Changes in the Mediterranean phytoplankton community related to climate warming

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Abstract

Little information is available on phytoplankton composition changes related to climate warming in the Mediterranean. This study presents three examples of plankton as biological indicators of warming. The tropical dinoflagellate *Citharistes regius* is found for the first time in the Gulf of Lions, NW Mediterranean, and is reported for the first time in the open waters of the Ionian and Levantine basins. The tropical genus *Microceratium* is recorded for the first time in the Mediterranean; it is here considered to be a "tropical morphotype", a life stage of *Karenia - Brachidinium - Asterodinium* species complex that appears under warm and highly stratified conditions. *Microceratium* is a biological indicator of "tropicalization", an adaptation of a local species to the tropical environmental conditions that prevail in summer in the open Mediterranean Sea. The diazotrophic cyanobacterium *Richelia intracellularis*, an endosymbiont of the diatoms *Rhizosolenia clevei* and *Hemiaulus* spp., is common in summer-autumn in the Mediterranean and often dominant in oligotrophic open surface waters. The consortium *Richelia intracellularis-Rhizosolenia clevei* is reported for the first time in the Bay of Marseille.

Keywords: phytoplankton; climate change; long-term series; Mediterranean; biodiversity; biological indicator.

Introduction

Ocean temperatures have generally risen as the atmosphere warms (+0.3 °C from 1950 to 2000, Levitus *et al.*, 2000). Surface warming increases the density vertical stratification of the ocean waters, leading to less mixing between the surface water layers, where phytoplankton live, and the deeper water layers, which contain the nutrients they need to flourish. The nutrient supply for phytoplankton will be reduced due to less upward mixing and a shallower "mixed layer", and stratification. These conditions are expected to favour the smaller phytoplankton fraction and motile groups such as flagellates and dinoflagellates versus diatoms, as observed in pigment signatures in the open NW Mediterranean (Marty *et al.*, 2002). Under a global warming scenario, we can expect geographical spreading of tropical species and species living in symbiotic associations with diazotrophic organisms, able to fix nitrogen. A number of studies show that the biodiversity of the Mediterranean is undergoing rapid alteration within the context of a globally changing climate. However, most of these studies correspond to macroscopic organisms (Francour *et al.*, 1994; Bianchi and Morri, 2000; Bianchi, 2007), and little is known about the changes of phytoplankton communities.

Projections for the Mediterranean basin for the 21st century indicate warmer and drier conditions, with a dramatic increase in the frequency and persistence of extreme events such as heat waves (Diffenbaugh *et al.*, 2007). These climatic anomalies provide a frame within which to investigate potential phytoplankton responses. In September 1999, a high mortality of sessile invertebrates was observed in the NW Mediterranean (Perez *et al.*, 2000). During this period, the dinoflagellate *Asterodinium* was observed for the first time in the western Mediterranean. *Asterodinium* was first described from tropical waters near Madagascar (Sournia, 1972b), and its occurrence was considered an indication of warming or "tropicalization" of the western Mediterranean (Gómez and Claustre, 2003). However, further studies suggested that *Asterodinium* may be a morphotype of a local species that is able to project body extensions under exceptional conditions. The tropical morphotype was described as a separate species from tropical waters (Gómez *et al.*, 2005). In summer 2003, the European region witnessed an exceptional heat wave, again associated with a mass mortality of sessile invertebrates (Garrabou *et al.*, 2009). In the NE English Channel, the 2003 summer heat wave was associated with an exceptional abundance of the dinoflagellates *Akashiwo sanguinea* and *Ceratium fusus*, and the first observations of some subtropical diatoms (Gómez and Souissi, 2007; 2008). To the best of my knowledge, no data exist on the response of the Mediterranean phytoplankton to the thermal anomaly of summer 2003.

The oligotrophic waters of the Mediterranean are characterized by a peculiarly high nitrate/phosphate ratio that differs from the Redfield ratio (N/P = 16) that predominates in the world ocean. It has been hypothesized that this might result from one or a combination of factors such as a high rate of biological nitrogen fixation (e.g. Béthoux *et al.*, 2002; Moutin, this volume). *Richelia intracellularis* as endosymbiont in the centric diatoms *Rhizosolenia clevei* and *Hemiaulus* spp. has been shown to have quantitatively substantial relevance in nitrogen fixation in Atlantic and Pacific warm waters (Carpenter *et al.*, 1999; Dore *et al.*, 2008). Oligotrophy associated with warming is expected to favour development of these symbiotic associations. However, very little is known about the distribution and tentative spreading of such symbiotic associations in the Mediterranean.

In comparison to the coasts of northern Europe, 19th century pioneers of plankton studies at the first marine stations founded along the coasts of Italy and France identified "quasi-tropical" conditions. For that reason, the Mediterranean is the locality where more species of dinoflagellates have been described (Gómez, 2003a; 2006a). Comparison of recent observations with historical bibliographical data will allow evaluation of changes in past decades. In this study, we report recent observations of phytoplankton composition from the Bay of Villefranche (1998-1999) (Gómez and Gorsky, 2003), the Bay of Marseille (2007-2008) and Banyuls-sur-mer (2008-2009), and open water research cruises PROSOPE (PROductivity of Oceanic PElagic Systems) in summer 1999 (Gómez and Claustre, 2003) and BOUM (Biogeochemistry from the Oligotrophic to the Ultra-oligotrophic Mediterranean) in summer 2009 (Figure 1). We combine recent data from sampling at monitoring sites with old bibliographic data in order to find examples of phytoplankton indicators of climate warming of the Mediterranean.

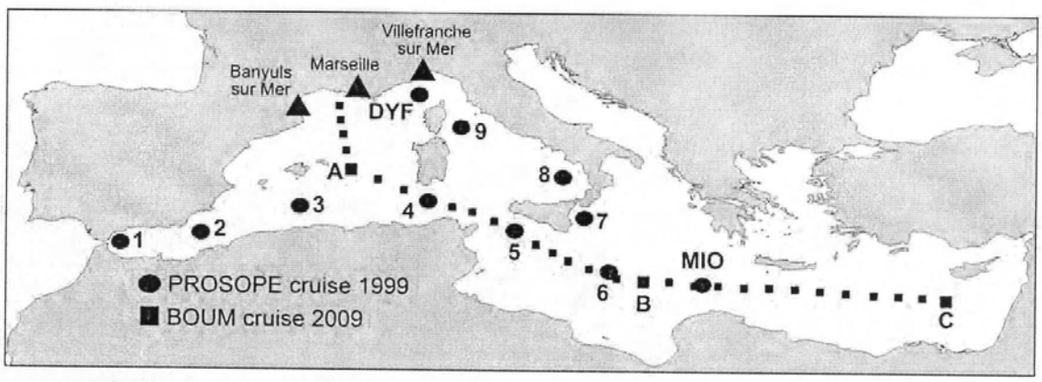

Figure 1. Map of sampling stations during the PROSOPE and BOUM cruises, and phytoplankton monitoring sites at Villefranche-sur-mer, Marseille and Banyuls-sur-mer.

OBSERVATIONS

1. Tropical dinoflagellates

Among the dinoflagellates, the order Dinophysiales has a special diversity in tropical waters. Most of the species are morphologically modified to harbour unicellular diazotrophic cyanobacteria as an adaptation for survival in oligotrophic waters. The genus *Histioneis*, that has clear tropical affinity, is well represented in the Mediterranean. However, distinctive tropical species such as *Histioneis highleyi*, *H. biremis* and the larger and highly ornamented species (i.e., *Histioneis megalocopa*-group) have not been recorded from the Mediterranean basin (Gómez, 2003a; 2007). Tropical species of the genus *Amphisolenia* characterized by ramified antapical extensions (i.e., *A. thrinax*) are absent in the Mediterranean.

The two species of the distinctive genus *Citharistes* were first described from the tropical Atlantic and Pacific Oceans. It seems that *Citharistes apsteini* was only cited from the open eastern Mediterranean (Kimor and Wood, 1975). In the Bay of Naples, there are historical citations of *Citharistes regius* by Schütt and Entz (*in* Schröder, 1906) and Schiller (1933) respectively. Later, it was reported in the Ligurian Sea (Halim, 1960a; Rampi and Bernhard, 1980) and the Tyrrhenian Sea (Magazzù and Andreoli, 1971). In the eastern Mediterranean, the first record from the Turkish coast is very recent (Polat, 2004). Historically, the Gulf of Lions is one of the best investigated regions in the world for phytoplankton. During this study, a live specimen of *Citharistes regius* was found off Banyuls-sur-mer in 2009 (Figure 2A). From the Lugol-fixed samples of the BOUM cruise, *Citharistes regius* appeared at five different stations of the Ionian and Levantine basin (Figures 2B-F). The tropical *Citharistes* is likely to have expanded its geographical range in recent years and can be considered an indicator of "tropicalization" in the Mediterranean.

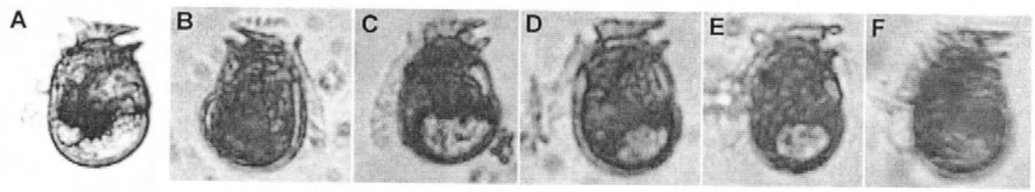

Figure 2. The tropical dinoflagellate *Citharistes regius*, found for the first time in the Gulf of Lions and in open waters of the Ionian and Levantine basins. **A.** Live specimen from Banyuls-sur-mer. **B-F.** Lugol-fixed specimens from the BOUM cruise.

2. Tropical morphotypes of local species

Dinoflagellates modify their morphologies to adapt to environmental conditions, and these morphotypes may be described as separate species. This phenomenon may be even more common in unarmoured dinoflagellates. During the thermal anomaly in September 1999, the genus *Asterodinium* appeared for the first time at several locations of the western Mediterranean (Gómez and Claustre, 2003). It was considered as a tropical species that spread its geographical range due to climate warming. However, further studies suggested that *Asterodinium* may be a life cycle stage of another species. Gómez *et al.* (2005), based on the observation of intermediate stages and detailed morphological studies by light and electron microscopy, suggested that *Asterodinium*, *Brachidinium*, *Microceratium* and *Karenia* may constitute a single species with high morphological versatility that is able to project body extensions as an adaptation to environmental conditions. Originally, *Microceratium* was only known from the tropical Indian and Pacific Oceans (Sournia, 1972b; Gómez, 2006b). During the BOUM cruise, records of *Asterodinium*, *Brachidinium* were numerous. The tropical *Microceratium* was found at five stations in the Levantine and Ionian Sea. This is the first record in the Mediterranean, and consequently it can be considered another biological indicator of "tropicalization" of the Mediterranean (Figures 3A-F). Here however, *Microceratium* is considered a life cycle stage of a local species, currently ascribed to *Karenia*, pooled in the past as *Gymnodinium* sp. This first occurrence of *Microceratium* in the Mediterranean

should be considered as an indicator of climate warming. However, it should not be considered as a non-indigenous taxon. *Microceratium* is the "tropical morphotype" of a local species that appears in the Mediterranean when environmental conditions resemble those in tropical waters.

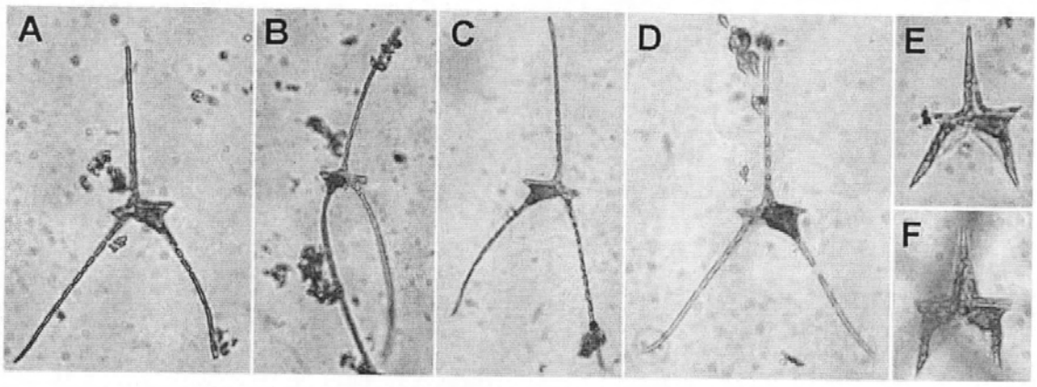

Figure 3. The dinoflagellate genus *Microceratium*, found for the first time in the Mediterranean. It is here considered to be a "tropical morphotype" of the local species, currently under the genus *Karenia*.

3. Symbiotic consortia of diatoms with diazotrophic cyanobacteria

The warming-induced oligotrophy of surface waters is expected to favour the development of diazotrophic organisms able to use atmospheric nitrogen as their sole nitrogen source. Surface blooms of the cyanobacterium *Trichodesmium* have been reported in some tropical waters (Dore *et al.*, 2008). *Trichodesmium* is commonly reported from the NW Mediterranean (Margalef, 1969, Figures 4A-B). In the Eastern Mediterranean, Hamza and Ben Maiz (1990) reported blooms of *Trichodesmium erythraeum* in summer in the Gulf of Gabes.

The diazotrophic cyanobacterium *Richelia intracellularis* is a symbiont which locates itself in the periplasmic space between the plasmalemma and silica cell wall in the diatoms *Rhizosolenia clevei*, *Hemiaulus* spp. and *Guinardia cylindrus* (Sundström, 1984), and more rarely as an epiphyte on *Chaetoceros* (Gómez *et al.*, 2005). The distribution of *Richelia*-diatom consortia have a clear tropical affinity, and were first described from the Red Sea. Analysis of a sediment core from the Levantine Basin reveals the historical occurrence of centric diatoms such as *Hemiaulus* and *Rhizosolenia* (Kemp *et al.*, 1999) that may harbour *Richelia intracellularis*. It is uncertain whether nitrogen fixation due to *Richelia intracellularis* is responsible for the peculiar high nitrate-phosphate ratio observed in Mediterranean deep waters. *Richelia intracellularis* is easily observable by light microscopy inside the frustule of *Rhizosolenia clevei*. However, the same endosymbiont in *Hemiaulus* spp. is hidden by the diatom chloroplasts, but visible by epifluorescent microscopy since the pigment composition of the cyanobacterium differs from that of the diatom (Figures 4E-H).

Historically, the phytoplankton composition of the Gulf of Lions has been intensively investigated. In the Bay of Marseille, Travers and Travers (1975, p. 253) remarked that they never found *Richelia intracellularis* in the frustules of *Rhizosolenia*. In this study, phytoplankton composition was examined from autumn 2007 to late summer 2008 in the Bay of Marseille. *Richelia intracellularis* as endosymbiont of *Rhizosolenia clevei* was observed in October 2007 and September 2008 (Figures 4C-D). In Banyuls-sur-mer, *Hemiaulus hauckii* was a common member of the summer phytoplankton assemblage, and all specimens examined revealed the presence of *Richelia intracellularis* under epifluorescent microscopy (Figures 4E-H). The *Hemiaulus-Richelia* consortia often appeared attached to the lorica of the tintinnid ciliate *Eutintinnus*. Oligotrophic conditions seem to favour the development of this peculiar association of three organisms, a cyanobacterium, a diatom and a ciliate (Figure 4I).

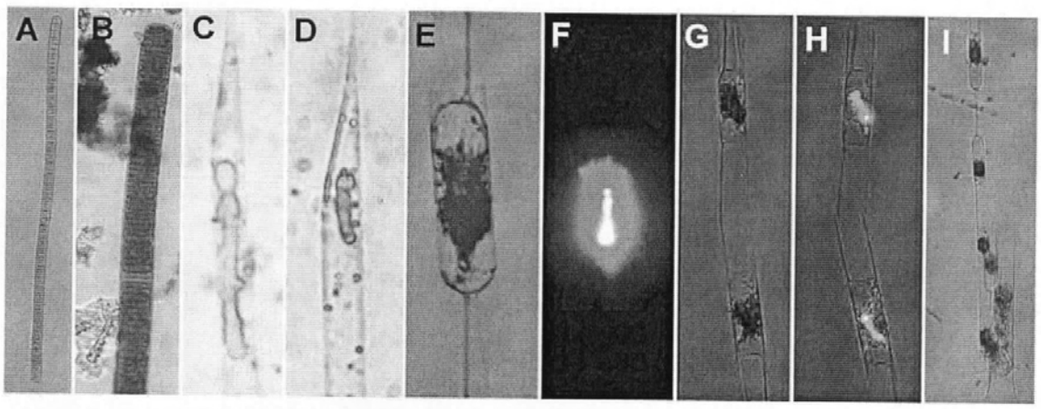

Figure 4. **A-B.** Tentatively, the cyanobacterium *Trichodesmium* from Banyuls-sur-mer. **C-D.** *Richelia intracellularis* endosymbiont in *Rhizosolenia clevei* from Endoume, Marseille and from the open Mediterranean during the BOUM cruise. **E-F.** *Richelia intracellularis* in *Hemiaulus hauckii*. **F-H.** Epifluorescent microscopy micrographs. **I.** Association between *Hemiaulus*, containing *Richelia*, and the ciliate *Eutintinnus*.

During the PROSOPE cruise in September 1999, *Hemiaulus hauckii* was the dominant microphytoplanktonic species in the surface layer during an oligotrophic period in the western and central Mediterranean (Table 1). The abundance was ~100 cells per litre. During the BOUM cruise in July-August 2009, *Hemiaulus hauckii* was present at most stations, especially in the surface waters of the eastern Mediterranean, with an average abundance of 20-50 cells per litre (Figure 5). During the PROSOPE or BOUM cruises, the presence of *Richelia* was not confirmed by epifluorescent microscopy because the samples were fixed with Lugol's solution. During the BOUM cruise, the abundance of *Richelia* as endosymbiont of *Rhizosolenia clevei* was very low, with average values of 2 cells per litre (Figure 5). Although the abundance of the diazotroph-diatom consortium is low, they are important primary producers in oligotrophic surface waters. It is uncertain whether these organisms are playing a role in the high nitrate-phosphate ratio of the Mediterranean.

Table 1. *Hemiaulus* as percentage of total microphytoplankton in upper 50 m depth during the PROSOPE cruise in 1999. At stations 3 and 8, 5 m depth samples were not available.

Depth (m)	St2 %	St3 %	St4 %	St5 %	St6 %	MIO %	St7 %	St8 %	St9 %	DYF %
5	29		100	61	50	40	0		0	0
15						0				0
25		0	25	0						0
30	0.2				100	100	0	0	0	0
50	1.4	0		0		66		0		0

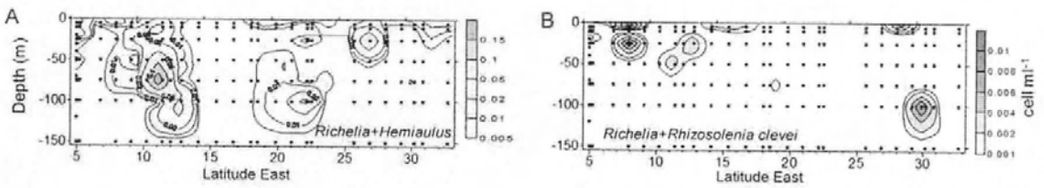

Figure 5. Distribution and abundance of *Richelia intracellularis* as endosymbiont in *Hemiaulus hauckii* (**A**) and *Rhizosolenia clevei* (**B**) during the BOUM cruise.

Our knowledge of the response of phytoplankton to climate change is restricted by the lack of long-term studies, especially those reporting species data, and by shortage of competent taxonomists. The lack of studies, especially in the southern and eastern Mediterranean basins, hinders differentiation between cryptic residents and new immigrant phytoplankton species.

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Bagnis R., Chanteau S., Chungue E., Hurtel J.M., Yasumoto T. and Inoue A., 1980. Origins of ciguatera fish poisoning: a new dinoflagellate, *Gambierdiscus toxicus* Adachi and Fukuyo, definately involved as a causal agent. *Toxicon,* 18: 199-208.

Barnes D.K.A., Galgani F., Thompson R.C. and Barlaz M., 2009. Accumulation and fragmentation of plastic debris in global environments. *Phil. Trans. R. Soc. B*, 364: 1985-1998.

Barone R. and Prisinzano A., 2007. Peculiarita comportamentale del dinoflagellato *Ostreopsis ovata* Fukuyo (Dinophyceae): la strategia del ragno. *Il Naturalista Siciliano*, 30: 401-418.

Barton A.D., Greene C.H., Monger B.C. and Pershing A.J., 2003. The continuous plankton recorder survey and the North Atlantic Oscillation: interannual- to multidecadal-scale patterns of phytoplankton variability in the North Atlantic Ocean. *Progr. in Oceanogr.*, 58: 337-358.

Bel Hassen M., Hamza A., Drira Z., Zouari A., Akrout F., Messaoudi S., Aleya L. and Ayadi H., 2009. Phytoplankton-pigment signatures and their relationship to spring-summer stratification in the Gulf of Gabes. *Est. Coast. Shelf Sci.*, 83: 296-306.

Belgrano A., Lindahl O. and Hernroth B., 1999. North Atlantic Oscillation primary productivity and toxic phytoplankton in the Gullmar Fjord, Sweden (1985-1996). Proceedings of the Royal.

Belin C., 1993. Distribution of *Dinophysis* spp. and *Alexandrium minutum* along french coasts since 1984 and their DSP and PSP toxicity levels. *In:* Toxic phytoplankton blooms in the Sea. Smayda T.J. & Shimizu Y. (eds), Amsterdam, Elsevier Sci. Publ., pp. 469-474.

Belin C. and Raffin B., 1998. Les espèces phytoplanctoniques toxiques et nuisibles sur le littoral français de 1984 a 1995, résultats du REPHY (réseau de surveillance du phytoplancton et des phycotoxines). Ifremer RST.DEL/MP-AO 98-16. 283 p.

Benitez-Nelson C.R., 2000. Phosphorus cycling in coastal marine ecosystems. *Investigacion Y Ciencia*, 5: 36-38.

BENTOX-NET, 2007. A network for the study of *Ostreopsis* spp. and other potentially toxic benthic microalgae.

Bentur Y. and Spanier E., 2007. Ciguatoxin-like substances in edible fish on the eastern Mediterranean. *Clin. Toxicol.,* 45: 695-700.

Berland B., Bonin D.J. and Maestrini S.Y., 1980. Azote ou phosphore ? Considérations sur le paradoxe nutritionnel de la Méditerranée. *Oceanol. Acta*, 3: 135-142.

Berman T. and Dubinsky Z., 1985. The autoecology of *Peridinium cinctum* fa. *westii* from Lake Kinneret. *Verh. Int. Ver. Limnol.*, 22: 2850-2854.

Besada E.G., Loeblich L.A. and Loeblich III A.R., 1982. Observations on tropical, benthic dinoflagellates from ciguatera-endemic areas: *Coolia, Gambierdiscus* and *Ostreopsis*. *B. Mar. Sci.,* 32: 723-735.

Béthoux J.P., Gentili B., Raunet J. and Tailliz D., 1990. Warming trend in the western Mediterranean deep water. *Nature*, 347: 660-662.

Béthoux J.P., Morin P., Chaumery C., Connan O., Gentili B. and Ruiz-Pino D., 1998. Nutrients in the Mediterranean Sea, mass balance and statistical analysis of concentrations with respect to environmental change. *Mar. Chem.*, 63: 155-169.

Béthoux J.P., Morin P. and Ruiz-Pino D.P., 2002. Temporal trends in nutrient ratios: chemical evidence of Mediterranean ecosystem changes driven by human activity. *Deep-Sea Res. II*, 49: 2007-2016.

Bianchi C., 2007. Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia,* 580: 7-21.

Bianchi C.N. and Morri C., 2000. Marine biodiversity of the Mediterranean Sea: situation, problems and prospects for future research. *Mar. Poll. Bull.*, 40: 367-376.

Bindof N.L. and Church J.A., 1992. Warming of the water column in the southwest Pacific Ocean. *Nature*, 357: 59-62.

Bingel F., Özsoy E. and Ünlüata Ü., 1993. A review of the state of the Fisheries and the Environment of the Northeastern Mediterranean (Northern Levantine Basin). Studies and reviews, GFCM. No 65, FAO.

Bomber J.W., Morton S.L., Babinachak J.A., Norris D.R. and Morton J.G., 1988. Epiphytic dinoflagellates of drift algae: another toxigenic community in the ciguatera food chain. *B. Mar. Sci.*, 18: 204-214.

Boni L., Milandri A., Poletti R. and Pompei M., 1993. DSP cases in the coast of Emilia Romagna (Northwestern Adriatic Sea). *In:* Toxic phytoplankton blooms in the sea. Smayda T.J. & Shimizu Y. (eds), Amsterdam, Elsevier Science Publisher, pp. 475-481.

Borkman D.J. and Smayda T.J., 2009. Gulf Stream position and winter NAO as drivers of long-term variations in the bloom phenology of the diatom *Skeletonema costatum* "species-complex" in Narragansett Bay, RI, USA. *J. Plankton Res.*, 31 (11): 1407-1425.

Bousnina A., 1997. Le climat de Sfax. Laboratoire de Climatologie, Faculté des Sciences Humaines et Sociales de Tunis (ed.), Altair, p. 80.

Brandhorst W., 1977. Les conditions de milieu au large de la côte tunisienne. *Bull. Inst. natn. Scient. Tech. Océanogr. Pêche Salammbô*, 4(2-4): 129-220.

Brankart J.M. and Pinardi N., 2001. Abrupt cooling of the Mediterranean Levantine Intermediate Water at the beginning of the eighties: observational ebidence and model simulation. *J. Phys. Oceanogr.*, 31(8): 2307-2320.

Bravo I., 1993. *Gymnodinium catenatum* en la costa mediterranea del sur de Espana. *In:* Actas del aula de trabajo sobre purgas de mar y fitoplancton toxico en la Peninsula Ibérica. Fraga S. (ed.). Informes Técnicos Instituto Espanol de Oceanografia, 144: 17.

Bravo I., Reguera B., Martinez A. and Fraga S., 1989. First report of *Gymnodinium catenatum* Graham on the Spanish Mediterranean coast. *In:* Toxic marine phytoplankton. Granéli E., Sundström B., Edler L. & Anderson D.M. (eds), New York: Elsevier, Inc., pp. 449-452.

Brescianini C., Grillo C., Melchiorre N., Bertolotto R., Ferrari A., Vivaldi B., Icardi G., Gramaccioni L., Funari E. and Scardala S., 2006. *Ostreopsis ovata* algal blooms affecting human health in Genoa, Italy, 2005 and 2006. *Eurosurveillance,* 11(36): pii=3040.

Buljan M., 1957. Fluctuation of temperature in the open Adriatic. *Acta Adriat.*, 8(7): 1-26.

Buljan M. and Zore-Armanda M., 1976. Oceanographic properties of the Adriatic Sea. *Oceanogr. Mar. Biol. Ann. Rev.*, 14: 11-98.

Caillaud A., Fraga S., Aligizaki K., Mohammad-Noor N., Nikolaidis G., Moestrup O. and Diogène J., 2009. Desarrollo de un ensayo celular para la deteccion de maitotoxinas en *Gambierdiscus* spp.. Estudio comparativo entre cepas de distintas procedencias. X Reuniao Oberica, Fitoplancton Toxico e Biotoxinas, Lisbon.

Camp J. and Delgado M., 1987. Hidrografia de las bahias del delta del Ebro. *Sci. Mar.*, 51: 351-369.

Caron D.A., Lim E.L., Sanders R.W., Dennett M.R. and Berninger U.G., 2000. Response of bacterioplankton and phytoplankton to organic carbon and inorganic nutrient additions in contrasting oceanic ecosystems. *Aquat. Microb. Ecol.*, 22: 175-184.

Carpenter E.J., Montoya J.P., Burns J., Mulholland M., Subramaniam A. and Capone D.G., 1999. Extensive bloom of an N_2-fixing diatom/cyanobacterial association in the tropical Ocean Atlantic. *Mar. Ecol. Prog. Ser.*, 185: 273-283.

• Diffenbaugh N.S., Pal J.S., Giorgi F. and Gao X.J., 2007. Heat stress intensification in the Mediterranean climate change hotspot. *Geophys. Res. Lett.*, 34: L11706, 1-6.

Diogène J., Paz B., Fernandez M., Mallat E., Canete E., Caillaud A., Elandaloussi L., de la Iglesia P., Cabado A.G., Lago J., Vieites J. and Franco J., 2008. Evidencia de Yessotoxinas en mejillon (*Mytilus galloprovincialis*) de la Bahia de Alfacs, Delta del Ebro. *In:* Actas de la IX Reunion Ibérica sobre Fitoplancton Toxico y Biotoxinas Cartagena 7-10 May 2007, Gilabert J. (ed.), pp. 215-221.

• Dore J.E., Letelier R.M., Church J.M., Lukas R. and Karl D.M., 2008. Summer phytoplankton blooms in the oligotrophic North Pacific Subtropical Gyre: historical perspective and recent observations. *Progr. Oceanogr.*, 76: 2-38.

Dowidar N.M., 1984. Phytoplankton biomass and primary productivity of the Southeast Mediterranean. *Deep-Sea Res.*, 31(6-8A): 983-1000.

Drira Z., Hamza A., Belhassen M., Habib Ayadi H., Bouaïn A. and Aleya L., 2008. Dynamics of dinoflagellates and environmental factors during the summer in the Gulf of Gabes. *Sci. Mar.*, 72: 59-71.

Dugdale R.C. and Goering J.J., 1967. Uptake of new and regenerated forms of nitrogen in primary productivity. *Limnol. Oceanogr.*, 12: 196-206.

Dulcic J., Beg Paklar G., Grbec B., Morovic M., Matic F. and Lipej L., 2007. On the occurrence of ocean sunfish *Mola mola* and slender sunfish *Ranzania laevis* in the Adriatic Sea. *J. Mar. Biol. Assoc. U.K.*, 87: 789-796.

Durando P., Ansaldi F., Oreste P., Moscatelli P., Marensi L., Grillo C., Gasparini R. and Icardi G., 2007. *Ostreopsis ovata* and human health: epidemiological and clinical features of respiratory syndrome outbreaks from a two-year syndromic surveillance, 2005-06, in north-west Italy. *Euro Surveill.*, 12(23):pii=3212 [available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=3212]

EASAC (European Academies Sciences Advisory Council), 2009. Ecosystems services and biodiversity in Europe.

EC, 2004. Regulation (EC) No 854/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption.

Ediger D. and Yilmaz A., 1996. Characteristics of deep chlorophyll maximum in the northeastern Mediterranean with respect to environmental conditions. *J. Mar. Syst.*, 9: 291-303.

Edwards M., Beaugrand G., Reid P.C., Rowden A.A. and Jones M.B., 2002. Ocean climate anomalies and the ecology of the North Sea. *Mar. Ecol. Prog. Ser.*, 239: 1-10.

Edwards M. and Richardson A., 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. *Nature*, 430: 881-884.

Edwards M., Johns D.G., Leterme S.C., Svendsen E. and Richardson A.J., 2006. Regional climate change and harmful algal blooms in the northeast Atlantic. *Limnol. Oceanogr.*, 51: 820-829.

Ehrenberg C.G., 1860. Einige Beobachtungen über das Meeresleuchten bei Neapel, Sorrento und Ischia. *Monatsberichte der Deutschen Akademie der Wissenschaften zu Berlin,* 1859: 791-793.

Eker E. and Kideys A.E., 2000. Weekly variations in phytoplankton structure of a harbour in Mersin Bay (northeastern Mediterranean). *Turk. J. Botany*, 24: 13-24.

Eker-Develi E., Kideys A.E. and Tugrul S., 2006. Role of Saharan dust on phytoplankton dynamics in the northeastern Mediterranean. *Mar. Ecol. Prog. Ser.*, 314: 61-75.

Fraga S., 2007. Global climate change and harmful algal blooms (HABs). 4th European Phycological Congress, Oviedo.

Fraga S. and Bakun A., 1990. Global climate change and harmful algal blooms: the example of *Gymnodinium catenatum* on the Galician Coast. *In:* Toxic phytoplankton blooms in the sea. Developments in marine biology, Smayda T.J. & Shimizu Y. (eds), 3: 59-65.

Fraga S., Riobo P., Diogène J., Paz B. and Franco J.M., 2004. Toxic and potentially toxic benthic dinoflagellates observed in Macaronesia (NE Atlantic Archipelagos). 11th International Conference on Harmful Algae, Capetown.

Francé J. and Mozetic P., 2008. First occurrence of the dinoflagellate *Ceratoperidinium yeye* in the Gulf of Trieste (northern Adriatic). *JMBA2 - Biodiversity Records*, pp. 1-3.

Francour P., Boudouresque C.F., Harmelin J.G., Harmelin-Vivien M.L. and Quignard J.P., 1994. Are the Mediterranean waters becoming warmer? Information from biological indicators. *Mar. Pollut. Bull.*, 28: 523-526.

Fuda J.L., Bengara L., Ben Ismail S., Curtil C., El Moumni B., Font J., Lefevre D., Millot C., Taupier-Letage I., Raimbault P., Rougier G., Sammari C. and Tamburini C., 2009. Recent dense water formation in the Med western basin, as observed by HYDROCHANGES. *In:* Dynamics of the mediterranean deep waters. CIESM Workshop Monograph n°38, [F. Briand ed.], Monaco, pp. 29-33.

Gacic M., 1980. Some characteristics of the response of the Adriatic Sea coastal region to the atmospheric forcing. *Acta Adriat.*, 31: 239-254.

Gacic M., Dadic V., Krstulovic N., Marasovic I., Morovic M., Pucher-Petkovic T. and Svilicic N., 1987. Near-shore transport processes induced by the wind. *Estuar. Coast. Shelf Sci.*, 24: 35-46.

Galil B.S., 2000. A sea under siege - Alien species in the Mediterranean. *Biol. Invasions,* 2: 177-186.

Garcés E., Delgado M., Maso M. and Camp J., 1999. *In situ* growth rate and distribution of the ichtyotoxic dinoflagellate *Gyrodinium corsicum* Paulmier in an estuarine embayment (Alfacs Bay, NW Mediterranean Sea). *J. Plankton Res.*, 21: 1977-1991.

Garcés E., Maso M., Vila M. and Camp J., 2001. Harmful algae events in the Mediterranean: are they increasing? *GOOS News*, 11: 9-11.

Garcés E., Fernandez M., Penna A., Van Lenning K., Gutierrez A., Camp J. and Zapata M., 2006. Characterization of NW Mediterranean *Karlodinium* spp. (Dinophyceae) strains using morphological, molecular, chemical, and physiological methodologies. *J. Phycology*, 42: 1096-1112.

Garrabou J., Coma R., Bensoussan N., Bally M., Chevaldonne P., Cigliano M., Diaz D., Harmelin J.G., Gambi M.C., Kersting D.K., Ledoux J.B., Lejeusne C., Linares C., Marschal C., Pérez T., Ribes M., Romano J.C., Serrano E., Teixido N., Torrents O., Zabala M., Zuberer F. and Cerrano C., 2009. Mass mortality in Northwestern Mediterranean rocky benthic communities of the 2003 heat wave. *Glob. Change Biol.*, 15: 1090-1103.

Genovesi B., Reynaud N., Nishitani G. *et al.*, 2009. *Alexandrium catanella* in Thau lagoon (France) is not a recent introduction from Asia? *Harmful Algae News*, 40: 1-3.

Giacobbe M.G., Penna A., Gangemi E., Maso M., Garcés E., Fraga S., Bravo I., Azzaro F. and Penna N., 2007. Recurrent high-biomass blooms of *Alexandrium taylorii* (Dinophyceae), a HAB species expanding in the Mediterranean. Proceedings of the 39th European Marine Biology Symposium, held in Genoa, Italy, 21-24 July 2004, 193: 125-133.

Gilabert J., 2001. Seasonal plankton dynamics in a Mediterranean hypersaline coastal lagoon: the Mar Menor. *J. Plankton Res.*, 23: 207-217.

Gill A.E., 1982. Atmosphere-ocean dynamics. Orlando, FL: AcademicPress, p. 662.

Giordani G., Zaldivar J.M. and Viaroli P., 2009. Simple tools for assessing water quality and trophic status in transitional water ecosystems. *Ecol. Indicators*, 9: 982-991.

Glaziou P. and Legrand A.M., 1994. The epidemiology of ciguatera fish poisoning. *Toxicon,* 32: 863-873.

Glibert P.M., Seitzinger S., Heil C.A., Burkholder J.M., Parrow M.W., Codispoti L.A. and Kelly V., 2005. The role of eutrophication in the global proliferation of harmful algal blooms: new perspectives and new approaches. *Oceanography*, 18(2): 198-209.

Goffart A., Hecq J.H. and Legendre L., 2002. Changes in the development of the winter-spring phytoplankton bloom in the Bay of Calvi (NW Mediterranean) over the last two decades: a response to changing climate? *Mar. Ecol. Prog. Ser.*, 236: 45-60.

Gomez F., 2003a. Checklist of Mediterranean free-living dinoflagellates. *Bot. Mar.*, 46: 215-242.

Gomez F., 2003b. The toxic dinoflagellate *Gymnodinium catenatum*: an invader in the Mediterranean Sea. *Acta Botanica Croatica*, 62: 65-72.

Gomez F., 2006a. The dinoflagellate genera *Brachidinium*, *Asterodinium*, *Microceratium* and *Karenia* in the open SE Pacific Ocean. *Algae*, 21: 445-452.

Gomez F., 2006b. Endemic and Indo-Pacific plankton in the Mediterranean Sea: a study based on dinoflagellate records. *J. Biogeogr.*, 33: 261-270.

Gomez F., 2007. Synonymy and biogeography of the dinoflagellate genus *Histioneis* (Dinophysiales: Dinophyceae). *Rev. Biol. Trop.*, 55: 459-477.

Gomez F. and Abboud-Abi Saab M., 2003. Records of *Ceratoperidinium* Margalef (Dinophyceae) from the Mediterranean Sea. *Vie Milieu*, 53(1): 43-46.

Gomez F. and Claustre H., 2003. The genus *Asterodinium* (Dinophyceae) as a possible biological indicator of warming in the western Mediterranean. *J. Mar. Biol. Ass.UK.*, 83: 173-174.

Gomez F. and Gorsky G., 2003. Microplankton annual cycles in the Bay of Villefranche, Ligurian Sea, NW Mediterranean Sea. *J. Plankton Res.*, 25: 323-339.

Gomez F., Furuya K. and Takeda S., 2005a. Distribution of the cyanobacterium *Richelia intracellularis* as an epiphyte of the diatom *Chaetoceros compressus* in the western Pacific Ocean. *J. Plankton Res.*, 27: 323-330.

Gomez F., Nagahama Y., Takayama H. and Furuya K., 2005b. Is *Karenia* a synonym of *Asterodinium-Brachidinium*? (Gymnodiniales, Dinophyceae). *Acta Botanica Croatica*, 64: 263-274.

Gomez F. and Souissi S., 2007. Unusual diatoms linked to climatic events in the northeastern English Channel. *J. Sea Res.*, 58: 283-290.

Gomez F. and Souissi S., 2008. The impact of the 2003 summer heat wave and the 2005 late cold wave on the phytoplankton in the north-eastern English Channel. *C.R. Biologies*, 331: 678-685.

Granéli E. and Johansson N., 2003. Effects of the toxic haptophyte *Prymnesium parvum* on the survival and feeding of a ciliate: the influence of different nutrient conditions. *Mar. Ecol. Prog. Ser.*, 254: 49-56.

Granéli E. and Flynn K., 2006. Chemical and physical factors influencing toxin content. *In:* Ecology of harmful algae, series: ecological studies, Granéli E. & Turner J. (eds), Springer Verlag, Heidelberg, 189: 229-241.

Grbec B., Morovic M., Kusipilic G. and Marasovic I., 2007. Climate regime shifts of the Adriatic Sea ecosystem. *Rapp. Comm. Inter. Mer Médit.*, 38: 153.

Grbec B., Morovic M., Dulcic J., Marasovic I. and Nincevic Z., 2008. Impact of the climatic change on the Adriatic Sea ecosystem. *Fresen. Environ. Bull.*, 17: 1615-1620.

Grbec B., Morovic M., Kuspilic G., Matijevic S., Matic F., Beg-Paklar G. and Nincevic-Gladan Z., 2009. The relationship between the atmospheric variability and productivity in the Adriatic Sea area. *J. Mar. Biol Ass. UK*, 89: 1-10.

Gregory M.R., 2009. Environmental implications of plastic debris in marine settings-entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Phil. Trans. R. Soc. B*, 364: 2013-2025.

Grubelic I., Antolic B., Despalatovic M., Grbec B. and Beg Paklar G., 2004. Effect of climatic fluctuations on the distribution of warmwater coral *Astroides calycularis* in the Adriatic Sea: new records and review. *J. Mar. Biol Ass. UK*, 84: 599-602.

Gruvel A., 1931. Les états de Syrie. Richesses marines et fluviales. Exploitation actuelle. Avenir. Soc. Edit. Geogr. colon., Paris, p. 453.

Guillard R.R.L. and Ryther J.H., 1962. Studies of marine plankton diatoms. I. *Cyclotella nana* (Hustedt) and *Detonula confervacea* (Cleve) Gran. *Can. J. Microbiol.*, 8: 229-239.

Hales S., Weinstein P. and Woodward A., 1999. Ciguatera (Fish Poisoning), El Nino, and Pacific Sea Surface Temperatures. *Ecosystem Health,* 5: 20-25.

Hales S., Kovats R.S. and Woodward A., 2000. What El Nino can tell us about human health and global climate change. *Global Change & Human Health,* 1: 66-77.

Halim Y., 1960a. Étude quantitative et qualitative du cycle écologique des Dinoflagellés dans les eaux de Villefranche-sur-Mer. Annales de l' Institut Océanographique, 38: 123-232.

Halim Y., 1960b. *Alexandrium minutum* nov. g. nov. sp. dinoflagellé provoquant des 'eaux rouges'. *Vie Milieu*, 11: 102-105.

Halim Y. and Labib W., 1996. First recorded toxic *Alexandrium minutum* Halim bloom. *Harmful Algae News*, 14: 2-3.

Hallegraeff G.M., 1993. A review of harmful algae blooms and their apparent global increase. *Phycologia,* 32: 79 - 99.

Hallegraeff G.M., 2003. Harmful algal blooms: a global overview *In:* Manual on harmful marine microalgae, Hallegraeff G.M., Anderson D.M. & Cembella A.D. (eds), UNESCO Publishing.

Hallegraeff G., Bolch C., Koerbin B. and Bryan J., 1988. Ballast water a danger to aquaculture. *Austalian Fischeries,* 47: 32-34.

Hallegraeff G. and Gollasch S., 2006. Anthropogenic introductions of microalgae. *In:* Ecology of harmful algae, Granéli E. & Turner J.T. (eds), Springer-Verlag Berlin, Berlin, pp. 379-390.

Hamza A. and Ben Maiz N., 1990. Sur l'apparition du phénomène "d'eau rouge" dans le golfe de Gabès en été 1988. *Bull. Inst. nat. scient. tech. Océanogr. Pêche, Salammbô*, 17: 5-15.

Hamza A. and El Abed A., 1994. Les eaux colorées dans le golfe de Gabès: bilan de six ans de surveillance (1989-1994). *Bull Inst. nat. Scie. Tech. Mer,* 21: 66 -72.

Hansen P.J., Lundholm N. and Rost B., 2007. Growth limitation in marine redtide dinoflagellates: effects of Ph versus inorganic carbon availability. *Mar. Ecol. Prog. Ser.*, 334: 63-71.

Harzallah A., 2002. État actuel et évolution de l'exploitation halieutique des lagunes (Bizerte). Institut National des Sciences et Technologie de la Mer, Salambôo, Tunisia, p. 128.

Hasle G.R., 1978. The inverted-microscope method. *In:* Phytoplankton manual, Sournia A. (ed.), Unesco Monographs on oceanographic methodology, 6: 191-196.

Hays G.C., Richardson A.J. and Robinson C., 2005. Climate change and marine plankton. *Trends Ecol. Evol.*, 20: 337-344.

Kamburska L. and Fonda-Umani S., 2009. From seasonal to decadal inter-annual variability of mesozooplankton biomass in the Northern Adriatic Sea (Gulf of Trieste). *J. Marine Syst.* doi:10.1016/j.jmarsys.2008.12.007

Kaniou-Grigoriadou I., Mouratidou T. and Katikou P., 2005. Investigation on the presence of domoic acid in Greek shellfish. *Harmful Algae*, 4: 717-723.

Karl D.M., Bidigare R.R. and Letelier R.M., 2001. Long term changes in plankton community structure and productivity in the North Pacific Subtropical Gyre: the domain shift hypothesis. *Deep-Sea Res. Part II*, 48: 1449-1470.

Karl D., Michaels A., Bergman B., Capone D.G., Carpenter R.C., Letelier R., Lipschultz F., Paerl H.W., Sigman D.M. and Stal L., 2002. Dinitrogen fixation in the world´s oceans. *Biochemistry*, 57-58: 47-98.

Karlovac J., Pucher-Petkovic T., Vucetic T. and Zore-Armanda M., 1974. Procjena bioloskih resursa Jadrana na osnovi planktona. *Acta Adriat.*, 16: 157-184.

Katara I., Illian J., Pierce G.J., Scott B. and Wang J., 2008. Atmospheric forcing on chlorophyll concentration in Mediterranean. *Hydrobiologia*, 612: 33-48.

Katikou P., 2008. Palytoxin and analogues: ecobiology and origin, chemistry, metabolism, and chemical analysis. *In:* Seafood and freshwater toxins: pharmacology, physiology, and detection, Botana L.M. (ed.), pp. 631-664.

Kemp A.E.S., Pearce R.B., Koizumi I., Pike J. and Rance S.J., 1999. The role of mat-forming diatoms in the formation of Mediterranean sapropels. *Nature*, 398: 57-61.

Khalaf G., Nakhlé K., Abboud-Abi Saab M., Tronczynski J., Mouawad R. and Fakhri M., 2006. Preliminary results of the oil spill impact on Lebanese coastal waters. *Leb. Sci. J.*, 7(2): 135-153.

Kideys A.E., Ünsal M. and Bingel F., 1989. Seasonal changes in net phytoplankton off Erdemli, Northeastern Mediterranean. *Doga, Turk. J. Botany.*, 13: 45-54.

Kimor B., 1983. Distinctive features of the plankton of the eastern Mediterranean. *Ann. Inst. Oceanogr.*, 59(2): 97-106.

Kimor B. and Wood E.J.F., 1975. A plankton study in the eastern Mediterranean Sea. *Mar. Biol.*, 29: 321-333.

Kirk J.T.O., 1994. Light & photosynthesis in aquatic ecosystems. Cambridge University Press, 2nd edition, p. 509.

Klein B., Roether W., Manca B.B., Bregant D., Beitzel V., Kovacevic V. and Luchetta A., 1999. The large deep water transient in the Eastern Mediterranean. *Deep-Sea Res. I*, 46: 371-414.

Koblentz-Mishke O.J., Volkovinsky V.V. and Kabanova J.G., 1970. Plankton primary production of the world ocean. Scient. Explor. of the South Pacific, National Academy of Sciences, Washington, D.C., pp. 183-196.

Koray T., 2001. A Checklist for phytoplankton of Turkish Seas. Ege. Univ. *Journal of Fisheries and Aquat. Sci.*, 18: 1-23.

Kovacevic V., Gacic M. and Poulain P.M., 1999. Eulerian current measurements in the Strait of Otranto and in the southern Adriatic. *J. Mar. Sys.*, 20: 255-278.

Krom M.D., Kress N., Brenner N. and Gordon L.I., 1991. Phosphorus limitation of primary productivity in the eastern Mediterranean Sea. *Limnol. Oceanogr.*, 36: 424-432.

Lacombe H., 1988. Considérations générales sur l'océanographie physique méditerranéenne. n° spécial : Océanographie pélagique méditerranéenne, Minas & Nival (eds), *Oceanol. Acta*, pp. 7-12.

Lagus A., Suomela J., Weithoff G., Heikkila K., Helminen H. and Sipura J., 2004. Species-specific differences in phytoplankton responses to N and P enrichment and the N:P ratio in the Archipelago Sea, northern Baltic Sea. *J. Plankkton Res.*, 26: 779-798.

Lakkis S. and Novel-Lakkis V., 1980. Composition, annual cycle and species diversity of the phytoplankton in Lebanese coastal waters. *J. Plankton Res.*, 23(9): 79-81.

Lancelot C., Rousseau V. and Gypens N., 2009. Ecologically based indicators for *Phaeocystis* disturbance in eutrophied Belgian coastal waters (Southern North Sea) based on field observations and ecological modelling. *J. Sea Res.*, 61: 44-49.

Landry M.R. and Hassett R.P., 1982. Estimating the grazing impact of marine micro-zooplankton. *Mar. Biol.*, 67: 283-288.

Leblanc K., Queguiner B., Garcia N., Rimmelin P. and Raimbault P., 2003. Silicon cycle in the Northwestern Mediterranean sea: seasonnal study of a coastal oligotrophic site. *Oceanol. Acta*, 26: 339-356.

Ledreux A., Krys S. and Bernard C., 2009. Suitability of the Neuro-2a cell line for the detection of palytoxin and analogues (neurotoxic phycotoxins). *Toxicon,* 53: 300-308.

Legendre L. and Fevre J.L., 1995. Microbial food webs and the export of biogenic carbon in the oceans. *Aquat. Microb. Ecol.*, 9: 69-77.

Legrand C., Rengefors K., Fistarol G. and Granéli E., 2003 Allelopathy in phytoplankton-biochemical, ecological and evolutionary aspects. *Phycologia*, 42: 406-419.

Lehane L.R. and Lewis J., 2000. Ciguatera: recent advances but the risk remains. *Int. J. Food Microbiol.*, 61: 91-125.

Lenoir S., Ten-Hage L., Turquet J., Quod J.P., Bernard C. and Hennion M.C., 2004. First evidence of palytoxin analogues from an *Ostreopsis mascarenensis* (Dinophyceae) benthic bloom in Southwestern Indian Ocean. *J. Phycology,* 40: 1042-1051.

Levandowsky M. and Kaneta P.J., 1987. Behaviour in dinoflagellates. *In:* The biology of dinoflagellates, Taylor F.J.R. (ed.), Blackwell Scientific Publications, Oxford, pp. 360-397.

Levitus S., Antonov J.I., Boyer T.P. and Stephens C., 2000. Warming of the world ocean. *Science*, 5461: 2225-2229.

Lewis R.J., 2001. The changing face of ciguatera. *Toxicon,* 39: 97-106.

Litaker R.W., Vandersea M.W., Faust M.A., Kibler S.R., Chinain M., Holmes M.J., Holland W.C. and Tester P.A., 2009. Taxonomy of *Gambierdiscus* including four new species, *Gambierdiscus caribaeus, Gambierdiscus carolinianus, Gambierdiscus carpenteri* and *Gambierdiscus ruetzleri* (Gonyaulacales, Dinophyceae). *Phycologia,* 48: 344-390.

Liu G., Janowitz G.S. and Kamykowski D., 2001. Influence of environmental nutrient conditions on *Gymnodinium breve* (Dinophyceae) population dynamics: a numerical study. *Mar. Ecol. Prog. Ser.*, 213: 13-37.

Lleti C., Matamoros E. and Camp J., 1995. Variabilidad ambiental interanual de las bahias del delta del Ebro y sus repercusiones sobre la acuicultura. *In:* Proceedings of the fifth national congress on aquaculture, Castello F. & Calderer A. (eds), pp. 947-952.

Llewellyn L.E., 2010. Revisiting the association between sea surface temperature and the epidemiology of fish poisoning in the South Pacific: reassessing the link between ciguatera and climate change. *Toxicon*, 56: 691-697.

Lopez J. and Arté P., 1971. Aguas rojas en las costas catalanas. *Investigacion Pesquera*, 35: 699-708.

Lopez J. and Arté P., 1973. Hidrografia y fitoplancton del Puerto del Fangar (delta del Ebro). *Sci. Mar.*, 37(1): 17-56.

Lorenzen C.J., 1966. A method for the continuous measurement of *in vivo* chlorophyll concentration. *Deep-Sea Res.*, 13: 223-227.

Ludwig W., Dumont E., Meybeck M. and Heussner S., 2009. River discharges of water and nutrients to the Mediterranean and Black Sea: major drivers for ecosystem changes during past and future decades? *Progr. Oceanogr.*, 80: 199-217.

Lugliè A., Giacobbe M.G., Sannio A., Fiocca F. and Sechi N., 2003. First record of the dinoflagellate *Alexandrium catenella* (Whedon & Kofoid) Balech (Dinophyta), a potential producer of paralytic shellfish poisoning, in Italian waters (Sardinia, Tyrrhenian Sea). *Bocconea*, 16: 1045-1051.

Lugliè A., Satta C., Padedda B., Pulina S. and Sechi N., 2008. What is *Chrysophaeum taylorii* Lewis & Bryan doing in Sardinia (Tyrrhenian Sea, Mediterranean)? *Harmful Algal News* 36, IOC/UNESCO, May 2008.

Lundholm N., Moestrup O., Hasle G.L. and Hoef-Emden K., 2003. A study of the *Pseudo-nitzschia pseudodelicatissime/cuspidate* complex (Bacillariophyceae): what is *P. pseudodelicatissima*? *J. Phycol.*, 39: 797-813.

Lürling M. and Scheffer M., 2007. Info-disruption: pollution and the transfer of chemical information between organisms. *Trends in Ecol. Evol.*, 22: 374-379.

Macedo M.F., Duarte P., Mendes P. and Ferreira J.G., 2001. Annual variation of environmental variables, phytoplankton species composition and photosynthetic parameters in a coastal lagoon. *J. Plankton Res.*, 23: 719-732.

Magazzu G. and Andreoli C., 1971. Trasferimenti fitoplanctonici attraverso lo stretto di Messina in relazione alle condizioni idrologiche. *Bollettino di Pesca, Piscicoltura e Idrobiologia* 26: 125-157.

Malacic V., Celio M., Čermelj B., Bussani A. and Comici C., 2006. Interannual evolution of seasonal thermohaline properties in the Gulf of Trieste (northern Adriatic) 1991-2003. *J. Geophys. Res.*, 111: C08009, doi: 10.1029/2005JC003267.

Manca B. and Giorgetti A., 1999. Flow patterns of the main water masses across transversal areas in the southern Adriatic Sea: seasonal variability. "The Eastern Mediterranean as a Laboratory Basin for the Assesment of Contrasting Ecosystems", Malanotte-Rizzoli P. & Eremeev V.N. (eds), Kluwer Academic Press, Dordrecht, Netherlands, pp. 495-506.

Mangialajo L., Bertolotto R., Cattaneo-Vietti R., Chiantore M., Grillo C., Lemée R., Melchiorre N., Moretto P., Povero P. and Ruggieri N., 2008. The toxic benthic dinoflagellate *Ostreopsis ovata*: quantification of proliferation along the coastline of Genoa, Italy. *Mar. Pollut. Bull.*, 56: 1209-1214.

Marasovic I., 1989. Encystment and Excystment of *Gonyaulax polyedra* during Red Tide. *Estuar. Coast. Shelf Sci.*, 28: 35-41.

Marasovic I. and Vukadin I., 1982. Red tide in the Vranjic basin (Kastela Bay). *Biljes. Notes, Institut za oceanografiju i ribarstvo, Split*, 48: 1-7.

Marasovic I., Gacic M., Kovacevic V., Krstulovic N., Kuspilic G., Pucher-Petkovic T., Odzak N. and Solic M., 1991. Development of the red tide in the Kastela Bay (Adriatic Sea). *Mar. Chem.*, 32: 375-385.

Marasovic I. and Pucher-Petkovic T., 1991. Eutrophication impact on species composition a natural phytoplankton community. *Acta Adriat.*, 32(2): 719-729.

Marasovic I., Grbec B. and Morovic M., 1995. Long term production changes in the Adriatic. *Neth. J. Sea Res.*, 34(4): 267-273.

Marasovic I., Vilicic, D. and Nincevic Z., 1999. South Adriatic ecosystem: interaction with the Mediterranean Sea. The Eastern Mediterranean as a Laboratory Basin for the Assessment of Contrasting Ecosystems (Malanotte-Rizzoli P. & Eremeev V.N.).

Marasovic I., Nincevic Z., Kuspilic G., Marinovic S. and Marinov S., 2005. Long-term changes of basic biological and chemical parameters at two stations in the middle Adriatic. *J. Sea Res.*, 54 (1): 3-14.

Margalef R., 1969. Composicion especifica del fitoplancton de la costa catalana-levantina (Mediterraneo Occidental) en 1962-67. *Investigaciones Pesqueras*, 33: 315-380.

Margalef R. and Herrera J., 1964. Hidrografia y fitoplancton de la costa comprendida entre Castellon y la desembocadura del Ebro, de Julio de 1961 a Julio de 1962. *Sci. Mar.*, 26: 49-90.

Martin J.L., Hanke A.R. and LeGresley M.M., 2009. Long term phytoplankton monitoring, including harmful algal blooms, in the Bay of Fundy, eastern Canada. *J. Sea Res.*, 61: 76-83.

Marty J.C., Chiavérini J., Pizay M.D. and Avril B., 2002. Seasonal and interannual dynamics of nutrients and phytoplankton pigments in the western Mediterranean Sea at the DYFAMED time-series station (1991-1999). *Deep-Sea Research* II, 49: 1965-1985.

Maso M., Garcés E., Pages F. and Camp J., 2003. Drifting plastic debris as a potential vector for dispersing Harmful Algal Bloom (HAB) species. *Sci. Mar.*, 67: 107-111.

Meunier A., 1919. Mikroplankton de la mer Flamande. III. Les Péridiniens. *In:* Memoirs du Musee d' Histoire Naturelle de Belgique Bruxelles, Hayez M. (ed.), p. 119.

Minas H.J., Minas M., Coste B., Gostan J., Nival P. and Bonin M.C., 1988. Production de base et de recyclage ; une revue de la problématique en Méditerranée nord-occidentale., n° spécial : océanographie pélagique méditerranéenne, Minas & Nival (eds). *Oceanol. Acta*, pp. 155-162.

Miralto A., Barone G., Romano G., Poulet S.A., Ianora A., Russo G.L., Buttino I., Mazzarella G., Laabir M., Cabrini M. and Giacobbe M.G., 1999. The insidious effect of diatoms on copepod reproduction. *Nature*, 402:173-176.

Moestrup O., Akselman R., Cronberg G., Elbraechter M., Fraga S., Halim Y., Hansen G., Hoppenrath M., Larsen J., Lundholm N., Nguyen L.N. and Zingone A. (eds), 2009. IOC-UNESCO Taxonomic Reference List of Harmful Micro Algae [available online at <http://www.marinespecies.org/HAB>]

Mollmann C., Muller-Karulis B., Kornilovs G. and St John M.A., 2008. Effects of climate and overshing on zooplankton dynamics and ecosystem structure: regime shifts, trophic cascade, and feedback loops in a simple ecosystem. *ICES J. Mar. Sci.*, 65: 302-310.

Montagnes D.J.S. and Franklin D.J., 2001. Effect of temperature on diatom volume, growth rate, and carbon and nitrogen content: Reconsidering some paradigms. *Limnol. Oceanogr.*, 46(8): 2008-2018.

Monti M., Minocci M., Beran A. and Ivesa L., 2007. First record of *Ostreopsis* cfr. *ovata* on macroalgae in the Northern Adriatic Sea. *Mar. Pollut. Bull.*, 54: 598-601.

Moore S.K., Trainer V.L., Mantua N.J., Parke M.S., Laws E.A., Backer L.C. and Fleming L.E., 2008. Impacts of climate variability and future climate change on harmful algal blooms and human health. *Environ. Health-Glob.*, 7(Suppl 2): S4.

Morel A., Bricaud A., André J.M. and Pelaez Hudlet J., 1990. Spatial & temporal evolution of the Rhône river plume as seen by CZCS imagery: consequences upon primary productions in the Gulf of Lions. *In:* EROS 2000, Martin J.M. & Barth H. (eds), NERC, Plymouth, U. K. *Wat. Pollut. Res. Rep.*, 20: 45-62.

Moutin T., 2000. Cycle biogéochimique du phosphate : rôle dans le contrôle de la production planctonique et conséquences sur l'exportation de carbone de la couche éclairée vers l'océan profond. *Océanis*, 26-4: 643-660.

Moutin T., Raimbault P. and Poggiale J.C., 1999. Production primaire dans les eaux de surface de la Méditerranée occidentale : calcul de la production journalière. *C.R. Acad. Sci., Paris, Sciences de la Vie*, 322: 651-659.

Penna A., Vila M., Fraga S., Giacobbe M.G., Andreoni F., Riobo P. and Vernesi C., 2005. Characterization of *Ostreopsis* and *Coolia* (Dinophyceae) isolates in the Western Mediterranean Sea based on morphology, toxicity and internal transcribed spacer 5.8S rDNA sequences. *J. Phycology*, 41: 212-225.

Peperzak L., 2003. Climate change and harmful algal blooms in the North Sea. *Acta Oecologica,* 24: S139-S144.

Perez T., Garrabou J., Sartoretto S., Harmelin J.G., Francour P. and Vacelet J., 2000. Mortalité massive d'invertébrés marins: Un événement sans précédent en Méditerranée nord-occidentale. *C.R. Acad. Sci., Paris, Sciences de la Vie*, 323: 853-865.

Pérez-Arellano J.L., Luzardo O.P., Pérez Brito A., Hernandez Cabrera M., Zumbado M., Carranza C., Angel-Moreno A., Dickey R.W. and Boada L.D., 2005. Ciguatera fish poisoning, Canary Islands. *Emerging Infectious Diseases,* 11: 1981-1982.

Peterson K.A., Lu J. and Greatbatch R.J., 2003. Evidence of nonlinear dynamics in the eastward shift of the NAO. *Geophys. Res. Lett.*, 30(2): 1030, doi:10.1029/2002GL015585.

Piccinetti C. and Manfrin G., 1969. Osservazioni sulla mortalita di pesci ed altri organismi verificatisi nel 1969 in Adriatico. *Note Laboratorio Biologia marina e Pesca Fano*, 3: 73-92.

Pimm S.L. and Redfearn A., 1988. The variability of population densities. *Nature*, 334: 613-614.

Pin L.C., Teen L.P., Ahmad A. and Usup G., 2001. Genetic diversity of *Ostreopsis ovata* (Dinophyceae) from Malaysia. *Marine Biotechnology,* 3: 246-255.

Pinckney J.L., Paerl H.W., Haugen E. and Tester P.A., 2000. Response of phytoplankton and *Pfiesteria*-like-dinoflagellate zoospores to nutrient enrichment in the Neuse River Estuary, North Carolina, USA. *Mar. Ecol. Prog. Ser.*, 192: 65-78.

Platt T., Fuentes-Yaco C. and Frank K.T., 2003. Spring algal bloom and larval fish survival. *Nature*, 423: 398-399.

Polat S., 2004. New record for a dinoflagellate species (*Citharistes regius* Stein) in the Northern Levantine Basin (Eastern Mediterranean). *Turk. J. Botany*, 28: 507-509.

Polat S., 2006. Size fractionated distribution of the phytoplankton biomass in the Iskenderun Bay, Northeastern Mediterranean Sea. *Fresen. Environ. Bull.*, 15(2): 417-423.

Polat S., 2007a. Seasonal dynamics of phytoplankton in a coastal marine ecosystem Iskenderun Bay, northeastern Mediterranean Sea. *Fres. Environmental Bull.*, 16(7): 756-763.

Polat S., 2007b. The Interannual variations of phytoplankton abundance in relation to hydrographical and meteorological factors in the Iskenderun Bay, northeastern Mediterranean Sea. Second Annual YÖK-SUNY Collaboration Symposium, Scientific Collaboration for Sustainable Development, 23-25 May 2007, Proceeding (Akinoglu A., Ulusoy R., Bada E. & Genc B. eds), pp. 335-340.

Polat S., Sarihan E. and Koray T., 2000. Seasonal Changes in the Phytoplankton of the Northeastern Mediterranean (Bay of Iskenderun). *Turk. J. Botany.*, 24: 1-12.

Polat S. and Piner M.P., 2002a. Seasonal variations in biomass, abundance and species diversity of phytoplankton in the Iskenderun Bay (Northeastern Mediterranean). *Pak. J. Botany*, 34: 101-112.

Polat S. and Piner M.P., 2002b. Nutrients and phytoplankton in the Babadillimani Bight, northeastern Mediterranean coast of Turkey. *Indian J. Mar. Sci.*, 31: 188-194.

Polat S. and Isik O., 2002. Phytoplankton distribution, diversity and nutrients at the NE Mediterranean Coast of Turkey (Karatas-Adana). *Turk. J. Botany*, 26: 77-86.

Polat S. and Koray T., 2007. Planktonic Dinoflagellates of Northern Levantine Basin Northeastern Mediterranean Sea. *Eur. Journal of Protistology*, 43: 193-204.

Sarno D. and Dahlman J., 2000. Production of domoic acid in another species of *Pseudo-nitzschia*: *P. multistriata* in the Gulf of Naples (Mediterranean Sea). *Harmful Algae News*, 21: 5.

Schiller J., 1933. Dinoflagellatae (Peridineae) in monographischer Behandlung. 1.Teil. *In:* Kolkwitz R. (ed.), Dr. L. Rabenhorst's Kryptogamen-Flora von Deutschland, Österreich und der Schweiz. Leipzig: Akademische Verlagsgesellschaft, pp. 1-617.

Schröder B., 1906. Beiträge zur Kenntnis des Phytoplanktons warmer Meere. *Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich*, 51: 319-377.

Selander E., Thor P., Toth G. and Pavia H., 2006. Copepods induce paralytic shellfish toxin production in marine dinoflagellates. *Proc. Royal Soc. B*, 273: 1673-1680.

Sellner K.G. and Fonda Umani S., 1999. Dinoflagellate blooms and mucilage production. *In:* Ecosystems at the land-sea margin: drainage basin to coastal sea, Malone T.C., Malej A., Harding Jr. L.W., Smodlaka N. & Turner R.E. (eds), Washington, American Geophysical Union, pp. 173-206.

Sfriso A. and Facca C., 2007. Distribution and production of macrophytes and phytoplankton in a Mediterranean coastal area: the Venice lagoon as a case study. *Mar. Envir. Res.*, 56: 617-636.

Shears N.T. and Ross P.M., 2009. Blooms of benthic dinoflagellates of the genus *Ostreopsis*; an increasing and ecologically important phenomenon on temperate reefs in New Zealand and worldwide. *Harmful Algae,* 8: 916-925.

Siano R., Kooistra W.H.C.F., Montresor M. and Zingone A., 2009. Unarmoured and thin-walled dinoflagellates from the Gulf of Naples, with the description of *Woloszynskia cincta* sp. nov. (Dinophyceae, Suessiales). *Phycologia*, 48: 44-65.

Simoni F., Gaddi A., Di Paolo C. and Lepri L., 2003. Harmful epiphytic dinoflagellates on Tyrrhenian Sea. *Harmful Algae News*, 24: 13-14.

Simoni F., di Paolo C., Gori L. and 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.

Smayda T.J., 1997. Bloom dynamics: physiology, behavior, trophic effects. *Limnol. Oceanogr.*, 42(5): 1132-1136.

Smith V.H., 2003. Eutrophication of freshwater and coastal marine ecosystems - a global problem. *Environ Sci. and Pollut. Res.*, 10: 126-139.

Sole J., Estrada M. and Garcia-Ladona E., 2006. Biological control of harmful algal blooms: a modelling study. *J. Marine Syst.*, 61: 165-179.

Solé J., Turiel A., Estrada M., Llebot C., Blasco D., Camp J., Delgado M., Fernandez-Tejedor M. and Diogène J., 2009. Climatic forcing on hydrography of a Mediterranean bay (Alfacs Bay). *Cont. Shelf Res.*, 29: 1786-1800.

Solic M., Krstulovic N., Marasovic I., Baranovic A., Pucher-Petkovic T. and Vucetic T., 1997. Analysis of time series of planktonic communities in the Adriatic Sea: distinguishing between natural and man-induced changes. *Oceanol. Acta,* 20: 131-143.

Solidoro C., Bastianini M., Bandelj V., Codermatz R., Cossarini G., Melaku Canu D., Ravagnan E., Salon S. and Trevisani S., 2009. Current state, scales of variability and decadal trends of biogeochemical properties in the Northern Adriatic Sea. *J. Geophys. Res.*, doi: 10.1029/2008JC004838.

Sommer H. and Meyer K.F., 1937. Paralytic shellfish poisoning. *Arch. Pathol.*, 24: 560-598.

Sommer U., 1996. Nutrient competition experiments with periphyton from the Baltic Sea. *Mar. Ecol. Prog. Ser.*, 140: 161-167.

Somot S., Sevault F. and Déqué M., 2006. Transient climate change scenario simulation of the Mediterranean Sea for the 21st century using a high-resolution ocean circulation model. *Clim. Dynam.*, 27(7-8): 851-879.

Sorokin Y.I., Sorokin P.Y. and Ravagnan G., 1999. Analysis of lagoonal ecosystems in the Po River Delta associated with intensive aquaculture. *Estuar. Coast. Shelf Sci.*, 48: 325-342.

Sournia A., 1972a. Une période de poussées phytoplanctoniques près de Nosy-Bé (Madagascar) en 1971. I. Espèces rares ou nouvelles du phytoplancton. Cahier O.R.S.T.O.M., série Océanographie 10(2): 151-159.

Sournia A., 1972b. Quatre nouveaux dinoflagellés du plancton marin. *Phycologia*, 11: 71-74.

Southward A.J., 1980. The western English Channel - an inconstant ecosystem? *Nature*, 285: 361-366.

Southward A.J., Langmead O., Hardman-Mountford N.J., Aiken J. *et al.*, 2005. Long-term oceanographic and ecological research in the western English Channel. *Adv. Mar. Biol.*, 47: 1-105.

Spanier E., Finkelstein Y. and Raikhlin-Eisenkraft B., 1989. Toxicity of the saupe, *Sarpa salpa* (Linnaeus, 1758), on the Mediterranean coast of Israel. *J. Fish Biol.*, 34: 635-636.

Specchiulli A., Focardi A., Renzi S. *et al.*, 2008. Environmental heterogeneity patterns and assessment of trophic levels in two Mediterranean lagoons: Orbetello and Varan, Italy. *Sci. Total Envir.*, 402: 285-298.

Sundström B.G., 1984. Observations on *Rhizosolenia clevei* Ostenfeld (Bacillariophyceae) and *Richelia intracellularis* Schmidt. *Bot. Mar.*, 27: 345-355.

Svedrup H.U., 1953. On conditions for the vernal blooming of phytoplankton. *J. Cons. Int. Explor. Mer*, 18: 287-295.

Tagmouti-Talha F., Chafak H., Fellat-Zarrouk K., Talbi M., Blaghen M., Mikou A., Guittet E., 1996. Detection of toxins in bivalves of Moroccan coasts. *In:* Harmful and toxic algal blooms: Intergovernmental Oceanographic Commission of UNESCO, Yasumoto T., Oshima T. & Fukuyo Y. (eds), pp. 85-87.

Tahri Joutei L., 1998. *Gymnodium catenatum* Graham blooms on Moroccan waters. *In:* Harmful algae: Xunta de Galicia and Intergovernamental Oceanographic Commission of UNESCO 1998, Reguera B., Blanco J., Fernandez M.L. & Wyatt T. (eds): pp. 66-69.

Taniyama S., Arakawa O., Terada M., Nishio S., Takatani T., Mahmud Y. and Noguchi T., 2003. *Ostreopsis* sp., a possible origin of palytoxin (PTX) in parrotfish *Scarus ovifrons*. *Toxicon,* 42: 29-33.

Taslakian A.J. and Hardy J.T., 1976. Sewage nutrient enrichment and phytoplankton ecology along the central coast of Lebanon. *Mar. Biol.*, 38: 315-325.

Taylor F.J.R., 1979. A description of the benthic dinoflagellate associated with maitotoxin and ciguatoxin, including observations on Hawaiian material. *In:* Toxic dinoflagellates blooms, Taylor D.L. & Seliger H.H. (eds), Elsevier North Holland Inc, Amsterdam, The Netherlands, pp. 44-56.

Tester P., Faust M.A., Vandersea M., Kibler S., Chinain M., Holmes M., Holland W. and Litaker R., 2006. Does *Gambierdiscus toxicus* type material exist? 12th International Conference on Harmful Algae, Copenhagen.

Thingstad T.F., Zweifel U.L. and Rassoulzadegan F., 1998. P limitation of heterotrophic bacteria and phytoplankton in the northwest Mediterranean. *Limnol. Oceanogr.*, 43(1): 88-94.

Tillmann U., John U. and Cembella A., 2007. On the allelochemical potency of the marine dinoflagellate *Alexandrium ostenfeldii* against heterotrophic and autotrophic protists. *J. Plankt. Res.*, 29: 527-543.

Tillmann U. and Hansen P.J., 2009. Allelopathic effects of *Alexandrium tamarense* on other algae: evidence from mixed growth experiments. *Aquat. Microb. Ecol.*, 57: 101-112.

Tillmann U., Alpermann T., Purificaçao R.C.D., Krock B. and Cembella A., 2009. Intrapopulation clonal variability in allelochemical potency of the toxigenic dinoflagellate *Alexandrium tamarense*. *Harmful Algae*, 5: 759-769.

Tognetto L., Bellato S., Moro I. and Andreoli C., 1995. Occurrence of *Ostreopsis ovata* (Dinophyceae) in the Tyrrhenian Sea during summer 1994. *Bot. Mar.*, 38: 291-295.

Totti C., Cucchiari E., Romagnoli T. and Penna A., 2007. Bloom of *Ostreopsis ovata* on the Conero riviera (NW Adriatic Sea). *Harmful Algae News*, 33: 12-13.

Travers A. and Travers M., 1975. Catalogue du microplancton du Golfe de Marseille. *Internationale Revue der gesamten Hydrobiologie*, 60: 251-276.

Tsiamis K., Panayotidis P. and Zenetos A., 2008. Alien marine macrophytes in Greece: a review. *Bot. Mar.*, 51: 237-246.

Tugrul S., Yemenicioglu S. and Dogan-Saglamtimur N., 2007. Long term trend monitoring in pollution sources of the Mediterranean coastal zone: Rivers and wastewaters (2003-2006). *Turkish J. Aquatic Life*, Issue 5-8: 596-606 (in Turkish).

Tugrul-Icemer G., Keles C. and Karaca H., 2007. Microbiological seawater quality in the Antalya beaches. *Turkish J. Aquatic Life*, Issue 5-8: 553-559 (in Turkish).

Tunin-Ley A., Ibanez F., Labat J.P., Zingone A. and Lemee R., 2009. Phytoplankton biodiversity and NW Mediterranean Sea warming: changes in the dinoflagellate genus *Ceratium* in the 20th century. *Mar. Ecol. Prog. Ser.*, 375: 85-99.

Turki S., 2005. Distribution of toxic dinoflagellates along the leaves of seagrass *Posidonia oceanica* and *Cymodocea nodosa* from the Gulf of Tunis. *Cah. Biol. Mar.*, 46: 29-34.

Turki S. and El Abid A., 2001. On the presence of potentially toxic algae in the lagoons of Tunisia. *Harmful Algae News*, 22: 11.

Turki S., Harzallah A. and Sammari C., 2006. Occurrence of harmful dinoflagellates in two different Tunisian ecosystems: the lake of Bizerte and the gulf of Gabes. *Cah. Biol. Mar.*, 47(3): 253-259.

Tziperman A. and Malanotte-Rizzoli P., 1991. The climatological seasonal circulation of the Mediterranean Sea. *J. Mar. Res.*, 49: 411-434.

Ukena T., Satake M., Usami M., Oshima Y., Naoki H., Fujita T., Kan Y. and Yasumoto T., 2001. Structure elucidation of ostreocin D, a palytoxin analog isolated from the dinoflagellate *Ostreopsis siamensis*. *Biosci. Biotech. Bioch.*, 65: 2585-2588.

Uronen P., Lehtinen S., Legrand C., Kuuppo P. and Tamminen T., 2005. Haemolytic activity and allelopathy of the haptophyte *Prymnesium parvum* in nutrient-limited and balanced growth conditions. *Mar. Ecol. Prog. Ser.*, 299: 137-148.

Usami M., Satake M., Ishida S., Inoue A., Kan Y. and Yasumoto T., 1995. Palytoxin analogs from the dinoflagellate *Ostreopsis siamensis*. *Journal of the American Chemical Society*, 117: 5389-5390.

Utermöhl H., 1931. Neue wege in der quantitativen erfassung des planktons (mit besonderer berücksichtingung des ultraplanktons). *Verh int Ver theor angew Limnol.*, 5: 567-596.

Utermöhl H., 1958. Zur Vervollkommnung der quantitativen Phytoplankton-Methodik. Mitteilungen der Internationalen Vereinigung fur theoretische und angewandte. *Limnologie*, 9: 1-38.