

D. CALVI¹, M.A. DELARIA², R. GENTILI¹, A. NAVONE³,
P.A. PANZALIS², S. CITTERIO¹, S. CARONNI¹

¹Dipartimento di Scienze della Terra e dell'Ambiente, Università di Milano Bicocca,
Piazza della Scienza, 1 – 20126 Milano.

²Area Marina Protetta Tavolara Punta Coda Cavallo, Via Dante 1, Olbia (SS).

³Pragma Due S.n.c. Ambiente, Qualità e Sicurezza, Via D'Annunzio 100, Olbia (SS).
d.calvi2@campus.unimib.it

FIRST DATA ON THE NEW EXPANSION OF THE MACROALGA CAULERPA TAXIFOLIA (CHLOROPHYTA) IN TAVOLARA PUNTA CODA CAVALLO MARINE PROTECTED AREA

PRIMI DATI SULLA NUOVA ESPANSIONE DELLA MACROALGA CAULERPA TAXIFOLIA (CHLOROPHYTA) NELL'AREA MARINA PROTETTA TAVOLARA PUNTA CODA CAVALLO

Abstract - In 2002, a patch of the tropical macroalga *Caulerpa taxifolia* (Vahl) C. Agardt was found in Tavolara Punta Coda Cavallo Marine Protected Area. Despite the species is considered one of the most invasive alien algae in the Mediterranean, in the MPA, after two manual eradications and several periodic surveys, *C. taxifolia* was slightly regressing until 2016. From 2017, instead, the patch appeared to be expanding again. The aim of this study, conducted in the summer of 2020, was, therefore, to characterize the mentioned patch of *C. taxifolia*, comparing the obtained data with those available for 2016. Results confirmed that a new expansion event is currently occurring in the MPA, presumably due to the presence of a newly recorded, highly invasive variety of *C. taxifolia*, *C. taxifolia* var. *distichophylla* (Sonder) Verlaque, Huisman and Procaccini, that is spreading also in other areas of the Mediterranean basin.

Key-words: *Caulerpa taxifolia*, invasive alien species, Tavolara Punta Coda Cavallo, Marine Protected Area, Sardinia

Introduction - Non-indigenous species (NIS) are widely recognized as one of the main drivers of global change, threatening native biodiversity, ecosystem functioning and services. Under favorable conditions, NIS may become invasive (Invasive Alien Species, IAS), causing significant environmental impacts, such as biodiversity loss and ecosystem services degradation. The Mediterranean Sea seems to be particularly vulnerable to such phenomenon and, in the last decades, an important increase of tropical and sub-tropical NIS has been observed (Zenetos & Galanidi, 2020). Among the NIS recorded in the Mediterranean Sea in the last 25 years, the green macroalga *Caulerpa taxifolia* (Vahl) C. Agardt (Chlorophyta) has raised serious concern due to its large diffusion in the basin and its ascertained negative impact on native communities. This macroalga, currently considered as IAS, was accidentally released into the Mediterranean Sea from the Oceanographic Museum of Monaco in 1984 and it rapidly spread in several areas of the western basin, heavily outcompeting the keystone autochthonous seagrass *Posidonia oceanica* L. Delile (De Villèle & Verlaque, 1995). Since 2002, *C. taxifolia* was recorded also in Tavolara Punta Coda Cavallo Marine Protected Area (TPCC MPA), in North-Eastern Sardinia. In the MPA, *C. taxifolia* mainly colonized a coastal area of Tavolara Island, establishing on a *P. oceanica* seabed at a depth of about 8 m. This patch was controlled through two manual eradications, carried out immediately after its discovery and again in 2007. Although the patch always reformed, data collected annually by MPA researchers showed that no significant increase of the occupied area occurred after the second eradication. Moreover, a technical report dated 2015 described a slight regression of the patch. However, from 2017, a new expansion was reported in the patch but no detailed data on this event were available.

Therefore, the aim of this study was to characterize the *C. taxifolia* patch of TPCC MPA, estimating its current area, the percent cover of the substratum and length of *C. taxifolia* blades, in order to compare the actual data with those collected during the previous years and to establish the magnitude of the above-mentioned new expansion event.

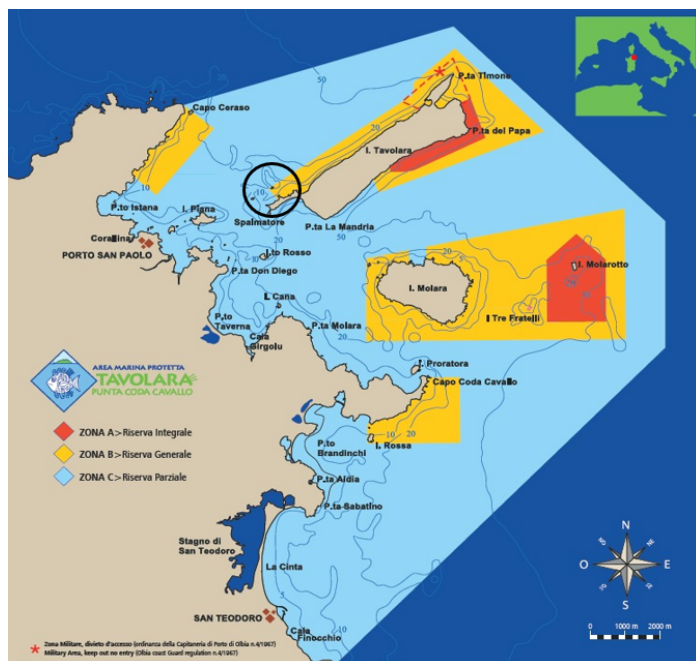


Fig. 1 – Tavolara Punta Coda Cavallo Marine Protected Area (TPCC MPA) and the study area (inside the circle).

L'Area Marina Protetta Tavolara Punta Coda Cavallo e l'area di studio (all'interno del cerchio).

around the colony was characterized, defining the type of substratum and the main species of macroalgae and seagrasses present therein. Moreover, the perimeter of the patch was estimated by means of a metric rib of substratum and ten 50x50 cm randomly positioned quadrats were photographed both in the central part of the patch and in the periphery, in order to estimate the percent cover of *C. taxifolia* (Dethier *et al.*, 1993) and its blade length, measured using Image J software. Finally, the data of the 2020 campaign were statistically analyzed and compared to those dating back to 2016 through ANOVA and SNK test. For the analysis, 2016 and 2020 datasets were treated as independent, due to the quite long time between the two samplings (Underwood, 1997).

Results - Both in 2016 and 2020, the substratum of the area around the patch was predominantly occupied by a *P. oceanica* meadow (~39%), dead mat (34%) and sand (~7%). In 2016 the patch extended for a total area of 206 m² and it was composed of a central zone surrounded by several peripheral spots, separated from each other by small residual portions of the original *P. oceanica* meadow. In 2020, instead, *C. taxifolia* peripheral spots increased both in size and in number, in some cases fusing together, and, although the shape of the main patch remained almost the same, it extended for a significantly higher area, reaching about 13 ha.

In 2016, the mean percent cover of *C. taxifolia* was about 4.9% in whole area occupied

Materials and methods - *C. taxifolia* patch in TPCC MPA is located along the coasts of Tavolara Island (Spalmatore di Terra; lat. 40°53.402' N; long. 09°40.590' E) (Fig. 1), on a partly degraded *P. oceanica* seabed at about 8 m depth. Field work was conducted by scuba diving (ARA) in two different years: 2016 and 2020. Since until 2015 the patch was still in regression, in 2016 only one monitoring sampling was performed in August, when vegetative growth should be at its peak. In 2020, instead, as the new expansion had already been noticed, more detailed data were acquired, performing three different samplings, in June, August and October, in order to collect data also during the beginning and the end of the growing season. In both 2016 and 2020 the same data were collected. In particular, an area of about 50 m²

by the patch. Highest values, close to 10%, were recorded in the central zone of the patch, while the lowest (between 1% and 2%) were found in the peripheral spots. In 2020, the percent cover of the substratum increased remarkably, reaching a mean value of 15.2%. However, contrary to 2016, a higher mean percent cover was recorded in the peripheral part of the patch (16.6%) while, in the central part, it reached lower values (13.9%). A different situation was observed for the blade length. In 2016, indeed, the mean length was about 5.4 cm, with a maximum of 14.6 cm and a minimum of 1.1 cm. In 2020, instead, shorter blades were observed, with a mean value of about 5.9 cm, a maximum of 12.3 cm and a minimum of 2.0 cm.

The observed differences in the percent cover between 2016 and 2020 were confirmed by statistical analyses; in particular, the SNK test run after the ANOVA highlighted a significant increase through in the last sampling (Fig. 2a). Instead, no significant difference was observed in the blade length (Fig. 2b).

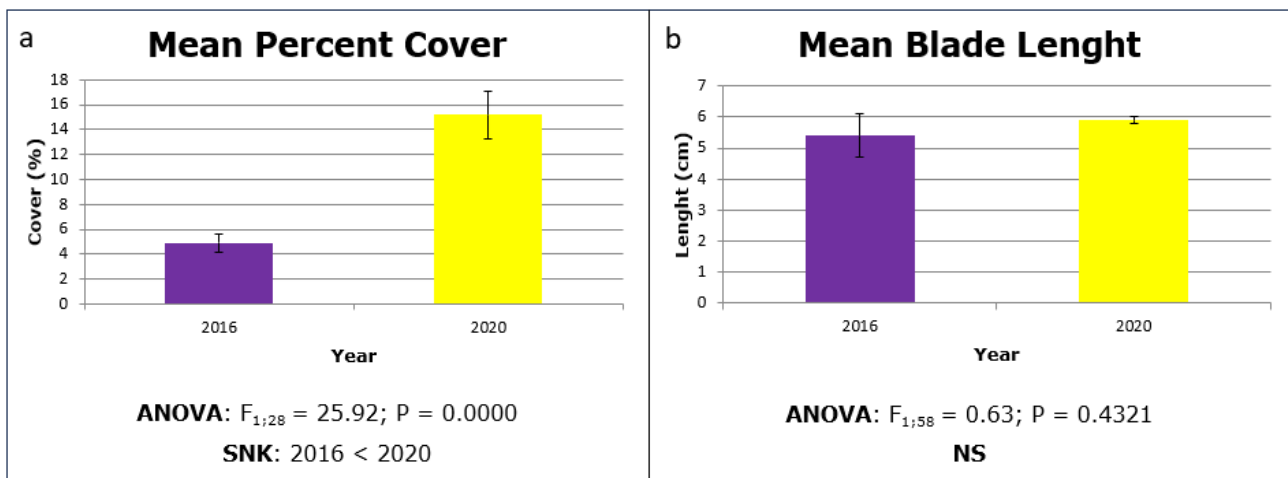


Fig. 2 - (a) Mean percent cover values of the substratum in 2016 and 2020; (b) mean blade length values in 2016 and 2020.

(a) Valori di copertura percentuale media del substrato nel 2016 e 2020; (b) valori di lunghezza media delle fronde nel 2016 e 2020.

Also, the statistical analyses performed on data collected during the three different samplings of 2020 evidenced some significant differences for both the percent cover and the blade length among sampling months. In detail, despite no significant differences were found for the mean percent cover in the central area of the patch (10.9% in June, 19.2% in August, 10.8% in October), mean values recorded in the peripheral area appeared to be significantly higher in October (40.6%) than in June (5.6%) and August (8.4%). Moreover, a progressive downsizing of the blades was observed throughout summer, with higher mean values in June (7.2% in the central area and 6.6% in the peripheral area) than in October (4.8% in the central area and 4.5% in the peripheral area).

Conclusions - The results of this study provide some interesting information on the current invasive dynamics of *C. taxifolia* in TPCC MPA. First, while all data collected up to 2016 suggested that the patch did not expand since the second eradication, the results of 2020 samplings highlight, instead, a quite different situation in terms of both the surface area occupied by the patch and the percent cover of the substratum. Between 2016 and 2020, indeed, the patch has grown from 206 m² to 13 ha and the percent cover in the area raised from 4.9% to 15.2%. These results show an unprecedented expansion occurred between 2016 and 2020. According to the data of

2020, the patch can be currently placed at the third and highest invasion level among those described by De Vaugelas *et al.* (1999). Patches belonging to this level can invade surface areas greater than 10 ha and they are usually composed by several large high-density spots with a surface extension that exceeds 1000 m² each and, near these, several smaller peripheral spots (De Vaugelas *et al.*, 1999). In particular, in the case of TPCC MPA, these peripheral spots seem to play a key role in the expansion of the species in our area. Indeed, during the last sampling, in October 2020, the peripheral spots appeared to be significantly denser than the central one, thus suggesting that the patch was rapidly and significantly expanding also in Autumn, at the end of the maximum growth period for the species that is usually summer (Boudouresque *et al.*, 1995).

These results agree with those available for other areas of the western Mediterranean basin, such as Sicily, Tyrrhenian Calabria, southern Sardinia and Tunisia, where a new variety of the macroalga, *Caulerpa taxifolia* var. *distichophylla* (Sonder) Verlaque, Huisman and Procaccini, was recently identified (Di Martino *et al.*, 2018). Morphologically, this highly invasive alga is quite similar to *C. taxifolia*, and it is hardly distinguishable as it looks like a slender form of it (Jongma *et al.*, 2013). Therefore, despite specific genetic analyses must still be done, it is possible to hypothesize that *C. taxifolia* var. *distichophylla* may be present in TPCC MPA too, where it could be responsible of the recent expansion of the already existing patch.

In conclusion, this study provides some important information on the new expansion of *C. taxifolia* that is affecting TPCC MPA, highlighting the need to monitor the patch through frequent samplings, in order to quickly detect any further expansion event. Moreover, the possible presence in the area of *C. taxifolia* var. *distichophylla* could be crucially dangerous for the start of a massive colonization in the MPA.

References

- 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. *Scie. Mar.*, **59** (1): 21-29.
- DE VAUGELAS J., MEINESZ A., BALLESTEROS E., ANTOLIC B., BELSHER T., CASSAR N., CECCHERELLI G., CINELLI F., COTTAROLDA J.M., ORESTANO C., GRAU A.M., JAKLIN A., MORUCCI C., RELINI M., SANDULLI R., SPAN A., TRIPALDI G., ZULJEVIC A., ZAVODNIK N., VAN KLAVEREN P. (1999) - Standardization proposal for the mapping of *Caulerpa taxifolia* expansion in the Mediterranean Sea. *Oceanol. Acta*, **22** (1): 85-94.
- DE VILLELE X., VERLAQUE M. (1995) - Changes and degradation in a *Posidonia oceanica* bed invaded by the introduced tropical alga *Caulerpa taxifolia* in the northwestern Mediterranean. *Bot. Mar.*, **38**: 79-87.
- DETHIER M.N., GRAHAM E.S., COHEN S., TEAR L.M. (1993) - Visual versus random-point percent cover estimations: 'objective' is not always better. *Mar. Ecol. Progr. Ser.*, **96**: 93-100.
- DI MARTINO V., STANCARELLI B., CANTASANO N. (2018) - The alien alga *Caulerpa taxifolia* (Vahl) C. Agardh var. *distichophylla* (Sonder) Verlaque, Huisman and Procaccini move their northern and western limits. *J. Black Sea/Mediterr. Environ.*, **24** (2): 140-148.
- JONGMA D.N., CAMPO D., DATTOLO E., D'ESPOSITO D., DUCHI A., GREWE P., HUISMAN J., VERLAQUE M., YOKES M.B., PROCACCINI G. (2013) - Identity and origin of a slender *Caulerpa taxifolia* strain introduced into the Mediterranean Sea. *Bot. Mar.*, **56** (1): 27-39.
- UNDERWOOD G.J.C. (1997) - Microalgal colonization in a saltmarsh restoration scheme. *Est. Coast. Shelf Sci.*, **44**: 471-481.
- ZENETOS A., GALANIDI M. (2020) - Mediterranean non indigenous species at the start of the 2020s: recent changes. *Mar. Biodiv. Rec.*, **13** (1): 1-17.