THE PELAGOS SANCTUARY IN THE LIGURIAN SEA: OUR LONG TERM STUDIES ON DEEP FAUNA[1]

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ABSTRACT

The authors, on the basis of the research they have been carrying out since the seventies, summarise the main characteristics of the Pelagos Sanctuary in terms of its bathyal and mesopelagic communities as well as its pelagic food webs. At the macrofaunal level of these webs, *Meganyctiphanes norvegica* is the key species and a *M. norvegica* - *Pasiphaea sivado* system regards a sizeable vertical space. Two basic oceanographic processes that generate upwelling are at the basis of a high biodiversity, which includes large charismatic pelagic species such as fin whale and bluefin tuna.

KEY WORDS: Macrobenthos, bathyal, mesopelagic, food webs, Mediterranean Sea, *Meganyctiphanes norvegica*.

INTRODUCTION

The Pelagos Sanctuary (Fig. 1), better known as the Sanctuary for Marine Mammals in the Mediterranean (www.sanctuaire-pelagos.org/it/) (Italian Law no. 391 of 11 October 2001, G.U. 253 of 30 October 2001), covers a surface area of 87,000 km^2, in large part in the Ligurian Sea (North-Western Mediterranean), where, mainly in the western part, the water is on average 2,500 m deep, a zone especially suited for studying deep fauna and its relationship with surface water and with both marine and atmospheric local oceanographic dynamics.

The aim of this paper is to summarise the main results obtained in the last few decades by means of our studies on faunistic and trophic subjects (key species, food webs) regarding the bathyal sea bed and the mesopelagic environment of the Ligurian Sea.

[1] These notes are a revision of a text prepared for the 49° SIBM Congress (2018, Cesenatico), theme "Deep Mediterranean: exploration, research and conservation" chaired by Renato Chemello.

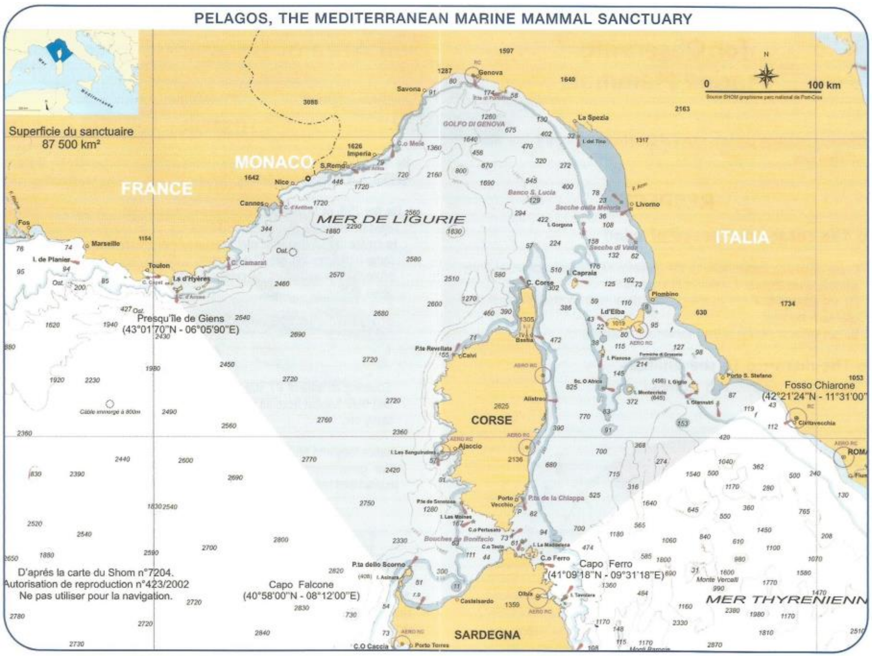

Figure 1. Pelagos, the Mediterranean Marine Mammal Sanctuary.

The oceanographic background

The circulation of water masses in the Ligurian Sea is of great interest because it is the ‘driving force’ which, together with the contribution of the system's northern winds, is responsible for the wealth of life in offshore waters. A Danish oceanographic expedition (Nielsen, 1912) described the presence in the Gulf of Genoa of three water masses: surface Atlantic water (AW), Levantine Intermediate Water (LIW) and Western Mediterranean deep water (WMDW). The large-scale dynamics of the Ligurian Sea are characterised by a wide-ranging and well-defined (anti-clockwise) cyclonic circulation that involves the entire basin and both the surface layer of AW and the intermediate layer of LIW to a depth of 600-700 m. The surface current (today called MAW, Modified Atlantic Water) coming from Gibraltar flows along the western coasts of Sardinia and Corsica and reaches the Gulf of Genoa, where it meets the Eastern Corsica Current (Fig. 2) generating the Northern Current (known locally as the Ligurian Current); this current is about 20 km wide and 150 m deep, with a mean annual flow of 1,8-2 million m^3/sec.

The current, permanent all year round, creates a transition area (front) where intense vertical movements of water, both downwards (convergences) and upwards (divergences) (Fig. 3) enrich and mix the nutrient salt content and also transfer organic particles and living plankton to deep consumers (Boucher et al., 1987; Sournia et al., 1990). The winds, in particular those coming from the north in winter, are the second most important factor of enrichment of the water; bearing low temperatures and favouring evaporation, they form dense surface water and vertical convective movements (downwelling) balanced by upwelling and the arrival of nutrients at surface level. This process also produces the formation of deep water (Jacques, 1990, 1994; Millot, 1999), an event occurring in few zones in the Mediterranean, and leads us to regard this sea as a miniature ocean (Lacombe, 1988, 1990; Astraldi & Gasparini, 1992). This complex oceanographic context explains why the offshore waters in the Ligurian Sea are much more productive (nutrient rich) than the coastal ones (Jacques, 1990, 1994).

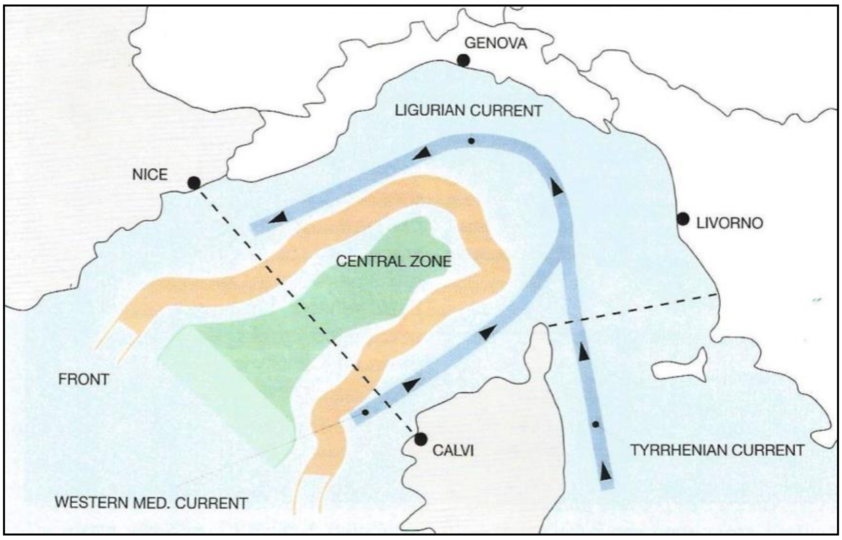

Figure 2. Main currents and associated dynamic structures in the Pelagos Sanctuary.

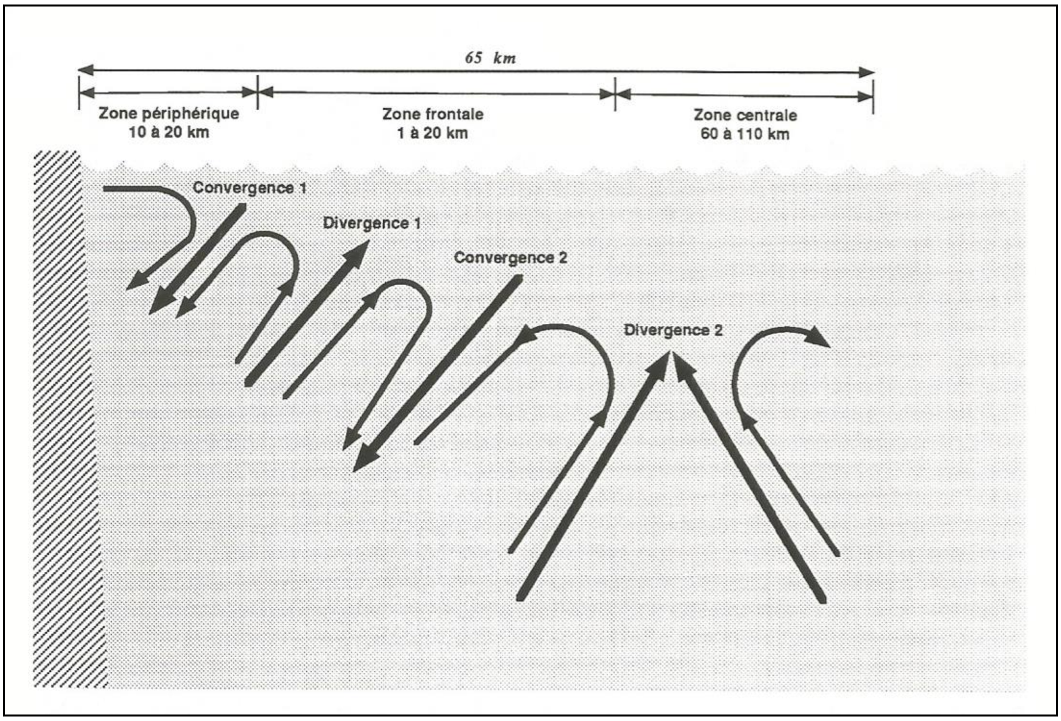

Figure 3. The Liguro-Provençal front with its vertical convergences and divergences (Jacques, 1994).

MATERIALS AND METHODS

Studies in deep waters using Ligurian Sea trawlers

A) Our studies began in 1970 on a voluntary basis and at the request of eastern Ligurian fishermen worried about the progressive reduction of red shrimp catches and interested to find out about possible predators and/or competitors of the shrimps. Red shrimps, *Aristeus antennatus* (Risso, 1816) and *Aristaeomorpha foliacea* (Risso, 1827), are the most important resource of this kind of fishery. All previous studies were based on landings. Working onboard, we were able to measure each day's entire catch (sometimes amounting to more than a thousand individual shrimps with the identification of instars) and directly observed the technical details of the fishing operations.

B) In the period 1977-1981, scientific surveys were carried out as part of the CNR (National Council of Research) programme "Oceanography and marine bottoms".

C) From 1985 to 2004, trawl surveys were carried out yearly in all the Italian seas, supported by funds provided by Italian Law no. 41/82 (Relini, 2000).

D) In 1994, with partial support from the EC, the MEDITS (International bottom trawl survey in the Mediterranean) project (Bertrand et al., 2002) began and is still in progress. The list of fishing surveys and monitoring of landed catches in several Ligurian harbours were recorded in Relini (2007a).

Studies of deep pelagic fauna by IKMT

Fishing surveys using IKMT nets (4.5 m ISAACS-KIDD Midwater Trawl) (2×2 mm mesh in the cod end) (Figs. 4, 5) towed by oceanographic ships belonging to the CNR (R/Vs Marsili, Minerva, Urania) were carried out since the seventies above the slope and in the nineties along transects from the Ligurian coast to Corsica. The upper part (800-1000 m) of the water column of about 2500 m was investigated. Once on board, the catch was divided into main categories (in terms of volume): *e.g*. fish, krill *Meganyctiphanes norvegica* (M. Sars, 1857), decapod crustaceans, other crustaceans, molluscs and gelatinous macroplankton (*i.e*. jellyfish, ctenophores, salps, etc.).

Figure 4. Recovery of the ISAACS-KIDD Midwater Trawl by R/V Minerva (G. Relini).

Studies of feeding of large pelagic species

A. Besides making observations and carrying out sampling at sea, for example on the larger species of Cetaceans, we worked in continuous collaboration with the 'Centro Studi Cetacei' and the Museum of Natural History of Genoa.
B. In the nineties the Ligurian Sea was included in National and European Community research with the obligation to report to the ICCAT (International Commission for the Conservation of Atlantic Tunas) both the fishery and biological data necessary for the management of large pelagic fish.

Figure 5. The IKMT at sea. The presence of a diver gives an idea of the size of the net (M. Relini).

RESULTS

Bathyal biocoenoses and related fishery resources

A summary, with photographic documentation, of bathyal biocoenoses and associated fishery resources was recorded in Relini et al. (1986). The faunistic observations mainly regarded bottoms where *Nephrops norvegicus* (Linnaeus, 1758) (Fig. 6) and *Aristeus antennatus* (Fig. 7) were fished. In the Gulf of Genoa the bathyal zone can be divided into two levels, epibathyal and mesobathyal, as suggested by Pérès & Picard (1964) and locally confirmed by Relini Orsi & Relini (1982). The bathymetric limit between the two levels was set by the authors at about 450 m depth in connection with a change in macrofauna fished by otter trawl. For instance, epibathyal *Nephrops norvegicus* is replaced in the mesobathyal by *Geryon longipes* A. Milne-Edwards, 1882; *Plesionika heterocarpus* (A. Costa, 1871) is substituted by *P. acanthonotus* (S.I. Smith, 1882) and especially by *P. martia* (A. Milne-Edwards, 1883); and *Munida tenuimana* (G.O. Sars, 1872) replaces *M. intermedia* (A. Milne-Edwards & Bouvier, 1899), etc.

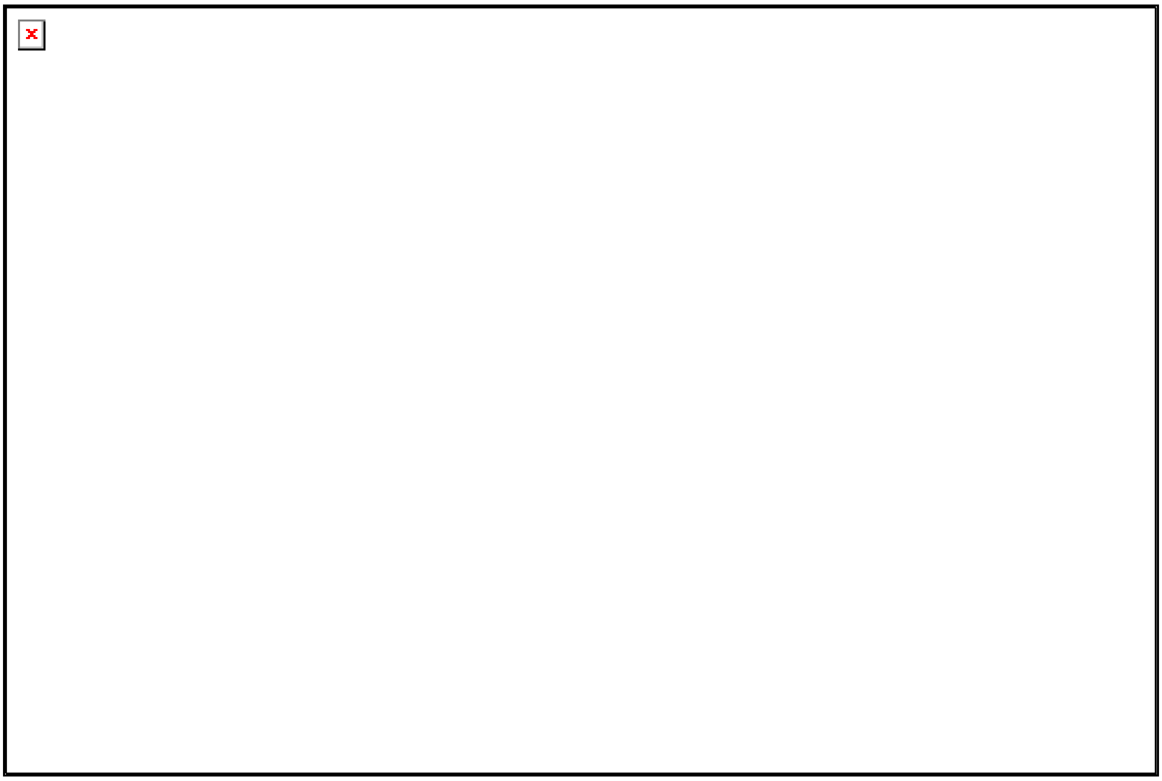

Figure 6. The typical bottom assemblage where Norway lobster (*N. norvegicus*) and blue whiting (*M. potassou*) are fished in the Ligurian Sea (G. Relini).

Figure 7. The bottom assemblage where red shrimps (*A. antennatus*) are fished in the Ligurian Sea (G. Relini).

Bathyal food webs

In relation to the food web of the red shrimp *A. antennatus* (Fig. 8), its own diet (Relini Orsi & Wurtz, 1977b) and the diet of the following species have been investigated: *Galeus melastomus* Rafinesque, 1810 (Relini Orsi & Wurtz, 1975), *Etmopterus spinax* (Linnaeus, 1758) (Relini Orsi & Wurtz, 1976, 1977a), *Mora moro* (Risso, 1810) (Relini Orsi, 1976a), *Geryon longipes* (Relini Orsi & Mori, 1977; Mori, 1982a), *Trachyrhynchus trachyrhynchus* (at present *T. scabrus* Rafinesque, 1810) (Relini Orsi & Wurtz, 1977b, 1979a), *Bathypolypus sponsalis* (P. Fischer & H. Fischer, 1892) (Relini Orsi & Wurtz, 1977b), *Chimaera monstrosa* Linnaeus, 1758 (Vacchi & Relini Orsi, 1979), *Nezumia aequalis* (Günther, 1878) (Relini Orsi & Wurtz, 1979b), *Paromola cuvieri* (Risso, 1816) (Mori, 1980), *Phycis blennoides* (Brünnich, 1768) (Relini Orsi & Fanciulli, 1981), and *Conger conger* (Linnaeus, 1758) (Mori, 1982b).

In these food webs, eurybathic micronekton (Euphausiids, Pasiphaeids, Sergestids, Oplophorids, etc.) is important as well as the small nektonic cephalopod *Heteroteuthis dispar* (Rüppel, 1844); some echinoderms as *Ophiocten abyssicolum* (Marenzeller, 1893) and the crustacean decapod *Calocaris macandreae* Bell, 1846 with a series of smallest benthic species are of importance on the bathyal bottoms (Fig. 8).

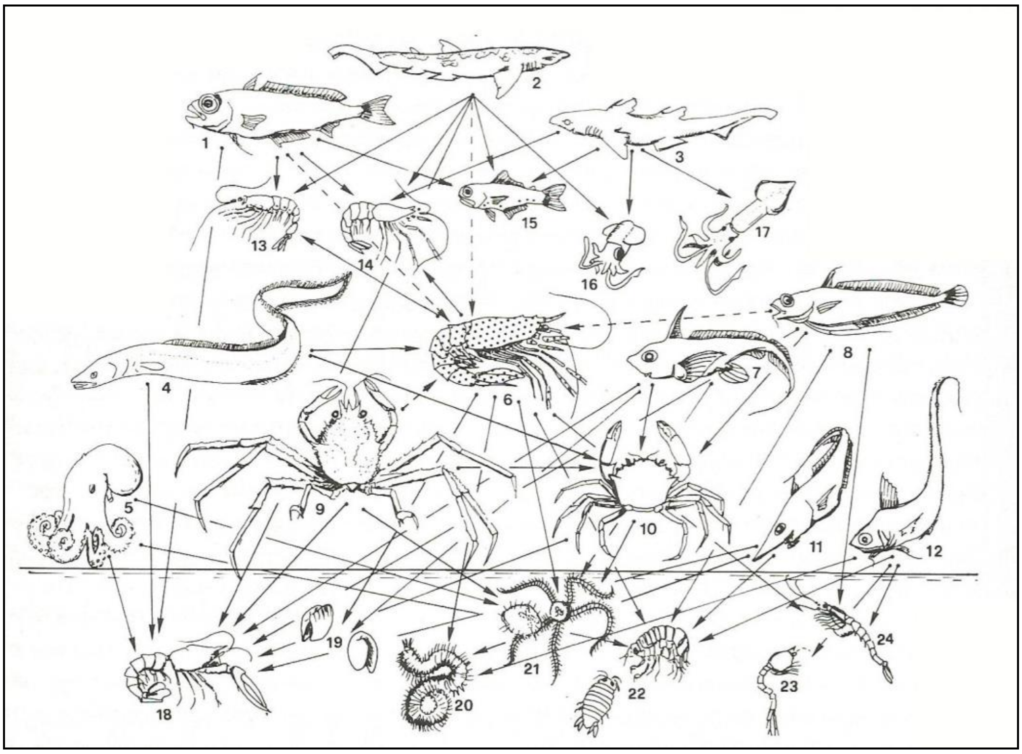

Figure 8. Food web concerning *A. antennatus* on the basis of knowledge of the diet of the main organisms investigated on the Ligurian bathyal fishing grounds. 1) *Mora moro*, 2) *Galeus melastomus*, 3) *Etmopterus spinax*, 4) *Conger conger*, 5) *Bathypolipus sponsalis*, 7) *Chimaera monstrosa*, 8) *Phycis blennioides*, 9) *Paromola cuvieri*, 10) *Geryon longipes*, 11) *Trachyrhynchus trachyrhynchus*, 12) *Nezumia aequalis*, 13) *Meganyctiphanes norvegica*, 14) *Pasiphaea multidentata*, 15) Myctophidae, 16) *Heteroteuthis dispar*, 17) Teuthoidea, 18) *Calocaris macandreae*, 19) Bivalvia, 20) Polychaeta, 21) *Ophiocten abyssicolum* and *Hemiaster expergitus*, 22) Isopoda and Amphipoda, 23) Cumacea, 24) Mysidacea (from Relini & Orsi Relini, 1987; drawing by M. Wurtz).

Two key species for the pelagic environment appeared to be *M. norvegica* and *Pasiphaea sivado* (Risso, 1816) (Figs. 9, 10). The abundance of the glass shrimp, *P. sivado*, in the Ligurian Sea was proved by catches using IKMT, observations made during trawl surveys and by the above-mentioned analyses of stomach contents. The glass shrimp proved to be an euryphagous consumer, with *M. norvegica* as its main prey. This predator-prey relationship enabled us to relate *P. sivado* abundance to that of *M. norvegica* and to indicate the two as a "*P. sivado* - *M. norvegica* system" that is more stable and durable than a single species (Orsi Relini & Relini, 1990). The abundance of euphausids and pasiphaeid shrimps in the offshore waters of the Ligurian Sea was in contrast to the poverty, already confirmed on many other occasions, of the coastal waters (Albertelli et al., 1981).

Figure 9. *Meganyctiphanes norvegica*, the krill of the Ligurian Sea. Juveniles on the left and adults on the right (M. Relini).

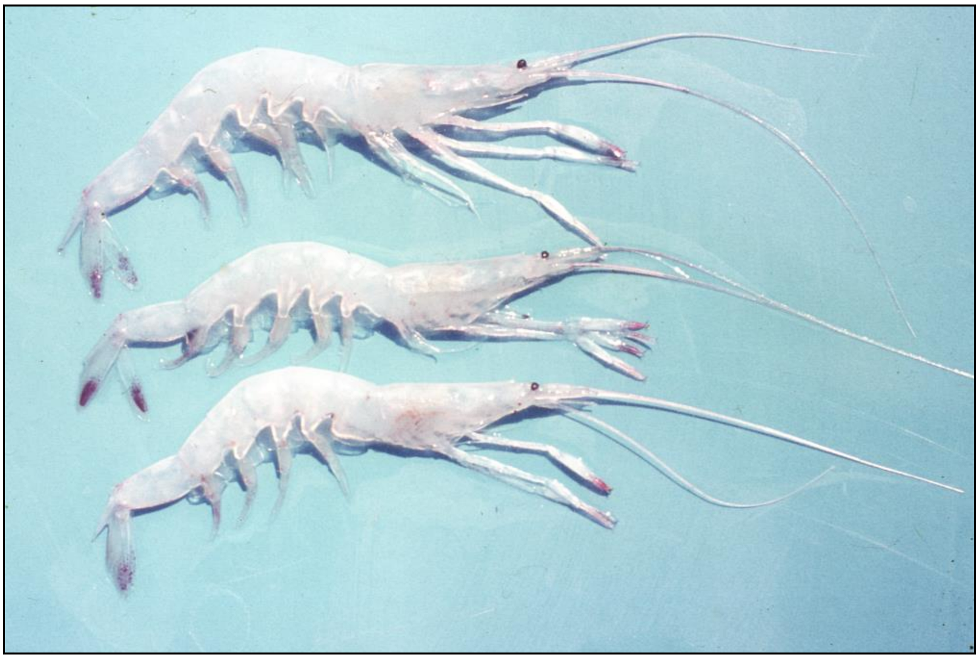

Figure 10. *Pasiphaea sivado*, the glass shrimp (M. Relini).

Meganyctiphanes norvegica

The abundance of *M. norvegica* is the main characteristic of the Cetacean Sanctuary, representing a unique phenomenon in the Mediterranean Sea; it was observed by IKMT surveys along transects from the Ligurian coast to Corsica (Orsi Relini et al., 1992; Relini et al., 1992, 1994). The effective consumption of the euphausid by *Balaenoptera physalus* (Linnaeus, 1758) has been checked analysing the faeces of finwhale (Orsi Relini & Giordano, 1992). A positive correlation between the quantity of *M. norvegica* in a zone (sampled with IKMT) and the number of finwhales observed in the same zone has been highlighted (Orsi Relini et al., 1992, see in the English version at page 276 the enclosure 1 prepared by F. Fiorentino; Relini et al., 1992). This euphausid is very important also in the diet of other large pelagic species (mammals, bony fishes, elasmobranchs) or of their prey as cephalopods.

A series of surveys have pointed out the fact that size structure and growth of *M. norvegica* (Fig. 11) are related to important horizontal displacements and to the circulation of the basin. In fact high biomasses are typically located approximately North of the 43°, in the same area where the adult component of the population is equal or prevails on the young group (Orsi Relini et al., 1998c).

Mature adults (or at least a consistent part of them) move to the coast for spawning and reach superficial waters at the end of winter. Sometimes they invade the shelf, with possibility of beaching. The coastal area of the Ligurian Sea seems to be a preferential site for spawning, given the frequency of beaching events recorded on the coast from Portofino to Monaco starting from those occurred in 1909 and 1913 (Issel, 1918). In any case, this spawning migration brings eggs in the Ligurian-Provençal coastal current, obtaining a maximum of transport and diffusion.

Large displacements of *M. norvegica* in the Ligurian-Provençal basin are known to its predators. It is interesting to notice that two main consumers of *M. norvegica*, the fin whale and the young bluefin tuna, are found in the Ligurian Sea especially in summer-autumn, in coincidence with the phase of rapid growth of the euphausiids and with the accumulation of fat reserves which precedes the reproduction. So *M. norvegica* is exploited at the maximum of its caloric values. At time of reproduction of *M. norvegica* (winter), both the majority of whales and tunas leave the area.

Cephalopods

Among 58 species of cephalopods recorded in the Italian seas (Bello, 2008), 54 (*i.e*. 93%) occur in the Pelagos Sanctuary and many of them (N=36) have also been found on trawlable bottoms; new species and/or subspecies sampled in the Ligurian Sea are under study. Direct sampling of mesopelagic fauna carried out by the method of midwater trawl (IKMT) during many different surveys gave a total of 18 cephalopod species, collected in a depth range of about 800 m. They include three meroplanktonic forms, namely, paralarvae of *Pteroctopus tetracirrhus* (Delle Chiaje, 1830), *Scaeurgus unicirrhus* (Delle Chiaje, 1841) and *Octopus defilippi* Verany, 1851 and 15 pelagic species. Histioteuthidae represent 47.3% of the total number, while the Sepiolid squid *Heteroteuthis dispar* (Rüppell, 1844) is the second most abundant species, followed by *Galiteuthis armata* Joubin, 1898, *Histioteuthis bonnellii* Ferrusac, 1835, *Chtenopteryx sicula* (Verany, 1851) and *Chiroteuthis veranyi* (Ferrussac, 1835). The analysis of top predators' stomach contents showed a different picture of cephalopod biodiversity, depending on the feeding habits of the single species. Swordfish feed upon a wide range of both mesopelagic and surface cephalopod prey, mainly *G. armata* and *T. sagittatus* (Lamarck, 1798) (Orsi Relini et al., 1995a), while Histioteuthidae are the main portion of ingested biomass for blue shark and cetaceans (Garibaldi & Orsi Relini, 2000; Garibaldi et al., 2009 and research in progress) (see below).

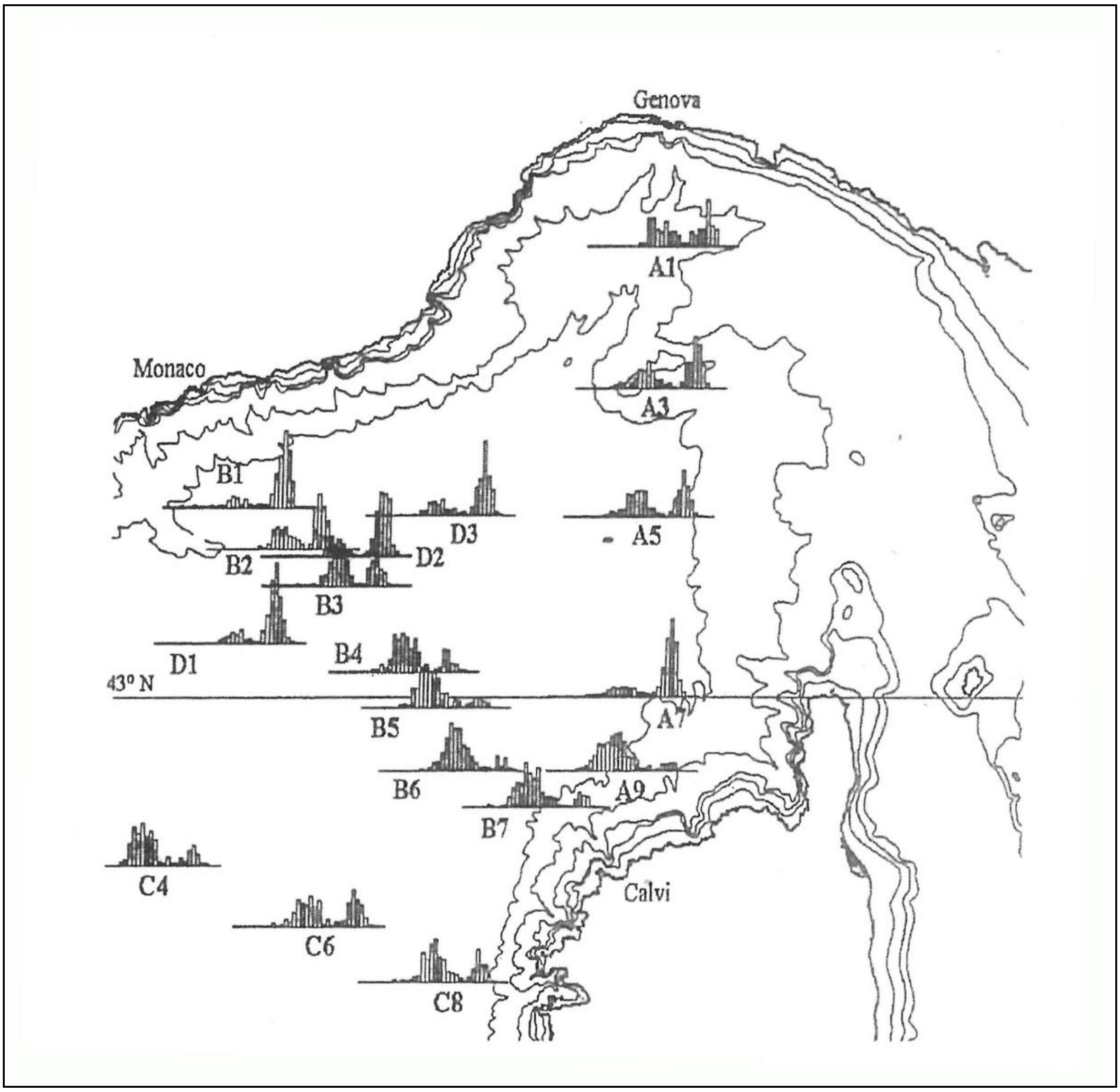

Figure 11. Frequency distribution of total length (from eye to telson) recorded in August 1991. Groupes of young *M. norvegica* prevail in the samples collected at the southern stations (from Orsi Relini et al., 1998c).

Small mesopelagic fish

Mediterranean small mesopelagic fish (size range of about 3-30 cm TL) are composed of nine families and about 40 species, untouched by fishing activities, but of great importance in the feeding of dolphins, swordfish and tuna, and indirectly also of teutophagous top predators. In particular, the most abundant cetacean in the sanctuary, the striped dolphin *Stenella coeruleoalba* (Meyen, 1833), feeds directly on small mesopelagic fish and cephalopods which are the two most important parts of its diet; a small portion of decapod crustaceans can be added. Among small mesopelagic fish only one species, *Lampanyctus crocodilus* Risso, 1810, can be found both in the water column and on mesobathyal trawlable bottoms. A comparison between our data (Orsi Relini et al., 2013) and those of the Smithsonian Expedition in 1970 (Goodyear et al., 1972) shows a uniformity of results, suggesting a stability across time of mesopelagic fish assemblages. For this reason, and because of their role in food webs, we have proposed considering small mesopelagic fish as a functional group useful for the description of GES (Good Environmental Status) of the MSFD (Marine Strategy Framework Directive) in oceanic areas of the Mediterranean such as that of the Pelagos Sanctuary (Orsi Relini et al., 2013).

Feeding of large pelagic fish and mammals

Stomach content analysis of large fish and Cetaceans shows that the mesopelagic community supports a large portion of the feeding of such top predators. In 1994 the mesopelagic community was described on the basis of an IKMT sample of 26932 fishes (40 species), 7135 Crustacean Decapods (13 species) and 93 Cephalopods (16 species) (Orsi Relini et al., 1994); of course, now more species are known.

a) Bluefin tuna are mainly represented by juveniles aged 0-4, starting from a minimum size of about 15 cm total length appearing in August. Their feeding is based on at least 30 species with the main biomasses due to small pelagic fish and/or krill, *M. norvegica* (Orsi Relini et al., 1998a,b). After reproduction adult fish of various sizes arrive in order to recover: Their feeding can be based on a richer range of fish prey and alternative krill predation remains possible.

b) Swordfish is present in the Ligurian Sea at all life-history stages. Their diet is based on at least 23 fish species, 18 cephalopods and 7 mainly mesopelagic crustaceans. Ingested biomass of three categories of prey is in the ratio 52:24:1 (Orsi Relini et al., 1998b). This diet partially overlaps with the diet of small dolphins.

c) *Stenella coeruleoalba* (Meyen, 1833). The most abundant cetacean in the Sanctuary feeds on small prey, both at surface and at mesopelagic levels. Its diet is similar to that of swordfish especially in the (uncommon) case that stomach content analysis regards healthy individuals accidentally killed in their offshore habitat. In this case small mesopelagic fish, mesopelagic cephalopods (*e.g.* Histioteuthidae), crustaceans (*e.g.* Sergestidae) and also krill can be observed (Orsi Relini, 1997). In cases where it is possible in the Sanctuary to study the stomach content of *D. delphis* Linnaeus, 1758 associated with *S. coeruleoalba*, the prey is similar in the two dolphin species (Orsi Relini & Relini M., 1993).

d) Medium-sized Cetaceans such as *Globicephala melas* (Traill, 1809) and *Grampus griseus* (Cuvier, 1812) (Orsi Relini, 1997) are more teuthofagous. These studies began with the stomach content of a long finned pilot whale of 3.5 m total length captured in the Eastern Ligurian Sea (Orsi Relini & Garibaldi, 1992). The content was made up entirely of Cephalopods (4 Families were represented) and formed an estimated biomass of 16.7 kg. This weight probably corresponded to more than one meal. According to the data of different geographical areas the pilot whale may sometimes also take fish, amounting to about 10% of total weight of food.

Ziphius cavirostris Cuvier, 1823. The gastric content of three deep-diving toothed *Ziphius cavirostris* whales stranded in the central zone of the Ligurian Sea, were examined. *Z. cavirostris* proved to feed 9 species of Cephalopods belonging to 7 Families: Histioteuthidae, Cranchiidae, Octopoteuthidae, Chiroteuthidae, Onychoteuthidae, Sepiolidae and Ommastrephidae (Orsi Relini & Garibaldi, 2005).

e) *B. physalus* can be present in the Sanctuary with all life-history stages and in fact the area includes a calving ground (Orsi Relini, 2000a). The feeding season apparently begins in spring (Relini et al., 1994) and in summer it is based only on *M. norvegica* in the area where the largest biomass occurs (Orsi Relini & Giordano, 1992).

f) Sperm whale *Physeter catodon* Linnaeus, 1758 also can be present with all life history stages. During our navigation in the Sanctuary we met sperm whales both in offshore and coastal waters (e.g. Capo Corso, Arenzano)[2]. Present studies on sperm whales in the Mediterranean (Mazzariol et al., 2018) confirm the existence of stomach contents composed of thousands of beaks in which Histioteuthidae are the dominant taxon.

g) Blue shark. *Prionace glauca* (Linnaeus, 1758) is the most common pelagic shark in the Sanctuary (Orsi Relini, 2000b) and has an important role as a scavenger. Accordingly, the diet includes a great number of items, birds included, with an average number of 8.7 prey items per stomach. A large amount of prey can be in the form of large-sized ammoniacal Cephalopods (Histioteuthidae), and it is supposed that these are slow swimming or dead individuals during or after their reproduction. In 71 stomachs 617 prey items belonging to about 30 species were identified: Cephalopods (N=569), Fish (N=14), Birds (N=10), Crustaceans (N=9), Cetaceans (N=6) and others (Garibaldi & Orsi Relini, 2000).

Bio-ecology of A. antennatus

After the first observations on *A. antennatus* reported above, the study of this species continued for a long period. In the eighties, while studying the reproductive biology (Relini Orsi & Relini, 1979; Orsi Relini & Semeria, 1983; Orsi Relini & Tunesi, 1987) it was established that the concentration of shrimps in the fishing zone in spring coincided with the meeting of adults of the two sexes and from summer to autumn with the presence of females ready to spawn. So the Ligurian custom of 6 months of mesobathyal fishery of red shrimps overlapped with the reproductive season of *A. antennatus*. The ovaric maturation and the fecundity of *A. antennatus* and *A. foliacea* were studied (Figs. 12, 13) and the former proved able to produce a larger number of eggs (Orsi Relini & Semeria, 1983).

After a period of red shrimp absence in the central and eastern Liguria (1980-84) (Relini & Orsi Relini, 1987) and two years of slow recovery with only a few large individuals (1985-86), in the summer of 1987 a large unexpected quantity of small shrimp appeared in the Gulf of Genoa and Western Liguria, allowing us to follow some cohorts across time and so to obtain interesting data on growth. The groups of recruits called the “1987 cohort” were made up of several subcohorts which we considered in terms of “instars”, that is to say, groups of individuals of the same size/age, separated by a moult. The 1987 cohort was followed in detail over a period of three years and the conclusion was that growth is slow and life span about nine years (Orsi Relini & Relini, 1998). The 1987 recruitment was revolutionary not only because the fishery became possible all year long but also because since then other recruitments have been observed at approx. 10-year intervals.

[2] In particular two young individuals met early in the morning off Arenzano gave the occasion to sample fecal materials in which was possible to recognize the skin of *Ocythoe tuberculata* Rafinesque, 1814. This record, unpublished, resulted new in respect of the enormous collection of materials assembled by M.R. Clarke (see for instance Clarke, 1986 and quoted references).

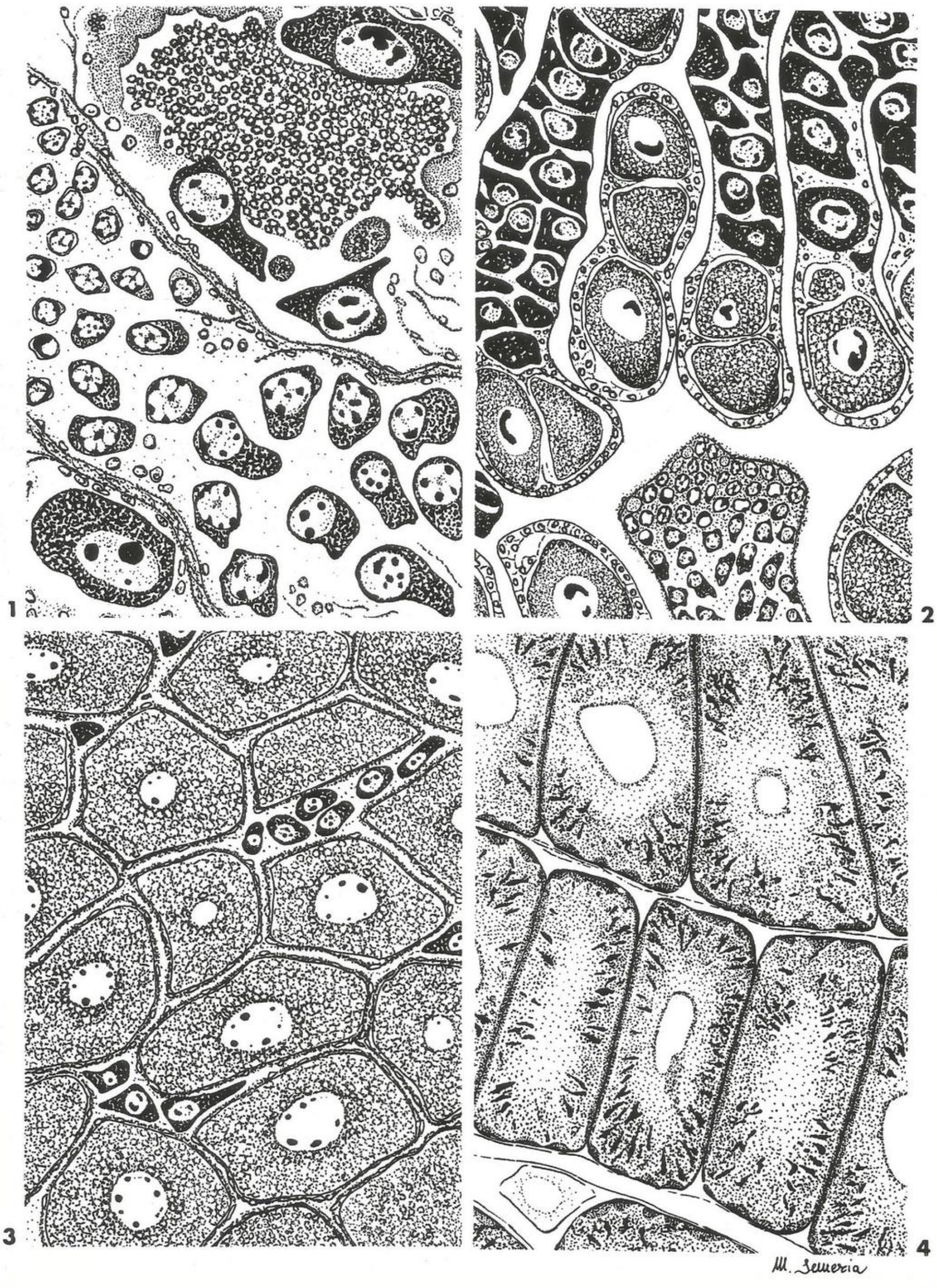

Figure 12. Drawings from the histological preparation of different ovarian stages. 1. *A. antennatus*: germinative centre and, above, ameboid oocytes phagocytizing yolk remnants of an abortive egg. 2. *A. foliacea*: early organization of tubular units composed of oocytes and follicular cells. 3. *A. antennatus*: hexagonal pattern of follicles in advanced maturation (‘light violet’ ovarian stage) (H.e. 160×). 4. *A. foliacea*: mucin-like substances in the peripheral cytoplasm in advanced maturation (‘dark grey’ ovarian stage) (Alcian-Blue-P.A.S. double stain 160×) (Orsi Relini & Semeria, 1983).

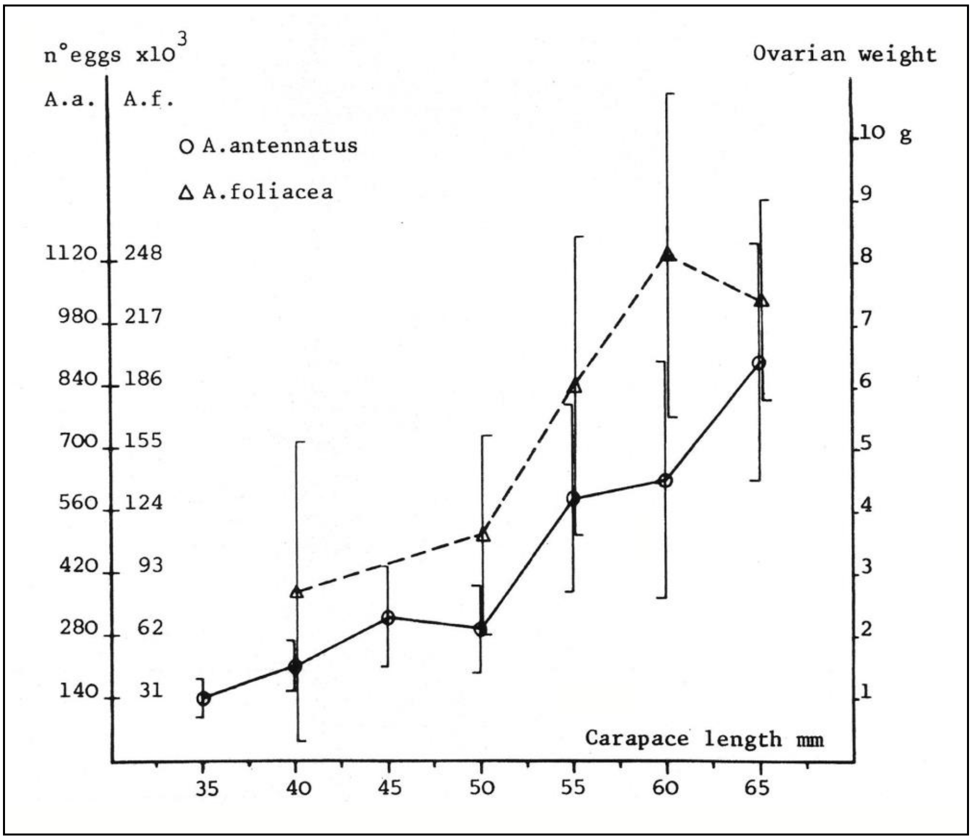

Figure 13. Fecundity of red shrimps. Weights of ripe ovaries in *A. antennatus* and *A. foliacea* of different carapace length. The number of eggs in thousands per g of weight is given on the left (Orsi Relini & Semeria, 1983).

Our results showed basic biological and ecological characteristics of this species. Large individuals (females ≥50 mm CL at age 5 onward) that are present in considerable percentages in the Ligurian Sea are very important because (i) their fecundity is very high and therefore greatly influences the reproductive potential and (ii) they represent the commercially most valuable part of the catch. In addition, substantial relationships between the life history of *A. antennatus* and local oceanographic processes exist because the long life span of the species enlarges the area to which eggs and larvae are transported in surface currents, as well as the active return movements in deep waters where adult life mainly takes place. In the study area, the Northern Current makes possible considerable horizontal displacement of *A. antennatus* eggs, larvae and early juveniles and, in general, attention to surface circulation may help identify affinities between distant Mediterranean populations. *A. antennatus* can be considered a species on the move on a Western Mediterranean large scale (Orsi Relini et al., 2012).

In recent years, much attention has been paid to climatic factors which possibly influence shrimp abundance: first maturity size decreased from 32 to 24 mm CL and the reproductive season, which in the past began in June/July, now starts in May (Orsi Relini & Relini, 2012).

Contributions to studies about biodiversity in the Sanctuary

During our studies, new records of deep fish, cephalopods and crustacean decapods occurred (Table 1).

Table 1. First record in the Ligurian Sea of deep fish, cephalopods, and crustacean Decapods.

FISH	**AUTHORS**
Paraliparis leptochirus (Tortonese, 1959) at present *Eutelichthys leptochirus* Tortonese, 1959	Relini Orsi & Relini, 1970
Bathypterois mediterraneus Bauchot, 1962 at present *B. dubius* Vaillant 1888	Tortonese & Relini Orsi, 1970
Oculospinus brevis Koefoed, 1927 at present *Cataetyx alleni* (Byrne, 1906)	Relini Orsi, 1971a
Physiculus dalwigki Kaup, 1858	Relini Orsi, 1971b
Coelorhynchus vaillantii Roule, 1916 at present *Caelorinchus mediterraneus* Iwamoto & Ungaro, 2002	Relini Orsi & Relini, 1971-72
Lesuerigobius friesii (Malm, 1874)	Relini Orsi & Relini, 1971-72
Bathophilus nigerrimus Giglioli, 1882	Relini Orsi & Relini, 1973
Cataetyx laticeps Koefoed, 1927	Relini Orsi & Gavagnin, 1974
Bellotia apoda Giglioli, 1883	Relini Orsi, 1976b
Nezumia aequalis (Günther, 1878)	Relini Orsi & Wurtz, 1979b
Synagrops japonicus (Döderlein, 1883)	Orsi Relini, 1990
Beryx splendens Lowe, 1834	Orsi Relini *et al*., 1995b
Carcharhinus falciformis (Müller & Henle, 1839)	Garibaldi & Orsi Relini, 2012
Gaidropsarus granti (Regan, 1903)	Orsi Relini & Relini, 2014
CEPHALOPODS	
Stoloteuthis leucoptera (Verrill, 1878)	Orsi Relini & Massi, 1991
Opisthoteuthis agassizii Verrill, 1883 at present *Opisthoteuthis calypso* Villanueva, Collins, Sánchez & Voss, 2002	Orsi Relini *et al*., 2001
DECAPODS CRUSTACEANS	
Pontophilus norvegicus (M. Sars, 1861)	Relini Orsi & Relini, 1972
Palinurus mauritanicus Gruvel, 1911	Relini Orsi & Relini, 1972
Ebalia nux A. Milne Edwards, 1883	Relini Orsi & Relini, 1972
Medaeus couchi (Couch, 1851) at present *Monodaeus couchi* (Couch, 1851)	Relini Orsi & Relini, 1972
Ergasticus clouei A. Milne Edwards, 1882	Relini Orsi & Relini, 1972
Acanthephyra eximia S.I. Smith, 1884	Relini Orsi, 1973
Galathea strigosa (Linnaeus, 1761)	Relini Orsi, 1973
Homola barbata (Fabricius, 1793)	Relini Orsi, 1973
Parthenope macrochelos (Herbst, 1790) at present *Spinolambrus macrochelos* (Herbst, 1790)	Relini Orsi, 1973
Funchalia woodwardi Johnson, 1868	Relini Orsi & Costa, 1975
Pandalina profunda Holthuis, 1946	Relini Orsi & Vacchi, 1978
Munida rutllanti Zariquiey Alvarez, 1952	Orsi Relini & Garibaldi, 2012

The most surprising first record (Orsi Relini & Relini, 1972) (not only for the Ligurian Sea but for the Italian seas) regarded the pink spiny lobster, *Palinurus mauritanicus* Gruvel, 1911, with an individual of about 7 kg (Fig. 14), fished by a trawler of the Santa Margherita Ligure fleet at 400 m depth off Punta Mesco (La Spezia) in 1960. The species proves to be quite common on the Ligurian sea mounts investigated using ROV by the research group of Prof. G. Bavestrello (ROV records which have been kindly showed to us by Marzia Bo).

Figure 14. The pink spiny lobster *Palinurus mauritanicus* fished off Punta Mesco (La Spezia) (photo kindly supplied by Andrea Ghiardello, fish-market keeper from S. Margherita Ligure during the 1960s).

Results dissemination

For students and other possible stakeholders a popular booklet (Fig. 15) has been published containing contributions from 16 authors belonging to Genoa University and CNR (Relini, 2007b).

An English edition is also available (http://www.minambiente.it/biblioteca/quaderni-habitat-n-16-dominio-pelagico-il-santuario-dei-cetacei-pelagos).

Discussion

We have tried to summarize long researches involving an area of the Ligurian Sea which has now taken on Mediterranean-wide importance under the name ‘Cetacean Sanctuary’.

Our studies began in collaboration with professional fishermen who are generally the best experts on the local environment and its marine fauna. We received major help from the work of researchers active at our University in the past (19th and 20th centuries) such as Corrado Parona and Raffaele Issel. Indeed, C. Parona, who was also chancellor of the University of Genoa, studied both Cetaceans and bluefin tuna and more in general the fishery in the Ligurian Sea and its local details (Parona, 1897, 1898, 1919). His data on neritic waters enabled us to chart significant changes in the species present on the Genoa fish market. Some species are no longer available, as they are either absent or very rare in fishery catches.

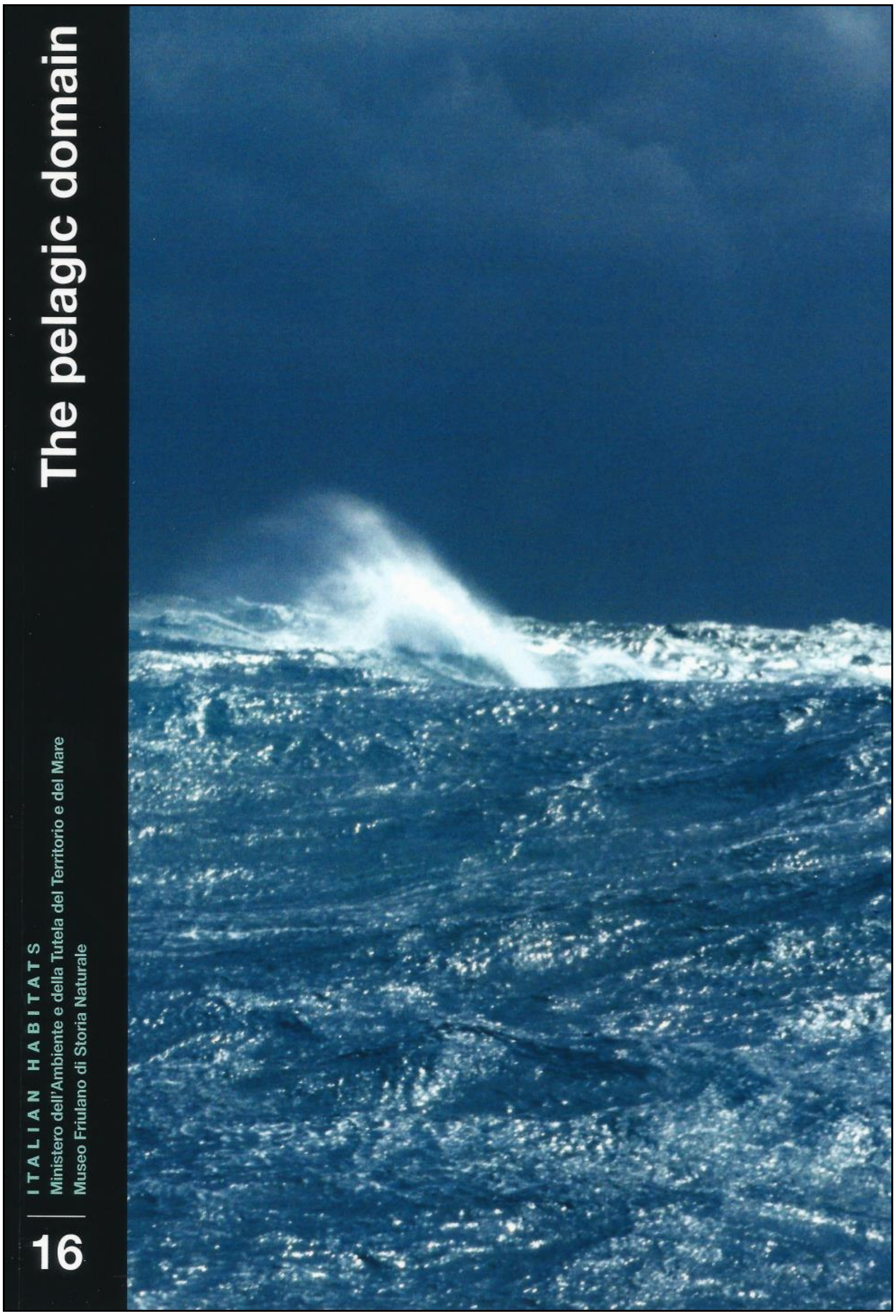

Figure 15. The cover of the booklet "The pelagic domain", Italian Habitats no. 16.

The first half of the twentieth century saw the appearance of the first Italian treatise on "Marine Biology" written in Genoa by Raffaele Issel (Manuali Hoepli, Milan, 1918). Issel directly observed the transformation of local fishery from sail to motorised navigation, which brought with it the opportunity to move from neritic waters to the slope. When new species began to appear in fish markets, he immediately understood their importance and organised a research project together with Alessandro Brian and Renato Santucci (Relini, 2015). Most of the results obtained, still now of great importance, were published in the 'Bollettino dei Musei di Zoologia e Anatomia Comparata della R. Università di Genova', an old name of Bulletin of Environmental and Life Sciences.

Mainly for trophic reasons, the organisms of trawlable bottoms are closely linked to those living in the water column. The high biomass of *M. norvegica* present in the Pelagos Sanctuary is the main biological characteristic of this zone and as far as it is known the most sizeable in the Mediterranean. Large pelagics like the fin whale and the bluefin tuna are aware of the abundance of krill and come to feed. Many other organisms feed directly or indirectly on krill. A direct correlation between number of fin whales and abundance of krill has been identified along specific transects from the Ligurian coast to Corsica (Orsi Relini et al., 1992). Measuring krill densities is more difficult than counting whales. A big vessel was required because the necessary gear was large and heavy. A comparison of the 4.5 m IKMT with lighter devices developed for other species of krill (a long experimental study regarding nets and vessels remained unpublished) showed that the latter were less efficient. Therefore cooperation with CNR Institutes and oceanographic ships was essential. After identifying the feeding area (Orsi Relini & Giordano, 1992), attention to times, sizes and locations of young fin whales (only measured individuals) showed that births occur in the sanctuary (Orsi Relini, 2000a). The mother-calf relationship lasts a long time (about 1 year) and includes cultural transmission with regard to places and modalities of feeding (Orsi Relini & Vallarino, 2017). For fin whales the coincidence between place of feeding and place of birth means that in autumn the future mother can use her food when the other whales have left the area; also any possible competition with other species is limited. Another calving ground, which has been known since Roman times, is located near Gibraltar (Orsi Relini et al., 2004). Movements of fin whales entering or leaving the Mediterranean are at present documented by a series of new studies (genetic investigations, satellite tagging, acoustic data, stable isotopes, etc.) which unfortunately have not reached the phase of general consensus.

CONCLUSIONS

The deep fauna of the Pelagos Sanctuary is very rich in terms of diversity, in particular in bathyal and mesopelagic environments, and contributes to a complex system of food webs which also involve species that are important in terms of fishery and conservation, such as bluefin tuna and cetaceans. This huge heritage of biodiversity must be protected and carefully managed.

Nominally, the Pelagos Sanctuary was established to protect mammals in particular cetaceans, but habitat protection is essential to the safeguarding of any species, so the Pelagos Sanctuary has had - and we hope will continue to have in future (no matter under which name) - a fundamental role in the protection and conservation of areas of broad and complex biodiversity and associated food webs. At present some components of food webs, like the key species *M. norvegica*, are not harvested by man in the Mediterranean but other components could be; luckily another main component, small mesopelagic fishes, remains untouched. Cephalopods may be a target fishery but this occurs primarily for benthic and demersal species and less for pelagic species. We reaffirm the basic importance of maintaining nutrition for large pelagic species by strictly banning the fishery of krill, small mesopelagic fish and pelagic cephalopods. However, we should also point out that past local fishing activities, on a smaller scale than present activities, certainly played a part in the conservation of the Ligurian heritage.

ACKNOWLEDGEMENTS - The authors are sincerely grateful to the fishermen of the Ligurian fleets and in particular to the late Benedetto Paccagnella from S. Margherita Ligure, Salvatore Portera from San Remo, and Adriano Andreis from Sori - skippers and owners of their vessels. We remember very fondly the kind collaboration and hospitality they offered us on board their trawlers and other fishing boats over the course of many years. We are grateful for the crucial collaboration provided by the oceanographic ships of the CNR. We would especially like to thank Dr Antonio Siccardi (Istituto per l'Automazione Navale, I.A.N., CNR, Genoa), Dr. Mario Astraldi and Gian Piero Gasperini (Istituto per lo studio della Dinamica delle grandi masse, CNR, Stazione Oceanografica c/o Centro ENEA Santa Teresa, La Spezia). The authors also wish to express their gratitude to the crews of the various oceanographic ships and all the students that have participated in the work both on board ships and in the laboratory. We are sincerely grateful to the Editors of the journal, prof. Loris Galli and coll. for their great care. We would like to acknowledge the assistance of Dr Rossana Simoni and Dr Sara Queirolo in editing this paper.

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DOI: 10.15167/2612-2960/BELS2019.1.1.1069