



Invasions of **alien species** pose a serious threat
to the unique Mediterranean biodiversity

aliens

in the Mediterranean





Caulerpa racemosa is a fast growing macroalgae native to Western Australia. It was introduced in the Mediterranean by shipping and aquarium trade related activities and nowadays extensive populations are found along the Mediterranean coastline. It is known to attain total coverage in certain areas within six months of entry, out-competing other native macroalgae and causing drastic changes in the composition of the phytobenthos.
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glossary

Alien species	Alien species, often referred to as non native, non indigenous or exotic species, are plants, animals, fungi and micro-organisms that have been transported inadvertently or intentionally, across ecological barriers and have become established in areas outside their natural range.
Biota	All of the organisms, including animals, plants, fungi, and microorganisms, found in a given area.
Exotic species	See Alien species.
Habitat	The locality in which an animal naturally grows or lives. It can refer either to the geographical area over which it extends, or the particular site in which an animal is found.
Hybridisation	The act or process of producing hybrids i.e. an animal or plant resulting from a cross between genetically unlike individuals.
Introduced species	See Alien species
Introduction	The deliberate or accidental release of species by humans into the wild in areas where this species is not native.
Native species	Plants, animals, fungi and microorganisms that occur naturally in a given area or region.
Non indigenous species	See Alien species
Nutrients	Nutrients are chemical compounds or elements essential for the maintenance and growth of animals and plants. Nutrients are divided into two main categories: (a) macronutrients which are compounds and elements required by organisms in large quantities. These mainly include carbohydrates, proteins, fats, water and also minerals (calcium, sulphur, phosphorus, potassium); (b) micronutrients which are elements required by organisms in small quantities and these include nitrogen, phosphorus, silicon and other trace elements.
Pathogens	A disease-causing micro-organism; a bacterium, fungus or virus.
Pathway	Any means that allows the entry or spread of an invasive species.
Pests	Any species (not necessarily alien) that live in places where they are not wanted and have detectable environmental or economic impact or both.
pH	A measure of the acidity or alkalinity of a solution.
Vector	Any living or non-living carrier that transports living organisms (intentionally or unintentionally).

MAJOR CHARACTERISTICS OF INVASIVE ALIEN SPECIES

- Rapid reproduction and growth;
- High dispersal ability (ability to move from one place to another);
 - Ability to adapt physiologically to new conditions;
- Ability to survive on various food types and in a wide range of environmental conditions.

aliens

in the Mediterranean

Percnon gibbesi is a tropical Atlantic crab, considered to be one of the most invasive decapod species of the Mediterranean with the ability to establish itself in both anthropogenically impacted areas (e.g. close to ports) and natural habitats.

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Invasive Alien Species: a major threat to biodiversity

The invasion by alien species of new regions and territories is a phenomenon of paramount and global importance. It has been estimated that during the last four centuries invasive alien species have contributed to nearly 40% of animal extinctions with known causes. Nowadays, it is widely recognized that biological invasions by alien species are a significant component of human-induced global environmental change incurred by rapidly accelerating human activities, such as trade, transport, travel, all of which are linked to the globalization of the economy and the expansion of human population. Invasive Alien Species (IAS) have affected native biodiversity in almost every type of ecosystem on Earth and consequently, the Mediterranean region too. As one of the greatest drivers of biodiversity loss, second only to habitat loss and fragmentation, they pose a threat to ecosystem integrity and function and, therefore, to human well-being.

what are Invasive Alien Species?

Alien Species, often referred to as non native, non indigenous or exotic species, are plants, animals, fungi and micro-organisms that have been transported inadvertently or intentionally across ecological barriers and have established themselves in areas outside their natural range. Not all alien species are harmful, but many can become aggressively invasive, spreading rapidly across the natural environment, interacting with native species and posing threats to native biota and/or ecosystems. IAS have negative impacts on native species by being direct predators or competitors, acting as vectors of disease, modifying the habitat, altering native species dynamics.

Trachemys scripta elegans is among the world's most commonly traded pets. It is native to North America and has been established in most European Mediterranean countries. It is a competitor to the Mediterranean pond turtle *Mauremys leprosa* and to the European pond turtle *Emys orbicularis*, which is endangered.

Photo © Thomais Vlachogianni / MIO-ECSDE



increased susceptibility of Mediterranean habitats to invasion by alien species

The unique combination of geological, geophysical and climatic factors in the Mediterranean has led to the development of a characteristic and highly diverse biota. This is also why the region has been included among the most important biodiversity hotspots of the world. The same factors have facilitated a long-standing human presence in the Mediterranean region, which has been a transport and trade hub for millennia.

Several species are used by humans for commercial reasons but also to provide a number of services. This, in combination with the volume, intensity and range of human activities, have made the Mediterranean with its geographical specificities, exceptionally susceptible to invasions by species throughout history. In modern times, rapidly accelerating human population and activities such as trade, transport, travel and tourism, but also agriculture and aquaculture, have led to the simultaneous increase of habitat loss, pollution and human-induced disturbances and facilitation of invasions. The impacts of invasive species in the region are therefore enhanced. Climate change also plays its role in further exacerbating these impacts.

pathways and vectors of invasion in the Mediterranean

The pathways and vectors that transport an invasive alien species are important components for a successful invasion. If the vector can be intercepted, then the invasion can be prevented. Most vectors are human-assisted transport mechanisms that move organisms across natural barriers.

There is no doubt that shipping activities are the most important pathway of IAS in the Mediterranean. Ballast tanks of ships and the fouling on the outside of ships' hulls are significant vectors for marine bioinvasions in the Mediterranean. Aquaculture and mariculture provide pathways for unintentional introductions of alien species including escaped fish species, their parasites and diseases and self dispersal of larvae and spawn. Other vectors of introduction include pets trade, introduction of plants for agricultural or forestry purposes, oil, gas and construction industries (as 'hitchhikers' or 'stowaways' on equipment), intentional introduction of alien species to control pest species, etc.

invasion



Apart from the above mentioned paths of introduction, there are other human activities with the potential to lead to introduction of IAS, which are often overlooked. These include water management systems such as large dams, which can alter the abiotic characteristics of receiving water bodies (e.g. salinity at outflow areas, etc.) or their hydrological regime (e.g. flow disturbance). In addition, climate change and in particular global warming affects sea-water temperature giving a distinct advantage to thermophilic invasive species over the native biota.

Moreover, in addition to the Strait of Gibraltar, which is a well-known access route to the Mediterranean, the opening of the Suez Canal in 1869, has fostered over the years the introduction of alien species of Indo-Pacific and Red Sea origin into the eastern Mediterranean Sea.



◀ *Myiopsitta monachus* is a small parrot, native to South America. It has managed to establish itself in several Mediterranean countries like Spain, France, Italy and Israel.

Photo © Milan Vorgin / DPPVN

▲ *Oxalis pes-caprae* is a short, perennial herb that is native to southern Africa. It is one of Europe's 100 worst invasive species, established in northern Mediterranean countries such as Spain, France, Malta, Italy, Greece and Turkey. It is also distributed in northern Africa. It can suppress other ruderal weedy species. This is a serious problem in the Mediterranean where the arable flora is of conservation value.

Photo © Thomais Vlachogianni / MIO-ECSDE

THE NILE DELTA & ASWAN DAM CASE

According to recent publications the Nile damming explains radical changes in circulation and salinity of the Mediterranean, both in the vicinity (Eastern Mediterranean and Levantine basins) but also to a large extent (up to 45%) over the last 40 years in the Western Mediterranean Deep Water.

As a result, pre-existing environmental barriers related to the physico-chemical characteristics of the water (e.g. salinity) have been diminished, thus providing the stimulus for the invasion of alien species and/or the opportunistic establishment of invasive or pest species in the Mediterranean.

why are they a problem?

Impacts on biodiversity and ecosystems

The impacts of alien species on biodiversity may be categorized according to whether their introduction has had negative, positive or no impact on native biota. In most cases alien species have harmful effects on native biota. In some cases however, they may be beneficial, for example when used for land reclamation.

Some of the negative impacts of IAS are significant, insidious, and usually irreversible, with implications either on individual species or at population and community levels. They may significantly alter ecosystem functions and processes, which perhaps are the most damaging. Alteration of habitat forms or functions, such as changes of e.g. the water table level, soil properties (nutrients, nutrient cycles, pH), fire regime or vegetation structure, can make habitats unsuitable for native species, but not for alien species.

At population and community level, IAS may out-compete native species, repressing or excluding them, indirectly transforming the structure and species composition of the ecosystem by changing the way in which nutrients are cycled through it. IAS may also affect native species by acting as vectors of pathogens, pests or parasites that cause disease to native species or even kill them. In addition, genetic impacts may arise through hybridisation between related native and non native species. Such effects may be accelerated or, in some cases even caused indirectly, through fragmentation of native populations and reduced abundance.

ALIEN SPECIES & THE 'TENS RULE'

Not all alien species are invasive. The successful introduction of an alien species is not a common occurrence and it is the outcome of a series of low-probability events. Only a few species succeed to establish viable populations when introduced in habitats which are outside their natural range.

To become invasive, a species must follow three steps: introduction, establishment, and spread. According to Williamson's 'Tens Rule' about 10% of these species succeed in each of the three transitions (i) from being simply imported to successfully introduced, (ii) from being introduced to becoming effectively established, and (iii) from being established to becoming harmful for other species and to biodiversity in general.

It is well known and accepted that disturbed habitats, be they urban areas, arable lands or river banks, are in general more vulnerable to invasion. Thus, disturbed urban sites tend to have a higher proportion of alien species than non-disturbed habitats.

Negative impacts on human well-being & economic development

Apart from significant negative environmental impacts, IAS can harm human livelihoods and economic opportunities in multiple ways. Notwithstanding their impact on the natural ability of the uninfected ecosystem to supply certain environmental goods, they also affect the integrity of ecosystems, undercutting essential environmental services. Economies and public health may be harmed by IAS which can clog waterways, damage powerlines and reduce energy production, decrease agricultural and timber output, depress tourism and spread diseases to people, domestic animals and cultivated plants.

impacts

Psittacula krameri is native to central Africa, Afghanistan, West Pakistan, the Indian Subcontinent and Myanmar and it has been introduced to several Mediterranean countries such as Spain, France, Italy, Slovenia, Greece, Turkey and Israel. It has been suggested that it may have detrimental effects on other native cavity-nesters and may limit resources available for native species such as *Passer domesticus*, *Columba oenas*, *Sitta europaea* and *Sturnus vulgaris*.

◀ Photo © Thomas Vlachogianni / MIO-ECSD



state and trends

of Invasive Alien Species in the Mediterranean: an overview

Terrestrial Plants

The Mediterranean region is characterised by highly diverse plant communities. Quite surprisingly, invasive plant species were so far not considered to have an impact in the region. According to researchers, from some 25.000 plant species in the region, just about one percent are non native and from these only a few are harmful to natural communities. However, recent data collated by the EU project DAISE, strongly suggests that in European countries, including Mediterranean ones, the tendency has been to underestimate invasive and alien species. Human made habitats, such as industrial areas, arable land, parks and gardens, etc., harbour most of the invasive alien plant species in the region. Riparian forests are also frequently invaded by alien trees such as the Black locust *Robinia pseudoacacia*, *Acer negundo*, *Lonicera japonica* and *Eucalyptus* species. Much less is known about the introduction and spread of alien lower plants and fungi, but what is known is that these taxa can have enormous impacts on crops and livestock.



Black locust (*Robinia pseudoacacia*)

The plant Black locust *Robinia pseudoacacia*, known also as false acacia, was introduced into a French garden in Europe from North America during the 16th century. Shortly after, it became widely distributed in Europe. Once introduced to an area, the false acacia expands readily into areas where its shade it blocks the light from other sun loving plants. Dense clones of false acacia create shaded islands with little ground vegetation. The large, fragrant blossoms of the Black locust compete with native plants for pollinating bees. In the past false acacia was planted extensively as a source of nectar for honeybees, and due to its hard wood which is resistant to rot, also for the production of various wood products. It is very hard or almost impossible to eliminate this tree.



▲ *Acacia dealbata* is a fast growing tree still planted for forestry, soil stabilization and as an ornamental plant. It is native to Australasia - Australia. It is one of Europe's 100 worst invasive species and it is established in several Mediterranean countries such as France, Spain and Italy.

Photo © Thomais Vlachogianni / MIO-ECSDE

◀ *Robinia pseudoacacia*

Photo © Milan Vogrin / DPPVN

plants

indicative examples
of IAS in the Mediterranean region

Terrestrial Animals

Several terrestrial non native animal species, vertebrates and invertebrates, have been introduced and established in Mediterranean countries. However, the number of such species seems to be quite low in comparison to the marine alien species invasions.

When it comes to bird species very few have managed to establish a population and breed successfully in the Mediterranean region. Their populations are usually small and only locally distributed. One of the most successful non native species with free living populations are parakeets, like the Ring-necked parakeet *Psittacula krameri*, the Mitred parakeet *Aratinga mitrata* and the Monk parakeet *Myiopsitta monachus*. These species compete with native cavity breeders for nest sites and have the potential to act as disease carriers that can be harmful to poultry, native birds and even humans. In some cases they can even cause significant damages to crops.

There are even fewer invasive species among mammals of the region. The most important one is the Brown rat *Rattus norvegicus* with well known negative effects on native fauna, especially in islands and also on humans. Locally distributed and harmful for native species and habitats are the Coypu *Myocastor coypus* and the Small Indian mongoose *Herpestes auro punctatus*, both being listed among the world's 100 worst invasive species (IUCN 2000).

The red-eared slider turtle *Trachemys scripta elegans*, a semi-aquatic turtle from North America is an invasive species massively traded worldwide as a pet. It has been introduced in most European Mediterranean countries and has managed to form free living populations. The slider turtle is a competitor of the Mediterranean pond turtle *Mauremys leprosa* and the European pond turtle *Emys orbicularis* which is endangered.

Herpestes auro punctatus

Photo © Milan Vogrin / DPPVN



Rattus norvegicus is native to northern China and is one of Europe's 100 worst invasive species, established in most northern Mediterranean countries. When present on islands, it induces declines in populations of small mammals, marine and land birds, as well as reptiles.

Photo © Milan Vogrin / DPPVN



Vipera ammodytes is native to countries of South-Eastern Europe and the Middle East (e.g. Syria). It is listed as strictly protected under the Bern Convention and the EU Habitat and Species Directive. The Small Indian mongoose was introduced deliberately to control *Vipera ammodytes*'s populations.

Photo © Milan Vogrin / DPPVN



animals

indicative examples of IAS in the Mediterranean region

Herpestes auropunctatus

The Small Indian mongoose *Herpestes auropunctatus*, is one of the world's 100 worst invasive species (IUCN 2000). The mongoose, which is native to southern Asia, is a predator of birds (especially ground nesters), small mammals, amphibians and reptiles, especially snakes.

It is well known that the mongoose was introduced in many islands of the Pacific and Indian Oceans and in the Caribbean Sea in the late 19th and early 20th century, to control introduced rats in sugar cane fields. Several studies reveal that the mongoose has contributed to the extinction and/or is largely responsible for the endangered status of certain species, mostly small mammals.

It is less known, that the mongoose was also introduced in some Croatian islands of the Adriatic Sea (e.g. Mljet, Hvar, etc.) and the Dalmatian coast, mainly in the early and mid 19th century, to control the poisonous nose-horned viper *Vipera ammodytes*. Since then, the Small Indian mongoose has spread also along the entire coastline of Montenegro, from the Croatian border in the north to the Albanian border in the south.

Its introduction in the Adriatic islands has led to detrimental effects on native species, such as the decrease of the viper population, as well as of other snakes and small mammals. Moreover, it has been found to affect the behaviour of the ship rat *Rattus rattus* with unknown further impacts on native biodiversity. It is worth noting that *Rattus rattus* was itself introduced to the western Mediterranean region over 2000 years ago.

Aquatic Species

Several alien species, vertebrates and invertebrates, are today affecting freshwater communities in the Mediterranean, imperilling native species and altering ecosystem processes.

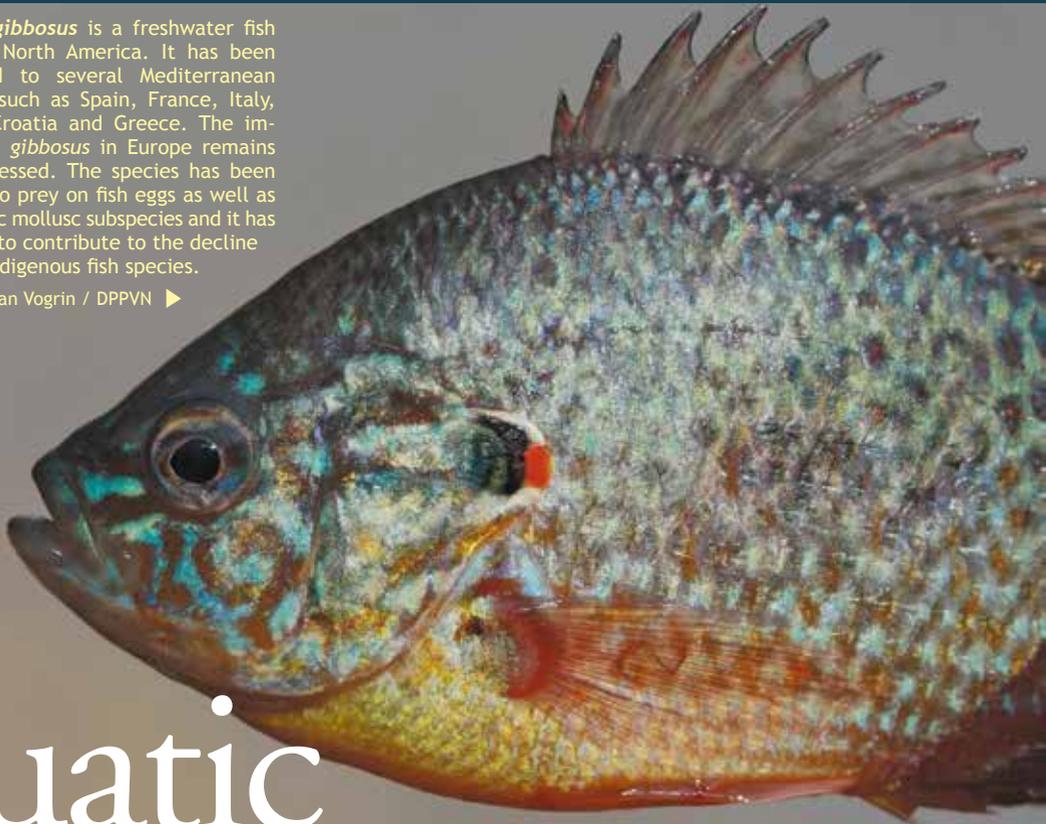
Freshwater fish are, among vertebrates, one of the most successful and harmful invaders in the Mediterranean region. Several freshwater fish species have been intentionally introduced in Mediterranean freshwaters for aquaculture, sport fishing, food production purposes and recently for “beauty care”¹. Illustrative examples are the Stone moroko *Pseudorasbora parva* and Brook trout *Salvelinus fontinalis* which are among the world’s 100 worst invasive species.

Among invertebrates, like insects, snails and nematodes, there are more than 2500 alien species in Europe. Some of them are also found in Mediterranean countries, like the Tiger mosquito *Aedes albopictus*, which came to Europe in 1979 from Asia and soon established itself as one of the worst invasive alien species in the region. The parasitic nematode *Anguillicoloides crassus*, which was introduced to Europe from Asia and is nowadays established in most northern European countries as well as in Morocco, Tunisia and Turkey, is considered to be one of the main threats to the European eel *Anguilla anguilla*.

¹ An example is the introduction of the “pedicure fish” *Garra rufa* in Lake Vouliagmeni (Greece). *Garra rufa* is a hardy species and must be considered invasive.

Lepomis gibbosus is a freshwater fish native to North America. It has been introduced to several Mediterranean countries such as Spain, France, Italy, Slovenia Croatia and Greece. The impact of *L. gibbosus* in Europe remains poorly assessed. The species has been reported to prey on fish eggs as well as an endemic mollusc subspecies and it has been said to contribute to the decline of some indigenous fish species.

Photo © Milan Vogrin / DPPVN ►



aquatic

14.

indicative examples
of IAS in the Mediterranean region



▲
Siganus rivulatus

Photo © Dimitris Poursanidis / terraSolutions (www.terrasolutions.eu)

The Lessepsian invasion in the Mediterranean Sea: the example of two rabbitfish species (*Siganus rivulatus* & *Siganus luridus*)

In 1869, the excavation of the Suez Canal, engineered by Ferdinand de Lesseps, opened the gate to a large number of Red Sea species (principally molluscs, decapods, crustaceans, polychaetes, algae and fish) that invaded the Mediterranean Sea generating dramatic modifications in the local communities. Among these species, which are often called Lessepsian, rabbitfish (or spinefoot) species are considered as one of the most invasive taxa, with high abundances in the eastern Mediterranean.

Two indicative examples are the species *Siganus rivulatus* and *Siganus luridus*, which are considered to be among the most successful Lessepsian fish species and have developed important populations in the eastern Mediterranean. These two herbivorous species were first recorded along the coasts of Israel and Palestine about seventy years ago. They have spread towards the west of the Mediterranean and can be found today in the southern Adriatic Sea, Sicily and Tunisia. In shallow coastal sites of Lebanon, siganids may comprise up to 80% of herbivorous fish populations while in rocky habitats along the Israeli coast they may comprise up to one third of the fish biomass.

The siganids have an impact on native species communities and food web along the Levantine rocky infralittoral. They compete with native herbivorous fish (e.g. the bogue *Boops boops* and the Salema porgy *Sarpa salpa*) reducing their abundance, since both species feed upon algae, and in some cases they have even replaced them. Moreover, these invasive fish species not only affect native fish, but also rocky habitats by feeding on algae and sea grasses. Their diet has a significant impact on the structure of the local algal community, since by feeding selectively they have nearly eradicated some of their favourite algae locally. In addition, their grazing pressure on the intertidal rocky algae may have benefited the proliferation of an alien Lessepsian mussel namely *Brachiodontes pharaonis* by providing suitable substrate for its settlement through the released space on rocky shores. However, it should be mentioned that both rabbitfish are edible and nowadays their commercial exploitation is important in the eastern Mediterranean Sea.

Aquatic marine species

The Mediterranean Sea is considered to be one of the main hotspots of marine alien species invasions on earth and the rate of introductions appears to be steadily increasing. Nearly 1000 species (~10-15% of all species inhabiting the Mediterranean Sea) have experienced a successful introduction into the Mediterranean Sea, including species from the Red Sea, the Black Sea and the Atlantic Ocean. The rate of introduction has increased to 1 species every 9 days. More than 50% of these species (> 500 species) have established durable populations and are spreading. The bulk of the alien species recorded in the Mediterranean Sea are seabed living animals (zoobenthos) and plants (phytobenthos) and fish living in the littoral and sub-littoral zones.

The majority of IAS in the South-Eastern Mediterranean has entered through the Suez Canal (81%), followed by vessels (13%) and aquaculture (3%). Aquaculture and shipping are the dominant means of introduction of species in the North-Western Mediterranean and in the Adriatic Sea.

Perhaps the most notorious and best studied invasive species in the Mediterranean are a pair of coenocytic chlorophytes *Caulerpa taxifolia* and *Caulerpa racemosa* var. *Cylindracea*. Both species are extremely invasive, characterized by a rapid spread and high growth rate, thus leading to drastic changes in the composition of the phytobenthos of native habitats and bringing about modifications to native biota. Other illustrative examples are two species of siganid fish *Siganus rivulatus* and *Siganus luridus*; the mytilid mussel *Brachidontes pharaonis*; the limpet *Cellana rota*; the goldband goatfish *Upeneus moluccensis*; the lizardfish *Saurida undosquamis*; etc.

Saurida undosquamis is a species of Indo-pacific origin with known introduction range in the Eastern Mediterranean, spanning from Libya to Albania. The sudden increase of this species led to the displacement of the native hake, *Merluccius merluccius*, in deeper waters.

Photo © Thanos Dailianis / Hellenic Centre for Marine Research



The pharaonic mussel (*Brachidontes pharaonis*)

A small mussel, *Brachidontes pharaonis*, is one of the earliest Red Sea invaders to enter the Mediterranean, already present in 1876 near the northern entrance of the Suez Canal, in Port Said, Egypt. In the past 25 years it has become abundant in midlittoral and infralittoral rocky habitats, especially along the rocky shores of the Eastern Mediterranean. It has been found in Lebanon, Israel, Syria, Turkey, Cyprus, Greece, Italy and Croatia.

The pharaonic mussel locally displaces the native mytilid *Mytilaster minimus*. In the early 1970s *Brachidontes pharaonis* was much rarer than the native *Mytilaster minimus*. By the end of the 1980s it was determined that it interfered with the process of settlement of the *Mytilaster* and detrimentally affected its survival and growth. In the late 1990s a rapid shift in dominance was recorded, with some of the *Brachidontes* populations reaching 300 specimens per 100 cm², while *M. minimus* was dramatically reduced to the extent that it is only rarely encountered.

The establishment of massive beds of *Brachidontes* has had significant effects on native biota of the hard substrate intertidal. The displacement of the native mussel by the larger, thicker-shelled Lessepsian alien appears to have changed predation patterns so that the population of the native whelk *Stramonita haemastoma*, that was found to preferentially prey on *Brachidontes*, increased greatly.



indicative examples of IAS in the Mediterranean region

marine

▲ *Halophila stipulacea* is a Lessepsian species introduced and established in several Mediterranean countries such as Tunisia, Italy, Albania, Greece, Turkey, Cyprus, Lebanon and Egypt. It out-competes the native Mediterranean seagrasses and can induce changes in sub-littoral communities.

Photo © Dimitris Poursanidis / terraSolutions (www.terrasolutions.eu)

Green alga species *Caulerpa taxifolia* nominated as among the “World’s Worst” 100 invaders

Caulerpa taxifolia or killer alga is an invasive marine species that is widely used as a decorative plant in aquaria. A cold-tolerant strain of this tropical green alga was unintentionally introduced into the Mediterranean in 1984 by the Oceanographic Museum of Monaco with aquaria outflow. In the last few decades, it has been able to colonize many intertidal habitats along the coasts of Croatia, France, Italy, Monaco, Spain and Tunisia and is still spreading in the Mediterranean.

C. taxifolia's rapid spread, high growth rate, and its ability to form dense meadows (up to 14,000 blades per m²) on various infralittoral bottom types, especially in areas plagued by higher nutrient loads, leads to formation of dense monocultures and replacement of native algal species. It reduces species richness of native hard substrate algae by 25-55%, and, under certain conditions, outcompetes *Cymodocea nodosa* and *Posidonia oceanica*. Moreover, caulerpenyne, the most potent repellent endotoxin which protects *C. taxifolia* against epiphytes and herbivores is toxic for molluscs, sea urchins and herbivorous fish.

The killer alga has effects on human livelihoods too, mostly related to the reduction of catches for commercial fishermen due to the elimination of fish habitats by *C. Taxifolia*, although the entangling of nets and boat propellers with this weed also affect efficiency. Furthermore, fish which are able to eat *C. Taxifolia*, such as the Mediterranean bream (*Sarpa salpa*), accumulate toxins in their flesh that make them unsuitable for human consumption.





Azzurro E, Golani D, Bucciarelli G, Bernardi G. Genetics of the early stages of invasion of the Lessepsian rabbitfish *Siganus luridus*. *J Exp Mar Biol Ecol* 333 (2): 190-201, 2006.

Bardsley DK, Edwards-Jones G. Invasive species policy and climate change: social perceptions of environmental change in the Mediterranean. *Environmental Science & Policy*, 2007, 10(3): 230-242.

Bariche M, Letourneur Y, Harmelin-Vivien M. Temporal fluctuations and settlement patterns of native and lessepsian herbivorous fishes on the Lebanese coast (Eastern Mediterranean). *Environmental Biology of Fishes* 70: 81-90, 2004.

Barun A, Simberloff D, Tvrtković N, Pascal M. Impact of the introduced small Indian mongoose (*Herpestes auropunctatus*) on abundance and activity time of the introduced ship rat (*Rattus rattus*) and the small mammal community on Adriatic islands, Croatia. *NeoBiota* 11: 51-61, 2011.

Blondel J, Aronson J. *Biology and Wildlife of the Mediterranean Region*. Oxford University Press, 1999.

Ceccherelli G, Cinelli F. Short-term effects of nutrient enrichment of the sediment and interactions between the seagrass *Cymodocea nodosa* and the introduced green alga *Caulerpa taxifolia* in a Mediterranean bay. *J Exp Mar Biol Ecol* 217: 165-177, 1997.

Delivering Alien Invasive Species In Europe (DAISIE) project inventory, <http://www.europe-aliens.org>

Čirović D, Raković M, Milenković M, Paunović M. Small Indian Mongoose *Herpestes auropunctatus* (Herpestidae, Carnivora): an invasive species in Montenegro. *Biological Invasions*, Vol 13, 2: 393-399, 2011.

European Environment Agency (EEA). *The impacts of invasive alien species in Europe*. EEA, Copenhagen, 2012.

Galil BS. Loss or gain? Invasive aliens and biodiversity in the Mediterranean Sea. *Mar Pollut Bull* 55 (7-9): 314-322, 2007.

Handbook of Alien Species in Europe. *Invading Nature - Springer Series in Invasion Ecology*, Vol. 3, Delivering Alien Invasive Species, 2009.

Harmelin-Vivien ML, Bitar G, Harmelin JG, Monestiez P. The littoral fish community of the Lebanese rocky coast (eastern Mediterranean Sea) with emphasis on Red Sea immigrants. *Biological Invasions* 7: 625 - 637, 2005.

Hassan M, Harmelin-Vivien M, Bonhomme F. Lessepsian invasion without bottleneck: example of two rabbitfish species (*Siganus rivulatus* and *Siganus luridus*). *J Exp Mar Biol Ecol* 291 (2): 219-232, 2003.

Heywood VH. *The role of New World biodiversity in the transformation of Mediterranean landscapes and culture*. *Boccone* 24: 69-93, 2012.

IUCN 2000: 100 of the world's worst invasive alien species. *Aliens* 12. IUCN, Auckland, New Zealand.

Kalogirou S, Wennhage H, Pihl L. Non-indigenous species in Mediterranean fish assemblages: Contrasting feeding guilds of *Posidonia oceanica* meadows and sandy habitats. *Estuarine, Coastal and Shelf Science* 96 (1): 209-218, 2012.

Katsanevakis S, et al. Invading European Seas: Assessing pathways of introduction of marine aliens. *Ocean & Coastal Management*, 76: 64-74, 2013.

Katsanevakis S, et al. The invasive crab *Percnon gibbesi* (Crustacea: Decapoda: Plagusidiidae) is spreading in the Aegean and Ionian Seas. *Marine Biodiversity Records*, 2010, 3: 1-5.

bibliography



Meinesz A, et al. The introduced green alga *Caulerpa taxifolia* continues to spread in the Mediterranean. *Biol Inv* 3: 201-210, 2001.

Rilov G, Crooks JA eds. *Biological Invasions in Marine Ecosystems*. Springer, Berlin, 2009.

Rilov G, Galil B. Marine Bioinvasions in the Mediterranean Sea - History, Distribution and Ecology. In: Rilov G, Crooks JA (eds) *Biological Invasions in Marine Ecosystems*. Springer, Berlin Heidelberg, 2009.

Rilov G, Gasith A, Benayahu Y. Effect of an exotic prey on the feeding pattern of a predatory snail. *Mar Environ Res* 54: 85-98, 2002.

Sarū G, Romano C, Caruso M, Mazzola A. The new Lessepsian entry *Brachidontes pharaonis* (Fischer P., 1870) (Bivalvia, Mytilidae) in the western Mediterranean: a physiological analysis under varying natural conditions. *Journal of Shellfish Research* 19(2): 967-977, 2000.

Sarū G, Romano C, Mazzola A. A new Lessepsian species in the western Mediterranean (*Brachidontes pharaonis* Bivalvia, Mytilidae): density, resource allocation and biomass. *J Mar Biol Ass* 363 (1-2): 130-136, 2008.

Sarū G, Romano C, Widdows J, Staff FJ. Effect of salinity and temperature on feeding physiology and scope for growth of an invasive species (*Brachidontes pharaonis* - MOLLUSCA: BIVALVIA) within the Mediterranean sea. *Journal of Experimental Marine Biology and Ecology*, 2008, 363(1-2), 130-136.

Secretariat of the Convention on Biological Diversity (SCBD). *Global Biodiversity Outlook 2*. Montreal 2006.

Skirris N, Lascaratos A. Impacts of the Nile River damming on the thermohaline circulation and water mass characteristics of the Mediterranean Sea. *Journal of Marine Systems*, 2004, 52 (1-4): 121-143.

Streftaris N, Zenetos A, Papatthanassiou E. Globalisation in marine ecosystems - The story of non indigenous marine species across European Seas. *Reviews in Oceanography and Marine Biology* 43:419-454, 2005.

Thessalou-Legaki M, et al. The establishment of the invasive crab *Percnon gibbesi* (H. Milne Edwards, 1853) (Crustacea: Decapoda: Grapsidae) in Greek waters. *Aquatic Invasions*, 2006, 1 (3): 133-136.

UNEP/MAP & Plan Bleu. *State of the Environment and Development in the Mediterranean*. UNEP/MAP & Plan Bleu, 2009.

Williamson M, Fitter A. *The varying success of invaders*. Ecology, 77: 1661-1666, 1996.

Williamson M. *Biological invasions*. Chapman & Hall, London, UK, 1996.

Zenetos A, et al. 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: 381 - 493, 2010.

Zenetos A, et al. Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. *Mediterranean Marine Science*, 13/2: 328-352, 2012.

► *Myocastor coypus* is native to the Patagonian sub-region of South America and has established itself in several Mediterranean countries. It is listed among the 100 most invasive alien species of Europe.

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