Monitoring Marine Invasive Species in Mediterranean Marine Protected Areas (MPAs): A strategy and practical guide for managers

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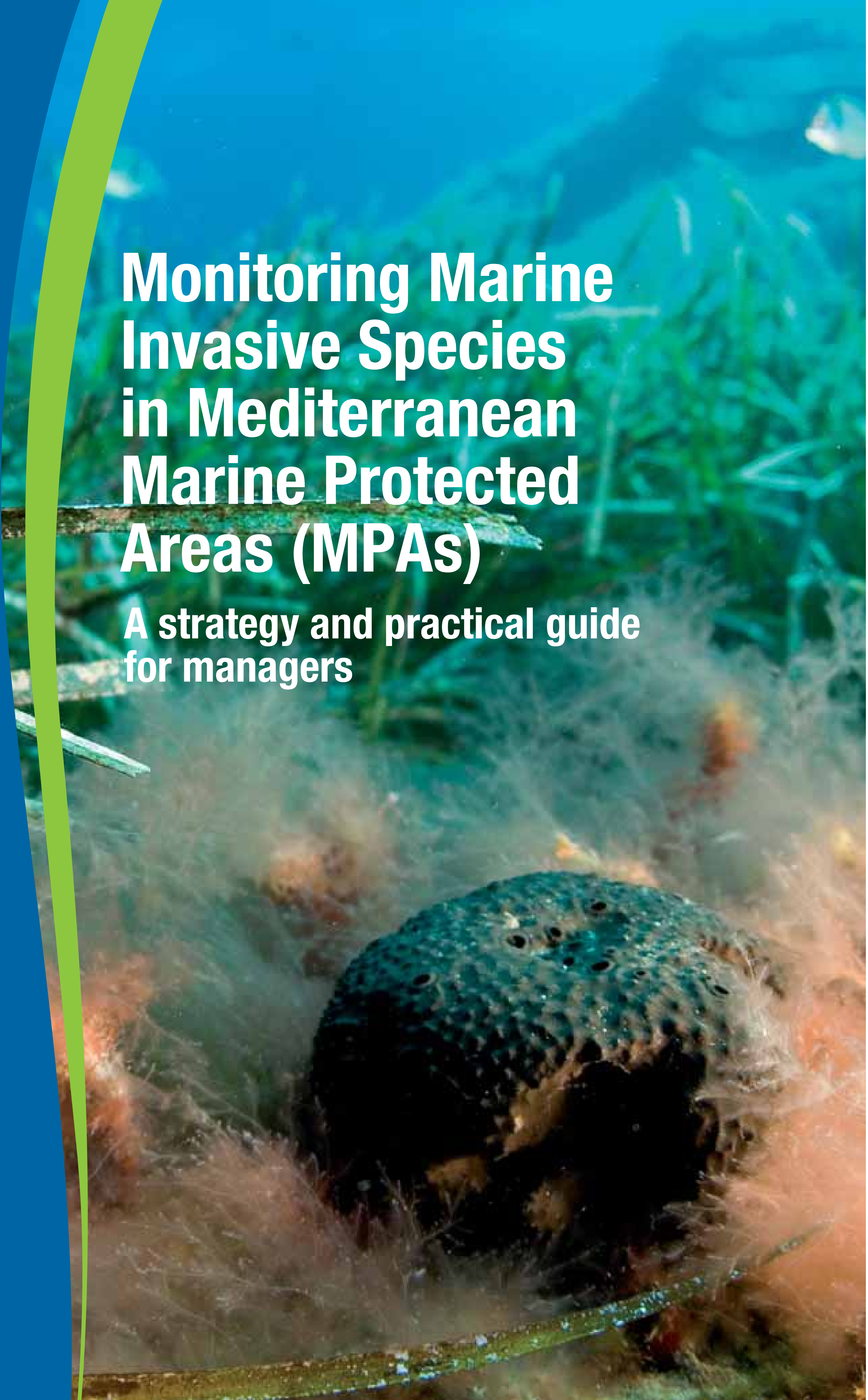

Monitoring Marine Invasive Species in Mediterranean Marine Protected Areas (MPAs)

A strategy and practical guide for managers

IUCN

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Monitoring Marine Invasive Species in Mediterranean Marine Protected Areas (MPAs)

A strategy and practical guide for managers

Otero, M., Cebrian, E., Francour, P., Galil, B., Savini, D.

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IUCN, International Union for Conservation of Nature, helps the world find pragmatic solutions to our most pressing environment and development challenges. IUCN is the world's oldest and largest global environmental organization, with more than 1,200 government and NGO members and almost 11,000 volunteer experts in some 160 countries. IUCN's work is supported by over 1,000 staff in 45 offices and hundreds of partners in public, NGO and private sectors around the world. The Centre was opened in October 2001 with the core support of the Spanish Ministry of Agriculture, Food and Environment, the regional Government of Junta de Andalucía and the Spanish Agency for International Development Cooperation (AECID). The Centre's mission is to influence, encourage and assist Mediterranean societies to conserve and use sustainably the natural resources of the region and work with IUCN members and cooperate with all other agencies that share the objectives of the IUCN.

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Monitoring species. Photo: L. Tunesi

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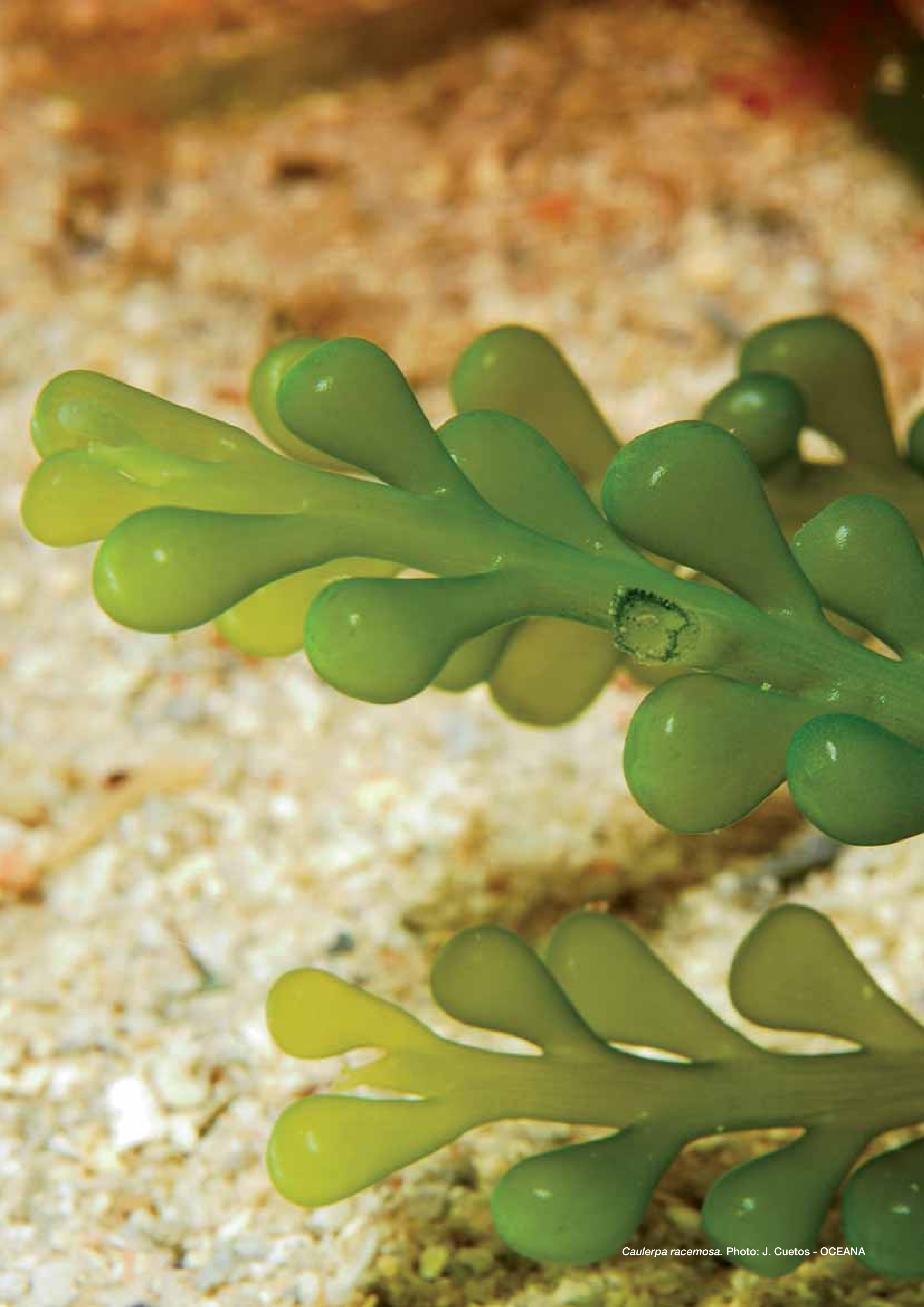

Caulerpa racemosa. Photo: J. Cuetos - OCEANA

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Marsupenaeus japonicus. Photo: A. Can - www.alpcan.com

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Marine invasive species What are they?

Alien species — sometimes termed exotic, introduced or non-native species — are plants and animals that have been intentionally or unintentionally introduced, have established populations and have spread into the wild in the new host region (IUCN, 2002). In their home ranges, these species live in balance with their local native environment, and populations are controlled by ecosystem interactions such as predation, parasitism and disease. However, once they arrive in a new environment, they may become established and invasive.

Following the IUCN definition, also adopted by the Convention on Biological Diversity, 'invasive alien species' (IAS, often abbreviated to 'invasive species') are those alien species which become established in natural or semi-natural ecosystems or habitats and become an agent of change, increasing in abundance and distribution and threatening native biological diversity (IUCN, revised 2012). IAS are introduced outside their natural range by human action, either direct or indirect, and can cause harm to biodiversity or ecosystem services by competing with and on some occasions replacing native species, and causing complex changes within the structure and function of the new hosting ecosystem (Galil, 2007, 2009). Invasive species often owe their success in colonizing new ecosystems to certain characteristics that make them more difficult to control and contain. These characteristics include the capacity to thrive in different environments and tolerate a wide range of environmental conditions, high growth and reproduction rates, a lack of natural predators and an ability to exploit a variety of food sources.

Codium fragile subsp. *fragile.* Photo: J.C. Calvin - OCEANA

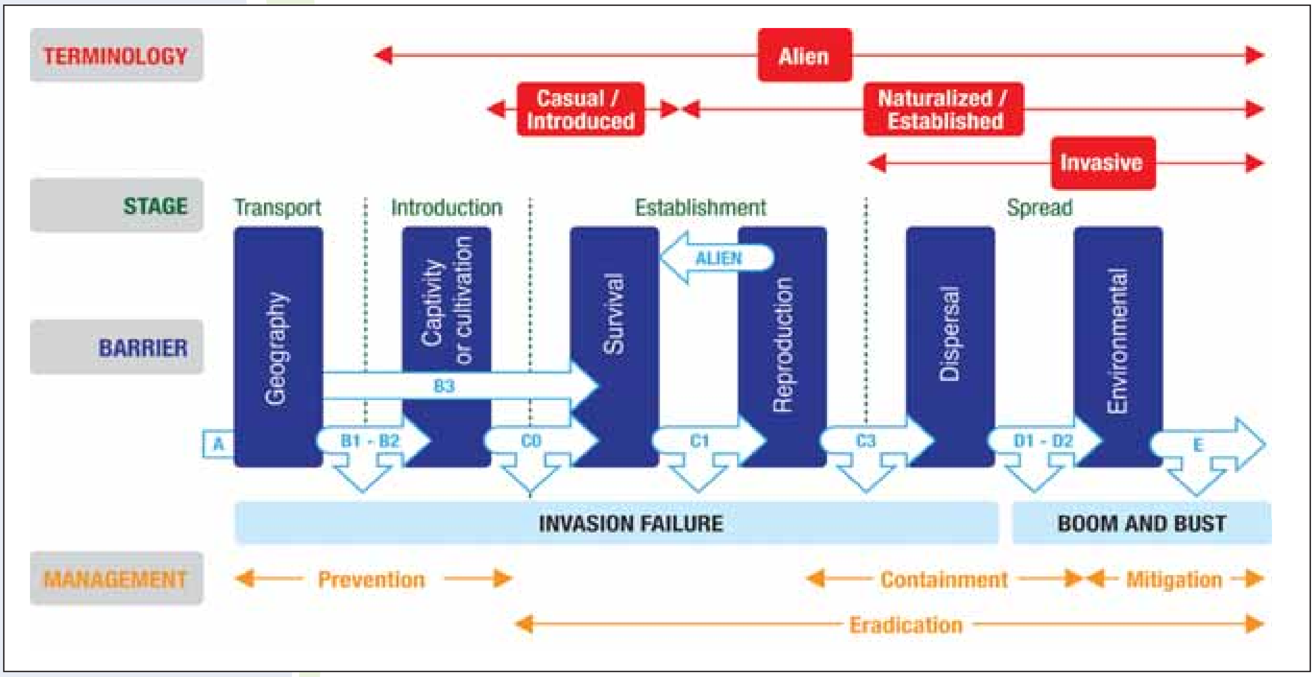


Fig. 1. *Schematic representation of major barriers limiting the spread of introduced alien species. The barriers are: (A) geographical barrier(s), (B) Captivity or cultivation (for those species), (C) Survival and reproduction barriers, (D) Local/regional dispersal barriers; and E) Environmental barrier(s). Arrows A through E indicates the paths followed by different species to reach different states from introduced alien to invasive species. From Blackburn et al., 2011.*

It is difficult to predict when an alien species will become invasive, as it does not always happen. Generally, the invasion process consists of several major stages, from the transport of a species into new habitats to its establishment and eventual spread (Fig. 1). Each of these stages is limited by a set of barriers that will determine whether or not the species will move on to the next stage in the invasion process and finally become an invasive species (Blackburn *et al.*, 2011). An alien species must progressively overcome a series of geographical, survival, reproductive and dispersal barriers before it can finally expand into a new environment. During this final stage of invasion, the species can ultimately also be affected by 'boom and bust' cycles and pass through periods of sudden population decline or growth, as observed in several marine alien species in the early years of invasion.

Because of this, it is generally assumed that the best factor for distinguishing an invasive species from other aliens is

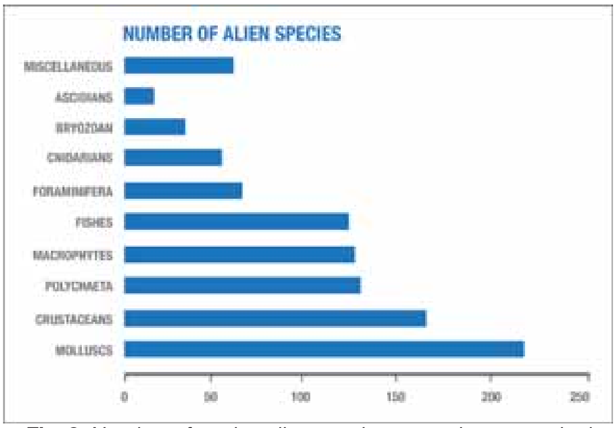
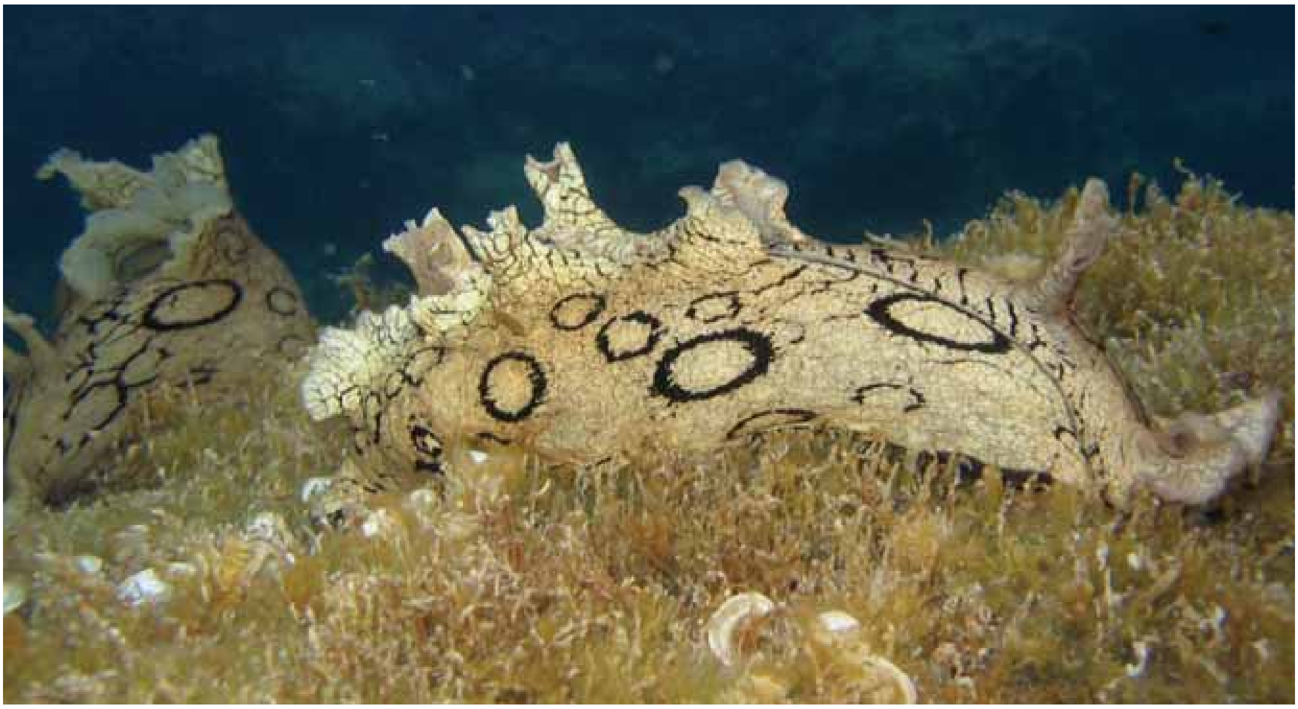


Fig. 2. *Number of marine alien species per major groups in the Mediterranean Sea. From Zenetos et al., 2012.*

that its invasiveness has been proven elsewhere in the world (Boudouresque and Verlaque, 2002). In this guide, we will use the term **invasive species** in accordance with the previous description to include **all alien species with proven invasive potential**, meaning that they are able to establish viable populations, can expand into previously uncolonized areas in the Mediterranean Sea and are capable of damaging the environment, the economy, or human health.

Marine invasive species are regarded as one of the main causes of biodiversity loss in the Mediterranean (Galil, 2007; Coll *et al.*, 2010), potentially modifying all aspects of marine and other aquatic ecosystems. They represent a growing problem due to the unprecedented rate of their introduction (Zenetos *et al.*, 2010) and the unexpected and harmful impacts that they have on the environment, economy and human health (Galil, 2008). This is a general phenomenon that extends to all regions of the Mediterranean (Galil, 2007, 2009; Zenetos *et al.*, 2010). That is why invasive species are considered 'focal species' and should be monitored in all regions (Pomeroy *et al.*, 2004).

More than 5% of the marine species in the Mediterranean are now considered non-native species (Zenetos *et al.*, 2012; Fig. 2). According to the latest regional reviews, 13.5% of those species are classed as being invasive in nature, with macrophytes (macroalgae and seagrasses) the dominant group in the western Mediterranean and Adriatic Sea, and polychaetes, crustaceans, molluscs and fishes in the eastern and central Mediterranean (Galil, 2009; Zenetos *et al.*, 2010; Zenetos *et al.*, 2012). The vast majority of alien species occur in the eastern Mediterranean; some are located exclusively in the south-eastern basin, others are restricted to the western basin, while others have colonized the entire Mediterranean.



Aplysia dactylomela. **Photo: E. Azzurro**

Invasive species and marine protected areas

Marine Protected Areas (MPAs) in the Mediterranean have not escaped this general trend and most of them have long been affected by introduced invasive alien species that threaten marine biodiversity (Fig. 3). However, very little is known about the origins and mechanisms of introduction of the various species, or about their densities, distributions, temporal patterns or ecological significance for Mediterranean biodiversity (Abdulla *et al.*, 2008). Many MPAs in the Mediterranean are located in proximity to major ports, have aquaculture farms in them or nearby, or are frequently used by small recreational or fishing boats as well as tourists. A large number of introduced species in a given MPA could be an indicator of high propagule pressure, probably due to the development of human activities that facilitate certain pathways of introduction (such as recreational navigation, aquaculture or the aquarium trade).

As a result, MPAs across the MedPAN Network face common challenges, among them the lack of awareness and understanding of the impacts of invasive species, the scarcity of information on best management practices and a lack of baseline information, guidelines and trained local staff to identify and gather more information on the introduction, spread and impact of alien species. Furthermore, most MPA personnel feel that the problem is too large and nothing can be done with the limited funds available, if any, to develop actions. At a regional level, the problem species differ from one MPA to another and there is still weak networking, coordination and collaboration on this issue.

Marine invasions in general have been under-studied and most countries have little IAS information available and limited or no formal programmes to collect information in MPAs (see Annexes 1 and 2). Furthermore, information is in many cases generated by research projects with short-term funding and sometimes restricted access. MPA management teams lack or have limited capacity and expertise to identify most non-native marine species and do not know how to combat a specific invasion when one occurs. Thus, alien species might be overlooked or pass unnoticed until they have become well established in the local ecosystem, by which time eradication is difficult, costly or impossible.

The objective of this guide is to cover part of these needs and aid Mediterranean MPAs in developing an effective IAS programme. To facilitate this, a draft Marine Invasive Alien Species Strategy for the MedPAN Network was prepared *a priori* and discussed in several regional workshops with MPA managers and experts (MedPAN Draft IAS Strategy, 2012). The overall aim of the strategy is to establish a common framework for MedPAN members to take action on marine invasive species. The present guide takes forward some of the described actions, addressing the key goals and main recommendations of the strategy, with a view to the prevention and early detection of new IAS entering the MPA environment. Furthermore, it contains information on the introduction pathways and impacts of major marine species that have invaded the Mediterranean Sea, on how to monitor and identify them and on what can be done to prevent their establishment and spread in MPAs.

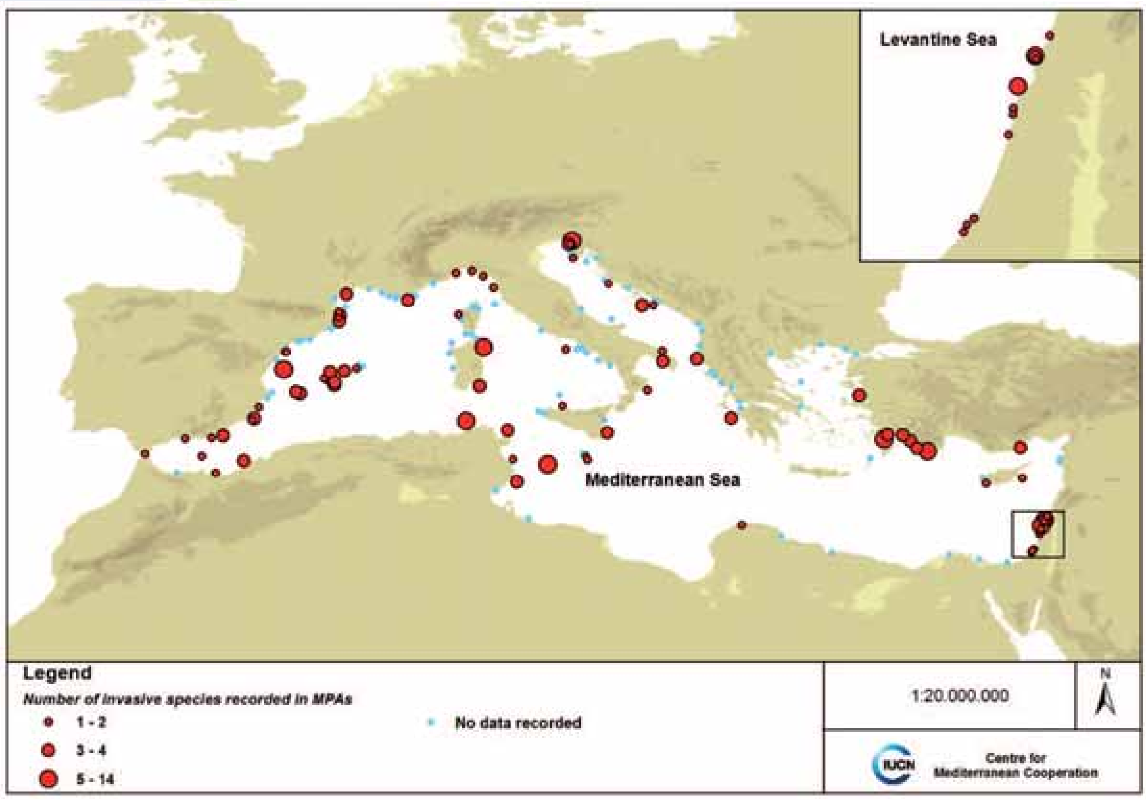


Fig. 3. *Invasive species in Mediterranean MPAs. Data collected from published and unpublished sources.*

The effects of invasive species

The introduction of invasive alien species is a major threat to ecosystem biodiversity, structure and function. They may displace native species, reduce community biodiversity, change species composition and abundance across habitats, modify habitat structure and produce cascading effects or trophic web shifts that could result in major negative impacts on the ecosystem (EEA, Technical report No 16/2012). Nevertheless, their effects on the biodiversity and habitats of the Mediterranean cannot be generalized, as alien species can cause very diverse effects at different locations or different times, sometimes with a strong invasive component and sometimes not.

Marine invasions can also have economic and human health implications. In Europe, the economic impacts of non-native terrestrial and aquatic species have been estimated to be at least EUR 12.5 billion per year, and probably amount to over EUR 20 billion (Kettunen *et al.*, 2009). Of that, the negative impact of aquatic invasive species alone has been estimated to cost the region at least EUR 2.2 billion per year. Nonetheless, there is limited comprehensive evidence for most economic impacts of invasive marine species. Examples of any potential benefits provided by some of these invasive species or benefits associated with the prevention and control programmes are even scarcer. Scientific research has only just started to glimpse the extent of some of these impacts in the Mediterranean and, for most of these introductions, the effects are completely unknown.

Non-native macroalgae (seaweeds) are particularly likely to become invasive in coastal environments; they can easily monopolize the available space, reduce biodiversity and change the whole ecosystem structure. Currently, the Mediterranean has the largest number of introduced marine plants in the world. More than 60 macroalgae have already been introduced and 8 or 9 of them have been proved to cause serious invasions (Piazzi and Balatta, 2009; Boudouresque and Verlaque, 2003). For most of them, however, and with the exception of the well-known *Caulerpa racemosa var. cylindracea*, their invasive nature does not seem to be a general phenomenon everywhere and it is possible that they may not become invasive in every area they colonize. This may be due to a variety of factors, such as the presence of a predator species or less-than-ideal habitat conditions.

Some common features of these macroalgae, such as their vegetative reproductive capacity (a single propagule can start a new colony), their production of toxic metabolites that deter grazers or their perennial status, make them more competitive than the native macroalgae species, increasing the probability that they will become invasive if they succeed in the new environment. Several of these species periodically become a major problem, clogging waterways, fouling nets, and changing nutrient regimes in areas around fisheries, desalination facilities and aquaculture systems. In MPAs, the spread of invasive macroalgae such as *Caulerpa sp.*, *Lophocladia lallemandii* or *Womersleyella setacea* Fig.4 & 5) might also reduce the attractiveness of the marine landscape for scuba divers and cause a decline in marine community diversity. Threatened or endangered species in those areas could also be at risk because of predation, parasitism and competition with these alien invaders.

Caulerpa racemosa var. cylindracea, an invasive alga endemic to south-western Australia, has spread rapidly throughout the Mediterranean, from Cyprus and Turkey to Spain and all around the larger islands — including in MPAs (Fig. 4). It can form a dense canopy that overgrows native algae and significantly decreases their diversity and cover. It increases siltation, reduces shoot density and biomass of some native seagrass meadows and prompts significant changes in the benthic macrofauna.

For instance, in Port-Cros National Park and Scandola Regional Park, the invasion by *Caulerpa racemosa* and *Womersleyella setacea* has been observed to affect the survival rate and growth of juvenile colonies of the gorgonian *Paramuricea clavata* (Cebrian *et al.*, 2012) and the reproductive capacity of sponge communities (de Caralt and Cebrian, 2013). Alien filamentous, turf-forming algae such as *Acrothamnion preissii* and *Womersleyella setacea* may establish an almost monospecific stratum suffocating the underlying communities and reducing species number and diversity in the affected area by trapping sediments.

Asparagopsis armata. Photo: B. Weitzmann.

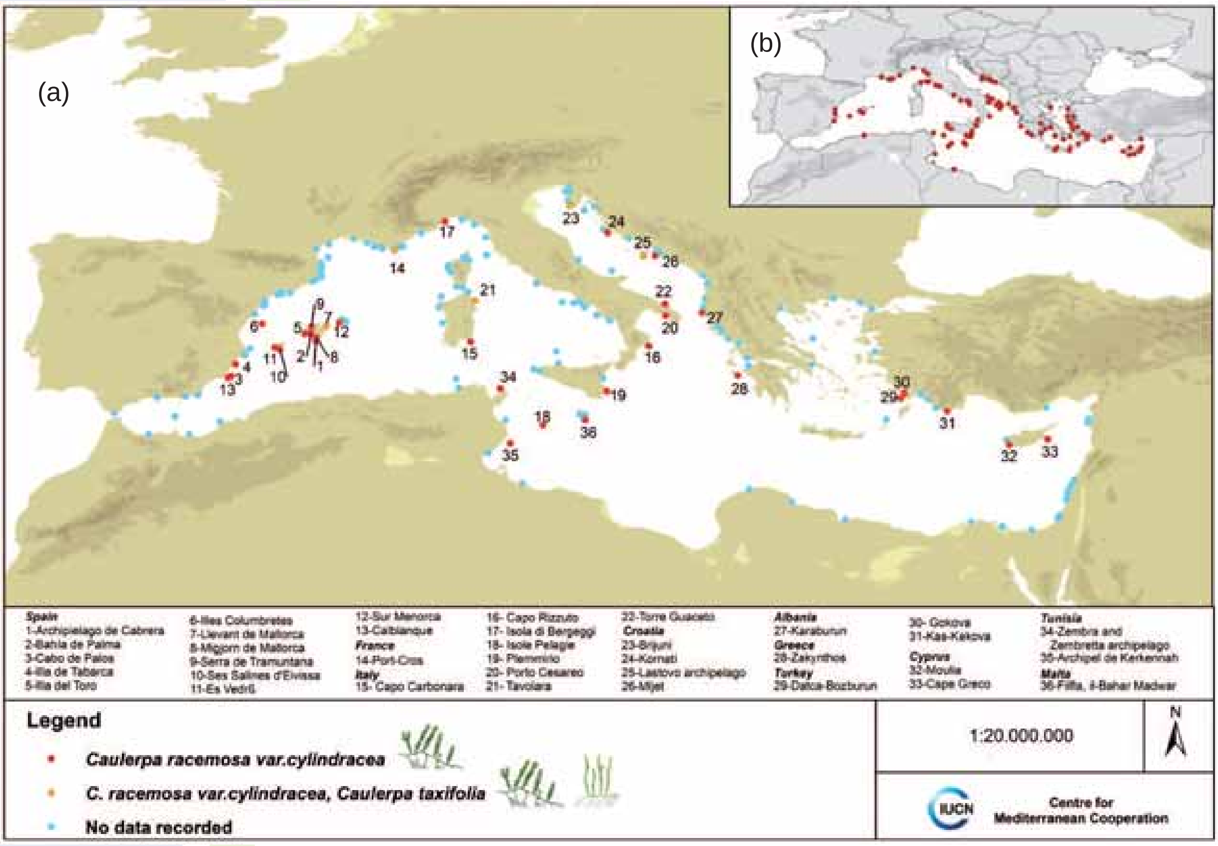


Fig. 4. *(a) Presence of* Caulerpa racemosa var. cylindracea *and* Caulerpa taxifolia *in Mediterranean MPAs. Data collected from published and unpublished sources; (b) Caulerpa racemosa observations in the Mediterranean Sea. From Klein and Verlaque, 2008.*

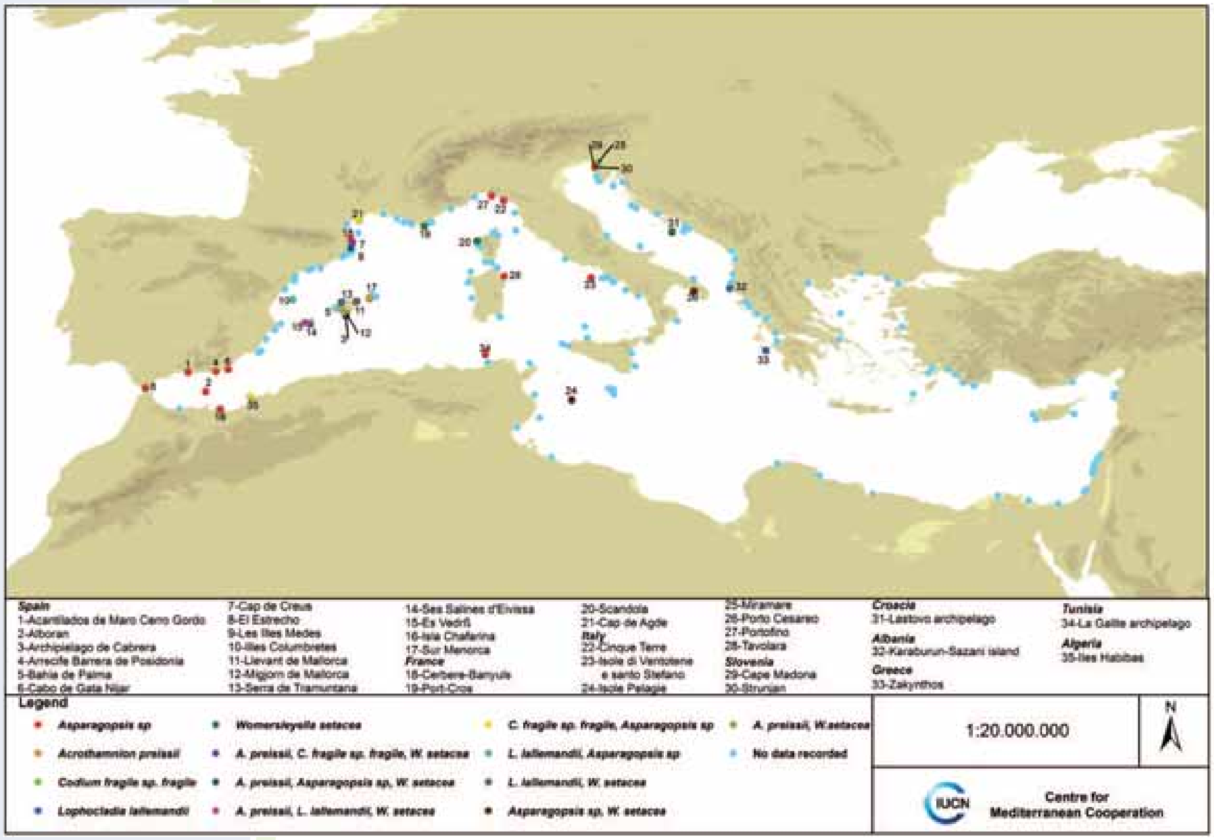


Fig. 5. *Presence of other invasive algae in Mediterranean MPAs. Data collected from published and unpublished sources.*

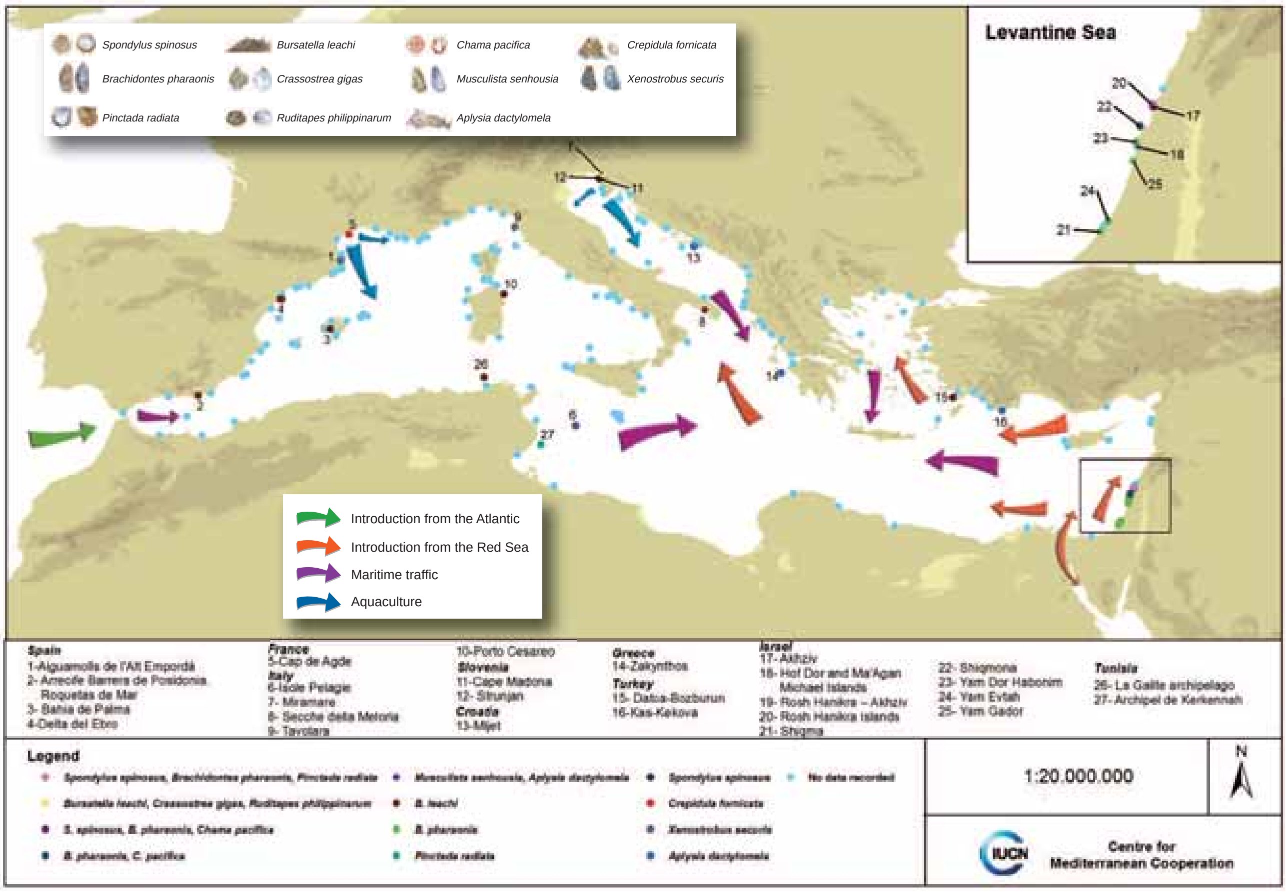


Fig. 6. *Potential introduction pattern of alien molluscs and presence in MPAs.*

More than 200 alien marine molluscs have been recorded off the Mediterranean coast. Most of them are of Indo-West Pacific origin and are believed to have entered the Mediterranean through the Suez Canal (Zenetos *et al.*, 2012). They display a distinct migration pattern beginning along the Mediterranean coast of Israel, moving north to the south coast of Turkey and Cyprus before entering the Aegean Sea and pushing westwards towards Malta, Italy and elsewhere (Fig. 6).

Aided by factors such as transport on or in ships (in hull fouling and ballast waters) and introduction through aquaculture activities, mollusc invasions are common in many Mediterranean coastal marine ecosystems, especially bays and estuaries. The Asian date mussel *Arcuatula (Musculista) senhousia*, for example, is an ecologically important global invader that has invaded estuaries in the Mediterranean. These mussels can form dense aggregations of up to 170,000 mussels per m^2 on mudflats, altering the habitat, reducing the diversity of large invertebrates, inhibiting the growth of seagrasses, and decreasing the abundance of suspension-feeding bivalves (Munari, 2008).

Some coastal lagoons have also suffered significant alterations to their native communities, particularly through the effects of bivalves introduced through aquaculture, such as the American oyster *Crassostrea gigas* or the Japanese carpet shell *Ruditapes philippinarum*. The spectacular invasion of these exotic species in some lagoon environments such as the Thau lagoon (south-western France) has altered the ecosystem to such a degree that these species have become an important part of the biomass and diversity of the lagoon flora and fauna (Boudouresque *et al.*, 2011).

Similarly, invasive alien crustaceans can have severe negative impacts on native ecosystems. They may completely change native communities through alteration of trophic interactions, interference competition, disease transmission or habitat modification (Snyder and Evans, 2006). For example, *Percnon gibbesi*, probably the most invasive decapod species found in the Mediterranean to date, has spread rapidly in the region and reached a number of MPAs (Fig. 7), forming thriving populations in a very short space of time. Its feeding habits (it consumes primarily algae but also other crabs, polychaetes, gastropods, crustaceans and jellyfish) may affect the structure of benthic communities, particularly algal assemblages, and it may compete with native species for food and shelter (Katsanevakis *et al.*, 2011). In addition, eight species of alien penaeid prawns have been recorded in the Mediterranean (Galil, 2007). Their introduction into the Mediterranean through the Suez Canal has created a lucrative parallel industry for Levantine fisheries, in particular for species like the Kuruma prawn *Marsupenaeus japonicus* or the speckled shrimp *Metapenaeus monoceros*. On the other hand, their spread has almost completely eliminated populations of the native penaeid prawn *Melicertus kerathurus* in those areas.

Other non-native species such as ascidians, corals, jellyfish or fishes are also expanding their distributional ranges from other seas across the Mediterranean. Occasional sudden blooms, like those of the comb jelly *Mnemiopsis leidyi* or the nomadic jellyfish *Rhopilema nomadica*, have adversely affected beach tourism in some areas, blocked water intake pipes in ports and other coastal developments, and clogged fishing nets thereby reducing catches.

Current numbers of alien fish species established in MPAs are unknown (Fig. 8 a, b) as much of the information gathered relates to coastal areas but not specifically to MPAs. Most introductions into the Mediterranean have entered through the Suez Canal, spreading through the Levantine basin and causing profound changes in coastal communities. Invasive fish species have produced significant ecological and socio-economic impacts in the invaded environments, causing large changes in the native communities of fish and other species. The case of Kas-Kekova MPA off Turkey's south-western Lycian coast is a clear example of these impacts. Here two invasive herbivorous fish species from the Red Sea (*Siganus luridus* and *S. rivulatus*) are responsible for creating and maintaining underwater barren grounds composed solely of bare rock and patches of crustose coralline algae. The grazing pressure by both fish populations has severely reduced the composition and biomass of algal assemblages, particularly erect and canopy-forming algae, shifting the original habitat to one dominated only by low-lying and turf-forming algae (Sala *et al.*, 2011).

Percnon gibbesi. Photo: C. Suárez - OCEANA

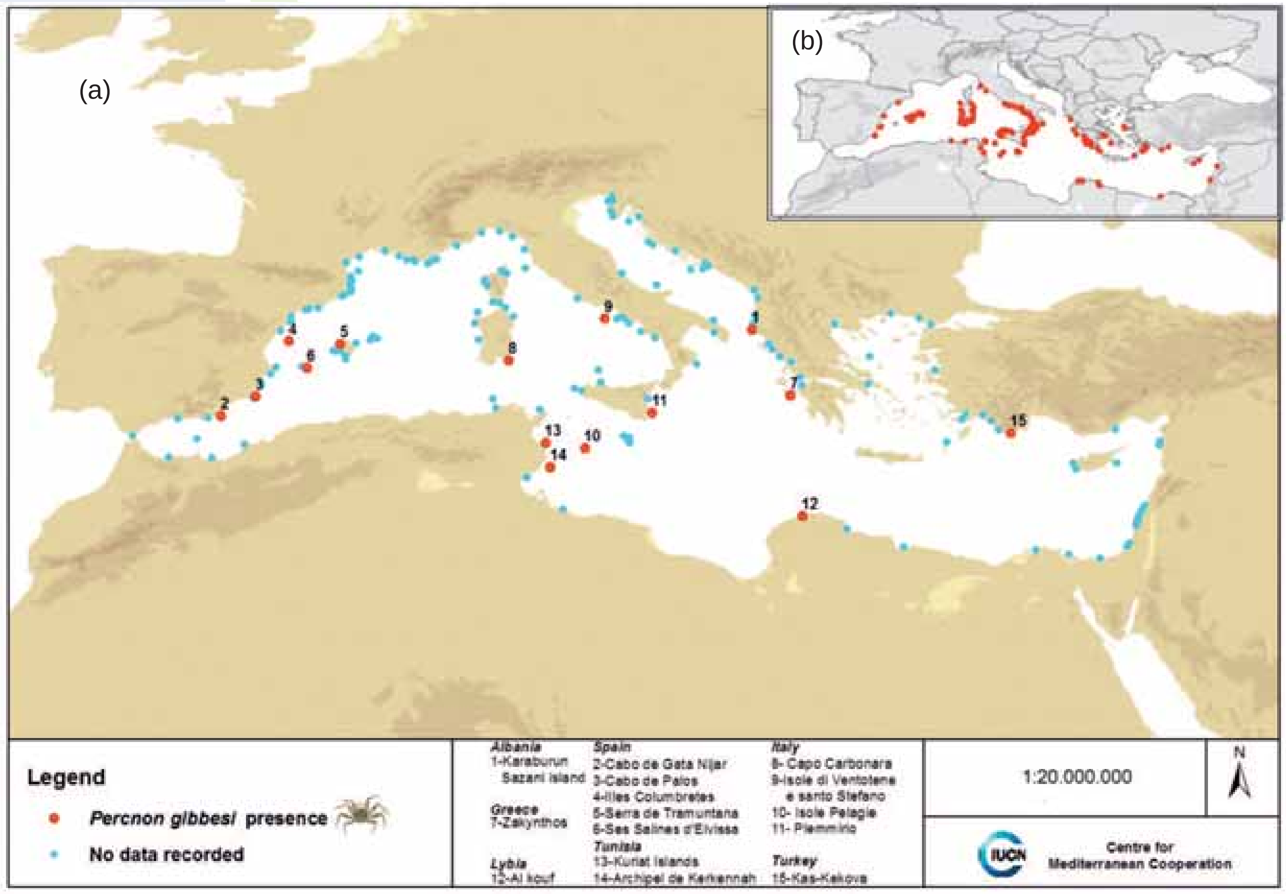


Fig. 7. *(a) Presence of the decapod* Percnon gibbesi *in Mediterranean MPAs. Data collected from published and unpublished sources; (b) Percnon gibbesi observations in the Mediterranean Sea. From Katsanevakis et al., 2011.*

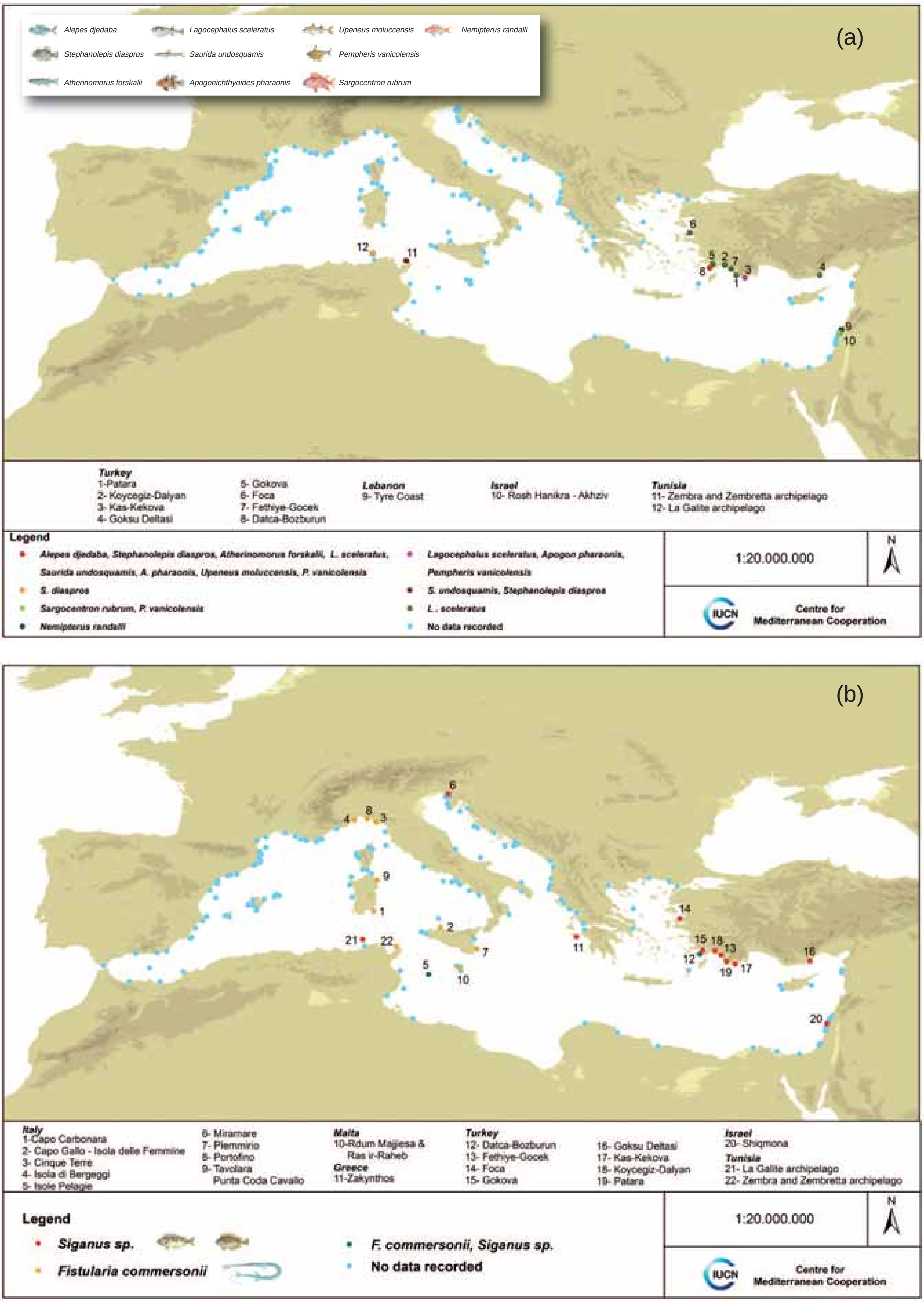


Fig. 8 a, b. *Presence of invasive alien fish species in Mediterranean MPAs. Data collected from published and unpublished sources.*

Pempheris vanicolensis and *Sargocentron rubrum*. Photo: E. Azzurro

Climate change and invasive species interactions

Climate change will have significant impacts on coastal zones, as it will drive the predicted rise in sea levels and sea and air temperatures and will also change other hydrological characteristics of the Mediterranean coasts where many MPAs are located. According to different scenarios on greenhouse gas emissions, and taking into account the uncertainties of scientific projections to date, coastal sea temperatures are expected to increase by at least 1–2.5 °C by the end of the 21st century over the whole basin (Di Carlo and Otero, 2012). The warmer and drier conditions that have already started to occur in some areas are expected to continue in the near future.

Temperature anomalies will also affect the Mediterranean's oceanographic features, leading to nutrient enrichment of its waters, plankton blooms and consequently changes to food webs and biological diversity. Climate change is likely to affect the structure of marine communities and provide further opportunities for alien species to spread and out-compete native species. In general, many native and alien species are shifting their areas of distribution towards higher latitudes (CIESM, 2008). As the majority of alien species in the Mediterranean are thermophilic (warmth-requiring species) that originated in tropical seas of the Indo-Pacific, warming sea temperatures will favour the introduction of more Red Sea species into the south-eastern Mediterranean and their rapid spread northwards and westwards. Similarly, it will also assist the spread of species of tropical Atlantic origin into the western basin (Fig. 9).

Consequently, invasive populations of alien thermophilic species are likely to develop adaptations that could lead to their exponential growth and further spread in the near future.

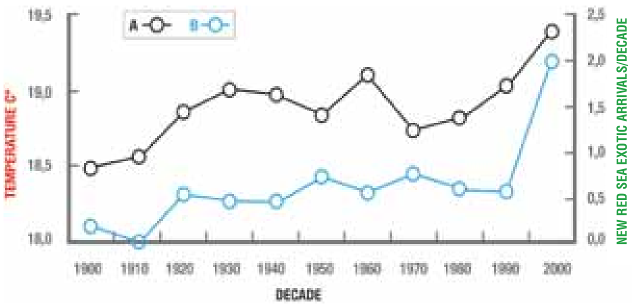
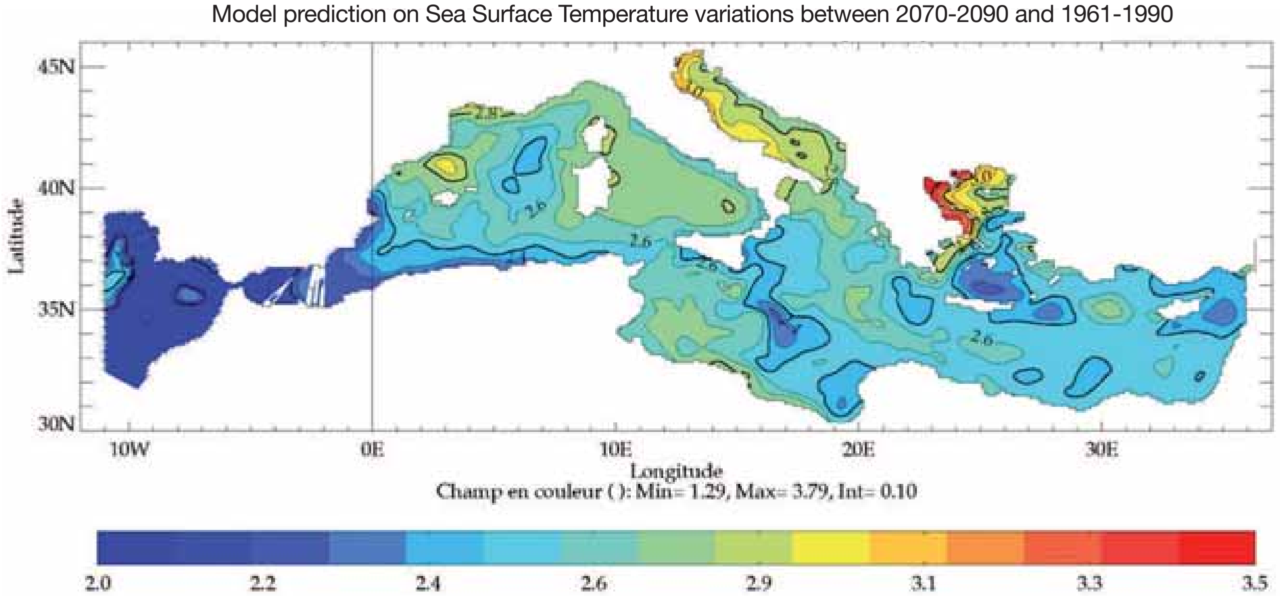


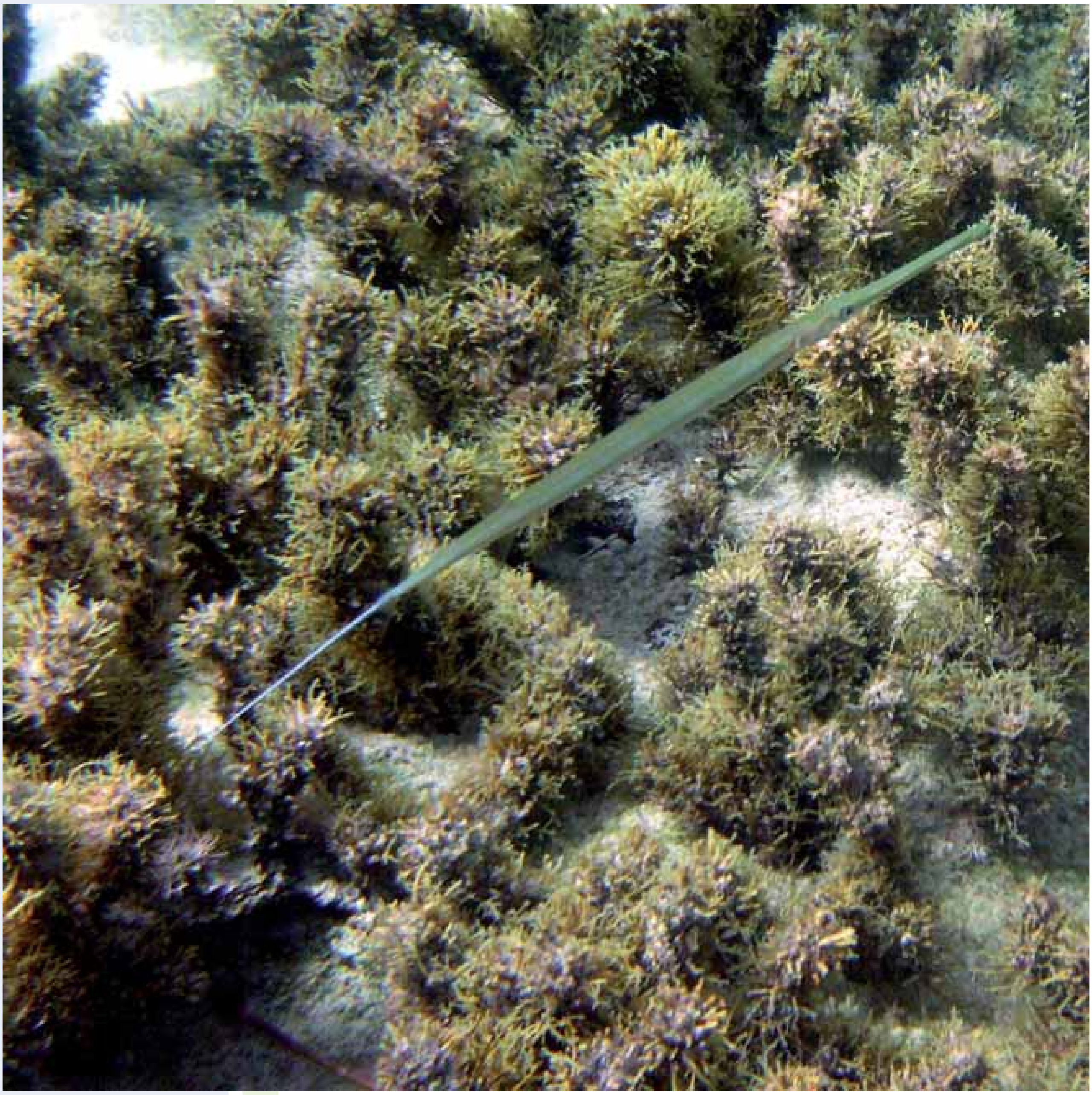
Fig. 9. *Historical invasion dynamic of alien fish species in the Mediterranean Sea (B) versus observed changes in the Mediterranean Sea water temperature per decade (A). From Ben Raïs Lasram F. and Mouillot D., 2009*

DIFFERENCES BETWEEN THE FUTURE CLIMATE (2070-2099) AND THE PAST CLIMATE (1961-1990)

Model prediction on Sea Surface Temperature variations between 2070-2090 and 1961-1990



Source: Piero Lionello, Università del Salento



Fistularia commersonii. Photo: G. Pergent

Range shifts among marine flora and fauna

There is good evidence that the species composition of the western Mediterranean fish fauna has changed over the last decade: some species introduced from the Red Sea that are well established within the eastern Mediterranean basin have started to spread into the western basin. At the same time, some Atlantic species have passed through the Gibraltar Strait and into the western basin.

Fish introduced through the Suez Canal

Since the opening of the Suez Canal in 1869, more than 80 Lessepsian fish species (species that have spread through the canal) have been recorded in the Mediterranean. Along the French coast in the north-western Mediterranean, the farthest point from the Suez Canal, only two Lessepsian species (*Fistularia commersonii* and *Siganus luridus*) have so far been recorded. These two species display different patterns of colonization (Table 1).

Siganus luridus is a species usually found in the western Indian Ocean and Red Sea. It was first recorded in the Mediterranean in 1956 and progressively continued its geographical expansion through the eastern basin. It reached north-eastern Tunisia around 1970, but crossed the Strait of Sicily only in 2004; it reached the French coast in 2008 (Daniel *et al*., 2009).

In contrast, *Fistularia commersonii*, widely distributed in the Indo-Pacific and eastern-central Pacific, was first recorded in the Mediterranean in January 2000 along the coast of Israel. Since then, the species has quickly spread throughout the eastern Mediterranean basin. It reached the Strait of Sicily in 2003–2004 and the French coast in 2007 and has now been recorded from the whole Mediterranean (Bodilis *et al*., 2011) (Fig. 9; Table 1).

TABLE 1. Patterns of spread of Atlantic and Lessepsian fish species in the Mediterranean. Data from Pastor & Francour (2010; *Parablennius pilicornis*), Bodilis *et al.* (2012b; *Pomadasys incisus*), Francour *et al*. (2010; *Lampris guttatus*), Francour & Mouine (2008; *Kyphosus sectatrix*), Bodilis *et al.* (2012a; *Pisodonophys semicinctus*), Daniel *et al.* (2009; *Siganus luridus*), and Bodilis *et al.* (2001; *Fistularia commersonii*).

SPECIES	DISTRIBUTION	FIRST ENTRANCE IN THE MEDITERRANEAN	NORTH SPAIN	TUNISIA	SICILY	NORTH ITALY	FRANCE	% OF ALL RECORDS
Atlantic species								
Parablennius pilicornis	Continuous	ca. 1960	1986	ca. 1970	1982	2003	2006	?
Pomadasys incisus	Continuous	before 1840	ca. 1900	1893	?	1991	2006-2011	50-70% since 2006
Lampris guttatus	Continuous	before 1800	?	2008	1979	1807	1826	60% since 2008
Kyphosus sectatrix	Patchy	before 1840	1996	2003	1883	1903	2006	70% since 2006
Pisodonophis semicinctus	Patchy	ca. 1950	?	1991	1997	1996	1980	60% since 1997
Lessepsian species								
Siganus luridus	Patchy	1956	no	1970	2003	no	2008	?
Fistularia commersonii	Patchy	2000	2007	2003	2002	2004	2007	?

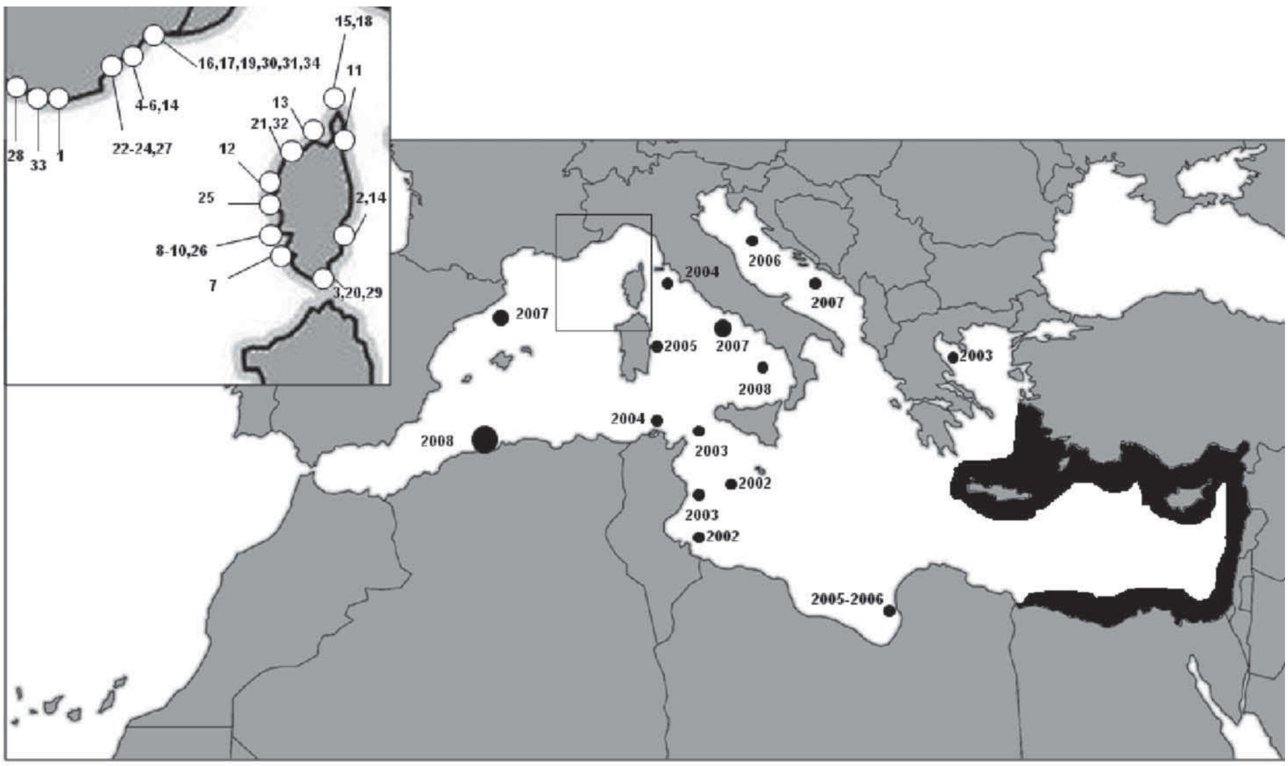


Fig. 10. *Location map of the records of* Fistularia commersonii *along the French coast. Numbers (inset map) denote records described in Table 2. Years indicate the spreading of the species within the Mediterranean Sea (modified from Bodilis et al., 2011). The black portion denotes the areas where the species is frequently observed (DAISIE, 2008). Circle sizes correspond to the number of individuals caught (small, from 1 to 5 individuals; medium, 12–15 individuals; large, more than 100 individuals). Source: P. Francour, P. Bodilis*

Atlantic fish species

Atlantic fish species have shown two patterns of spread (Table 1): a) continuous dispersal throughout the whole western basin (for example the opah *Lampris guttatus*, the ringneck blenny *Parablennius pilicornis* and the bastard grunt *Pomadasys incisus*), and b) patchy dispersal, as in the case of the Bermuda sea chub *Kyphosus sectatrix* and the snake eel *Pisodonophis semicinctus*. All of these fish species have reached the Adriatic Sea (at least the southern part) or the eastern basin. Two species, *P. pilicornis* and *P. incisus*, have displayed a stable distribution in the western basin since they first arrived in the Mediterranean and established permanent populations. These two species spread both clockwise and anticlockwise along the western Mediterranean coasts, eventually meeting on the south-east coast of France (Fig. 10; *Parablennius pilicornis*, dates in black). The number of individuals of all Atlantic species has increased during the last decade, whether their spread has been continuous or patchy, and these species are now relatively frequent where they were rare before. Their increasing numbers are having an impact on native populations and may lead to a reduction in the abundance of endemic species.

A review of the spread and/or establishment of these species suggests that their successful invasion may have occurred along three main pathways:

(1) a recent spread through the Strait of Sicily from the eastern to the western basin after 2004/2005;

(2) a constant spread into the western basin through the Gibraltar Strait since their first reported entry into the Mediterranean, involving the establishment of Mediterranean populations;

(3) a sequential spread into the western basin through the Gibraltar Strait, with alternating spreading phases spaced several decades apart. These pathways are considered natural, i.e. they are not human induced.

The changes in the main current circulation in the Mediterranean during the last few decades coupled with the present warming of the western basin may well explain the recent spread of Red Sea species towards the western basin. The reversal of the North Ionian Gyre in 1997 from anticyclone to cyclone, driven by the Bimodal Oscillating System mechanism, had a major impact on exchanges between the eastern basin and the Ionian Sea (Civitarese *et al*., 2010). Moreover, recent studies (including Soto-Navarro *et al*., 2012) have detected a rising salinity trend in Atlantic waters in the period 2003–2007, implying a higher salinity input into the Mediterranean. The sharp rise in the abundance of several Atlantic species in the western basin since 2006 maybe related to this trend. However, the geographical distribution of these species is sometimes highly complex because the natural pathways may be disturbed by human transportation.

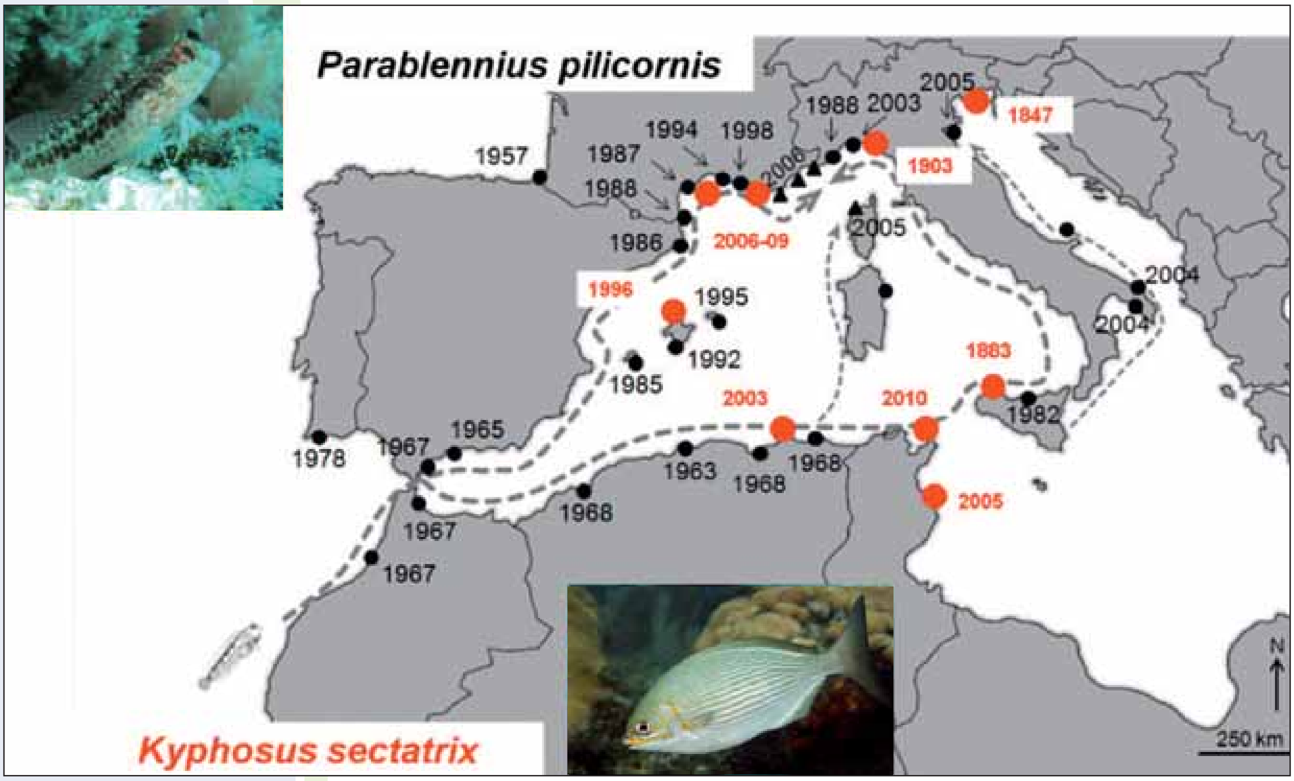


Fig. 11. *Map of the western Mediterranean with the dates of first observations of* Parablennius pilicornis *(in black; triangles mark the meeting point along the south-eastern French coast) and its potential pathway of expansion (arrows) (modified from Pastor & Francour, 2010).* Kyphosus sectatrix *(in red), another Atlantic species, shows a patchy distribution and two phases of spreading, at the beginning and at the end of the 20th century (modified from Francour & Mouine, 2009).*

Parablennius pilicornis. Photo: M. Otero - Kyphosus sectatrix. Photo: K. Bryant

Origin and dispersal of marine invasives

The most important factor that may have contributed to the disparity in the richness and identity of recorded alien species in different parts of the Mediterranean basin is human-associated transport mechanisms. Vectors and pathways, the magnitude of transfer and the geographic sources of the species clearly differ from one region to another, affecting both the species pool and the number of propagules delivered. This variation is perhaps most pronounced between the eastern and the western basins of the Mediterranean. The majority of alien species recorded in the Levant entered through the Suez Canal, whereas mariculture and shipping have been more important means of alien species introduction in the north-western Mediterranean and the Adriatic Sea.

Suez Canal

The Suez Canal has supplied the largest number of successfully established aliens in the Mediterranean Sea in terms of magnitude, frequency and duration of transfer. For decades, the ongoing migration of marine species through the Suez Canal has helped to explain the richness of Red Sea alien species in the eastern Mediterranean Sea, particularly in the Levant area (from Libya and Egypt in the south to Israel, Lebanon and Syria in the east).

Since its opening in 1869, the canal has undergone several major enlargements over the years. Its most recent expansion, completed in January 2010, increased its depth to allow the passage of vessels with drafts of up to 66 ft. The canal's typical cross-sectional area, which was 304 m^2 in 1869, 1,800 m^2 in 1962 and 3,600 m^2 in 1980, is at present 5,200 m^2.

The Suez Canal Authority is currently evaluating a new proposal for increasing the canal's depth or doubling its width to attract loaded very-large crude carriers (VLCCs) and ultra-large crude carriers (ULCCs) (www.suezcanal.gov.eg). A deeper, wider canal will enlarge the saltwater passage to the Mediterranean and consequently enable the migration of more Red Sea species. With the continuous removal of high salinity barriers and the canal's expansion over the years, the influx of these aliens has not abated; quite the opposite, since they have recently been recorded spreading to even deeper waters in the Mediterranean, increasing the spatial extent of invasion not only to coastal ecosystems but also to adjacent environments.

Shipping

Ships can transport alien species in ballast water, as hull fouling or as solid ballast (i.e. with sand, rocks, soil, etc.). Hull fouling on ships was recognized as a vector for alien introductions when non-native serpulid polychaetes were found for the first time in the Mediterranean. It is likely that some, perhaps many, other early introductions have been overlooked.

Shipping has been implicated in the dispersal of numerous neritic organisms, from micro-organisms and macrophytes to fish. Ballast is usually taken into dedicated ballast tanks

Fig. 12. *Map of maritime transportation routes in the Mediterranean. Sources: REMPEC; Beilstein, M., Bournay, E., Environment and Security in the Mediterranean: Desertification, ENVSEC, 2009. By R. Pravettoni - GRID-Arendal*

or into empty cargo holds when offloading cargo, and is discharged when loading cargo or bunkering (fuelling). Ballast water therefore consists mostly of port or near-port waters that can contain many viable alien organisms even after long voyages. After these organisms are flushed into a new port environment, some of them may begin to crowd out native species and disrupt local ecosystems.

Shipping is also an important vector for secondary introductions — the dispersal of an alien beyond its primary location of introduction. The widely invasive algae *Caulerpa taxifolia* and *Caulerpa racemosa* var. *cylindracea* were spread across the Mediterranean by ships, fishing boats and recreational craft. Several Red Sea aliens such as the mussel *Brachidontes pharaonis* have also spread as far west as Sicily in ship fouling. Additionally, shipping trade routes have ensured that the Mediterranean exports biota as well as importing it: the Indo-West Pacific portunid crab *Charybdis hellerii*, which has been present in the eastern Mediterranean since the 1920s, has been transported in ballast tanks to Latin America, and other species such as the veined rapa whelk, *Rapana venosa,* native to the Sea of Japan, have spread to the Aegean and Adriatic Seas, possibly by larval transport in ballast waters from the Black Sea.

Mariculture

The increasing market-driven demands for exotic fish and shellfish and the decline in wild fisheries have created a surge of marine aquaculture (mariculture) along the shores of the Mediterranean in the last 30 years. Production of shellfish has increased exponentially, and two commercially important shellfish, the American oyster *Crassostrea gigas* and the Manila clam *Ruditapes philippinarum*, were intentionally introduced into the Mediterranean for this purpose in the 1960s and 1970s, respectively.

Unrestricted transport of commercially important alien oysters has also resulted in numerous unintentional introductions of pathogens, parasites and pest species. Oyster farms have served as gateways into Mediterranean coastal waters for other associated species as well as several non-native algae. At Thau lagoon, for example, the spread of the brown alga *Sargassum muticum* has locally displaced the native alga *Cystoseira barbata* by blocking light penetration and thus inhibiting the growth and recruitment of the native species. Similarly, the slipper limpet *Crepidula fornicata*, native to the Atlantic coast of North America, also arrived with culture animals in the mussel beds near Toulon (France) in 1957. Parasitic copepods, such as *Mytilicola orientalis* and *Myicola ostreae*, and the toxic dinoflagellate *Alexandrium catanella* are examples of associated alien species introduced into some areas that may render commercial molluscs and other species unfit for human consumption.

Other pathways by which aliens enter MPAs

There are also multiple other vectors or pathways that can bring invasive species into MPAs. Increasing maritime traffic, visits by recreational boats and aquaculture farms in or near protected areas are leading to an increase of marine introductions into many MPAs, with severe ecological impacts on biodiversity in some cases.

Less obvious, although considered the third most important source for the introduction of alien aquatic species, are aquarium and ornamental escapees (IUCN, Lowe *et al.*, 2000). The dumping of unwanted organisms, escapes from tanks and breeding farms, the drainage of water containing organisms from tanks and public aquariums and the direct release of unwanted pets are activities that can bring alien species into the marine environment. A good example of an aquarium species turned invasive is the killer alga *Caulerpa taxifolia,* an alga that now continues to spread through the Mediterranean.

Ports and small marinas act not only as gateways for alien species but also as reservoirs. They can produce a constant spillover of new invaders into surrounding areas, where MPAs may be located, and thereby contribute to their successful establishment.

The growth of marinas in many Mediterranean coastal areas in recent years could be providing a platform for the spread of invasives as these sites are closely associated with the movements of vessels (fishing or recreational boats or commercial ships) carrying alien species as hull fouling. Although antifouling paints help to control fouling, hulls are still an important means of transport for invasive species.

Likewise, small fishing and recreational boats clearly have a high potential for spreading marine organisms. On arrival, transported alien species may release gametes that successfully colonize new areas or they may be discharged from boats and their fragments may re-grow, establishing new populations. Fishing gear, bait products, propellers and anchors, recreational equipment such as scuba-diving gear, and other types of commercial fishing tools have also been implicated in the transport of non-native fauna and flora.

Izola port, Slovenia. Photo: M. Otero

Management strategy and actions against invasive species

The relationship with all the different activities performed *within or in close proximity* to MPAs which may act as dispersal vectors for potentially damaging species is the key to the management of present and future introductions of alien species in protected areas. Regulations, monitoring and awareness raising among fishing and recreational boat owners may help greatly to reduce the establishment of new species. Awareness is particularly important not only within MPAs but also in their surrounding areas to reduce continuous spillover effects from adjacent areas. Educational displays addressing aquarium retailers and hobbyists can also help to prevent escapes from aquariums.

Preventing the establishment of new invasive species should be treated as the top priority. Experience has demonstrated that, once a species is established, prompt control measures may still be effective although they are time consuming and require considerable effort.

The National Park of Port Cross has explored a variety of methods to control the spread of the killer alga *Caulerpa taxifolia,* and now follows a well-structured planning and management protocol to control and eradicate it in different areas of the park (Cottalorda *et al.*, 2010). As the alga can be spread by vessel anchors, diving equipment and fishing nets, management regulations aimed at restricting the further propagation of *Caulerpa* include a ban on anchoring by recreational vessels and on fishing in high-risk areas, the restricted use of buoys for mooring and diving, and awareness-raising activities.

Management also involves a good monitoring programme with volunteer divers and technicians that every year mark out the newly colonized zones so that more experienced workers can then work to eradicate the new colonies through manual harvesting and the use of opaque plastic sheeting to restrict the plants' photosynthesis. These measures have made it possible to significantly slow down the expansion of *Caulerpa taxifolia* within the National Park boundaries.

Eradicating *Caulerpa taxifolia* in Port Cros MPA (France). Photo: A. Rosenfeld - Port Cros National Park

The methods for addressing invasive alien species in MPAs need to be site specific and appropriate to the particular conditions of each site and to the species concerned. Eradication of some species may be possible when an introduced species is identified at an early stage of colonization and still has a limited spatial distribution.

Monitoring. Photo: S. Ruitton - Port Cros National Park

The guiding principles on invasive species adopted by the Convention on Biological Diversity (2002) and the Guidelines for Protected Areas (Tu, 2009) reflect these findings: prevention should be the priority, followed by early detection, rapid response and possible eradication when prevention fails. Following these recommendations, the Draft Marine Invasive Alien Species Strategy for the MedPAN Network provides a framework for common and individual management actions for MPAs (MedPAN Draft IAS Strategy, 2012).

Each MPA management plan should have an IAS strategy integrated into the overall plan. The plan should cover all stages, from developing and implementing specific management plans for high-priority invasive species in vulnerable sites, to identifying opportunities to help prevent new invasions and the spread of established invaders (Fig. 13). Moreover, it should also focus on increasing awareness among the general public and specific groups, building collaboration programmes to address solutions with research and stakeholder groups, and monitoring invasive species' impacts in order to prioritize management actions (see MedPAN Draft IAS Strategy, 2012)

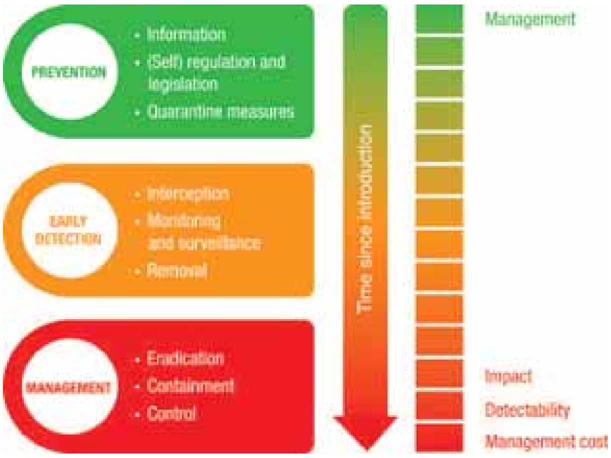


Fig. 13. *Management strategy against invasive species. From Simberloff et al., 2013*

The bryozoan *Tricellaria inopinata.* Photo: G. Breton – Port Vivant

A priority list of species with the greatest potential impact

Vigilance and regular monitoring are a critical component of any effective IAS management programme and such action can result in lower cost and resource use than implementing a long-term control programme after an alien species has become established. To support monitoring in Mediterranean MPAs, a priority list of the species with the greatest potential impact (The Black List for Mediterranean MPAs) has been developed with the assistance of Mediterranean taxonomic and IAS experts, following a series of evaluations and ranking exercises. The purpose of the list is to help identify the most invasive and damaging species in MPAs that may be easily identified by non-specialists, so that they can then be targeted by monitoring and management actions. Some of the species may be very harmful throughout the region, while others might be a major problem in just a few countries or MPAs. Moreover, the Black List may serve as a basis for the development of invasive species monitoring at national or MPA level if this information has not previously been produced. Managers should focus on identifying IAS that are or may potentially be present in their protected areas and may become invasive, by using this list and any other available information from their region.

The present Black List, however, is not static and will need to be revised every 2–3 years with the assistance of the Advisory Group and other expert groups from the Mediterranean region (IUCN Invasive Species Specialist Group and CIESM exotic-species experts, among others) in the light of new information on risk assessments and environmental impacts.

This list therefore presents a wide range of marine invasive organisms that occur in the Mediterranean Sea. The species included meet one or more of the following criteria:

a) they are known to be highly invasive in nature (high invasive potential). They are high-risk species that are actually or potentially ecologically harmful and have the potential to become established over large areas;

b) they can be easily recognized and identified by technicians and MPA managers;

c) they are known to cause significant economic and ecological impacts, degrade and transform natural ecosystems, or negatively affect native species, or they have, or may have, deleterious effects on human health.

Black List of Marine Invasive Species

Algae

1. *Acrothamnion preissii*
2. *Asparagopsis armata*
3. *Asparagopsis taxiformis*
4. *Caulerpa racemosa var. cylindracea*
5. *Caulerpa taxifolia*
6. *Codium fragile sp. fragile*
7. *Lophocladia lallemandii*
8. *Stypopodium schimperii*
9. *Womersleyella setacea*

Angiosperm

10. *Halophila stipulacea*

Cnidarians

11. *Oculina patagonica*
12. *Rhopilema nomadica*

Molluscs

13. *Aplysia dactylomela*
14. *Arcuatula (Musculista) senhousia*
15. *Brachidontes pharaonis*
16. *Bursatella leachii*
17. *Chama pacifica*
18. *Crassostrea gigas*
19. *Crepidula fornicata*
20. *Limnoperna (Xenostrobus) securis*
21. *Pinctada imbricata radiata*
22. *Rapana venosa*
23. *Spondylus spinosus*
24. *Venerupis (Ruditapes) philippinarum*

Crustaceans

25. *Marsupenaeus japonicus*
26. *Metapenaeus monoceros*
27. *Metapenaeus stebbingi*
28. *Percnon gibbesi*

Ascidians

29. *Herdmania momus*
30. *Microcosmus squamiger*

Combjellies/Ctenophores

31. *Mnemiopsis leidyi*

Fishes

32. *Alepes djedaba*
33. *Apogonichthyoides pharaonis*
34. *Atherinomorus forskalii*
35. *Fistularia commersonii*
36. *Lagocephalus sceleratus*
36. *Lagocephalus spadiceus*
36. *Lagocephalus suezensis*
37. *Nemipterus randalli*
38. *Parexocoetus mento*
39. *Pempheris vanicolensis*
40. *Plotosus lineatus*
41. *Sargocentron rubrum*
42. *Saurida undosquamis*
43. *Siganus luridus*
44. *Siganus rivulatus*
45. *Stephanolepis diaspros*
46. *Upeneus molluccensis*
47. *Upeneus pori*

Monitoring programme design

Standard monitoring protocols for marine invasive alien species in MPAs with examples of work conducted in protected areas

There is a variety of monitoring methods and programmes operating in MPAs, but few of them are specifically designed to monitor alien species and marine invasive alien species. Monitoring the abundance and distribution patterns of alien species, particularly those that are invasive in nature, will help us to detect problems early, understand the relative risk of invasions by different species into MPA environments, identify the potential patterns of invasions and see how to target management efforts so as to reduce further risks. The spatial and habitat distribution of a given IAS can further provide useful information to help identify which areas are most at risk of being invaded in the future.

A monitoring programme must cover all stages of assessment, be simple, and record the presence and status of different species, through a science-based approach. It can also take advantage of existing programmes in the MPA in which specialist teams monitor native species diversity, and it can also use trained volunteers (such as recreational diving club members) specially to report sightings in new areas or of new species.

Underwater visual surveys

To monitor the occurrence and spatial distribution of invasive species inside an MPA, a series of sampling stations should be selected beforehand. These stations should be chosen to be representative of all the habitats, depth ranges, substrates and wave exposure conditions found in each individual MPA. The number of sampling stations will therefore be variable and will depend on the MPA's size and habitat heterogeneity as well as the logistical and financial facilities available.

The monitoring, conducted by two scuba divers, should follow linear transects perpendicular to the shore and it should be run twice a year in summer and winter to detect the presence of alien species of seasonal occurrence. If that is not possible due to logistical or financial constraints, the monitoring should be run at least once a year, preferably in summer, and at the same time each year. Perennial plant species display their greatest growth over summer making them easier to detect at this time.

On vertical walls and steep slopes, monitoring can be undertaken in two stages (Fig. 12). The first stage (during the descent) will serve to identify the main topographic and bathymetric features and the succession of habitats at different depths from the surface to the deepest zone reached in each transect. In the second stage (during the ascent), the divers will carefully examine each of the benthic communities found for approximately ten minutes to detect the presence or absence of possible invasive and/or alien species. If an alien species is found, its relative abundance should be estimated. This may be performed by using semi-quantitative methods such as the Braun Blanquet scale.

Braun Blanquet cover-abundance scale

Braun-Blanquet scale	Range of cover (%)
5	75-100
4	50-75
3	25-50
2	5-25
1	<5; numerous individuals
+	<5; few individuals

A similar procedure could be followed when an invasive species is detected. If it is feasible during the same dive, its abundance should be recorded in each habitat. Taking photographs of unidentifiable species or potential biological invaders can be a valuable aid to confirm identification.

On more level substrates, monitoring can be performed along transects 25 m long and 5 m wide at each station. Along each transect, the divers should swim in one direction at constant speed, identifying and recording the presence of each alien species encountered. To record the spatial distribution and density of different taxonomic groups, a variety of standard methodologies can be used. This work can be conducted during a second visit to the area.

Monitoring species. Photo: L. Tunesi

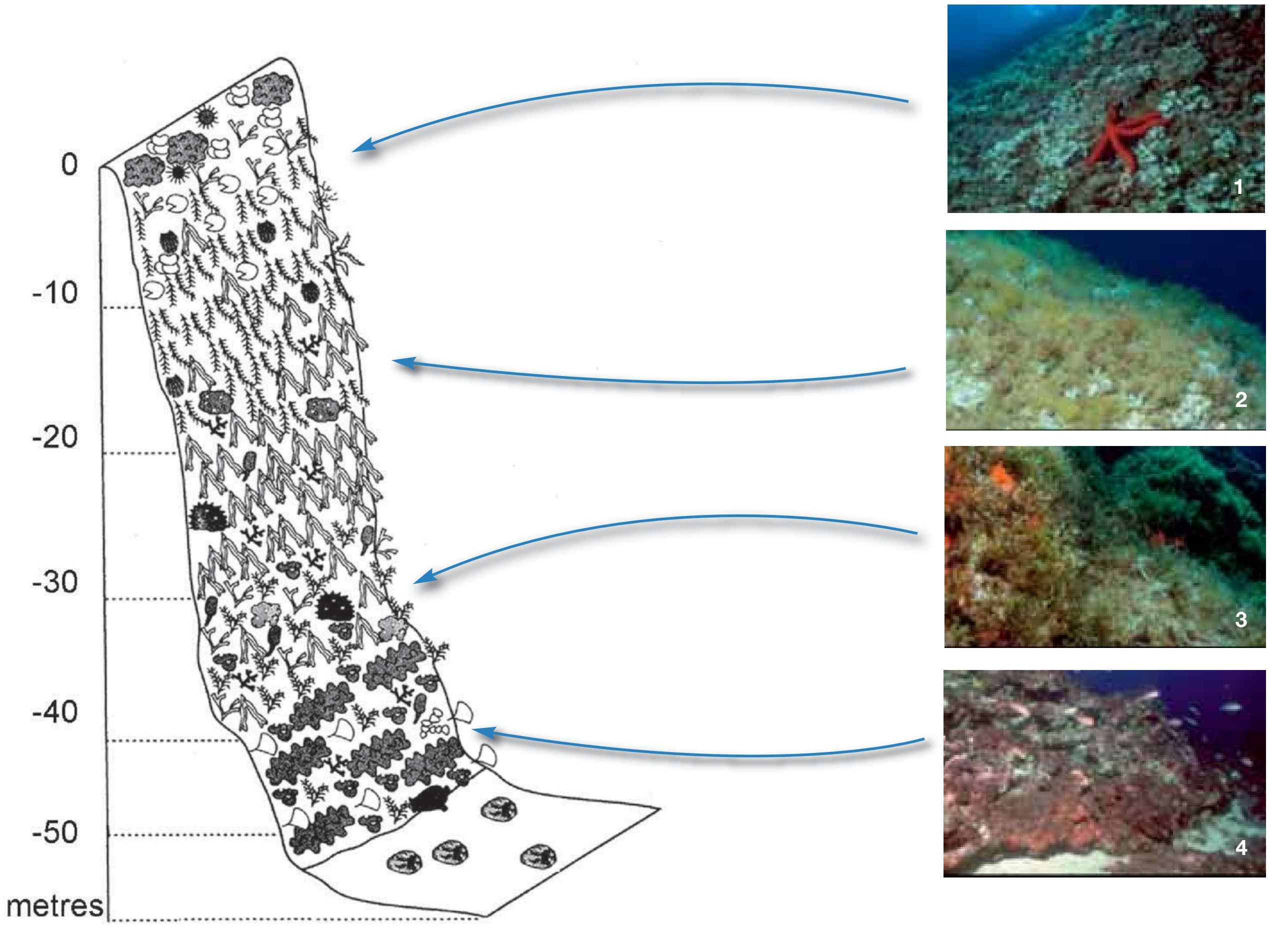
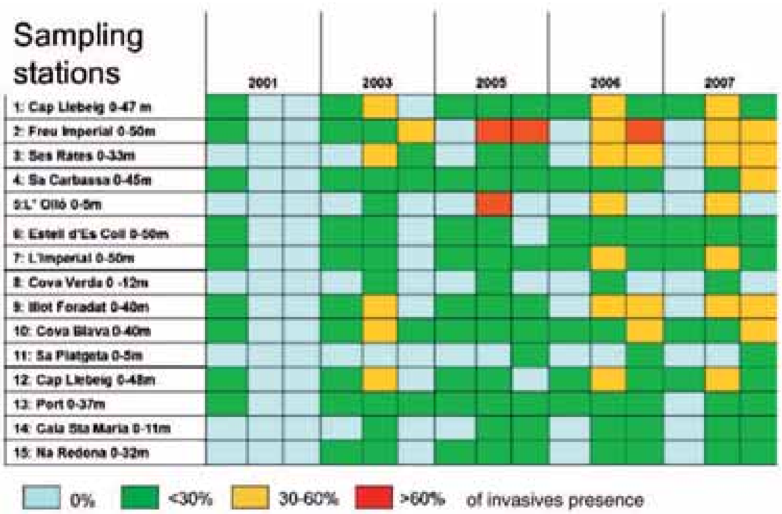


Fig. 14. *Graphical representation of a transect at a sampling station representative of highly exposed rocky bottoms. 1. Exposed photophilic algae; 2. Cystoseira sp. beds; 3. Shade-loving algal communities dominated by Dictyopteris polypodioides and invertebrates; 4. Coralligenous outcrops invaded by Womersleyella setacea. Bathymetric transect: Jordi Corbera. Photos: E. Ballesteros*

TABLE 2. Example of the information that can be obtained from a qualitative estimate of the invasive species present at each sampling station monitored in Cabrera National Park (Spain) along the years. Source: E. Ballesteros *et al.*



Bursatella leachii. Photo: B. Weitzmann

Monitoring invasive algae

For each different habitat, the coverage of invasive algae may be quantified by using 25 cm x 25 cm quadrats, each subdivided into 25 subquadrats of 5 cm x 5 cm (Cebrian *et al.*, 2000; Fig. 13). In each habitat type, divers position 20 quadrats (covering a total area of 1.25 m^2) randomly over the substrate and record the number of subquadrats in which the specific invasive alga occurs.

Monitoring sessile invertebrates and species with scattered distribution

Bathymetric transects performed in different habitats at each sampling station may firstly identify the depth at which other invasive species are most abundant. At each depth, two transects (50 m x 1 m) located randomly should be monitored by a scuba-diving team. In those cases where invasive species may be of a considerable size (e.g. the invasive coral *Oculina patagonica*), only colonies or individuals with at least 50% of their surface area lying within the belt transect should be considered and counted to avoid bias in the sampling (Nugues and Roberts, 2003).

Monitoring invasive fishes

At each sampling station, the abundance and size of any invasive fish should be recorded along transects. An observer should dive at an approximately constant speed along three 25 m x 5 m transects at each sampling station and at a fixed depth (where invasive fishes are most abundant).

Along each transect the observer will identify the species, count the number of individuals observed and estimate the approximate size of all individuals (in 2 cm increments of total length, TL). Fish biomass (g wet weight m-2) can be estimated from size data using length-weight relationships from the available literature and databases (Froese and Pauly, 2009).

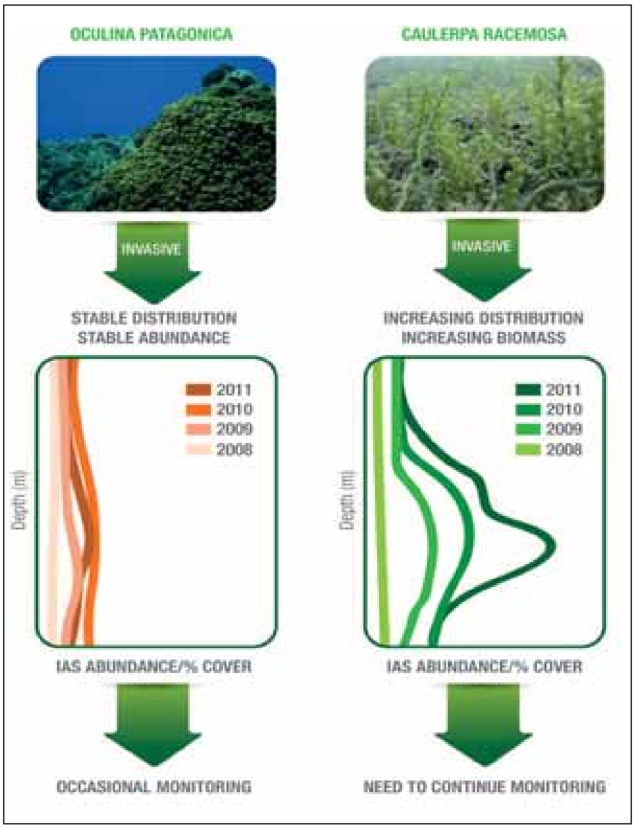


Fig. 16. *Monitoring can be used to illustrate the extent and the depth range of invasive colonizers over time. Some species, such as* Caulerpa racemosa var. cylindracea*, might start their colonization at greater depths and move to shallower waters after a few years, making it more difficult to detect them if surveys are only conducted in shallow environments.*

Fig. 15. *Semi-quantitative method to calculate percentage of cover of benthic species. Photo: E. Ballesteros*

Stephanolepis diaspros. Photo: A. Can – www.alpcan.com

Reporting the discovery of non-native species: Collecting specimens, recording information and reporting

Digital photographs of unknown specimen(s) can be a very valuable tool for taxonomic experts to identify or verify species. In some cases, specimens may also be collected for further taxonomic identification if it seems necessary. During this process, care should be taken to avoid spreading the species into other areas.

The simplest method of obtaining algae for identification involves placing a sample of the algae in a sealable container with water and immediately storing it at a low temperature until it can be brought to an expert for identification. Invertebrates can be stored in a closed box with alcohol or be frozen and fishes should be placed in double plastic bags and frozen.

Within the MedPAN Network, an alert system set up to report new observations on IAS could provide online information for managers and organizations on the spread of IAS. Managers and interested institutions could receive information on the arrival of new species into nearby areas and direct their efforts towards planning and managing the invasives while their numbers are still small. Records could be displayed with species information, locations and maps, and the status and dates of new sightings per species or per area (see Table 3).

The organization of the alert system communication protocol will thus ensure that information about any new species detected in the MPA is quickly passed on so that an assessment and remedial action can be proposed (see MedPAN Draft IAS Strategy, 2012).

TABLE 3

DATA NEEDED FOR REPORTING SIGHTINGS	
–	**Contact information (name and e-mail address)**
–	**Monitoring location:**
	Latitude and longitude in decimal degrees MPA name City, country Habitat type (e.g. bay, pier, marina, rocky shore, seagrass bed, intertidal)
–	**Observation details:**
	Date, time
–	**Species observations:**
	Scientific name of species: (optional) Abundance (e.g. on Braun Blanquet scale) per depth Range of depth(s) where it occurs Additional material (e.g. photos)

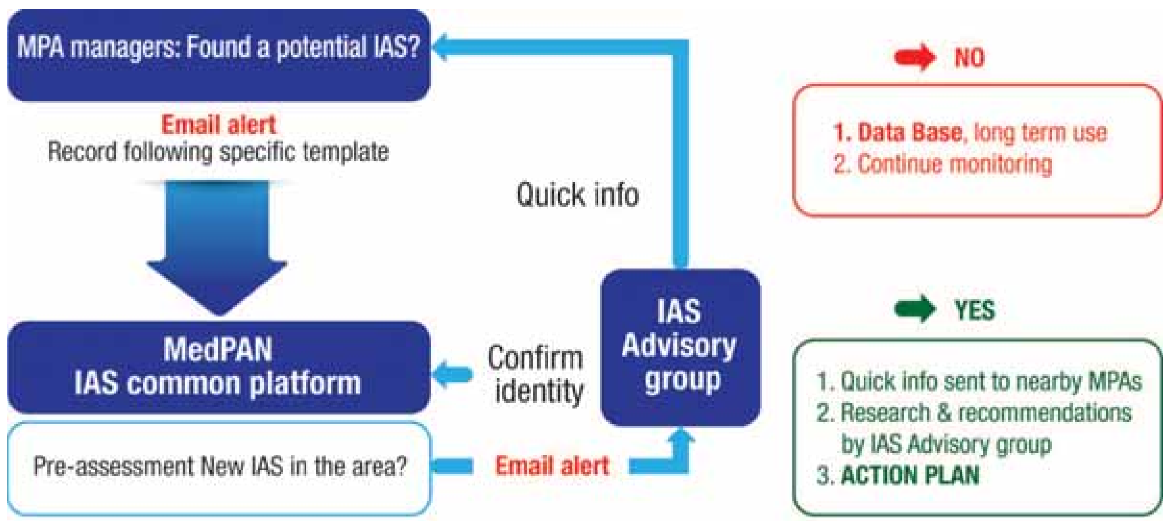


Fig. 17. *Proposed IAS alert system for the MedPAN Network*

Examples of monitoring programmes conducted by volunteers

Marine monitoring is expensive and labour intensive, but training volunteers to conduct marine surveys can significantly enhance both prevention and the early detection of invasive species, as well as helping with limited funding constraints. In some Mediterranean MPAs and in other coastal areas, local volunteer organizations, fishermen and wildlife enthusiasts can assist in monitoring the coastal waters and gather new information to aid the early identification of new invasive species. More importantly, the involvement of local volunteers can have other benefits for the MPA, such as facilitating a sense of ownership and appreciation for the local marine environment.

For example, last year several recreational diving clubs and schools in Malta surveyed a number of localities around the MPA between Filfla and Għar Lapsi (North Malta) for marine invasive species. Before the sampling started, researchers from the University and the Malta Environment and Planning Authority (MEPA) introduced the volunteers to the identification and survey methodology in an hour-long training session. Participants were provided with simple field guides (slates) to identify the species of concern and the monitoring protocol to follow at each site. By marking these transects, volunteers collected data on the presence and abundance of species. After the corroboration of the data by experts, preliminary information already showed the presence of the invasive fishes *Fistularia commersonii, Siganus luridus and Stephanolepis diaspros* along this coast.

Since 2009, the NGO For-Mare has been involving volunteer university students and members of the public in monitoring the distribution of marine alien species in Italian MPAs. This successful programme follows a series of summer student training courses (June–September) on Marine Applied Ecology. Practical work includes the use of visual census techniques for assessing the abundance and distribution of alien species in five MPAs: Cinque Terre (Ligurian Sea), Bergeggi Island (Savona, Ligurian Sea), Pelagie Islands (Strait of Sicily), Torre Guaceto (Lecce, Adriatic Sea) and Porto Cesareo (Lecce, Ionian Sea). Additionally, at some sites, tourists can follow shorter summer monitoring courses to recognize native endangered species and their non-native competitors. Volunteers are provided with underwater digital cameras and guided by teachers on a brief snorkelling tour in the study area, where they can learn and gain confidence with species identification before starting surveying other areas. Thus volunteers play a leading role in data collection and interpretation in strict collaboration with teachers and experts.

Local knowledge can also provide an alternative information source. A study conducted in several Italian localities, including the Linosa and Lampedusa MPAs in the Pelagie Islands (Strait of Sicily), using fishermen's knowledge provided important information on the presence and dynamics of invasive species such as *Fistularia commersonii* and *Siganus luridus* (Azzurro et al., 2011).

Invasive species trainning of marine volunteers in Malta. Photo: MEPA (Malta Environment and Planning Authority), MedPAN North Project.

Poster for the identification on invasive species in the Ligurian MPAs. Source: V. Cappenera, Portofino MPA. MedPAN North project.

Mediterranean invasive species factsheets

The following factsheets have been developed to provide MPAs with identification assistance and general information about individual invasive species. Each sheet contains photographs, illustrations and narrative descriptions to highlight important anatomical structures and features of a particular species. The species are grouped taxonomically into macrophytes (algae and seagrasses), cnidarians (jellyfish, corals, sea anemones and hydras), molluscs, crustaceans, ascidians, comb jellies or ctenophores, and fishes. Within each group, they are ordered alphabetically by scientific name.

For each species, there is a description of the main characteristics that can be used to identify the species (*Key identifying features*) and a general description of the habitat and other characteristics for field observations (*Field identification signs and habitat*). *Similar species* includes information on how to differentiate the species from other species (native or alien) that can be found in the Mediterranean and are similar in appearance. The *Brief history and route of introduction* explains the general known distribution of the species in the Mediterranean to date, its origin and the likely pathway of introduction and spread. A general description of potential or documented *Ecosystem and economic impacts* summarizes the available information on the consequences of the species' invasions or its potential impacts, and a *Management options* section aims to provide some alternatives for action in MPAs, if there are any in light of present knowledge. A brief list of references for *Further reading* gives suggestions on other documents for consultation, mostly freely available online.

It should be noted that the information provided on the distribution of species is taken from the current scientific literature; however, as species may spread to new areas quickly, this information may soon become out of date. Consultation of existing databases (see Annex 2) is therefore recommended.

Black List of Marine Invasive Species

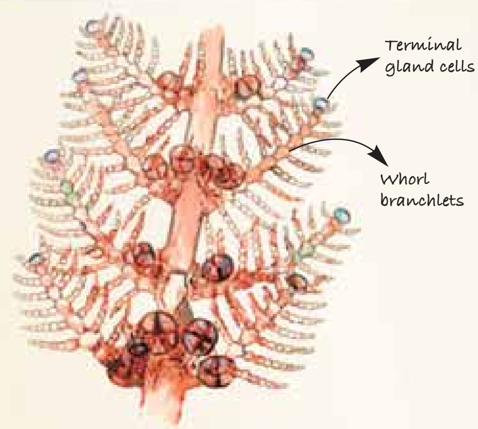
Crassostrea gigas. Photo: L. Schroeder - www.PNWSC.org

ALGAE

Scientific Name:
Acrothamnion preissii

Common name: not assigned

Reproduction
identification
Picture
Brief history



Key identifying features

Clumps of loose algae, rose-red in colour and highly branched, 0.5–1.5 cm long, forming dense monospecific mats up to 1 cm thick. The thallus is attached to the substrate or other algae by rhizoids.

The species can only be identified under a binocular microscope. Consequently, accurate identification might need to be checked by a specialist in this group.

Central cells are cylindrical, without cortication; main branches measure 150–300 μm long and 40–60 μm wide. In general, each central cell produces 3–4 lateral branches distally. Terminal gland cells, observed at the end of most branches, are transversely ovoid, 16–22 μm in diameter.

Acrothamnion preissii. Photo: E. Ballesteros

Field identification signs and habitat

Often found as an epiphyte on sea grasses such as *Posidonia oceanica* or various algae, from shallow subtidal zones to depths of nearly 40 m. As an invasive species, it forms dense cotton-wool-like tufts, mostly in dim light conditions (i.e. on *Posidonia oceanica* rhizomes, in maerl beds, or in cave entrances and crevices).

Acrothamnion preissii. Photo: B. Weitzmann

Acrothamnion preissii. Photo: B. Weitzmann

Reproduction
In the Mediterranean Sea only vegetative reproduction is known and no fertile specimens have been found.

Similar species
Although it can easily be confused with other filamentous red algae (i.e. *Womersleyella setacea*) when directly observed in the field, the presence of terminal gland cells at the end of most branches is a useful character for identifying *Acrothamnion preissii.*

Womersleyella setacea. Photo: E. Ballesteros

Brief history of its introduction and pathways
An Indo-Pacific species native to Western Australia, New Zealand, South Africa and Japan that has probably been introduced into Europe by maritime transport (on ship hulls). At present, it is mainly distributed in the north-western Mediterranean, forming invasive populations in France, Italy, Monaco and Spain.

Ecological impacts
Ecological impacts of the red alga *Acrothamnion preissii* are still largely unknown but, when invasive, it becomes dominant outcompeting or replacing most native algal species.

Economic impacts
Unknown.

Management options
Once it has become invasive, **eradication** and even containment are not possible. The species might be controlled most efficiently and effectively, and at the lowest cost, early in the invasive process.

Further reading
Ferrer, E., *et al.* 1994. The spread of *Acrothamnion preissii* (Sonder) Wollaston (Rhodophyta , Ceramiaceae) in the Mediterranean Sea: New record from the Balearic Islands. Fl. Medit. 4, 163-166.

Klein, J.C. & Verlaque, M., 2011. Macroalgae newly recorded, rare or introduced to the French Mediterranean coast. Cryptogamie Algologie 31(2), 111-130.

Piazzi,I. & F. Cinelli., 2000. Effects of expansion of introduced Rhodophyceae *Acrothamnion preisii* and *Womersleyella setacea* on the algal communites of *Posidonia oceanica* rhizomes in the western Mediterranean. Cryptogam. Algol., 21(3): 291-300.

Drawings: Juan Varela

ALGAE

IUCN

Scientific Name:
Asparagopsis armata

Key identifying features

A red seaweed with two morphologically different stages during its development, a gametophyte stage and a tetrasporophyte stage. Its cylindrical, bare main stolons (1mm wide, 200 mm long) are irregularly branched, with bushy fronds. Its lower branchlets are long and have hooks that resemble harpoons.

Field identification signs and habitat

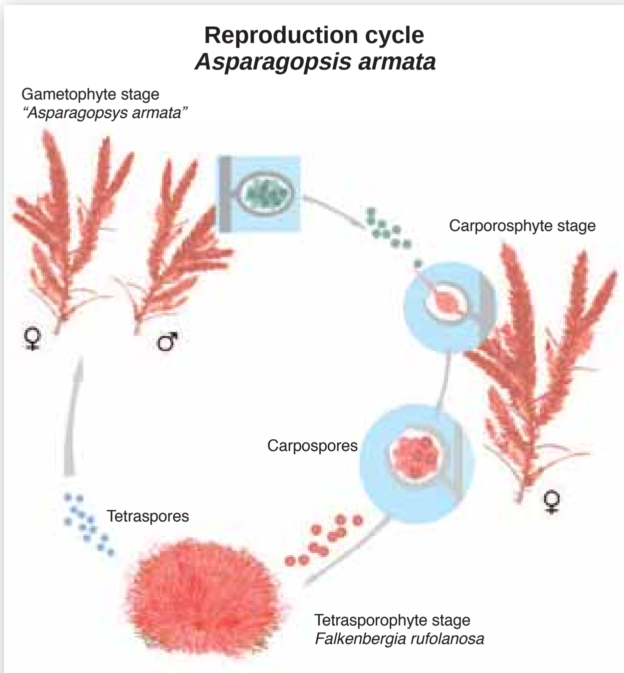
The gametophyte stage is pale purplish-red, quickly degenerating when removed from the water and becoming distinctly orange. It can be found growing as an epiphytic alga on other algal species, especially *Corallina* sp. The tetrasporophyte stage is a brownish-red, filamentous, branched alga, forming dense cotton-wool-like tufts 15 mm in diameter.

Usually this alga develops on infralittoral rocky bottoms from the surface to a depth of 40 m.

Asparagopsis armata. Photo: E. Talledo - OCEANA

Reproduction

It is able to reproduce sexually and has a two-phase (heteromorphic diplohaplontic) life cycle with two main morphologically different stages during its development. The gametophyte phase, which was the form named *Asparagopsis armata*, has either male or female organs; this is followed by a microscopic carposporophyte middle stage, and then by the tetrasporophyte phase, which was originally named *Falkenbergia rufolanosa*. The gametophyte and sporophyte stages are also capable of reproducing vegetatively. Drifting gametophytes readily attach to other algae by barbed branchlets and produce new shoots. '*Falkenbergia*' also disperses by flotation.



Similar species

Gametophytes of *Asparagopsis armata* can be easily misidentified as another successful invader, *Asparagopsis taxiformis*, but the presence of harpoon-like hooks in *A. armata* distinguishes it. *A. armata* is able to survive and thrive in colder environments than *A. taxiformis*, which has an affinity for much warmer waters. The genus as a whole appears to have a high invasive potential. These seaweeds disperse with water currents, attached to floating objects.

Asparagopsis taxiformis

Another alien species of red algae, *Bonnemaisonia hamifera*, occurs in similar habitats. It can be distinguished in its gametophyte stage by the crozier-shaped, hook-like, modified branches that it forms.

Bonnemaisonia hamifera

Brief history of its introduction and pathways

Native to Western Australia, this species was probably introduced into European waters through oyster aquaculture. Nowadays it is distributed throughout Europe in both the Atlantic and the Mediterranean basin, and it is highly invasive.

Asparagopsis taxiformis. Photo: B. Weitzmann

Ecological impacts

Unknown, but it probably outcompetes native species for space and light.

Economic impacts

Pharmaceutical trials have shown the potential pharmaceutical compounds of *A. armata* that exhibites strong activity against fish pathogenic bacteria.

Management options

Once it has become invasive, **eradication** and even containment are not possible. The species might be controlled most efficiently and effectively, and at the lowest cost, early in the invasive process.

Further reading

Altamirano M., Román A., De la Rosa J. C., Barrajón-Mínguez, A., Barrajón-Menech, A., Moreno, C., Arroyo, C. 2008. The invasive species *Asparagopsis taxiformis* (Bonnemaisoniales, Rhodophyta) on Andalusian coasts (Southern Spain): reproductive stages, new records and invaded communities. Acta Botánica Malacitana, Nº 33, 2008, 5-10.

Ní Chualáin, F., Maggs, C.A., Saunders, G.W. & Guiry, M.D., 2004. The invasive genus Asparagopsis (Bonnemaisoniaceae, Rhodophyta): molecular systematics, morphology, and ecophysiology of Falkenbergia isolates. Journal of Phycology 40: 1112-1126.

Drawings: Juan Varela

ALGAE

Scientific Name:
Asparagopsis taxiformis

Key identifying features

A red alga that exhibits two morphologically different life stages. The gametophyte stage (*Asparagopsis taxiformis*) is a pale purplish-red alga, up to 30 cm in height, forming conspicuous monospecific stands when invasive. Its fronds are bushy, with a cylindrical axis up to 1 mm wide and 200 mm long, arising from bare, creeping stolons; it is irregularly branched, branches being 5–10 mm long.

Field identification signs and habitat

This species usually grows on infralittoral rocky bottoms from the sea surface to a depth of 50 m. The sporophyte stage (*Falkenbergia hillebrandii*) is filamentous, rose-red in colour, much branched and forming dense cotton-wool-like tufts 15 mm in diameter. *Asparagopsis taxiformis* can be an epiphyte on other organisms, especially on *Corallina* species, colonizing many different habitats from littoral pools to rocky bottoms down to 20 m in depth.

Asparagopsis taxiformis. Photo: E. Ballesteros

Asparagopsis taxiformis. Photo: J.C. Garcia

Reproduction

It is able to reproduce sexually and asexually and has a macroscopic gametophyte phase, referred to as *Asparagopsis*, and a macroscopic tetrasporophyte phase known as the '*Falkenbergia*' stage.

Its highly successful vegetative reproduction may account for the rapid spread of the species, which has an attachment system consisting of basal stolons and rhizoids that facilitate the establishment of reproductive fragments.

Similar species

This species resembles *Asparagopsis armata*; however, the presence of harpoon-like hooks in the gametophyte stage of *A. armata* and the absence of them in *A. taxiformis* is a distinguishing character. The tetrasporophyte of *A. taxiformis* is, however, apparently indistinguishable from that of *A. armata*. The genus as a whole is noted for its high invasive potential.

Asparagopsis armata

Brief history of its introduction and pathways

Native to Western Australia, this species shows invasive behaviour around the Indo-Pacific region, including Japan and Hawaii. *Asparagopsis taxiformis* was probably introduced to the Mediterranean via maritime transport, and is currently widespread throughout the Mediterranean and along the Atlantic coast of Europe.

Asparagopsis armata. Photo: M. Otero

Ecological impacts

Unknown, but it probably outcompetes native species for space and light.

Economic impacts

Unknown. Trials have shown the potential pharmaceutical compounds of antifungal and antibiotic activity of this algae.

Management options

Once it has become invasive, **eradication** and even containment are not possible. The species might be controlled most efficiently and effectively, and at the lowest cost, early in the invasive process.

Further reading

Altamirano J. *et al.* 2008. The invasive species *Asparagopsis taxiformis* (Bonnemaisoniales, Rhodophyta) on Andalusian coasts (Southern Spain): reproductive stages, new records and invaded comunities. Acta Botánica Malacitana, 33, 5-10.

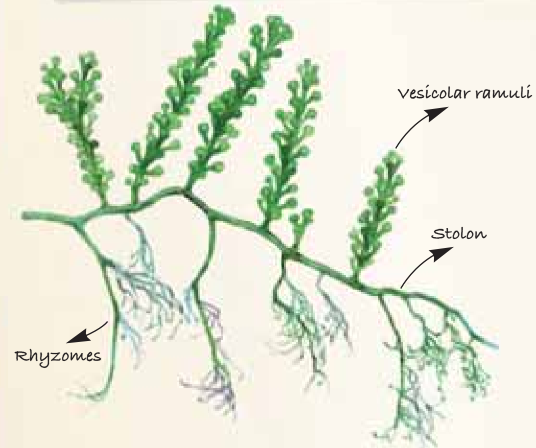
Andreakis, N. *et al.*, 2004. *Asparagopsis taxiformis* and *Asparagopsis armata* (Bonnemaisoniales, Rhodophyta): genetic and morphological identification of Mediterranean populations. Eur. J. Phycol. , 39: 273 – 283.

Drawings: Juan Varela

ALGAE

Scientific Name:
Caulerpa racemosa var. cylindracea

Common name: Grape alga



Reproduction | identification | Picture | Brief history

Key identifying features

Caulerpa racemosa var. *cylindracea* is a green alga with erect fronds up to 11 cm (exceptionally 19 cm) in length that bears rounded, vesicular branchlets (also called ‘ramuli’). Its fronds are slightly inflated above their attachment to the stolon, which is fixed to the substrate by thin rhizoids

Field identification signs and habitat

This alga occurs in different morphologies and sizes, especially frond length, depending on the region, depth and season. It can be found from the intertidal zone to depths of more than 60 m.

Caulerpa racemosa. Photo: K. Ellenbogen - OCEANA

Caulerpa racemosa. Photo: B. Weitzmann

Caulerpa racemosa. Photo: E. Ballesteros

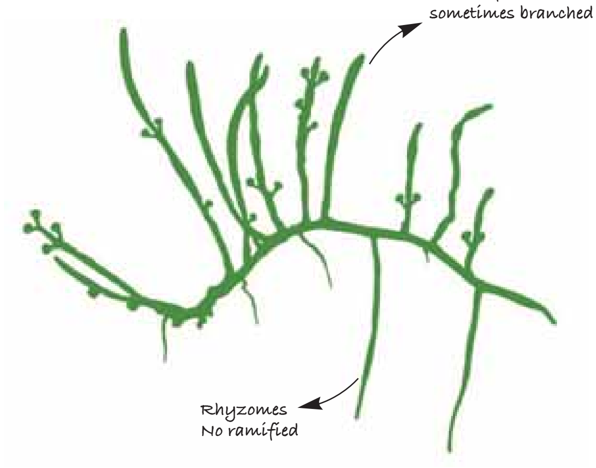
Reproduction

Caulerpa racemosa var. *cylindracea* is able to reproduce sexually and vegetatively. In sexual reproduction, the whole plant forms gametes, which are released simultaneously, resulting in the death of the parent plant.

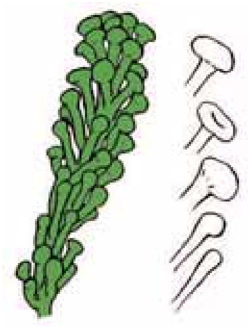
Vegetative reproduction may occur in three ways, by growth, fragmentation or formation of propagules (ramuli dispersion). Fragmentation may occur in any part of the alga as a consequence of anthropogenic or natural causes, such as currents or grazing by animals. The plant is capable of rapid propagation from fragments.

Similar species

Caulerpa racemosa var. *cylindracea* resembles the two native *Caulerpa racemosa* varieties. It is particularly similar to *C. racemosa* var. *lamourouxii f. requienii*, but in this native variety the surface is much smoother, the bladder-like ramuli are rounded but less inflated and shorter, and the erect fronds can be partly unbranched, slightly compressed or of irregular width. The other native variety, *Caulerpa racemosa* var. *turbinata*, has the ends of its branchlets flattened.



Caulerpa racemosa lamourouxii



Caulerpa racemosa turbinata

Brief history of its introduction and pathways

C. racemosa var. *cylindracea* is an endemic species from south-western Australia. The mode of introduction of the invasive Mediterranean variety of *Caulerpa racemosa* var. *cylindracea* into the Mediterranean Sea remains speculative; however, maritime traffic (ballast water and ship hull fouling) and the aquarium trade are the most likely vectors for the introduction of this high-impact alga. *C. racemosa* can still be found in aquarium stores and is sold by internet retailers.

Ecological impacts

Caulerpa racemosa var. *cylindracea* represents an important threat to the diversity of benthic coastal ecosystems (i.e. seagrass beds, maerl beds and coarse sediments), since it alters habitat characteristics, competes with native species and changes native benthic communities. This species is now found carpeting many coastal areas. It is considered to be one of the 100 worst invasive species in the Mediterranean, as it can alter the physical and chemical conditions of the environment (including water movement, sediment deposition and substrate characteristics), as well as causing profound changes to benthic assemblages of algae and invertebrates.

Economic impacts

The economic impact of *C. racemosa* var. *cylindracea* has never been quantified, although there are reports of fishing nets being clogged and broken by this invasive alga, thereby reducing fish catches. The monotonous seascape produced by the dominance of this alga may also reduce the attractiveness of a site for underwater tourism (such as spearfishing, scuba diving and free diving).

Management options

Prevention: Stronger legislation and local regulations controlling the activities of the aquarium trade, shipping, fishing and mariculture are urgently needed to prevent the further spread of this species.
Eradication: Experimental eradication studies or programmes for *C. racemosa* in the Mediterranean are rare. They have been applied with some effectiveness in small areas (400–1,000 cm^2), especially in restricted areas such as bays and harbours. The standard procedure is manual removal of the weed at 3 to 4-week intervals. Nevertheless, *C. racemosa* fragments tend to recolonize these areas again after a period of 2 to 18 months.

Further reading

Verlaque, M., *et al.* 2000. The *Caulerpa racemosa* complex (Caulerpales, Ulvophyceae) in the Mediterranean Sea. Botanica Marina 43, 49–68.

http://www.europe-aliens.org/pdf/Caulerpa_racemosa.pdf

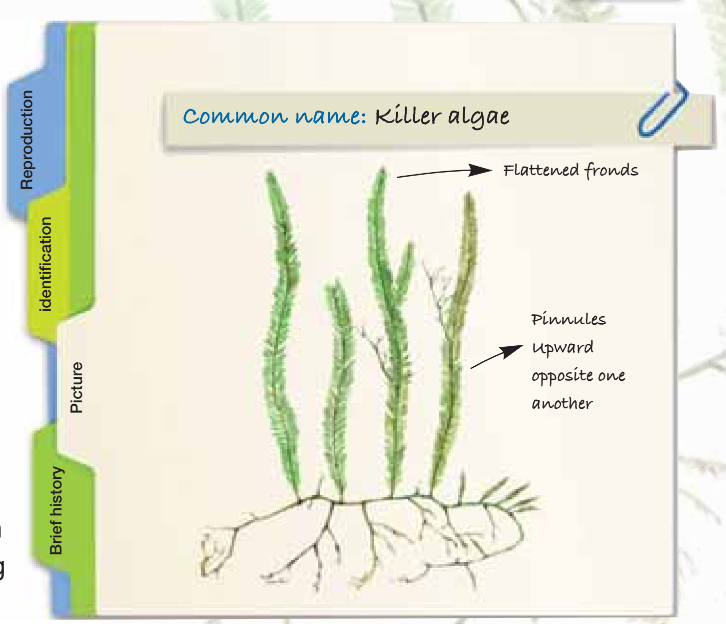
Cebrian E., *et al.* 2011. Exploring the effects of invasive algae on the persistence of gorgonian populations. Biological Invasions DOI: 10.1007/s10530-012-0261-6.

Klein J, Verlaque M., 2008. The *Caulerpa racemosa* invasion: a critical review. Marine Pollution Bulletin 56, 205–225.

Drawings: Juan Varela

ALGAE

Scientific Name:
Caulerpa taxifolia



Key identifying features

Caulerpa taxifolia is a light to dark green alga with upright feather-like fronds. The fronds, up to 10 cm in length, are flattened laterally and rise from a creeping main stolon anchored by rhizoids to the substrate. Small side branchlets (pinnules) attached to the fronds are flattened and slightly curved upwards, narrowing towards the tips.

Field identification signs and habitat

C. taxifolia can colonize all types of available substrate including rocky, sandy and muddy bottoms, sheltered and exposed habitats, and polluted or pristine waters from the surface down to a depth of 80 m.

Reproduction

Sexual reproduction of this alga in the Mediterranean remains unknown, because only male gametes have been found to date. However, it reproduces vegetatively very successfully by fragmentation. During summer (June to September) the stolon can grow up to 3.2 cm per

Caulerpa taxifolia. Photo: E. Ballesteros day and form completely new fronds every other day, reaching densities of approximately 5,000 fronds per square metre.

Similar species

This species resembles other *Caulerpa* species, especially *C. sertularioides. C. sertularioides* is a more delicate alga with cylindrical branches, different from the flattened branchlets of *C. taxifolia*. Its rising branchlets are also more rounded towards their tips, compared to the more angular, squared-off branches of *C. taxifolia*.

Caulerpa sertularoides

Brief history of its introduction and pathways

Caulerpa taxifolia was accidentally introduced into the Mediterranean from a public aquarium in Monaco. Since then, it has spread rapidly due to its natural vegetative dispersal mechanism, its lack of natural grazers and the ease of anthropogenic dispersion by boats, anchors, fishing nets and aquaria.

Natural dispersion occurs near the central invasion zone, but its wider spread is facilitated by transport on pleasure boat anchoring equipment and on fishing nets.

Ecological impacts

Caulerpa taxifolia appears to be having a major impact in several locations, where it invades a large number of habitats such as seagrass beds, modifies organic and inorganic components of the sediment and potentially threatens biodiversity. A decline in biodiversity and in fish biomass have been seen in areas that *C. taxifolia* has invaded. For this reason, it is important to differentiate it from native species.

Economic impacts

Their economic impact has never been quantified, but the killer algae frequently become entangled in nets and round anchors, reducing fishing catches. The algae also continue to be found in the aquarium trade.

Management options

Prevention: Stronger legislation and local regulations controlling the activities of the aquarium trade, shipping and mariculture are urgently needed.

Eradication: Various methods have been proposed and tested: manual uprooting, a range of underwater suction devices, physical control with dry ice, hot water jets, chemicals and underwater welding devices to boil the plants *in situ*. The variable, limited results of these different attempts have precluded the establishment of any permanent control programmes.

Another possible form of control is the introduction of natural predators into the invaded environment. Several research programmes are testing the use of biological control methods involving the artificial introduction of grazing mollusc species.

Further reading

http://www.europe-aliens.org/pdf/Caulerpa_taxifolia.pdf

Cottalorda, J. M. *et al*, 2010. Le Parc national de Port-Cros: une structure référence dans la mise en oeuvre de stratégies de contrôle de la Chlorobionte envahissante *Caulerpa taxifolia* (Valh) C. Agardh. Sci. Rep. Port-Cros natl. Park, Fr., 24: 105-126.

Drawings: Juan Varela

ALGAE

Scientific Name:
Codium fragile subsp. *fragile*

Key identifying features

A large, dark green alga consisting of one to several erect fronds, 15–20 cm high, with abundant cylindrical branches in a dichotomous or fastigiated pattern, and attached to the substrate by a broad spongy basal disc. The cylindrical branches are 0.3–1 cm in diameter. Shape and structure may vary depending on the environmental conditions.

The species can only be distinguished from several other similar varieties or subspecies under a binocular microscope by the shape of the microscopic flask-shaped outer structures (utricles). *Codium fragile* subsp. *fragile* has a hairy surface and the utricles at the tips of the branches form regular cylinders with a sharp terminal point.

Field identification signs and habitat

Like other *Codium* species, *C. fragile* subsp. *fragile* is soft and spongy to the touch. It tolerates large variations in salinity and temperature, enabling it to colonize a wide range of environments. It appears to thrive on intertidal and shallow subtidal rocky bottoms, and in sheltered habitats such as harbours and bays.

Codium fragile subsp. *fragile* Photo: Poloniato - WWF; Miramare MPA

Codium fragile. Photo: E. Ballesteros

Reproduction

Its success as a rapid colonizer may be attributed to its range of propagation techniques. It can reproduce either sexually or by releasing small propagules in the water column, which are dispersed locally. It also reproduces vegetatively by fragmentation of the thallus, forming new plants that are dispersed by currents and re-attach elsewhere, or from basal holdfasts that remain after fragmentation. The plant is perennial, proliferating each spring from a persistent basal portion.

Similar species

Due to its morphology, *C. fragile* subsp. *fragile* could be mistaken for two other *Codium* species: the native *C. vermilara* and *C. decorticatum*, and only microscopic examination of the utricles, which are only cylindrical in *C. fragile*, can reveal the difference.

In *Codium vermilara*, branches frequently bear simple or forked proliferations and the tips of the utricles are rounded with numerous hairs. *Codium decorticatum* is a species with fewer branches that can reach a height of 1 metre. Its utricles are regular cylinders, dilated at the tip but without a sharp point.

Codium fragile *Codium vermilara* *Codium decorticatum*

Flask-shaped outer structures (utricles) of Codium fragile subsp. fragile, C. vermilara and C. decorticatum

Brief history of its introduction and pathways

Native to the North Pacific Ocean and Japan, this subspecies is nowadays widespread, having been introduced on shellfish for aquaculture, on recreational boats and on ship hulls. Secondary introductions are probably from aquaculture farms, vessels and fouling on fishing nets.

Ecological impacts

The closely packed frond structure of *C. fragile* traps sediments, eventually changing the nature of the substrate. It is a 'low-lying' alga, making it difficult for some large invertebrates and fish to find refuge or food between the bushy parts of the alga and the seabed. It also has a profound effect on native communities, outcompeting other algae and invertebrates.

Economic impacts

C. fragile also has serious economic implications for aquaculture industries, as it has been found to overgrow and smother oyster beds.

Management options

Prevention: Preventing the spread of *C. fragile* through quarantine measures such as compulsory isolation protocols for shellfish to be cultured in new regions (the main vector of introduction) and public education are some of the few ways to ensure it does not spread further. **Eradication:** There are a few options available to manage *C. fragile*, although with some limitations. Chemical herbicides are not a viable control option as they have adverse effects on native communities. Mechanical removal techniques such as trawling, cutting, and suctioning have been tried in different areas. They help to reduce the density of *C. fragile* temporarily, but these methods are generally expensive and the populations quickly rebound to normal densities. Manual removal could be an alternative, but great care is needed as the algae readily reproduce from fragments.

Further reading

http://www.europe-aliens.org/pdf/Codium_fragile.pdf

Bridgwood, S., 2010. *Codium fragile ssp. fragile* (Suringar) Hariot summary document. 2010. Fisheries Research Report No. 202. Department of Fisheries, Western Australia. 12 p.

C. Rodríguez-Prieto, *et al.*, 2013. Guía de las macroalgas y fanerógamas marinas del Mediterráneo Occidental. Omega, Barcelona. 656 p.

Drawings: Juan Varela

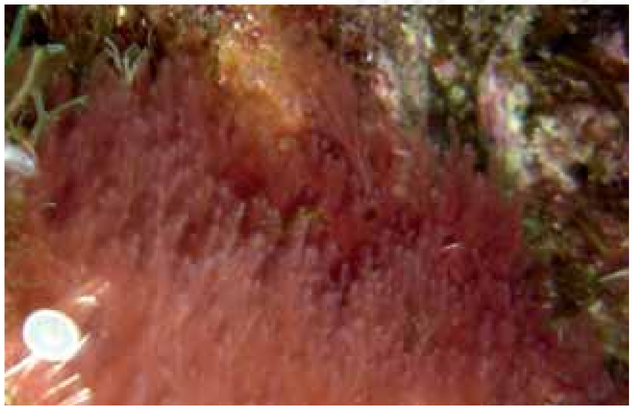
ALGAE

Scientific Name:
Lophocladia lallemandii

Common name: not assigned

Key identifying features

Lophocladia lallemandii is a red filamentous alga up to 15 cm in height and pseudo-dichotomously branched, which usually appears as a mat of red filaments intertwined with themselves or with other algae. Erect filaments 0.5 cm in diameter arise from a basal disc. They are composed of one central cell surrounded by four pericentral cells with very little cortication (outer covering layer).



Lophocladia lallemandii. Photo: B. Weitzmann

Field identification signs and habitat

It settles on all types of substrate (bare bedrock, macroalgae on rocky bottoms, *Posidonia oceanica* seagrass meadows and coralligenous communities). This alga displays pronounced seasonal production, with maximum development in summer and autumn (when most individuals bear reproductive structures) and a drastic decline in winter.

Lophocladia lallemandii and *Posidonia oceanica.* Photo: I. Relanzón - OCEANA

Reproduction

L. lallemandii is able to reproduce sexually and asexually, and both forms have the same appearance. It reproduces sexually only during summer and autumn (from April to October), while its vegetative reproductive activity occurs throughout the year, with minimal growth during late autumn and winter. Moreover, besides reproducing vegetatively through spore dispersal, it can spread by fragmentation: *Lophocladia* is easily broken and free-floating filaments produce small, disc-like holdfasts that are able to attach to a large variety of floating substrates.

Algae with reproductive organs, tetraspores and carpospores.
Photos: E. Cebrian

Similar species

The species can easily be confused in the field with other red filamentous algal species.

Brief history of its introduction and pathways

Lophocladia lallemandii is one of the numerous macroalgal species introduced into the Mediterranean probably from the Red Sea via the Suez Canal. It has now spread throughout most of the Mediterranean, with the exception of Moroccan waters and the north-western Mediterranean.

Ecological impacts

Due to its high invasive potential, *L. lallemandii* is able to cover most kinds of substrate, giving the benthic seascape a homogeneous appearance. The behaviour of *L. lallemandii* seems to be very aggressive, especially when colonizing *Posidonia oceanica* meadows, as it forms such extensive, dense mats within the meadows that it causes a major decrease in seagrass density and growth that can lead to the death of the plants. It also affects the invertebrate community living on *P. oceanica* leaves by outcompeting it for space.

Economic impacts

Unknown.

Management options

Because it can reproduce and spread so fast, it is impossible to eradicate *L. lallemandii* populations, at least by manual methods. The species might be controlled most efficiently and effectively, and at the lowest cost, early in the invasive process.

Further reading

Ballesteros, E., Cebrian, E., Alcoverro, T., 2007. Mortality of shoots of *Posidonia oceanica* following meadow invasion by the red alga *Lophocladia lallemandii*. Bot. Mar. 50, 8–13.

Cebrian E, Ballesteros E., 2010. Invasion of Mediterranean benthic assemblages by red alga *Lophocladia lallemandii* (Montagne) F. Schmitz: depth-related temporal variability in biomass and phenology. Aquat Bot. 92, 81–85.

Deudero S., *et al*, 2010. Interaction between the invasive macroalga *Lophocladia lallemandii* and the bryozoan *Reteporella grimaldii* at seagrass meadows: density and physiological responses. Biological invasions Vol. 12, No 1, 41-52.

Drawings: Juan Varela

ALGAE

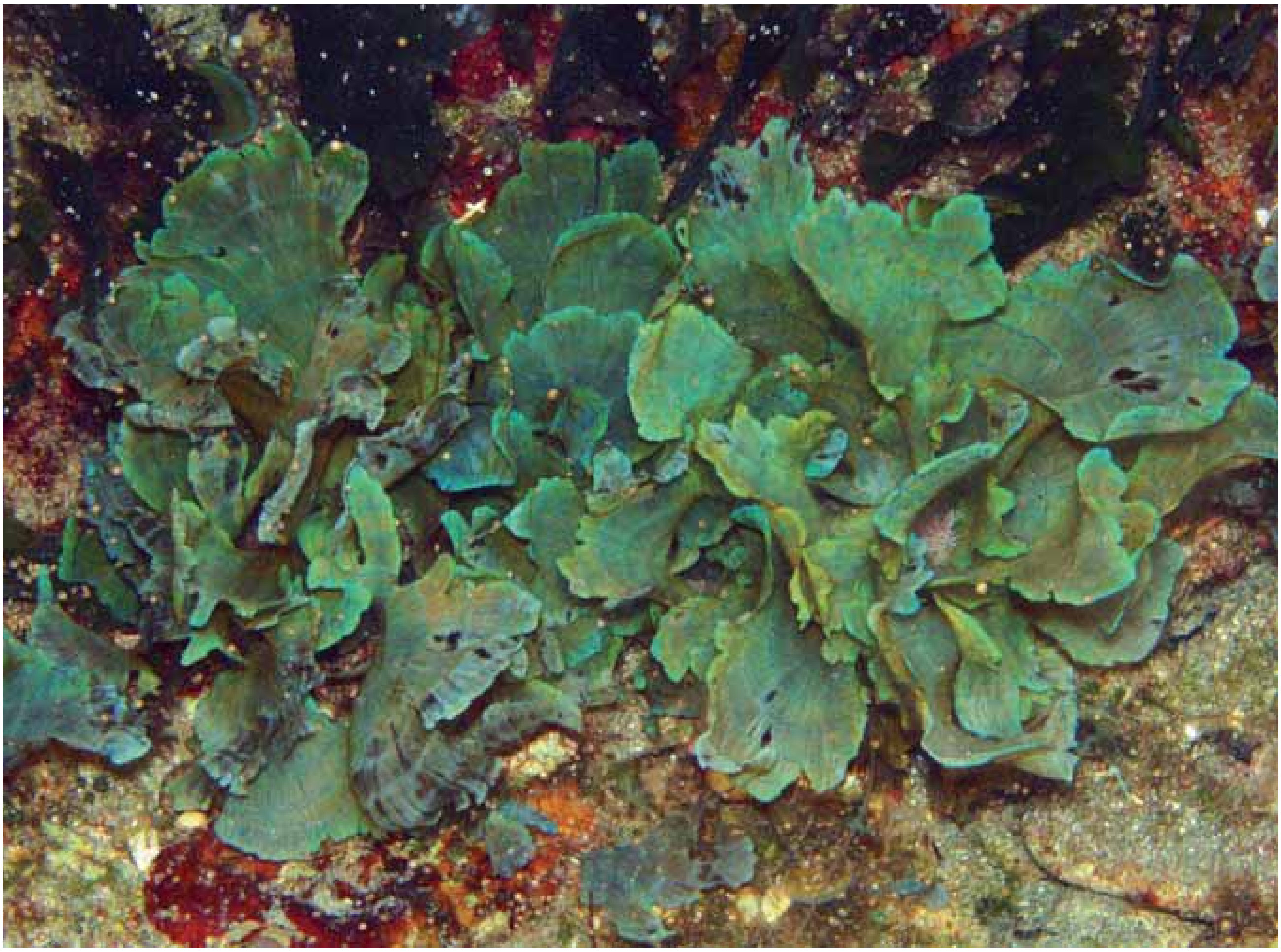
Scientific Name:
Stypopodium schimperi

Key identifying features

Stypopodium schimperi is a laminar brown alga that has thin, fan-shaped appendages with longitudinal divisions. It can reach a height of 30 cm and is almost transparent in appearance with a slight brown coloration. The appendages are covered with concentric rows of hairs without any calcification.

Field identification signs and habitat

Stypopodium schimperi is predominantly found on rocky substrates at depths of 0–20 m, although in the eastern Mediterranean it can be found down to 80 m.



Stypopodium schimperi. Photo: D. Koutsogiannopoulos

Stypopodium schimperi. Photo: E. Cebrian

Reproduction

Stypopodium schimperi undergoes alternation of generations; it can reproduce by both gametophyte and sporophyte structures, which are morphologically similar. Gametophytes can, however, be distinguished by the presence of discontinuous dark bands between the concentric bands.

Similar species

It can be confused with the native alga *Zonaria tournefortii*. Both species are highly polymorphic, and the best character to distinguish them under a microscope is the number of cortical cell layers: 4–5 cell layers in *S. schimperi* and 1–2 in *Z. tournefortii.*

Zonaria tourneforti

Drawings: Juan Varela

Brief history of its introduction and pathways

Native to the Indian Ocean, *S. schimperi* was probably introduced into the Mediterranean through the Suez Canal. At present, it is distributed throughout the eastern Mediterranean.

Ecological impacts

These are unknown; however, this brown alga tolerates varied local conditions and has no known predators.

Economic impacts

Unknown.

Management options

Prevention: Unknown. **Eradication:** Unknown.

Further reading

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Einav, R. (2007). Seaweeds of the eastern Mediterranean coast. pp. [i-vi],[1-5]6-266. Ruggell, Liechtenstein: A.R.G. Gantner Verlag K.G.

Verlaque, M. & C.-F. Boudouresque, 1991. *Stypopodium schimperi* (Buchinger ex Kützing) Verlaque et Boudouresque comb. nov. (Dictyotales, Fucophyceae), algue de mer Rouge récemment apparue en Méditerranée. Cryptogamie, Algologie 12: 195-211, 69 figs.

Common name: not assigned

Womersleyella setacea. Photo: E. Ballesteros

Scientific Name:
Womersleyella setacea

Key identifying features

Filamentous alga, rose-red to brownish in colour, usually epiphytic and forming perennial, extensive, dense cotton-wool-like tufts 1 cm high.

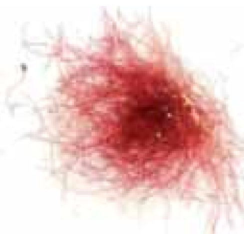
Accurate identification might need to be checked by a specialist in this group. It can only be identified under a binocular microscope. Plants form dense monospecific mats of prostrate and erect filamentous branches. Prostrate filaments anchor the thallus to the substrate by means of rhizoids, and erect filaments are usually very little branched and composed of segments 50–100 μm in diameter. Filaments are not corticated and comprise one central cell surrounded by four pericentral cells.

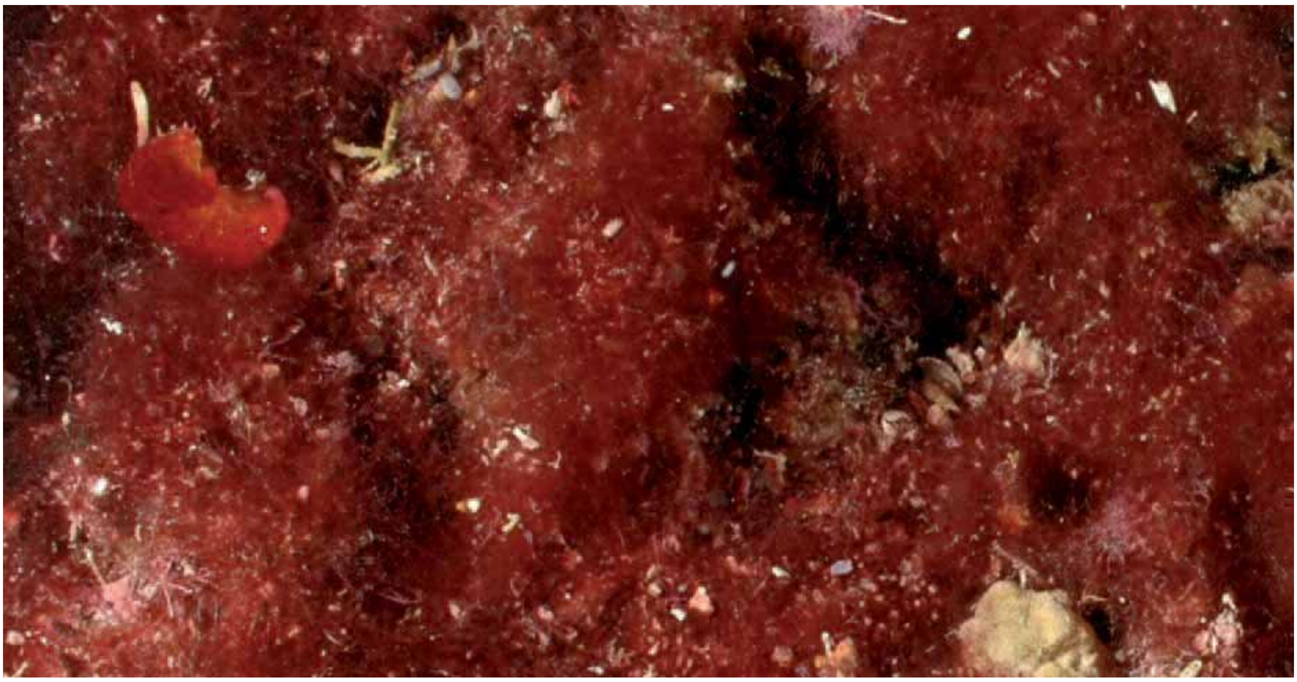
Field identification signs and habitat

It is usually found at depths below 15 m, and mainly in dimly lit habitats (with a preference for low temperatures) such as coralligenous outcrops.

Reproduction

Despite the species' abundance, Mediterranean populations seem to show only vegetative reproduction, primarily by fragmentation.



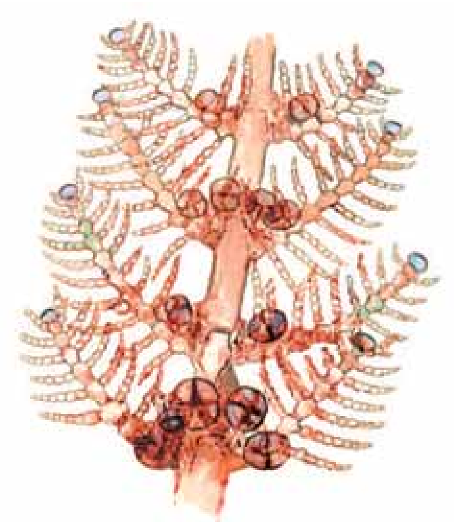


Womersleyella setacea. Photo: E. Cebrian

Womersleyella setacea. Photo: E. Ballesteros

Similar species

It can easily be confused in the field with other red algal species of similar structure (i.e. *Acrothamnion preissii*).



Acrothamnion preissii

Brief history of its introduction and pathways

Womersleyella setacea was described originally from the Hawaiian Islands and later reported in other tropical localities in both the Pacific and Atlantic Oceans. It was first observed in Mediterranean coastal waters in the 1980s in Provence (France) and Italy, and rapidly spread throughout the Mediterranean to Corsica, the Mediterranean coasts of Spain, the Balearic Islands, the northern Adriatic Sea, Malta and Greece. The origin and mode of introduction of this red filamentous species remain unknown, but a suggested main vector is hull fouling on commercial ships.

Ecological impacts

In many Mediterranean localities it has substantial adverse effects on native communities by modifying benthic assemblages and outcompeting key native species (i.e. *Paramuricea clavata, Cystoseira spinosa* and various sponge species). Its fast growth, ability to exploit nutrients and persistence form the basis of *Womersleyella setacea*'s success in outcompeting native macroalgae and benthic invertebrates on Mediterranean rocky bottoms. Another characteristic of this invader is its ability to trap sediments, preventing the attachment of other competing filamentous algae. This hinders the settlement of native species and the survival of their juvenile stages, and consequently reduces the species diversity and composition of local algal communities.

Economic impacts

Unknown.

Management options

Once it has become invasive, eradication and even containment are not possible. The species might be controlled most efficiently and effectively, and at the lowest cost, early in the invasive process.

Further reading

Cebrian E. Rodríguez-Prieto C., 2012. Marine Invasion in the Mediterranean Sea: The Role of Abiotic Factors When There Is No Biological Resistance. PLoS ONE 7(2): e31135.

Nikolić, V. *et al*, 2010. Distribution of invasive red alga *Womersleyella setacea* (Hollenberg) R.E. Norris (Rhodophyta, Ceramiales) in the Adriatic Sea. ACTA ADRIAT., 51(2): 195 – 202.

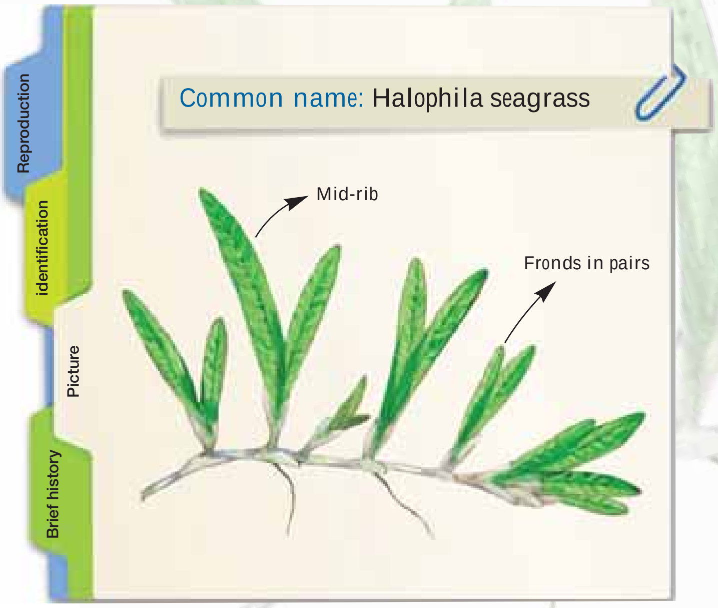
DAISIE. http://www.europe-aliens.org/speciesFactsheet.do?speciesId=100988

Drawings: Juan Varela

ANGIOSPERM

IUCN

Scientific Name:
Halophila stipulacea



Key identifying features

This euryhaline marine seagrass consists of thin, creeping rhizomes (0.5–2 mm in thickness) from which pairs of thin leaves emerge at regular intervals. The leaves have a serrated edge and are 3–6 cm long and 2.5–8 mm wide. The rhizomes are fixed to the sand by roots emerging from each node.

Field identification signs and habitat

In its original range, *Halophila stipulacea* grows in a wide range of environmental conditions and coastal substrates. However, this species has a much narrower ecological distribution in the eastern Mediterranean, being limited to soft substrates (sand and mud) only.

It can be found forming monospecific or mixed meadows with the native sea grass, *Cymodocea nodosa.*

Halophila stipulacea. Photo: J. Garrabou

Halophila stipulacea. Photo: P. Francour

Reproduction

Male and female plants are separate, producing solitary male or female flowers at each leaf node. It is a fast-growing species and produces many seeds, colonizing and spreading rapidly from small populations. In the Mediterranean the main flowering season occurs in July–August, with fruits ripening in September.

Similar species

The seagrass species native to the Mediterranean Sea (*Posidonia oceanica, Cymodocea nodosa, Zostera noltii* and *Z. marina*) are characterized by longer leaves arranged in groups (not pairs), with older leaves on the outside.

Caulerpa prolifera, a native green alga, has dark green, oval-shaped leaf blades that are about 1.5–2.5 cm wide and 6–15 cm long. The leaves of this species grow from a few tough stolons, emerging perpendicularly at 1–2 cm intervals; they are usually oval or linearly elongated with a smooth edge. *C. prolifera* is distinguished from *H. stipulacea* by the lack of a prominent mid-rib along the length of the leaves.

Caulerpa prolifera

Cymodocea nodosa. Photo: J.M. Ruiz

Posidonia oceanica. Photo: M. Otero

Brief history of its introduction and pathways

Native to the Indian Ocean, *H. stipulacea* entered the Mediterranean from the Red Sea after the opening of the Suez Canal in 1869. The Aegean populations may have originated from fragments carried by Greek fishing boats, and spread thereafter probably by ship transport.

Ecological impacts

Studies suggest that *H. stipulacea* is capable of displacing native seagrasses such as *Posidonia oceanica* and *Cymodocea nodosa* and their associated communities. Further research is needed to confirm this and provide further details of the extent of these interactions. *H. stipulacea* beds expand rapidly and tolerate a wide range of environmental conditions, potentially threatening local and regional biodiversity. This species is included among the 100 Worst Invasive Alien Species in the Mediterranean.

Economic impacts

Unknown.

Management options

Prevention: Unknown. **Eradication:** Unknown.

Further reading

http://www.europe-aliens.org/pdf/Halophila_stipulacea.pdf

Malm T., 2006. Reproduction and recruitment of the seagrass *Halophila stipulacea*. Aquatic Botany. 85 (4), 347-351.

Sghaier, Y. R., et al., 2011. Occurrence of the seagrass *Halophila stipulacea* (Hydrocharitaceae) in the southern Mediterranean Sea. Botanica Marina 54: 575–582.

Drawings: Juan Varela

Scientific Name:
Oculina patagonica

Photo: ISME

Key identifying features

This is a stony colonial coral that can harbour symbiotic algae (zooxanthellae). Its colonies, yellowish-brown in colour, are encrusting or form clumps, and the polyps have short, thick, highly fused tentacles. The corallites, tubular skeletons of the polyps, are crowded, up to 5 mm in diameter, with neat and round, walls and both long and short septo-costae (radial elements).

Oculina patagonica. Photo: D. Kersting

Field identification signs and habitat

The colonies are generally encrusting, thicker in the centre with a thin edge spreading over the substrate. However, the form of the colony varies with depth and other characteristics of the environment. Bleaching of *O. patagonica* may be seen at some sites, starting on the outer edges of the colony and spreading inwards.

It is an opportunistic species, able to thrive in various littoral habitats, encrusting on vertical and horizontal surfaces in natural pristine sites as well as in marinas, harbours and heavily polluted areas.

Reproduction

It is able to reproduce both sexually by broadcast spawning and asexually by budding new polyps from existing ones, resulting in crowded, genetically identical colonies. Its successful proliferation is also due to its early reproductive maturity and high growth rate.

Oculina patagonica. Photo: E. Cebrian

Similar species

Oculina patagonica resembles the native scleractian coral *Cladocora caespitosa*. The calcareous colonies of *C. caespitosa* are, however, globular, homogeneous and sometimes more than 50 cm in diameter.

Colonies of *O. patagonica* are more low-growing and encrusting and have connective tissue between the polyps that makes the shape of the skeleton readily apparent.

Cladocora caespitosa. Photo: J.A. Fayos

Brief history of its introduction and pathways

The origin of this species is uncertain. It is perhaps from South America: northern Argentina and southern Brazil. Previously unknown in the Mediterranean, specimens were tentatively identified as *Oculina patagonica* in 1908 and regarded as a species accidentally brought into the Mediterranean by shipping from the temperate south-western Atlantic. It has now been recorded in Italy, Spain, France, Turkey, Lebanon, Israel, Egypt, Tunisia and Algeria.

Ecological impacts

The increase of this opportunistic species may affect the stability of algal communities as the dominant trophic group on shallow rocky Mediterranean substrates. It overgrows calcareous structures such as serpulid worm tubes, vermetid shells and barnacles, and can completely eliminate algae and other soft-bodied attached organisms. It also out-competes the indigenous *Cladocora caespitosa*, which is overgrown when the two species come into contact.

Economic impacts

Unknown.

Management options

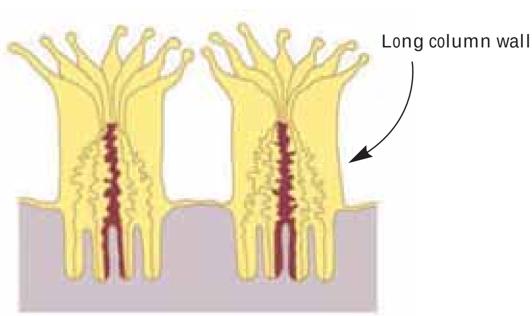
Prevention: Unknown. **Eradication:** Unknown

Further reading

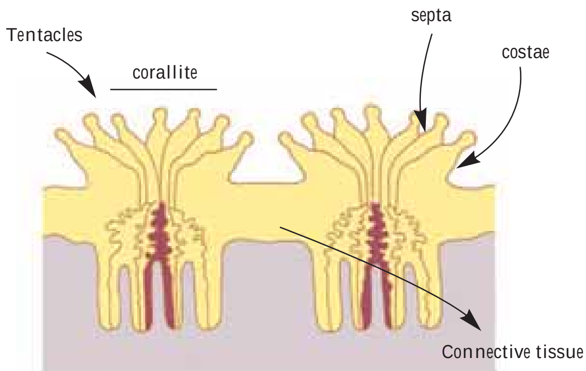
Sartoretto S., *et al.*, 2008. The alien coral *Oculina patagonica* De Angelis, 1908 (Cnidaria, Scleractinia) in Algeria and Tunisia. Aquatic Invasions Vol 3, Issue 2, 173-180.

Coma R., *et al.*, 2011. Sea Urchins Predation Facilitates Coral Invasion in a Marine Reserve. PLoS ONE 6(7): e22017. doi:10.1371/journal.pone.0022017.

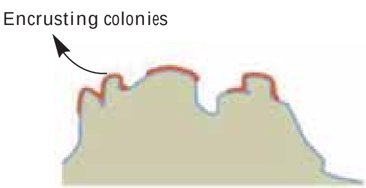
Fine M. , Zibrowius H., Loya Y., 2001. *Oculina patagonica*: a non-lessepsian scleractinian coral invading the Mediterranean Sea. Marine Biology 138, 1195-1203.



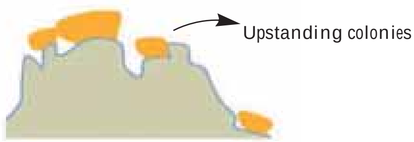
Coral skeleton of *C. caespitosa*



Coral skeleton of *O. patagonica*



Oculina patagonica



Cladocora caespitosa

Drawings: Juan Varela

IUCN

Scientific Name:
Rhopilema nomadica

Reproduction
identification
Picture
Brief history

Common name: Nomad jellyfish

Key identifying features

This solid, large jellyfish is light blue in colour with tiny granules on the bell. The bell of this jellyfish can range from 10 to 90 cm in diameter, usually 40–60 cm, and the whole animal can weigh 40 kg. Hanging from the centre are eight large mouth-arms divided at mid-length into two ramifications with numerous long filaments.

Field identification signs and habitat

This species can form dense aggregations in coastal areas during summer months, although it can also appear all year round.

Reproduction

Its life cycle involves a small (usually < 2 mm) benthic polyp stage that reproduces asexually, and a large swimming medusa stage that reproduces sexually. Spawning usually occurs in July and August.

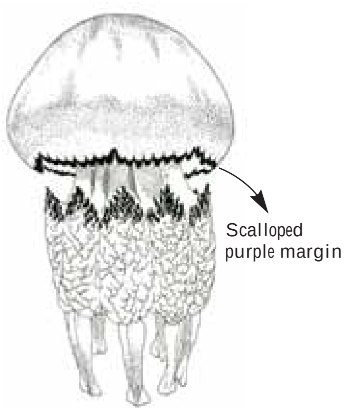
Rhopilema nomadica. Photo: D. Edelist

Rhopilema nomadica. Photo: Ori

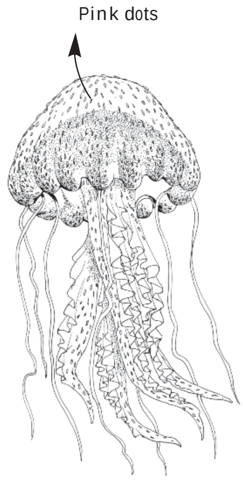
Similar species

The most similar jellyfish is the native Mediterranean *Rhizostoma pulmo*. It differs from *Rhopilema nomadica* in its smooth bell surface and a dark purple band around its undulated margin. It has four pairs of very large mouth arms on its under surface but no tentacles.

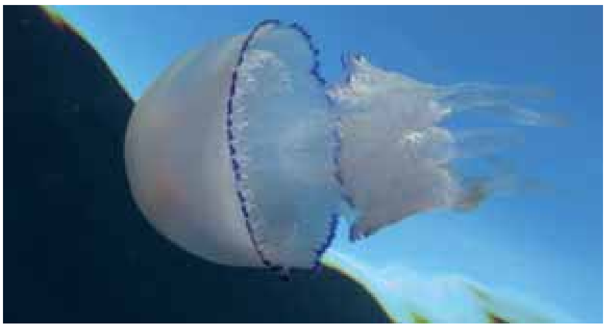
Another common native species is *Pelagia noctiluca*. It is much smaller and mushroom-shaped, with a bell up to 10 cm in diameter. The medusa varies from pale red to mauve-brown or purple in colour and the bell surface is covered in pink granules. It has eight tentacles, pink in colour. The mouth arms can be 5 times the bell height.



Rhizostoma pulmo



Pelagia noctiluca



Rhizostoma pulmo. Photo: Biologiamarina.org

Brief history of its introduction and pathways

Originally from East Africa and the Red Sea, *R. nomadica* entered the Mediterranean through the Suez Canal, and spread with the currents along the Mediterranean coasts. Since the mid-1980s large swarms of this species have appeared along the coasts of the Levant every year, from Egypt to Turkey.

Ecological impacts

The nomad jellyfish is a voracious predator that consumes vast amounts of shrimp, mollusc and fish larvae, and can cause major trophic cascades in the marine food web, with a resulting impact on biodiversity.

Economic impacts

This jellyfish can inflict painful injuries to bathers and affect coastal tourism. Furthermore, large swarms can clog fishing nets, consequently reducing catches, and block cooling water intakes of coastal industrial facilities and desalination plants.

Management options

Eradication may be impossible in practice. Public awareness campaigns to alert authorities, first-aid workers and the general public might prevent injuries caused by this species.

Further reading

Deidun A., Arrigo S., Piraino, S. 2011. The westernmost record of *Rhopilema nomadica* (Galil, 1990) in the Mediterranean – off the Maltese Islands. Aquatic Invasions Vol 6, Supplement 1: S99–S103.

http://www.europe-aliens.org/pdf/Rhopilema_nomadica.pdf

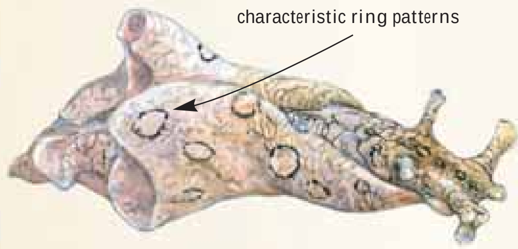
Pelagia noctiluca. Photo: H. Hillewaert

Drawings: Juan Varela

Scientific Name:
Aplysia dactylomela

Reproduction
identification
Picture
Brief history

Common name: Spotted Sea hare



Key identifying features

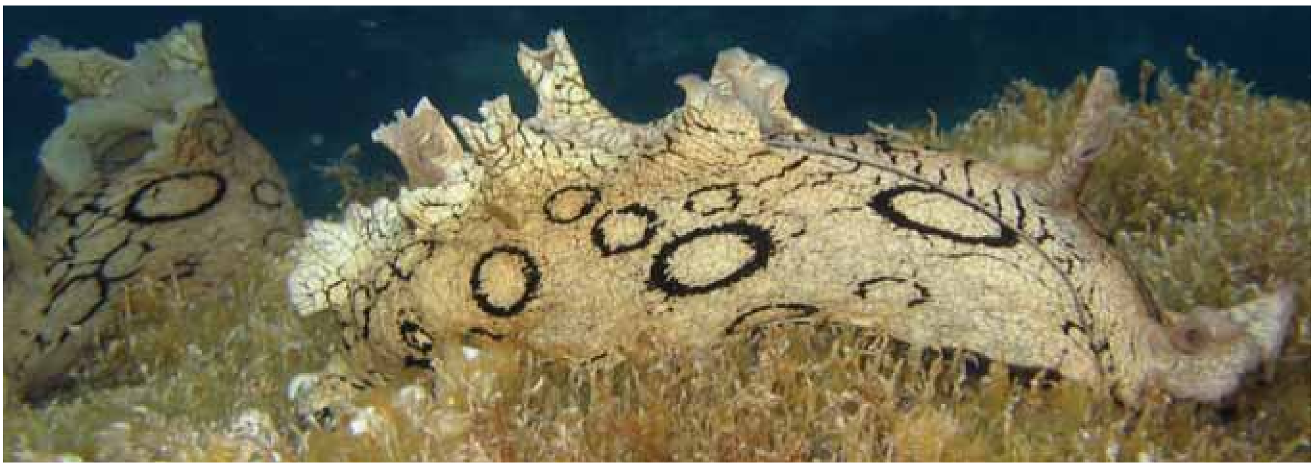
A large sea slug without an external shell. The body is smooth and soft, pale greenish yellow with conspicuous black rings, sometimes pink due to the ingestion of red algae. A pair of wings covers the dorsal part of its body and hides a thin shell that can easily be felt by touch. They also hide a small aperture to the animal's gill. Average adult size is 10 cm, although they can reach up to 40 cm in length. The head bears 4 soft horn-like structures, two of them like long ears originating on the dorsal part of the head (which is why the animal resembles a hare) and the other two, similar in shape, near the mouth.

Field identification signs and habitat

It occurs on both rocky shores and sand with dense algal cover, especially in very shallow waters like rock pools, to a maximum depth of 40 m. It is an herbivorous species, grazing preferably on green algae.

During the day it hides under large rocks or in crevices. At night, it is usually seen either crawling like an ordinary sea slug on seaweeds, or swimming by undulating the wings in a very characteristic slow, rhythmic, elegant motion. If disturbed or handled, it can release a purple ink or pale malodorous mucus.

Aplysia dactylomela. Photo: A. Lodola



Aplysia dactylomela. Photo: E. Azzurro

Reproduction

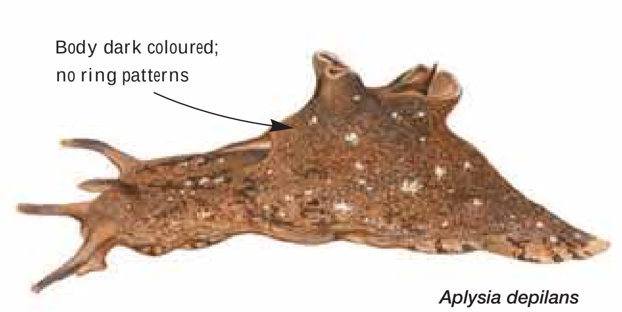
It is hermaphroditic. When mating, one individual acts as a male and crawls onto another one to fertilize it, sometimes forming chains of up to 12 individuals. Eggs form long, tangled strings which may be orange, yellow, green or brown in colour.

Similar species

Aplysia punctata. Smaller in size, the adults can be confused with young *A. dactylomela.* The body is not patterned with black rings but only small pink or brown dots.

Aplysia punctata

Aplysia depilans can grow to about 30 cm. It is brown to greenish-brown in colour with blotches of white, yellow or grey, often with blackish veining. When disturbed, it produces both white and purple secretions.



Aplysia depilans

Brief history and route of introduction

Aplysia dactylomela was first recorded in the Mediterranean Sea off Lampedusa Island in 2002. Now it is widespread throughout the Central-Eastern Mediterranean from Sicily and Malta to Croatia, Greece, Montenegro, Turkey and Cyprus. Its routes of introduction in the Mediterranean are still unclear due to the fact that its native range includes the two seas that are in connection with the Mediterranean basin: the Atlantic and the Red Sea. There are three main hypotheses: 1) it arrived in ballast water (water pumped into and out of ships to adjust their buoyancy; minute marine organisms and their larvae can thus be easily moved around the world's oceans and introduced into new regions); 2) it spread through the Suez Canal; 3) it spread naturally through the Gibraltar Strait (if this is the case it should not be considered an alien species as such, but a tropical Atlantic species colonizing the Mediterranean through natural range expansion).

Ecological impacts

To date there have been no studies quantifying the ecosystem impact of this species. However, the species is a grazer of algae and this may influence the composition and diversity of algal communities in a given location.

Economic impacts

The giant right neuron of *A. dactylomela* is very similar to that of humans and is used in neurological research. A small market for *A. dactylomela* specimens has been created to supply neurological research laboratories with this structure.

Management options

There is still no feasible management plan in place for **controlling** this species. A suggested **prevention** measure is to build up local public awareness combined with monitoring to help in preventing its introduction into MPAs. **Early eradication** of new populations by hand removal could be an option to be explored.

Further reading

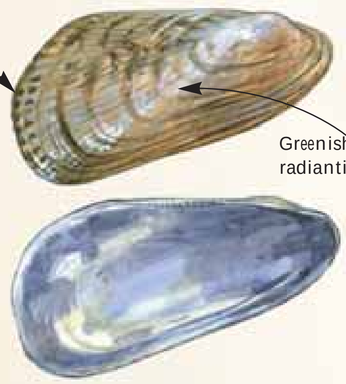
Pasternak G., Galil B., 2010. Occurrence of the alien sea hare *Aplysia dactylomela* Rang, 1828 (Opisthobranchia, Aplysiidae) in Israel. Aquatic Invasions Vol. 5, Issue 4: 437–440.

Yokeş M.B., 2006. *Aplysia dactylomela*: an alien opisthobranch in the Mediterranean. JMBA2 - Biodiversity Records

Drawings: Juan Varela

Scientific Name:
Arcuatula (Musculista) senhousia

Common name: Asian date mussel



Key identifying features

The two valves are oval, elongated and similar in shape and size. The surface of the shell is marked with red lines that look like rays extending toward the edge. The longest side of the shells is slightly concave. The shell is shiny and pale olive-green with purple concentric stripes that sometimes are also visible inside. Adults can reach up to 3 cm in length and 1 cm in width.

Field identification signs and habitat

Arcuatula senhousia occurs on soft, muddy bottoms of bays and estuaries, preferably in sheltered areas from the intertidal zone down to a depth of 20 m. The mussels construct a nest of trapped sediment where many individuals live together. *A. senhousia* forms dense mats of individuals on the bottom (up to 8,000 individuals per square metre). Males and females are not different to the naked eye.

Reproduction

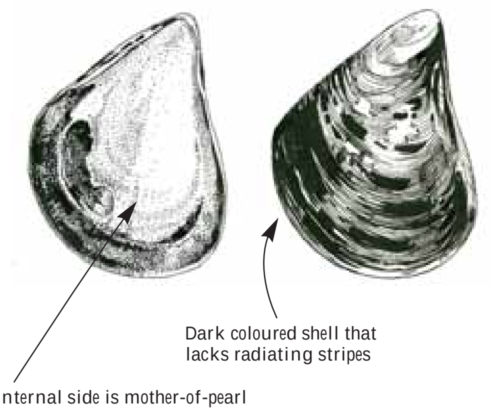
In the Mediterranean Sea, sperm and eggs are released in the water from September to November. It is a species with high fecundity, rapid growth and good dispersal ability, making it a successful invader. Larvae live in the plankton for up to 55 days until they settle on the bottom. The Asian date mussel can reach adult size in only nine months and live for a maximum of two years. Adults can live for several days out of the water; they are tolerant of low salinities, oxygen concentrations and temperatures.

Arcuatula (Musculista) senhousia. Photo. A.N. Cohen, Center for Research on Aquatic Bioinvasions (CRAB)

Arcuatula (Musculista) senhousia. Photo. S. Guerrieri

Similar species

Mytilus galloprovincialis (young individuals). *Arcuatula senhousia* often lives in *M. galloprovincialis* beds, therefore young Mediterranean mussels can be confused with the alien species. Major differences are that in *M. galloprovincialis*: 1) the colour of the shell is shiny blue-violet or black; 2) the interior of the shell is mother-of-pearl; 3) it lacks red lines on the outer surface of the shell.



Mytillus galloprovincialis juvenile

Mytilus galloprovincialis. Photo. L. Rignanese

Brief history and route of introduction

Originally from the south-western Pacific, it was first recorded in the Mediterranean at Tel Aviv (Israel) in 1960. Thereafter, it has been reported in Egypt (1969), France (1984), the Adriatic Sea (1992), Slovenia (1997), Italy (Gulf of Taranto) (2001), Italy (Leghorn) (2001), Sardinia (Gulf of Olbia) (2002), and Sicily (Siracusa) (2006). The main pathway of introduction is through transfer with bivalve seed stock for aquaculture purposes; this species can also be spread by ship's ballast waters (water pumped into and out of ships as ballast to maintain the correct buoyancy) or fouling (the communities encrusting a ship's hull).

Ecological impacts

Arcuatula senhousia forms dense aggregations that can change the physical structure of the bottom, dominating benthic communities and outcompeting other filter-feeding bivalves for food. It also develops on the roots of sea grasses slowing down their growth.

Economic impacts

The species' economic impact has not been quantified yet; however, it is highly possible that bivalve culture and harvesting might suffer due to strong competition. The Asian date mussel can damage marine engines by clogging cooling water intakes or industrial water intake pipes.

Management options

A suggested **prevention** measure is to build up local public awareness combined with monitoring to help prevent its introduction into MPAs. **Control** actions are impossible as the large bivalve mats, if removed either manually or mechanically (e.g. by dredges), are easily fragmented and the detached individuals can spread to form new populations.

Further reading

http://www.europe-aliens.org/pdf/Musculista_senhousia.pdf
http://www.ciesm.org/atlas/Musculistasenhousia.html

Drawings: Juan Varela

Molluscs

Scientific Name:
Brachidontes pharaonis

Key identifying features

The shell is formed of two elongated, trapezoidal valves that are equal in shape and size. The shell surface is characterized by distinctly sculpted ribs radiating from the hinge of the two valves towards the shell margin. The ribs are coarser towards the margin. The internal shell margin is serrated. The outside of the shell is dark brown, while the interior is violet. Adult shells can reach up to 4 cm in length.

Field identification signs and habitat

The rayed Erythrean mussel is found in shallow and sheltered marine areas and in hypersaline waters (> 45 PSU). It can live in polluted waters such as those close to municipal waste-water pipes. It can reach very dense populations of up to 11,000 individuals per square metre. It can also tolerate high water temperatures of up to 31 °C.

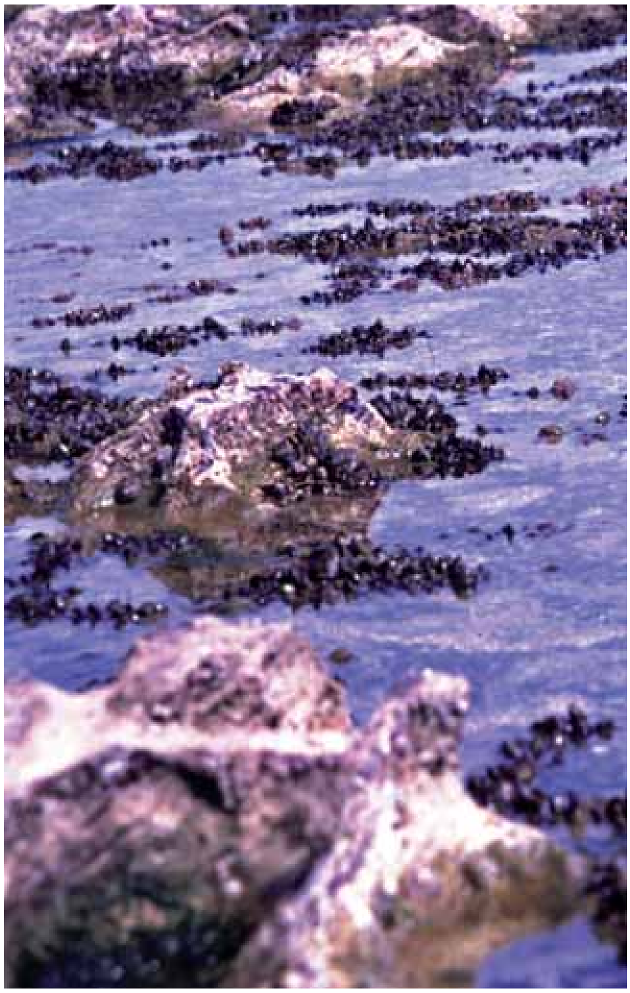
Brachidontes pharaonis. Photo: H. Nier

Reproduction | identification | Picture | Brief history

Common name: Rayed Erythrean mussel

Reproduction

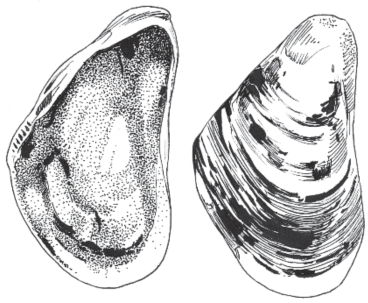
It reproduces all year around and has a short development cycle that results in young bivalves in about 10-20 days. Adults live for up to five years.



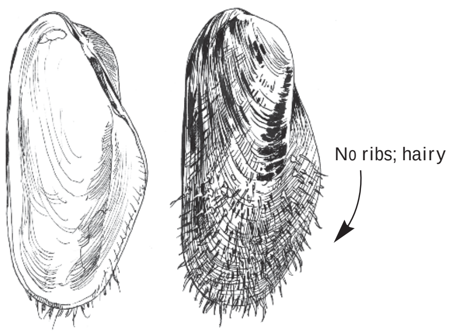
Brachidontes pharaonis in the intertidal. Photo: B. Galil

Similar species

Mytilaster minimus, Gregariella petagnae and *Mytilaster lineatus*. Major differences are that in *M. minimus*: 1) the shell surface is smooth and only concentric growth lines with no ribs are evident; and 2) the internal shell margin is smooth. *Gregariella petagnae* has a hairy shell and *Mytilaster lineatus*, an endemic species from the Adriatic, is very similar in shape but has numerous rib lines on the shell surface.



Mytilaster minimus



Gregariella petagnae

Brief history and route of introduction

Brachidontes pharaonis is a classic example of an introduced species from the Red Sea and Indian Ocean that was introduced into the Mediterranean after the opening of the Suez Canal in 1869. It was first recorded in 1876 in Egypt. Since then it has been recorded in Lebanon, Israel, Italy (Sicily), Malta, Greece, Syria, Cyprus and Croatia. The latest record was in 2007 from Izmir in Turkey. These bivalves can also be easily spread by boat fouling (in the communities encrusting a ship's hull).

Ecological impacts

This species can deplete the phytoplankton concentration in the water column, constraining the growth of other filter-feeding animals such as *Mytilaster minimus*. It is a preferred prey of the gastropod *Stramonita haemastoma*.

Economic impacts

The economic impact of this species has not yet been quantified anywhere; however, dense mats of these bivalve populations in industrial facilities and salt works might result in high energy consumption and economic losses.

Management options

Suggested **prevention** actions are: a) to conduct local public awareness campaigns combined with monitoring; and b) to identify and remove rayed Erythrean mussels from the hull fouling assemblages on vessels. **Control actions** to eradicate this species from the environment are not feasible due to the small size and large number of individuals forming new populations. If MPA managers or port authorities plan to check the hulls of boats entering marine reserves, *B. pharaonis* should be a target species to look for and scrape off the keel once the boat is out of the water.

Further reading

http://www.europe-aliens.org/pdf/Brachidontes_pharaonis.pdf

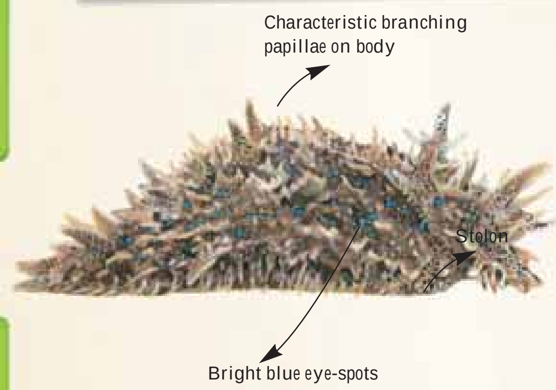
http://www.ciesm.org/atlas/Brachidontespharaonis.html

http://convittofoscarini.it/didattic/conchiglie/bivalvi/specie/MytilasterLineatus.htm

***Mytilaster lineatus*. Photo: J. Zauoali**

Drawings: Juan Varela

Common name: Ragged sea hare



Scientific Name:
Bursatella leachii

Key identifying features

This large sea slug can reach more than 10 cm in length. The body has numerous long, branching, white papillae (finger-like outgrowths) that give the animal its ragged appearance. A key distinctive feature is its grey-brown body with dark brown blotches on the white papillae and bright blue eye-spots scattered over the body. The head bears four tentacles: two olfactory tentacles originating on the dorsal part of the head resembling long ears, and two oral tentacles, similar in shape, near the mouth. Adults lack an external shell.

Field identification signs and habitat

This species occurs most commonly in shallow, sheltered waters, often on sandy or muddy bottoms with *Caulerpa prolifera*, well camouflaged in seagrass beds, and occasionally in harbour environments. If disturbed or touched it can release purple ink.

Its behaviour varies with the time of day, as it is more active during the daytime and hides at night. In the early morning sea hares are found clustered together in groups of 8–12 individuals, and they disperse to feed on algal films during the day. They reassemble again at night.

Bursatella leachii. Photo: B. Weitzmann

Reproduction

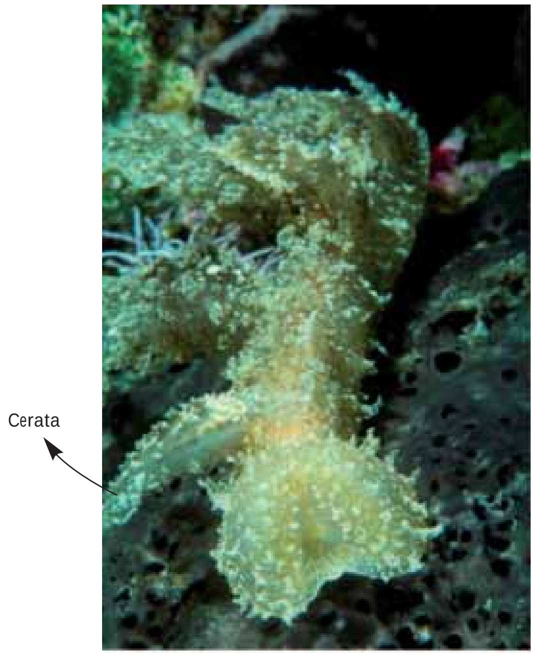
Bursatella leachii is a hermaphroditic species with a very fast life cycle and continuous reproduction. When mating, one individual acts as a male and crawls onto another one to fertilize it. A large mass of tangled strings of purple eggs is produced and the larvae develop within 20 days. Sexually mature sea hares appear after 2–3 months.

Bursatella leachii. Photo: D. Poloniato- WWF-MPA Miramare

Bursatella leachii. Photo: B. Weitzmann

Similar species

There are no similar species in the Mediterranean Sea. In contrast to *Aplysia, Bursatella leachii* does not have large mantle flaps and cannot swim. Other species, such as the endemic *Tethys fimbria* and the genus *Melibe*, have large oral hoods (ceratas) used in the capture of food and a set of prominent cerata (outgrowth structures) along each side of the body.



Melibe fimbriata. Photo: M. Draman

Brief history of its introduction and pathways

Originally found in warm temperate and tropical waters throughout the world, this species was probably introduced into the Mediterranean through the Suez Canal, although ballast waters discharged from cargo ships (water pumped into the ships elsewhere as ballast to adjust buoyancy) could also explain its occurrence in harbours. The first record of the species in the Mediterranean Sea was in Israel in 1940. Subsequently, the species was also recorded from Turkey, Malta, Italy (Taranto, Sicily, Lecce, Naples, Venice, Sardinia), Slovenia, Croatia and around the Spanish coast, including the Balearic Islands and Almería in the Alboran Sea. It has been also reported in the Nador Lagoon (Morocco) and in other coastal lagoons and littoral areas around the Mediterranean.

Ecological impacts

No studies have yet quantified the ecosystem impact of this species in the Mediterranean. The sporadic high densities reported at some sites and its habit of feeding on microalgal (cyanobacterial) mats may influence the dynamics of some natural habitats.

Economic impacts

In its native waters, ragged sea hares can reach very high densities (more than 600 individuals per square metre) and they are believed to adversely affect commercial shrimping operations. Positive economic impacts include the existence of a small aquarium trade for this sea hare and the potential pharmacological use of its ink gland.

Management options

A suggested **prevention** action is to conduct local public awareness campaigns combined with monitoring. A suggested **control** action is physical hand removal of new populations by MPA technicians.

Further reading

Ibáñez-Yuste A., Garrido-Díaz A., Espinosa-Torre F., Terrón-Sigler A., 2012. Primera cita del molusco exótico *Bursatella leachii* de Blainville, 1817 (Mollusca: opistobranchia) en el litoral mediterráneo andaluz. Chronica naturae, 2: 25-31.

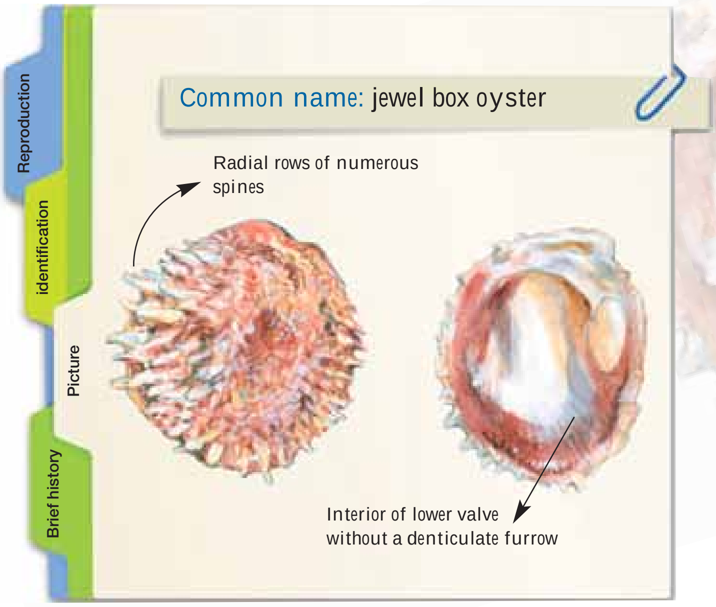
Zakhama-Sraieb, R., Ramzi S., Y Charfi- Cheirkhroucha, F., 2009. On the occurrence of *Bursatella leachii* De Blainville, 1817 and *Pinctada radiata* (Leach, 1814) in the Gar El Melh lagoon (NE Tunisia). Aquatic Invasions. Vol 4, Issue 2:381-383

http://www.ciesm.org/atlas/Bursatellaleachi.html

Tanrıkul, T. T.; Akyol, O., 2012. First report on reproduction of Lessepsian ragged sea hare, *Bursatella leachii* (de Blainville, 1817) (Mollusca: Gastropoda) in Izmir Bay (Aegean Sea, Turkey). Journal of FisheriesSciences.com, Vol. 6 No. 2 pp. 96-98.

Drawings: Juan Varela

Scientific Name:
Chama pacifica



Key identifying features

A large ovoid-shaped oyster that can grow to about 8–10 cm in length. The shell is usually thick and irregularly rounded. The valves are different sizes, the lower one usually being larger and deeper than the upper, which is usually flat.

The external valve surface bears short spines that curve out from the surface and are larger and more prominent on the larger valve near the shell margin. The internal margin of the shells is encircled by a rim of close, fine ridges that look like a zip fastener. The external colour is highly variable, from white to pinkish-red with pale-rose blotches around the shell margin; the spines are often white.

Field identification signs and habitat

Chama pacifica occurs on rocky shores and hard substrates, usually on exposed sites from the intertidal zone down to a few metres' depth, occasionally to 40 m. It is able to thrive in harbour environments and is usually found together with other oysters (*Spondylus sp.*) on bare rocks where it attaches tightly to the substrate with one valve. Fouling organisms often attach to the shells. It has a low tolerance to salinity changes, particularly low salinity.

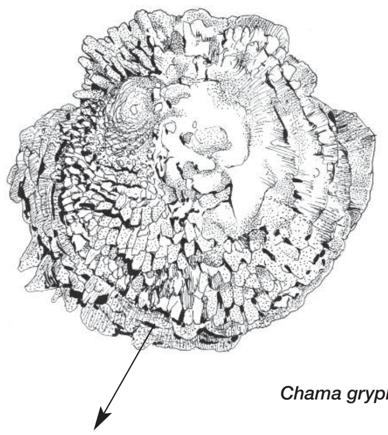
Reproduction

Sexes are separate and fertilization is external. The jewel box oyster has a single, annual, temperature-dependent spawning season, usually occurring during spring and summer when the water temperature is higher than 21 °C. This prolonged spawning period partly contributes to the success of the species in new environments. Eggs hatch as free-swimming planktonic larvae.

Chama pacifica. **Photo: D. Riek**

Similar species

The native oyster *Chama gryphoides* can be distinguished by its smaller size (up to 2.5 cm), irregular radial 'ribs' arranged in concentric rows and the white colour of its shell.



Chama gryphoides. Photo: J. Ben Souissi

Brief history of its introduction and pathways

Widespread in the Indo-West Pacific, *C. pacifica* was recorded for the first time in the Mediterranean Sea from Alexandria (Egypt) in 1905. From here, it colonized many areas of the south-eastern basin: Israel, Lebanon, Cyprus, Turkey, Syria and Greece. Its presence in the Mediterranean is due to the opening of the Suez Canal, while it has probably been spread further by ships and recreational boats as part of the hull fouling assemblage.

Ecological impacts

Chama pacifica has become an important component of the eastern Mediterranean shallow benthos, and is occasionally found in association with Erythrean spiny oyster, *Spondylus spinosus*, another alien oyster. Both species singly or together can form dense aggregations, producing solid reefs at some sites and completely replacing native species such as the European thorny oyster, *Spondylus gaederopus*, or the smaller oyster, *Chama gryphoides*. Competition and reduced plankton availability caused by decreased water flow can also slow down the growth of other benthic organisms.

Economic impacts

It is a valuable species for seashell collectors, with a small trading market. The impact of this invasive species is unknown.

Spondylus spinosus. Photo: K. Sangiouloglou

Management options

A suggested **prevention** action is to conduct public awareness campaigns combined with monitoring. **Control** actions are feasible only in specific circumstances, such as when individuals are localized in a very confined area. Fouling communities on recreational boats and ships can be removed but larvae can re-establish previous densities. These bivalves are also strongly attached to the sea bottom and their eradication involves the removal of part of the local benthic communities and their substratum. This procedure clearly has a considerable impact and must be shown to be justifiable by means of an environmental impact assessment, as in the case of the other alien bivalve *Spondylus spinosus*.

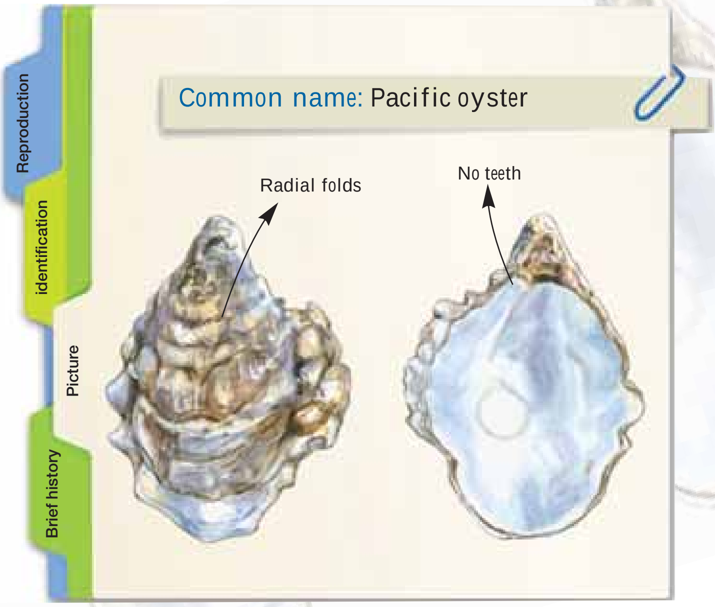
Further reading

Crocetta, F. & Russo, P., 2012. The alien spreading of *Chama pacifica* Broderip, 1835 (Mollusca: Bivalvia: Chamidae) in the Mediterranean Sea. Turk J Zool 37:1-5.

http://www.ciesm.org/atlas/Chamapacifica.html

Drawings: Juan Varela

Scientific Name:
Crassostrea gigas



Key identifying features

The Pacific oyster shell is extremely rough and irregular and usually elongated, although its shape can be variable. Adults can be larger than 40 cm but the usual size is 10–15 cm. The two valves are unequal in size and shape, with large, irregular, rounded radial folds. The upper flat valve is smaller than the lower cup-shaped valve. It is typically whitish grey with veins of purple and greenish brown. The shell interior is pure white with a smooth, shiny surface.

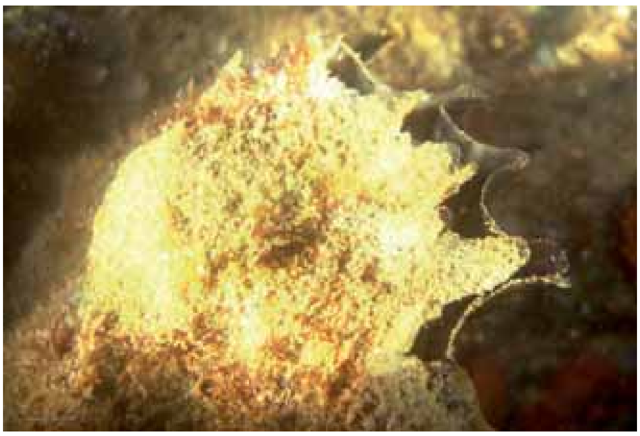
Field identification signs and habitat

This species occurs on rocky and muddy bottoms from the intertidal zone down to a depth of about 15 m in shallow, sheltered bays. It can be found in estuaries and coastal sites as it tolerates a wide range of water temperatures (4–35 °C) and salinities (10–40 psu).

Reproduction

Pacific oysters can be hermaphrodites or change sex during their lives. Spawning depends on water temperature and generally occurs at around 18 °C in summer. Fertilization is external and the larval cycle ranges from 3 to 4 weeks. Oyster spat that has settled on hard substrate becomes reproductive after a year.

Crassostrea gigas. Photo: L. Schroeder - www.PNWSC.org



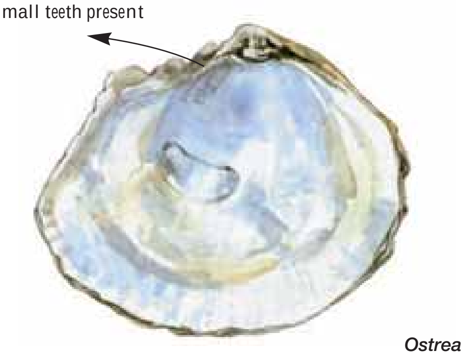
Crassostrea gigas. Photo: B. Weitzmann

Crassostrea gigas. Photo: A.M. Arias

Ostrea edulis. Photo: H. Zell

Similar species

The Mediterranean native oyster *Ostrea edulis* differs from the alien *C. gigas* mainly in that it is usually rounder and flatter and has small teeth on the inner surface of the valves, near the hinge.



Ostrea edulis

Brief history of its introduction and pathways

Crassostrea gigas is native to the north-western Pacific. Introduced initially to north-western Europe by aquaculture during the industry's boom in the 1960s, it is still spreading naturally and colonizing sheltered bays and coastal inlets. In the Mediterranean, the species was introduced into the lagoons of the northern Adriatic and into Greece for aquaculture purposes in the 1980s, and it has now established wild populations in the Ligurian, Tyrrhenian, Ionian and Adriatic Seas. Occasional wild colonies of Pacific oysters have also been found in the eastern Mediterranean basin (Greece and Turkey).

Ecological impacts

Colonization by the Pacific oyster has resulted in ecological competition with native species in many places. At some Mediterranean sites, *C. gigas* has also formed dense reefs and dramatically changed the original habitat. As a result, it has significantly altered local biodiversity and biomass. The reefs it forms, however, may also provide a rich habitat and refuge for other species and may play an important role in the local marine food web. Imported *C. gigas* spat and adults from other areas have also introduced several hitchhiking marine species, including seaweeds, pathogens and parasites. Overall, the long-term effects of its explosive invasions are unknown.

Economic impacts

The introduction of *C. gigas* has had a highly significant economic impact as a farmed product. As it has great fecundity, is highly resistant to pathogens and diseases and grows to marketable size more quickly than *O. edulis*, it is now the most important species in oyster culture. As a side effect, however, the establishment of wild populations of *C. gigas* might contribute to the decline of native commercial bivalve molluscs, essentially by outcompeting them for food and space.

Management options

Suggested **prevention** actions to avoid Pacific oysters becoming established in the wild should include education and public awareness-raising, together with a monitoring program to control invasive species associated with ballast water, marinas and aquaculture. Monitoring also helps in detecting colonies early and eradicating or containing them before further spread occurs. Aquaculture farms near MPAs should be encouraged to cultivate native species or use sterile triploid seed oysters. **Control** action is feasible only in particular conditions, such as where many individuals are localized in a very restricted area and, if possible, before spawning occurs. Large-scale oyster removal experiments with mussel dredges have been conducted in the Netherlands with limited success. Prior to any control actions, an environmental impact assessment of the control procedure should be carried out, as in the case of *Chama pacifica* or *Spondylus spinosus*.

Further reading

http://www.ciesm.org/atlas/Crassostreagigas.html

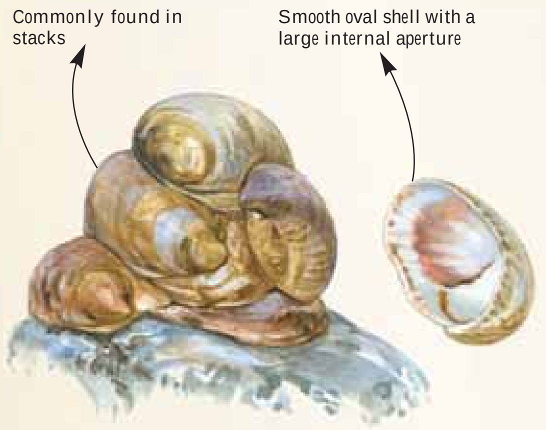
http://www.europe-aliens.org/pdf/Crassostrea_gigas.pdf

Miossec, L., Le Deuff, R-M., and Goulletquer, P. 2009. Alien species alert: *Crassostrea gigas* (Pacific oyster). ICES Cooperative Research Report No. 299. 42 pp.

Drawings: Juan Varela

Reproduction identification Picture Brief history

Common name: Slipper limpet



Scientific Name:
Crepidula fornicata

Key identifying features

The slipper limpet is a snail with a smooth, oval-shaped shell that shows irregular concentric growth lines. It is white, cream, yellow or pinkish with brown or red veins or spots. Inside it has a thin lamina extending halfway across the shell aperture. In the Mediterranean, slipper limpets can attain sizes of up to 3 cm. They are commonly found attached one on top of the other forming stacks of 2–20 animals, with the largest at the base attached firmly to an object with its muscular foot.

Field identification signs and habitat

This species is a filter-feeder occurring within sheltered coastal bays and estuaries, sometimes in low-salinity environments. It settles on other shells or hard substrates on mud and sand-gravel bottoms from lowest water down to depths of about 30 m. It can also survive prolonged periods out of the water, especially if exposed to freezing temperatures, and polluted waters where turbidity is particularly high.

Reproduction

Crepidula fornicata is a hermaphrodite, changing sex during its life. Females brood eggs that are internally fertilized by males that stack on top of them. Usually a few large females are on the bottom and several smaller males stack on top. Eggs contained in capsules hatch into planktonic larvae which, after a short larval period, settle on hard substrates in response to a water-soluble chemical secreted by adults. They attach to a stack and reach maturity as young males in about two months, subsequently undergoing a sex change to become females. Occasionally solitary (not stack-forming) individuals occur, in which case they self-fertilize.

Crepidula fornicata. Photo: C. Scouppe

Similar species

The native species *Crepidula moulinsii* and *Crepidula unguiformis* could be confused with *C. fornicata. C. moulinsii* has a more rounded and convex shell shape that shows a wrinkled surface and light brown stripes whereas *C. unguiformis* has a white shell of elongated shape and flatter surface.

Crepidula moulinsi. Photo: A. Pierluigi

Crepidula unguiformis. Photo: Guido and P. Poppe

Brief history of its introduction and pathways

Originally from the western Atlantic, from the St Lawrence estuary to northern Mexico, the species was first observed in Europe on the west coast of Britain in 1872, probably introduced in association with culture oyster spat, and it then spread along other European coasts. The slipper limpet may also potentially spread via boat fouling (in the communities encrusting a ship's hull) or attached to floating objects and marine litter. In the Mediterranean it was first reported in southern France (Thau Lagoon) in 1982. Since then it has followed the same path as the Pacific oyster (*Crassostrea gigas*), having been reported also in Malta, Italy and Greece.

Ecological impacts

Its high-density colonies (up to several thousand individuals per square metre) have major effects on the macro-benthic fauna and flora, as they compete for food with other filter-feeding invertebrates and increase carbon release. Moreover, the production of large amounts of faeces and pseudo-faeces, increasing the deposition of mud, can have a considerable impact on sediment composition and the associated biota (such as free-living coralline algae).

An unexpected positive impact is that its feeding activities may prevent blooms of harmful algae.

Economic impacts

The slipper limpet can become a pest on commercial oyster and mussel farms, reducing the productivity of aquaculture and natural harvesting grounds. Additional costs are associated with sorting and cleaning shells fouled by *C. fornicata* before marketing. It is also known to foul man-made structures and equipment.

Management options

Suggested **prevention** actions to avoid slipper limpet settlement should include education and public awareness-raising combined with monitoring, particularly close to and inside aquaculture farms. **Early detection** is possible by monitoring shellfish grounds and mollusc culture sites in the proximity of MPAs on a periodic basis. Oyster spat, juvenile mussels or clams with attached slipper limpets should be removed. **Control** action in the case of this species is feasible as its presence is sporadic in the Mediterranean.

Further reading

http://www.ciesm.org/atlas/CrepidulForni.html

http://www.europe-aliens.org/pdf/Crepidula_fornicata.pdf

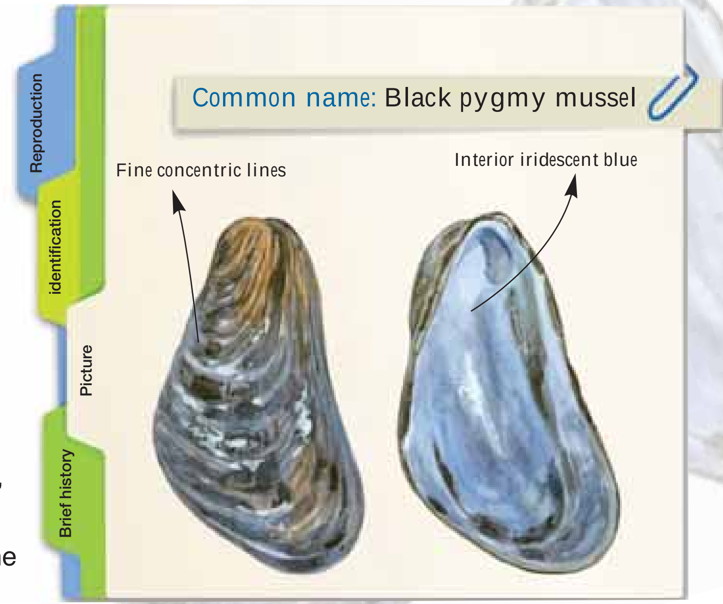
http://www.nobanis.org/speciesInfo.asp?taxaID=229

Global Invasive Species Database:

http://www.issg.org/database/species/ecology.asp?si=600&fr=1&sts=

Drawings: Juan Varela

Scientific Name:
Limnoperna (Xenostrobus) securis



Key identifying features

The thin, elongated shell, almost triangular in shape, is formed of two valves of similar shape and size. The shell is shiny and smooth, with a sculpture of fine concentric lines. Young individuals are yellowish brown, while the adults are dark brown or black, up to 2–3 cm in length. The interior of the shell is iridescent blue.

Field identification signs and habitat

The black pygmy mussel is found exclusively in estuaries and lagoons, often together with the mussel *Mytilus galloprovincialis*, on any kind of submerged or partially emergent hard substratum or oyster shells and occasionally also on sandy and muddy bottoms in crevices and holes. It is a filter-feeder of microscopic plankton and organic particles. These small mussels form dense clumps of up to 50,000 individuals per square metre attaching themselves to the substrate with strong threads.

Adults can survive several days out of the water; they are tolerant of wide ranges of salinity, oxygen concentration and temperature. The species is not found in the sea or in the downstream parts of estuaries where salinity is constantly high.

Reproduction

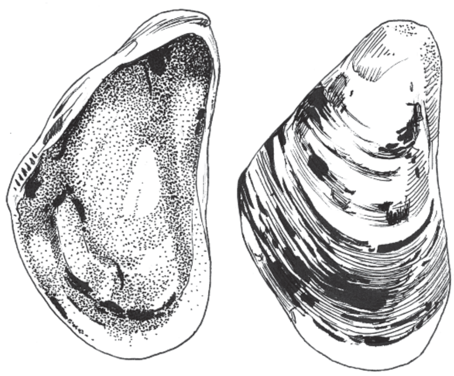
The facility with which the pygmy mussel reproduces partially explains its success as an invader. It is a fast-growing species with a short life span, living on average for only 1 year or occasionally 2–3 years. Fertilization takes place in the water column and free swimming larvae disperse on water currents, helping to colonize new habitats.

Xenostrobus securis. Photo: Guido and P. Poppe

Xenostrobus securis. Photo: M. Taru

Similar species

Limnoperna securis resembles the common Mediterranean species, *Mytilaster minimus*. The major differences are that *L. securis*: 1) has a generally darker shell; 2) is narrower and more elongated, whereas *M. minimus* is squatter in shape; 3) lacks internal shell teeth where the two valves are hinged; 4) is adapted to living at low salinities, unlike *M. minimus* which is found in marine waters.



Mytilaster minimus

Brief history of its introduction and pathways

Originally from the south-eastern Pacific (New Zealand and southern Australia), *L. securis* was first reported in the Mediterranean in Italy (in the Po river delta) in 1992. Since then, it has been found in coastal lagoons and estuaries of France and Italy (the Tyrrhenian, Ligurian and Adriatic Seas) and Spain (northern Catalonia). It was accidentally introduced with seed bivalves for aquaculture purposes, but it can also be spread in ships' ballast waters (water pumped into and out of ships to adjust their buoyancy) or by fouling (in the communities encrusting a ship's hull).

Ecological impacts

Considered to be one of the worst invasive alien species in Europe (European Environment Agency, 2007), its gregarious behaviour and high-density populations living on muddy bottoms can smother the native infaunal communities. Due to its high filtration rates, it may affect nutrient cycling, reducing the food available to other filter-feeders; it is therefore a major competitor of native species. It can also produce changes in the physico-chemical characteristics of the habitat and affect turbidity and sedimentation.

Economic impacts

The species' economic impact has not yet been quantified, but it is highly possible that bivalve culture and harvesting may suffer due to strong competition. By overgrowing commercially harvested molluscs, especially the mussel *Mytilus galloprovincialis*, it can reduce their growth and yield. *L. securis* can act as a key host for pathogens of commercially cultured species. Its rapid growth can contribute to the fouling of submerged structures, pipelines, ropes and boat hulls.

Management options

Suggested **prevention** measures include conducting local public awareness campaigns combined with the monitoring of populations, which makes **early detection** possible. Black pygmy mussels should be removed from seed bivalves intended for mariculture purposes. **Control:** eradication of this species from the environment is unfeasible at the moment due to its small size and the large numbers of individuals forming new populations.

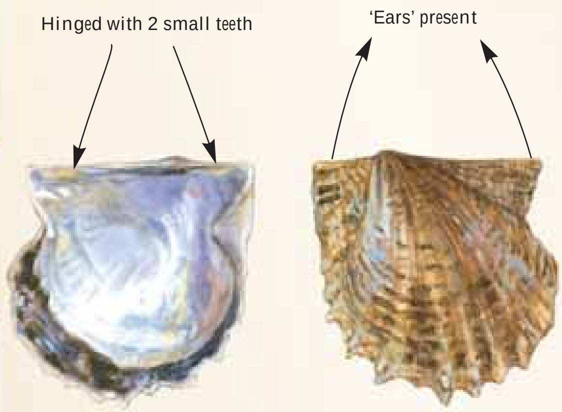
Further reading

http://www.ciesm.org/atlas/Xenostrobussecuris.html

Barbierie *et al*., 2011. New records of the pygmy mussel *Xenostrobus securis* (Bivalvia: Mytilidae) in brackish-water biotopes of the western Mediterranean provide evidence of its invasive potential. Marine Biodiversity Records, Vol 4, 1-4

Drawings: Juan Varela

Common name: Rayed pearl oyster



Scientific Name:
Pinctada imbricata radiata

Key identifying features

The shell is rounded and irregular in shape, the two valves being flattened and developing obliquely in one direction. The side of the shell where the two valves are hinged forms a straight line with a short, rounded 'ear' at one end. One valve is more convex than the other; thus the whole shell is variable in thickness. On the upper surface are irregular concentric ribs and along the edge are scaly spines. The shell is brown-purple occasionally mixed with green, pale yellow or white. The interior is covered with nacre. Shell length is usually 5–6 cm, sometimes up to 10 cm.

Field identification signs and habitat

This oyster is found at depths of 5–25 m attached to hard surfaces (natural or artificial) such as rocks, nets, buoys and docks, as well as in seagrass meadows on sandy-muddy sediments, usually in marine habitats with relatively rough hydrodynamic conditions. It may also attach to the shells of the noble pen shell *Pinna nobilis* or other animals. The oysters attach in clusters of several to many individuals by means of byssal threads, and may form assemblages consisting of pearl oyster shells, worm tubes, algal clumps and anemones, which camouflage the pearl oyster shells. They tolerate a wide range of water temperatures (13–35 °C).

Reproduction

This oyster commonly begins life as a male and when larger than 3 cm it changes sex, becoming female. Spawning occurs in the water column mainly in summer and early autumn, but reproduction can occur all year around. Free-swimming larvae then metamorphose into juvenile pearl oysters.

Pinctada radiata. Photo: B. Michele

Pinctada radiata. Photo: M. Draman

Similar species

Pteria hirundo is a native oyster up to 7 cm long. It is easily distinguished by its highly irregular shell shape, in which the valve hinge is straight with two longer asymmetrical lateral 'ears'.

The non-native pearl oyster *Pinctada margaritifera* can be distinguished by its larger size (up to 20 cm), regular radial ribs arranged in concentric rows and greyish green shell with white or yellowish radial rows of scales.

Pteria hirundo

Pinctada margaritifera. Photo: Jaxshells

Brief history of its introduction and pathways

Originally from the eastern Indian Ocean, Arabian Gulf and Red Sea, the rayed pearl oyster was first recorded in Egyptian Mediterranean waters in the late 19th century, five years after the opening of the Suez Canal (1869). Therefore the primary pathway of introduction was the opening of the canal. Since then the species has successfully spread through the south-eastern basin, while in the western basin it occurs only sporadically. Commercialization of molluscs for mariculture and shipping activities are other reasons for its spread. As larvae can survive in the water column for up to 30 days, they can also be transported in ballast waters, while juveniles and adults can be part of the assemblages encrusting ships' hulls (fouling).

Ecological impacts

The gregarious behaviour of *P. imbricata radiata* in forming extensive oyster beds can modify the structure of habitats and native communities. It may also potentially outcompete other filter-feeding native organisms for food and space. Its broad tolerance of temperatures and air exposure as well as some pollution, and its expanding distribution earn it a place among the worst alien species in Europe (European Environment Agency, 2007).

Economic impacts

These have not been quantified but fouling by rayed pearl oysters can affect mussel farms. In the Arabian Gulf, where it is a native species, its economic impact is positive as it is exploited there for its natural pearls.

Management options

Suggested **prevention** measures include conducting local public awareness campaigns combined with the monitoring of populations, which makes **early detection** possible. Rayed pearl oysters should be removed from seed bivalves intended for mariculture purposes. A suggested **control** action is physical hand removal of new populations by MPA technicians.

Further reading

http://www.ciesm.org/atlas/Pinctadaradiata.html

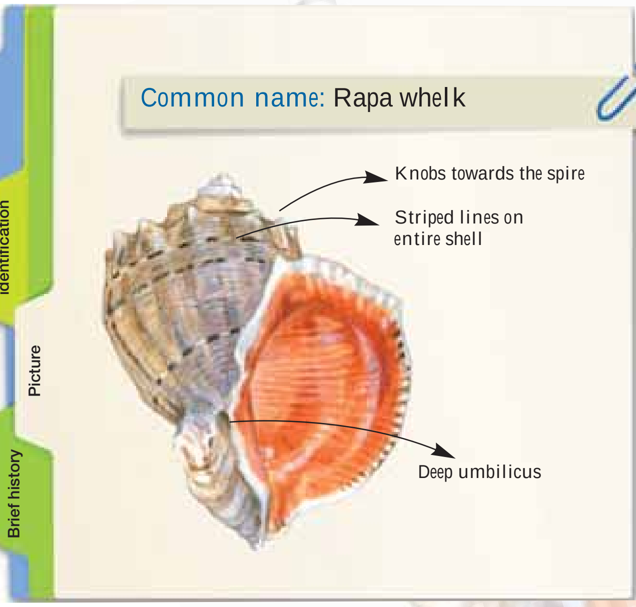
http://www.europe-aliens.org/pdf/Pinctada_radiata.pdf

Katsanevakis S, *et al.*, 2008. Molluscan species of minor commercial interest in Hellenic seas: Distribution, exploitation and conservation status. Mediterranean Marine Science, 9 (1):77-118.

Drawings: Juan Varela

MOLLUSCS

Scientific Name:
Rapana venosa



Key identifying features

This large marine snail, 11–13 cm in shell length, has a heavy, short, sculptured shell with a large inflated body whorl that gives it a spherical appearance. It is nearly as wide as it is long. The colour of the shell can vary from light grey to dark brown, often with light stripes along the spiral ribs.

An obvious distinguishing feature is the deep orange colour of the inside of the aperture, which contains small, elongate teeth on the outer lip. It has a short, wide siphonal canal and pronounced knobs leading to the spire, which are more or less evident depending on the erosion of the shell. Juvenile individuals do not have the orange aperture and the spire is relatively higher.

Field identification signs and habitat

The rapa whelk lives at depths of 2–40 m on sandy and rocky mixed bottoms in marine and brackish estuarine and, less frequently, inner lagoon waters. It often lies buried in the sand to avoid predators and preys on other mollusc species, such as oysters and clams. It tolerates low salinities, polluted waters and oxygen-deficient waters.

Reproduction

Artificial breakwaters, jetties and other man-made marine structures are optimal sites for its reproduction. At such sites rapa whelks congregate to mate and lay their eggs. They reproduce continuously from April to September at temperatures of 12–28 °C. Eggs are deposited in elongated (up to 2 cm) egg capsules that change colour from pale yellow to almost black as the embryos develop. After two weeks free swimming larvae are released into the water column; they later metamorphose into juvenile whelks and migrate to the sea bottom.

Rapana venosa. Photo: Guido and P. Poppe

Similar species

This whelk resembles the native whelk *Stramonita haemastoma*, but the smaller overall size (up to 7 cm), narrower aperture, lack of umbilicus and more tapered shape of the latter distinguish it from the non-native species.

Stramonita haemastoma

Stramonita haemastoma. Photo: C. Tripodi

Brief history of its introduction and pathways

Originally from Sea of Japan, Yellow Sea and East China Sea, the rapa whelk was first introduced into the Black Sea and reported for the first time in the Mediterranean in Italy (Ravenna) in 1973. Thereafter, it spread all along the northern Adriatic coasts from the Marano lagoon to Ancona. There are also sporadic records of the rapa whelk in the Tyrrhenian Sea (from Livorno, Elba Island, Sabaudia, Messina and Cagliari). The species was also recorded from Greece (northern Aegean Sea) and Slovenia in the 1990s.

Larvae are likely to have arrived in ships' ballast water, while young whelks could also have been hidden amongst commercial bivalve seeds and been transferred to new farm seedling areas.

Ecological impacts

The rapa whelk is a voracious predator of bivalve molluscs and may also compete with native species for space; it causes a major decline in local bivalve populations. In other invasive environments, young rapa whelks are generalist predators and consume large numbers of barnacles, mussels, oyster spat, and small oysters, as well as other whelks.

Economic impacts

These whelks can decimate local shellfish populations and damage the industry that they support. They also use fishing nets for attaching their spawn, adding a lot of weight to the nets. Empty shells may be marketed as tourist souvenirs and the meat of this species is consumed along the Romanian Black Sea coast and in Turkey.

Management options

A suggested **prevention** action is to conduct local public awareness campaigns combined with monitoring. There are no proven **control** methods; nevertheless, physical hand removal of adults by MPA technicians, local groups and fishermen could be explored. Removal of egg cases from any hard structure present on the bottom can also effectively address these invasions.

Further information

http://www.ciesm.org/atlas/Rapanavenosa.html

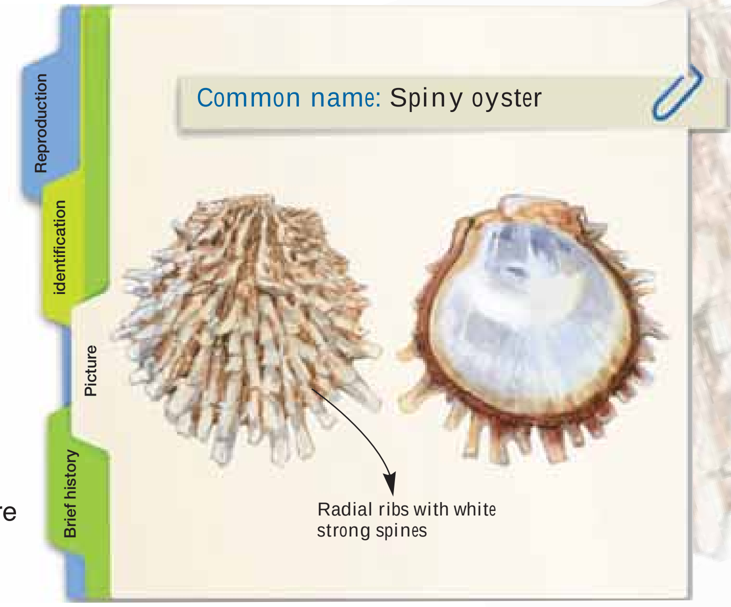
http://www.nobanis.org/MarineIdkey/Gastropods/RapanaVenosa.htm

http://www.europe-aliens.org/pdf/Rapana_venosa.pdf

ICES. 2004. Alien Species Alert: *Rapana venosa* (veined whelk). Edited by Roger Mann, Anna Occhipinti, and Juliana M. Harding. ICES Cooperative Research Report No. 264. 14 pp.

Drawings: Juan Varela

Scientific Name:
Spondylus spinosus



Key identifying features

Adults can be up to 12 cm in width. The lower valve is cemented very firmly to a hard surface and is more cup-shaped. The upper valve is rather flat and covered with fine short spines, which gradually become longer and arranged in rows close to each other. The outline of the shell is oval and irregular. The interior of the shell, where the two valves connect, has two teeth of equal size on each side. The external colour of the shells is purple, brick-red, red-brown or orange-brown, while the hinge area is white with dark spots. The interior is white, becoming darker (beige) in the hinge area.

Field identification signs and habitat

The spiny oyster occurs on rocky bottoms at depths of 2–40 m. It can form large populations of up to 15 individuals per square metre and often can be found together with another alien bivalve, *Chama pacifica.*

Reproduction

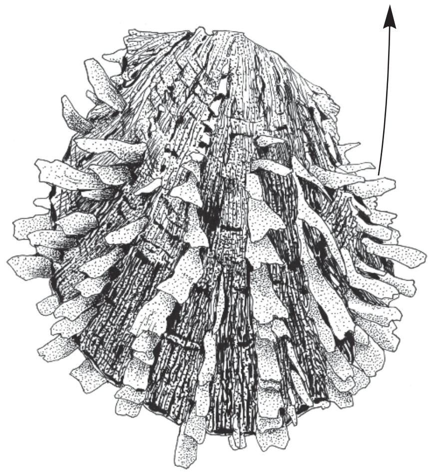
The size at first reproduction of the spiny oyster is 30 mm shell length. In the eastern Mediterranean, gonad development began when seawater temperature was ~20°C and spawning take place at ~27°C (June-August).

Spondylus spinosus. Photo: Guido and P. Poppe

Spondylus spinosus. Photo: F. Favero

Similar species

This oyster resembles another Mediterranean alien species, *Spondylus groschi*, but the latter's larger number of main ribs (6–16 compared with 6–7 in *S. spinosus*), the homogeneous shape of its spines (large and flat like a palette knife) and their colour (compared with white spines in *S. spinosus*) distinguish these two non-native species.



Spondylus groschi

Brief history of its introduction and pathways

Native to the Indo-Pacific and Red Sea, the spiny oyster was first recorded in the Mediterranean in 1988 in Israel, subsequently spreading to the Turkish and Lebanese coasts; it is presently confined to the eastern Mediterranean Sea. It is presumed that it arrived via the Suez Canal and its further dissemination was assisted by ships.

Ecological impacts

The spiny oyster, either alone or together with the jewel box oyster, *Chama pacifica*, can form dense aggregations that produce solid reefs at some sites, completely replacing native oyster species. Competition and reduced plankton availability caused by decreased water flow can also slow down the growth of other benthic organisms.

Economic impacts

The economic impact of this invasive species is unknown. It is a valuable species for seashell collectors, with a small trading market. In Lebanon it is also harvested and sold for food in restaurants.

Management options

A suggested **prevention** action is to conduct public awareness campaigns combined with monitoring. **Control** actions are feasible only in specific circumstances, such as when individuals are localized in a very confined area. Fouling communities on recreational boats and ships can be removed, but larvae can soon re-establish previous densities. These bivalves are also strongly attached to the sea bottom and their eradication implies the removal of part of the local benthic communities and their substratum. This procedure clearly has a considerable impact and must be shown to be justifiable by means of an environmental impact assessment, as in the case of the other alien bivalve *Chama pacifica*.

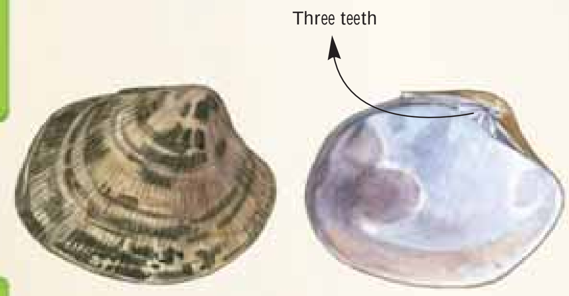
Further reading

Shabtay, A., 2011. The invasive oyster *Spondylus spinosus* Schreibers, 1793 in the Israeli Mediterranean coast. PhD thesis, Tel Aviv University, 97pp.

http://www.ciesm.org/atlas/Spondylusspinosus.html

Drawings: Juan Varela

Common name: Japanese carpet shell, or Manila clam



Scientific Name:
Venerupis (Ruditapes) philippinarum

Key identifying features

The shell is formed of two valves of equal shape and size. Three teeth are present inside where the two valves are hinged. The shell is oval in outline, thick, and longer than high. The shell surface shows evident radial ribs that are more pronounced towards the margin, while the inside shell is smooth. The colour is extremely variable, usually cream, with irregular brown spots and/or stripes. The internal surface of the shells is often pinkish/purplish or pale yellow/brown. Adults can reach up to 5 cm in shell length.

Field identification signs and habitat

The Japanese carpet shell or Manila clam is a filter-feeder, generally found in estuaries and lagoons, on sandy and muddy bottoms, from the surface to a few metres' depth. It can reach high concentrations of individuals (over 2,000 per square metre) and live for several days out of the water, as it is tolerant of a wide range of salinities, oxygen concentrations and temperatures.

Reproduction

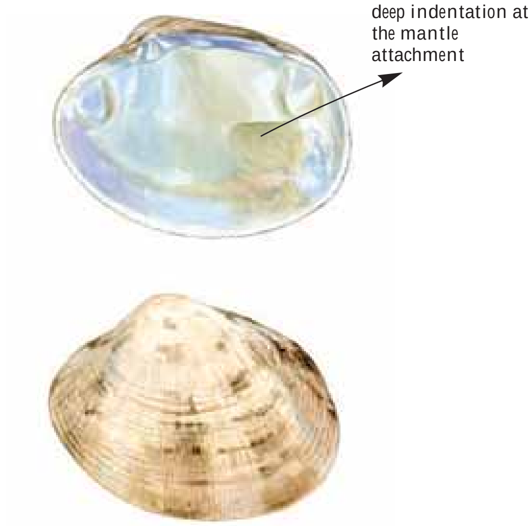
It requires temperatures above about 12 °C to spawn and reproduction usually occurs from June to September at water temperatures of 20–23 °C. Its larvae spend 3–4 weeks drifting in the plankton, then settle to the bottom and attach by threads to rocks or shells.

Ruditapes philippinarum. **Photo: Junta de Andalucia**

Ruditapes philippinarum. **Photo: L. Schroeder_www.PNWSC.org**

Similar species

In the Mediterranean, the Japanese carpet shell *Venerupis philippinarum* is most likely to be confused with the cross-cut carpet shell clam, *Ruditapes decussatus*, whose shell surface has radiating and concentric ridges that are more widely spaced. In *Ruditapes decussatus* the outline of the shell is more elongated than oval, it lacks teeth inside the valves near the hinge, and the inside of the shell is generally completely white.



Ruditapes decussatus

Brief history of its introduction and pathways

Venerupis philippinarum is native to the Indo-Pacific region. Broodstock was introduced for farming along the Atlantic coast of France to replace the native clam *Ruditapes decussatus* in 1972. Since then, culture has spread to the Mediterranean Sea in Italy, France and Turkey, the first seedlings having been introduced in the Venice lagoon in 1983. Wild populations now thrive in all the lagoons along the northern Adriatic coast and in other coastal areas.

Ecological impacts

Its high potential for dispersal, fast growth and great ability to adapt to new environments as an invasive species can have a major impact on the macro-benthic fauna and flora, since it competes for food and space with other filter-feeding invertebrates. It can supplant the indigenous grooved carpet shell, *Venerupis decussata*, and lead to the extinction of other local mollusc populations, as has been observed in the Venice lagoon.

An abundance of bivalves can significantly increase sediment erosion and re-suspension rates and over-enrich sediments with biodeposits, leading to sediment anoxia which inhibits nitrification and kills benthic fauna. This species can destabilize the sediment, and it may also compete for resources with other species and inhibit their population recruitment by ingesting pelagic larvae, which may lead to changes in benthic communities.

Economic impacts

The Japanese carpet shell is one of the most important species in shellfish farming. World production of this one species accounts for 20% of the global shellfish market. Italy is the largest European producer of *Venerupis philippinarum* with 90% of the market, worth over 100 million euros. The negative economic impact of the species has not yet been quantified.

Management options

Suggested **prevention** actions are to avoid the establishment of further wild populations by means of education and public awareness-raising, together with a monitoring programme to monitor parasites that can infect native bivalves. Monitoring in MPAs also facilitates **early detection** of populations so that they can be eradicated or contained before they can spread further. Aquaculture farms near MPAs should be encouraged to cultivate other, native species.
Control: eradication of this species from the environment is unfeasible at the moment due to the large numbers of individuals forming new populations. Only in particular conditions, as where a new population is localized in a very restricted area, can targeted trawling to eradicate the species be attempted.

Further reading

Sladonja et al, 2011. Manila Clam (*Tapes philippinarum* Adams & Reeve, 1852) in the Lagoon of Marano and Grado (Northern Adriatic Sea, Italy): Socio-Economic and Environmental Pathway of a Shell Farm. Aquaculture and the Environment - A Shared Destiny, Dr. Barbara Sladonja (Ed.).

http://www.ciesm.org/atlas/Ruditapesphilippinarum.html

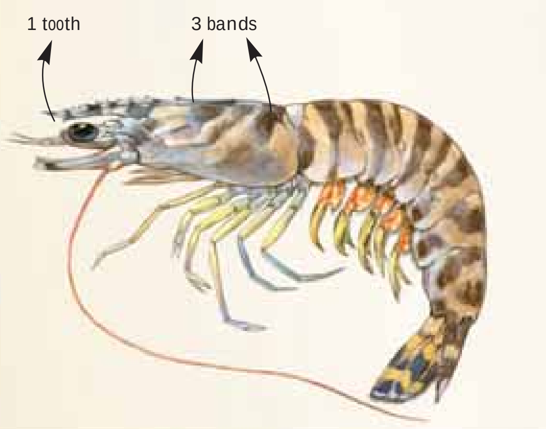
http://www.nobanis.org/MarineIdkey/Bivalvia/RuditapesPhilippinarum.htm

Drawings: Juan Varela

Scientific Name:
Marsupenaeus japonicus

Reproduction | identification | Picture | Brief history

Common name: Japanese tiger prawn, kuruma prawn



Key identifying features

The overall body colour is generally pale pink or blue. The carapace is smooth and glossy with no hairs, and there are brownish transverse bars on the upper side of the abdomen. The rostrum has 9-10 sharp teeth on the upper margin and a single tooth on the lower margin. The last pair of appendages (uropods) has brown, yellow and blue transverse stripes, and the first three pairs of walking legs bear claws.

Males can reach a total length of 17 cm, females 27 cm. A key taxonomical feature for this species' identification is the pouch-like thelycum (external receptacle) on the last pair of walking legs of fertilized females.

Reproduction

The spawning season runs from April to November and begins when the seawater temperature exceeds 20 °C. Larvae require water temperatures above 24 °C for growth. The average life-span is approximately 2.5 years.

Field identification signs and habitat

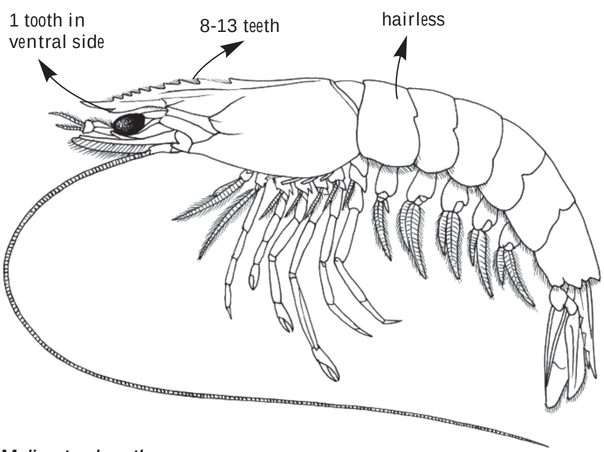
The Japanese tiger prawn inhabits mainly bays and inland seas, from the coastline to depths of about 90 m, but usually less than 50 m. It prefers sandy and sandy-mud bottoms, where it lies buried during the day and roams on the bottom at night.

Marsupenaeus japonicus. Photo: B. Galil

Marsupenaeus japonicus. Photo: M. Draman

Similar species

The first two pairs of walking legs of the native shrimp *Melicertus kerathurus* have spines and transverse dark bands on the first four segments of the abdomen.



Melicertus kerathurus

Melicertus kerathurus. Photo: A.M. Arias

Brief history of its introduction and pathways

Native to the Indian and western Pacific Oceans, this species' first Mediterranean record was as *Penaeus canaliculatus* in Egypt in 1924. The species had migrated through the Suez Canal and has spread subsequently along the Levantine coast (Israel, Lebanon, Syria, Cyprus and southern Turkey) to the Greek island of Rhodes. Other records, from the Adriatic coast of Italy, France, the Amvrakikos and Vistonikos Gulfs (Greece), the Sea of Marmara, and the Mar Menor (Spain), are most probably due to escapes from aquaculture facilities.

Ecological impacts

This prawn competes with the native shrimp *Melicertus kerathurus* for resources. Farmed prawns can also create major problems for native shrimp species and wild fishes by transferring parasites and disease if escapes from aquaculture facilities occur.

Economic impacts

Marsupenaeus japonicus is commercially important for fisheries in the Levant and in pond aquaculture around the Aegean Sea and in the central and western Mediterranean. It has almost supplanted the previously commercially important native penaeid prawn *Melicertus kerathurus* from the easternmost part of the Mediterranean.

Marsupenaeus japonicus. Photo: A.M. Arias

Management options

Strict controls on aquaculture procedures and transport may prevent further introductions.

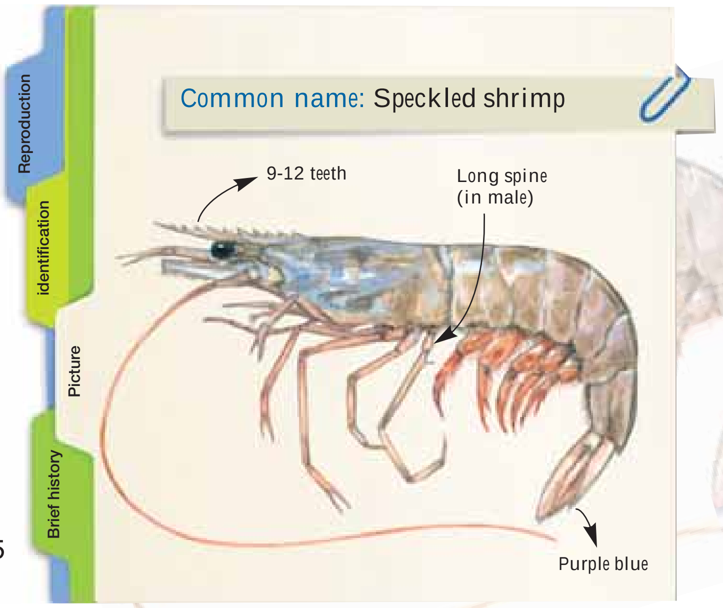
Further reading

http://www.europe-aliens.org/pdf/Marsupenaeus_japonicus.pdf

Bariche, M. 2012. Field identification guide to the living marine resources of the Eastern and Southern Mediterranean. FAO Species Identification Guide for Fishery Purposes. Rome, FAO. 610 pp.

Drawings: Juan Varela

Scientific Name:
Metapenaeus monoceros



Key identifying features

The body is covered with short hairs and is pale grey speckled with dark brown spots. The antennae are orange-red. The maximum length of adult males is 15 cm and of females 20 cm. The rostrum has 9–12 teeth on the upper margin. Males are easily distinguished from other shrimps in bearing a prominent curved spine on their fifth walking leg. The first and third walking legs bear a basal spine.

Field identification signs and habitat

The speckled shrimp is found to a depth of 170 m, commonly 10–30 m, on sandy or sandy-mud bottoms.

Reproduction

Spawning occurs twice a year, with the first peak in May–June and the second in October–November in Tunisia, and in May and July–October in Egypt. In Tunisia, the size for males to reach sexual maturity is 7.6 cm and for females 12.2 cm, although the smallest mature specimen found in Egyptian waters was 9.5 cm. The larvae can be transported over long distances, a possible means of new introductions.

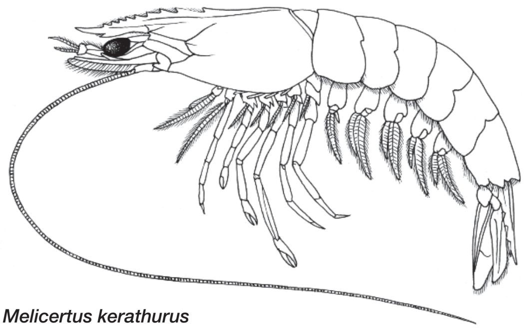
Metapenaeus monoceros. Photo: B. Yokes

Metapenaeus monoceros. Photo: Olfa Ben Abdallah.

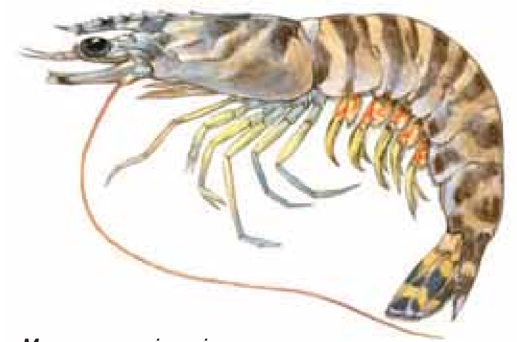
Metapenaeus monoceros. Photos: B. Yokes

Similar species

The Mediterranean shrimp *Melicertus kerathurus* lacks the curved spine on the fifth walking leg in males and its carapace is hairless. The kuruma shrimp, *Marsupenaeus japonicus*, differs from the speckled shrimp in its prominent colour pattern, with transverse dark bands on the first four segments of the abdomen.



Melicertus kerathurus



Marsupenaeus japonicus

Brief history of its introduction and pathways

Native to the Indo-West Pacific, the speckled shrimp was first recorded in the Mediterranean (as *Penaeopsis monoceros*) in Egypt in 1924, and has subsequently been found in Israel, southern Turkey, Cyprus, Lebanon, Syria, Tunisia and Italy.

The native species, *Melicerthus kerathurus.* Photo: A.M. Arias

Ecological impacts

It may pose a threat to the native penaeid shrimp *Melicertus kerathurus* as it outcompetes native species for food and territory.

Marsupenaeus japonicus. Photo: A. Can - www.alpcan.com

Economic impacts

It is commercially important in Egypt, Israel, Lebanon, Turkey and Tunisia, where is caught by trawlers in offshore and beach seines.

Management options

No management options have yet been described.

Further reading

Streftaris, N. *et al.*, 2005. Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas. Oceanogr. Mar. Biol. Ann. Rev. 43, 419-453.

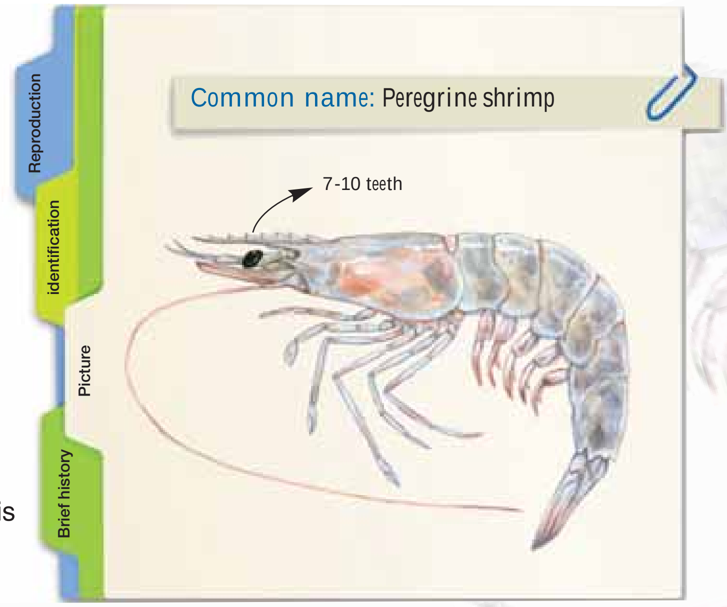
Bariche, M., 2012. Field identification guide to the living marine resources of the Eastern and Southern Mediterranean. FAO Species Identification Guide for Fishery Purposes. Rome, FAO. 610 pp.

Ben Hadj Hamida-Ben Abdallah, O. et al., 2009. Reproductive biology of the speckled shrimp *Metapenaeus monoceros* (Fabricius, 1798) (Decapoda: Penaeidae) in the gulf of Gabes (Southern Tunisia, Eastern Mediterranean). Cahiers de Biologie Marine Vol. 50 No. 3 pp. 231-240.

Serpil Yilmaz, Z. Arzu B. Ozvarol and Y. Ozvarol, 2009. Fisheries and Shrimp Economy, Some Biological Properties of the Shrimp *Metapenaeus monoceros* (Fabricus, 1798) in the Gulf of Antalya (Turkey). Journal of Animal and Veterinary Advances, 8: 2530-2536.

Drawings: Juan Varela

Scientific Name:
Metapenaeus stebbingi



Key identifying features

This shrimp reaches a maximum length of 11 cm in males and 14 cm in females. The smooth carapace is cream-coloured and speckled with rust-coloured spots. The antennae and margins of the tail fan are reddish. The rostrum has 7–10 teeth on the upper margin. The first and third pairs of walking legs have a basal spine. The longest segment of the fifth walking leg of males (the merus) bears a notch on the inner margin.

Field identification signs and habitat

This species inhabits sandy or sandy-mud bottoms down to 90 m in depth. Juveniles occur in shallow coastal waters and adults usually further offshore, buried in the substrate in daytime and foraging at night.

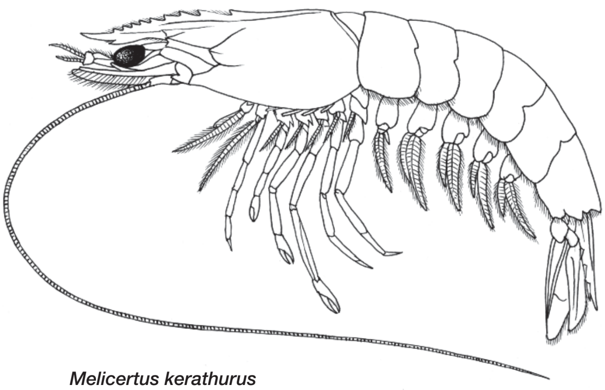
Reproduction

Females attain sexual maturity at a relatively small size (5.5–6.0 cm in length). The highest percentage of mature females occurs between May and June, but the breeding season generally lasts from April to October.

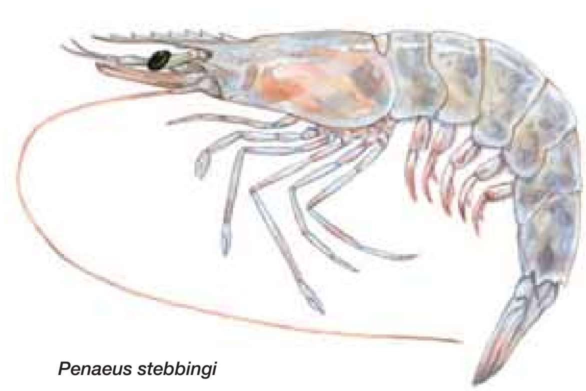
Metapenaeus stebbingi. Photo: Olfa Ben Abdallah

Similar species

The native Mediterranean *Melicertus kerathurus* can be distinguished from *Metapenaeus stebbingi* by the transverse dark bands on the first four segments of the abdomen and by the spines on its first and second pairs of walking legs.



Melicertus kerathurus



Penaeus stebbingi

Brief history of its introduction and pathways

Native to the Indo-West Pacific, the peregrine shrimp was first recorded in the Mediterranean in Egypt in 1924. It has subsequently been recorded in Israel, Lebanon, southern Turkey, Syria and Tunisia.

Ecological impacts

Currently the impacts of this invasive shrimp on the native fauna in areas where it has been introduced are uncertain. The peregrine shrimp may have an advantage over the native Mediterranean prawn *Melicertus kerathurus* in competing for food resources, thereby affecting populations of this native species.

Economic impacts

The peregrine shrimp is nowadays a commercially important species for fisheries in the Levant Sea. It is also a farmed species in ponds along the coast of Turkey.

Management options

No management options have yet been described.

Further reading

Hamida-Ben Abdallah, O. *et al.*, 2006. Premiere observation de la crevette faucon *Metapenaeus stebbingi* (nobili, 1904) dans le Golfe de gabes. Bull. Inst. Natn. Scien. Tech. Mer de Salammbô, Vol. 33, 133-136.

Bariche, M. 2012. Field identification guide to the living marine resources of the Eastern and Southern Mediterranean. FAO Species Identification Guide for Fishery Purposes. Rome, FAO. 610 pp.

Metapenaeus stebbingi. Photo: J. Zaouali

The native species, *Melicerthus kerathurus.* Photo: A. M. Arias

Drawings: Juan Varela

Scientific Name:
Percnon gibbesi

Common name: Sally lightfoot crab

Key identifying features

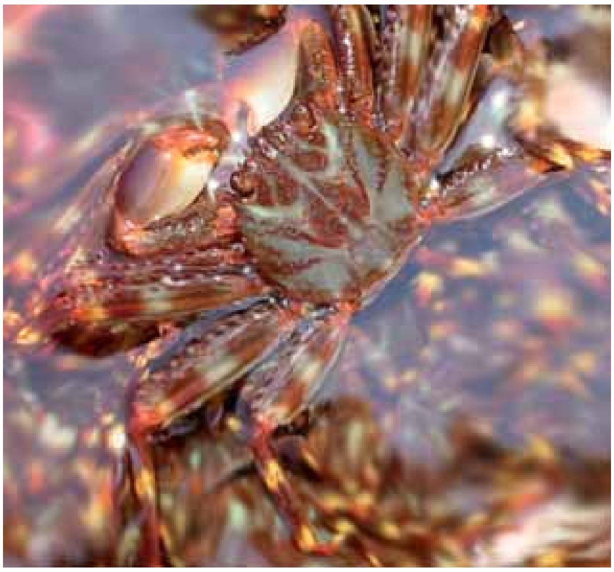
This mimetic, relatively small crab is up to 3 cm across. Its body is flat and square-shaped with a smooth surface. The carapace is brownish green in colour, and the long, flattened legs are banded with golden yellow rings. The ventral surface is pale. The walking legs have a row of spines along the leading edge. The eyestalks and claws are orange; the claws are small in females and large and unequal in males.

Field identification signs and habitat

It is found on rocky shorelines, in the crevices of rocks or on man-made structures such as ports and marinas at depths of 0.5–4 m.

Reproduction

Berried females have been recorded from May to September and juvenile crabs (carapace length ≤ 1.5 cm) are present from October until March, suggesting the crab breeds during the summer months and recruitment takes place throughout the winter.



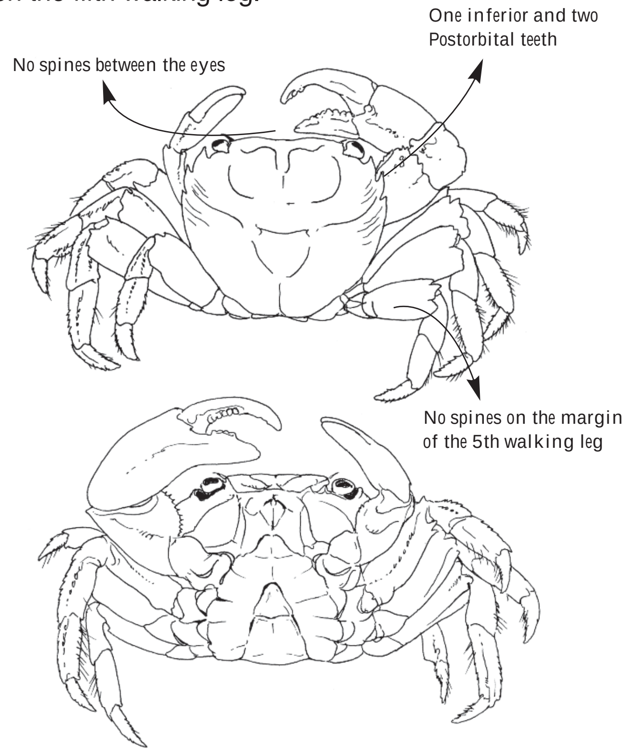
Percnon gibbesi. Photo: E. Azzurro

Percnon gibbesi. Photo: A. Lodola

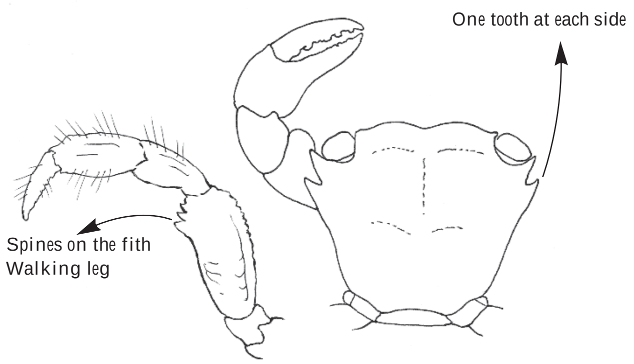
Percnon gibbesi. Photo: E. Azzurro

Similar species

Percnon gibbesi may be distinguished from the native Mediterranean Pachygrapsus species by its deeply incised anterior shape, its colour pattern and its prominently spinose walking legs (particularly on the longest segment). *Pachygrapsus marmoratus* is mainly distinguished by the number of orbital teeth and its spoon-tipped claws; the colour of the species varies considerably and can be brown, purple, green or black. *Pachygrapsus transversus* is dark green to black in colour with a creamy ventral surface; it can be distinguished from *P. marmoratus* by having one tooth on each side of its carapace and 2–3 spines on the fifth walking leg.



Pachygrapsus marmoratus



Pachygrapsus transversus

Brief history of its introduction and pathways

It is native to the west and east coasts of America and the eastern Atlantic from Madeira to the Gulf of Guinea. In the Mediterranean, it was first recorded from Linosa Island, Italy, with nearly simultaneous records from the Balearic Islands, Sardinia, off the Ionian coast of Calabria, the south-eastern Tyrrhenian Sea, Sicily, Pantelleria Island and Malta. It then spread northward along the Tyrrhenian coast to the Gulf of Naples and Giglio Island. In 2005, it was recorded from Crete and Antikythira, Greece, as well as the Mediterranean coast of Turkey. Since then, it has spread along both the Ionian and the Aegean coasts. It is also known from Tunisia, Libya and Egypt. It may spread in the ballast waters of ships and on fishing nets as well as being transported in its larval stage by water currents.

Ecological impacts

The sally lightfoot crab is a strictly herbivorous crab, consuming filamentous and calcareous algae. It is unclear whether it competes with other algivorous animals in its habitat, such as sea urchins, but exclusion of native crabs may occur in some areas. Its habitat overlaps with the native crab *Pachygrapsus marmoratus*, an omnivorous species that also feeds on filamentous algae, and the pebble crab *Eriphia verrucosa*, a carnivorous species that feeds on molluscs and polychaetes.

Economic impacts

Unknown.

Management options

Eradication may be impossible in practice as this species is too widespread in the Mediterranean Sea. Appropriate controls on vessel fouling (including on fishing and recreational vessels) and fishing nets may prevent further introductions.

Further reading

Katsanevakis, S. et al. 2011.Twelve years after the first report of the crab *Percnon gibbesi* (H. Milne Edwards, 1853) in the Mediterranean: current distribution and invasion rates. Journal of Biological Research-Thessaloniki 16: 224 – 236.

http://www.europe-aliens.org/pdf/Percnon_gibbesi.pdf

Drawings: Juan Varela

Scientific Name:
Herdmania momus

Common name: Giant pink ascidian

Reproduction | identification | Picture | Brief history

Key identifying features

This is a relatively large, translucent, pink or red-coloured ascidian that can grow up to 18 cm in height; its body size tends to be larger in the Mediterranean. Generally it has an inflated, spherical body with two short, cylindrical siphons on the top and side. Tiny calcareous spicules lie under the surface of the outer tunic and internal structures. The gut can sometimes be distinguished through the transparent body, forming a loop enclosing one of the gonads.

Small giant-pink ascidians (young individuals) have a soft, thin, transparent tunic, while in larger, older individuals it is thicker, more opaque and leathery.

Field identification signs and habitat

The species is distinguished by its bright red colour, large size, particularly in older individuals, and its distinctive siphons. It is found mostly on smooth artificial substrates such as breakwaters, jetties and artificial reefs down to depths of 20 m. Small organisms such as algae may be attached to the surface, making its identification difficult.

Reproduction

Reproduction through gamete release takes place in the Mediterranean when the water temperature is 22–25 °C (around June and November). Fertilization and larval development occur in the water column, and the development of juveniles is relatively rapid.

Brief history of its introduction and pathways

Originally a tropical Indo-West Pacific species, it is also common in the Red Sea, including the Gulf of Suez and the Suez Canal. It was first recorded in the eastern Mediterranean in Israel in 1958, and in Cyprus, Turkey and Lebanon since 2000, as it has spread along the Levantine coast. Its colonization of Mediterranean regions may be aided by transport in ships' ballast water and fouling.

Herdmania momus. Photo: J. Garrabou

Herdmania momus. Photo: Dr. Noa Shenkar

Herdmania momus. Photo: Dr. Noa Shenkar

Similar species

There are no similar species in the Mediterranean Sea.

Ecological impacts

Populations of *H. momus* are expanding both globally and across the eastern Mediterranean, and these populations have not yet been shown to outcompete native species or invade natural ecosystems. Its potential invasive status is uncertain.

Economic impacts

Like other ascidians, it can be a nuisance fouler on ships, recreational vessels and other submerged man-made structures.

Management options

Regulations and management concerning fouling on commercial and recreational vessels may prevent further introductions.

Further reading

Shenkar N., Loya Y., 2008. The solitary ascidian *Herdmania momus:* native (Red Sea) versus non-indigenous (Mediterranean) populations. Biol. Invasions 10:1431–1439.

Rius, M, Shenkar, N., 2012. Ascidian introductions through the Suez Canal: The case study of an Indo-Pacific species. Mar. Pollut. Bull. 64 (10), 2060-8.

Drawings: Juan Varela

Common name: Sea squirt

Scientific Name:
Microcosmus squamiger

Key identifying features

Microcosmus squamiger is a solitary (non-colonial) ascidian up to 4 cm in height which looks like a globular tube with two short openings (siphons) on the top. It attaches to a hard substrate by a stalk. When the individuals are contracted (as when touched) the siphons are hidden. The body surface (tunic) is wrinkled, leathery brown or reddish, often with other organisms (such as algae) growing or encrusted on its surface. Internally, the tunic is softer and purple in colour.

Field identification signs and habitat

Microcosmus squamiger occurs in the Mediterranean Sea in shallow littoral rocky habitats, particularly inside marinas, harbours and aquaculture facilities, where it forms dense aggregations that can reach more than 2,000 individuals per square metre. It can also spread locally and colonize nearby natural rocky habitats.

Reproduction

Microcosmus squamiger is a simultaneous hermaphrodite, capable of producing and releasing both sperm and eggs almost at the same time. It reproduces in summer and fertilized eggs develop normally at 20–25 °C in a relatively short period of time. Old ascidians seem to die afterwards, to be replaced by new individuals the following winter.

Microcosmus squamiger. Photo: C. Griffiths and M. Rius

Microcosmus squamiger covered with algae and sediments.
Photo: B. Weitzmann

Similar species

Microcosmus squamiger can be confused with the very similar and also alien species *Microcosmus exasperatus*. The species differ in some internal characters, such as the shape of the siphonal spines, which in *M. squamiger* are fingernail shaped and short, while in *M. exasperatus* they are pointed and longer.

MIcrocosmus exasperatus

Microcosmus exasperatus. Photo: Shih-Wei

Brief history of its introduction and pathways

Microcosmus squamiger is native to south-east Australia and has now spread to temperate waters worldwide. It was first recorded as introduced in the Mediterranean Sea in the 1960s (as *M. exasperatus*), and it is now very common around the western Mediterranean in Morocco, Tunisia, Spain (including Ceuta and the Balearic Islands), France (including Corsica), the Tyrrhenian Sea (coast of Italy) and Malta. Given its presence in harbours, marinas and aquaculture farms, it is thought to have been introduced in the ballast waters of shipping vessels, in fouling on ships and recreational boats, and through aquaculture.

Ecological impacts

Microcosmus squamiger can form dense aggregations (from about 500 up to about 2,300 individuals per square metre) in the shallow sublittoral zone, closely carpeting rocky areas and becoming a major structure-forming organism that colonizes all the available substrate and alters local native communities. It can be found on natural and artificial hard substrates, in or close to harbours and marinas.

Economic impacts

Microcosmus squamiger is considered a pest to bivalve culture in some areas, where it competes for food and space. It is also a nuisance fouler on ships, recreational vessels and other submerged man-made structures.

Management options

Strict controls on aquaculture procedures and transport as well as regulations and management concerning fouling on commercial and recreational vessels may prevent further introductions.

Further reading

Rius M. *et al.,* 2009. Population dynamics and life cycle of the introduced ascidian *Microcosmus squamiger* in the Mediterranean Sea. Biol. Invasions 11, 2181–2194.

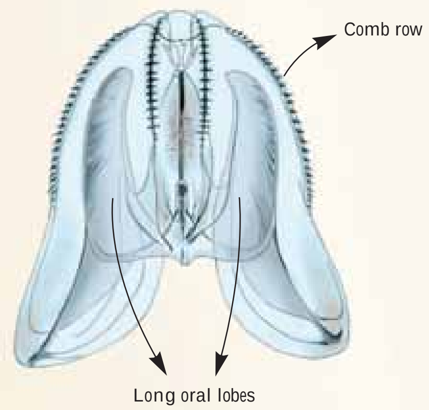
Rius, M. *et al*., 2012. Tracking invasion histories in the sea: facing complex scenarios using multilocus data. PLoS ONE 7, e35815.

Drawings: Juan Varela

Scientific Name:
Mnemiopsis leidyi

Reproduction | identification | Picture | Brief history

Common name: Warty comb jelly



Key identifying features

This gelatinous planktonic organism (a ctenophore) somewhat resembles a jellyfish. It is oval in shape, laterally compressed, transparent and approximately 7–12 cm in length and 2.5 cm in diameter. It has 8 ciliated bands or ‘combs’ (rows of small ‘plates’ made of tiny hair-like cilia) running the length of its body and two large oral lobes on either side which open wide when feeding. Four smaller lobes are situated underneath the oral lobes.

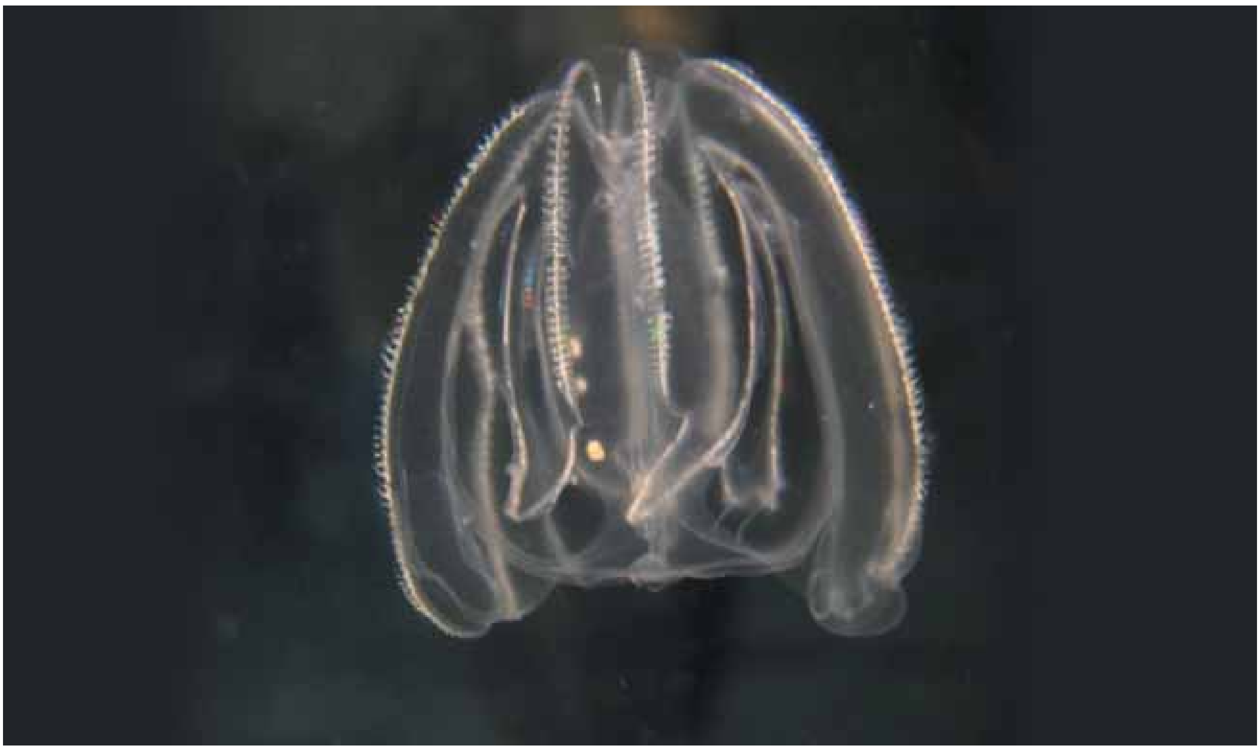
Field identification signs and habitat

This species can be found in the water column of shallow estuaries, bays and coastal marine waters forming large aggregations. It is capable of producing bioluminescence, and the ciliated bands may glow green at night. The animal is usually transparent or translucent.

Reproduction

Mnemiopsis leidyi has both male and female reproductive organs and is able to fertilize itself. It reproduces at a phenomenal rate: a large individual can release as many as 12,000 eggs a day. Under optimum temperature (15–30 °C) and nutrient conditions, eggs can hatch and develop into free-swimming adults within 14 days.

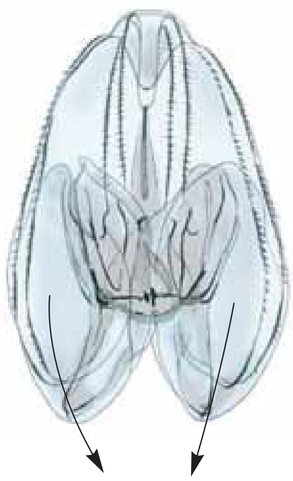
It also has the ability to regenerate from fragments larger than one-quarter of the body.



Mnemiopsis leidyi. Photo: L. van Waltraven

Similar species

The most obvious distinguishing feature is the extent of the animal´s oral lobes: in *M. leidyi*, they span nearly the entire length of the body, while in native ctenophores and in *Bolinopsis vitrea*, another alien species, they only reach half-way along the body. Moreover, *B. vitrea* also lacks papillae (warts) on its body.



Bolinopsis vitrea

Brief history of its introduction and pathways

Native to the Atlantic coasts and estuaries of North and South America, *Mnemiopsis leidyi* was first introduced to the Black Sea via the ballast water of ships. The Black Sea *M. leidyi* population spread into the Sea of Marmara with the currents and thence into the north-western Aegean Sea, where it was first recorded in 1990. Soon afterwards, it was recorded off the Mediterranean coast of Turkey and in Syria. In the mid 2000s it appeared in France and the northern Adriatic Sea, and nowadays large blooms of this species are commonly reported in Israel, Italy and Spain.

Ecosystem impacts

It is a voracious feeder, preying on zooplankton, pelagic fish eggs and larvae. Large aggregations can reduce native zooplankton communities, have negative effects on fish feeding (by competition) and cause major trophic cascades in the marine food web, thereby affecting biodiversity. In the Black and Caspian Seas it caused the collapse of many fish stocks and affected the entire ecosystem, transforming pelagic food webs into comb-jelly food webs. Its effects on the Mediterranean are so far insignificant, or at least less dramatic.

This species has been nominated as one of the 100 'World's Worst' invaders (IUCN, 2005).

Ecological impacts

Invasion by this species has caused significant harm to small-scale commercial fishing operations by reducing catches and fouling fishing gear. As it feeds on zooplankton, it consumes commercially important fish eggs and larvae and can affect local fish production, causing total stock depletion.

Blooms affect coastal tourism and can clog the cooling water intakes of industrial facilities and desalination plants.

Management options

Eradication may be impossible in practice since the species is too widespread in the Mediterranean Sea. Appropriate regulation of the treatment and/or exchange of ships' ballast water may prevent further introductions.

Further reading

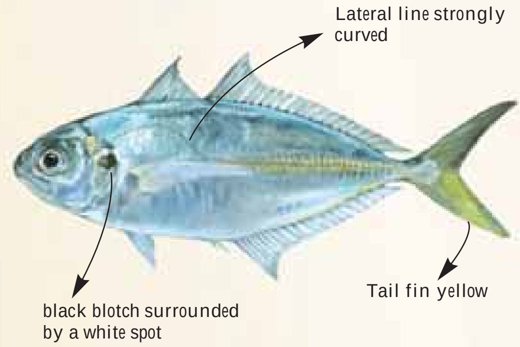
Shiganova T. A. *et al*, 2001. Population development of the invader ctenophore *Mnemiopsis leidyi*, in the Black Sea and in other seas of the Mediterranean basin. Marine Biology 139, 431-445.

http://www.europe-aliens.org/pdf/Mnemiopsis_leidyi.pdf

Global Invasive Species Database: *Mnemiopsis leidyi* http://www.issg.org/database/species/ecology.asp?si=95&fr=1&sts=

Scientific Name:
Alepes djedaba

Common name: Shrimp scad



Key identifying features

The body is ellipsoid and compressed, up to 40 cm in length (commonly 10–20 cm). The first dorsal fin has 8 spines and is triangular in shape, while the second dorsal fin (with 1 spine and 22–25 soft rays) is long and anteriorly elevated. The anal fin has two detached spines followed by a single spine attached by a membrane to 18 to 20 soft rays, some of which are elevated anteriorly. The last dorsal and anal fin rays are elongated. The tail fin is deeply forked. The lateral line has a series of 39 to 51 scutes (enlarged and thickened scales), is arched anteriorly and straightens under the first to third dorsal rays. The posterior part of the pectoral fins, when folded along the flanks, overlaps the first scutes. The back is grey with a white belly; the tail fin and the posterior part of the lateral line are yellow; the upper lobe of the tail fin is dusky to black.

An obvious distinguishing feature is a black spot present on the upper margin of the operculum (gill cover), bordered above by a smaller white spot.

Field identification signs and habitat

The shrimp scad is a pelagic species inhabiting inshore waters, where it forms schools near rock reefs, often in turbid waters. It also gathers in large schools above artificial man-made reefs such as harbours and jetties. Juveniles can be found sheltered among the tentacles of the jellyfish, *Rhopilema nomadica* or *Phyllorhiza punctata*. In the Mediterranean it feeds mainly on fishes.

Reproduction

In the Indo-Pacific region the presence of maturing and mature specimens in most months of the year indicates a prolonged spawning season, but in the Mediterranean the spawning period is probably shorter.

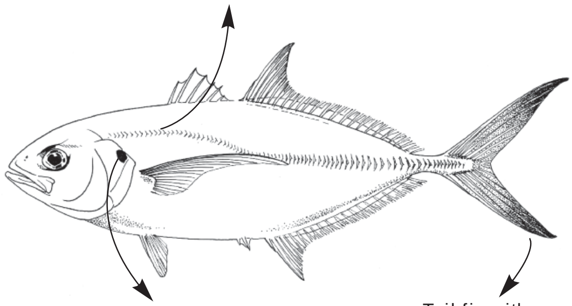
Alepes djedaba. Photo: P. Consoli

Rhopilema nomadica. Photo: D. Edelist

Similar species

The shrimp scad can be confused with several other species of the Carangidae family. Several *Caranx* species and *Pseudocaranx dentex* have a similar ellipsoidal, compressed body shape and a line of scutes along the lateral line. However, the posterior part of their pectoral fins, when folded along the flanks, does not overlap the first scutes.

Alepes djedaba can also be distinguished from native Mediterranean species by the presence of an adipose membrane covering the posterior half of the eyes, and a black spot on the edge of the gill cover.



Caranx crysos

Caranx rhonchus. Photo: A.M. Arias

Brief history of its introduction and pathways

The shrimp scad is widely distributed in the Indo-Pacific. The first individual in the Mediterranean Sea was recorded along the Palestinian coast in 1927 (as *Caranx calla*). It has subsequently been recorded in the Aegean Sea, Egypt and Greece and is now a very common species in the Levant.

Ecological impacts

The shrimp scad can form large schools around natural or artificial reefs. Competition with some native zooplanktivorous species such as *Chromis chromis* or *Sardinella aurita* may occur. In addition, many researchers consider that the lower predation pressure on *A. djedaba* in shallow waters can lead to a greater abundance of juvenile shrimp scads in these habitats.

Economic impacts

In the Mediterranean its large schools are caught by beach seine, purse seine and trammel nets, as this fish has some commercial value.

Management options

These include a) **early eradication** of new populations by MPA operators through fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

Further reading

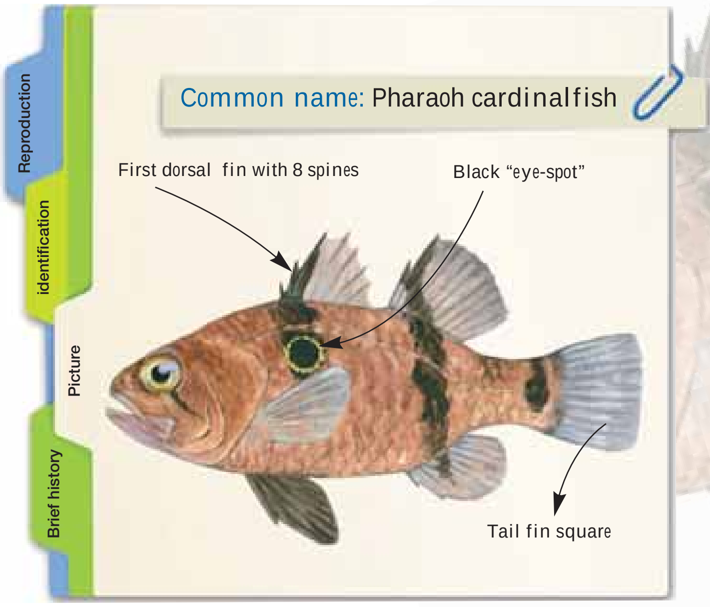
Carpenter, K.E., *et al.* 1997. FAO Species Identification Field Guide for Fishery Purposes. Living marine resources of Kuwait, eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates.

http://www.ciesm.org/atlas/Alepesdjedaba.php

Alepes djedaba. Photo: P. Consoli

Drawings: Juan Varela

Scientific Name:
Apogonichthyoides pharaonis



Remarks on systematic determination

According to Gon and Randall (2003), the species formerly known in the Mediterranean as *Apogon nigripinnis* should be referred to as *Apogonichthyoides pharaonis* (common synonym *Apogon pharaonis*); *Apogonichthyoides nigripinnis* is restricted to the eastern Indian and western Pacific Oceans. According to FishBase only *A. nigripinnis* migrated to the Mediterranean through the Suez Canal, and *A. pharaonis* is not regarded as a migrant through the Suez Canal. However, we follow Zenetos *et al.* (2010) in considering only *A. pharaonis* to be a non-indigenous species in the Mediterranean.

The systematics of the Apogonidae is rather complex and accurate identification of the different species has to be done by a specialist in this group. These difficulties have resulted in several misidentifications in the literature. Consequently, all field observations of Apogonidae individuals must be checked by a specialist in this group to identify the species.

Key identifying features

The body is oblong and compressed, up to 10 cm in length (commonly 7–8 cm). Two distinct dorsal fins are present; in the first dorsal fin (8 spines) the two first spines are very short and the third is the longest. The second dorsal fin (1 spine, 8–9 soft rays) lies directly above the anal fin (2 spines, 7–8 soft rays). The tail fin is square and the pelvic fins (1 spine, 5 soft rays) begin below the base of the pectoral fins (15–16 soft rays).

The mouth is large and oblique with teeth present in the jaws and on the vomer (a median bone in the roof of the mouth) and palatine bones (also in the roof of the mouth). The eye is large and the pre-operculum (area just anterior to the gill) has a smooth ridge and a serrated edge. A single spine projecting from the operculum is present at the level of centre of eye.

The body is crossed by three vertical black bars on a grey-brown background, one below each dorsal fin and the last on the narrowest part of the fish's body where the tail fin is attached.

A characteristic black 'eye-spot' encircled by a yellow ring is present on the flank within the first bar. The leading edge of the first dorsal fin is dark and that of the pelvic fins is white.

Field identification signs and habitat

The adults occur inshore and on deep offshore reefs. It is a nocturnal species, like *Apogon imberbis*. During the day it is found among seagrasses or close to or inside small caves.

Apogon pharaonis. Photo: M. Draman

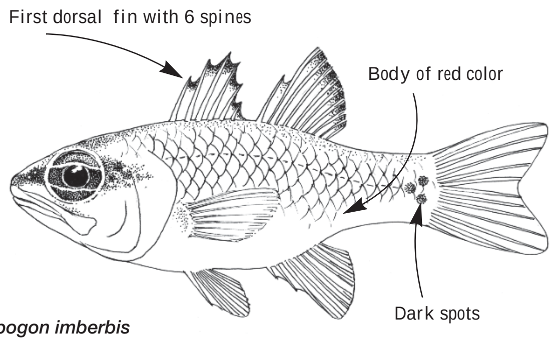
Reproduction

The males brood the eggs in their mouths until the young are free-swimming.

Similar species

There are now several Apogonidae species in the Mediterranean, four of them non-indigenous.

Apogon imberbis, the cardinal fish, is the only native species. It is easy to identify by its red colour and its 6 spines in the first dorsal fin.



Apogon imberbis

The other cardinal species that have entered from the Red Sea are *Apogon queketti*, the spotfin cardinal, recorded off Turkey in the Levantine basin; *Apogon smithi*, Smith's cardinalfish, recorded off Israel; *Ostorhinchus fasciatus*, the broadbanded cardinalfish (reported as *Apogon fasciatus*) off Israel and Turkey and *Cheilodipterus novemstriatus*, the twospot cardinalfish recorded off Israel and Lebanon.

These Apogonidae species do not have the characteristic black ‘eye-spot’ on the body, and the body colour is tan to brown, with a pinkish tinge. *O. fasciatus* is clearly distinguished from the other *Apogon* species by a blackish mid-lateral stripe which extends to the end of the tail fin.

Apogon imberbis. Photo: L. Sanchez Tocino

Brief history of its introduction and pathways

Due to taxonomic confusion and misidentification, the history of this cardinalfish’s introduction and its pathways are unclear. It is native from the Suez region of the Red Sea to South Africa. In the Mediterranean the Pharaoh cardinalfish was first recorded in Palestine in 1947, misidentified as *Apogon taeniatus*; it has subsequently been recorded in Cyprus and Turkey. The species is now common from the southern coast of Israel to the Levantine Sea.

Ecological impacts

The lack of nocturnal competitors might facilitate the population growth and spread of the non-indigenous species of Apogonidae, such as the bullseye, in the Mediterranean. The Apogonidae family constitutes the second largest species group by numbers in the sea around Turkey.

Other Pempheridae species such as *Pempheris vanicolensis* inhabit caves during the day. There is no documented evidence of competition between the Pharaoh cardinalfish *A. pharaonis* and *P. vanicolensis* or with the native species *Apogon imberbis*. However, daily migration movements of the Pharaoh cardinalfish out of the cave to forage at night and back in the morning may increase the transfer of organic matter into the cave and thereby have an impact on the cave-associated invertebrate fauna.

Economic impacts

This species has been reared in captivity but is of low commercial value, except as ornamental fish species. The economic impact of its invasion is unknown.

Management options

These include a) **early eradication** of new populations by MPA technicians through hand fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

Further reading

Zenetos A. *et al.* 2010. Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union’s Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. Mediterranean Marine Science 11 (2): 381–493.

Gon O. and Randall J.E., 2003. A review of the cardinalfishes (Perciformes: Apogonidae) of the Red Sea, Smithiana Bulletin, Vol. 1-48 pp.

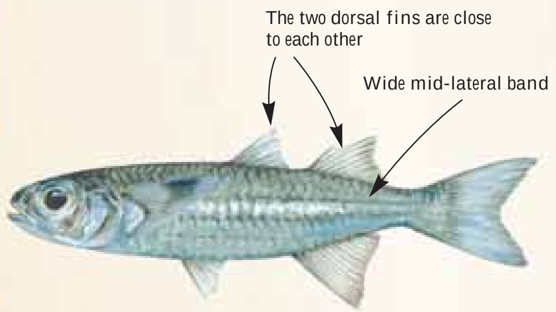
Drawings: Juan Varela

FISHES

Scientific Name:
Atherinomorus forskalii

Reproduction | identification | Picture | Brief history

Common name: Hardyhead silverside



Key identifying features

The body is rather deep but not very compressed (body width being roughly 2/3 body depth), growing up to 15 cm in length (commonly 2–10 cm). It has a grey back with a white belly and two separate dorsal fins: the first has 7–8 flexible spines and the second dorsal 1–2 spines and 8–11 soft rays. The anal fin lies directly below the second dorsal fin and has 1 spine, rarely 2, with 12–17 soft rays.

The tail fin is forked. The head is large, almost straight dorsally or somewhat convex in shape, and with large eyes. The mouth is protrusive and the edge of the pre-opercular (a bone lying in front the gill cover) bears a notch in angle.

A characteristic broad, silvery, mid-lateral band runs from the upper margin of the pectoral fin to the base of tail fin.

Field identification signs and habitat

This species, like all other Atherinidae, lives in shallow waters close to the coast, near the surface. It forms large schools and feeds on zooplankton and small bottom-living invertebrates.

Reproduction

The eggs are large, with adhesive filaments to anchor them to solid objects.

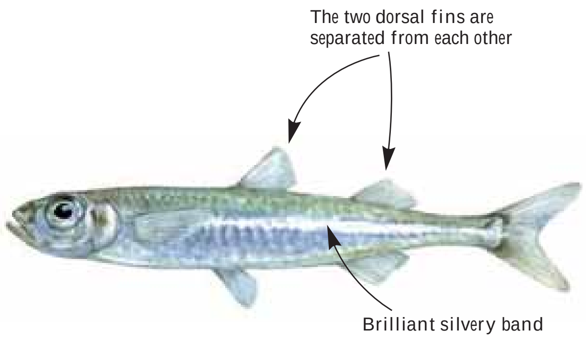
Atherinomorus forskalii. Photo: P. Consoli

Atherinomorus forskalii. Photo: E. Azzurro

Atherinomorus forskalii. Photo: P. Consoli

Similar species

The Indo-Pacific marine atherinid fishes *Atherinomorus forskalii*, *A. lacunosus, and A. pinguis* are similar to each other in having a broad mid-lateral band (roughly equal to or greater than the mid-lateral scale width), a large mouth, and no distinct tubercle at the posterior end of the dentary bones. The three species have long been confused with each other and regarded as a single species. *Atherinomorus forskalii* is endemic to the Red Sea and is the only species to have migrated to the eastern Mediterranean through the Suez Canal. It differs from *A. lacunosus* and *A. pinguis* in having prominent, large teeth that form very obvious tooth ridges.



A native species, *Atherina hepsetus*

Atherinomorus lacunosus. Photo: J.E. Randall

Brief history of its introduction and pathways

Atherinomorus forskalii is endemic to the Red Sea. The first record in the Mediterranean was in waters off Alexandria, Egypt, in 1902 (as *A. lacunosus*). It has subsequently been recorded in Israel, Turkey, Lebanon, Greece, Libya, and Tunisia.

Ecological impacts

Little is known of its biology. The presence of large schools could have a positive effect as *A. forskalii* is an important prey for larger species. However, as a plankton eater consuming small crustaceans and the eggs and larvae of other species, its impact, although not yet known, may be significant.

Economic impacts

It is a very common species in some Mediterranean countries but, due to its small size, it is not generally commercially fished, except in Egypt.

Management options

These include a) **early eradication** of new populations by MPA technicians through fishing, and b) maintenance of healthy and abundant assemblages of top predators (tuna, seagulls, etc.) to encourage natural **control** through predation.

References

http://www.ciesm.org/atlas/Atherinomorusforskali.php

Kimura, S. *et al*., 2007. Redescriptions of the Indo-Pacific atherinid fishes *Atherinomorus forskalii, Atherinomorus lacunosus*, and *Atherinomorus pinguis*. Ichthyological Research, Vol 54, Issue 2, 145-159

Drawings: Juan Varela

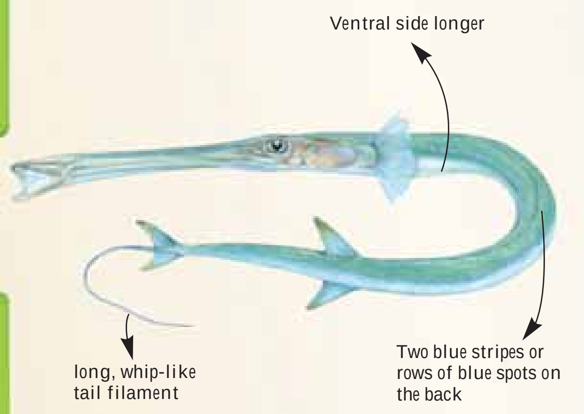
FISHES

IUCN

Scientific Name:
Fistularia commersonii

Reproduction | identification | Picture | Brief history

Common name: Bluespotted cornetfish



Key identifying features

This fish has an elongated body shape, smooth skin, a long tubular mouth (snout) with highly serrate ridges, and a long head. It is grey to olive-green, grading to silvery white ventrally, often with blue spots. At night, when the fish is resting close to the bottom, broad, dark stripes appear on the back; these stripes are sometimes visible during the day.

In the Mediterranean its maximum size is 115–120 cm, and the smallest size ever recorded was 19 cm.

The tail fin is forked, with two characteristic, very elongated, filamentous middle rays forming a long, whip-like tail filament. The dorsal (14–17 soft rays; no spine) and anal (14–16 soft rays; no spine) fins are on the posterior part of the body, and opposite each other.

Field identification signs and habitat

Adult bluespotted cornetfish occur on sandy bottoms or above seagrass meadows (*Posidonia oceanica* or *Cymodocea nodosa*), but always adjacent to rocky reef areas. They are either solitary or live in schools of 10–20 individuals.

Fistularia commersonii. Photo: E. Azzurro

Reproduction

The reproductive season lasts at least six months, from May to October, with a peak in August. Spawning starts at an average water temperature of 22°C.

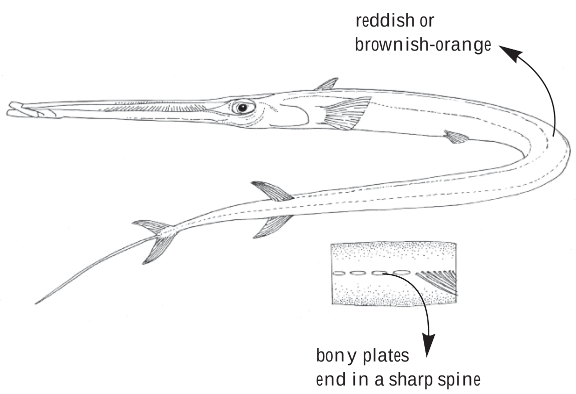
Fistularia commersonii. Photo: G. Pergent

Fistularia commersonni juvenile. Photo: E. Azzurro

Similar species

The body shape and filamentous middle rays distinguish this species from all other Mediterranean fishes. Young specimens (less than 20–30 cm long) can be confused underwater with members of the Belonidae family; however, they can be distinguished from them by the long whip-like tail filament. In addition, Belonidae species are more frequently observed in open water just below the sea surface, while the bluespotted cornetfish is always closer to the bottom.

Another Fistularidae species recorded in the Mediterranean is *Fistularia petimba*, the red cornetfish. This species is an Atlantic migrant, recorded only from the Alboran Sea. Its shape is very similar, but it is generally longer (up to 2 m); it has also bony plates along the midline of the back (absent in *F. commersonii*), and is reddish or brownish-orange in colour.



Fistularia petimba

Brief history of its introduction and pathways

The bluespotted cornetfish is widely distributed in the Indo-Pacific and eastern central Pacific. The first individual recorded in the Mediterranean Sea was captured in January 2000 by a fisherman on the coast of Israel. It spread rapidly westwards to Rhodes, the south-eastern Aegean Sea, Greece, the southern shores of Italy in 2002, the northern Tyrrhenian Sea in 2004, Sicily and Malta coasts, the southern coast of Spain in 2007, and the French Mediterranean coast also in 2007. It was repeatedly recorded in Corsica and along the Alpes-Maritimes and Var coast (France) in 2010.

Having achieved such a widespread range over such a short period of time, *F. commersonii* is the fastest and farthest Lessepsian fish migrant ever recorded.

Ecological impacts

The bluespotted cornetfish is an extremely voracious predator and is aggressive when in schools. It is one of the top predators in the seas it has invaded, feeding on fish fry and benthic fishes (adults of small fish species or juveniles), including commercially important Centracanthidae, Sparidae and Mullidae species, and a large number of gobiids. The spread of *F. commersonii* into shallow coastal habitats and its rapid increase in abundance may potentially have adverse effects on the local fish communities on which it preys. Adults could furthermore compete with native piscivorous species by exploiting local resources faster.

Economic impacts

In the Indo-Pacific region, *Fistularia commersonii* is a species of minor importance in commercial fisheries. In the Mediterranean it is still little appreciated and generally discarded; however, it is increasingly acquiring economic importance in eastern Mediterranean local markets. This is due to the fact that it has white, palatable flesh and no spines, and that consumers have eventually got used to its unusual, elongated, flute-like shape.

Management options

Early eradication of new populations by MPA technicians through hand or spear fishing is suggested.

References

Azzurro E. *et al.*, 2012. *Fistularia commersonii* in the Mediterranean Sea: invasion history and distribution modeling based on presence-only records. Biological Invasions, Oct.

http://www.ciesm.org/atlas/Fistulariacommersonii.php

http://www.europealiens.org/pdf/Fistularia_commersonii.pdf

Drawings: Juan Varela

IUCN

Scientific Name:
Lagocephalus sceleratus,
Lagocephalus spadiceus,
Lagocephalus suezensis

Key identifying features

These three species of the genus Lagocephalus are capable of inflating their bodies by swallowing water. When not inflated their bodies are elongated and slightly laterally compressed. The largest is *L. sceleratus* with a maximum length of 110 cm (commonly 20–60 cm), followed by *L. spadiceus* at 40 cm (commonly 5–30 cm), and 18 cm for *L. suezensis* (commonly 7–15 cm). The single dorsal fin (10-19 soft rays) and the anal fin (8–12 soft rays) are both pointed with a short base and lie opposite each other.

The tail fin is slightly concave. The head is long and triangular with a small mouth and two strong teeth in each jaw. The body is smooth with no scales, while only very small spinules (spines) can be seen on its belly and dorsal surface.

In *L. sceleratus*, apart from the two conspicuous lateral lines, the body is silvery to grey with regular black dots on its back, except for the belly which is white.

Field identification signs and habitat

These pufferfishes occur in coastal habitats from sandy bottoms to seagrass meadows, down to a depth of 100 m. They inflate their bodies when threatened. In the Mediterranean this fish family is carnivorous, feeding mainly on shrimps, but also on crabs, fish (including individuals of the same species), squids, molluscs and cuttlefish.

Reproduction

In the Levant, *L. sceleratus* spawning takes place during early summer. Their eggs and larvae are planktonic.

Reproduction | identification | Picture | Brief history

Lagocephalus sceleratus

Common name: Silver-cheeked toadfish

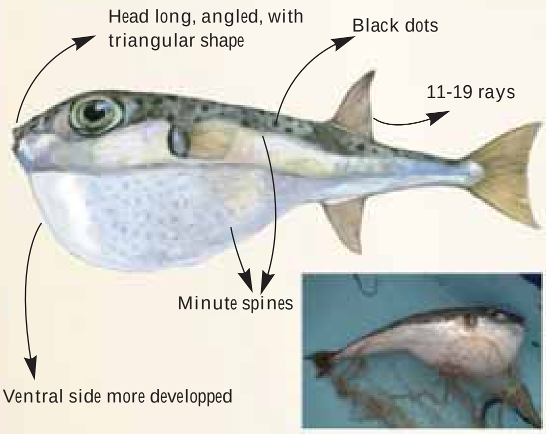


Photo: N. Michailidis

Reproduction | identification | Picture | Brief history

Lagocephalus spadiceus

Common name: Half-smooth golden puffer

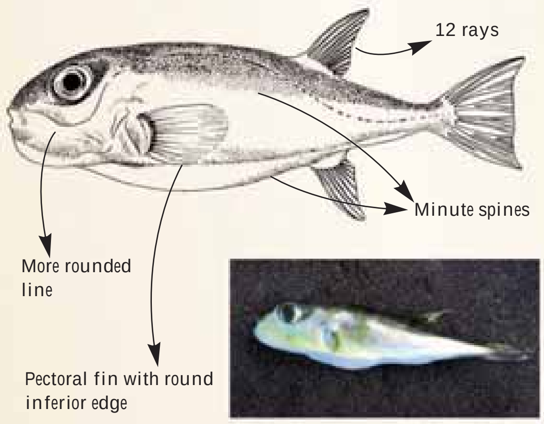


Photo: M. Kesl

Reproduction | identification | Picture | Brief history

Lagocephalus suezensis

Common name: Suez puffer

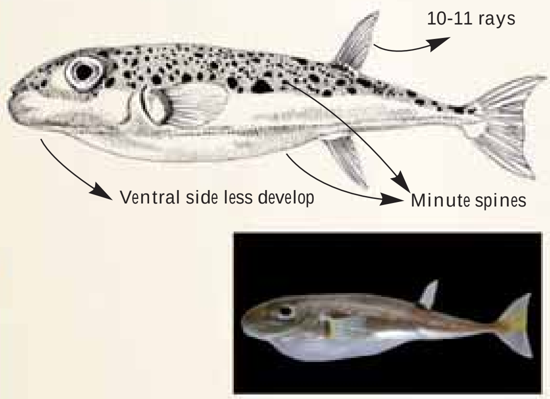


Photo: B. Galil

Similar species

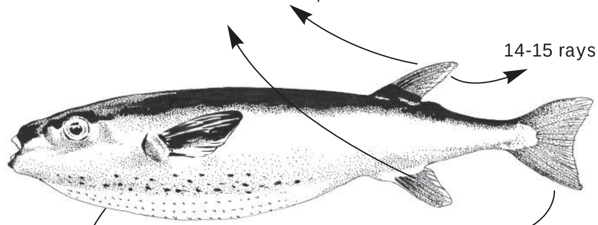
The genus Lagocephalus includes four species inhabiting the Mediterranean. Only *L. lagocephalus* (Linnaeus, 1758) is native, while the other three species, *L. spadiceus, L. suezensis* and *L. sceleratus*, migrated from the Red Sea to the Levantine basin by way of the Suez Canal.

Lagocephalus spadiceus can be distinguished from all the others by the presence of spinules on the belly and back (from the eye to half-way to the dorsal fin, with another patch ventrally from the throat to half-way along the belly), the lack of black dots on its back, yellow dorsal and pectoral fins, and a dusky tail fin with white tips.

Lagocephalus sceleratus has a distinct wide silver stripe on the sides, a dark grey dorsal surface with many regularly distributed small black spots, a silvery white ventral surface, and pronounced, strong teeth.

Lagocephalus suezensis is blackish brown to olive grey in colour with irregular brown to grey dots in various sizes. It has a bright silver stripe along the side and a white belly.

The native species, *Lagocephalus lagocephalus*, has dorsal and anal fins with white bands. The body is smooth (without dots) except for well-developed spinules on the belly from chin to anus. In adults the lower tail fin lobe is longer than the upper one. The back is dark blue and the belly is white.



Lagocephalus lagocephalus

Brief history of its introduction and pathways

Lagocephalus sceleratus is a tropical Indo-West Pacific species, and has recently entered the Mediterranean through the Suez Canal. Soon after it was first detected in 2003 in Turkey, the species underwent a population explosion in many areas around the Levant Basin, including Israel, Turkey, Crete, Egypt and possibly in Libya and Tunisia. More recently it was also recorded into the North Adriatic waters.

Lagocephalus suezensis was first recorded in Lebanon in 1977 (as *L. sceleratus*), and later found in Israel, Syria, Turkey, Greece and Libya.

Lagocephalus spadiceus was first recorded in the Dodecanese Islands, Greece, in 1930, and it has subsequently been recorded in Turkey, Israel and Tunisia.

Ecological impacts

L. sceleratus is one of the most important species in terms of biomass in both *Posidonia oceanica* meadows and sandy areas in Rhodes (Greece).

Lagocephalus species are regarded as some of the worst invasive species in the Mediterranean Sea, and they have a significant impact on the fisheries sector. However, the role of these invasive species within the coastal ecosystem and their effect on local populations are still unknown.

Economic impacts

These species are very dangerous to eat as their flesh is poisonous. The dramatic spread of these highly poisonous fishes along the Mediterranean coast reinforces the need for a public information campaign to raise awareness of the dangers to human health. Despite landings are prohibited in countries like Turkey, it is illegally landed and consumed the Mediterranean coasts.

Lagocephalus sceleratus attacks fishes caught in nets and on lines and can cause serious damage to both fishing gear and catch.

Management options

These include a) **early eradication** of new populations by MPA technicians through spear fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

References

Nader M., Indary S., Boustany L., 2012. FAO EastMed The Puffer Fish *Lagocephalus sceleratus* (Gmelin, 1789) in the Eastern Mediterranean. GCP/INT/041/EC – GRE – ITA/TD-10. Athens 2012: 39 pp.

http://www.ciesm.org/atlas/Lagocephalussceleratus.php

http://www.ciesm.org/atlas/Lagocephalusspadiceus.php

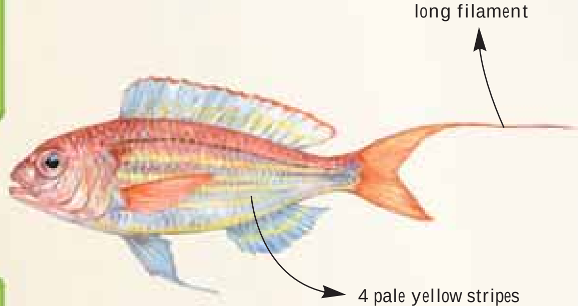
http://www.ciesm.org/atlas/Lagocephalussuezensis.php

Drawings: Juan Varela

Scientific Name:
Nemipterus randalli

Reproduction | identification | Picture | Brief history

Common name: Randall's threadfin bream



Key identifying features

The body is ellipsoid and slightly compressed. It is up to 30 cm in length, commonly 5–20 cm, although in the Mediterranean they seem smaller. The upper part of the body is pinkish, becoming silvery on the ventral surface. There are 3 or 4 pale yellow stripes along the sides, and a golden dot on the pectoral base. The dorsal fin is pale bluish, with the upper margin edged in red, with closely packed yellow markings on the lower three-quarters of the fin. The anal fin is pale bluish with a narrow yellow medial band. The eye is salmon pink. The tail fin has a red margin and is forked, with a characteristic long filament extending from the upper edge of the upper lobe, sometimes missing.

It has a single, continuous dorsal fin with 10 spines and 9 soft rays, and a slightly pointed anal fin (3 spines, 7 soft rays). The pectoral fin (15–17 soft rays) is long and pointed.

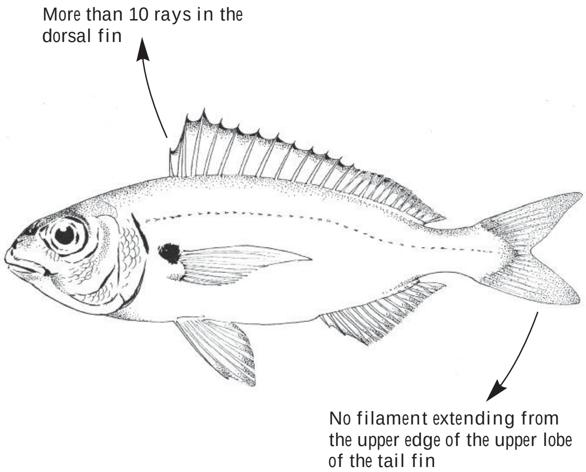
Field identification signs and habitat

Randall's threadfin bream is a benthic species, occurring on open sandy and muddy sea beds down to depths of 20–200 m; in the Mediterranean it is mainly found at 30–80 m.

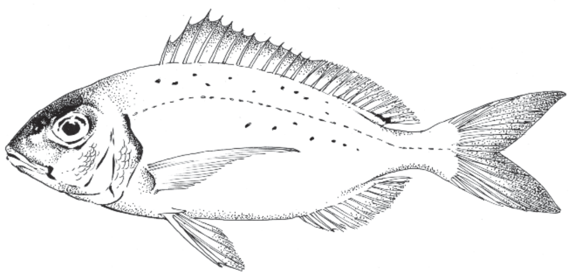
Nemipterus randalli. Photo: P. Consoli

Similar species

The long filament that extends from the upper edge of the upper lobe of the tail fin distinguishes this species from others. If this tail filament is broken, medium-sized Randall's threadfin breams look like some Sparidae species (*Pagellus* spp.). *Pagellus* species, however, have a first dorsal fin with 11–13 spines (compared with 10 spines in *N. randalli*), and molar teeth in the jaw.



Pagellus acarne



Pagellus erythrinus

Pagellus acarne. Photo: L. Sanchez Tocino

Brief history of its introduction and pathways

Randall's threadfin bream is widespread in the western Indian Ocean, including the Red Sea and the East African Coast. In the Mediterranean it was first recorded off Israel in 2005, as *Nemipterus japonicus*; it has subsequently been recorded from Lebanon, Egypt, and from Mersin Bay to Antalya in Turkey. *Nemipterus randalli* appears to have an established population in the eastern Mediterranean that extends at least from Haifa Bay, Israel, to the Cevlik coast of Iskenderun Bay, Turkey.

Ecological impacts

Randall's threadfin bream feeds principally on small benthic invertebrates (polychaetes, crustaceans, cephalopods and molluscs) and small fishes. Its rapid spread and increasing abundance can reduce the biodiversity of benthic decapod crustaceans in particular, as well as native fish communities feeding on these species.

Economic impacts

In the Western Indian Ocean, Randall's threadfin bream is an important target species for local fisheries (small commercial trawlers). In the Mediterranean, it is caught in large numbers by trawling and to a lesser extent by trammel nets and long lines. It may well form the basis of an important future fishery in some Mediterranean areas.

Management options

These include a) **early eradication** of new populations by MPA technicians through spear fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

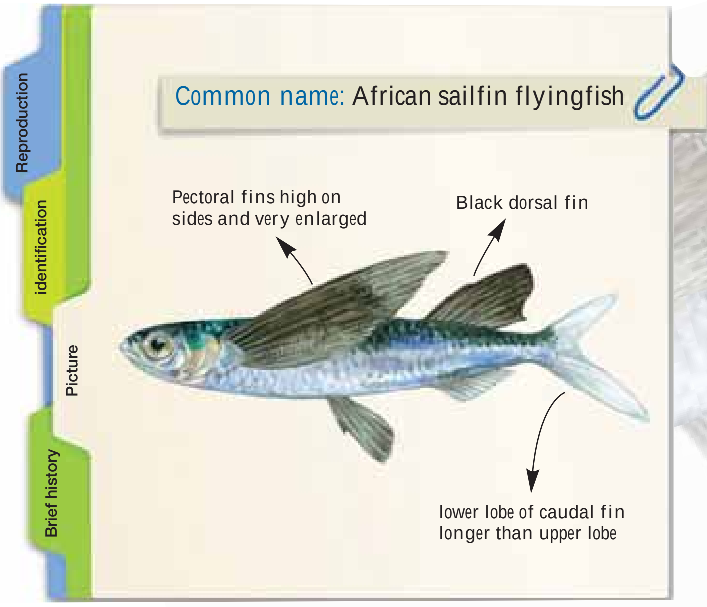
References

http://www.ciesm.org/atlas/Nemipterusrandalli.php

Bariche, M., 2012. Field identification guide to the living marine resources of the Eastern and Southern Mediterranean. FAO Species Identification Guide for Fishery Purposes. Rome, FAO. 610 pp.

Drawings: Juan Varela

Scientific Name:
Parexocoetus mento



Key identifying features

The body is elongated, compressed and rounded ventrally. It is up to 12 cm (commonly 7–10 cm) in length. The dorsal colour is dark blue, with a silvery white belly. The dorsal fin is dark and the pectoral fins are greyish.

It has a short head, large eyes and a small mouth with the upper jaw protruding. The dorsal fin has 9–12 soft rays, and the anal fin 10–12 soft rays; the longest dorsal fin rays barely reach the tail fin base. The anal fin base lies directly below the dorsal fin base. The tail fin is deeply forked, and its lower lobe is longer than the upper. The pectoral fin is long; the pelvic fins have 13–14 soft rays but they do not reach beyond the anal fin base.

Field identification signs and habitat

It is mainly found in large schools in near-shore waters and never spreads to the open sea. When the African sailfin flyingfish is threatened, it can leap out of the water and glide over the surface.

Reproduction

Flyingfish eggs are negatively buoyant and typically have long sticky filaments that serve to attach them to floating objects.

Parexocoetus mento. Photo: Philip C. Heemstra - CIESM Atlas of Exotic Fishes in the Mediterranean

Similar species

There are several other Exocoetidae species in the Mediterranean. In all of them the pectoral fins reach back beyond the anal fin base; in *P. mento*, however, the pectoral fin is long but does not reach beyond the anal fin base.

The native species, *Dactylopterus volitans.* Photo: X. Corrales

The native species, *Hirundichthys rondeletii.* Photo: B. Noble Fishbase

Brief history of its introduction and pathways

This species originates from the Indo-Pacific region; it is widespread from East Africa, including the Red Sea, to Australia. It migrated through the Suez Canal to the Mediterranean, where it was first recorded from Palestine in 1935, and it has subsequently been recorded in the Aegean Sea and eastern Mediterranean in the coastal waters off Syria, Egypt, Libya, Albania, and Tunisia.

Ecological impacts

It feeds on zooplankton and also on small fishes. Its impacts are unknown.

Economic impacts

This species is caught occasionally in purse seines but its relatively small size means that it is of little commercial importance. As its main food is pelagic invertebrates and fish larvae, it could have a major impact on other commercial species.

Management options

These include a) **early eradication** of new populations by MPA technicians through fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

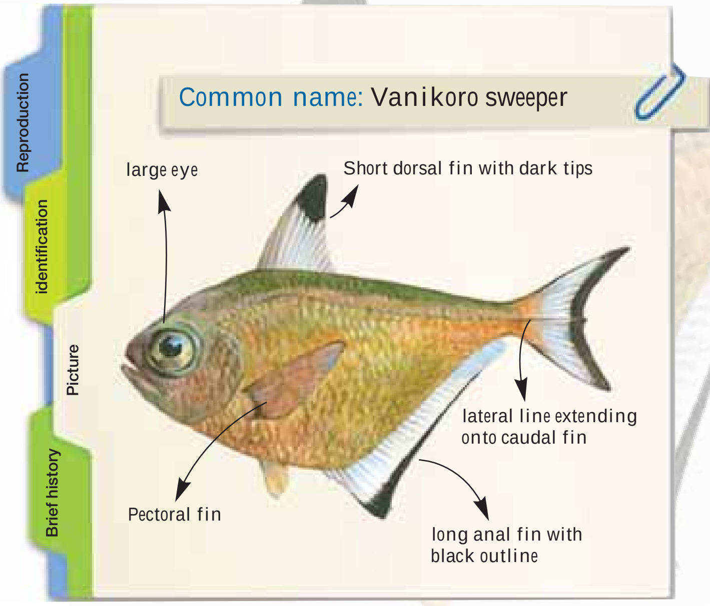
References

http://www.ciesm.org/atlas/Parexocoetusmento.php

Bariche, M., 2012. Field identification guide to the living marine resources of the Eastern and Southern Mediterranean. FAO Species Identification Guide for Fishery Purposes. Rome, FAO. page 348

Drawings: Juan Varela

Scientific Name:
Pempheris vanicolensis



Key identifying features

This small to medium-sized fish can grow to 20 cm. Its body is deep and strongly compressed, the belly is triangular, the mouth is oblique, and the eyes are large. The dorsal fin is very short, usually higher than long, and much shorter than the anal fin. An obvious distinguishing feature is the dark leading edge of the short dorsal fin, expanding to produce dark tips on the soft rays (total 6 spines, 9 soft rays); the posterior region of the tail fin is also dark. The pectoral fin is translucent with a distinct black outline forming a V-shape along the lower edge. The anal fin (3 spines, 31–43 soft rays) is very long. The lateral line is complete, gently curved, and extends onto the tail fin.

This fish is brown bronze in colour, with a greenish sheen over the back. The pectoral fins are yellow without a black basal spot; the tip of the dorsal fin is black, and the base of the anal fin is often black.

Field identification signs and habitat

The Vanikoro sweeper is found mainly on shallow rocky reefs at depths of less than 20 m. Adults occur in groups under ledges in caves during daytime. At night, they leave the caves to forage on planktonic organisms in open waters, and return to their caves shortly before sunrise. The fishes form age-related groups of juvenile or adult forms which, although occurring together with other groups in the same habitat, preserve their bond during the day and even during night migrations to other habitats.

The Vanikoro sweeper feeds on planktonic crustaceans and, to a lesser extent, on polychaete worms.

Reproduction

The spawning season lasts from April to September in the Mediterranean, and the eggs and larvae are planktonic.

Pempheris vanicolensis and *Sargocentron rubrum.* Photo: E. Azzurro

Pempheris vanicolensis. Photo: M. Draman

Similar species
The body shape and the habitat of this species differ significantly from all other Mediterranean species and a misidentification is unlikely.

Brief history of its introduction and pathways
The Vanikoro sweeper is an Indo-West Pacific species that is also present in the Red Sea. It invaded the Mediterranean Sea through the Suez Canal. It was first recorded in Lebanon in 1979, and subsequently along many other coasts in the eastern and central Mediterranean Sea (Israel, Lebanon, Greece, Rhodes, Turkey, Egypt, Libya and the Gulf of Gabes in Tunisia).

This species experienced a rapid population expansion almost immediately after entering the Mediterranean, and it is now very common in the Levant.

Ecological impacts
The lack of nocturnal competitors may have facilitated the population growth and spread of this non-indigenous species in the Mediterranean. Like other Pempheridae sweepers, *Pempheris vanicolensis* inhabits caves during the day. There is no documented evidence of competition with the native species *Apogon imberbis*. However, the daily migration out of the cave to forage at night and back in the morning could increase the transfer of organic matter into the cave and thereby have an impact on the cave-associated invertebrate fauna.

Economic impacts
No impact is likely. Due to its relatively small size and its nocturnal habits, it has little importance in local fisheries.

Management options
These include a) **early eradication** of new populations by MPA technicians through hand fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

References
Golani. D and Diamant, A., 1991. Biology of the sweeper, *Pempheris vanicolensis* Cuvier & Valenciennes, a Lessepsian migrant in the eastern Mediterranean, with a comparison with the original Red Sea population. Journal of Fish Biology 38, 8 19-827.

http://www.ciesm.org/atlas/Pempherisvanicolensis.php

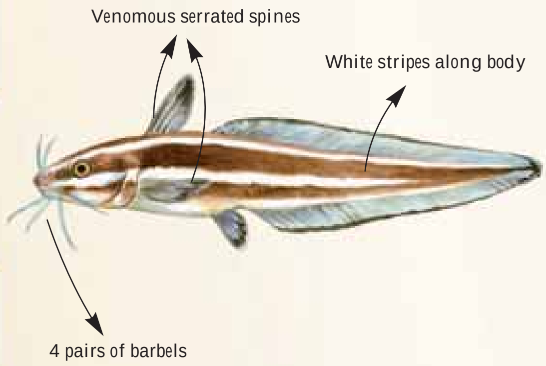
Pempheris vanicolensis. Photo: A. Can - www.alpcan.com

Pempheris vanicolensis. Photo: A. Can - www.alpcan.com

Drawings: Juan Varela

Scientific Name:
Plotosus lineatus

Common name: Striped eel catfish



Key identifying features

Adult fish can reach lengths of about 32 cm, commonly 10–25 cm. The body is long and cylindrical, flattening into an eel-like tail. It has no scales. The body is brown with two narrow white stripes along each side, one running above the eye and the other below; the belly is white.

Two dorsal fins are present. There is a venomous serrated spine in the first dorsal fin and in each of the pectoral fins. The first dorsal fin is short, with 1 stout spine and 4 soft rays, and the second dorsal fin is long (85–105 soft rays) and confluent with the anal fin (70–81 soft rays).

The head is round, large and broad, with a mouth surrounded by 4 pairs of barbels, one nasal pair, one maxillary pair and two pairs on the lower jaw.

Field identification signs and habitat

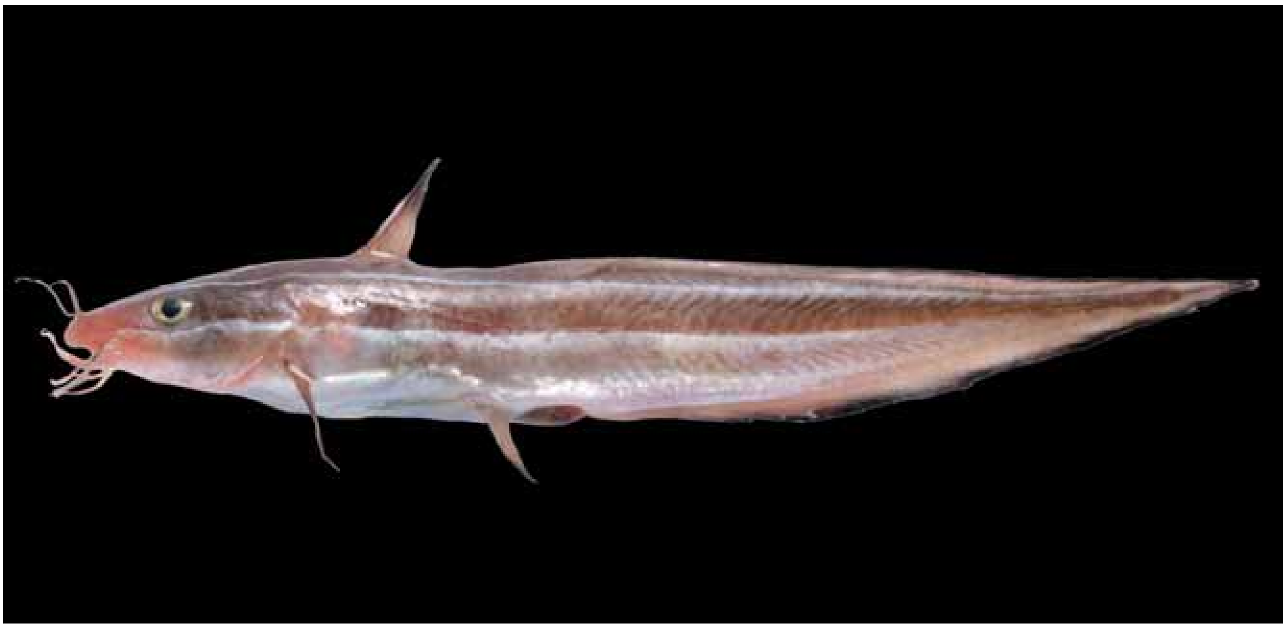
This is the only catfish found in estuaries, lagoons and open coasts of of sandy and muddy habitats.

The juveniles form dense schools, sometimes containing hundreds of individuals. The adults, however, are solitary or occur in smaller groups of around 20 individuals and are known to hide under rock ledges during the day.

The adults are usually seen stirring the sand incessantly for crustaceans, molluscs, worms, and sometimes fishes.

Reproduction

Striped eel catfish reaches sexual maturity after 1–3 years, at a length of 140 mm. Spawning in Israel occurs in the spring and recruitment from July to September.



***Plotosus lineatus*. Photo: B. Galil**

Plotosus lineatus. Photo: E. Azzurro

Similar species

The four pairs of barbels together with the shape and colour of this catfish distinguish it from any other Mediterranean fish species.

Brief history of its introduction and pathways

This is an Indo-Pacific species, occurring in the Red Sea and East Africa eastwards to Japan, Australia and Micronesia. It entered the Mediterranean through the Suez Canal, and was first found in Israel in 2002 by trawlers. Within 3 years, it had spread along the entire Israeli coast and it now inhabits all sandy and muddy substrates down to depths of approximately 80 m.

Ecological impacts

It is a carnivorous species that feeds mostly on benthic invertebrates such as crustaceans, molluscs, polychaete worms and the occasional fish. The most dominant species consumed are other alien species from the Red Sea. It is thought that the increased abundance of these prey species may have set the stage for the catfish to migrate, resulting in a complete change to the native community structure.

Economic impacts

Plotosus lineatus is taken as by-catch; however, there is no commercial value for this species because of the highly venomous serrate spine in the first dorsal and pectoral fins. The venom is dangerous, and even fatal in rare cases, posing a threat to fishermen. The striped eel catfish has however a significant commercial value in the aquarium industry.

Management options

These include a) **early eradication** of new populations by MPA technicians through hand fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

References

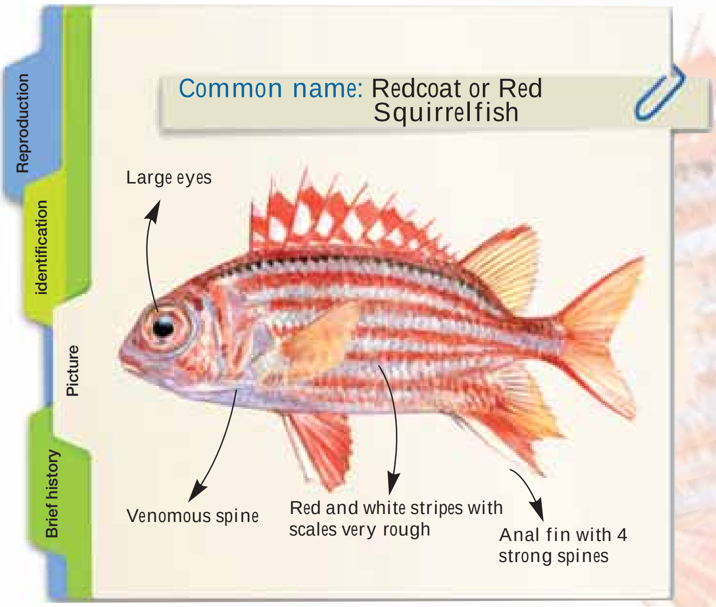
Edelist D. *et al.,* 2012. The invasive venomous striped eel catfish *Plotosus lineatus* in the Levant: possible mechanisms facilitating its rapid invasional success. Marine Biology, Vol 159, Issue 2, 283-290

http://www.ciesm.org/atlas/Plotosuslineatus.php

Drawings: Juan Varela

IUCN

Scientific Name:
Sargocentron rubrum



Key identifying features

This medium-sized fish can reach lengths of up to 32 cm, commonly 12–25 cm. The body is ovate and moderately compressed with large eyes and very rough skin with hard scales. The first dorsal fin has 11 spines and 12–14 soft rays, the last spines being the shortest. It is red with white tips. The anal fin (4 spines; 8–10 soft rays) is red with a white front edge and lies below the posterior, soft ray part of the dorsal fin.

The body is covered with alternate brownish red and silvery white stripes of equal width. The tail fin is deeply forked and its leading edge is red. The head is slightly convex in profile and covered with bones bearing grooves, ridges and spinules. There is a stout, venomous spine on its cheek, and 1–2 spines level with the eye.

Field identification signs and habitat

The redcoat squirrelfish is a shallow-water species usually found in rocky areas and protected habitats such as bays and lagoons at depths of 10–40 m. It is a nocturnal species, and spends most of the daylight hours in the shade of rock crevices, usually in areas subject to strong currents. It schools in small groups in many cases but is also found singly. It feeds mainly on benthic crabs and shrimps, but also preys on small fishes.

Reproduction

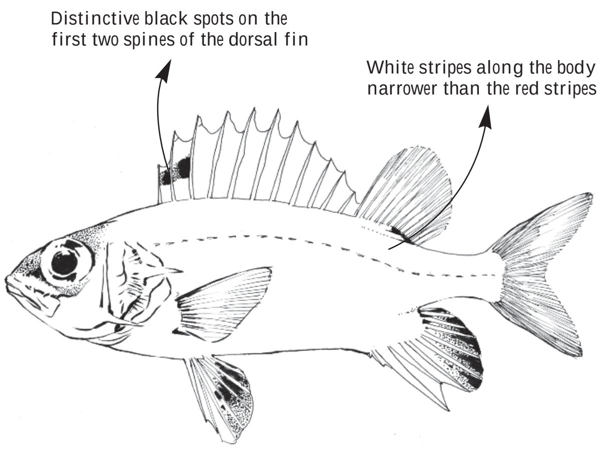
Reproductive season in the Mediterranean Levant lasts from July to August.

Sargocentron rubrum. Photo: M. Draman

Similar species

There is no similar native species in the Mediterranean. The colour pattern in combination with the stout spine on the cheek distinguishes this fish from all other Mediterranean species.

Its closest relative, *Sargocentron hastatum*, occurs in the eastern Atlantic but until now has not been recorded in the Mediterranean Sea. It is red with white and yellow stripes (the white ones narrower than the red) and has distinctive black spots on the first two spines of the dorsal fins.



Sargocentron hastatum

Brief history of its introduction and pathways

This is an Indo-West Pacific species, occurring from the Red Sea to the western Pacific, from southern Japan to Australia. In the Mediterranean it was first recorded in Palestine in 1947, and subsequently in Lebanon, Rhodes, Cyprus, Greece, Turkey, and Libya.

The redcoat squirrelfish is considered to be one of the first fish species to have spread into the Mediterranean.

Ecological impacts

The lack of nocturnal competitors may have facilitated the population growth and spread of the non-indigenous redcoat squirrelfish in the Mediterranean. In the Levant, the redcoat is now one of the most common species, easily encountered in small groups of 5–10 individuals among rocks and in caverns at depths of 15–40 m. It shares the habitat with *Apogon imberbis*, an indigenous Mediterranean species.

At some sites its spread onto artificial reefs has been correlated with a decrease in numbers of several indigenous groupers and sparids. However, more studies will be needed to reveal its interactions with prey and competitors. Its daily migration out of the cave to forage at night and back in the morning could increase the transfer of organic matter into the cave and thereby have an impact on the cave-associated invertebrate fauna.

Economic impacts

The redcoat is caught in small numbers mainly by trammel net or occasionally by hook and line, mainly at night at depths of 20–40 m. Some reports have associated increased catches of this species with a decline in the number of groupers and other commercial species caught.

Management options

These include a) **early eradication** of new populations by MPA technicians through spear fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

References

Golani, D. & A. Ben-Tuvia, 1985. The biology of the Indo-Pacific squirrelfish, *Sargocentron rubrum* (Forsskål), a Suez Canal migrant to the eastern Mediterranean. J . Fish Biol. 27, 249-258.

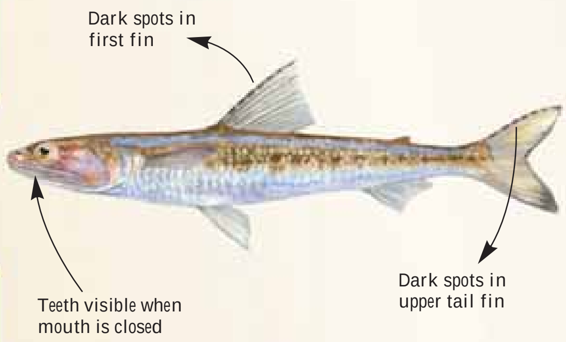
http://www.ciesm.org/atlas/Sargocentronrubrum.php

Drawings: Juan Varela

Reproduction | identification | Picture | Brief history

Scientific Name:
Saurida undosquamis

Common name: Brushtooth lizardfish



Key identifying features

This small bottom-dwelling fish has a slender cylindrical body, a cigar-like head and a large mouth with long jaws and dense rows of sharp slender teeth, even on its tongue. It reaches a length of up to 50 cm, normally 15–35 cm.

It has a single, short-based dorsal fin with 11–12 soft rays, and a small, rayless (adipose) fin near the tail. The anal fin has 11–12 soft rays, and the tail fin is forked.

Dorsal colour is brown-beige with a silvery white belly. A distinguishing feature is a series of dark spots on the first dorsal fin ray and the upper edge of the tail fin. The body sometimes has 8–10 dark spots along the lateral line.

Field identification signs and habitat

This lizardfish lives on sandy or muddy bottoms of coastal waters down to depths of 100 m, usually between 30–70 m. It feeds mainly on bottom-living invertebrates and fishes (anchovy and striped mullet *Mullus surmuletus*, and also non-indigenous fish species from the Red Sea, such as *Equulites klunzigeri*, young *Saurida undosquamis*, and *Siganus* spp.).

Saurida undosquamis. Photo: B. Galil

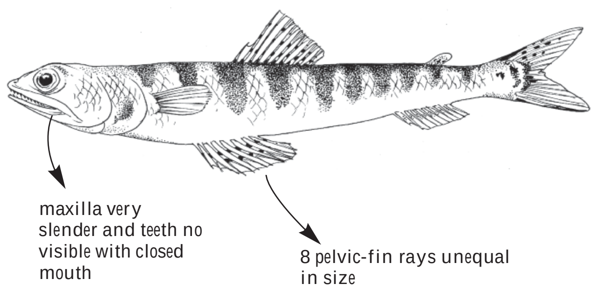
Saurida undosquamis. Photo: D. Harasti

Reproduction

In the Mediterranean, the spawning season extends over 12 months of the year with peaks from April to December (April to September in the Levantine Sea).

Similar species

The shape and the habits of the brushtooth lizardfish are very similar to those of the native Mediterranean lizardfish, *Synodus saurus. Saurida undosquamis*, however, has a more slender body and a characteristic series of dark spots on the first dorsal ray and upper edge of the tail fin. *Synodus saurus* lacks these dark spots on the tail fin, has pelvic fins with inner rays that are much longer than the outer ones, and has a single band of teeth on the palatines rather than two.



The native species, *Synodus saurus*

Synodus saurus. Photo: E. Azzurro

Brief history of its introduction and pathways

This is an Indo-West Pacific Ocean species, including the Red Sea. In the Mediterranean, it was recorded first in Israel in 1952 and subsequently in Cyprus, Turkey, Greece, Libya, Crete, Egypt, Albania and Croatia. This species is now very common throughout the eastern basin and it has also appeared recently in Italian waters (Cape Peloro, Strait of Messina).

Ecological impacts

The brushtooth lizardfish is a voracious predator. The native and the non-indigenous lizardfish species occupy different, depth-related habitats; however, interaction and competition between the two for the same prey fish may be possible. High densities of the non-indigenous *S. undosquamis* could therefore displace the native species (*S. saurus*). Adults could furthermore compete with other native piscivorous species by exploiting local resources faster.

Economic impacts

The brushtooth lizardfish is now an important commercial fish in the eastern Mediterranean, where it is caught by trawlers in large quantities. A sudden increase in brushtooth lizardfish catch came at the expense of certain economically important native species, such as the hake *Merluccius merluccius* and the lizardfish *Synodus saurus*, along some Mediterranean coasts.

Management options

These include a) **early eradication** of new populations by MPA technicians through hand or spear fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

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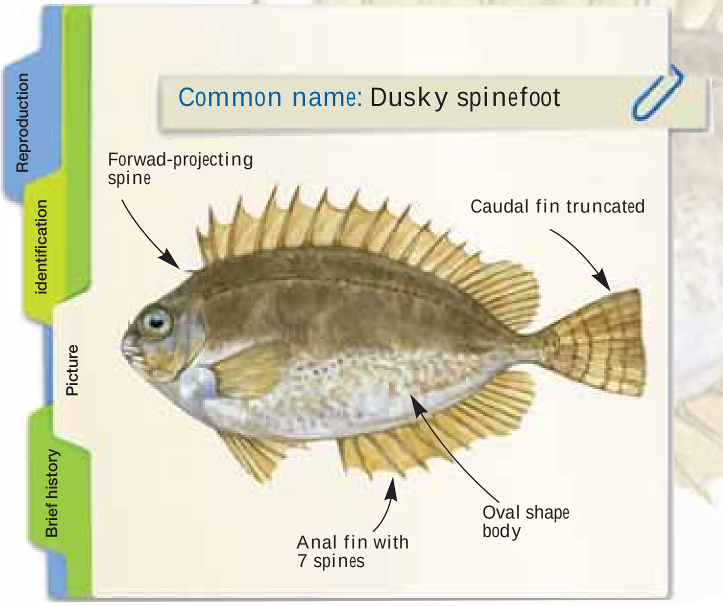
http://www.ciesm.org/atlas/Sauridaundosquamis.php

Drawings: Juan Varela

IUCN

Scientific Name:
Siganus luridus



Key identifying features

The body is deep, ellipsoid, and compressed; the scales are small and embedded in the skin. The maximum length reported is 30 cm (total length; commonly 5–20 cm).The dorsal fin (13–14 spines and 10 soft rays) begins above the pectoral fin base. The pelvic fin begins behind the pectoral fin base, and its inner spine is connected by a membrane to the abdomen. The anal fin (7 spines, 9 soft rays) begins beneath the 8th to 10th dorsal spines and has a rounded margin. The caudal fin is truncated. The anterior spines of the median fins are slender and sharp, and the posterior spines are stout; all the spines are venomous. The anterior nostril has a long, broad flap covering the posterior nostril when depressed. The mouth is small with distinct lips. The maxilla does not reach the vertical plane through the eye. The incisor teeth are in a single row. The colour is dark brown to olive green with a touch of yellow on the fins, but varies regionally. At night, the colour is very mottled.

Field identification signs and habitat

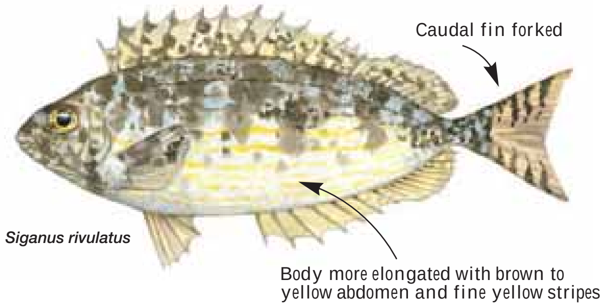
It occurs in small schools in shallow water close to the bottom. It prefers hard bottoms of compacted sand with rock, usually covered with vegetation. The adults are solitary but groups of 3 or 4 adults have also been observed; the juveniles form larger schools. However, huge schools of adults (up to 5,000 individuals) are sometimes observed along the Mediterranean coast. It feeds on a wide range of benthic algae, mainly coarse brown algae, but seagrasses are also reported in its diet. *Siganus luridus* feeds at more or less the same rate in all seasons. It may suddenly stop and erect its fins (dorsal, anal and pelvic), presenting an encircling array of venomous spines to potential predators.

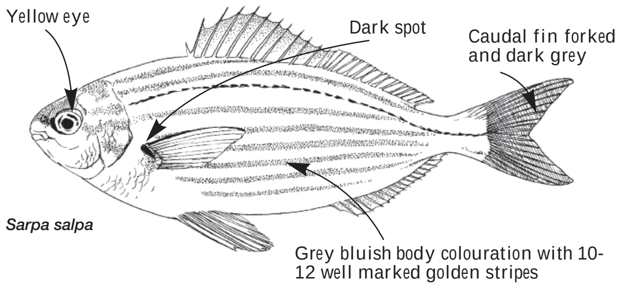
Siganus luridus. Photo: O. Sagué

Siganus luridus. Photo: P. Bodilis - ECOMERS

Similar species

Two species of the rabbitfish family Siganidae are now present in the Mediterranean, both having arrived via the Suez Canal. *Siganus rivulatus*, the marbled spinefoot, can be distinguished by its forked caudal fin. Their diets overlap considerably. Both these rabbitfish also share a common habitat and diet with the native herbivorous fish *Sarpa salpa*, the salema. The salema has characteristic horizontal yellow lines on its body, yellow circles round its eyes, and a black dot at the base of the pectoral fins.





Sarpa salpa. Photo: M. Otero

Brief history and route of introduction

The dusky spinefoot is a species usually found in the western Indian Ocean and Red Sea. It was first recorded in the Mediterranean in 1956 along the Israeli coast and progressively continued its geographical expansion through the eastern Mediterranean. In 2008, two specimens were caught along the French Mediterranean coast at a depth of about 5-10 m in a site mostly characterized by rocky bottoms mixed with *Posidonia oceanica* beds. In 2010, it was also recorded in two different localities in the Adriatic Sea (Gulf of Trieste and southern Adriatic Sea, island of Mljet). Several specimens were also observed and photographed in France close to the Italian border between November 2011 and July 2012.

Ecological impacts

The two species belonging to the Siganidae family, *Siganus luridus* and *S. rivulatus*, have become very common in most parts of the eastern Mediterranean and strongly interact with native herbivorous fish species through competition for food resources and habitat. The spread of these two herbivorous species can result in a drastic decrease in seaweed formations. Some of these, such as *Cystoseira* spp. forests, are ecologically very important as nurseries for a number of littoral fish species. These *Cystoseira* forests are currently considered to be a threatened habitat in several regions of the Western Mediterranean. It will therefore be crucial to monitor the establishment of rabbitfish assemblages in the Western Mediterranean in the future.

Economic impacts

Due to its great abundance in the Eastern Mediterranean, the dusky spinefoot is regularly caught by small-scale professional and non-professional fishers. However, it is of low commercial value.

Management options

Suggested **control** measures are a) **early eradication** of new populations by MPA technicians through spear fishing, and b) maintenance of healthy and abundant predator assemblages to encourage natural control through predation.

Further reading

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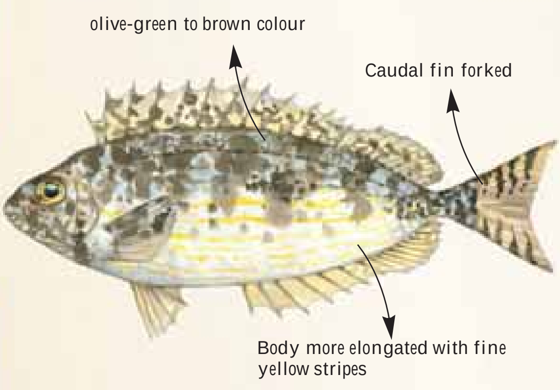
http://www.ciesm.org/atlas/Siganusluridus.php

Drawings: Juan Varela

IUCN

Scientific Name:
Siganus rivulatus

Common name: Marbled spinefoot



Key identifying features

This medium-sized fish has an ellipsoidal, compressed body covered with small scales embedded within the skin. It grows to a length of up to 27 cm, commonly 5–25 cm.

The dorsal fin, with 13–14 spines and 10 soft rays, begins above the pectoral fin base, and the first dorsal spine points forward. Key taxonomical features for this species' identification are pelvic fins with two stout spines connected by a membrane to the abdomen, and the forked tail fin. There are 7 spines in the anal fin with 8–10 soft rays. The anterior spines of the median fins are slender, whilst the posterior spines are stout, all of the spines being venomous. The mouth is small with distinct lips.

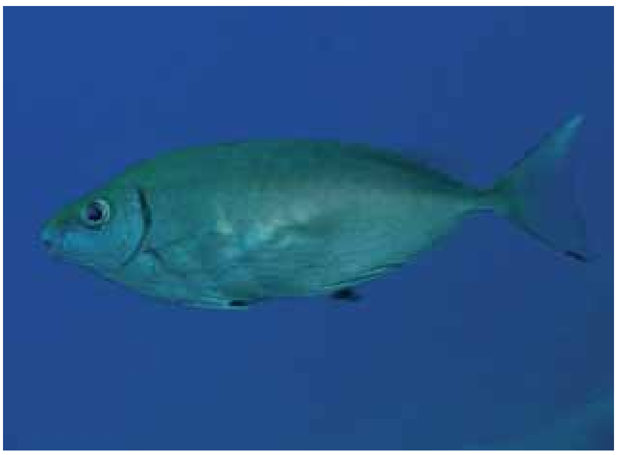
Body colour is brown to grey green, and light-brown to yellow on the belly. There are fine, often faint, yellow-gold stripes on the lower half of body. At night or when frightened, the colour is very mottled, with six diagonal bars across the flank.

Field identification signs and habitat

The marbled spinefoot lives in shallow waters, preferring hard bottoms of compacted sand with rock, usually covered with vegetation. Adults live in small groups of 50 to several hundred individuals, feeding mainly green and red algae, such as *Ulva* spp. and *Hypnea* spp., and seagrasses (*Posidonia oceanica*).

Reproduction

The spawning season lasts from May to September.

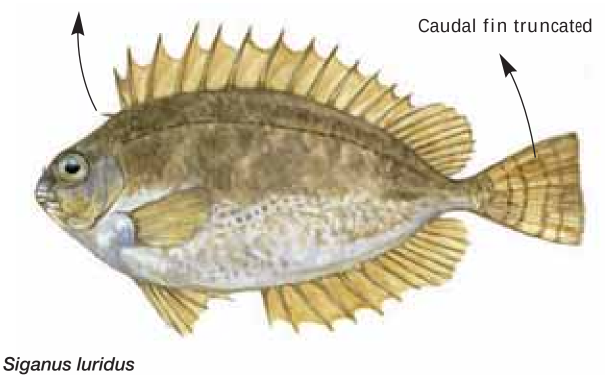


Siganus rivulatus. Photo: P. Francour

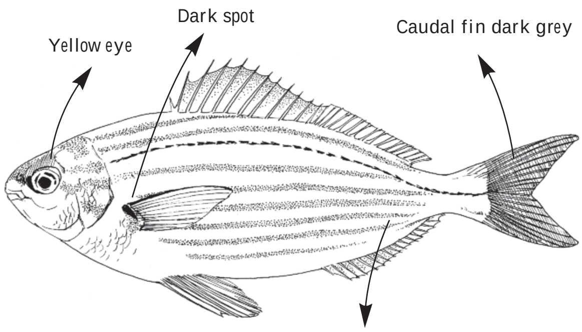
Siganus luridus. Photo: B. Daniel

Similar species

Two non-indigenous species of Siganidae are now present in the Mediterranean: the marbled spinefoot, *Siganus rivulatus*, and the dusky spinefoot, *Siganus luridus*. The native salema, *Sarpa salpa*, also shares the same habitat and diet. The salema has characteristic horizontal yellow lines along its body; its eyes are ringed with yellow, and it has a black dot at the base of the pectoral fins. The tail fin shape distinguishes between the two *Siganus* species: *Siganus rivulatus* has a forked tail fin with narrow, translucent yellow stripes, whereas Siganus luridus has a straight or slightly concave tail fin and a uniform body colour.



Siganus luridus



Sarpa salpa

Brief history of its introduction and pathways

The marbled spinefoot is a species usually found in the western Indian Ocean and Red Sea. It was first recorded in the Mediterranean in 1927 along the Palestinian coast and spread progressively through the eastern Mediterranean: Syria, Cyprus, the Aegean Sea, Libya, Tunisia, the Ionian Sea and the southern Adriatic (Croatia). *S. rivulatus* has not yet been reported from the western Mediterranean; however, its presence has been suspected in Corsica since 2010.

Ecological impacts

The two herbivorous fish species belonging to the Siganidae family, *Siganus luridus* and *S. rivulatus*, have become very common in most parts of the eastern Mediterranean and strongly interact with the native herbivorous fish *Sarpa salpa* through competition for food resources and habitat. The spread of these two alien herbivorous species can result in a drastic decrease in algal biomass, locally eradicating certain algae such as *Cystoseira* spp. forests, and reducing important nursery habitats for many species.

Economic impacts

Due to its great abundance in the eastern Mediterranean, the dusky spinefoot is regularly caught by professional small-scale fisheries and non-professional fishermen. However, its commercial value is low. The venomous spines can cause painful injuries to bathers and fishers and the damage it may do to diving tourism and the local fishing industry still needs to be assessed.

Some fish farming trials have also been conducted in countries such as Cyprus, Israel and Egypt.

Management options

These include a) **early eradication** of new populations by MPA technicians through spear fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

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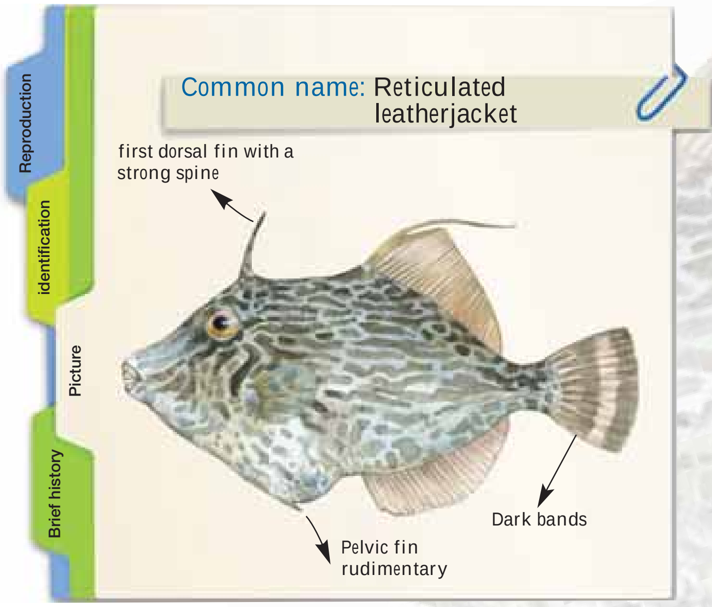
Drawings: Juan Varela

Scientific Name:
Stephanolepis diaspros



Key identifying features

This is a medium-sized fish up to 25 cm in length (commonly 7–15 cm). It has a deep, highly compressed body covered with smooth to rough shagreen-like skin composed of very small scales with delicate spinules.

The first of the two dorsal fins consists of a single strong anterior spine just above the eyes; the second fin is often long and filamentous and has 30–33 soft rays, as does the anal fin directly below it. The pelvic fins are poorly developed and are more like flaps of skin. The mouth is small with pointed teeth.

The body colour is variable, brown to olive green-grey with darker markings. The dorsal and anal fins are yellow to orange. Adult males usually have dark bands between the end of the anal fin and the base of the tail fin.

Field identification signs and habitat

The reticulated leatherjacket lives in small groups in coastal rocky habitats usually covered with vegetation, such as algal forests or seagrass meadows. It has been also recorded in a coastal lagoon in Tunisia (Bizerte lagoon). Young individuals also feed in open waters on sandy and muddy substrates.

Reproduction

In Tunisia, spawning season last from July to December.

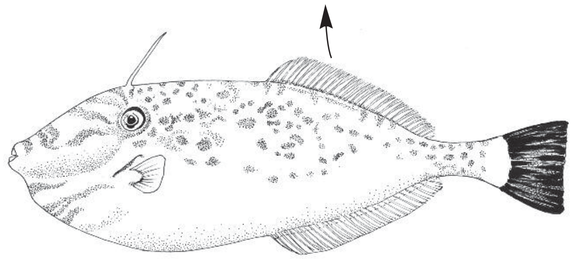
Stephanolepis diaspros, female. Photo: P. Francour

Stephanolepis diaspros, male. Photo: A. Can - www.alpcan.com

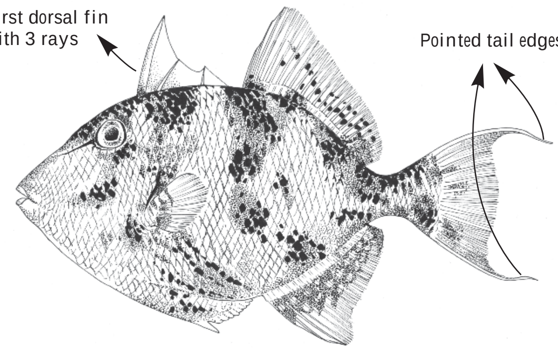
Similar species

The Monacanthidae is a fish family typical of tropical seas. The only closely related Atlantic species occurring in the Mediterranean is the unicorn leatherjacket filefish *Aluterus monoceros*, recorded from the Zembra and Zembretta MPA, in Tunisia, and the Chafarinas Islands in the Alboran Sea. *S. diaspros* can be distinguished from *A. monoceros* by the first ray in the second dorsal fin, which is often long and filamentous; its much longer body; and the rough shagreen-like skin composed of very small scales with delicate spinules.

The native species *Balistes capriscus* differs from *S. diaspros* in having a first dorsal fin with three dorsal spines.



Aluteros monoceros



Balistes capriscus

Brief history of its introduction and pathways

This is a western Indian Ocean species, recorded from the Persian Gulf to the Red Sea. In the Mediterranean it was first recorded in Palestine in 1927 and subsequently from Syria, Cyprus, Rhodes, Gulf of Gabes (Tunisia), Gulf of Taranto (Italy), Crete, Saronikos Gulf (Greece), Gulf of Palermo (Sicily) and the southern Adriatic. It is now very common throughout the eastern basin.

Ecological impacts

Stephanolepis diaspros feeds on a large variety of benthic invertebrates, and sometimes on algae and plants.

Both the non-indigenous monocanthid species, *A. monoceros* and *S. diaspros*, and the native one, *B. capriscus*, live in similar habitats and feed on similar prey items, with probable overlaps. They are therefore likely to compete for food and have an impact on local faunal diversity.

Balistes capriscus. Photo: L. Sanchez Tocino

Economic impacts

Due to its size, *S. diaspros* is not an important commercial species in the eastern Mediterranean basin. In some places, it is even seen as a nuisance to fisheries and all caught specimens are discarded.

Management options

These include a) **early eradication** of new populations by MPA technicians through hand and spear fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

References

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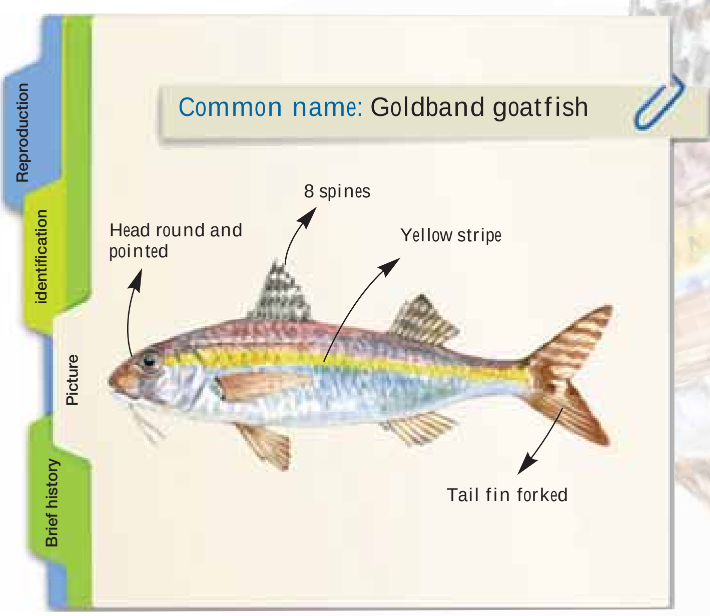
http://www.ciesm.org/atlas/Stephanolepisdiaspros.php

Drawings: Juan Varela

Scientific Name:
Upeneus moluccensis



Key identifying features

This is a medium-sized fish up to 20 cm in length (commonly 7–18 cm) with an elongated, moderately compressed body. It has a rounded snout with two short, thin barbels. Two well-separated dorsal fins are present; the first of them has 8 spines (the first spine is minute and the second spine is the largest), while the second fin has 8–9 soft rays, directly above the anal fin (which has 1 spine and 6–8 soft rays). Between the two dorsal fins there are 5–7 scales. The tail fin is deeply forked, the upper lobe marked with diagonal black bars.

The dorsal colour is pinkish-red, and the belly is white. A distinct longitudinal yellow stripe runs from the eye to the tail.

Field identification signs and habitat

The goldband goatfish is found in coastal waters with muddy and sandy substrates at depths of 20-130 m, where it forms large schools. It usually swims fast, stopping briefly to feed on benthic animals detected by the barbels on its chin.

Reproduction

The spawning season extends from the end of July to October.

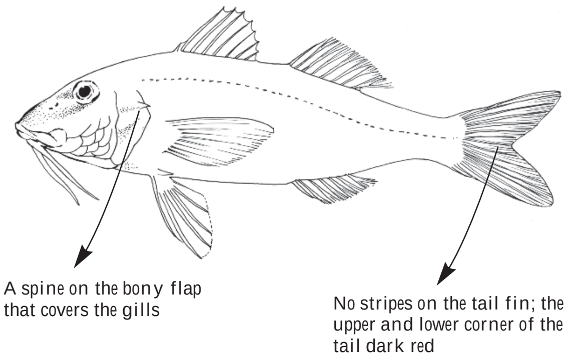
Upeneus moluccensis. Photo: B. Galil

Upeneus moluccensis. Photo: P. Consoli

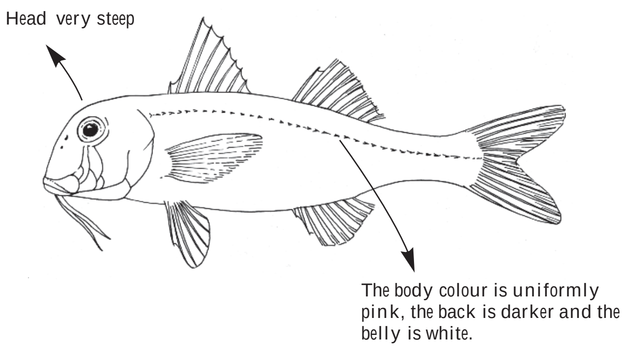
Similar species

Five species of the family Mullidae occur in the Mediterranean: two are non-indigenous Red Sea species, the goldband goatfish *Upeneus moluccensis* and the brownband or Por's goatfish *U. pori;* and two are the indigenous Mediterranean goatfishes, the red mullet *Mullus barbatus* and the striped mullet *M. surmuletus*. The fifth member of the family is the west African goatfish, *Pseudupeneus prayensis*.

Both *Mullus* species are easily distinguished from the goldband goatfish *U. moluccensis* by the lack of teeth in their upper jaws, and their steep- or very steep-sloping heads. *Upeneus pori* has no yellow longitudinal stripe; both tail fin lobes are striped; and it has seven dorsal spines. *Pseudupeneus prayensis* has a spine on the bony flap that covers the gills, and no stripes on the tail fin.



Pseudupeneus prayensis



Mullus barbatus

Brief history and route of introduction

The goldband goatfish is an Indo-West Pacific species recorded from the Red Sea to New Caledonia, and north to Japan. Introduced to the Mediterranean via the Suez Canal, it was first recorded in Palestine in 1947 (as *Mulloides auriflamma*) and subsequently in Lebanon, Syria, Turkey, Rhodes, Egypt, Cyprus and Libya. The goldband goatfish is now very abundant along the Levant coasts.

Ecological impacts

Each of the Mullidae species occupies a different, depth-related habitat; however, interaction and possible competition between them for the same prey (small crustaceans, molluscs, etc.) might occur. The non-indigenous mullets occupy shallow waters (20–30 m in depth), whereas the indigenous species dominate greater depths. High densities of the non-indigenous *Upeneus moluccensis* and *U. pori* might therefore displace the native species (Mullus spp.).

Conversely, the goldband goatfish is reported to be one of the prey species consumed by *Saurida undosquamis*, another Red Sea migrant.

Economic impacts

The goldband goatfish is commercially important in trawl fisheries in the Levant Sea. It is sold fresh in markets, or utilized for fish meal. In the eastern Mediterranean, the two non-native *Upeneus* species account for a significant proportion of commercial Mullidae catches. However, there are no precise data for the annual catch of goldband goatfish. Fishermen normally find it difficult to separate goatfishes into different species and so they are considered to be a single catch category in most fishery statistics.

The reduction in catches of native goatfishes (red mullet and striped mullet) and its possible correlation with the non-indigenous species have not yet been assessed.

Management options

These include a) **early eradication** of new populations by MPA technicians through fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

References

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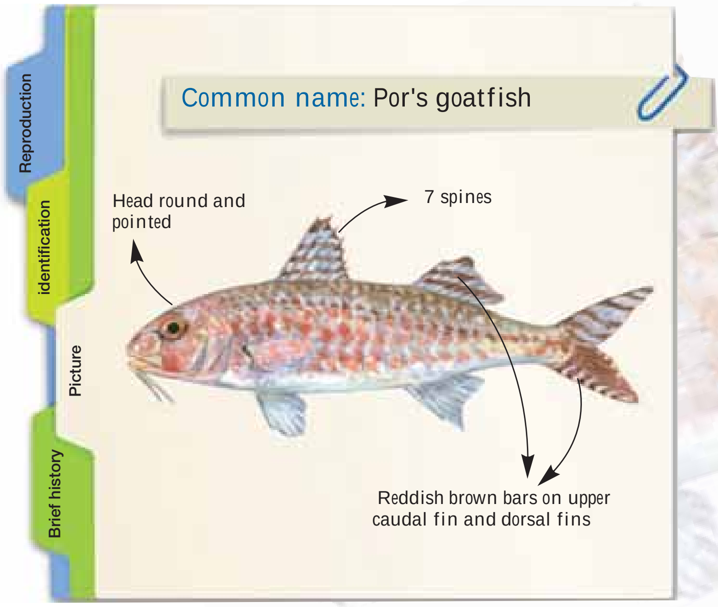
http://www.ciesm.org/atlas/Upeneusmoluccensis.php

Drawings: Juan Varela

Scientific Name:
Upeneus pori



Key identifying features

This is a medium-sized fish up to 19 cm in length (commonly 5–14 cm) with an elongated, moderately compressed body. It has a rounded snout with two short, thin barbels. Two well-separated dorsal fins are present; the first of them has 7 spines and the second has 8–10 soft rays, lying directly above the anal fin (which has 1 spine and 6–8 soft rays). The tail fin is deeply forked.

The back and sides of this goatfish are mottled reddish-brown and the belly is white. The tail fin lobes are striped with 3–7 reddish-brown bars with white interspaces on the upper lobe and 4–5 of the same colour on the lower lobe.

Upeneus pori. Photo: A. Can - www.alpcan.com

Field identification signs and habitat

This species is typically found in waters to a depth of 50 m on sandy, gravel and muddy seabeds. It feeds on small benthic invertebrates, mainly crustaceans and, to a lesser extent, polychaetes.

Reproduction

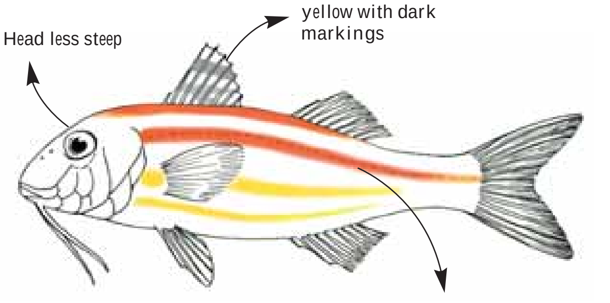
The spawning season for Por's goatfish lasts from March to September. The eggs and larvae are planktonic and larvae settle 6–9 months after hatching, upon reaching a length of 3–4 cm.

Upeneus pori. Photo: P. Consoli

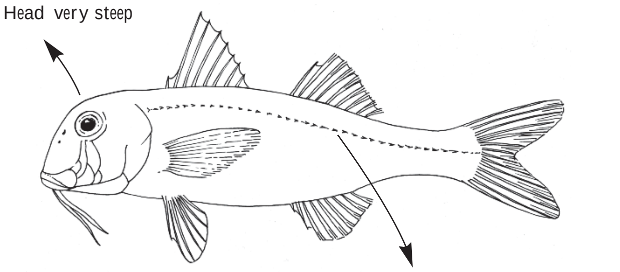
Similar species

Five species of the family Mullidae occur in the Mediterranean: two are non-indigenous Red Sea species, the goldband goatfish *Upeneus moluccensis* and the brownband or Por's goatfish *U. pori*; and two are the indigenous Mediterranean goatfishes, the red mullet *Mullus barbatus* and the striped mullet *M. surmuletus*. The fifth member of the family is the west African goatfish, *Pseudupeneus prayensis*.

Both *Mullus* species are easily distinguished from Por's goatfish *U. pori* by the lack of teeth in their upper jaws, and their steep- or very steep-sloping heads. *Upeneus moluccensis* has a very distinct single yellow longitudinal stripe, a lower tail lobe without dark bars, and eight dorsal spines. *Pseudupeneus prayensis* on the other hand, has a spine on the bony flap that covers the gills, and no stripes on the tail fin.



Mullus surmuletus



Mullus barbatus

Brief history of its introduction and pathways

Por's goatfish is a western Indian Ocean species that occurs from the Red Sea to southern Oman. It entered the Mediterranean through the Suez Canal, and was first recorded in Iskenderun (Turkey) in 1950 (as *Upenoides* (= *Upeneus*) *tragula*) and subsequently in Israel, Lebanon, Rhodes, Cyprus, the Aegean coast of Turkey, Egypt, Libya, southern Tunisia, and even in the lagoon of Bizerte, a brackish area in north-eastern Tunisia. It is now very abundant in the Levant.

Ecological impacts

Each of the Mullidae species occupies a different, depth-related habitat; however, interaction and possible competition between them for the same prey (small crustaceans, molluscs, etc.) might occur. High densities of the non-indigenous *Upeneus moluccensis* and *U. pori* might therefore displace the native species (*Mullus* spp.).

Mullus surmuletus. Photo: L. Sanchez Tocino

Economic impacts

Por's goatfish is a commercially important demersal species in the eastern Mediterranean, especially for the small-scale fishing sector in places such as Rhodes and Turkey. The reduction in catches of native goatfishes (red mullet and striped mullet) and its possible correlation with the non-indigenous species have not yet been assessed.

Management options

These include a) **early eradication** of new populations by MPA technicians through fishing, and b) maintenance of healthy and abundant assemblages of top predators to encourage natural **control** through predation.

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Drawings: Juan Varela

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Annex 2. Essential websites and databases

For general information on invasive species there are various databases and websites. They provide a valuable source of information, most through online databases, on the distribution and facts of alien species in the Mediterranean and elsewhere with useful links.

Global Coverage

CABI Invasive Species Compendium (ISC)
http://www.cabi.org/isc/

Food and Agriculture Organization (FAO), database on Introductions of Aquatic Species (DIAS)
http://www.fao.org/figis/servlet/static?dom=collection&xml=dias.xml

FISHBASE
http://www.fishbase.org/

Global Invasive Species Programme (GISP)
http://www.gisp.org

TNC's Global Invasive Species Team (GIST) was disbanded in March 2009.

Global Invasive Species Database (GISD)
http://www.invasivespecies.net/

Global Invasive Species Information Network (GISIN)
http://www.gisinetwork.org

GloBallast Partnerships: To implement sustainable, risk-based mechanisms for the management and control of ships' ballast water and sediments to minimize the adverse impacts of aquatic invasive species transferred by ships.
http://globallast.imo.org/

The IUCN Invasive Species Specialist Group and IUCN Global Invasive Species Database (GISD),
http://www.issg.org/#ISSG
http://www.issg.org/database/welcome/

The Nature Conservancy (TNC)
http://www.nature.org/invasivespecies
http://tncinvasives.ucdavis.edu/

European Coverage

European Alien Species Information Network (EASIN)
http://easin.jrc.ec.europa.eu/

European Information System for Alien Species (COST TD1209)
http://www.cost.eu/domains_actions/fa/Actions/TD1209

North European and Baltic Network on Invasive Alien Species European (NOBANIS) Database
http://www.nobanis.org/

European Environment Agency 'Signals':
http://www.eea.europa.eu/pressroom/newsreleases/killer-slugs-and-otheraliens

Delivering Alien Invasive Species Inventories for Europe (DAISIE)
http://www.europe-aliens.org/

Mediterranean Coverage

CIESM Atlas of Exotic Species in the Mediterranean Sea is linked to NISbase, a distributed database managed by the Smithsonian Institute, aiming at a census of all non-indigenous aquatic species introduced around the world.
http://www.nisbase.org/nisbase/index.jsp

MAMIAS Database from Regional Activity Centre For Specially Protected Areas (RAC/SPA) of the Barcelona Convention
http://www.rac-spa.org/
http://www.mamias.org

ESENIAS
East and South European Network for Invasive Alien Species. Regional data portal on invasive alien species (IAS) in East and South Europe (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Kosovo under UNSC Resolution 1244/99, FYR Macedonia, Montenegro, Serbia, Romania (invited country) and Turkey.
http://www.esenias.org/

National Coverage

InvasiBer, Especies Exóticas Invasoras de la Península Ibérica (Spain)
http://invasiber.org/

Ellenic Network on Aquatic Invasive Species (ELNAIS) - Greece
elnais.ath.hcmr.gr

SIDIMAR, Italy
http://www.sidimar.tutelamare.it/distribuzione_alieni.jsp

National Biodiversity Information Facilities - BIFs;
http://www.gbif.org/participation/participant-nodes/bif/

Other Relevant Documents

Assessing Large Scale Environmental Risks for Biodiversity with Tested Methods (ALARM)
http://www.alarmproject.net

EU website:
http://ec.europa.eu/environment/nature/invasivealien/index_en.htm

Scope for EU action:
http://ec.europa.eu/environment/nature/invasivealien/docs/2006_06_ias_scope_options.pdf

Caulerpa racemosa var. cylindracea. Photo: E. Azzurro

Annex 3. Invasive species policy

At the international level there are several treaties, policies and legal instruments that address the threats from invasive species to protected areas:

- At the tenth meeting of the Conference of the Parties (COP 10) in Nagoya in 2010, the Convention on Biological Diversity (CBD) adopted a new Strategic Plan for Biodiversity 2011–2020, and a set of targets (Aichi targets), including Target 9 on alien species: '*By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.*' Furthermore, Decision X/31 on Protected areas '[…] invites Parties to consider the role of IAS management as a cost effective tool for the restoration and maintenance of protected areas and the ecosystem services they provide, and thus to include management of invasive alien species in the action plans for implementation of the programme of work on protected areas […].'

- Under the Bern Convention (1979), the European Strategy on Invasive Alien Species provides a framework for action, including encouraging the development of national strategies to minimize adverse impacts of invasive alien species on Europe's biodiversity.

- At the Barcelona Convention, the Action Plan of the Barcelona Convention Contracting Parties concerning species introductions and invasive species in the Mediterranean Sea promotes the development of coordinated efforts to prevent, control and monitor the effects of species introductions (adopted by the Contracting Parties in 2003 and amended in 2005). It focuses particularly on capacity building, the institutional and legislative framework, data collection and monitoring, cooperation among states, and the preparation of guidelines and technical documents (updated version adopted by the Contracting Parties Meeting in Almería, 2008; UNEP-MAP-RAC/SPA, 2005).

- Moreover, the Contracting Parties of the Barcelona Convention adopted 11 Mediterranean Ecological Objectives as part of the Decision 20/4 associated to implementing the ecosystem approach roadmap (UNEP(DEPI)/MED WG.373/3, 25 January 2013). One specific objective refers that *"Non-indigenous species are at levels that don't adversely affect the Mediterranean ecosystem".* The determination of the associated operational objectives to achieve it, the indicators and target is presently under preparation. The development of monitoring programmes at the national level related to the abundance and distribution of these species as well as the creation of early warning systems covering particularly risk areas and MPAs might be used for gathering information to define the Environmental Status.

- The International Maritime Organization (IMO) produced the International Convention for the Control and

Cres-Lošinj Marine Protected Area (Croatia). Photo: M. Tempesta

Management of Ships' Ballast Water and Sediments in February 2004 in response to the risk from ballast water invasions. This convention, which still needs to be ratified by the countries to enter into effect, requires the establishment of ballast water management systems on ships, with the goal of preventing the movement of live organisms.

At EU level, the 'Biodiversity strategy to 2020' (COM (2011)244) sets a specific target to address the issue of IAS and proposes the preparation of a dedicated legislative instrument to tackle the problem. While work is still under way on developing specific EU legislation to combat IAS and on the EU Strategy on Invasive Species, the management of marine invasive species could be considered to fall under different regulations that partially cover certain aspects of IAS:

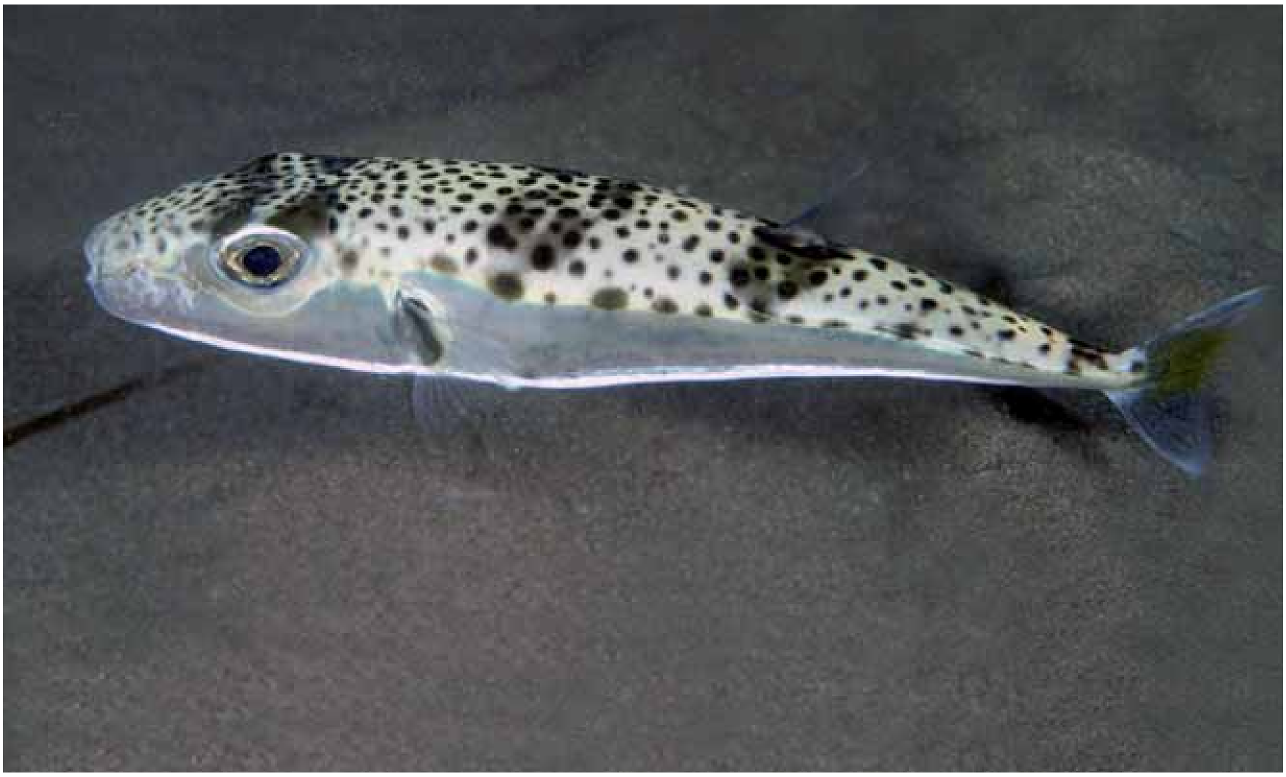
- The Marine Strategy Framework Directive (Directive 2008/56/EC), whose overall objective is to achieve good environmental status in the EU´s marine waters by 2020, uses IAS as one of the key descriptors for the initial marine strategy assessment. The criteria for assessing progress towards good environmental status will be based, *inter alia,* on (1) the abundance and spatial distribution of non-indigenous species (NIS), in particular invasive species; and (2) the environmental impact of invasive non-indigenous species.

- Similarly, the Habitats Directive (Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora) and the Birds Directive (Directive 2009/147/EC) include a very general provision requiring that Member States avoid or regulate the introduction of alien birds or other alien species in protected areas, although this is currently not reflected in the corresponding reporting formats (Article 17 of the Habitats Directive and Article 12 of the Birds Directive).

- The Aquaculture Regulation (Council Regulation (EC) No 708/2007 of 11 June 2007 concerning use of alien and locally absent species in aquaculture) establishes a framework to assess and minimize the possible impact of alien and locally absent species used in aquaculture, including procedures for risk assessment, to ensure adequate protection of aquatic habitats from the use of non-native species.

- The EU Water Framework Directive (Directive 2000/60/EC) also refers to IAS issues.

In parallel, there are numerous laws and regulations that offer management options to prevent the introduction of IAS or to control established invasive populations in the Mediterranean. Nevertheless, the wide range of tools, from simple to advanced, and enforcement methods makes it difficult to minimize the risk of IAS from neighbouring areas. A comprehensive strategy to effectively manage the IAS threat to MPAs requires addressing IAS at the MPA site level, at the protected area system (national and MedPAN) level, and via national and international policies (Tu, 200; MedPAN Draft IAS Strategy, 2012). Managers can assist in the development and enforcement of some of these policies by keeping policy makers and relevant institutions informed, while also supporting IAS coordination programmes, documenting the current impacts of IAS on their protected areas and identifying the resources needed to address IAS prevention and management.



Lagocephalus sceleratus. Photo: A. Can - www.alpcan.com

North East of Malta MPA. Photo: M. Otero

Photo: A. Rosenfeld - Port Cros National Park

The MedPAN collection

The MedPAN collection is a series of publications designed to provide Marine Protected Areas (MPA) managers and other stakeholders in the Mediterranean, guidance, practical and useful information, experience feedback or overviews on key MPA management issues.

The MedPAN collection is fully adapted to the Mediterranean context. It gathers publications developed by different key players in the Mediterranean MPA community under a unified look and feel.

The MedPAN collection is an initiative of the MedPAN organization and several partners, including RAC/SPA, WWF, IUCN Mediterranean, ACCOBAMS, the French MPA Agency and the Conservatoire du Littoral. It is edited by MedPAN, the network of MPA managers in the Mediterranean.

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