

## Mediterranean Marine Science

Vol 13, No 1 (2012)



### Surveying *Caulerpa* (Chlorophyta) species along the shores of the eastern Mediterranean

S. UKABI, Z. DUBINSKY, Y. STEINBERGER, A. ISRAEL

doi: [10.12681/mms.18](https://doi.org/10.12681/mms.18)

#### To cite this article:

UKABI, S., DUBINSKY, Z., STEINBERGER, Y., & ISRAEL, A. (2012). Surveying *Caulerpa* (Chlorophyta) species along the shores of the eastern Mediterranean. *Mediterranean Marine Science*, 13(1), 5-11. <https://doi.org/10.12681/mms.18>

## Surveying *Caulerpa* (Chlorophyta) species along the shores of the eastern Mediterranean

S. UKABI<sup>1,2</sup>, Z. DUBINSKY<sup>1</sup>, Y. STEINBERGER<sup>1</sup> and A. ISRAEL<sup>2</sup>

<sup>1</sup> The Mina and Everard Goodman Faculty of Life Sciences, Bar-Ilan University, Ramat-Gan 52900, Israel

<sup>2</sup> Israel Oceanographic & Limnological Research, Ltd., The National Institute of Oceanography,  
P.O. Box 8030, Tel Shikmona, Haifa 31080, Israel

Corresponding author: [shimrit\\_y@hotmail.com](mailto:shimrit_y@hotmail.com)

Received: 22 March 2011; Accepted: 11 October 2011; Published on line: 24 February 2012

### Abstract

*Caulerpa* (Chlorophyta) species inhabiting intertidal and shallow subtidal areas along the Israeli Mediterranean shores (i.e., presence/absence) were surveyed on a seasonal basis from 2007 to 2009. We recorded the presence of three species: *C. prolifera*, *C. mexicana*, and *C. scalpelliformis*. These species were noticeable in autumn and inconspicuous during winter, thus revealing seasonality and population dynamics. There were no indications of well-known invasive species such as *Caulerpa racemosa* var. *cylindracea* and *Caulerpa taxifolia*. This study is the first of a kind that assesses the geographical distribution and seasonality of the genus *Caulerpa* along the Israeli shores.

**Keywords:** *Caulerpa*, distribution, Mediterranean.

**List of nonstandard abbreviations:** C, Center; M, *C. mexicana*; N, North; P, *C. prolifera*; R, *C. racemosa*; S, *C. scalpelliformis*; So, South

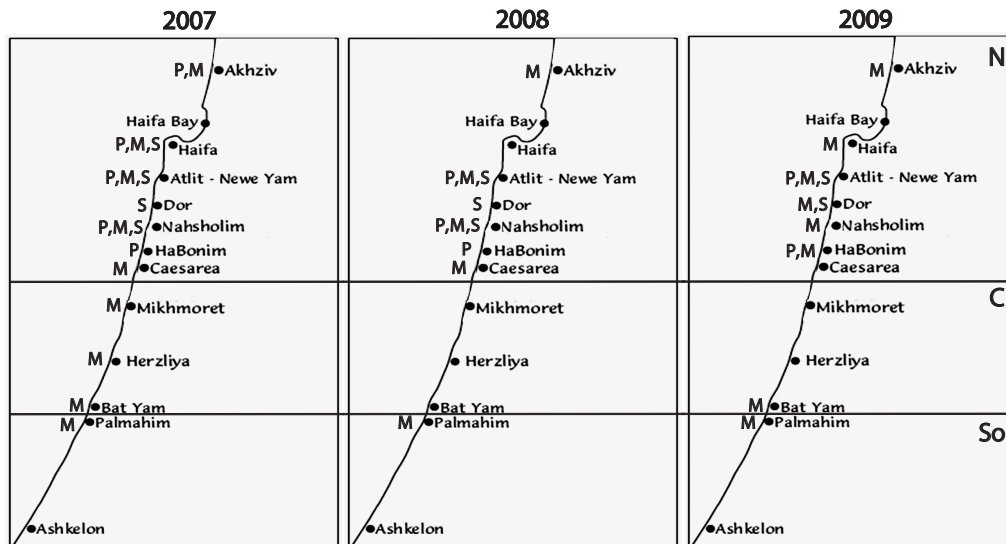
### Introduction

*Caulerpa* species are common in both shallow and deep waters of tropical and subtropical seas. They are multinucleated (coenocyte), colonial, modular, and lack cellulose in their cell walls (Silva, 1992). *Caulerpa* species produce branched axes and attaching rhizoids, and are capable of vegetative reproduction. The genus includes over 75 species worldwide (Famà *et al.*, 2002), with only six described for the Mediterranean Sea, namely, *C. prolifera*, *C. mexicana*, *C. scalpelliformis*, *C. olivieri*, *C. racemosa* [with *C. racemosa* var. *lamourouxii* f. *requienii*, *C. racemosa* var. *turbinata* and *C. racemosa* var. *cylindracea* – all recognized as separate taxonomical identities (see Verlaque *et al.*, 2003)], and *C. taxifolia* (Guiry & Guiry, 2011; UNEP, 1999; Einav & Israel, 2007, Table 1). Two of these, *C. racemosa* var. *cylindracea* and *C. taxifolia*, are known to be invasive and have caused great environmental concern in Mediterranean countries during recent years (Boudouresque *et al.*, 1995; Meinesz *et al.*, 1998; Verlaque *et al.*, 2000, 2003).

The eastern and western basins of the Mediterranean Sea have different thermal regimes. In the eastern Mediterranean Sea, temperatures range from 17 to 30°C in winter and summer, respectively, and are higher than

those in the western basin by about 1.5°C for both seasons (Kress & Herut, 2001). The eastern Mediterranean basin has a wide, shallow, and sandy continental shelf as well as prominent abrasion intertidal platforms made of limestone and biogenic rocks (Einav & Israel, 2007). In addition, salinities at the eastern basin are higher, with values of 3.9‰ and 3.6‰ for the eastern and western basins, respectively (Berman *et al.*, 1984). The eastern Mediterranean Sea is especially susceptible to biological invasions through the Suez Canal. Indeed, most of the approximately 100 known aquatic macrophytes introduced into the Mediterranean Sea have originated from the Indo-Pacific Sea (Galil *et al.*, 1990; Boudouresque & Verlaque, 2002, 2005; Ribera, 2002; Boudouresque *et al.*, 2005; Zenetos *et al.*, 2005; Rilov & Galil, 2009).

Ecological studies of the genus *Caulerpa* have focused on *Caulerpa taxifolia* and *Caulerpa racemosa* because of their invasive properties (Meinesz & Hesse, 1991; Argyrou *et al.*, 1999; Meinesz, 2001; Verlaque *et al.*, 2000, 2003). Up to now, *C. taxifolia* has not been reported for the Israeli Mediterranean (Einav & Israel, 2007). *C. racemosa* was collected for the first time in 1926 by Hamel in Sousse Harbor, Tunisia, and later its presence was reported throughout the eastern basin of the Mediterranean Sea (Verlaque *et al.*, 2000; Aleem, 1950;



**Fig. 1:** Distribution of *Caulerpa* species along the Israeli Mediterranean coast (N – north, C – central, So – south) during 2007-2009 (P – *C. prolifera*; M – *C. Mexicana*; S – *C. scalpelliformis*).

Lipkin, 1975), including Israel (Rayss & Edelstein, 1960). At that time, no reports of invasive properties for *C. racemosa* var. *cylindracea* were suggested. *C. racemosa* var. *lamourouxii* f. *requienii* has been spreading within the Levantine area since the early 50s, intensifying during the 90s (Verlaque *et al.*, 2000). The variant *C. racemosa* var. *cylindracea* (Verlaque *et al.*, 2003; ARGYROU *et al.*, 1999), which is native of southwest Australia, has reached the shores of over 15 Mediterranean countries, including all major Mediterranean islands, such as the Balearic Islands, Corsica, Crete, Cyprus, Sardinia, and Sicily (Verlaque *et al.*, 2003; Klein & Verlaque, 2008; Rivera-Ingraham *et al.*, 2010).

Studies conducted during 1922-1999 (Fig. 1 and references therein) identified 4 species for the Israeli Mediterranean Sea (*C. prolifera*, *C. mexicana*, *C. scalpelliformis* and *C. racemosa*). From these and other investigations, the importance of seasonality on population dynamics in the Mediterranean Basin, in which high algal densities are apparent during autumn each year, has been underlined (www.algaebase.org; UNEP, 1999, Table 1). In the current study, we aimed to address the diversity and seasonal as well as longitudinal distribution of *Caulerpa* species along the shores of the Israeli Mediterranean Sea.

## Materials and Methods

*Caulerpa* species were surveyed during the years 2007-2009 from the intertidal and subtidal zones by snorkeling and visually monitoring the rocky and sandy bottoms of 11 field sites. These locations cover ca. 135 km of exposed shoreline, from north to south. The sites were further divided into three geographical areas: northern

stations (Akhziv, Haifa, Atlit, Dor, Habonim, Nahsholim, and Sdot Yam), central stations (Mikhmoret, Herzliya, and Bat-Yam), and a southern station (Palmahim). For comparison purposes, the sampling sites included those in which *Caulerpa* species were described in previous studies (see Figure 1 and references therein). Monitoring strips 150 m long and 3 m wide in the intertidal, as well as snorkeling down to 2-3 m depth in the subtidal, both served to verify the presence or absence of *Caulerpa* at each site. In addition, potholes and tide pools from the intertidal were surveyed for the possible presence of the species. Therefore, mapping of *Caulerpa* in this study was based on whether the algae were present or not in a defined sampling site. The survey was conducted on a seasonal basis with nearly monthly visits to the sites on days with low tides and calm seas.

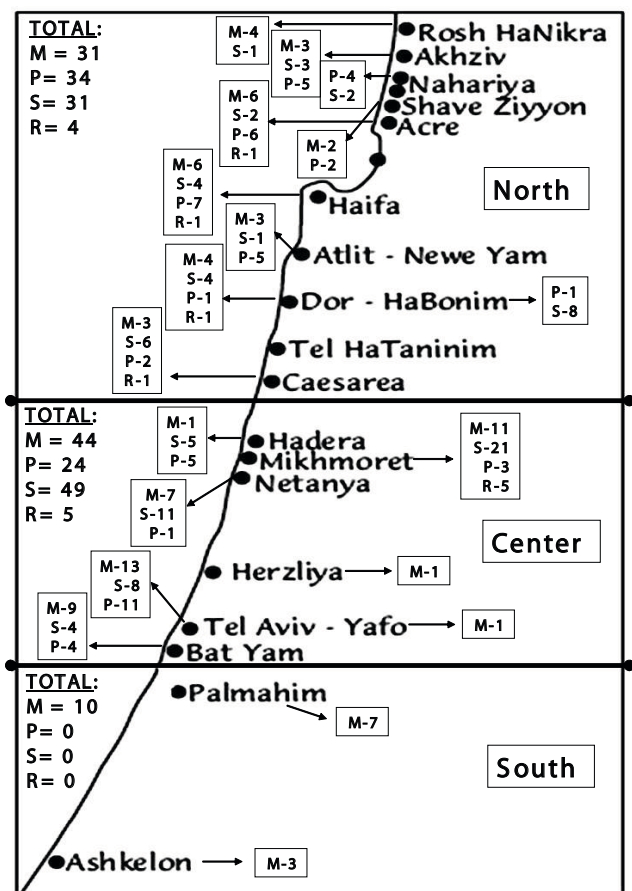
## Results and Discussions

The goal of our study was to follow the seasonal changes of *Caulerpa* species that could be related to their geographical distribution. The results showed that only *C. mexicana* grows at all sampling sites, with *C. prolifera* and *C. scalpelliformis* predominant in the northern locations (Fig. 1). All three *Caulerpa* species prevail during the entire year except for winter, when seaweeds were scarce and hard to find (Table 2). Seasonality was particularly noticeable when mapping during 2007 and 2009. *C. racemosa* was never observed during the course of this study (Fig. 1 and Table 2).

Summarizing seaweed surveys carried out for the Israeli Mediterranean shores between 1926 and 1999 (Fig. 2) revealed that (1) *C. prolifera* is abundant in the northern areas; (2) *C. scalpelliformis* thrives in the central ar-

**Table 1.** Distribution of *Caulerpa* species from Mediterranean countries.

Countries	<i>C. Prolifera</i>	<i>C. mexicana</i>	<i>C. scapelliformis</i>	<i>C. taxifolia</i>	<i>C. racemosa</i>	<i>C. ollivieri</i>	Reference (UNEP, 1999; Portal: <a href="http://www.algaebase.org">www.algaebase.org</a> )
Albania	+	-	-	-	+	-	UNEP, 1999; Verlaque <i>et al.</i> , 2000
Algeria	+	-	-	-	-	-	Gallardo <i>et al.</i> , 1993
Croatia	+	-	-	+	+	-	UNEP, 1999; Verlaque <i>et al.</i> , 2000; Nuber <i>et al.</i> , 2007; Blazina <i>et al.</i> , 2009
Cyprus	-	-	-	-	+	-	UNEP, 1999; Argyrou <i>et al.</i> , 1999; Verlaque <i>et al.</i> , 2000
Egypt	+	+	+	-	+	-	Papenfuss, 1968; UNEP, 1999; Aleem, 1993; Gallardo <i>et al.</i> , 1993; Aleem 1950; Verlaque <i>et al.</i> , 2000;
France	+	-	-	+	+	+	Gallardo <i>et al.</i> , 1993; UNEP, 1999; Uchimura <i>et al.</i> , 2000; Chisholm <i>et al.</i> , 2007; Hill <i>et al.</i> , 1998; Thibat <i>et al.</i> , 2004; Belsher & Meinesz, 1995; Boudouresque & Verlaque, 2005; Bartoli & Boudouresque, 1997; Pawlowski <i>et al.</i> , 1998; Verlaque <i>et al.</i> , 2000; Renoncourt & Meinesz 2002; Ruitton <i>et al.</i> , 2005, 2006; Meinesz & Hesse, 1991; Meinesz <i>et al.</i> , 1993; Boudouresque <i>et al.</i> , 1994; Meinesz <i>et al.</i> , 1998; Gayol <i>et al.</i> , 1995; Komatsu <i>et al.</i> , 1997
Greece	+	-	-	-	+	-	Gerloff & Geissler 1974; Haritonidis & Tsekos 1976; Tsekos & Haritonidis 1977; Athanasiadis 1987; Gallardo <i>et al.</i> , 1993; Donat <i>et al.</i> , 1997; UNEP, 1999; Tsirika & Haritonidis 2005; Panayotidis & Montesanto ,1994,1998; Panayotidis & Zuljevic , 2001; Verlaque <i>et al.</i> , 2000
Israel	+	+	+	-	+	-	Hoffman, 2004; Rayss & Edelstein, 1960; Einav, 1993, 1998; Lundberg, 1986; Pawlowski <i>et al.</i> , 1998; UNEP, 1999; Lipkin & Safriel, 1971; Levi & Friedlander, 2004; Friedlander <i>et al.</i> , 2006; Rayss, 1941; Lipkin & Friedmann 1967; Lipkin, 1972; Gallardo <i>et al.</i> , 1993
Italy	+	-	-	+	+	-	UNEP, 1999; Gallardo <i>et al.</i> 1993; Rindi <i>et al.</i> 2002; Piazzi <i>et al.</i> , 1994, 1997a,b, 2001, 2007; Piazzi & Ceccherelli, 2002; Ceccherelli & Cinelli, 1997; Pawlowski <i>et al.</i> , 1998; Montefalcone <i>et al.</i> , 2007; Giaccone, 1969; Feoli & Bressan, 1972; Piazzi <i>et al.</i> , 2000; Cecere <i>et al.</i> , 1996; Furnari <i>et al.</i> , 1999; Alongi <i>et al.</i> , 1993; Verlaque <i>et al.</i> , 2000; Serio <i>et al.</i> , 2006; Valera-Alvarez <i>et al.</i> , 2006; Bussotti <i>et al.</i> , 1996; Gambi & Terilzzi, 1998; Piazzi & Cinelli, 1999; Fama <i>et al.</i> , 2000; Buia <i>et al.</i> , 1998; Raniello <i>et al.</i> , 2004, 2006; Piazzi & Balata, 2008; Durano <i>et al.</i> , 2002; Sant <i>et al.</i> , 1996; Gacia <i>et al.</i> , 1996; Delgado <i>et al.</i> , 1996
Lebanon	+	+	+	-	+	-	UNEP, 1999; Hamel, 1926, 1931a, 1931b; Verlaque <i>et al.</i> , 2000; Gallardo <i>et al.</i> , 1993
Libya	+	-	-	-	+	-	Gallardo <i>et al.</i> , 1993; Nizamuddin, 1991; Verlaque <i>et al.</i> , 2000; UNEP, 1999
Malta	+	-	-	-	+	-	Price, 1970; UNEP, 1999; Gallardo <i>et al.</i> , 1993
Morocco	+	-	-	-	+	-	Gallardo <i>et al.</i> , 1993; UNEP, 1999; Benhissoune <i>et al.</i> , 2001; Verlaque <i>et al.</i> , 2000; Conde Poyales, 1992;
Spain	+	+	+	+	+	-	Gallardo <i>et al.</i> 1993; UNEP, 1999; Valera-Alvarez <i>et al.</i> , 2006; Terrados & Marba. 2006; Ferrer <i>et al.</i> , 1997; Pawlowski <i>et al.</i> , 1998; Bellón, 1921; Bellón, 1940; Seoane-Camba, 1965; Ballasteros & Romero 1982; Barcelo & Seoane 1982; Pérez-Ruzafa & Honrubia 1984; Gallardo <i>et al.</i> 1985; Soto & Conde 1989; Pérez-Ruzafa 1990; Terrados & Ros 1992; Flores-Moya <i>et al.</i> 1995; De la rosa <i>et al.</i> , 2006; Rueda & Salas 2003; Pérez-Ruzafa <i>et al.</i> 2008; de los Santos <i>et al.</i> , 2009; Mercado <i>et al.</i> 2009; Holmer <i>et al.</i> , 2004; Pena Martín <i>et al.</i> 2003
Syria	+	+	+	-	+	-	UNEP, 1999; Bitar <i>et al.</i> , 2003; HuveA, 1957; Verlaque <i>et al.</i> , 2000; Gallardo <i>et al.</i> , 1993
Tunisia	+	-	-	-	+	-	Ben Maiz <i>et al.</i> , 1987; Gallardo <i>et al.</i> 1993; UNEP, 1999; Hamel, 1926, 1930, 1931a, Djellouli <i>et al.</i> , 1998; Verlaque <i>et al.</i> , 2000
Turkey	+	-	+	+	+	+	Aysel <i>et al.</i> , 2006; Ertan <i>et al.</i> , 1998; Gallardo <i>et al.</i> , 1993; Güven & Öztig, 1971; Güner <i>et al.</i> , 1985; UNEP, 1999; Taskin <i>et al.</i> , 2008; Cevik <i>et al.</i> , 2006; Evirgen, 1997; Mayhoub, 1976



**Fig. 2:** *Caulerpa* species (P – *C. prolifera*, M – *C. mexicana*, S – *C. scalpelliformis*, and R – *C. racemosa*) monitored along the Israeli Mediterranean shores between 1926 and 1999. Observations of each of the species are indicated by numbers for the specific sampling site and for each geographical location (summarized from Rayss (1941); Edelstein (1960, 1962); Rayss & Edelstein (1960); Lipkin (1962); Lipkin & Safriel (1971); Ramon (1985); Lundberg (1986, 1996); Einav (1993, 1998); Einav & Israel (2007).

eas; (3) *C. mexicana* is the only species that expands to the south; and (4) *C. racemosa* is rare and described in the central and northern stations only (Rayss, 1941; Edelstein, 1960, 1962; Rayss & Edelstein, 1960; Lipkin, 1962; Lipkin & Safriel, 1971; Ramon, 1985; Lundberg, 1986, 1996; Einav, 1993, 1998; Einav & Israel, 2007). These studies made no reference to the presence of *C. taxifolia*. Thus, altogether, it seems that *Caulerpa* distribution has remained quite the same, except for the fact that *C. racemosa* was unaccounted for in this study. From a seasonal viewpoint, data of 1926-1999 indicate that *C. mexicana* thrives along the coast from north to south all year long, although it was described as being “more abundant” in autumn and summer at the central stations, and in winter at the northern stations (Fig. 3). These observations suggest physiological features allowing a broader tolerance to temperatures among species (Streftaris *et al.*, 2005), and may be based on fast acclimation of photosynthesis

and respiration to changing seawater temperatures, such as for *C. prolifera* (Terrados & Ros, 1992). *C. prolifera*, *C. scalpelliformis*, and *C. racemosa* were not observed in the south at all, with *C. racemosa* scarcely observed except in summer and winter (Figs. 2 and 3). Seasonality for *C. scalpelliformis* was evident by the fact that its presence occurred mainly during summer at the north and central sampling sites, in agreement with findings in this (Fig. 1 and Table 2) and other studies (Womersley, 1984; Ertan *et al.*, 1998).

Seawater flows from the Atlantic Ocean into the western basin of the Mediterranean Sea, thus buffering water characteristics such as salinity, temperature, nutrient concentrations, and currents (Lascaratos *et al.*, 1999). The eastern basin is largely oligotrophic and exhibits exceptionally low primary productivity (Berman *et al.*, 1984; Yacobi *et al.*, 1995) and low nutrient concentrations, particularly during summer (Salihoglu *et al.*, 1990; Krom *et al.*, 1991; Psarra *et al.*, 2000). However, occasional nutrient-rich upwellings during this time of the year have been reported (Yacobi *et al.*, 1995). A warm-core eddy south of Cyprus and a cold-core eddy near Rhodes are localized sites with nutrient enrichment that might support high biological activity (Yacobi *et al.*, 1995). These eddies create a unique oceanographic condition along the Israeli coast, characterized by fast and strong current velocities in winter and summer, which get slower during spring and autumn, with a general counter-clockwise movement of seawater masses in the eastern basin (Oren & Komarovskiy, 1961; Pinardi *et al.*, 2003). Therefore, such a unique natural barrier impedes seawater from the west to move and replace seawater masses in the east. Consequently, we argue that the quite different oceanographic conditions for the eastern and western basins may be among the reasons why the invasive *C. taxifolia* has not yet penetrated into this part of the Mediterranean. Similar temperature barriers may have prevented the spread of *C. racemosa* var. *cylindracea*. *C. racemosa* has not been observed on the Israeli Mediterranean shore for at least two decades, nor was it found during the course of this study.

## Conclusions

This survey corroborated the presence of three out of the four *Caulerpa* species described in previous studies for the Israeli Mediterranean Sea. The invasive *C. taxifolia* and *C. racemosa* var. *cylindracea* were unaccounted for. This study also emphasizes the effect of seasonality on population dynamics, with high and visible biomasses in autumn and ephemeral presence during winter. The present survey should encourage long-term monitoring to assess climate-change effects and biodiversity of seaweeds in the Mediterranean Sea.

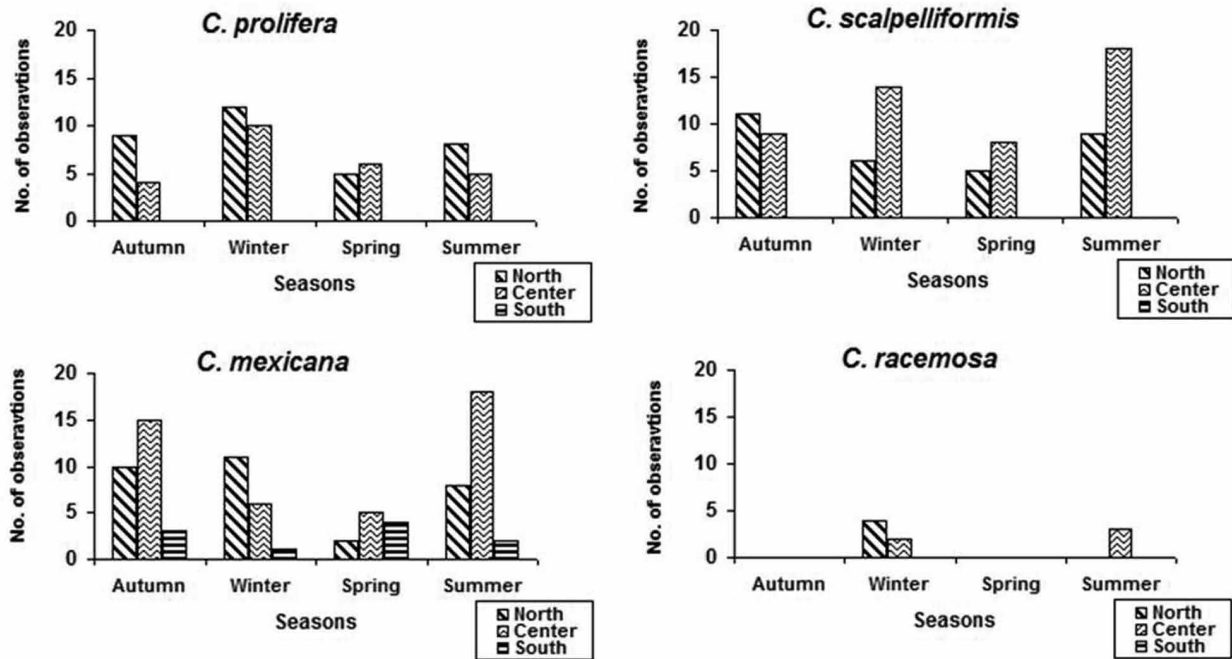


Fig. 3: Seasonal distribution of *Caulerpa* species (*C. prolifera*, *C. mexicana*, *C. scalpelliformis*, and *C. racemosa*) along the Israeli Mediterranean shores, as surveyed during 1926-1999.

Table 2. *Caulerpa* species found along the Israeli Mediterranean coast at different location (North, Center, South) during different seasons along the study years 2007-2009. (S-*C. scalpelliformis*, P-*C. prolifera*, M-*C. mexicana*)

YEAR	Seasons/ species	NORTH			CENTER			SOUTH		
		S	P	M	S	P	M	S	P	M
2007	winter	+	+	+	-	-	-	-	-	-
	spring	+	+	+	-	-	+	-	-	+
	summer	+	+	+	-	-	+	-	-	+
	autumn	+	+	+	-	-	+	-	-	+
2008	winter	+	+	-	-	-	-	-	-	-
	spring	+	+	+	-	-	-	-	-	+
	summer	+	+	+	-	-	-	-	-	-
	autumn	-	-	+	-	-	-	-	-	-
2009	winter	-	-	-	-	-	-	-	-	-
	spring	-	+	+	-	-	-	-	-	+
	summer	+	+	+	-	-	+	-	-	+
	autumn	-	-	-	-	-	+	-	-	-

## Acknowledgements

We are thankful to Mr. Razy Hoffman for his assistance with the surveys and his expertise in seaweed taxonomy. We are also grateful to members of the Marine Biology labs of the Israel Oceanographic & Limnological Research in Haifa for their assistance. Special thanks to Ms. Sharon Victor for her useful comments. This research is part of the Ph. D. thesis of Shimrit Ukabi.

## References

- Aleem, A.A., 1950. Some news records of marine algae from the Mediterranean Sea. *Meddelanden Göteborgs Botaniska Trädgård*, 18: 275-288.
- Argyrou, M., Demetropoulos, A. & Hadjichristophorou, M., 1999. Expansion of the macroalga *Caulerpa racemosa* and changes in softbottom macrofaunal assemblages in Moni Bay, Cyprus. *Oceanologica Acta*, 22: 517-528.
- Berman, T., Townsend, D.W., Elsayed, S.Z., Trees, C.C. & Azov,

- Y., 1984. Optical transparency, chlorophyll and primary productivity in the Eastern Mediterranean near the Israeli coast. *Oceanologia Acta*, 7: 367-372.
- Boudouresque, C.F. & Verlaque, M., 2002. Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes. *Marine Pollution Bulletin*, 44: 32-38.
- Boudouresque, C.F. & Verlaque, M., 2005. Nature conservation, marine protected areas, sustainable development and the flow of invasive species to the Mediterranean Sea. *Travaux Scientifiques Du Parc National de PortCros*, 21: 29-54.
- Boudouresque, C.F., Meinesz, A., Ribera, M.A. & 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: 21-29.
- Boudouresque, C.F., Ruitton, S. & Verlaque, M., 2005. Large-scale disturbances, regime shift and recovery in littoral systems subject to biological invasions. p.85-101. In: *Large-scale disturbances (Regime shifts) and recovery in aquatic ecosystems: Challenges for management towards sustainability*, V. Velikova & N. Chipev (Eds). UNESCO Publisher.
- Edelstein, T., 1960. *The biology and ecology of deep sea algae of the Haifa Bay*. Unpublished PhD Thesis, The Hebrew University of Jerusalem, Jerusalem, 144 pp. (in Hebrew)
- Edelstein, T., 1962. On the algal associations and the ecology of the Benthonic flora of the Haifa Bay. *Recueil des Travaux de la Station Marine d'Endoume, Bulletin*, 27: 209-211.
- Einav, R., 1993. *Ecophysiological adaptation strategies of intertidal marine macroalgae. Mediterranean, Israel*. PhD Thesis. Dissertationes botanicae, J. Cramer, Berlin, Stuttgart, 75 pp.
- Einav, R., 1998. Two observations of seaweeds from the Israeli coast: *Boodleopsis pusilla* and *Caulerpa prolifera* (Forsskal) Lamouroux, (Chlorophyta, Caulerpales). *Israel Journal of Plant Sciences*, 46: 81-82.
- Einav, R. & Israel, A., 2007. Seaweeds on the abrasion platforms of the intertidal zone of Eastern Mediterranean shores. p. 193-207. In: *Algae and cyanobacteria in extreme environments*. J. Seckbach (Ed). Dordrecht, The Netherlands, Springer.
- Ertan, O., Turna, I. & Cormaci, M., 1998. A new record for the marine algal flora of Turkey: *Caulerpa scalpelliformis* (Brown ex Turner) C. Agardh (Caulerpales, Chlorophyceae). *Turkish Journal of Botany*, 22: 285-287.
- Famà, P., Wysor, B., Kooistra, W.H.C.F. & Zuccarello, G.C., 2002. Molecular phylogeny of the genus *Caulerpa* (Caulerpales, Chlorophyta) inferred from chloroplast *tufA* gene. *Journal of Phycology*, 38: 1040-1050.
- 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 (Leiden)*, 64: 95-105.
- Guiry, M.D. & Guiry, G.M., 2011. *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org> [searched on 21 September 2011]
- Hamel, G., 1926. Quelques algues rares ou nouvelles pour la flore méditerranéenne. *Bulletin du Muséum National d'Histoire Naturelle, Paris*, 32 (6): 420. (in French)
- Klein, J. & Verlaque, M., 2008. The *Caulerpa racemosa* invasion: A critical review. *Marine Pollution Bulletin*, 56: 205-225.
- Kress, N. & Herut, B., 2001. Spatial and seasonal evolution of dissolved oxygen and nutrients in the Southern Levantine Basin (Eastern Mediterranean Sea): chemical characterization of the water masses and inferences on the N:P ratios. *Deep-Sea Research I*, 48: 2347-2372.
- Krom, M.D., Brenner, S., Kress, N. & Gordon, L.I., 1991. Phosphorus limitation of primary productivity in the Eastern Mediterranean. *Limnology & Oceanography*, 36 (3): 424-432.
- Lascaratos, A., Roether, W., Nittis, K., & Klein, B., 1999. Recent changes in deep water formation and spreading in the eastern Mediterranean Sea: a review. *Progress in Oceanography*, 44: 5-36.
- Lipkin, Y., 1962. *Ecological observations at Mikhmoret coast. The estival aspect of marine vegetation*. MSc Thesis. The Hebrew University of Jerusalem, Jerusalem.
- Lipkin, Y., 1975. Ecological distribution of *Caulerpa* in the Red Sea. *Journal of the Marine Biological Association of India*, 15: 160-167.
- Lipkin, Y. & Safriel, U., 1971. Intertidal zonation of rocky shores at Mikhmoret (Mediterranean, Israel). *Journal of Ecology*, 59: 1-30.
- Lundberg, B., 1986. Variations in algal vegetation along the Mediterranean shore line of Israel as possible basis for planning of marine nature reserves. p. 221-231. In: *Environmental quality and ecosystem stability*. Z. Dubinsky & Y. Steinberger (Eds). Ramat-Gan, Bar-Ilan University Press.
- Lundberg, B., 1996. *Composition of the seaweed vegetation along the Mediterranean coast of Israel*. Nature Conservation in Israel, Research & Surveys, Suppl. 3, Jerusalem, Nature Reserves Authority, 112 pp.
- Meinesz, A., 2001. *Killer algae: The true tale of a biological invasion*. Chicago, University of Chicago Press, 360 pp.
- Meinesz, A. & Hesse, B., 1991. Introduction of the tropical alga *Caulerpa taxifolia* and its invasion of the Northwestern Mediterranean. *Oceanologica Acta*, 14: 415-426. (in French)
- Meinesz, A., Cottalorda, J.M., Chiaverini, D., Cassar, N. & De Vaugelas, J., 1998. *Suivi de l'invasion de l'algue tropicale Caulerpa taxifolia en Méditerranée: situation au 31 dec 1997*. Antipolis, Laboratoire Environnement Marin Littoral, Université de Nice-Sophia, 238 pp. (in French)
- Oren, O.H. & Komarovskiy, B., 1961. The influence of the Nile flood waters on the shore waters of Israel. *Rapports et Procès-Verbaux des Réunions, Conseil International pour l'Exploration scientifique de la Mer Méditerranée*, 16: 655-659.
- Pinardi, N., Allen, I., Demirov, E., De Mey, P., Korres, G., et al., 2003. The Mediterranean ocean forecasting system: first phase of implementation (1998-2001). *Annales Geophysicae*, 21: 3-20.
- Psarra, S., Tselepides, A. & Ignatiades, L., 2000. Primary productivity in the oligotrophic Cretan Sea (NE Mediterranean): seasonal and interannual variability. *Progress in Oceanography*, 46: 187-204.
- Ramon, E., 1985. Algae. p. 12-92. In: *Plants and animals of the Land of Israel*. A. Alon (Ed). (in Hebrew)
- Rayss, T., 1941. Sur les *Caulerpes* de la côte Palestinienne. *Palestine Journal of Botany, Jerusalem Series*, 2: 103-124. (in French)

- Rayss, T. & Edelstein, T., 1960. Deux *Caulerpes* nouvelles sur les cotes Méditerranéennes d'Israël. *Revue Générale de Botanique*, 67: 602-620. (in French)
- Ribera, M.A., 2002. Review of non-native marine plants in the Mediterranean Sea. p. 291-310. In: *Invasive aquatic species of Europe. Distribution, impact and management*. E. Leppäkoski, S. Gollasch & S. Olenin (Eds). London, Kluwer Academic Publishers.
- Rilov, G. & Galil, B.S., 2009. Marine bioinvasions in the Mediterranean Sea - history, distribution and ecology. p. 549-575. In: *Biological invasions in marine ecosystems: ecological, management, and geographic perspectives*. Heidelberg, Germany, Springer-Verlag.
- Rivera-Ingraham, G.A., García-Gómez, J.C. & Espinosa, F., 2010. Presence of *Caulerpa racemosa* (Forsskål) J. Agardh in Ceuta (Northern Africa, Gibraltar Area). *Biological Invasions*, 12: 1465-1466.
- Salihoglu, I., Saydam, C., Basturk, O., Yilmaz, K., Gocmen, D., *et al.*, 1990. Transport and distribution of nutrients and chlorophyll a by mesoscale eddies in the northeastern Mediterranean. *Marine Chemistry*, 29: 375-390.
- Silva, P.C., 1992. Geographic patterns of diversity in benthic marine algae. *Pacific Science*, 46: 429-437.
- Streftaris, N., Zenetos, A. & Papanathanassiou, E., 2005. Globalisation in marine ecosystems: The story of non-indigenous marine species across European seas. *Oceanography & Marine Biology: an Annual Review*, 43: 419-453.
- Terrados, J. & Ros, J.D., 1992. The influence of temperature on seasonal variation of *Caulerpa prolifera* (Forsskal) Lamouroux photosynthesis and respiration. *Journal of Experimental Marine Biology & Ecology*, 162: 199-212.
- UNEP, 1999. Proceedings of the Workshop on Invasive *Caulerpa* Species in the Mediterranean. MAP Technical Report Series No. 125, Athens. 317 pp.
- Verlaque, M., Boudouresque, C.F., Meinesz, A. & Gravez, V., 2000. The *Caulerpa racemosa* complex (Caulerpales, Ulvophyceae) 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.
- Womersley, H.B.S., 1984. *The marine benthic flora of Southern Australia, Part I*. Government Printer 329, South Australia.
- Yacobi, Y.Z., Zohary, T., Kress, N., Hecht, A., Robarts, R.D. *et al.*, 1995. Chlorophyll distribution throughout the southeastern Mediterranean in relation to the physical structure of the water mass. *Journal of Marine Systems*, 6 (3): 179-190.
- Zenetos, A., Cinar, M.E., Pancucci-Papadopoulou, M.A., Harmelin, J.G., Furnari, G. *et al.*, 2005. Annotated list of marine alien species in the Mediterranean with records of the worst invasive species. *Mediterranean Marine Science*, 6 (2): 63-118.