SEASONAL CHANGES IN POPULATIONS OF *CAULERPA TAXIFOLIA* VAR. *DISTICHOPHYLLA* IN THE MALTESE ISLANDS

Therese Ellul [1]*, Julian Evans [1] and Patrick J. Schembri [1]
[1] Department of Biology, Faculty of Science, University of Malta - therese.ellul.11@um.edu.mt

Abstract
Caulerpa taxifolia var. *distichophylla*, an alien alga in the Mediterranean Sea, was first recorded from the Maltese Islands in 2013. Initial observations suggested that it underwent complete frond regression in winter, possibly due to the colder temperatures. Since then it has spread rapidly and has become abundant in the infralittoral in some localities. The present two-year study on the Maltese populations indicates that the alga is able to resist low seawater temperatures during the winter and is not regressing completely, potentially increasing its ecological impact.

Keywords: Mediterranean Sea, Phytobenthos, Alien species, Population Dynamics, Malta Channel

Introduction
In the Mediterranean, *Caulerpa taxifolia* var. *distichophylla* (hereafter *Ctvd*) is an invasive green alga that was first reported in 2007 from the Gulf of Iskenderun, SE Turkey [1]. By 2018 it had spread to several other areas in the East Basin: Sicily, Cyprus, Malta, Rhodes, and Libya. More recently it expanded its range and crossed to the West Basin where it has now reached Sardinia and Tunisia [2]. This was against expectations, as the 15°C winter isotherm was thought to limit spread of this thermophilic species to the area around Sicily [3]. The species was first reported from Malta in 2013 [4], making *Ctvd* the second non-native species of the family Caulerpaceae recorded from Malta; *Caulerpa cylindracea* was recorded from Malta in 1997. Field observations made in Malta suggested that *Ctvd* fronds regress in winter and grow back in spring and summer resulting in a marked seasonal change in frond density during the year [4]. Here we report on a two-year study on frond phenology made to see if fronds indeed regressed, to what extent, and if there is inter-annual variability.

Materials and Method
Using SCUBA diving, monthly frond density counts were taken at Bahar ic-Caghaq (BC) and Marsaskala Bay (MS) between June 2016 and June 2018 (Fig 1). Mean frond density at each site was estimated from 12 replicate counts made using a 0.25m X 0.25m quadrat placed at random within a 2m X 2m patch of substratum colonized by *Ctvd*.

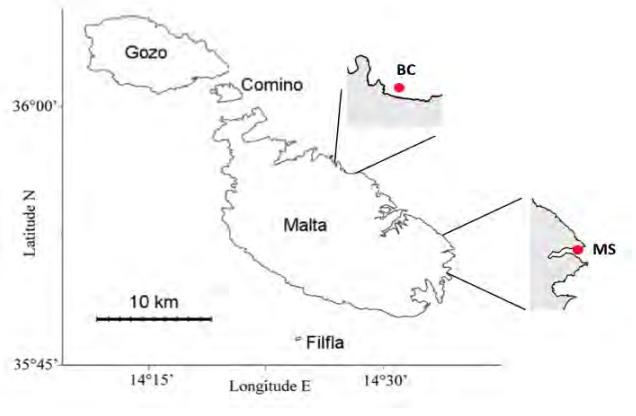

Fig. 1. Map of the Maltese islands showing the location of the two study sites: Bahar ic-Caghaq (BC) and Marsaskala Bay (MS).

Results
Frond densities of *Ctvd* were highest during the summer months and decreased during the winter months at both sites. The highest density was recoded in July 2016 from Bahar ic-Caghaq (972 N/m^2 ± 417.01 SD). Between December and March 2018, fronds were still present in low densities at both sites, and had not fully regressed, unlike the complete absence of fronds during the same period in the previous year and in the winter of 2013-2014 [4].

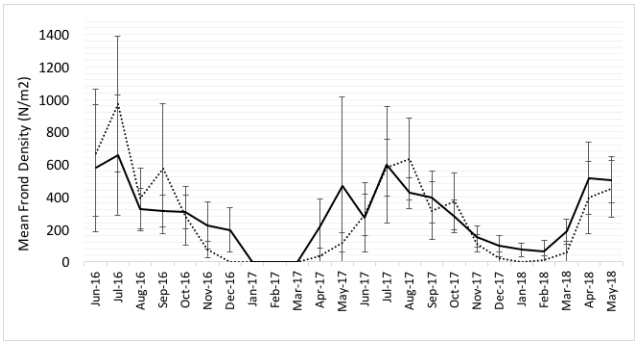

Fig. 2. Mean density of *Ctvd* fronds recorded between June 2016 – May 2018 at Bahar ic-Caghaq (dotted line) and Marsaskala Bay (bold line). Error bars are ± 1 standard deviation.

Discussion
The inter-annual variability found in the present study suggests that *Ctvd* may be increasing its invasive capacity, as the low seawater temperature during the winter months is not always causing complete regression of the fronds. It appears that the alga has a higher temperature tolerance than previously thought, which can explain its range expansion and successful establishment in the western basin and its survival at low winter temperatures. The ecological impact of *Ctvd* is likely to be greater should the alga keep its fronds during winter than if the fronds regress and grow back each year.

Acknowledgments
This research was partly funded by the Elisabeth Mann Borgese Award (2017-2018) awarded to TE by the International Ocean Institute (IOI).

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