SOUTHERN SPECIES IN THE LIGURIAN SEA (NORTHERN MEDITERRANEAN): NEW RECORDS AND A REVIEW.

SPECIE TERMOFILE IN MAR LIGURE: NUOVE SEGNALAZIONI E REVISIONE CRITICA

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ABSTRACT

A total of 20 epibenthic species, which can be qualified as warm-water elements, are reported in the Ligurian Sea. Their increased occurrence in the last few years deserves attention as a possible biological effect of climatic change and consequent sea water warming.

KEY WORDS

Marine biogeography, dispersal, climatic change, benthos, Ligurian Sea, Mediterranean Sea

INTRODUCTION

From a biogeographical standpoint, the Mediterranean Sea constitutes a well-defined unit (BRIGGS, 1974; VERMEIJ, 1980). Nevertheless, the vastness of the basin, its tormented geological history (MALDONADO, 1985), and the many climatic and hydrological influences upon it, caused an obvious differentiation within the marine biota of this sea (CIESM, 1981; PÉRÈS, 1985; TORTONESE, 1985). Thus, up to ten different "biogeographical sectors" are usually distinguished within the Mediterranean (PÉRÈS & PICARD, 1964; FREDJ, 1974).

As a whole, the major differences in species composition and community physiognomy occur along a North-South axis. The Tyrrhenian Sea is the sector inhabited by the most typical Mediterranean flora and fauna, with most endemic species and

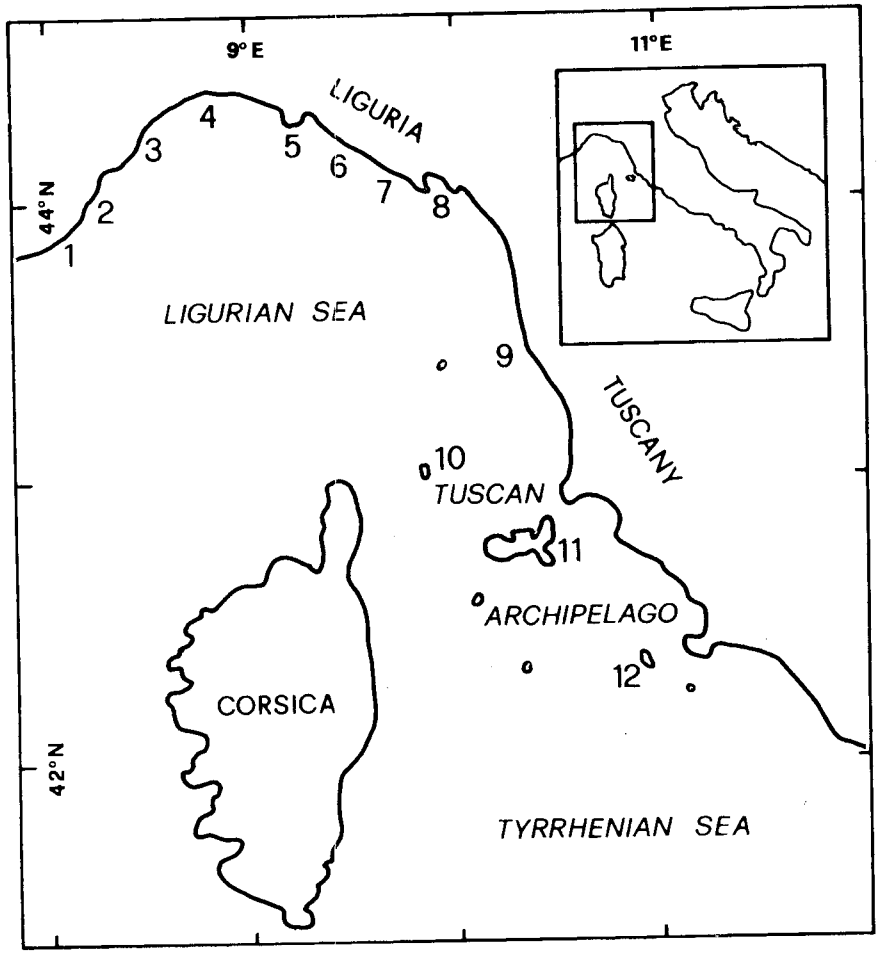

Fig. 1 - Geographical setting of the area in the north-western corner of the Mediterranean, showing the boundary between Ligurian and Tyrrhenian seas (Tuscan Archipelago). Numbers indicate places mentioned in the text: 1) Imperia; 2) Gallinaria; 3) Bergeggi; 4) Genoa (including Cogoleto and Quarto); 5) Portofino (including Camogli, Rapallo, and gulf of Tigullio); 6) Punta Manara; 7) Cinque Terre; 8) islands (including Tino) and coast near La Spezia; 9) Leghorn; 10) Capraia; 11) Elba; 12) Giglio.

Atlantic-Mediterranean elements, plus a fairly high percentage of species with subtropical affinities. The Ligurian Sea, situated to the north, is colder, and thus characterized by a very marked diminution of the subtropical element and by the presence of some species from cold-temperate waters which seem to be missing elsewhere. This gives the Ligurian Sea a boreal affinity (Rossi, 1969;

ALBERTELLI *et al.*, 1981; CATTANEO VIETTI *et al.*, 1988). The physical oceanography of the Tyrrhenian and Ligurian seas is summarized by TAIT (1985), whereas a closer view of different aspects of Ligurian Sea oceanography can be found in FANUCCI *et al.* (1990) and DAGNINO *et al.* (1990). The biogeographic boundary between Tyrrhenian and Ligurian Sea can be set at the Tuscan Archipelago (CASTELLI *et al.*, 1988; LARDICCI *et al.*, 1990) (Fig. 1).

Of course these kinds of boundaries are never sharp, and occurrences of southern, warm-water species in the Ligurian Sea have been reported from time to time. Such occurrences have always been explained as being tied to the presence of "thermophilic oases" (TORTONESE, 1958; SARÀ, 1985) at particular sites, which were supposed to enjoy warmer local conditions thanks to topography and shelter from cold northern winds.

In the last few years, we found some of these species to be more frequent and widespread in the Ligurian Sea than expected. The present paper is intended to report these findings, and to review them together with literature data. Finally, an attempt will be made to critically discuss the occurrence of warm-water species within the frame of different hypotheses.

MATERIALS AND METHODS

Warm-water species in the Ligurian Sea were observed during routine environmental monitoring work done by the diving scientists of the Centro Ricerche Ambiente Marino (CRAM) of ENEA in S.Teresa (La Spezia). Periodical SCUBA diving cruises are carried out every year in different sites between the Tuscan Archipelago and the western Ligurian Sea. Underwater work is aimed to survey epibenthic communities and uses mainly line-transects (BIANCHI *et al.*, 1991). The principal survey areas in recent years have been: Gallinaria Island (Western Riviera), Portofino (Gulf of Genoa), the islands and coast near La Spezia, and some of the islands of the Tuscan Archipelago.

Ligurian Sea records of southern species from the literature (see BIANCHI et *al.*, 1987, for references) are also taken into account in the present paper.

RESULTS

A total of 20 benthic species, which can be qualified as warm-water elements, have been observed by ourselves or quoted in the literature. A number of mostly pelagic fishes, more frequently seen

in the last three years than ever, have been added to these by BIANCHI & MORRI (1993): in this paper, however, we shall discuss exclusively epibenthic species, including reef fishes. Species are referred to in alphabetical order within higher taxa.

Algae

Acrothamnion preissii (Sonder) Wollaston - Found at Gallinaria Island, September 1991, on dead Posidonia mats and on stony bottoms, 8 to 15 m depth. *A. preissii* is an Indopacific species first discovered in the Mediterranean near Leghorn (CINELLI & SARTONI, 1969). Its distribution and ecology in this sea have been recently summarized by CINELLI *et al.* (1984).

Caulerpa prolifera (Forsskål) Lamouroux - Mentioned as abundant in the late 50s near Portofino (TORTONESE, 1958, 1962), it was not found in the 80s, although actively sought (MORRI *et al.*, 1988). However, it was found again in the summer of 1991 (TUNESI & VACCHI, in press). *C.prolifera* is a warm-water species reaching its northern limit in the Ligurian Sea, where it was considered by MEINESZ (1980) to be in a state of regression.

Cystoseira spinosa Sauvageau - Found at the Island of Bergeggi in June 1988 and at Gallinaria Island in September 1991; in both cases on dead *Posidonia* mats, at about 10 m depth. According to GIACCONE & BRUNI (1973), this species can mainly be found in the southern part of the Mediterranean.

Dasycladus vermicularis (Scopoli) Krasser - Found on coarse biodetritic sand at 20 m depth at Gallinaria Island, in September 1991. *D.vermicularis* is an element of tropical Atlantic origin, never found before in the Ligurian Sea. According to CINELLI (1979), the growth of *Dasycladus* in the northwest Mediterranean is restricted to the first few meters depth: the present record, therefore, is to be considered not only as the northernmost, but also as particularly deep.

Galaxaura oblongata (Ellis & Solander) Lamouroux - Rather common in several sites of Gallinaria Island in September 1991, between 5 and 15 m depth on rocks among other algae. Also seen in July 1992 at 10 m at Tino Island (near La Spezia). Regularly seen in the last five years at Giglio Island (Tuscan Archipelago). *G. oblongata* is a circumtropical species (PAPENFUSS *et al.*, 1982), previously found in the Ligurian Sea at Portofino (TORTONESE, 1958). Its thermophilic character was underlined by TORTONESE (1962).

Penicillus capitatus Lamarck - Found at Gallinaria Island in September 1991, on dead *Posidonia* mats, at 10-15 m depth.

Regularly seen in the last five years at Elba and Giglio islands (Tuscan Archipelago). *P. capitatus* is a tropical Atlantic species, reaching the northern limit of its range in the Mediterranean. MEINESZ (1980) reviewed its distribution in the Ligurian Sea and listed a series of historical records, concluding that in the present century it appears to have become rarer (however, it should be noted that Meinesz did his research in the seventies).

Pseudochlorodesmis furcellata (Zanardini) Boergesen - Found at Capraia Island in September 1985 (3 m depth), at the Island of Bergeggi in June 1988 (2-15 m), at Paraggi (near Portofino) in June 1989 (26 m), at Portofino in April 1991 (16 m) and July 1993 (6.5 m), at Gallinaria Island in September 1991 (7-11 m), always on rocky walls. Regularly seen at Giglio Island (Tuscan Archipelago) in the last five years. *P. furcellata* is a circumtropical species common on all western Mediterranean coasts (MEINESZ, 1980).

Sponges

Axinella polypoides Schmidt - We discovered in September 1991 an extremely rich population of this species at Gallinaria Island, at 35-40 m depth, and another small population at Punta Manara (30-33 m), in July 1993. TORTONESE (1958) was the first to notice the occurrence of *A. polypoides* in the Ligurian Sea. URIZ (1982) gives a detailed list of its records in the Mediterranean. According to our experience, this species seems to be by far more abundant in the southern Italian seas (*e.g.*, Sardinia, Apulia). *A. polypoides* is a warm-water species ranging from the Mediterranean to the gulf of Guinea: in the north-east Atlantic it is substituted by the sibling species *A. dissimilis* (Bowerbank), which has sometimes been considered a synonym (see DONADEY *et al.*, 1985, for a discussion about the distinction between the two species).

Cnidarians

Astroides calycularis (Pallas) - A dead colony of a dozen polyps was found in September 1989 under a overhang 6.5 m deep at Scoglio di Mezzo Franco (Giglio Island, Tuscan Archipelago): possibly it settled in one of the previous years, but did not survive the subsequent winter. *A. calycularis* is a typical and well known southern species, thriving in the south-west Mediterranean and Ibero-Moroccan Gulf. The northern limit of its range is the region of Naples, and it has never been found alive north of Ventotene Island, *i.e.* about 40°48' N (ZIBROWIUS, 1980).

Halocordyle disticha (Goldfuss) - Although the hydroid fauna of the Ligurian Sea has been well studied in the past (see BOERO & FRESI, 1986, for references), this species was found only once: Rapallo (near Portofino), June 1948 (ROSSI, 1950: *Pennaria d.*). It seems to have become more frequent in very recent years: we heard of its occurrence at Cogoleto (near Genoa) in the summer of 1988, and we saw it at Tino Island and in other sites of the Gulf of La Spezia in August 1987, July 1989, July 1990, July 1992, and October 1993, as well as at Portofino in July 1993, always on rocks in shallow waters (3-9 m depth). *H. disticha* is a circumtropical species which can be seen in the southern Mediterranean during summer (MORRI & BOERO, 1986).

Phyllangia mouchezi (Lacaze-Duthiers) - A living colony was collected in November 1992 at 35 m depth at Gallinaria Island (MORRI, 1992). Another colony was found at 28 m depth at Tino Island (Gulf of La Spezia) in November 1993. Previously recorded in the Ligurian Sea by ROSSI (1957: *Coenocyathus m.*), *P. mouchezi* is considered by ZIBROWIUS (1980) to be almost absent from the colder parts of the Mediterranean.

Molluscs

Charonia lampas lampas (L.) - We heard of the occurrence of this species on two occasions: in the late 70s, at Quarto (near Genoa), and the late 80s near La Spezia. DE LONGIS (1987: as *C. rubiconda*) reports a finding at San Lorenzo, near Imperia. TEMPLADO (1991) summarized the distribution of *Ch. l. lampas* in the Mediterranean: it occurs only in the western basin, being rare in the northern sector. According to RUSSO *et al.* (1990), the specimens found in cold areas may be derived from allochtonous larvae, since *Ch.l.lampas* has a planktonic, long-term, free-swimming larva (teleplanic).

Patella ferruginea Gmelin - We found this species to be very common at Capraia Island (Tuscan Archipelago) in the summer of 1985. It has been reported from the Ligurian Sea proper only twice, and only in very recent years (DE LONGIS, 1987; PORCHEDDU & MILELLA, 1991). In an older study of the species of *Patella* in the gulf of Tigullio (east of Portofino), ZOLEZZI (1942) did not mention it. According to PORCHEDDU & MILELLA (1991), who also provided a distribution map, *P. ferruginea* is a warm-water species which entered the Mediterranean during the Riss-Würm interglacial (Tyrrhenian II), and is now threatened with extinction also because of human harvesting.

Crustaceans

Calcinus tubularis (L.) - We recognized a specimen of this species in a vermetid tube at Gallinaria Island, June 1992, 3 m depth. *C. tubularis* is widely spread throughout the Mediterranean Sea, but more common in its southern parts (ZIBROWIUS, 1978: as *C. ornatus*). PÉRÈS & PICARD (1964: as *C. ornatus*) consider it as a typical thermophilic element.

Echinoderms

Centrostephanus longispinus (Philippi) - We saw a specimen at Portofino in June 1990 at about 30 m depth. Its occurrence in the Ligurian Sea was discovered for the first time at the beginning of the 70s (TORTONESE, 1975a). FRANCOUR (1991) updated and analysed knowledge about the distribution of *C. longispinus* in the Mediterranean, confirming the thermophily of this species, the only member of the tropical family Diadematidae in the Mediterranean Sea. Apparently it has become more common in the Ligurian Sea since 1985. Francour assumed that Ligurian specimens of *C. longispinus* arise from a distant zone of reproduction: the larvae could be emitted in the south of Italy (Naples, Sicily) and be transported by the «Liguro-Provençal» current.

Chaetaster longipes (Retzius) - This species was discovered in September 1991 at Gallinaria Island and turned out to be abundant at about 40 m during subsequent dives in 1992. TORTONESE (1957) considers *C. longipes* to be a thermophilic species: previous records in the Ligurian Sea date from 1956 (TORTONESE, 1957) and 1964 (PASTORINO & CANU, 1965). However, it is perhaps an infrequent species also in the rest of the Mediterranean (TORTONESE, 1965a). This last opinion is shared by ZIBROWIUS (1991), who explicity states that the presumed thermophily of *C. longipes* is likely to be a misinterpretation.

Hacelia attenuata (Gray) - We saw this species at Portofino in April 1991, at 31 m depth on the "coralligenous" bottoms of the so-called "Secca dell'Isuelo". It was very common at the "Formiche" of Capraia Island (Tuscan Archipelago) in September 1985, 15-20 m depth. TORTONESE (1957) was the first to notice the occurrence of this thermophilic species at Portofino: his records were confirmed several times in subsequent years (*e.g.*, TORTONESE, 1962; PASTORINO & CANU, 1965). Although the Portofino population of *H. attenuata* is apparently persistent, its presence also at Gallinaria Island in 1957 (TORTONESE, 1958) was not confirmed by our searching in 1991 and 1992.

Ophidiaster ophidianus (Lamarck) - A specimen of *O. ophidianus* was found at Capraia Island (Tuscan Archipelago) in the summer of 1985 at 15 m depth. In the Ligurian Sea proper, it has been found around Portofino promontory in 1896 and 1956 (TORTONESE, 1957), and in 1964 (PASTORINO & CANU, 1965). *O. ophidianus* is a thermophilic species of east tropical Atlantic origin, which in the Mediterranean is more frequently found south of Naples (TORTONESE, 1965a).

Fishes

Sparisoma (Euscarus) cretense (L.) - Three specimens (green phase) were observed in September 1991 at Giglio Island (Tuscan Archipelago) on rocky bottoms less than 10 m deep. *S. cretense* is a subtropical east Atlantic and south-eastern Mediterranean species (TORTONESE, 1975b), not known in Italian seas north of Sicily (BINI, 1968). It reproduces from August to October and has floating eggs (TORTONESE, 1975b).

Thalassoma pavo L. - The first time we saw this species in the Ligurian Sea was in September 1991 at Gallinaria Island, in very shallow waters (1-3 m depth). In the summer of the same year it had been seen at Portofino by amateur divers, and in October 1985 it had been encountered in the Cinque Terre, not far from La Spezia (RELINI *et al.*, 1988). We met it again in the summer of 1992 (Gallinaria) and 1993 (Portofino). Previous records in the Ligurian Sea were very scarce: one specimen in December 1902 at Camogli, near Portofino (TORTONESE & TROTTI, 1949), and two in 1911 at Portofino (TORTONESE, 1965b). According to KLAUSEWITZ (1973), *Thalassoma* is a postglacial tropical invader of pre-Mediterranean-Tethys origin. In the Mediterranean Sea it is by far more common in the southern part (BINI, 1968; TORTONESE, 1975b). High temperatures are crucial for the sexual maturation of the species and possibly reproduction does not occur every year (BINI, 1968): we saw mature males only twice in the Ligurian Sea (June and September 1992, Gallinaria Island). *T. pavo* is known to reproduce in June and July and has pelagic eggs (TORTONESE, 1975b).

DISCUSSION

The main problems in discussing records of southern species in the Ligurian Sea are the sparseness of the data and that many of the records, especially the old ones, are incomplete. It is often impossible to know exactly the year of occurrence of a certain species, because authors of systematic and/or floro-faunistic works

do not always state how long before publishing they collected their specimens. Similarly, findings of the adults of long-living species give no information about the exact year of settling. There is, unfortunately, no real historical series of surveys. The data are very irregularly scattered and rather 'random'. In many surveys, the recording of a species greatly reflects the presence of a relevant specialist!

Algae, for instance, have been poorly studied since the beginning of the present century (see BARBERIS *et al.*, 1979, for references). However, we have fifteen years experience of scientific diving in the Ligurian Sea and we never saw, before 1991, the warm-water species listed above, although we regularly saw them in southern Italy in those years.

Some of the presumed warm-water invertebrate species are rather rare and localized even in the Tyrrhenian Sea: thus, new findings may not be clues to recent settlings, but simply records of previously overlooked populations. This could be true especially in the case of the sponge *Axinella polypoides* and the sea-star *Chaetaster longipes*.

However, many of the records remain of great interest. The records of the ornate wrasse, *Thalassoma pavo*, appear unquestionable. The Ligurian Sea fish fauna has been adequately studied since the beginning of the 19th century (see TORTONESE, 1965b, for references). *Thalassoma* is a well known fish, easy to recognize: it has been found in 1902, 1911, 1985, 1991, 1992, and 1993. It is difficult to believe that it was present but overlooked in the intervening years. It is a preferred subject for underwater photography, and many 'photographic fish-hunting' competitions have been held every year in Liguria since the sixties: how can we explain that nobody noticed it, if it was present? Thus, at least in the case of *Thalassoma,* we can grant these data with a certain reliability and take them as examples of periodical range extension of southern species into the Ligurian Sea.

Discussing the expansion in the Ligurian Sea of *Pomatomus saltatrix*, a pelagic warm-water fish more abundant in the south and east Mediterranean, TORTONESE (1954) suggested two different hypotheses to explain such periodical range extensions. Although we are dealing with benthic species, Tortonese's hypotheses deserve to be taken into account, since the benthic species we are talking about have pelagic eggs, larvae, or propagula (*e.g.*, TORTONESE, 1975b: *Sparisoma cretense* and *Thalassoma pavo*; RUSSO *et al.*, 1990: *Charonia lampas lampas*; FRANCOUR, 1991: *Centrostephanus longispinus;* etc.).

The first hypothesis stated that an abnormal and relevant numerical increase within its normal range caused the expansion of the species even in seas where formerly it seldom occurred. Random increases in population density due to intrinsic factors are well known in many animal species, and thus such a hypothesis has been invoked in many cases. It could also explain the occurrence of *Thalassoma pavo* in the Ligurian Sea. However, if we accept that range extensions have simultaneously occurred for others of the species we discussed above, this hypothesis does not seem tenable anymore.

The second of Tortonese's hypotheses stated that changes in environmental conditions, chiefly in temperature, favoured diffusion northwards. This hypothesis appears to be more plausible when many species are involved simultaneously, and attractive due to the present concern with the biological effects of climatic changes and global warming (BETHOUX *et al.*, 1990; SOUTHWARD & BOALCH, 1993).

Analysing Ligurian Sea temperature data from the hydrological data bank of ENEA-CRAM (BRUSCHI & SGORBINI, 1986), COPELLO (1992) found evidence of cyclic changes in the period 1957-1980, with - for instance - a minimum in 1969-71, and two maxima in 1958-62 and at the end of the 1970s.

Unfortunately, historical, long term data on inshore water temperature of the Ligurian Sea are not available. However, air temperature data have been collected since 1833 by the Meteorological Observatory of Genoa (FLOCCHINI *et al.*, 1983), and we can assume that surface water temperatures in the coastal zone are reasonably correlated with mean annual air temperatures (SOUTHWARD *et al.*, 1988).

From the analysis of air temperature trend it can be easily seen that climatic fluctuations are evident, warmer periods alternating with colder ones, although in a rather irregular manner (Fig. 2). Smoothing the data by moving averages over eleven year periods (SOUTHWARD *et al.*, 1975), the well known warming in the thirties and forties (CUSHING & DICKSON, 1976) can be easily recognized.

ASTRALDI & GASPARINI (1992) gave evidence that the so-called "Tyrrhenian current", flowing northwards between Tyrrhenian and Ligurian seas, exhibits great variation on a year to year and seasonal basis according to atmospheric-climatic conditions. This warm Tyrrhenian current is the carrier of long-living pelagic larvae, eggs or propagula of southern species: due to variations in current intensity, the arrival of allochthonous larvae ("supply-side": LEWIN, 1986) would be strongly affected by climatic fluctuations.

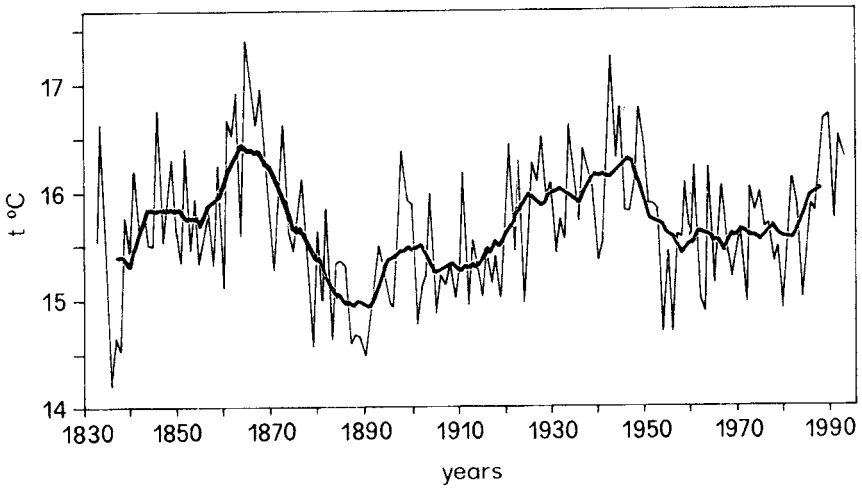

Fig. 2 - Trend of air temperature (annual means, °C) at Genoa, 1833 to 1993. Bold line = moving averages over eleven-year periods. From the data of the Meteorological Observatory of Genoa.

Being warmer, Tyrrhenian water can be easily recognized in satellite infra-red thermal imagery (Fig. 3): entering the Ligurian Sea, this warmer current is pushed against the coast by the rather steady Ligurian-Provençal gyre (ASTRALDI *et al.*, 1980). It flows westwards along the coast, and apparently there it remains somewhat entrapped (see also the surface temperature maps produced by PICCO, 1990), perhaps forming the coastal 'termophilic oases' hypothesized in the past. Once arrived in this 'termophilic oases', southern organisms can settle and survive long enough to succeed in establishing adult populations. According to most authors (BINI, 1968; FRANCOUR, 1991; RUSSO *et al.*, 1990), these should be sterile 'pseudopopulations' (*sensu* MILEIKOVSKI, 1971) and need to be restored by further invasions.

As a conclusion, we suggest that the occurrence in the Ligurian Sea of warm-water species is linked to year-to-year climatic variability and fluctuations, rather than to the existence of permanent "thermophilic oases", although the formation of these could in turn be crucial for the survival of southern species. From this point of view, the establishment of warm-water species in the Ligurian Sea has to be considered a rather unlikely event, and the scarcity of records in one and a half centuries could be realistic, and not only due to mere lack of investigations. The apparent increase

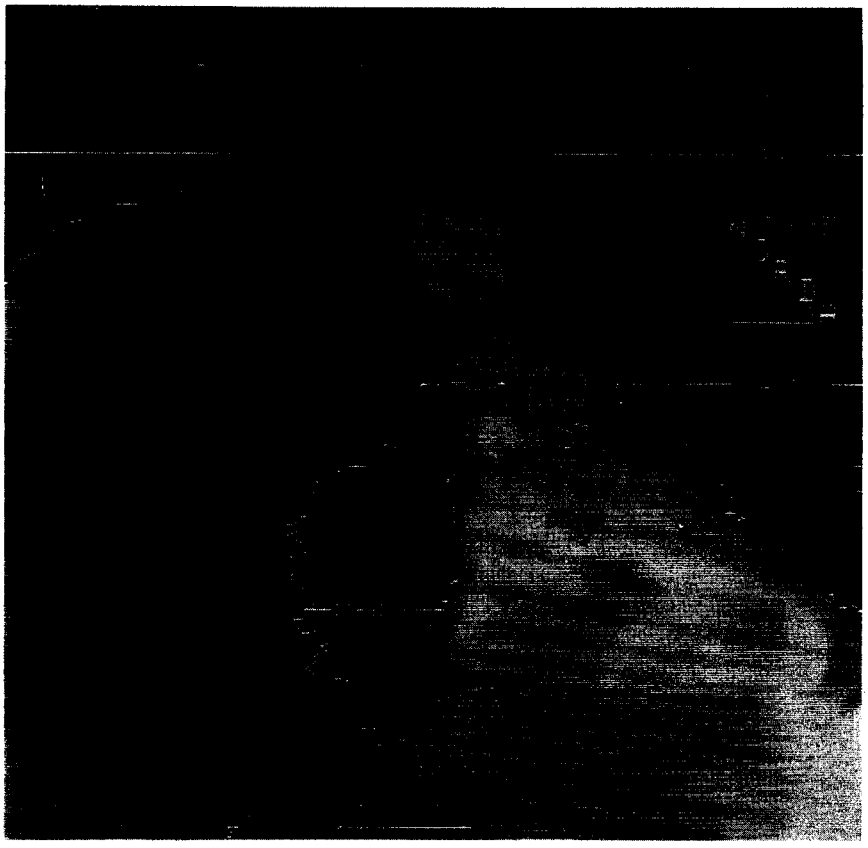

Fig. 3 - Satellite infra-red thermal imagery of the northwestern Mediterranean Sea (AVHRR NOAA 9, March 28th, 1986). The whitest areas are the warmest.

in occurrence of southern species observed in recent years in the Ligurian Sea, therefore, deserves attention as a possible biological effect of climatic change and consequent warming of sea water already hypothesized for the northern Mediterranean by BETHOUX *et al.* (1990).

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RIASSUNTO

Il mar Ligure si differenzia dal mar Tirreno per una maggiore affinità 'fredda' della sua flora e fauna: tuttavia, la presenza in mar Ligure di specie termofile è stata segnalata in alcune occasioni. I rinvenimenti recenti di una ventina di specie termofile epibentiche (7 alghe, 11 invertebrati, e 2 pesci di scogliera) vengono discussi criticamente con i dati di letteratura. La presenza di specie termofile sembra essere aumentata in questi ultimi anni, e può essere dovuta a due cause: 1) espansioni demografiche a carico delle singole specie; 2) fluttuazioni climatiche che spostano le frontiere biogeografiche. Serie storiche di dati di temperatura ed informazioni idrologiche depongono a favore della seconda ipotesi.

SUMMARY

With respect to the neighbouring Tyrrhenian Sea, the Ligurian Sea is colder and its biota has a boreal affinity: however, the occurrence of southern, warm-water species in the Ligurian Sea has been reported from time to time. The recent findings of 20 thermophilic epibenthic species (7 algae, 11 invertebrates, and 2 reef fishes) are critically discussed together with literature data. Warm-water species occurrence seems to have increased in the last few years, and may be due to two causes: 1) demographical expansions affecting the individual species; 2) climatic fluctuations shifting biogeographical boundaries. Historical series of temperature data and hydrological information favour the second hypothesis.

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