius* Linnaeus, 1758; bluefin tuna *Thunnus thynnus* Linnaeus, 1758; and small tunas) in the Ligurian Sea during the last 20 years, with the aim of completing the general review of the Ligurian Sea environment [4] published in this journal.

2. Materials and methods

Studies carried out on large pelagic fish in the Ligurian Sea during the period of 1990–2007 were summarised, taking into account both specific aspects of the study area and general results concerning these fish.

3. Results and discussion

3.1. *Swordfish*

3.1.1. *Exploitation*

Swordfish were assessed by the International Commission for the Conservation of Atlantic Tunas (ICCAT), on the basis of the identification of three stock units (North Atlantic, South Atlantic and Mediterranean), whose geographical limits are not clearly defined in terms of the displacement capabilities of the fish, but are conventionally set at 5°N and 8°W, respectively.

Ligurian swordfish longline fishery has artisanal characteristics: boats are small (range 8–16 m LOA), employing two or three fishermen as crew, and fishing trips usually last only one day, with a limited number of hooks deployed per setting (650 hooks on average). The two main ports are Imperia and Sanremo, in the western Ligurian Sea, and constitute ∼70% of the whole pelagic Ligurian fleet. The main fishing season generally extends from May to December, when a variable number of boats are active, 6 to 25 fishing units per day, although some boats are also used during the winter months.

Fishing activities have been monitored since 1990, both at landings and directly on board the professional fishing vessels. This has allowed the collection of measures [5,6] and samples, in order to investigate the size composition of the fished stock and the main biological parameters of the species.

From these types of data and length/frequency distributions, the recruitment index was obtained, which gave the number of 1-year-old specimens caught per 1000 hooks (CPUE age 1) [7]. Young-of-the-year (YOY), which are excluded from the recruitment index, were particularly abundant during 1994 and a small tagging campaign by ICCAT ‘yellow spaghetti’ was carried out in the western Ligurian Sea.

An estimate of the mean annual CPUE value (CPUE weight = catch in kg per thousand hooks, in accordance with ICCAT methods) was performed over the entire period and covers 17 consecutive fishing seasons (Figure 1). The overall mean CPUE value is 116.46 kg per 1000 hooks (SD = 33.23), one of the best of all the Italian seas [8].

After the first two years, when CPUE decreased, a general increase was seen until 2007, although some fluctuations did occur, especially during the period 2004–2006. Coupling this trend with the types of gear used in the study area, we observed that the scarcest catches coincided with driftnet activities (‘spadare’ in 1990–1992, and more recently smaller driftnets, such as thonailles) [9]. However climatic factors also apparently influenced the catches. In fact, a significant negative relationship was found between CPUE weight and Winter North Atlantic oscillation (NAO) Index (Figures 2 and 3) [10]. A relationship was found between CPUE (age 1) and CPUE (weight) obtained after 3 years (Figure 4), so the recruitment index was predictive of the catch [10].

In the North Atlantic, the swordfish recruitment index, namely CPUE age 1, and not CPUE kg, was negatively correlated to NAO [11]; in the Ligurian Sea the NAO–recruitment index relationship was not significant.

These complex relationships suggest that in the large NE Atlantic waters where Spanish vessels fish the swordfish, NAO oscillations affect the surface currents with which the young fish are associated, and so recruitment, in terms of the arrival of young fish with the Gulf Stream, is linked to the NAO, whereas large fish move independently of the currents. In our study area, we verified that recruitment of important commercial fish, e.g. hake, may be related to the flux in the Corsica Channel which is influenced by the NAO: in fact, with strong currents more eggs and larvae are transported into the Ligurian Sea from the north Tyrrhenian spawning ground [12]. If this type of relationship does not exist for swordfish, we may suppose that recruits (in this case, fish of age 1) are born locally, i.e. in the same Sanctuary area. Swordfish driftnets catch larger

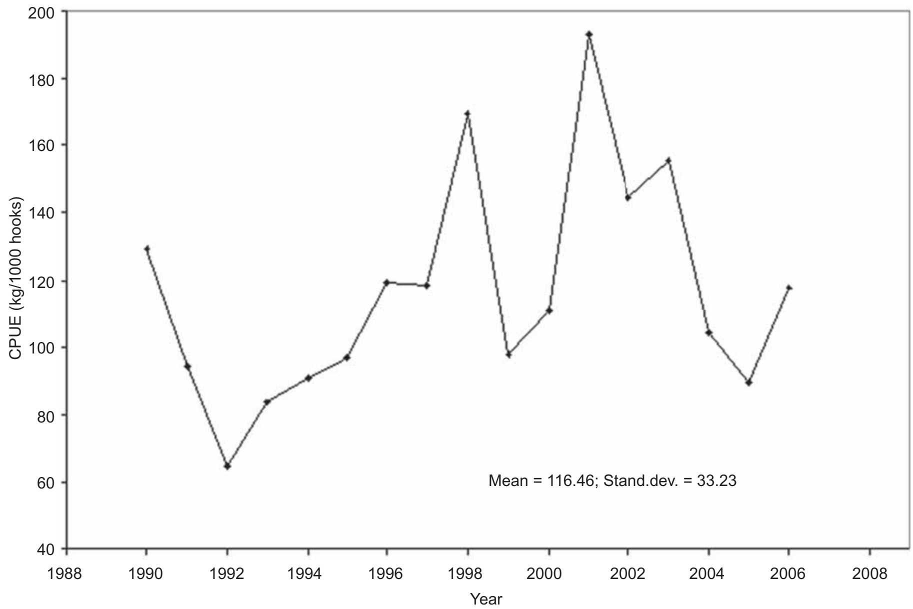

Figure 1. Time series for swordfish longline CPUE (kg per 1000 hooks) [10].

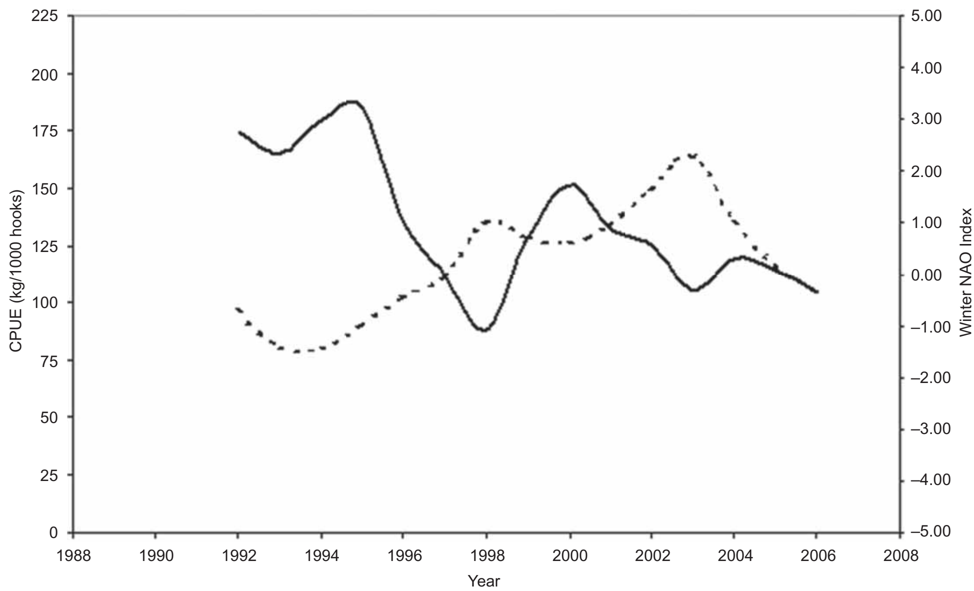

Figure 2. The time series for swordfish longline CPUE (kg) (dotted line) and Winter NAO Index (solid line), both smoothed by running averages, are specular [10].

fish than longlines [13] and therefore the negative influence of this gear on catches may be due to the elimination of female spawners and the consequent reduction in recruitment. The negative NAO–CPUE (weight) relationship may have trophic causes; for example, the production of small pelagic fish [14]. In fact, when Winter NAO Index values are low, rainfall in Liguria is abundant, favouring the thriving of anchovies. Further research is necessary to verify and to give substance to the current hypotheses.

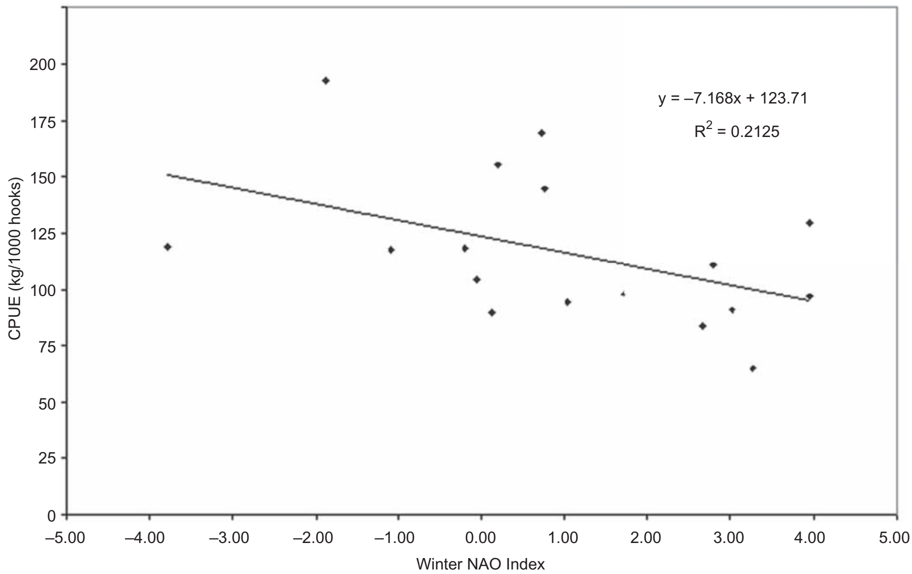

Figure 3. Negative correlation ($\alpha = 0.05$) between swordfish longline CPUE and Winter NAO Index [10].

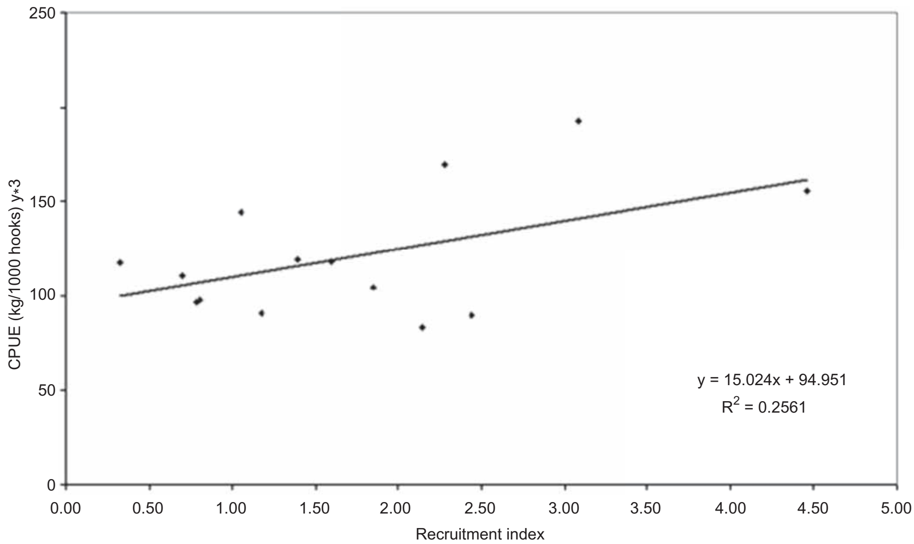

Figure 4. Correlation between the CPUE (age 1), i.e. the recruitment index, and CPUE (W) recorded 3 years later, in the longline catches of the Ligurian Sea [9].

3.1.2. *Biological characteristics*

The Mediterranean swordfish is smaller than its North Atlantic counterpart and, compared with the latter, shows a clear seasonality in reproduction [15].

All life stages were found in the Ligurian Sea, from post-larva [16] to advanced ages, namely 11 years [17]. In a sample of 3358 sexed individuals, the overall sex ratio was 55% females, with a ratio very close to parity in the youngest individuals and a prevalence of females from 125 cm Lower Jaw–Fork Length (LJFL) onwards; only females were found in fish >180 cm LJFL. Female gonadosomatic indexes showed a peak in July, then tailed off September. Female maturity at ogive length indicated $L_{50} = 148.77$ cm LJFL [15].

The study of age and growth was based on anal fin ray sections, and, for YOY, on serial monthly l/f distributions. Both a standard Von Bertalanffy growth function and seasonalised functions are available [18] (Figure 5). The former is very close to the Von Bertalanffy growth

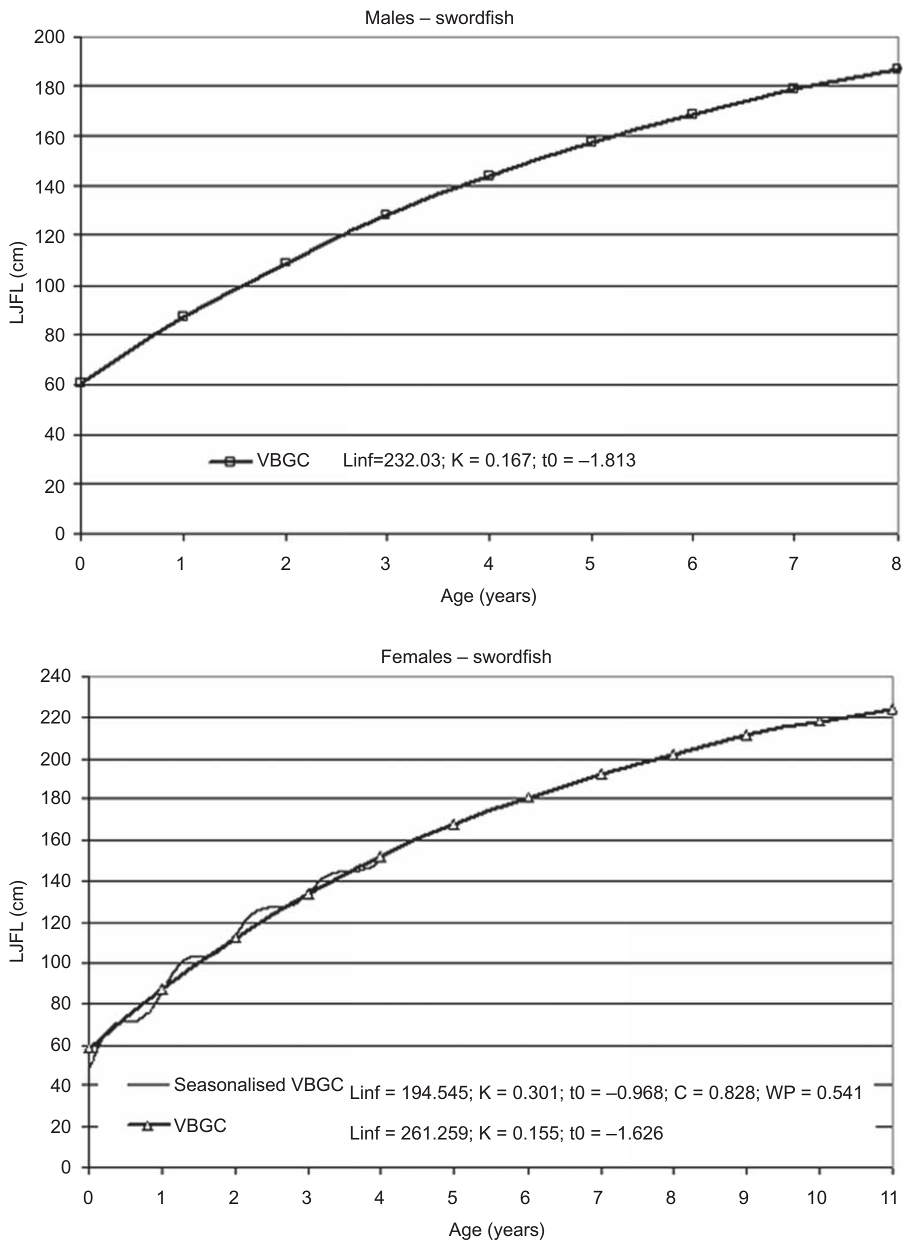

Figure 5. Growth of swordfish in the Ligurian Sea, represented by male and female Von Bertalanffy growth curves (VBGC). Age 8 (males) and age 11 (females) correspond to the oldest fish found in the study area. A seasonalised VBGC is used to describe female juvenile life.

curve obtained by Tserpes and Tsimenidis in the Aegean Sea [19], which is routinely used in ICCAT assessments [20].

The growth curve was validated by the recapture of a tagged specimen 3 years after its release [21]; this was the first datum of its kind in the Mediterranean Sea and resulted from the above-mentioned 1994 tagging campaign. In recent years, some recaptures have also occurred in the Aegean Sea and there has been one in the Atlantic.

Feeding in swordfish was studied in the Liguria Sea in comparison with other top predators from offshore waters [22], some of which represent by-catches of professional swordfish fisheries [23–25].

The role of mesopelagic fauna (fishes, cephalopods, crustaceans) was prominent with respect to surface prey. Therefore, owing to its size, swimming velocity and vertical distribution, the swordfish is the best mesopelagic prey sampler for offshore waters, in terms of species richness. The overall diet composition for swordfish in the Ligurian Sea includes 23 species of fish, 17 cephalopods and 6 crustaceans [26], partially overlapping with the diet of the striped dolphin.

Recent pioneer satellite tagging of the Mediterranean swordfish has been carried out in the Ligurian Sea and the Messina Strait (eastern Sicily) [27]. Despite some technical difficulties, this small-scale experiment has shown the displacement abilities of the fish (e.g. the distance between Sicily and Ligurian Sea was covered in two months) and the diel vertical migrations of the fish between surface and deep water (to ∼600 m), which had previously been ascertained using stomach content analysis [22].

3.2. *Bluefin tuna*

3.2.1. *Exploitation*

Stock assessment for this species is performed by ICCAT, which has long distinguished two stock units, conventionally separated by the 45°W meridian: the western stock, breeding in the Gulf of Mexico, and the eastern Atlantic Mediterranean stock, breeding in the Mediterranean.

Recent satellite tagging of relevant numbers of large oceanic fish [28] confirmed the location of the two above-mentioned spawning areas, reinforcing the ICCAT two-stocks approach; however, it also showed that large tunas (∼200 kg) which had been resident along the coast of the USA for years were able to cross the Atlantic within a short time (∼1 month) and enter the Mediterranean to spawn. More generally, it was ascertained that the Atlantic offers common feeding areas for large fish of different origins, and fishing activities in the western Atlantic are also based on fish born in the Mediterranean [29,30]. This explains the interest of American countries in Mediterranean and European exploitation of this species. As a matter of fact, the western stock is smaller and at a critical exploitation status, with respect to the eastern stock, despite the latter being fished in large quantities. The Mediterranean offers not one but several spawning areas, namely the waters around the Balearic Islands, South Sardinia, Sicily (both the south Tyrrhenian Sea and Sicily Strait), Crete and Cyprus. In the past, this long series of spawning grounds also included the Black Sea, where, during the 1970s, an environmental crisis led to the disappearence of several large pelagic fish species. Recent larval campaigns have confirmed these spawning areas [31–36], with the exclusion of the Marmara and Black Seas.

Italian seas host different components of the bluefin fished stock, with spawning aggregations in southern waters and schools of juveniles particularly frequent in the Adriatic and Ligurian Seas. Studies carried out in the Ligurian Sea have ascertained that the bluefin juvenile phase is represented by the age range YOY to age 4 (Figure 6).

The finding of YOY is generally occasional; however, during autumn 1994, they were so abundant that it was possible to carry out a tagging campaign, releasing 543 specimens [37]. During spring of the same year, *Posidonia oceanica* (Linnaeus) Delile, 1813 meadows showed a

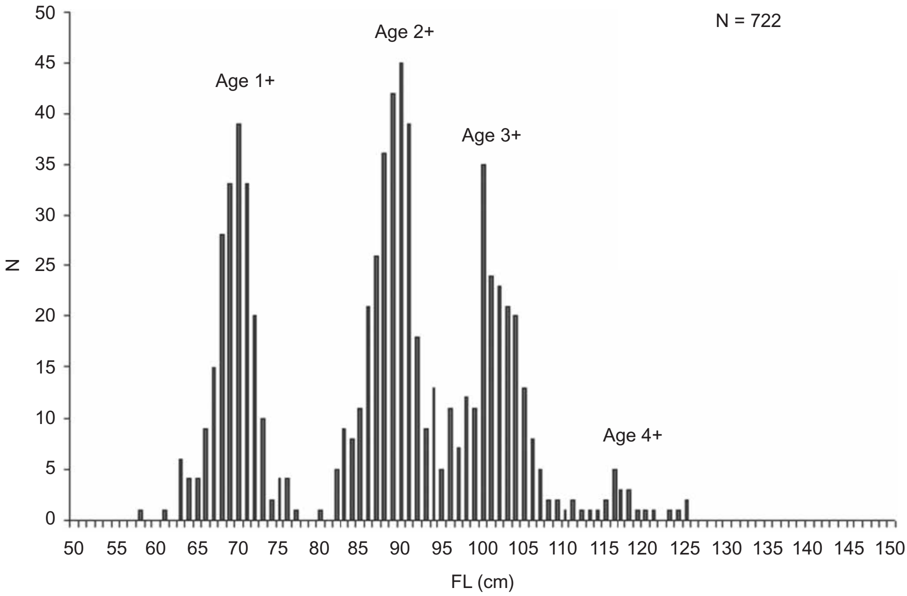

Figure 6. Length/frequency distribution of bluefin caught by tuna purse seines in the Ligurian Sea. Samples were measured from 21 August to 2 October 2002.

very abundant production of fruits, and during the summer oceanographers noted an inversion of the currents at the Corsica channel [38], which has apparently not reoccurred to date. We were not able to establish relationships among these events, but it is intriguing that ancient Mediterranean legends indicate a relationship between the abundance of fruits from a 'sea oak' and the abundance of tuna and that the aforementioned sea oak was later identified as *P. oceanica* [39]. After such observations, the hypothesis remained that the young bluefin were arriving from west. In recent years, research has indicated the importance of the Balearic spawning area [28,34–36]. On the basis of recaptures, the longest track of a released YOY bluefin ended in the waters of Tarragona, Spain.

At present, the ICCAT considers the bluefin overexploited and a reconstruction of the stock by means of a series of limitations and controls on catches is being attempted. No type of fishing which targets the bluefin is currently allowed in the Ligurian Sea, and fish quotas which in the past were allocated to the few Ligurian vessels using purse seines have been transferred to other regions. The small catches shown in Table 1 occurred as a by-catch of other fishing activities. However, in previous years very variable quantities, including large catches by exogenous vessels (e.g. ∼1000 t in 1999), were observed. Unfortunately, it is impossible to derive CPUE data from the landings of purse seiners.

This is very important and unresolved for tuna. In fact, fishery trends can be studied only if CPUE are measured regularly. Large pelagic gear from which this type of data can be derived are longlines and driftnets. The former should be encouraged in the Ligurian Sea, where they have artisanal characteristics, as a tool for monitoring the bluefin stock, independent of the size/age caught (at present 30 kg or 115 cm fork length (FL) are the minimum sizes allowed, on the basis of ICCAT suggestions). Figure 7 shows the inconsistency of this diktat with respect to the structure of the Ligurian fished stock. The indicated size combination was apparently derived from the need to avoid capturing the smallest female spawners, a category not present in the Ligurian Sea (see below).

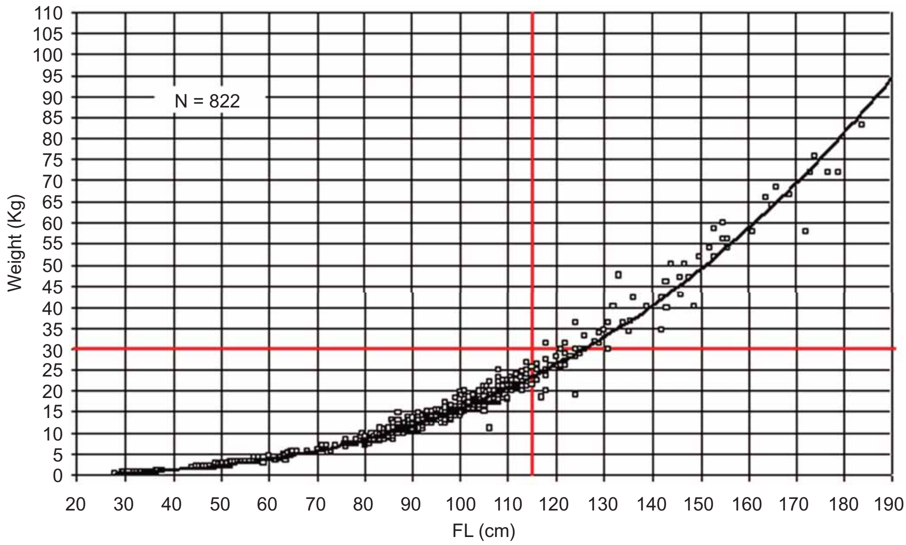

Figure 7. Length/weight relationship of bluefin caught in the Ligurian Sea and minimum size (in length and weight) allowed by the 2007 EC regulation. No Ligurian fish corresponds to the indicated combination of length and weight, which was probably derived using oceanic material. The limit in terms of length, indicates a fish of age 4; the limit in terms of weight indicates a fish close to age 5.

3.2.2. *Biology of juvenile tuna*

In the 1990s, study of the size structure of the Ligurian fished stock allowed juvenile growth to be described in a seasonalised form (Figure 8) [40–43].

The function was based on the identification of seven cohorts (1989–1995) which represented the age range 3 months to 4 years. A new study of growth was performed about 10 years later [44], following the 2003 cohort: growth, studied using two different modalities, namely fin spine

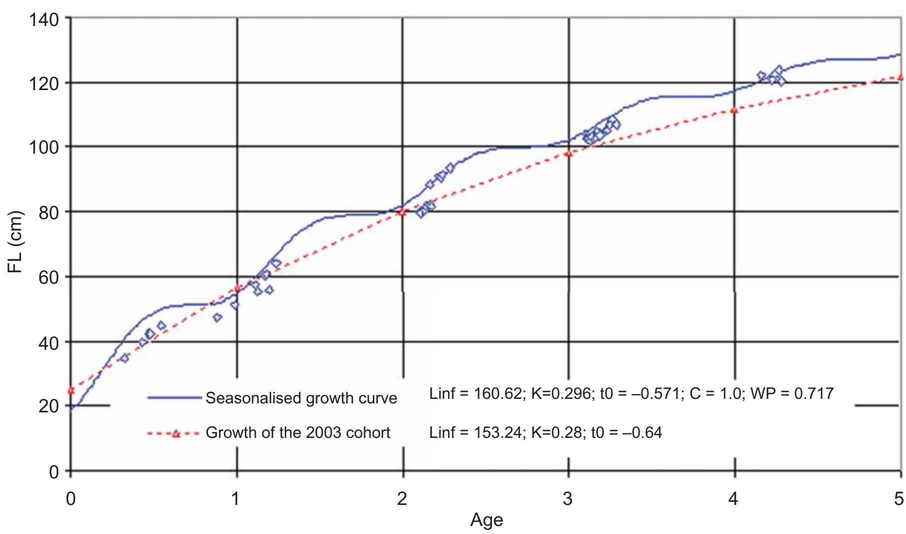

Figure 8. Growth of young bluefin tuna of the Ligurian Sea, figured in traditional and seasonalised form [18]. The latter allows us to verify the growth performances of caged specimens.

sections and Bhattacharya identification of cohorts, was figured in the traditional form (nonseasonalised track in Figure 8). Such growth function seems to show a slight reduction in size but it takes into account only one (abundant) cohort and not an average track, as in the former case. Lengths at various ages, obtained using the two above-mentioned functions and by a very recent study [45] on the same subject are shown in Table 3. The seasonalised growth function proved useful to verify growth rates of caged bluefin in the Tyrrhenian Sea [46].

The growth rate observed in the Ligurian Sea is also very close to that registered in Atlantic waters for the same age groups [47,48].

Study of the feeding habits of young tuna in the Ligurian Sea has shown that the most important prey are both small pelagic fish (as can be observed everywhere) and Ligurian krill, *Meganyctiphanes norvegica* (M. Sars, 1857); fish of age 2 onwards, in particular, frequently showed monospecific meals of this crustacean (Figure 9). Consumption of krill, which occurs in deep water and cannot therefore be used to track the fish, explains, at least in part, the great variability in annual catches. Schools of young tuna feeding on krill are the most important competitors of the fin whales that frequent the same offshore waters of the Pelagos Sanctuary.

Sexual maturation of tuna in the Mediterranean was indicated at a $L_{50} = 103$ cm FL in the female (age 3) [49]. However, in the Ligurian Sea we have observed mature males at this age, but not females. Given that the Ligurian Sea is not a spawning area, differential displacements of maturing/nonmaturing fish could be hypothetised.

Recent genetic studies on bluefin tuna within the framework of PRIN 2005–2007 (project leader F. Tinti) compared genetic diversity in the current Mediterranean fished stock and in specimens fished about a century ago (skeletal collection of M. Sella). Temporal stability in genetic diversity

Table 3. Fork length (cm) of bluefin tuna during the first years of life.

Age 1	Age 2	Age 3	Age 4	Ref.
54.96	82.03	102.17	117.14	[42]
56.42	80.06	97.93	111.64	[44]
62	79.6	101.4	115.9	[45]

Figure 9. Stomach content of a bluefin tuna (117 cm FL) caught on 29 October 2006; the content is composed exclusively of krill (∼1 kg).

was assessed, as well as significant changes in the genetic structure of the stock. Such results argue that stock overexploitation has not yet corrupted the genetic potential of bluefin tuna and that Atlantic Mediterranean bluefin tuna are not fully panmictic [50].

3.3. *Small tunas*

Five of the six species listed in Table 2 have been recorded in the Ligurian Sea: plain bonito *Orcynopsis unicolor* (Geoffroy Saint-Hilaire, 1817) and skipjack tuna *Katsuwonus pelamis* (Linnaeus, 1758) with only occasional presences, whereas bullet tuna (*A. rochei rochei*), little tunny *Euthynnus alletteratus* (Rafinesque, 1810) and Atlantic bonito (*S. sarda*) form commercial products. From a quantitative point of view, only two species deserve attention: the Atlantic bonito and the bullet tuna.

S. sarda is defined as an epipelagic, neritic, schooling species [51]; however, large specimens (to a maximum of ∼90 cm FL) can be found in offshore waters.

Genetic studies [52], as well as tagging data, suggest the existence of at least two Mediterranean stocks, one in the area of the Black Sea–Aegean Sea and one from the Ionian Sea to the Algarve [53]. Biological parameters of the central western Mediterranean population were summarised on the basis of a rich literature [53]. Some uncertainties regarding growth were overcome by considering that reproduction is strictly seasonal (May to July) and therefore cohorts form clear Gaussian components in l/f distributions. So, size at ages 1 and 2 was derived from catches in the tuna traps of the western Mediterranean [54–56].

A. rochei rochei represents a singular case among fishery resources of the Mediterranean. In fact, in the above-mentioned larval surveys, it was always the most abundant species of tuna, and abundant catches can be frequently observed. However, in general it is rarely appreciated because of the spectacular extension of its circulatory system. Such an anatomical device, which produces high temperatures in a small body mass (maximum weight in the Mediterranean is between 1 and 2 kg) also represents a large food waste fraction; moreover the meat is easily perishable.

A. rochei rochei is defined as an epipelagic, neritic as well as oceanic species [51], cosmopolitan in warm waters, where it generally shares its distribution with a similar species, *A. thazard thazard* (Lacepede, 1800). The Mediterranean represents an exception to this picture, because only one species is present [57]. For a long time, Mediterranean ichthyologists did not recognise the existence of two species and assigned the oldest name available to the Mediterranean fish, namely the binomial nomenclature of Lacepede. In some Mediterranean countries, the name *A. thazard* is still in use, so FAO and ICCAT statistics are frequently not based on species but on mixed categories to avoid the problem of species identification.

Anatomical and genetic studies of *A. rochei rochei* were addressed within the framework of the MIUR research programme (2005–2006) [58,59]. Samples from the Ligurian Sea [60], in particular, were also used to describe basic biological parameters, including reproduction and growth [61]. The species *A. rochei* deserves a taxonomical revision of its subspecies, given that the most recent genetic studies confirmed the existence of only one species in the Mediterranean, but its morphological characteristics result in peculiar patterns typical of both *A. rochei* and *A. thazard* from Indo-Pacific populations.

Long-term fishery trends for both *S. sarda* and *A. rochei rochei* in the Ligurian Sea have been studied by monitoring the catches of the tuna trap located at Camogli [62].

Annual catches from tuna traps represent CPUE which are a proxy for abundancy indices [63]. The tuna trap at Camogli differs from those aimed at large tuna spawners, which survive in scarce numbers in Sardinia and Sicily, because it is of reduced size and the fact that it targets different fish. In fact, fishing is confined to a coastal assemblage of fish, which in the past included tuna, but currently generally lacks this component. The fishing season lasts from April to September and

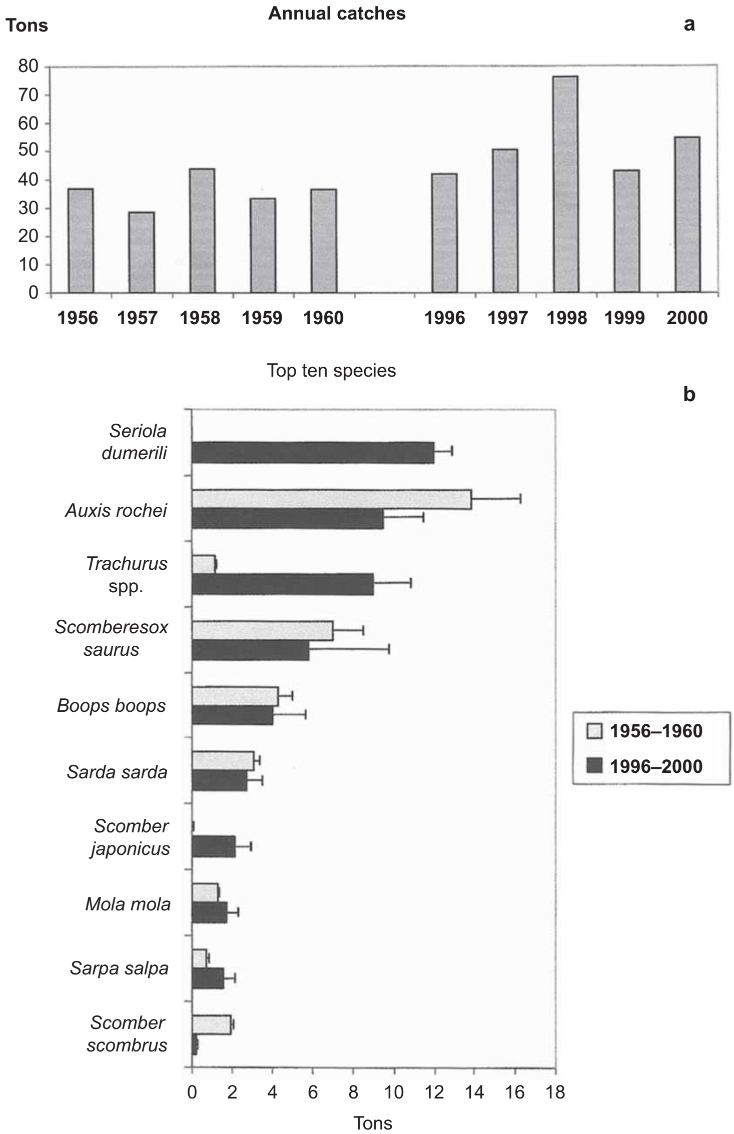

Figure 10. Annual catches and top 10 species observed at the Camogli tuna trap during the 1950s and 1990s, respectively [62].

the total annual catch is ∼50 t of fish, comprising ∼40 species. The top 10 species are shown in Figure 10, which compares two consecutive 5 year periods, 1956–1960 and 1996–2000, separated by 40 years. If only bony fish are taken into account, there is no decrease in fished biomass, but there is a qualitative transformation of the product.

The absence of tuna in the top 10 species was already clear 50 years ago. In recent times, *S. sarda* and *A. rochei rochei* have appeared somewhat reduced (but recent catches of *A. rochei rochei* are only part of the fish available in the trap, because of its scarce commercial value). By contrast, Carangids, such as *Seriola dumerili* (Risso, 1810) and *Trachurus* spp. Rafinesque, 1810, have increased greatly. The temperate–boreal *Scomber scombrus* (Linnaeus, 1758) was replaced by the temperate–tropical *Scomber japonicus* Houttuyn, 1782. The two species of sparids, *Sarpa salpa* (Linnaeus, 1758) and *Boops boops* (Linnaeus, 1758), showed a moderate increase and decrease, respectively, according to their major or minor tropical affinity [60]. Such comparisons were carried out in the last years of the exploitation of the sunfish *Mola mola* (Linnaeus, 1758); this species was part of Mediterranean traditional fishing, but was banned under EC regulations, so in recent years comparison with the past in such quantitative detail has not been possible. At present, in the Camogli tuna trap, *M. mola* is discarded alive.

The sunfish and all medusivorous fish [64,65], both large and small species, are currently flourishing in the Ligurian Sea. For the last 10 years, the Camogli tuna trap has shown four medusivorous species (or species group) within the top 10, namely *Trachurus* spp., *M. mola*, *Scomber japonicus* and *Scomber scombrus* [62].

In our opinion, this aspect of the composition of coastal fish assemblages deserves attention. In fact, a large predation on jellyfish could be considered the response of a healthy ecosystem to the cnidarian blooms: in recent years we have frequently observed evidence of this in the Ligurian Sea.

4. Conclusions

The offshore waters of the Ligurian Sea host a rich, large pelagic fauna, which, besides the cetaceans to which the Pelagos Sanctuary is dedicated, includes pelagic sharks, turtles and large bony fish both of surface and mesopelagic waters.

Swordfish and tuna play an important role in the natural ecosystem and as fishing resources. Given the artisanal characteristics of Ligurian fisheries in terms of the number of boats, gross tonnage, gear, etc. [1], it is clear how these have a limited impact on large pelagic nekton. In general, this is the case for all professional fishing activities of the Ligurian Sea, including those considered the most destructive, such as trawling. It must be remembered that the total number of Ligurian trawlers does not reach the number present in a single port in other regions.

Trends in fishing and the biological characteristics of the large pelagic fish observed in the Ligurian Sea over the past 20 years do not show any alarming aspects. On the contrary, there has been a negative trend of in the number of sharks caught [62,66,67]; sharks are probably not resident, but are characterised by seasonal appearances.

The case of bluefin in the Ligurian Sea is peculiar, because the study area hosts only a fraction of the fished stock formed by young individuals. In contrast to other Italian areas where there are tuna traps aimed at spawners, we have not observed reductions in total catches, or in fish size. The current characteristics of juveniles are of the same as those observed 20 years ago.

Certainly there are many problems regarding large pelagic fish at a Mediterranean scale: illegal unregulated unreported (IUU) fishing activities by EC and non-EC countries target both swordfish and tuna. For swordfish, one of the most relevant problems is due to Moroccan driftnets in the Alboran Sea and west of Gibraltar, which threaten not only the target fish, but also selachians and cetaceans. For bluefin, purse seiner catches in all Mediterranean waters are confined to caging activities: in terms of transported fish, the real quantities involved remain unknown. So-called tuna farming, or capture-based aquaculture, consists of the fattening, over months, of captured specimens and employs huge quantities of edible fish (both local and imported). This practice is considered highly profitable given the high price commanded by the farmed tuna compared with the low commercial value of the small pelagic fish used as tuna feed.

Apparently nobody is calculating the costs to the ecosystem, other than those associated with the presence of organic waste in the proximity of the cages, but the small pelagic fish used as food include the competitors and also the consumers of jellyfish.

Global changes seem to include jellyfish blooms [68–71]; anthropogenic causes possibly involved include pollution and overfishing, and a reduction in the numbers of top predators is frequently cited as a possible cause. However, large pelagic top predators only occasionally eat jellyfish, whereas regular feeding can be observed in smaller species such as small scombrids and carangids [64,65], which since our study about 10 years ago has resulted in growth at the Camogli tuna trap. So, in the Ligurian Sea we have the answer of a healthy ecosystem to jellyfish blooms and if a relationship does exist between bluefin tuna and jellyfish blooms, in our opinion, it must be associated with farming activities which consume large quantities of local small pelagic fish. Tuna farms, luckily, have never existed in the Ligurian Sea.

Large migratory fish cannot be separated by supranational management (ICCAT), however, local traditions and ancient fisheries should not be ignored. In the secular history of bluefin tuna fishing, the establishment and management of tuna traps were frequently in the hands of Ligurian families [72]. However, large tuna traps were never implanted in the Ligurian Sea, where, by contrast, tens of small traps have been active between La Spezia and Marseille for over four centuries. The reason for this is that Ligurian bluefin are typically young individuals. Moderate fishing of young bluefin was apparently not destructive, nor would it be today after the dismission of purse seiners. We hope for a future of regular artisanal fishing and the continuing absence of tuna caging.

Lesser species, such as bonito and bullet tuna, could be further exploited by fishermen, in part to offset losses caused by recent European regulations.

Acknowledgements

National funding (Ministero delle Politiche Agricole, Alimentari e Forestali, Law n° 41/1982) and EC Projects (DG XIV) are gratefully acknowledged.

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