

Mediterranean Marine Science
Volume 7/1, 2006, 87-118

Alien Marine Species in the Mediterranean - the 100 'Worst Invasives' and their Impact

N. STREFTARIS and A. ZENETOS

Hellenic Center for Marine Research, Institute of Oceanography
P.O. Box 712, 190 13, Anavissos, Attica, Greece

e-mail: nstrefta@ath.hcmr.gr

Abstract

A number of marine alien species have been described as invasive or locally invasive in the Mediterranean because of their proliferation, and/or their geographical spread and/or impact on native populations. Based on that information and on the documented impact they have on the biodiversity and socioeconomics of the basin, a preliminary list of the 100 'worst' Invasive Alien Species (IAS) in the Mediterranean has been produced and presented in this work along with details on their impact. Emphasis is given to their impact on socioeconomics (fisheries/aquaculture, health & sanitation, infrastructure & building), documented for 43 species. Such selection of the 'worst' IAS was difficult and controversial and is expected to attract much attention and scientific criticism since not only can the documentation of the impact of IAS be controversial, but also their inventory can be biased towards the effort and resources devoted to the study of the impact of certain species/taxonomic groups. Thus, while marine plants (phytobenthos and phytoplankton) are fairly well studied, less attention has been paid to the impact of vertebrates and even less to invertebrates. Nevertheless, the list highlights the need for continued research on the issue (monitoring aliens and their impact for an integrated ecosystem based management approach over the entire area). The preliminary list can provide the basis for selecting indicator species within the Mediterranean and thus be the common ground to build cooperation about IAS within countries in the region.

Keywords: Worst Invasive Alien Species; Mediterranean; Impact; Biodiversity; Socioeconomics.

Introduction

A number of definitions have been applied to describe the term Invasive Alien Species (IAS); in many of them the term invasive is associated with established species which are agents of change and threaten native biological diversity (IUCN, 2002), or with species that threaten the diversity or abundance of native species, the ecological stability of infested ecosystems, economic activities de-

pendent on these ecosystems and/or human health (EPA, 2001).

Biological invasions in marine habitats represent a recognized worldwide threat to the integrity of native communities, to economy and even to human health. Invasive species are believed to accelerate the decline of native populations already under environmental stress, leading to population losses and extinctions on a local scale (RICCIARDI, 2004), but not globally (GUREVITCH

& PADILLA, 2004). The extent of the impact has been so severe that invasive species are regarded as the second biggest cause of biodiversity loss after habitat destruction (BREITHAUPT, 2003), constituting one of the four greatest threats to the world's oceans on local, regional and global scales (IMO 2000-2004). This 'biological pollution' (CARLTON & GELLER, 1993) can be detrimental to the host ecosystem since unlike other forms of marine pollution where ameliorative action can be taken and their effects can be reversed, their impact is more often irreversible (CARLTON, 1989).

In general, however, the impact of most invasive species remains unknown, and the predictability of their direct and indirect effects remains uncertain (RUIZ *et al.*, 1997). In most regional European Seas the alterations of marine ecosystems due to new introductions and the associated socioeconomic impacts have been poorly studied with few well-documented cases reported and rarely quantified (LEPPAKOSKI *et al.*, 2002).

Among invasive alien species, the 'worst' invasive species have been the focus of many environmental programs and initiatives. A list of '100 of the World's Worst IAS' has been compiled by IUCN/GISP, whereas a list of the worst IAS threatening biodiversity in Europe has been endorsed by the SEBI2010 Working Group 5¹. However, both lists are very generic, covering all environments (terrestrial, freshwater, marine) at global or Pan-European scale and the contribution of marine species is underestimated.

The aim of this work is to give an overview of the situation in the Mediterranean by presenting a list of the 'worst' invasive marine species which will be the common ground to build cooperation about IAS within

countries in the region. Moreover, it will give an idea of what priorities may be needed for the different countries in developing control programs, and starting environmental monitoring of IAS species.

Methods

Selecting 'worst' invasive species is a difficult task and will be surely criticised by scientists. Since no objective criteria are available at the moment, the choice of 'worst' invasive species is subjective. Depending on personal interest some species will be favoured over others. For a rapid assessment of this indicator, a preliminary list of 'worst IAS' of the Mediterranean by taxonomic groups was compiled through a literature search.

The criteria used for selecting the 'worst invasive species' in the Mediterranean were based on the criteria used by the IUCN/GISP for the list '100 of the World's Worst Invasive Alien Species' and endorsed by the SEBI2010 Working Group 5. In this task, we have included species that have either a documented impact and/or possess the potential to cause serious negative impacts on biological diversity and socio-economy. Thus, as 'worst IAS' have been defined invasive species that have an impact on:

Biodiversity

In general alien species pose a threat to biodiversity by impacting on:

- Native species
- Ecosystems either directly (affecting hydrology, nutrient cycling, and other processes, mainly by the so-called 'ecosystem engineers'), or indirectly by changing the whole ecosystem structure and functioning (introduced species often consume or prey on native ones, overgrow them, compete with them, attack them, or hybridise with them).
- Unique biodiversity of endemic species, isolated (pristine) ecosystems and conservation areas

¹ As part of the SEBI2010 process (Streamlining European 2010 Biodiversity Indicators <http://biodiversity-chm.eea.eu.int/information/indicator/F1090245995>) the Expert group 5 on 'Trends in invasive alien species' is developing a list of 'Worst invasive species threatening biodiversity in Europe'.

Socio-economics

New incursions of marine alien species continue and some existing species are extending their range. By doing so, they can be detrimentally affect the socioeconomic values of an area by impacting on fisheries & aquaculture, health & sanitation, and infrastructure & building.

- *Fisheries & Aquaculture*: Alien species, including imported livestock pests, reduce yields drastically, either directly (e.g. pests) or indirectly (e.g. clogging of nets). IAS may also greatly increase the effort required to clean fishing gear and aquaculture.
- *Health & Sanitation*: The unintentional introduction of toxic species, parasites and pathogens has an impact on both the ecosystem and human health,
- *Infrastructure & Building*: Alien species may induce habitat modification and alteration of physical conditions. They may also cause fouling (for example may clog water pipes and/or foul propellers), and may become navigational hazards.

In general, it does not seem a great problem to separate biodiversity and economic impact, although they sometimes go hand in hand. Nevertheless, in lists of 'worst' aliens there are some 'pest' species with a negative economic impact or which affect human or animal health, but without a known ecological impact so far. In the preliminary list of 'worst IAS' of the Mediterranean presented in this paper however, the impact has been clearly indicated on the two major categories: biodiversity and socioeconomics, with special attention to the latter and its subdivisions (fisheries & aquaculture (F), health & sanitation (H), and infrastructure & building (I)).

Results

1. Records of 'Worst Invasive' Alien Species

A number of alien species have been described as invasive or locally invasive by different authors in different parts of the Mediterranean because of their prolifera-

tion, and/or their geographical spread and/or impact on native populations. ZENETOS *et al.*, (2005) presented some of the 'worst' IAS per eco-functional/taxonomic group. Table 1 summarises the top '100 Worst IAS' based on the documented impact they have on biodiversity and socioeconomic values. By definition all introduced species have an impact on biodiversity (SEBI2010: WG5). However, only those having a serious impact are selected for our preliminary list. The literature upon the attributions of a species on the list is given below (brief notes on their geographical distribution in ZENETOS *et al.*, (2005)). Details of their impact are presented in the relevant sections that follow.

1.1. Plants

Many authors have provided lists of invasive macrophytes in the Mediterranean. WALLENTINUS (2002) for example has provided a different perspective in which 25 macroalgae are considered as invasive and nine as highly invasive. The current list is based on the list of invasive species produced by BOUDOURESQUE & VERLAQUE (2002b) and references therein and on the list of invasive or potentially invasive exotic macroalgae which according to a screening protocol, defined in the ALIENS project, is based on species with: a) large and fast spread in Europe (e.g. *Heterosiphonia japonica*); b) invasive behaviour in Europe (e.g. *Sargassum muticum*); c) high impact on recipient assemblages and/or human activities (e.g. *Caulerpa* spp.) (VERLAQUE *et al.*, 2005).

Microscopic algal species (phytoplankton) responsible for the occurrence of Harmful Algal Blooms have been regarded as invasive by many authors. For details see section 3.2 'Impact on health'.

1.2. Vertebrates

Fish: Among the alien fish eighteen species are characterised as successful invaders and of economic importance and twelve as very common or prevalent but of no eco-

conomic importance due to their small size (GOLANI *et al.*, 2002). However the term invasive is not used when describing the impact of alien fish species due to the lack of reliable information on distribution and abundance prior to the opening of Suez Canal (GOLANI, 1998). The ‘Worst Fish IAS’ found in Table 1 are based on the works of GOLANI *et al.*, (2002; 2006); GOREN & GALIL, (2005), HARMELIN-VIVIEN *et al.*, (2005).

1.3. Invertebrates

Mollusca: Many authors have provided lists of invasive molluscs in the Mediterranean. The selected species in Table 1 are based on lists of invasive species produced by OCCHIPINTI AMBROGI (2002a,b), ZIBROWIUS (2002), GOFAS & ZENETOS (2003), ZENETOS *et al.*, (2003) and individual species reported in BLANCHARD (1996) and HOPPE (2002).

Polychaeta: Alien polychaetes have been reported as invasive throughout the Mediterranean by KOÇAK *et al.*, (1999), ZIBROWIUS (2002), ÇINAR *et al.*, (2005), ÇINAR (2006).

Crustacea: our list has been compiled based on the alien crustaceans that have been reported as very abundant with recorded impact on biodiversity and the socioeconomic values of the area by GALIL 1986, GALIL *et al.*, (2002 & 2006), ZIBROWIUS (2002), THESSALOU-LEGAKI *et al.*, (2006).

Other invertebrates: When assessing the scale and impact of ship-transported alien fauna in the Mediterranean, invertebrate species have been regarded as invasive primarily based on their spread by ZIBROWIUS (2002), and individual species were also regarded as such by GALIL *et al.*, (1990), OCCHIPINTI AMBROGI (2000a,b), GALIL & ZENETOS (2002), HYAMS *et al.*, (2002), MERİÇ *et al.*, (2002), YOKES & MERİÇ (2004).

Table 1
The ‘100 Worst Invasive Species’ in the Mediterranean
F: Fisheries/Aquaculture - H: Health & Sanitation - I: Infrastructure & Building.

Species Latin name	Common name	Biodiversity	Socio-economy			SEBI 2010
			F	H	I	
PLANTS						
PHYTOBENTHOS						
<i>Acrothamnion preissii</i>	A red alga	+	+			+
<i>Antithamnion nipponicum</i>	A red alga	+	+	+		
<i>Asparagopsis armata</i>	Harpoon weed	+	+			+
<i>Asparagopsis taxiformis</i>	Limu kohu	+				+
<i>Bonnemaisonia hamifera</i>	A red alga	+				
<i>Caulerpa racemosa</i>	Grape caulerpa	+	+			+
<i>Caulerpa taxifolia</i>	Killer alga	+	+			+
<i>Codium fragile</i>	Dead man’s finger	+	+	+		+
<i>Colpomenia peregrina</i>	A brown alga	+	+			
<i>Desmarestia viridis</i>	A brown alga	+	+	+		
<i>Grateloupia turuturu</i>	A red alga	+	+			
<i>Halophila stipulacea</i>	A sea grass	+				+
<i>Heterosiphonia japonica</i>	A red alga	+	+			
<i>Lophocladia lallemandii</i>	A red alga	+				
<i>Polysiphonia morrowii</i>	A red alga	+	+			+
<i>Sargassum muticum</i>	Jap weed	+	+	+		+

Continued

Table 1 (Continued)

Species Latin name	Common name	Biodiver- sity	Socio- economy			SEBI 2010
			F	H	I	
<i>Styopodium schimperi</i>	A brown alga	+			+	+
<i>Undaria pinnatifida</i>	Wakeme, Asian kelp	+	+		+	+
<i>Womersleyella setacea</i>	A red alga	+	+			+
PHYTOPLANKTON						
<i>Alexandrium catenella</i>	A dinoflagellate	+	+	+		+
<i>Alexandrium taylori</i>	A dinoflagellate	+	+			
<i>Coolia monotis</i>	A dinoflagellate	+	+	+		
<i>Ostreopsis ovata</i>	A dinoflagellate	+	+	+		
VERTEBRATES						
<i>FISH</i>						
<i>Alepes djedaba</i>	Shrimp scad	+				
<i>Callionymus filamentosus</i>	Dragonet	+				
<i>Dussumieria elopoides</i>	Slender rainbow sardine	+				
<i>Lagocephalus sceleratus</i>	Elongated pufferfish	+		+		
<i>Fistularia commersonii</i>	Bluespotted cornetfish	+				+
<i>Herklotsichthys punctatus</i>	Spotted herring	+				
<i>Pempheris vanicolensis</i>	Vanikoro sweeper	+				
<i>Plotosus lineatus</i>	Eel catfish	+		+		
<i>Sargocentron rubrum</i>	Redcoat	+				
<i>Saurida undosquamis</i>	Brushtooth lizard fish	+				+
<i>Scomberomorus commerson</i>	Narrowbarred Spanish mackerel	+				
<i>Seriola fasciata</i>	Lesser amberjack	+		+		+
<i>Siganus luridus</i>	Dusky spine foot	+		+		+
<i>Siganus rivulatus</i>	Marbel spine foot	+		+		+
<i>Sillago sihama</i>	Silver sillago	+				
<i>Sphoeroides pachygaster</i>	Blunthead puffer	+	+	+		+
<i>Sphyraena chrysotaenia</i>	Yellow stripe barracuda	+				
<i>Upeneus moluccensis</i>	Goldband goatfish	+				
<i>Upeneus pori</i>	Por's goatfish	+				
INVERTEBRATES						
<i>MOLLUSCA</i>						
<i>Anadara demiri</i>	Arc shell	+				+
<i>Anadara inaequalvis</i>	Arc shell	+				+
<i>Brachidontes pharaonis</i>	Variable mussel	+			+	
<i>Bursatella leachi</i>	Ragged sea hare	+				
<i>Chama pacifica</i>	Large Pacific Chama	+				+
<i>Cerithium scabridum</i>	A gastropod	+				
<i>Crassostrea gigas</i>	Pacific giant oyster	+			+	
<i>Crepidula aculeata</i>	Spiny Slippersnail	+				
<i>Crepidula fornicata</i>	Slipper limpet	+	+			+

Continued

Table 1 (Continued)

Species Latin name	Common name	Biodiversity	Socio-economy			SEBI 2010
			F	H	I	
<i>Musculista senhousia</i>	Green bugmussel	+				+
<i>Mya arenaria</i>	Soft shell clam	+				+
<i>Pinctada radiata</i>	Pearl oyster	+				+
<i>Rapana venosa</i>	Veined rapa whelk	+	+			+
<i>Rhinoclavis kochi</i>	A gastropod	+				
<i>Ruditapes philippinarum</i>	Manila clam	+	+		+	+
<i>Spondylus spinosus</i>	Shiro-toge-umi-giku	+				+
<i>Strombus persicus</i>	Persian Conch	+				
<i>Teredo navalis</i>	Shipworm	+				+
<i>Xenostrobus securis</i>	Little Brown Mussel	+				+
POLYCHAETA						
<i>Branchiomma luctuosum</i>	Tube worm	+				
<i>Ficopomatus enigmaticus</i>	Australian tube worm	+			+	+
<i>Hydroides dianthus</i>	Tube worm	+			+	
<i>Hydroides dirampha</i>	Tube worm	+			+	
<i>Hydroides elegans</i>	Tube worm	+			+	
<i>Hydroides heterocerus</i>	Tube worm	+				
<i>Hydroides homoceros</i>	Tube worm	+				
<i>Hydroides minax</i>	Tube worm	+				
<i>Hydroides operculatus</i>	Tube worm	+			+	
<i>Hydroides branchyacanthus</i>	Tube worm	+				
<i>Leonnates persicus</i>	Mud worm	+				
<i>Polydora cornuta</i>	Mud worm	+	+			+
<i>Pomatoleios kraussii</i>	Tube worm	+			+	
<i>Pseudonereis anomala</i>	Mud worm	+				
<i>Spirobranchus tetraceros</i>	Tube worm	+				
<i>Spirorbis marioni</i>	Tube worm	+			+	+
<i>Streblospio gynobranchiata</i>	Mud worm	+				
CRUSTACEA						
<i>Callinectes sapidus</i>	Blue crab	+	+			
<i>Charybdis longicollis</i>	Swimming crab	+	+			
<i>Charybdis helleri</i>	Spiny hands	+				
<i>Dyspanopaeus sayi</i>		+				
<i>Erugosquilla massavensis</i>	Mantis shrimp	+				
<i>Elasmopus pecteniscrus</i>	An amphipod					
<i>Eriocheir sinensis</i>	Chinese mitten crab	+	+		+	+
<i>Marsupenaeus japonicus</i>	Tiger prawn Karuma	+				+
<i>Melicertus hathor</i>	A shrimp	+				
<i>Metapenaeus monoceros</i>	Speckled shrimp	+				
<i>Metapenaeus stebbingi</i>	Penegrine shrimp	+				
<i>Mytilicola orientalis</i>	Red worm	+	+			

Continued

Table 1 (Continued)

Species Latin name	Common name	Biodiver- sity	Socio- economy			SEBI 2010
			F	H	I	
<i>Penaeus semisulcatus</i>	Green tiger prawn	+				
<i>Percnon gibbesi</i>	Nimble spray crab	+				+
<i>Portunus pelagicus</i>	Blue swimming crab	+				
OTHER INVERTEBRATES						
<i>Amphistegina lobifera</i>	A foraminiferan	+				
<i>Amphisorus hemprichii</i>	A foraminiferan	+				
<i>Asterina burtoni</i>	A starfish	+				
<i>Microcosmus exasperatus</i>	An ascidian	+				+
<i>Oculina patagonica</i>	A stony coral	+				
<i>Rhopilema nomadica</i>	A jelly fish	+	+	+	+	+
<i>Tricellaria inopinata</i>	A bryozoan	+				+

2. Impact on biodiversity

2.1 Plants

Caulerpa species

Caulerpaceae - *Caulerpa taxifolia* and *Caulerpa racemosa* var. *cylindracea* - are perhaps the most notorious invaders in the Mediterranean; in many cases their invasive spread has radically altered the structure and function of native ecosystems causing a decrease in biodiversity and representing a very serious ecological problem in the Mediterranean (GRAVEZ *et al.*, 2001). They are considered particularly invasive since they are good colonisers of unvegetated sediments, have wide tolerance of stress and are unaffected by nutrient and light limitation. In other words, they possess a high capacity for vegetative growth and population persistence (WILLIAMS, 1990; MEINESZ *et al.*, 1995; CHISHOLM *et al.*, 1996; DELGADO *et al.*, 1996; CECCHERELLI & CINELLI, 1999a; PIAZZI & CINELLI, 1999; WILLIAMS & GROSHOLSZ, 2002).

The mechanisms, by which *Caulerpa* spp. might affect native vegetation, especially the seagrasses, are still unclear (CECCHERELLI & CINELLI, 1997). A correlation with sediment environment has been suggested as extremely high sulfate reduction rates, and sulfide concentrations in colonised sediments

have been reported (HOLMER *et al.*, 2004). Despite the abundant scientific reports available no efforts have yet been made to elucidate the role of ecosystem biodiversity in the susceptibility of Mediterranean macrophyte assemblages to impacts by invasive *Caulerpa* species (MARBÀ *et al.*, 2005).

Caulerpa racemosa var. *cylindracea*

Thirteen years after the first record in the early 1990's of the invasive variety of *C. racemosa* var. *cylindracea* (for identification see VERLAQUE *et al.*, 2003), nearly the entire Mediterranean basin was reported colonized, reaching as far as the Canary Islands; by 2005 it has colonised the coasts of 11 nations (Albania, Croatia, Cyprus, France, Greece, Italy, Libya, Malta, Spain, Tunisia and Turkey, and all major Mediterranean islands), growing on all kind of substrata, both in polluted and unpolluted areas, between 0 and 70 m depth, demonstrating an excessive rate of proliferation (VERLAQUE *et al.*, 2000, 2003, 2004; PIAZZI *et al.*, 2001a, 2005; BOUDOURESQUE & VERLAQUE, 2002b; MEINESZ *et al.*, 2003; RUITTON *et al.*, 2005).

The invasive ability and strong competitive characteristics of *C. racemosa* have been demonstrated in many works (CECCHERELLI & CINELLI 1997; PIAZZI *et al.*, 1997, 2001a; PIAZZI & CINELLI,

1999; CECCHERELLI *et al.*, 2000; CECCHERELLI & CAMPO, 2002). First indications of the impacts suggested alarming changes in community structure both on phyto-benthos as well as on zoobenthos (see below). However, when examining the impact on the zoobenthos in Cyprus, ARGYROU *et al.*, (1999) demonstrated contradictory effects (decreased abundance of gastropods and crustaceans, but increased abundance of polychaetes, bivalves and echinoderms).

Experimental work (PIAZZI *et al.*, 2001a; PIAZZI & CINELLI, 2003; BALATA *et al.*, 2004) has shown that *C. racemosa* var. *cylindracea* invasions have a great impact on Mediterranean macroalgal assemblages on dead mattes of *Posidonia oceanica* and rocky bottoms, with greater impact on the former. Within 6 months the alga had completely overgrown the substrata and had impoverished the algal assemblages by reducing the species cover, number of species and diversity (affecting primarily turf and encrusting species, compared to erect species); the impact was so extensive that the algal assemblage did not seem to recover even when *C. racemosa* diminished following a seasonal cycle.

Interestingly, whereas the dead matte of *P. oceanica* appears to be the most favorable substratum for colonization, no colonization has been observed on dense meadows in many other Mediterranean regions; dense *P. oceanica* meadows seem to prevent *C. racemosa* var. *cylindracea* invasion (PIAZZI & CINELLI, 1999, 2003; CECCHERELLI *et al.*, 2000; PIAZZI *et al.*, 2001a, 2005; RUITTON *et al.*, 2005). Nevertheless other studies have demonstrated some changes in the vegetative cycle and production of *P. oceanica* (DUMAY *et al.*, 2002).

Contrasting results have emerged when the impact on other native seagrasses was investigated. Some results suggest reduction in the distribution of *Cymodocea nodosa* as a result of competitive displacement by *C. racemosa*: *C. nodosa* shoot density was reduced even by 50% (CECCHERELLI &

CINELLI 1997; CECCHERELLI & CAMPO, 2002). Conversely, a positive influence was found on the *Zostera noltii* shoots (CECCHERELLI & CAMPO, 2002).

Caulerpa taxifolia

The invasive proliferation of *Caulerpa taxifolia*, the 'killer alga' (MEINESZ, 1999), is the most infamous example of the impact of invasive species. In the Mediterranean, the alga is causing a 'major ecological event' (BOUDOURESQUE *et al.*, 1995). Even though *C. taxifolia* is not considered as so invasive as *C. racemosa* var. *cylindracea* (PIAZZI *et al.*, 2001b; BALATA *et al.*, 2004), it has reached high abundances (MEINESZ *et al.*, 1995; CECCHERELLI & CINELLI 1997, 1998). The small colony of 1m² (accidentally introduced in 1984 by the Oceanographic Museum of Monaco) had spread to more than 6,000 hectares by 1996 (MEINESZ *et al.*, 1998). It covered more than 13000 hectares along 191 km of coastline in six countries (Monaco, France, Italy, Spain, Croatia and Tunisia) by 2000. The area colonized along the Mediterranean French coast increased from 77.3 km² to 122.7 km² between 2001 and 2004, and the species is still expanding, out-competing native species and seriously reducing diversity (MEINESZ *et al.*, 2001, 2004). Yacht anchors and fishing gears appear to have carried it over great distances (MADL & YIP 2003).

Caulerpa taxifolia is known to have a major impact on marine ecosystems, which is mainly attributed to a toxic nature (synthesis of terpenoids), an ability to colonize all parts of the littoral zones and all substrata, and a high ecological fitness. The toxic terpenoids synthesized in higher concentrations than in tropical waters (GUERRIERO *et al.*, 1992) inhibit the growth of *Cystoseira barbata* and *Gracilaria bursa-pastoris* (FERRER *et al.*, 1997), and can explain the superior competitiveness of *Caulerpa* against native macroalgae. They also negatively affect several phytoplanktonic organisms (LEMEE *et al.*, 1997). Lastly they protect

C. taxifolia against grazers (RUITTON & BOUDOURESQUE, 1994). *Caulerpa taxifolia* can drastically reduce marine biodiversity (mainly by displacing native algae and altering seagrass beds) (BOUDOURESQUE *et al.*, 1992; VERLAQUE & FRITAYRE, 1994a,b; de VILLELE & VERLAQUE, 1995; CECCHERELLI & CINELLI 1997, 1999a), disturb zoobenthos (BELLAN-SANTINI *et al.*, 1994; HARMELIN-VIVIEN *et al.*, 1996) and modify organic and inorganic components of the sediment (CHISHOLM & MOULIN 2003). The *C. taxifolia* impact differs also according to the sensitivity and susceptibility of macrophyte assemblages (PIAZZI *et al.*, 2001a; VERLAQUE & FRITAYRE, 1994a, b; de VILLELE & VERLAQUE, 1995; BALATA *et al.*, 2004). Dramatic decreases (with impoverishment reaching up to 75%) have been observed in photophilic subtidal assemblages of rocky substrates, which appear particularly vulnerable to invasions (VERLAQUE & FRITAYRE 1994a, b; KLEIN *et al.*, 2005). *Caulerpa taxifolia*, like *C. racemosa*, especially colonizes the *Cymodocea nodosa* meadows and sparse *Posidonia oceanica* beds, causing the decay and regression of seagrasses (MEINESZ & HESSE 1991; BOUDOURESQUE *et al.*, 1992; MEINESZ *et al.*, 1993; CECCHERELLI & CINELLI, 1997, 1998, 1999a). In invaded *P. oceanica* meadows, the percentage of dead shoots can reach up to 45% and the living shoots possess abnormal yellowish leaves (de VILLELE & VERLAQUE, 1995). Even a facilitative effect of seagrasses on *C. taxifolia* has been demonstrated, which may cause indirect negative effects on seagrasses (CECCHERELLI & CINELLI, 1997, 1998). Invasion appears to be successful when seagrass meadows are already experiencing a decline as a result of deteriorated environmental quality. There are suggestions that *C. taxifolia* is not capable of invading the dense and healthy *P. oceanica* meadows (MARBÀ *et al.*, 1996, 2005; CECCHERELLI & CINELLI, 1999b; JAUBERT *et al.*, 1999; PEIRANO *et al.*, 2005).

Impoverishment has also been reported in faunal assemblages. Polychaeta and mainly amphipod abundance (and to a lesser degree species richness) has been reduced), whereas the molluscan community appears either to be benefited or to be impacted the least (BELLAN-SANTINI *et al.*, 1994, 1996). Decreases have been observed in fish species in number, density and biomass (HARMELIN-VIVIEN *et al.*, 1996; GELIN *et al.*, 1998; RELINI *et al.*, 1998) along with an increase in numbers of green forms of labrid fish in populations living within *C. taxifolia* meadows (ARIGONI *et al.*, 2002). In contrast, other authors (FRANCOUR *et al.*, 1995; GELIN *et al.*, 1998) have suggested that no simple relation exists between the presence of *C. taxifolia* and fish community.

Sargassum muticum

The macrophyte *Sargassum muticum* reported in the Venice lagoon, Italy (RIBERA SIGUAN, 2002) and the Thau lagoon and other parts of the Languedoc-Roussillon coast, France (BOUDOURESQUE, 1994; VERLAQUE, 2001) is known to have a direct impact on the indigenous floral assemblages. It inhibits their recruitment and growth (CRITCHLEY, 1983), even leading to the eradication of many species e.g. *Cystoseira barbata* in Venice (OCCHIPINTI AMBROGI, 2002b) and in the Thau lagoon (GERBAL *et al.*, 1985; BOUDOURESQUE, 1994). It is also reported to have altered the vegetal landscape of canals in the Venice lagoon, together with other invasive algae (CURIEL *et al.*, 1999), imposing a burden on the economy.

Womersleyella setacea*, *Acrothamnion preissii

Mediterranean turfs are largely composed of two introduced Rhodophyta: *Acrothamnion preissii*, colonising many parts of the western basin (BOILLOT *et al.*, 1982; CINELLI *et al.*, 1984; FERRER *et al.*, 1994; PIAZZI *et al.*, 1996, 2002), and *Womersleyella setacea* colonising wide zones throughout the Medi-

terranean Sea (AIROLDI *et al.*, 1995; ATHANASIADIS, 1997).

These turfs have an adverse impact on *Posidonia oceanica* meadows in the W. Mediterranean: the diversity of the epiphytic macroalgal community of the rhizomes has been found to decrease as the result of invading filamentous Rhodophyta (PIAZZI & CINELLI, 2000). In a study area in the Ligurian Sea (Italy) both total percentage cover and diversity were found to be lower in invaded areas than in control areas: the invasive Rhodophyta were reported to constitute more than 90% of the epiphyte cover in *P. oceanica* rhizomes and along with *C. racemosa* were discovered to occupy about 50% of macroalgal cover on dead *P. oceanica* mattes, throughout the year (PIAZZI & CINELLI, 2003). Similar high values have been recorded for *Womersleyella setacea* abundance in the area (AIROLDI *et al.*, 1995).

Womersleyella setacea is also known to have an impact on the coralligenous communities, as it has been found to form a monospecific layer covering the coralligenous substrata in the Scandola reserve (Corsica) (RIBERA & BOUDOURESQUE, 1995).

Asparagopsis armata*, *Codium fragile

These have been reported as forming monospecific coverages, dominating many algal assemblages. *Asparagopsis armata* is known to cover 100 % of the upper infralittoral (0-10 m depth) in winter in the NW Mediterranean and to dominate many infralittoral assemblages in the Marseilles area along with *Codium fragile* (RIBERA & BOUDOURESQUE, 1995). The dense populations of *A. armata* are maintained, probably because the main Mediterranean herbivores, i.e. the sea urchin *Paracentrotus lividus* and the fish *Sarpa salpa*, avoid it (SALA & BOUDOURESQUE, 1997).

Undaria pinnatifida*, *Desmarestia viridis*, *Antithamnion nipponicum

Impacts of *Desmarestia viridis*, *Undaria*

pinnatifida, and *Antithamnion nipponicum* (= *pectinatum*) on coastal lagoon ecosystems have also been reported (CURIEL *et al.*, 1998). Proliferations of *Laminaria japonica* have been reported in the Thau lagoon where its accumulation and decomposition have resulted in anoxia during summer (ANONYMOUS, 1982).

2.2. Vertebrates

Notwithstanding, definite changes in fish communities in the Levantine ecosystem have been attributed to Lessepsian migrants.

According to OREN (1957) populations of red mullet (*Mullus barbatus*) and hake (*Merluccius merluccius*) have been forced to migrate to deeper waters by the aliens *Upeneus moluccensis* and *Saurida undosquamis*, respectively. However GOLANI (1998, and personal communication) argues against the evidence of such displacement as 'it is difficult to determine whether the colonisers displaced the local species or whether the latter occupied the same bathymetric niche prior to its confamilial colonisation'. According to GOLANI (1998) there are these two cases that deserve further study. The populations of narrow-barred Spanish mackerel *Scomberomorus commerson* and the dragonet *Callionymus filamentosus* have dramatically increased at a time when the indigenous meager *Argyrosomus regius* (once of the most common commercial species in Israel) and three other confamilial to the *C. filamentosus* species, have almost completely disappeared.

Along the Lebanese rocky coasts, the Lessepsian migrants represent 13% of the species richness and 19% of the total abundance of individuals (HARMELIN-VIVIEN *et al.*, 2005), while almost half of the trawl catches on the Mediterranean coast of Israel consist of alien fish species (GOLANI & BEN TUVIA, 1995). Similarly invading species have been found to comprise 62% of the demersal fish biomass in the Gulf of Iskenderun, Turkey (GÜCÜ & BINGEL, 1994). The invasive fish dominate the structure and

function of littoral ecosystems on the Levantine coast, representing 50-90% of the fish biomass (GOREN & GALIL, 2005).

2.3. Invertebrates

In the Mediterranean, fast expanding invaders outcompete local species. This can have a major impact on the ecosystem as many sudden changes in faunal community diversity and structure are attributed to this competition. Another alarming issue is the number of unintentional introductions of pathogens and parasites, with species imported for aquaculture.

Mollusca

In coastal lagoons *Musculista senhousia* has been found to alter native benthic communities (CROOKS, 1998). Enormous proliferations of *Anadara inaequalis* in the N. Adriatic (RINALDI, 1985), replacing the native *Cerastoderma glaucum* (OCCHIPINTI AMBROGI, 2000), and of *Mya arenaria* in the Berre lagoon, Marseilles, (ZIBROWIUS, 2002) have been reported. The predatory gastropod *Rapana venosa* was initially regarded to have potential impact on native bivalves and on the environment in the Northern Adriatic (ZENETOS *et al.*, 2003), but no clear cut sign of impacts in the Northern Adriatic Sea has been recorded (OCCHIPINTI AMBROGI 2000, 2001a; SAVINI & OCCHIPINTI AMBROGI, 2006).

Imported mollusca for aquaculture purposes

Imported bivalves for aquaculture purposes (especially oysters and clams) are among the best-known examples of negative impacts of alien species in European seas in general and in Mediterranean in particular as the case of the Venice lagoon has demonstrated. The Manila clam *Ruditapes philippinarum* and the Pacific oyster *Crassostrea gigas* are considered as the most spectacular invasions in the lagoon of Venice (OCCHIPINTI AMBROGI, 2000).

Among alien species in the lagoon, the

Manila clam, *Ruditapes philippinarum* is surely the most well-adapted and widespread species. The species was introduced into the lagoon in 1983, to enhance the depressed fisheries and aquaculture activities. At present, Italy is the largest clam producer in Europe, with an estimated production in 1998 of 40 000 MT. The exploitation of the clam banks represents one of the main sources of environmental disturbance in the Venice lagoon. About 600 boats equipped with mechanical dredges, operate without any management strategies, causing heavy stress on benthic communities: a single fishing haul can affect the macrozoobenthos organism density: (PRANOVI *et al.*, 2004) and the whole lagoon ecosystem (PRANOVI *et al.*, 2003; SFRISO *et al.*, 2003).

As for *Crassostrea gigas*, that is also intensely cultivated in the brackish lagoons of Southern France. Collecting methods are not as impacting as in the case of burrowing clams but mostly related to the influence on particulate matter dynamics between the water column and the bottom (OCCHIPINTI AMBROGI, 2000).

Polychaeta

Fouling serpulid worms have become a nuisance in ports and marinas throughout the Mediterranean. *Hydroides elegans*, *H. dianthus*, *H. elegans*, *H. dirampha*, *Ficopomatus enigmaticus* and *Spirorbis marioni* are known to foul harbours throughout the Mediterranean and are regarded as major foulants on artificial surfaces (KOÇAK *et al.*, 1999; ZIBROWIUS, 2002).

According to a recent study of the Levantine coasts of Turkey 'the alien serpulid species dominated rocks, molluscs (Brachidontes pharaonis, Thais rugosa and Spondylus gaederopus) and artificial substrates (i.e. dock's pilings, ropes and tires), comprising more than 95% of the specimens found in these habitats. On the algae such as Ulva sp. and Cystoseira sp. sampled in this study, alien species accounted for more than 85% of the specimen' (ÇINAR, 2006).

The serpulid worm *Hydroides elegans* was found to comprise 65 % of the population in the polluted marinas but was only infrequently found in the non-polluted (KOÇAK *et al.*, 1999). Similarly spionid worms now constitute the key indicators of polluted areas. According to ÇINAR *et al.*, (2005) in Izmir bay (Turkey) *Streblospio gynobranchiata* and *Polydora cornuta* have replaced dominant indicator species such as *Malacoceros fuliginosus* and *Capitella capitata* reaching maximum densities of 34,270 ind m⁻² and 3170 ind m⁻², respectively, and accounting for more than 60% of total faunal populations in the majority of samples collected in winter. Their impact becomes more significant when considering that they constitute more than 90% of the total individuals and 50% of total biomass at some stations.

Crustacea

GALIL & ZENETOS (2002) while reviewing impacts of exotics on the eastern Mediterranean populations reported the rapid decrease of populations of the prawn *Melicertus kerathurus* and the shrimp *Alpheus dentipes*, attributed to invasive displacement by *Marsupenaeus* (= *Penaeus*) *japonicus*. A fisheries commodity, the shrimp *Squilla mantis* has been displaced into deeper waters by the mantis shrimp *Erugosquilla massavensis*.

The crab *Dyspanopeus sayi* was reported as very abundant in the lagoon of Venice (OCCHIPINTI AMBROGI, 2000) with a potential impact on native crabs (GALIL *et al.*, 2002) but already in 2001 it had almost disappeared in the canal of Venice (OCCHIPINTI AMBROGI, 2001b) and now its presence is limited to the marine sectors of the lagoon near the mouths (MIZZAN *et al.*, 2005).

Other Invertebrates: Echinoderms, Bryozoans, Corals and Foraminifera

The bryozoan *Tricellaria inopinata* was discovered to have a profound impact on the bryozoan community by colonizing all possible hard substrata in the lagoon of Ven-

ice and outcompeting the native species in adapting to the altered physical and chemical parameters of the ecosystem. (OCCHIPINTI AMBROGI, 2000; OCCHIPINTI AMBROGI & SAVINI, 2003). However, the synergy between the invader and the stress already imposed in the ecosystem is not clear (OCCHIPINTI AMBROGI, 2000).

Invasive displacement has also been reported in echinoderms. The sea star *Asterina burtoni* has increased in number in the Eastern Mediterranean, causing a rapid decrease in the population of the native *A. gibbosa* (GALIL & ZENETOS, 2002).

When assessing the scale and impact of ship-transported alien fauna in the Mediterranean, ZIBROWIUS (2002) reported the vast spread of the Scleractinian coral *Oculina patagonica* in Spain, the Ligurian coast of Italy, Alexandria, Lebanon, Israel, Tunisia (recently it was also reported in Greece, SALOMIDI *et al.*, 2006) and the dense populations of the ascidian *Microcosmus exasperatus* in Mediterranean harbours.

The Lessepsian foraminifer *Amphistegina lobifera* appears to be the worst invasive species in Turkey changing all the habitat type and coastal structure (MERİÇ *et al.*, 2002; YOKES & MERİÇ, 2004). It is actually regarded as a 'very good example to show how much a 'harmless' alien species can actually have the potential to destroy an ecosystem' (YOKES pers. commun.) *A. lobifera* populations in Turkey have expanded to such an unprecedented extent that the dead tests are locally accumulated as a 30-60 cm thick layer on the sea bed [Antalya, Kas, Kekova, Bes Adalar and Uc Adalar] (MERİÇ *et al.*, 2002) reaching densities of more than 350 specimens/g of sediment (YOKES & MERİÇ, 2004) suggesting a deposition rate of 2,5-4 cm/year. In Israel *A. lobifera* appears to be the most abundant of foraminiferans in hard substrata, reaching densities of almost 180 specimens /g (HYAMS *et al.*, 2002). *Amphisorus hemprichii* is also considered invasive in Turkish waters (YOKES pers. commun.) where it has been spreading rapidly in

southwestern coasts over the past two years. It has also been observed in Israel recently (HYAMS *et al.*, 2002).

3. Impact on socio-economic values

3.1 Impact on Fishery/Aquaculture (Including Pests)

Many cases of economic losses to fisheries and aquaculture associated with invasive species have been reported

Caulerpa taxifolia infestations are also renowned for their negative impact on fishing, both commercial and recreational (e.g.: tourism and SCUBA diving activities). *Womersleyella setacea* clogs up fishing nets in France (VERLAQUE, 1989) and the same happens with *Acrothamnion preissii* and fishing gear in Italy (CINELLI *et al.*, 1984) and with *Asparagopsis armata* (M. VERLAQUE pers. commun). Similarly, *Antithamnion nipponicum* (= *pectinatum*), *Caulerpa taxifolia*, *Codium fragile*, *Colpomenia peregrina*, *Heterosiphonia japonica*, *Desmarestia viridis*, *Grateloupia turuturu*, *Polysiphonia morrowii*, *Sargassum muticum* and *Undaria pinnatifida* foul shellfish aquaculture facilities in coastal lagoons and (VERLAQUE, 1994, 2001; CECERE *et al.*, 2000; M. VERLAQUE pers. commun.).

Dinoflagellate blooms of *Alexandrium taylori*, *Alexandrium catenella*, *Ostreopsis ovata* and *Coolia monotis* have an impact on the economy by impacting on fisheries (as well as on human health and tourist activities) (see 3.2.).

Displacement of native fish and prawns (due to *Upeneus moluccensis* and *Saurida undosquamis*, *Erugosquilla massavensis* reported in section 2) has also economic implications, as these animals are fishery commodities which now require more effort for their harvesting. Abundant populations of fish of no economic importance are another example of economic burden to fishermen as fish are caught in fishing gear and have to be discarded, as in the case of *Sphoeroides pachygaster* (GOLANI *et al.*, 2002).

The mollusc *Crepidula fornicata* has been found to compete with commercial shellfish (BLANCHARD, 1996). *Rapana venosa*, being an active predator of epifaunal bivalves, poses a serious threat to cultivated (as well as natural) populations of oysters and mussels (ZENETOS *et al.*, 2003).

Crustaceans have also been regarded as economic pests (GALIL *et al.*, 2002). *Dyspanopeus sayi* reported abundant in the Venice lagoon feeds on bivalves and may affect local clam farming (although its presence is now regarded as limited (OCCHIPINTI AMBROGI, 2001b; MIZZAN *et al.*, 2005)). *Eriocheir sinensis* reported in the Narbonne littoral lagoons is capable of causing considerable damage to fisheries by consuming netted fish and by cutting nets. *Callinectes sapidus* has also been reported to affect nets and netted fish, and finally *Charybdis longicollis* hampers trawl fishermen. The parasitic copepod *Mytilicola orientalis* has been found to infect the indigenous oyster *Ostrea edulis* (STOCK, 1993) as well as the blue mussel, *Mytilus edulis* and is considered a serious pest (HOLMES & MINCHIN, 1995).

The mass swarms of the jellyfish *Rhopilema nomadica* reported along the Levantine coast and as far north as the southeastern coast of Turkey, imposed a financial strain on fisheries (as well as tourism, and coastal installations, see 3.2. and 3.3) (GALIL & ZENETOS, 2002).

3.2 Impact on health

Harmful Algal Blooms (HABs) are increasing both in intensity and frequency in the Mediterranean Sea (GARCÉS *et al.*, 2000; PENNA *et al.*, 2005). HABs pose a significant and expanding threat to marine ecosystems and socioeconomic values (human health, amenities and fishery resources) either as toxin producers (toxic HABs) or as causatives of anoxic conditions (High-Biomass HABs). However, the mechanisms of the insurgence of blooms of toxic strains in resident populations are poorly known, even if it is suspected that long range transport

of cysts and propagules with ballast water might be involved.

Recurrent blooms of the non-toxic dinoflagellate *Alexandrium taylori* have been detected in the western Mediterranean (Catalan coast, Balearic Island, Sicily and Italian west coast) over the past 15 years. High biomass blooms during summer have led to deterioration of water quality for recreational uses, and to economic losses for the tourist industry (PENNA *et al.*, 2001; GIACOBBE & YANG, 1999; GARCÉS *et al.*, 1999, 2000, 2002; BASTERRETXEA *et al.*, 2005). Similar surface water discolorations have been observed in the Eastern Mediterranean (Amvrakikos Bay, Greece, STRATEGY Workshop, 2004).

Toxic red tide species are on the rise in many parts of the Mediterranean. A new PSP toxin in the Mediterranean strain of *Alexandrium andersonii*, previously reported as non-toxic, has been detected in Italy (Gulf of Naples) raising concern about potential toxic events (CIMINIELLO *et al.*, 1999). Similar concern has been raised in Alexandria (Egypt) as a result of the detection of *Alexandrium catenella* (MIKHAIL, 2001). *A. catenella* is known to cause toxic events in the western Mediterranean. In spring 1998, the first toxic event was detected, covering 100 km of the Catalan coast (GARCÉS *et al.*, 2000) recurring in 1999 (VILA *et al.*, 2001). A bloom observed in 1994 in Valencia was later attributed to this species (GÓMES *et al.*, 1996). The presence of *Gymnodinium catenatum* in the western Mediterranean has also been perceived as a probable 'protagonist of future red tide events' (GÓMEZ & CLAUSTRÉ, 2001).

Ostreopsis ovata and *Coolia monotis* have been detected in the Tyrrhenian Sea, (Tuscany coast and the islands of Elba, Giannutri, and Giglio), in Sicily, Sardinia and also in the Ionian Sea (*O. ovata* in Bari). The outbreaks of these red tides have been considered responsible for inflammation of the upper respiratory tract and conjunctivitis in swimmers (SIMONI *et al.*, 2003, 2004). Fur-

thermore, shellfish and *Arbacia* sp. mortality has been observed during *Ostreopsis ovata* blooms on Marina di Massa reefs and additional studies have indicated the presence of DSP-like and ciguatoxin-like toxins (SIMONI *et al.*, 2004). Potentially toxic epiphytic assemblages comprising the *Coolia monotis* (and genera *Ostreopsis*, *Prorocentrum* and *Amphidinium*) which have impacts not only on molluscs' safety but also on tourist activities as well, were recorded in Greek coastal waters in 2003 (STRATEGY Workshop, 2004).

In general, dinoflagellate blooms (such as those of *Alexandrium taylori*, *Alexandrium catenella*, *Ostreopsis ovata* and *Coolia monotis* in addition to their direct impact on human health, impact on tourist activities in the areas where they occur.

The jellyfish *Rhopilema nomadica* reported along the Levantine coast and as far north as the southeastern coast of Turkey, is most certainly a health issue to swimmers in the area, and has an impact on tourism (GALIL & ZENETOS 2002).

Invading fish also constitute a health threat to humans. Following the recent occurrence of *Lagocephalus sceleratus* (Gmelin, 1789) in the Mediterranean Sea, (AKYOL *et al.*, 2005), new findings revealed that the species is now very common along the Levantine coasts of Turkey (BILECENOGLU *et al.*, 2006) and the south Aegean (CORSINI *et al.*, 2006). The species is a potential risk to humans, since it contains tetrodotoxin (TTX) that may be a source of food poisoning. Two cases of poisoning of people who had consumed this fish were reported from Israel and Lebanon (GOLANI *et al.*, 2006).

Plotosus lineatus is notorious for being highly venomous, with venom glands located along the dorsal and pectoral spines (GOLANI, 2002). Several cases of injury were followed by hospitalization in Israel (GOLANI *et al.*, 2006). Other not so severe threats include: *Siganus luridus*, a food fish that is occasionally poisonous (with all spines slightly venomous), with very pain-

ful stinging but not lethal; several cases of ciguatera-like effects have been attributed to consumption of *S. luridus* (FISHBASE); *Siganus rivulatus* which has a very painful, but non-lethal, sting: all spines are slightly venomous (FISHBASE); *Seriola fasciata*, is associated with reports of ciguatera poisoning (FISHBASE) and *Spherooides pachygaster* which can be poisonous, due to its capacity to produce tetrodotoxin (nevertheless, some puffers are successfully exploited around the world and are highly valued as food).

3.3 Impact on Infrastructure

A financial burden associated with the proliferation of alien species is the mechanical removal of accumulated material on the beaches and the nuisance to tourism, as in the case of the removal of *Codium fragile* from the coasts of Marseille in the 1960s (BOUDOURESQUE, 1994) and the *Cladophora* sp. proliferation along the coasts of Cyprus (RIBERA & BOUDOURESQUE, 1995). *Sargassum muticum*, *Undaria pinnatifida* and *Antithamnion nipponicum* (= *pectinatum*) are regarded as navigational hazards to the users of the canals along many of the Venice lagoon canals as they alter the sea bed and canal landscape and entangle boats (RIBERA & BOUDOURESQUE, 1995; OCCHIPINTI AMBROGI & SAVINI, 2003). *Styopodim schimperi* has also been reported to have an impact on infrastructure facilities. The species is large ecosystem engineer and seasonally huge quantities are cast ashore on the Syrian beaches. (M. VERLAQUE pers. commun.).

Fouling serpulid worms have become a nuisance in ports and marinas throughout the Mediterranean. *Hydroides elegans*, *H. dianthus*, *H. dirampha*, *Ficopomatus enigmaticus* and *Spirorbis marioni* are known to foul harbours throughout the Mediterranean and are regarded as major foulants of artificial surfaces (KOÇAK *et al.*, 1999; ZIBROWIUS, 2002). *Ficopomatus enigmaticus* and *H. dianthus* are building extensive reefs in the lagoon of Orbetello (Tuscany, Italy).

Both formed layers of 1m thick which covered about 7 % and 1.5% of the lagoon area respectively (BIANCHI & MORRI, 2001).

Pomatoleios kraussii together with an alien bivalve species, *Brachidontes pharaonis*, may form a calcareous belt the thickness of which reaches approximately 3-5 cm. Rocks in 0-1 m depths in Iskenderun harbour were largely covered with this species. In Mersin Bay, the population density of *Hydroides operculatus* was very high. These two species were also observed on hulls of fishing boats in harbours, indicating that they have a potential to cause economic trouble to ship owners and others using sea-water intake pipes (ÇINAR, 2006).

The bivalvia mollusca *Spondylus spinosus*, *Chama pacifica*, *Crassostrea gigas*, which live on hard substrata, can thrive in harbour environments. The dense aggregations they form, may act as 'ecosystem engineers' generating solid reefs.

Fouling/clogging is also a problem with the mass swarms of the jellyfish *Rhopilema nomadica* reported along the Levantine coast and as far north as the southeastern coast of Turkey where they are reported to have clogged coastal installations (GALIL & ZENETOS, 2002). Finally, the crustacean *Eriocheir sinensis* has a documented impact by damaging river banks through burrowing (GALIL *et al.*, 2006).

Discussion

In the Mediterranean the impact of invasive species on biodiversity (from species to community to ecosystem level) and to a lesser extent on socioeconomic values and health have been partially covered in various syntheses (BOUDOURESQUE, 1994; BOUDOURESQUE & RIBERA, 1994; VERLAQUE, 1994; RIBERA & BOUDOURESQUE, 1995; GOLANI, 1998; GALIL, 2000a&b; OCCHIPINTI AMBROGI, 2000, 2001a, 2002a,b; ZIBROWIUS, 2002; BOUDOURESQUE & VERLAQUE, 2002a; GALIL & ZENETOS, 2002; GO-

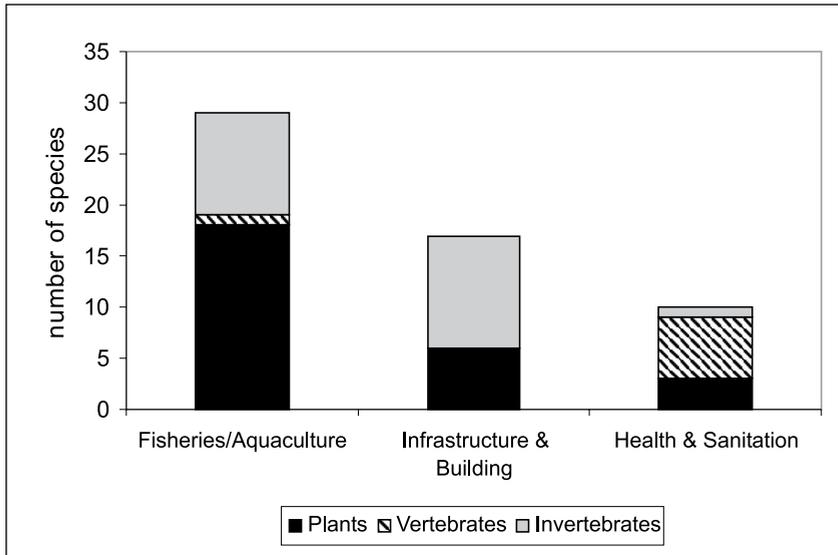


Fig. 1: Numbers of ‘worst IAS’ impacting on socioeconomy per taxonomic group.

FAS & ZENETOS, 2003; OCCHIPINTI-AMBROGI & SAVINI, 2003; GOREN & GALIL, 2005).

A preliminary list of the 100 ‘worst IAS’ in the Mediterranean by taxonomic groups (Table 1) was compiled through a literature search. All 100 ‘worst IAS’ have an impact on biodiversity (35 documented cases and the rest pose a potential threat) and 43 of them have a documented impact on socio-economic values. Considering that the most recent inventory of marine alien species in the Mediterranean has documented the existence of 745 aliens, out of which 385 are established (ZENETOS *et al.*, 2005), the list of ‘worst IAS’ is expected to increase

The impact of the ‘worst IAS’ on socio-economical values is shown graphically in Figure 1.

The Figure however is rather biased towards the effort and resources (both human and financial) devoted to the study of the impact of certain species/taxonomic groups. Thus, although the marine plants (phytobenthos and phytoplankton) are fairly well studied, it has to be noted that taxonomic difficulties often prevent the incontrovert-

ible designation of alien phytoplankton species related to HABs. Less attention has been paid to the impact of vertebrates and even less to invertebrates. Exceptions are the studies on *Ruditapes philippinarum* (review by OCCHIPINTI AMBROGI 2002b) and on polychaetes (ÇINAR, 2006).

Another issue that has to be emphasized is that absence from the list does not imply that a species poses a lesser threat. It must be pointed out that some of the species that have been nominated as among 100 of the ‘World’s Worst’ invaders (ISSG, 2006), although present in the Mediterranean, are not included in our preliminary list of ‘worst IAS’, mainly because of their sporadic recording and minimal dispersal. These are:

***Mnemiopsis leidyi*:** Known for causing anoxia in bottom-near waters due to massive deposition of dead individuals and serious economic losses due to the imposed decline in fisheries stock, as well as clogging water intakes in the Black Sea. It has recently invaded the Baltic Sea and North Sea (JAVIDPOUR *et al.*, 2006). In the Mediterranean it has been reported in Turkey (UYSAL & MUTLU, 1993) and Greece (SHIGANOVA

et al., 2001) in low numbers, where it is not known to have any impact.

Liza haematocheila (Temminck & Schlegel, 1845) [=*Mugil soiyu* Basilewsky, 1855]: One of the six alien species which have a significant impact on the Black Sea ecosystem. Although present in the Mediterranean, no impact has been reported.

Gambusia affinis: potential pest according to FISHBASE. Present in Greece, Italy (1919-21), Spain (1921), Cyprus (1988), Albania, Turkey, Malta, Bosnia, Slovenia, but no impact has been reported.

Abundant populations of alien fish without direct economic use are also not included in the 'worst IAS' despite the fact that they can be considered as pests, an economic burden to fishermen who have to discard them from their gear (GOLANI *et al.*, 2002). These are: *Cynoglossus sinusarabici*, *Stephanolepis diaspros*, *Lagocephalus spadiceus* and *Lagocephalus suezensis*.

Bacteria (but also other parasites and disease causing organisms) associated with aquaculture are also not included despite the fact that they are considered a major threat connected with the development of the worldwide transport of marine biota and hence of paramount importance when dealing with alien species. One of the reasons is that with the exception of a few studies (e.g. the parasite *Perkinsus atlanticus* and the bacterium *Photobacterium damsela* subsp. *Piscicida*), there is little data on the Mediterranean alien bacteria/parasites.

The parasite *Perkinsus atlanticus*, first detected in Spain in 1990 (SANTMARTÍ *et al.*, 1995), had been widely distributed along the Catalan coast by 1994, where it has been found in *Ruditapes decussatus* and *Ruditapes philippinarum* in the Ebro river delta (RIERA *et al.*, 1995). It was associated with high mortalities of both bivalve species in 1990 and also of *Ostrea edulis* and *Crassostrea gigas* (SANTMARTÍ *et al.*, 1995).

The bacterium *Photobacterium damsela* subsp. *piscicida* (formerly *Pasteurella piscicida*) reported in the Mediterranean since

1991 (associated with a fish fry imported for aquaculture) has been responsible for fish mortalities due to Pasteurellosis. From 1990 it has caused economic losses in different Mediterranean countries including France, Italy, Spain, Greece, Turkey and Malta (BAKOPOULOS *et al.*, 1995, 1997; CANDAN *et al.*, 1996) affecting primarily gilthead sea bream (*Sparus aurata*), seabass (*Dicentrarchus labrax*) and sole (*Solea* spp.).

On the other hand, recent studies have demonstrated a lesser impact of species that had been initially considered to have a serious impact on biodiversity in the Mediterranean (e.g. *Rapana venosa* and *Dyspanopaeus say* in the Venice lagoon: MIZZAN *et al.*, 205; SAVINI, & OCCHIPINTI AMBROGI, 2006).

As pointed out above, selecting the 'worst' IAS is a difficult task that attracts much attention and scientific criticism. The debate is ongoing since even the documentation of the impact of IAS can be controversial, because of the lack of clear evidence on the nature of such impacts and on the interaction between invaders and other anthropogenic stressors that influence such impact (RUIZ *et al.*, 1999). Invasive success (and impact) depends not only on the invaders' competitive advantage over native enemies/competitors, but also on the environmental characteristics of the host ecosystem (primarily species richness and disturbance) and the level of stress already imposed on it (RIBERA & BOUDOURESQUE, 1995; COHEN & CARLTON, 1998; GOODWIN *et al.*, 1999; OCCHIPINTI AMBROGI, 2000; KEANE & CRAWLEY, 2002). These environmental characteristics that render an environment or habitat vulnerable or resistant to biological introductions are the focus of debate. The hypothesis known as Elton's 'biotic resistance hypothesis' (ELTON, 1958), which assumes that a species-rich ecosystem will be more resistant to introductions than a species-poor one, has been verified by several researchers (LOOPE & MUELLER-DOMBOIS, 1989; PIMM, 1989; REJMÁNEK, 1989; SIM-

BERLOFF, 1989; LODGE, 1993).

In the Mediterranean, there is evidence supporting the theory as environments under stress (polluted or physically degraded) appear to be more prone to invasion than pristine sites (RIBERA & BOUDOURESQUE, 1995; KOÇAK *et al.*, 1999; GALIL, 2000b; OCCHIPINTI AMBROGI, 2000; OCCHIPINTI-AMBROGI & SAVINI, 2003; see also references in 2.1 Impact on Biodiversity - *Caulerpa* species). In addition, the fact that environments that are known for their low biodiversity (lagoonal or estuarine habitats and polluted harbours) are recipient areas for IAS related to mariculture and vessel-transported aliens respectively (ZIBROWIUS, 1992), provide further support for this theory. However there are suggestions of the opposite. When examining the frequency of introduced macrophytes in the shallow subtidal macrophytic assemblages along the French Mediterranean coast, no relationship was established between the number of introduced species, the species richness of the host macrophyte assemblages and disturbances (KLEIN *et al.*, 2005).

While recent attention has focused on the adverse impacts of accidentally introduced species, beneficial aspects of introductions are also known, as alien species have become fisheries commodities for the aquaculture and fishing community and industry. Intentionally introduced species have significantly contributed to aquaculture production (FAO DIAS 1998), as well as fisheries (stocking) and recreational angling (MINCHIN & ROSENTHAL, 2002).

A well known example is the successful stocking of the Venice lagoon with the introduction of the oyster *Crassostrea gigas* and the clam *Tapes philippinarum* in order to replace depleted populations of two native species. Both species are fully acclimatised and exploited by fishermen (OCCHIPINTI AMBROGI, 2002a) Similarly, *Marsupenaeus japonicus*, initially imported for aquaculture, has become commercially important in the Aegean Sea and the Central and West-

ern Mediterranean both in aquaculture and in fisheries as wild populations have been established. The species is also exploited by fishermen in the Levantine where it invaded via the Suez Canal (GALIL *et al.*, 2002).

However, considering the high permeability of aquaculture facilities, all introductions for the purpose of aquaculture should be regarded and administered as possible, even probable, introductions into the wild. To reduce environmental and other risks, the ministries responsible and the aquaculture industry need to pursue management practices that prevent escapes and reduce the number of inadvertent releases. Proper decision protocols, containment, contingency planning, and end-user education are proactive means of coping with potentially invasive species (ICES 2005; HEWITT *et al.*, 2006).

Even unintentionally introduced species that have exhibited an invasive character have become locally of commercial importance. Not surprisingly invading prawns make up most of the catches along the coasts of Egypt and Israel (GALIL, 1993).

Examples of alien species that have become fishery resources in the Levantine area are: the gastropod *Strombus persicus*; the prawns *Marsupenaeus japonicus*, *Metapenaeus monoceros*, *M. stebbingi*, *Penaeus semisulcatus* and *Melicertus hathor*; the crabs *Portunus pelagicus*, and *Callinectes sapidus* (EEA, 1999; GALIL *et al.*, 2002, GALIL & ZENETOS, 2002) and species of fish such as the mullids *Upeneus moluccensis* and *U. pori*, the Red sea obtuse barracuda *Sphyranea chrysotaenia*, the clupeids *Dussummiera elopsoides* and *Herklotsichthys punctatus*, the brushtooth lizard fish *Saurida undosquami* as well as the *Etrumeus teres*, *Hemiramphus far*, *Atherinomorus lacunosus*, *Sargocentron rubrum*, *Sillago sihama*, *Alepes djedaba*, *Liza carinata*, *Gymnamodytes semisquamatus*, *Siganus luridus*, *S. rivulatus*, *Scomberomorus commerson* and *Solea senegalensis* (GOLANI *et al.*, 2002).

Protection against invasive species has been the focus of many environmental pro-

grams, initiatives and policies and strategies. The Bern Convention on the Conservation of European Wildlife and Natural Habitats has developed a European Strategy on Invasive Alien Species, which offers specific advice to countries and international organisations on measures to combat the threat. In February 2004, the International Maritime Organisation (IMO) adopted the International Convention for the Control and Management of Ship's Ballast Water and Sediments. The Convention will in the short term require ships to exchange their ballast water in the open sea. Later, ballast water quality standards will come into force. Ratification is unfortunately only proceeding slowly and it seems unlikely that the Convention will come into force in the near future. The implementation of the EU Marine Strategy Directive, currently under development, should include measures to limit the spread of IAS in European Seas.

The information value of the preliminary list regards not only pressure on biodiversity but is increased through the focus on socio-economic impacts at the species level. As such, it provides the basis to examine the feasibility of endorsing indicator species within the Mediterranean for monitoring aliens and their impact for an integrated ecosystem-based management approach over the entire area. Considering the high number of new introductions in the Mediterranean (ZENETOS *et al.*, 2005), it is inevitable that new invaders with detrimental effects will pop up in the basin. Keeping records up to date is difficult and highlights the need for continuous research on the issue, not only recording the distribution of species but focusing on the impacts of the most invasive ones.

The work will continue under the Integrated Project (IP) SESAME (Southern European Seas: Assessing and Modelling Ecosystem Changes). The list of 'worst IAS' is considered a good management tool in order to assess both the current status of the ecosystem of the region and the impact of climate change and anthropogenic activities. Thus, it is fore-

seen that individual fact sheets on worst invasive species and their impact on biodiversity and socio-economy will be produced for the Mediterranean and the Black Sea.

Acknowledgements

The work was initiated under the auspices of the SEBI2010 - Streamlining European 2010 Biodiversity Indicators - Expert Group 5: Numbers and costs of invasive alien species. The programme is performed in collaboration between EEA, ECNC (the European Centre for Nature Conservation) and UNEP-WCMC. We would like to thank the participants of the SEBI WG5 (Melanie Josefson, Jose Rico, Franco Andaloro, Francesco Passarelli, and MA. Pancucci-Papadopoulou), who have substantially contributed to the nomination of some Worst Invasive Species. Special thanks are due to A. Occipinti Ambrogi and M. Verlaque whose constructive criticism and suggestions have improved the manuscript.

References

- AIROLDI, L., RINDI, F. & CINELLI, F., 1995. Structure, seasonal dynamics and reproductive phenology of a filamentous turf assemblage on a sediment influenced, rocky subtidal shore. *Botanica Marina*, 8: 227-237.
- AKYOL, O., ÜNAL, V., CEYHAN, T. & BILECENOGLU, M., 2005: First record of the Silverside Blaasop, *Lagocephalus sceleratus* (Gmelin, 1789), in the Mediterranean Sea. *Journal of Fish Biology*, 66: 1183-1186.
- ANONYMOUS, 1982. Status (1980) of introduction of non-indigenous marine species to North Atlantic waters. *ICES Cooperative Research Report*, 116: 1-87.
- ARGYROU, M., DEMETROPOULOS, A. & HADJICHRISTOPHOROU, M., 1999. Expansion of the macroalga *Caulerpa racemosa* and changes in soft bottom macrofaunal assemblages in Moni

- Bay, Cyprus. *Oceanologica Acta*, 22: 517-528.
- ARIGONI, S., FRANCOUR, P., HARME-LIN-VIVIEN, M. & ZANINETTI, L., 2002. Adaptive colouration of Mediterranean labrid fishes to the new habitat provided by the introduced tropical alga *Caulerpa taxifolia*. *Journal of Fish Biology*, 60 (6): 1486-1497.
- ATHANASIADIS, A., 1997. North Aegean marine algae. IV. *Womersleyella setacea* (Hollenberg) R.E. Norris (Rhodophyta, Ceramiales). *Botanica Marina*, 40: 473-476.
- BAKOPOULOS, V., ADAMS, A. & RICHARDS, R. H., 1995. Some biochemical properties and antibiotic sensitivities of *Pasteurella piscicida* isolated in Greece and comparison with strains from Japan, France and Italy. *Journal of Fish Diseases*, 18: 1-7.
- BAKOPOULOS, V., PERIC, Z., RODGER, H., ADAMS, A. & RICHARDS, R. H., 1997. First report of fish pasteurellosis from Malta. *Journal of Aquatic Animal Health*, 9: 26-33.
- BALATA, D., PIAZZI, L. & CINELLI, F., 2004. A comparison among assemblages in areas invaded by *Caulerpa taxifolia* and *C. racemosa* on a subtidal Mediterranean rocky bottom. *Marine Ecology*, 25 (1): 1-13.
- BASTERREXTEA, G., GARCÉS, E., JORDI, A., MASÓ, M. & TINTORE, J., 2005. Breeze conditions as a favouring mechanism of *Alexandrium taylori* blooms at a Mediterranean beach. *Estuarine Coastal and Shelf Science*, 62 (1-2): 1-12.
- BELLAN-SANTINI, D., MAUD, P.M., BELLAN, G. & VERLAQUE, M. 1994. Résultats préliminaires sur la faune d'invertébrés du peuplement à *Caulerpa taxifolia* des côtes de Provence (Méditerranée Nord-occidentale). pp 365-369. In: *First International workshop on Caulerpa taxifolia*. Boudouresque, C.F., Meinesz, A. & Gravez, V. (Eds.), Groupement d'Intérêt Scientifique Posidonie Publishers, Marseille, France.
- BELLAN-SANTINI, D., ARNAUD, P.M., BELLAN, G. & VERLAQUE, M., 1996. The influence of the introduced tropical alga *Caulerpa taxifolia*, on the biodiversity of the Mediterranean marine biota. *Journal of the Marine Biological Association of the United Kingdom*, 76(1), 235-237.
- BIANCHI, C.N & MORRI, C., 2001. The battle is not to the strong: Serpulid reefs in the lagoon of Orbetello (Tuscany, Italy). *Estuarine, Coastal and Shelf Science*, 53: 215-220.
- BILECENOGLU, M., KAYA, M. & AKALIN, S., 2006. Range expansion of silver-stripe blaasop, *Lagocephalus sceleratus* (Gmelin, 1789), to the northern Aegean Sea. *Aquatic Invasions*, 1 (4): 289-291.
- BLANCHARD, M., 1996. Spread of the slipper limpet *Crepidula fornicata* (L., 1758) in Europe. Current state and consequences. *Scientia Marina*, 61 (Suppl. 2): 109-118.
- BOILLOT, A., CARAM, B. & MEINESZ, A., 1982. Sur l'*Acrothamnion preissii* Rhodophycée (Ceramiales, Ceramiacée) nouvelle pour la flore française. *Cryptogamie, Algologie*, 3: 21-24.
- BOUDOURESQUE, C.-F., 1994. Les espèces introduites dans les eaux côtières d'Europe et de Méditerranée: état de la question et conséquences. pp. 8-27. In: *Introduced species in coastal waters*. Boudouresque, C.F., Briand, F. & Nolan, C. (Eds.), Luxembourg: European Commission publications.
- BOUDOURESQUE, C.-F. & RIBERA, M.A., 1994. Les introductions d'espèces végétales et animales en milieu marin - conséquences écologiques et économiques et problèmes législatifs. pp. 29-102. In: *First International workshop on Caulerpa taxifolia*. Boudouresque, C.F., Meinesz, A. & Gravez, V. (Eds.), Groupement d'Intérêt Scientifique Posidonie Publishers, Marseille, France.
- BOUDOURESQUE, C.-F. & VERLAQUE, M. 2002a. Assessing scale and impact of ship-transported alien macrophytes

- in the Mediterranean Sea. pp.53-61. In: *Alien marine organisms introduced by ships in the Mediterranean and Black seas*. F. Briand (Ed.), CIESM Workshop Monographs 20. Monaco.
- BOUDOURESQUE, C.-F. & VERLAQUE, M., 2002b. Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes. *Marine Pollution Bulletin*, 44: 32-38.
- BOUDOURESQUE, C.-F., MEINESZ, M., VERLAQUE, M. & KNOEPPFLER-PEGUY, M., 1992. The expansion of the tropical alga *Caulerpa taxifolia* (Chlorophyta) in the Mediterranean. *Cryptogamie, Algologie*, 13: 144-145.
- BOUDOURESQUE, C.-F., MEINESZ, A., RIBERA, MA. & BALLESTEROS, E., 1995. Spread of the green alga *Caulerpa taxifolia* (Caulerpales, Chlorophyta) in the Mediterranean: Possible consequences of a major ecological event. *Scientia Marina*, 59 (Dec) Suppl. 1: 21-29.
- BREITHAUPT, H., 2003. Aliens on the shores. Biodiversity and national economies are being threatened by the invasion of non-native species. *EMBO reports*, 4 (6): 547-550.
- CANDAN, A., KUCUKER, M. A. & KARATAS, S., 1996. Pasteurellosis in cultured sea bass (*Dicentrarchus labrax*) in Turkey. *Bulletin of the European Association of Fish Pathologists*, 16: 150-153.
- CARLTON, J.T., 1989. Man's role in changing the face of the ocean: biological invasions and implications for conservation of near-shore environments. *Conservation Biology*, 3: 265-273.
- CARLTON, J.T. & GELLER, J.B. 1993. Ecological roulette: the global transport of non-indigenous marine organisms. *Science*, 261, 78-82.
- CECCHERELLI, A, G. & CAMPO, D., 2002. Different effects of *Caulerpa racemosa* on two co-occurring seagrasses in the Mediterranean. *Botanica Marina*, 45: 71-76.
- CECCHERELLI, G. & CINELLI, F., 1997. 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. *Journal of Experimental Marine Biology and Ecology*, 217: 165-177.
- CECCHERELLI, G. & CINELLI, F., 1998. Habitat effect on spatiotemporal variability in size and density of the introduced alga *Caulerpa taxifolia*. *Marine Ecology Progress Series*, 163: 289-294.
- CECCHERELLI, G. & CINELLI, F., 1999a. The role of vegetative fragmentation in dispersal of the invasive alga *Caulerpa taxifolia* in the Mediterranean. *Marine Ecology Progress Series*, 182, 299-303.
- CECCHERELLI, G. & CINELLI, F., 1999b. Effects of *Posidonia oceanica* canopy on *Caulerpa taxifolia* size in a north-western Mediterranean Bay. *Journal of Experimental Marine Biology and Ecology*, 240:19-36.
- CECCHERELLI, G., PIAZZI, L. & CINELLI, F., 2000. Response of nonindigenous *Caulerpa racemosa* (Forsskål) J. Agardh to the native seagrass *Posidonia oceanica* (L.) Delile: effect of density of shoots and orientation of edges of meadows. *Journal of Experimental Marine Biology and Ecology*, 243: 227-240.
- CECERE, E., PETROCELLI, A. & SARACINO, D., 2000. *Undaria pinnatifida* (Fucophyceae, Laminariales) spread in central Mediterranean: its occurrence in the Mar Piccolo of Taranto (Ionian Sea, southern Italy). *Cryptogamie, Algologie*, 21: 305-309.
- CHISHOLM, J.R.M. & MOULIN, P., 2003. Stimulation of Nitrogen Fixation in Refractory Organic Sediments by *Caulerpa taxifolia* (Chlorophyta). *Limnology and Oceanography*, 48(2): 787-794.
- CHISHOLM, J.R.M., DAUGA, C., AGERON, E. & GRIMONT, P.A.D., 1996. 'Roots' in mixotrophic algae. *Nature*, 381: 382.
- CIMINIELLO, P., FATTORUSSO, E., FORINO, M. & MONTRESOR, M.,

1999. A new PSP-like toxin in *Alexandrium andersonii* (Dinophyceae). *Harmful Algae News*, 18.
- ÇINAR, M.E., 2006. Serpulid species (Polychaeta: Serpulidae) from the Levantine coast of Turkey (eastern Mediterranean), with special emphasis on alien species. *Aquatic Invasions* 1(4): 223-240.
- ÇINAR, M.E., ERGEN, Z., DAGLI, E. & PETERSEN, M.E., 2005. Alien species of spionid polychaetes (*Streblospio gynobranchiata* and *Polydora cornuta*) in Izmir Bay, eastern Mediterranean. *Journal of the Marine Biological Association of the United Kingdom*, 85: 821- 827.
- CINELLI, F., SALGHETTI-DRIOLI, U. & SERENA, F., 1984. Nota sull' areale di *Acrothamnion preissii* (Sonder) Wollaston nell Alto Tirreno. *Quadri di Museo di Storia Naturale Livorno*, 5: 57-60.
- COHEN, A.N. & CARLTON, J.T., 1998. Accelerating invasion rate in a highly invaded estuary. *Science*, 279: 555-558.
- CORSINI, M., MARGIES, P., KONDILATOS, G. & ECONOMIDIS, P.S., 2006. Three new exotic fish records from the SE Aegean Greek waters. *Scientia Marina*, 70 (2): 319-323.
- CRITCHLEY, A.T., 1983. The establishment and increase of *Sargassum muticum* (Yendo) Fensholt population within the Solent area of Southern Britain. II. An investigation of the increase in canopy cover of the alga at low water. *Botanica Marina*, 26, 547-552.
- CROOKS, J.A., 1998. Habitat alteration and community-level effects of an exotic mussel *Musculista senhousia*. *Marine Ecology Progress Series*, 162: 137-152.
- CURIEL, D., BELLEMO, G., MARZOCCHI, M., SCATTOLIN, M. & PARISI, G., 1998. Distribution of introduced Japanese macroalgae *Undaria pinnatifida*, *Sargassum muticum* (Phaeophyta) and *Acrothamnion pectinatum* (Rhodophyta) in the lagoon of Venice. *Hydrobiologia*, 385: 17-22.
- DELGADO, O., RODRIGUEZ PRIETO, C., GACIA, E. & BALLESTEROS, E., 1996. Lack of severe nutrient limitation in *Caulerpa taxifolia* (Vahl) C Agardh, an introduced seaweed spreading over the oligotrophic northwestern Mediterranean. *Botanica Marina*, 39(1): 61-67.
- DE VILLELE, X. & VERLAQUE, M., 1995. Changes and degradation in a *Posidonia oceanica* bed invaded by the introduced tropical alga *Caulerpa taxifolia* in the north-western Mediterranean. *Botanica Marina*, 38: 79-87.
- DUMAY, O., FERNANDEZ, C. & PERGENT, G., 2002. Primary production and vegetative cycle in *Posidonia oceanica* when in competition with the green algae *Caulerpa taxifolia* and *Caulerpa racemosa*. *Journal of Marine Biological Association of the United Kingdom*, 82: 379-387.
- EEA. 1999. *State and pressures of the marine and coastal Mediterranean environment*. Environmental Assessment Series 5, Luxembourg, Office for the Official Publications of the European Communities.
- ELTON, CS., 1958. *The ecology of invasions by animals and plants*. John Wiley & Sons, New York. 181 p.
- EPA-United States Environmental Protection Agency, 2001. <http://www.epa.gov/gmpo/nonindig.html>. *Aquatic nuisance species*, Annual Report, 2001.
- FAO Database on Introductions of Aquatic Species (DIAS). 1998. *Database on Introductions of Aquatic Species*. Online. Available HTTP: <http://www.fao.org/waicent/faoinfo/fishery/statist/fisoft/dias/index.htm>
- FERRER, E., RIBERA, M.A. & GOMEZ-GARRETA, A. 1994. The spread of *Acrothamnion preissii* (Sonder) Wollaston (Rhodophyta, Ceramiaceae) in the Mediterranean Sea: new record from the Balearic Islands. *Flora Mediterranea*, 4: 163-166.
- FERRER, E., RIBERA, M.A. & GOMEZ-GARRETA A., 1995. Efect des extraits de *Caulerpa taxifolia* (Vahl.) C. Agardh

- sur deux macrophytes. p. 28. In: *Méditerranéennes. Rapports et procès-verbaux des réunions*, Commission internationale pour l'Exploration scientifique de la mer Méditerranée, 34 (Abstr).
- FERRER, E., GOMEZ-GARRETA, A. & RIBERA, M.A., 1997. Effect of *Caulerpa taxifolia* on the productivity of two Mediterranean macrophytes. *Marine Ecology Progress Series*, 149: 279-287.
- FISHBASE: website www.fishbase.org
- FRANCOUR, P., HARMELIN-VIVIEN, M., HARMELIN, J.G. & DUCLERC, J., 1995. Impact of *Caulerpa taxifolia* colonization on the littoral ichthyofauna of North-Western Mediterranean Sea: preliminary results. *Hydrobiologia*, 300/301: 345-353.
- GALIL, B.S., 1986. Red Sea decapods along the Mediterranean coast of Israel: ecology and distribution. In: *Environmental quality and ecosystem stability, vol. IIIA/B*. Dubinsky, Z. & Steunberger, Y. (Eds.), pp. 179-183, Ramat-Gan, Bar-Ilan University Press.
- GALIL, B.S., 1993. Lessepsian migration: New findings on the foremost anthropogenic change in the Levant Basin fauna. p. 307-318. In: *Symposium Mediterranean Seas 2000*, Della Croce (Ed.) NFR.
- GALIL, B.S., 2000a. The 'Silver Lining' -the economic impact of Red Sea species in the Mediterranean. p.265-267. In: *Marine Bioinvasions: Proceedings of the First National Conference*. J. Peterson (Ed.), Cambridge, Massachusetts, MIT Press.
- GALIL, B.S., 2000b. A sea under siege -alien species in the Mediterranean. *Biological Invasions*, 2: 177-186.
- GALIL, B.S. & ZENETOS, A., 2002. A sea change -exotics in the Eastern Mediterranean Sea. p.325-336. In *Invasive Aquatic Species in Europe. Distribution, Impacts and Management*. E. Leppakoski, S., Gollasch & S. Olenin (Eds.), Dordrecht, Boston, London. Kluwer Academic Publishers.
- GALIL, B.S., SPANIER, E. & FERGUSON, W.W., 1990. The Scyphomedusae of the Mediterranean coast of Israel, including two Lessepsian migrants new to the Mediterranean. *Zoologische Mededelingen*, 64: 95-105.
- GALIL, B.S., FROGLIA, C. & NOEL, P.Y., 2002. *CIESM Atlas of Exotic Species in the Mediterranean. Volume 2: Crustaceans: decapods and stomatopods*. F. Briand (Ed.), Monaco, CIESM Publishers, 192p.
- GALIL, B.S., FROGLIA, C. & NOEL, P.Y., 2006. *CIESM Atlas of Exotic Crustaceans in the Mediterranean*. On Line: <http://www.ciesm.org/atlas/appendix2.html>.
- GARCÉS, E., MASÓ, M. & CAMP, J., 1999. A recurrent and localized dinoflagellate bloom in a Mediterranean beach. *Journal of Plankton Research*, 21: 2373-239.
- GARCÉS, E., MASÓ, M., VILA, M. & CAMP, J., 2000. Harmful algae events in the Mediterranean: are they increasing? *Harmful Algae News*, 20:1.
- GARCÉS, E., MASÓ, M. & CAMP, J., 2002. Role of temporary cysts in the population dynamics of *Alexandrium taylori* (Dinophyceae). *Journal of Plankton Research*, 24: 681-686.
- GELIN, A., ARIGONI, S., FRANCOUR, P., HARMELIN, J-G. & HARMELIN-VIVIEN, M., 1998. Réponse des populations de certains poissons Serranidae et Labridae à la colonisation des fonds par *Caulerpa taxifolia* en Méditerranée. pp.197-208. In: *Third International Workshop in Caulerpa taxifolia*. Boudouresque, C.F., Gravez, V., Meinesz, A. & Palluy, F. (Eds.), Groupement d'Intérêt Scientifique Posidonie Publishers, Marseille. France.
- GERBAL, M., BEN MAIZ, N. & BOUDOURESQUE, C.F., 1985. Les peuplements à *Sargassum muticum* de l'étang de Thau: données préliminaires sur la flore algale. *Congrès National des Sociétés Savantes*, 110: 241-254.
- GIACOBBE, M. & YANG, X. 1999. The life history of *Alexandrium taylori* (Dinophyceae). *Journal of Phycology*, 35:

- 331-338.
- GOFAS, S. & ZENETOS, A., 2003. Exotic molluscs in the Mediterranean basin: current status and perspectives. *Oceanography and Marine Biology: An Annual Review*, 41: 237-277.
- GOLANI, D., 1998. Impact of Red Sea fish migrants through the Suez Canal on the aquatic environment of the Eastern Mediterranean. *Bulletin Series Yale School of Forestry and Environmental Studies*, 103: 375-387.
- GOLANI, D., 2002. The Indo-Pacific striped eel catfish, *Plotosus lineatus* (Thunberg, 1787) (Osteichthyes: Siluriformes) a new record from the Mediterranean. *Scientia Marina*, 66: 321-323.
- GOLANI, D. & BEN-TUVIA, A., 1995. Lessepsian migration and the Mediterranean fisheries of Israel. pp. 279-289. In: *Conditions of the world's aquatic habits, Proceedings of the World Fishery Congress Theme 1*. N. B. Armantrout (Ed.), New Delhi, Oxford & IBH Pub. Co. Pvt. Ltd.
- GOLANI, D., ORSI-RELINI, L., MASSUTI, E. & QUINGNARD, J.P., 2002. *CIESM Atlas of Exotic Species in the Mediterranean Volume 3: Fishes*. F. Briand (Ed.), Monaco. CIESM Publishers, 256p.
- GOLANI, D., ORSI-RELINI, L., MASSUTI, E. & QUINGNARD, J.P., 2006. *CIESM Atlas of Exotic Fishes in the Mediterranean*. On Line: <http://www.ciesm.org/atlas/appendix1.html>
- GÓMEZ, C., ALCOBER, J. & BERNABEU, A., 1996. Seguimiento de las poblaciones fitoplanctónicas en las bateas mijilloneras del Puerto de Valencia 1991-1994. p. 29-38. In: *IV Reunion Iberica de fitoplancton toxico y biotoxinas*. Matamoros, E. & Delgado, M. (Eds.), St. Carles de la Rapita (Tarragona): Generalitat de Catalunya, Departament d'Agricultura, Ramaderia i Pesca,
- GÓMEZ, F. & CLAUSTRE, H., 2000. Spreading of *Gymnodinium catenatum* Graham in the western Mediterranean Sea. *Harmful Algae News*, 22: 1-3.
- GOODWIN, B.J., MCALLISTER, A.J. & FAHRIG, L., 1999. Predicting invasiveness of plant species based on biological information. *Conservation Biology*, 13: 22-426.
- GOREN, M. & GALIL B., S., 2005. A review of changes in the fish assemblages of Levantine inland and marine ecosystems following the introduction of non-native fishes. *Journal of Applied Ichthyology*, 21: 364-370.
- GRAVEZ, V., RUITTON, S., BOUDOUR-ESQUE, C.F., MEINESZ, A., SCABBIA, G. & VERLAQUE, M. (ed.), 2001. *Fourth International Workshop on Caulerpa taxifolia*. GIS Posidonie Publ., France, 406 pp.
- GÜCÜ, A.C. & BINGEL, F., 1994. Trawlable species assemblages on the continental shelf on the North Eastern Levant Seas (Mediterranean) with an emphasis on Lessepsian migration. *Acta Adriatica*, 35: 83-100.
- GUERRIERO, A., MEINESZ, A., D'AMBROSIA, M. & PIETRA, F., 1992. Isolation of toxic and potentially toxic sesqui- and monoterpenes from tropical green seaweed *Caulerpa taxifolia* which has invaded the region of Cap Martin and Monaco. *Helvetica Chimica Acta*, 75: 689.
- GUREVITCH, J. & PADILLA, D.K. 2004. Are invasive species a major cause of extinctions? *Trends in Ecology and Evolution*, 19 (9): 470-474.
- HARMELIN-VIVIEN, M., HARMELIN, J.G. & FRANCOUR, P., 1996. A 3-year study of the littoral fish fauna of sites colonised by *Caulerpa taxifolia* in the NW Mediterranean (Menton, France). p. 391-397. In: *Second International Workshop on Caulerpa taxifolia*. Ribera M.A., Ballesteros, E., Boudouresque. C.F., Gomez, A., & Gravez, V. (Eds.), Publications Universitat Barcelona.
- HARMELIN-VIVIEN, M.L., BITAR, G., HARMELIN, J.-G. & MONESTIEZ, P.,

2005. The littoral fish community of the Lebanese rocky coast (eastern Mediterranean Sea) with emphasis on Red Sea immigrants. *Biological Invasions* (2005), 7: 625-637.
- HEWITT, C., CAMPBELL, M. & GOLASCH, S., 2006. *Alien species in aquaculture -Considerations for responsible use*. IUCN, World Conservation Union, Global Marine Programme. 32 pp.
- HOLMER, M., DUARTE, C.M., BOSCHKER, H.T.S. & BARRÓN, C., 2004. Carbon cycling and bacterial carbon sources in pristine and impacted Mediterranean seagrass sediments. *Aquatic Microbial Ecology*, 36: 227-237.
- HOLMES, J.M.C. & MINCHIN, D., 1995. Two exotic copepods imported into Ireland with the Pacific oyster *Crassostrea gigas* (Thunberg). *Irish Naturalists' Journal*, 25: 17-20.
- HOPPE, K. N., 2002. *Teredo navalis* -the cryptogenic shipworm, pp. 116-119. In: *Invasive Aquatic Species in Europe. Distribution, Impacts and Management*. E. Leppakoski, S. Gollasch & S. Olenin (Eds.), Dordrecht, Boston, London. Kluwer Academic Publishers.
- HYAMS, O., ALMOGI-LABIN, A. & BENJAMINI, C., 2002. Larger foraminifera of the southeastern Mediterranean shallow continental shelf off Israel. *Israel Journal of Earth Sciences*, 51: 169-179.
- ICES 2005. ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2005. 30 p.
- IMO, 2000-2004. *Global Ballast Water Management Project: The Problem*. On line.: <http://globallast.imo.org/index.asp?page=problem.htm&menu=true>
- ISSG (Invasive Species Specialist Group), 2006. 100 of the World's Worst Invasive Alien Species. On line <http://www.issg.org/database/species/>
- IUCN-The World Conservation Union, 2002. Policy recommendations Papers for Sixth meeting of the Conference of the Parties to the Convention on Biological Diversity (COP6). The Hague, Netherlands, 7-19 April 2002. <http://www.iucn.org/themes/pbia/wl/docs/biodiversity/cop6/invasives.doc>.
- JAUBERT, J.M., CHISHOLM, J.R.M., PASSERON-SEITRE, G., DUCROT, D. & RIPLEY, H.T., 1999. No deleterious alterations in *Posidonia* beds in the bay of Menton (France) eight years after *Caulerpa taxifolia* colonization. *Journal of Phycology*, 35: 1113-1119.
- JAVIDPOUR, J., SOMMER, U. & SHIGANOV, A T., 2006. First record of *Mnemiopsis leidyi* A. Agassiz 1865 in the Baltic Sea. *Aquatic Invasions*, 1 (4): 299-302.
- KEANE, R.M. & CRAWLEY, M.J., 2002. Exotic plant invasions and the enemy release hypothesis. *Trends in Ecology and Evolution*, 17: 164-170.
- KLEIN, J., RUITTON, S., VERLAQUE, M. & BOUDOURESQUE, C.F., 2005. Species introductions, diversity and disturbances in marine macrophyte assemblages of the northwestern Mediterranean Sea. *Marine Ecology Progress Series*, 290:79-88.
- KOÇAK, F., ERGEN, Z. & ÇINAR, M.E., 1999. Fouling organisms and their developments in a polluted and an unpolluted marina in the Aegean Sea (Turkey). *Ophelia*, 50(1): 1-20.
- LEMEE, R., PESANDO, D., ISSANCHOU, C. & AMADE, P., 1997. Microalgae: a model to investigate the ecotoxicity of the green alga *Caulerpa taxifolia* from the Mediterranean Sea. *Marine Environmental Research*, 44(1): 13-25.
- LEPAKOSKI, E., GOLASCH, S. & OLENIN, S., 2002. *Invasive Aquatic Species in Europe. Distribution, Impacts and Management*. Dordrecht, Boston, London., Kluwer Academic Publishers.
- LODGE, D. M., 1993. Biological invasions-lessons from ecology. *Trends in Ecology and Evolution*, 8: 133-137.
- LOOPE, L.L. & MUELLER-DOMBOIS, D., 1989. Characteristics of invaded islands, with special reference to Hawaii.

- pp. 257-280. In: *Biological invasions: a global perspective. Scientific Committee on Problems of the Environment (SCOPE)*. Drake J.A., Mooney H.A., Di Castri F., Groves R.H., Kruger F.J., Rejmánek M., Williamson M., Chichester (Eds.), UK: John Wiley & Sons Ltd.
- MADL, P. & YIP, M., 2003. Literature review of *Caulerpa taxifolia*. Online. Available HTTP: <http://www.sbg.ac.at/ipk/avstudio/pierofun/ct/caulerpa.htm>
- MARBÀ, N., DUARTE, C.M., CEBRIÁN, J., ENRÍQUEZ, S., GALLEGOS, M.E., OLESEN, B. & SAND-JENSEN, K., 1996. Growth and population dynamics of *Posidonia oceanica* in the Spanish Mediterranean coast: elucidating seagrass decline. *Marine Ecology Progress Series*, 137: 203-213.
- MARBÀ, N., DUARTE, C.M., DÍAZ-ALMELA, E., TERRADOS, J., ALVAREZ, E., MARTÍNEZ, R., SANTIAGO, R., GARCIA, E. & GRAU, A. M., 2005. Direct evidence of imbalanced seagrass (*Posidonia oceanica*) shoot population dynamics along the Spanish Mediterranean. *Estuaries*, 28: 51-60.
- MEINESZ, A., 1999. *Killer Algae*. University of Chicago Press, Chicago, 376 p.
- MEINESZ, A. & HESSE, B. 1991. Introduction et invasion de l'algue *Caulerpa taxifolia* en Méditerranée nord-occidentale. *Oceanologica Acta*, 14: 415-426.
- MEINESZ, A., DE VAUGELAS, J, HESSE, B. & MARI, X., 1993. Spread of the introduced tropical green alga *Caulerpa taxifolia* in northern Mediterranean waters. *Journal of Applied Phycology*, 5:141-147.
- MEINESZ, A., BENICHO, L., BLACHER, J., KOMATSU, T., LEMEE, R., MOLENAAR, H. & MARI, X., 1995. Variations in the structure, morphology and biomass of *Caulerpa taxifolia* in the Mediterranean Sea. *Botanica Marina*, 38: 499-508.
- MEINESZ, A, COTTALORDA, J.M., CHIAVERINI, D., CASSAR, N. & DE VAUGELAS, J (Eds), 1998. *Suivie de l'invasion de l'algue tropicale Caulerpa taxifolia en Méditerranée: situation au 31 décembre 1997*. Laboratoire Environnement Marin Littoral -Université de Nice Sophia-Antipolis, LEML publisher, 283p.
- MEINESZ, A., BELSHER, T., THIBAUT, T., ANTOLIC, B., BEN MUSTAPHA, K., BOUDOURESQUE, C-F, CHIAVERINI, D., CINELLI, F., COTTALORDA, J-M., DJELLOULI, A., EL ABED, A., ORESTANO, C., GRAU, AM., IVESA, L., JAKLIN, L., LANGAR, H., MAS-SUTI-PASCUAL, E., PEIRANO, A., TUNESI, L., DE VAUGELAS, J., ZAVODNIK, N. & ZULJEVIC, A., 2001. The introduced green alga *Caulerpa taxifolia* continues to spread in the Mediterranean. *Biological Invasions*, 3:201-210.
- MEINESZ, A., JAVEL, F., COTTALORDA, J. M., et al., 2003. *Suivi de l'invasion des algues tropicales Caulerpa taxifolia and Caulerpa racemosa en Méditerranée: situation devant les côtes françaises et monégasques au 31 décembre 2002*. Laboratoire Environnement Marin Littoral -Université de Nice Sophia-Antipolis, LEML publisher, 115 p.
- MEINESZ, A., JAVEL, F., COTTALORDA, J.M. & GARCIA, D., 2004. *Caulerpa* online. World-wide electronic publication. Laboratoire Environnement Marin Littoral, Université de Nice Sophia-Antipolis. <http://www.caulerpa.org> (10.xi.2004).
- MERICİ, E., AVŞAR, N., BERGIN, F. & YOKES, B., 2002. The Proliferation of *Amphistegina* (Lessepsian migrants) population at the Three-Islands (ÜçAdalar, Antalya), a new observation from the Turkish Coast. pp. 27-34. In: *Workshop on Lessepsian Migration Proceedings*, Turkish Marine Research Foundation, Istanbul, Turkey.
- MIKHAIL, S.K., 2001. Toxic red tide species are on the rise in Alexandrian waters (Egypt). *Harmful Algae News*, 22.
- MINCHIN, D. & ROSENTHAL, H. 2002.

- Exotics for stocking and aquaculture, making correct decisions. pp. 206-215. In: *Invasive Aquatic Species in Europe. Distribution, Impacts and Management*. E. Leppakoski, S. Gollasch & S. Olenin, Dordrecht (Eds.), Boston, London. Kluwer Academic Publishers.
- MIZZAN, L., TRABUCCO, R., & TAGLIAPIETRA, G. 2005. Nuovi dati sulla presenza e distribuzione di specie alloctone del macrozoobenthos della Laguna di Venezia. *Bollettino della Società Veneziana di Storia Naturale e del Museo Civico di Storia Naturale*, 56: 69-88.
- OCCHIPINTI AMBROGI, A., 2000. Biotic invasions in a Mediterranean lagoon. *Biological Invasions*, 2(2): 165-176.
- OCCHIPINTI AMBROGI, A., 2001a. Transfer of marine organisms: a challenge to the conservation of coastal biocoenoses. *Aquatic Conservation: Marine Freshwater Ecosystem*, 11: 243-251.
- OCCHIPINTI AMBROGI, A., 2001b. Report on the current status of introductions in Italy (Marine environment). Report of the Working Group on Introductions and Transfers of Marine Organisms, Barcelona March 21-23, 2001 Advisory Committee on the Marine Environment ICES CM 2002/ACME:08 Ref. E, F, pp. 59-63. International Council for the Exploration of the Sea, Copenhagen, Denmark. (<http://www.ices.dk/reports/ACME/2001/WGITMO01.pdf>)
- OCCHIPINTI AMBROGI, A., 2002a. Current status of aquatic introductions in Italy. pp. 311-324. In: *Invasive Aquatic Species in Europe. Distribution, Impacts and Management*. E. Leppakoski, S. Gollasch & S. Olenin (Eds.), Dordrecht, Boston, London. Kluwer Academic Publishers.
- OCCHIPINTI AMBROGI, A., 2002b. Susceptibility to invasion: assessing the scale and impact of alien biota in the Northern Adriatic. pp. 69-73. In: *Alien marine organisms introduced by ships in the Mediterranean and Black seas*, edited by F. Briand, CIESM Workshop Monographs, 20, Monaco.
- OCCHIPINTI AMBROGI, A. & SAVINI, D., 2003. Biological invasions as a component of global change in stressed marine ecosystems. *Marine Pollution Bulletin*, 46: 542-551.
- OREN, O.H., 1957. Changes in the temperature of the Eastern Mediterranean Sea in relation to the catch of the Israel trawl fishery during the years 1954/55 and 1955/56. *Bulletin de l'Institut Océanographique* (Monaco), 1102: 1-12.
- PENNA, A., GIACOBBE, MG., ANDREONI, F., GARCÉS, E., BERLUTI, S., CANTARINI, R., PENNA, N. & MANGANI, M., 2001. Blooms of *Alexandrium taylori* (dinophyceae) in preliminary molecular analysis of different isolates. pp. 218-221. In: *9th International Conference on Harmful Algal Blooms*, Hobart (Australia) 7-11 Feb 2000.
- PENNA, A., GARCÉS, E., VILA, M., GIACOBBE, M., FRAGA, S., LUGLIE, A., BRAVO, I., BERTOZINNI, E. & VERNESI, C., 2005. *Alexandrium catenella* (Dinophyceae), a toxic ribotype expanding in the NW Mediterranean Sea. *Marine Biology*, 148: 13-23.
- PEIRANO, A., DAMASSO, V., MONTEFALCONE, M., MORRI, C. & BIANCHI, C.N., 2005. Effects of climate, invasive species and anthropogenic impacts on the growth of the seagrass *Posidonia oceanica* (L.) Delile in Liguria (NW Mediterranean Sea). *Marine Pollution Bulletin*, 50, 817-822.
- PIAZZI, L. & CINELLI, F., 1999. Développement et dynamique saisonnière d'un peuplement méditerranéen de l'algue tropicale *Caulerpa racemosa* (Forsskål) J. Agardh. *Cryptogamie, Algologie*, 20: 295-300.
- PIAZZI, L. & CINELLI, F., 2000. Effets de l'expansion des Rhodophyceae introduites *Acrothamnion preissii* et *Womersleyella setacea* sur les communautés algales des rhizomes de *Posidonia oceanica* de Méditerranée occidentale. *Cryp-*

- togamie, *Algologie*, 21 (3): 291-300.
- PIAZZI, L. & CINELLI, F. 2003. Evaluation of benthic macroalgal invasion in a harbour area of the western Mediterranean Sea. *European Journal of Phycology*, 38: 223-231.
- PIAZZI, L., PARDI, G. & CINELLI, F. 1996. Ecological aspects and reproductive phenology of *Acrothamnion preissii* (Sonder) Wollaston (Ceramiaceae, Rhodophyta) in the Tuscan Archipelago (Western Mediterranean). *Cryptogamie, Algologie*, 17: 35-43.
- PIAZZI, L., BALESTRI, E., MAGRI, M. & CINELLI, F., 1997. Expansion de l'algue tropicale *Caulerpa racemosa* (Frosskäl) J. Agardh (Bryopsidophyceae, Chlorophyta) le long de la côte toscane (Italie). *Cryptogamie, Algologie*, 18: 343-350.
- PIAZZI, L., CECCHERELLI, G. & CINELLI, F., 2001a. Threat to macroalgal diversity: effects of the introduced green alga *Caulerpa racemosa* in the Mediterranean. *Marine Ecology Progress Series*, 210: 149-159.
- PIAZZI, L., BALATA, D., CECCHERELLI, G. & CINELLI, F., 2001b. Comparative study of the growth of the two cooccurring introduced green algae *Caulerpa taxifolia* and *Caulerpa racemosa* along the Tuscan coast (Italy, western Mediterranean). *Cryptogamie, Algologie*, 22:459-466.
- PIAZZI, L., BALATA, D. & CINELLI, F., 2002. Epiphytic macroalgal assemblages of *Posidonia oceanica* rhizomes in the western Mediterranean. *European Journal of Phycology*, 37: 69-76.
- PIAZZI, L., MEINESZ, A., VERLAQUE, M., AKCEALI, B., ANTOLIC', B., ARGYROU, M., BALATA, D., BALLESTEROS, E., CALVO, S., CINELLI, F., CIRIK, S., COSSU, A., D'ARCHINO, R., DJELLOULI, A.S., JAVEL, J., LANFRANCO, E., MIFSUD, C., PALA, D., PANAYOTIDIS, P., PEIRANO, A., PERGENT, G., PETROCELLI, A., RUITTON, S., ZULJEVIC, A. & CECCHERELLI, G., 2005. Invasion of *Caulerpa racemosa* var. *cylindracea* (Caulerpales, Chlorophyta) in the Mediterranean Sea: an assessment of the spread. *Cryptogamie, Algologie*, 26(2): 189-202.
- PIMM, S.L., 1989. Theories of predicting success and impact of introduced species. pp. 351-367. In: *Biological invasions: a global perspective. Scientific Committee on Problems of the Environment (SCOPE)*. Drake J.A., Mooney H.A., Di Castri F., Groves R.H., Kruger F.J., Rejmánek M., Williamson M., Chichester (Eds.), UK: John Wiley & Sons Ltd.
- PRANOVI, F., LIBRALATO, S., RAICEVICH, S., GRANZOTTO, A., PASTRES, R. & GIOVANARDI, O., 2003. Mechanical clam dredging in the Venice lagoon: ecosystem effects evaluated with a trophic mass-balance model. *Marine Biology*, 143: 393-403.
- PRANOVI, F., DA PONTE, F., RAICEVICH, S. & GIOVANARDI, O., 2004. A synoptic-multidisciplinary study of the immediate effects of mechanical clam-harvesting in the Venice lagoon. *ICES Journal of Marine Science*, 61: 43-52.
- RELINI, G., RELINI, M., & TORCHIA, G., 1998. Fish biodiversity in a *Caulerpa taxifolia* meadow in the Ligurian Sea. *Italian Journal of Zoology*, 65(Suppl S): 465-470.
- REJMÁNEK, M., 1989. Invasibility of plant communities. pp. 369-388. In: *Biological invasions: a global perspective. Scientific Committee on Problems of the Environment (SCOPE)*. Drake J.A., Mooney H.A., Di Castri F., Groves R.H., Kruger F.J., Rejmánek M., Williamson M. (Eds.), Chichester, UK: John Wiley & Sons Ltd.
- RIBERA, M.A. & BOUDOURESQUE, C.-F., 1995. Introduced marine plants, with special reference to macroalgae: mechanisms and impact. *Progress in Phycological Research*, 11, 217-268.
- RIBERA SIGUAN, M.A., 2002. Review of non native marine plants in the Mediterranean Sea. pp. 291-310. In: *Invasive*

- Aquatic Species in Europe. Distribution, Impacts and Management*, E. Leppakowski, S. Gollasch & S. Olenin (Eds.), Dordrecht, Boston, London. Kluwer Academic Publishers.
- RICCIARDI, A., 2004. Assessing species invasions as a cause of extinction. *Trends in Ecology & Evolution*, 19 (12): 619.
- RIERA, V., BIGAS, M., SANTMARTÍ, M., & DURFORT, M., 1995. Prevalencia del protozoo parásito *Marteilia refringens* en las poblaciones de ostra plana (*Ostrea edulis* L.) del Maresme (NE Barcelona). *Actas del V Congreso Nacional de Acuicultura*: 242-247.
- RINALDI, E., 1985. Alcunti dati significanti sulla proliferazione di *Scapharca inaequivalvis* (Bruguière, 1789) in Adriatico lungo la costa Romagnola. *Bolletino Malacologico Milano*, 21: 41-42.
- RUITTON, S. & BOUDOURESQUE, C.-F., 1994. Impact de *Caulerpa taxifolia* sur une population de l'oursin *Paracentrotus lividus* à Roquebrune-Cap Martin (Alpes-Maritimes, France), pp 371-378. In: *First International Workshop on Caulerpa taxifolia* edited by Boudouresque C.F., Meinesz A. and Gravez V., GIS Posidonie, Marseille.
- RUITTON, S., JAVEL, F., CULIOLI, J.M., MEINESZ, A., PERGENT, G. & VERLAQUE, M., 2005. First assessment of the *Caulerpa racemosa* (Caulerpales, Chlorophyta) invasion along the French Mediterranean coast. *Marine Pollution Bulletin*, 50: 1061-1068.
- RUIZ, G.M., CARLTON, J.T., GROSHOLZ, E.D. & HINES, A.H., 1997. Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent and consequences. *American Zoologist*, 37: 621-632.
- RUIZ, G.M., FOFONOFF, P. & HINES, A.H., 1999. Non-indigenous species as stressors in estuarine and marine communities: assessing invasion impacts and interactions. *Limnology and Oceanography*, 44: 950-972.
- SALA, E. & BOUDOURESQUE, C.F., 1997. The role of fishes in the organisation of a Mediterranean sublittoral community. I: algal communities. *Journal of Experimental Marine Biology and Ecology*, 212: 22-44.
- SALOMIDI, M., BELLOU, N., PANCUCCI-PAPADOPOULOU, M.A. & ZIBROWIUS, H., 2006. First observation of an invasive scleractinian coral in Greek waters. Proceedings of 41st European Marine Biology Symposium/, September 4-8 2006, Cork, Ireland.
- SANTMARTÍ, M., GARCÍA VALERO, M., J., MONTES, J., PECH, A. & DURFORT, M., 1995. Seguimiento del protozoo *Perkinsus* sp., en las poblaciones de *Tapes decussatus* y *Tapes semidecussatus* del Delta del Ebro, pp. 260-265. In: *Actas del V Congreso Nacional de Acuicultura* (10-13 de mayo, 1995. Sant Carles de la Ràpita, Tarragona, Espapa), edited by F. Castelló y A. Calderer. Publicaciones de la Universidad de Barcelona. Barcelona, Spain.
- SAVINI, D. & OCCHIPINTI AMBROGI, A. 2006. Consumption rates and prey preference of the invasive gastropod *Rapana venosa* in the Northern Adriatic Sea. *Helgoland Marine Research*, 60: 153-159.
- SFRISO, A., FACCA, C., & GHETTI, P.F. 2003. Temporal and spatial changes of macroalgae and phytoplankton in shallow coastal areas: The Venice lagoon as a study case. *Marine Environmental Research*, 56: 617-636.
- SHIGANOVA, T.A, MIRZOYAN, Z.A, STUDENIKINA, E.A, VOLOVIK, S.P, SIOKOU-FRANGOU, I., ZERVOUDAKI, S., CHRISTOU, E.D., SKIRTA, A.Y. & DUMONT, H.J, 2001. Population development of the invader ctenophore *Mnemiopsis leidyi* in the Black Sea and other seas of the Mediterranean basin. *Marine Biology*, 139: 431-445.
- SIMBERLOFF, D. 1989. Which insect in-

- roductions succeed and which fail, pp. 61-75. In: *Biological invasions: a global perspective. Scientific Committee on Problems of the Environment (SCOPE)*. Drake J.A., Mooney H.A., di Castri F., Groves R.H., Kruger F.J., Rejmánek M., Williamson M. (Eds.), Chichester, UK: John Wiley & Sons Ltd.
- SIMONI, F., GADDI, A., DI PAOLO, C. & LEPRI, L., 2003. Harmful epiphytic dinoflagellate on Tyrrhenian Sea reefs. *Harmful Algae News*, 24: 13-14.
- SIMONI, F., DI PAOLO, C., GORI, L. & LEPRI, L., 2004. Further investigation on blooms of *Ostreopsis ovata*, *Coolia monotis*, *Prorocentrum lima* on the macroalgae of artificial and natural reefs in the Northern Tyrrhenian Sea. *Harmful Algae News*, 26: 5-7.
- STOCK, J.H., 1993. Copepoda (Crustacea) associated with commercial and non-commercial Bivalvia in the East Scheldt, The Netherlands. *Bijdragen tot de Dierkunde*, 63(1): 61-64.
- STRATEGY WORKSHOP, 2004. Management of recreational waters in relationship with harmful microalgae blooms (HAB) in the Mediterranean Sea, 24-26 October 2004, Calvia (Mallorca). STRATEGY: <http://www.icm.csic.es/bio/projects/strategy>
- THESSALOU-LEGAKI, M., ZENETOS, A., KAMBOUROGLOU, V., CORSINI FOKA, M., KOURAKLIS, P., DOUNAS, C & NICOLAIDOU, A., 2006. The establishment of the invasive crab *Percnon gibbesi* (H. Milne Edwards, 1853) (Crustacea: Decapoda: Grapsidae) in Greek waters. *Aquatic Invasions* 1(3): 133-136.
- UYSAL, Z. & MUTLU, E., 1993. Preliminary note on the occurrence and biometry of Ctenophoran *Mnemiopsis leidyi* finally invading Mersin Bay. *Doğa, Turkish Journal of Zoology*, 12: 229-236.
- VERLAQUE, M., 1989. Contribution à la flore des algues marines de la Méditerranée: espèces rares ou nouvelles pour les côtes françaises. *Botanica Marina*, 32, 101-113.
- VERLAQUE, M., 1994. Inventaire des plantes introduites en Méditerranée: origines et répercussions sur l'environnement et les activités humaines. *Oceanologica Acta*, 17: 1-23.
- VERLAQUE, M. 2001. Checklist of the macroalgae of the Thau Lagoon (Hérault, France) a hot spot of marine species introduction in Europe. *Oceanologica Acta*, 17: 1-23.
- VERLAQUE, M. & FRITAYRE, P., 1994a. Incidence de l'algue introduite *Caulerpa taxifolia* sur le phytobenthos de Méditerranée occidentale. 2. Les peuplements d'algues photophiles de l'infralittoral. pp. 349-353. In: *First International workshop on Caulerpa taxifolia*. Boudouresque, C.F., Meinesz, A. & Gravez, V. (Eds.), GIS Posidonie publ., Marseille.
- VERLAQUE, M. & FRITAYRE, P., 1994b. Modifications des communautés algales méditerranéennes en présence de l'algue envahissante *Caulerpa taxifolia* (Vahl) C. Agardh. *Oceanologica Acta, Fr.*, 17 : 659-672.
- VERLAQUE, M., BOUDOURESQUE, C.F., MEINESZ, A. & GRAVEZ, M., 2000. The *Caulerpa racemosa* (Caulerpales, Ulvophyceae) complex in the Mediterranean Sea. *Botanica Marina*, 43: 49-68.
- VERLAQUE, M., DURAND, C., HUISMAN, J.M., BOUDOURESQUE, C.F. & LE PARCO, Y., 2003. On the identity and origin of the Mediterranean invasive *Caulerpa racemosa* (Caulerpales, Chlorophyta). *European Journal of Phycology*, 38: 325-339.
- VERLAQUE, M., AFONSO-CARRILLO, J., GIL-RODRIGUEZ, M.C., DURAND, C., BOUDOURESQUE, C.F. & LE PARCO, Y., 2004. Blitzkrieg in a marine invasion: *Caulerpa racemosa* var. *cylindracea* (Bryopsidales, Chlorophyta) reaches the Canary Islands (north-east Atlantic). *Biological Invasions*, 6(3): 269-281.
- VERLAQUE, M., RUITTON, S. & BOU-

- DOURESQUE C.F., 2005. List of invasive or potentially invasive exotic macroalgae in Europe. 5th PCRD European Program 'ALIENS' Algal Introductions To European Shores - Wp 10 Screening Protocol. < <http://www.uniovi.es/ecologia/aliens/E-aliens.htm>.>
- VILA, M., GARCÉS, E., MASÓ, M., & CAMP, J. 2001. Is the distribution of the toxic dinoflagellate *Alexandrium catenella* expanding along the NW Mediterranean coast. *Marine Ecology Progress Series*, 222: 73-83.
- WALLENTINUS, I., 2002. Introduced marine algae and vascular plants in European aquatic environments. pp. 27-52. In: *Invasive Aquatic Species in Europe. Distribution, Impacts and Management*. E. Leppakoski, S. Gollasch & Olenin, S. (Eds.), Dordrecht, Boston, London. Kluwer Academic Publishers.
- WILLIAMS, L., 1990. Experimental studies of Caribbean seagrass bed development. *Ecological Monographs*, 60(4): 449-469.
- WILLIAMS, S.L. & GROSHOLSZ, E.D., 2002. Preliminary reports from the *Caulerpa taxifolia* invasion in southern California. *Marine Ecology Progress Series*, 233: 307-310.
- YOKES, M.B. & MERİÇ, E., 2004. Expanded populations of *Amphistegina lobifera* from the Southwestern coast of Turkey. pp. 232-233. In: *4th International Congress 'Environmental Micropaleontology, Microbiology and Meiobenthology'*. V. Yanko-Hombach, M. Gormus, A. Ertunc, M. McGann, R. Martin, J. Jacob & S. Ishman (Eds.) Isparta, Turkey, September 13-18, 2004.
- ZENETOS, A., GOFAS, S., RUSSO, G. & TEMPLADO, J., 2003. *CIESM Atlas of Exotic Species in the Mediterranean, Volume 3: Molluscs*. F. Briand (Ed.). Monaco: CIESM Publishers, 376p.
- ZENETOS, A., ÇINAR, M.E., PANCUCCI-PAPADOPOULOU, A.M., HARMELIN, J.G., FURNARI, G., ANDALORO, F., BELLOU, N. STREFTARIS, N., & ZIBROWIUS, H., 2005. Annotated list of marine alien species in the Mediterranean with records of the worst invasive species. *Mediterranean Marine Science*, 6/2: 63-118.
- ZIBROWIUS, H., 1992. Ongoing modification of the Mediterranean marine flora and fauna by the establishment of exotic species. *Mésogée*, 51: 83-107.
- ZIBROWIUS, H., 2002. Assessing scale and impact of ship-transported alien fauna in the Mediterranean. pp. 62-68. In: *Alien marine organisms introduced by ships in the Mediterranean and Black seas*, edited by F. Briand, CIESM Workshop Monographs 20, Monaco.

Accepted in March 2007