Journal of Applied Phycology 13: 457–460, 2001.

Note

Interannual variation of the abundance of *Mazzaella cornucopiae* (Rhodophyta, Gigartinales) from Pacific Canada in relation to changes in abiotic variables

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Received 11 January 2001; revised 6 March 2001; accepted 13 March 2001

Key words: abiotic variables, carrageenophyte, Gigartinales, interannual variability, intertidal zone, *Mazzaella cornucopiae*, population dynamics, Rhodophyta

Abstract

The seaweed *Mazzaella cornucopiae* (Postels & Ruprecht) Hommersand is common in rocky intertidal areas from Pacific Canada and is a potential economic resource. In both 1993 and 1994, the abundance of *M. cornucopiae* from Prasiola Point, southern Barkley Sound, was high in spring and summer and low in fall and winter. In 1995, however, the abundance in summer was unexpectedly low, and this trend deepened in 1996. Correlations between the temporal changes of abundance and of some abiotic variables were done as a first approach to explaining these changes of abundance. The abiotic variables used were air temperature, sea surface temperature, wave height, all three measured on an oceanic buoy close to Prasiola Point, and seawater salinity, determined for coastal waters from northern Barkley Sound. These were the closest sites to Prasiola Point for which reliable abiotic data existed. None of the correlations were significant. Field observations done at Prasiola Point suggest that air temperatures reached higher values there than at the oceanic buoy. Together with irradiance, *in situ* air temperature may have had an important role in the interannual differences of abundance through a higher physical stress on thalli, resulting in the high proportion of bleached tissues observed in summer 1996. Future studies on the population dynamics of *M. cornucopiae* should benefit from quantifying these variables *in situ*.

The seaweed *Mazzaella cornucopiae* (Postels & Ruprecht) Hommersand (Rhodophyta, Gigartinales) is common in rocky intertidal areas of the Pacific coast of Canada. Due to the existence of carrageenans in its cell walls and to the antiviral and cytotoxic activity reported for tissue extracts (Kim et al., 1997), this species constitutes a potential economic resource. Between 1993 and 1995, its population dynamics was studied at Prasiola Point (48°49′N, 125°10′W), on the southern coast of Barkley Sound (Scrosati & DeWreede, 1997; Scrosati, 1998). Genets (each thallus that develops from a single spore) of this clonal species (*sensu* de Kroon & van Groenendael, 1997) are generally impossible to identify in the field, because of high frond densities, genet break-up into clonal fragments (*sensu* Eriksson & Jerling, 1990), and, possibly, coalescence between neighboring young genets, as observed for other species of the Gigartinales (Santelices et al., 1999).

Cover provides a non-destructive estimate of abundance and is easy to measure. During the first part of the population study for Prasiola Point, the cover of *M. cornucopiae* varied in a more or less predictable way (Scrosati, 1998). The cover was high in spring-summer 1993, low in fall-winter 1993–1994, high again in spring-summer 1994, and low again in fall-winter 1994–1995. However, the cover did not reach the expected high values in spring–summer 1995, but it decreased steadily from winter 1994–1995. The formal monitoring program for this population ended in summer 1995, but an isolated observation was made in summer 1996. The cover (20 ± 9%; mean ± S.E., n = 7) was then even lower than for the previous summer and represented the lowest summer value since 1993 (Figure 1A).

One of the first steps in a population study is to describe the temporal variation of abundance. The following step is usually to identify the main factors that determine the observed pattern (Underwood et al., 2000). This note addresses this issue by investigating the relationship between relevant abiotic variables and the cover of *Mazzaella cornucopiae* over time.

Abiotic factors greatly affect seaweed growth, while biotic factors, such as competition and herbivory, generally have a secondary role (Graham & Wilcox, 2000). Seaweed growth rates are also determined by circannual endogenous rhythms (Lüning, 1993), but large interannual changes in population abundance are likely to be caused by interannual changes in external conditions. For intertidal seaweeds, the main abiotic variables that affect performance are temperature, light, wave force, salinity, and nutrient concentration (Lobban & Harrison, 1994; Davison & Pearson, 1996; Graham & Wilcox, 2000). The abiotic variables that could be estimated reliably close to Prasiola Point between 1993 and 1995 were air temperature, sea surface temperature, wave height, and seawater salinity. Temperature affects metabolic processes, such as respiration and photosynthesis. Although seasonal thermal acclimation of enzymes may occur (Davison, 1991; Lobban & Harrison, 1994), strong interannual changes of temperature may greatly affect seaweed abundance (e.g., Ladah et al., 1999). Both air and seawater temperature are important for intertidal seaweeds, since their values may differ considerably even during one same day. Intense wave action may detach seaweeds (Denny, 1995; Gaylord, 2000); wave height is an estimate of wave force. Seawater salinity influences physiological processes that are affected by osmotic and ionic stresses (Kirst, 1989). However, changes in seawater salinity are generally smaller than the salinity changes of water on frond surfaces between high and low tides (Lobban & Harrison, 1994), so interannual changes of seawater salinity might not affect the dynamics of *Mazzaella cornucopiae* significantly.

The cover of *Mazzaella cornucopiae* was measured about every two months between June 1993 and July 1995 in seven 100-cm^2 permanent quadrats. For each quadrat, percent cover of *M. cornucopiae* was determined using a frame with 100 square divisions. For each division of 1 cm^2, cover was recorded as positive when 50% or more was occupied by *M. cornucopiae*. Sampling dates were 4–6 June 1993, 17–19 August 1993, 15–17 October 1993, 10–12 December 1993, 24–26 February 1994, 26–28 April 1994, 22–24 June 1994, 19–21 August 1994, 5–7 October 1994, 2–4 December 1994, 28–30 January 1995, 30 March 1995, 14–16 May 1995, and 11–13 July 1995. Monthly means for the abiotic variables were obtained from the Institute of Ocean Sciences (Sidney, British Columbia). Air temperature, sea surface temperature, and wave height, from crest to trough, were recorded at an offshore buoy located in La Pérouse Bank (48°50′N, 126°W) and salinity was recorded at Amphitrite Point (48°55′N, 125°32′W). These are the closest sites to Prasiola Point where environmental data were regularly and reliably measured. It was assumed that sea surface temperature and seawater salinity would have been similar at Prasiola Point, La Pérouse Bank, and Amphitrite Point, since these sites are a few km from one another. The seasonal pattern of change of air temperature was also likely to be similar at Prasiola Point and La Pérouse Bank, although the temperature range was probably higher at Prasiola Point, since it is a coastal area. Wave height was probably lower at the protected side (east) of Prasiola Point, where the population was located, than at La Pérouse Bank, but personal observations at Prasiola Point indicated that its seasonal variation was similar.

The relationship between the monthly means of percent cover and of abiotic variables was determined with Pearson correlation coefficients (Howell, 1992). A significant correlation does not directly imply causation, but it suggests its possible existence. Data transformations were necessary, because a certain degree of spurious correlation might have arisen due to the autocorrelative nature of the original time series. First-differenced times series of the logarithm of raw data were used, that is, a given variable X_t was transformed into a new variable Z_t following: $Z_t = \log_{10} X_t - \log_{10} X_{t-1}$, where t was a given sampling date (Bjørnstad et al., 1999). Thus, the synchrony of change was taken as a measure of association between percent cover and abiotic variables. Assessing the significance of a correlation coefficient requires random sampling (Howell, 1992). As times series are serially dependent,

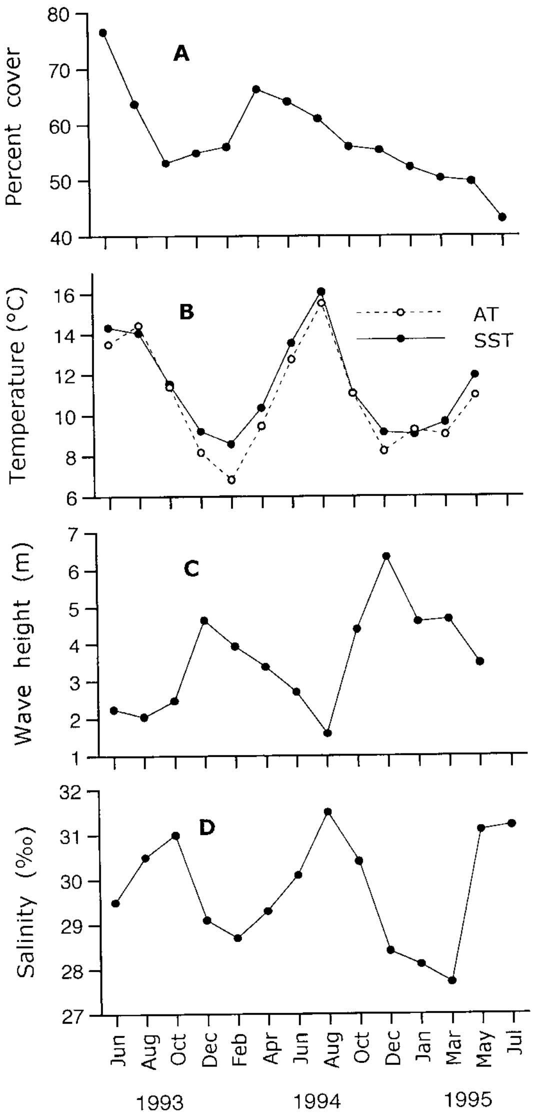

Figure 1. Temporal variation of monthly means of: A) Percent cover of *Mazzaella cornucopiae*; B) Air temperature (AT) and sea surface temperature (SST); C) Wave height; D) Seawater salinity.

the significance of correlation coefficients were determined with randomization tests (Edgington, 1987; Bjørnstad et al., 1999), using the program Randomization Tests for DOS, developed by E.S. Edgington (University of Calgary, Canada).

The temporal variation of percent cover of *Mazzaella cornucopiae* was briefly described above and statistically analyzed in Scrosati (1998), so only the temporal variation of its monthly means is shown here (Figure 1A). All the abiotic variables considered here had high values in spring-summer and low values in fall-winter, except wave height, which followed the opposite trend (Figure 1B-D). None of the correlations (r) were significant: 0.26 ($p = 0.44$, n = 12), with air temperature, 0.32 ($p = 0.33$, n = 12), with sea surface temperature, –0.09 ($p = 0.77$, n = 12), with wave height, and –0.10 ($p = 0.76$, n = 13), with seawater salinity. This suggests that these abiotic variables did not play a major role in the unexpected decrease of cover that occurred in 1995 (and continued until 1996, at least). Having in mind the limitations of a correlation study to understanding cause-effect relationships (Howell, 1992), the explanation for the unexpected decrease of cover should be looked for among other variables.

At Prasiola Point, the main competitors of *Mazzaella cornucopiae* are *Fucus gardneri* Silva and *Pelvetiopsis limitata* Gardner (Phaeophyceae, Fucales), while snails of the genus *Littorina* are grazers (Kim, 1995, 1997; Kim & DeWreede, 1996a, b). The decrease of *M. cornucopiae* cover generally resulted in bare substrate, suggesting that interspecific competition did not much influence the observed decrease. The possible regulatory effects of herbivory by snails on *M. cornucopiae* populations is unclear, as the feeding experiments done by Kim & DeWreede (1996a) were in laboratory conditions.

Irradiance and air temperature, which affect desiccation rates during low tides, were not monitored regularly where thalli of *Mazzaella cornucopiae* occurred. Bleaching of fronds of *M. cornucopiae* is associated with strong desiccation and irradiance (Scrosati & DeWreede, 1998). Bleaching constitutes a disruptive stress (*sensu* Davison & Pearson, 1996), because it lethally damages tissues. In spring and summer, the lowest (and longest) of the two daily low tides occurs mainly during daytime at Prasiola Point, so thalli are exposed to direct sunlight for long periods. At the Tofino A climate station of Environment Canada, the average number of sun hours per month was 234 ± 20 (mean ± S.E., n = 4) between April and July 1995, higher than for the equivalent period of 1993 (147 ± 23 hours) and 1994 (192 ± 27 hours). Additionally, my field observations in May 1995 and July 1996 at Prasiola Point suggest that the weather was drier and warmer than for the same months of 1993 and 1994. In July 1996, for example, bleaching was more extended among fronds than in previous years. Even many holdfast areas, normally protected from direct sunlight by fronds, were bleached, which had not occurred in previous years. This suggests that irradiance and air temperature should be measured *in situ* to understand better the population dynamics of *M. cornucopiae* in the future.

Acknowledgements

To Jean-Paul Danko, Eduardo Jovel, Tania Thenu, and Laura Wong, for their assistance in the field. Research was funded by a grant from the Natural Sciences and Engineering Research Council of Canada (5-89872) to Robert DeWreede. Additional financial support came from a University Graduate Fellowship, an Edith Ashton Memorial Scholarship, and a Kit Malkin Scholarship (granted by the University of British Columbia), a PRA Fellowship (granted by the Organization of American States), and research funds from Ronald Foreman. Completion of this study was possible thanks to a research grant (RM-7) from the Northwest Biological Research Center (CIBNOR, La Paz, Baja California Sur, Mexico).

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