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Short research note

Persistence of gametophyte predominance in *Chondrus crispus* (Rhodophyta, Gigartinaceae) from Nova Scotia after 12 years

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Abstract

Gametophytes predominated clearly over tetrasporophytes in an intertidal population of *Chondrus crispus* at Tor Bay (Nova Scotia, Canada) in the summer of 1991. Since this species is perennial and the rocky substrate is stable at this site, we predicted that gametophyte predominance would persist after several years. We confirmed this hypothesis by re-sampling the same area in the summer of 2003. This is one of the first long-term studies of the relative abundance of life-history phases done unequivocally at the same site for the Gigartinaceae.

The identification of natural patterns is an essential step in ecology, and must be done before any speculation on causal processes may take place (Underwood et al., 2000). Regarding the population ecology of the Gigartinaceae (Rhodophyta), several studies have investigated the spatial patterns of relative abundance of gametophytes and tetrasporophytes (Scrosati & DeWreede, 1999), which are the two life-history phases with independent life in these algae. Examples of factors that may affect the proportion of each phase across space are depth (Craigie & Pringle, 1978; Lazo et al., 1989), salinity (Lindgren & Åberg, 1996), and wave exposure (Phillips, 1994; Mudge & Scrosati, 2003). Temporal patterns of variation in phase relative abundance have also been investigated, normally comparing seasons for a few consecutive years (May, 1986; DeWreede & Green, 1990; Bolton & Joska, 1993; Dyck & DeWreede, 1995; Otaíza et al., 2001; Morley et al., 2003; Thornber & Gaines, 2003). The long-term variation of the relative abundance of life-history phases is largely unknown, one reason possibly being that the few researchers on this subject have generally been unable to sample exactly the same sites after several years. Probably the first long-term study on this for the Gigartinaceae was done on *Mazzaella splendens* (Setchell & Gardner) Fredericq, which was sampled with a difference of 10 years at Pigeon Point, California (Hansen & Doyle, 1976; Dyck et al., 1985). However, it is uncertain whether the exact same area was sampled in both occasions because of the difference in survey teams, which might explain the high difference in the proportion of phases observed between both surveys (L. Dyck, pers. comm.).

Reliable long-term information is increasingly being recognized as important for the better understanding of ecological systems (Barry et al., 1995; Bjørnstad & Grenfell, 2001; Inchausti & Halley, 2001; Sousa, 2001; Haddad et al., 2002). Along such a line, a recent study compared the proportion of life-history phases of *Mazzaella parksii* (Setchell & Gardner) Hughey, P. C. Silva & Hommersand (= *M. cornucopiae*, according to Hughey et al., 2001) from Prasiola Point (Pacific Canada) after 7–8 years of the initial survey at that site. Results showed that patterns in the proportion of life-history phases were persistent on a whole-population basis and across an elevation gradient, in agreement with previous expectations based on substrate stability and the perennial nature of the species (Scrosati & Mudge, 2004). More long-term studies done unequivocally at the same sites are needed. In 1991, one of us sampled a population of *Chondrus crispus* Stackhouse (Fig. 1) at Tor

Figure 1. Thalli of *Chondrus crispus* observed at low tide at an intertidal site near Tor Bay. Photograph taken on 31 July 2003 by R. Scrosati.

Bay (Atlantic Canada) to determine the proportion of life-history phases (Scrosati et al., 1994). As an additional contribution to long-term studies on this for the Gigartinaceae, we decided to re-sample the same site 12 years later. Since *C. crispus* is a perennial species (Taylor & Chen, 1994) and it occurs on stable, rocky substrate at the study site (Scrosati et al., 1994), we predicted that the predominance of gametophytes observed in 1991 would hold in 2003.

On 31 July 2003, we haphazardly sampled 136 thalli of *Chondrus crispus* at the intertidal zone of Tor Bay (45° 11′ N, 61° 21′ W), on the Atlantic coast of Nova Scotia, Canada. This site faces the open ocean directly and has a gentle slope with large granitic boulders as the main substrate. The sampled thalli occurred in the low intertidal zone, below the elevation where fucoid seaweeds (*Ascophyllum* and *Fucus*) predominate. To determine the proportion of life-history phases for any rhodophyte population, counts of genets (defined as the thallus that develops from a single spore; Scrosati, 2002) of gametophytes and tetrasporophytes should be done. At the study site, *C. crispus* generally occurs as spatially separated thalli (= clumps), composed each of a variable number of fronds arising from a small holdfast. Since most thalli were entirely vegetative at the time of collection and both life-history phases are morphologically similar in this species (McLachlan et al., 1989), phase identification was achieved by analyzing one frond sample from each thallus with the resorcinol-acetal test in the laboratory (Garbary & DeWreede, 1988). This test is based on the fact that gametophytes and tetrasporophytes have different carrageenans in cell walls, which results in reagent solutions with gametophyte samples turning red and those with tetrasporophyte samples remaining colourless or turning light pink in *C. crispus*. Frond samples were tested simultaneously with *C. crispus* samples of known life-history phase, due to their reproductive condition (using three fronds per phase per run), thus acting as controls for colour. Coalescence of neighboring genets (Tveter-Gallagher & Mathieson, 1980) might have occurred in the field, possibly resulting in some chimeric thalli (that is, thalli each consisting of more than one original genet). By collecting only one frond sample per selected thallus, however, we ensured that each selected genet was sampled only once.

Five out of the 136 frond samples (3.7%) gave intermediate colours with the resorcinol-acetal test, so they could not be assigned to either life-history phase and were excluded from final calculations. The remaining 131 samples gave unequivocal results, according to the controls. At the time of sampling, this population of *Chondrus crispus* consisted of 62% of gametophytes and 38% of tetrasporophytes. This corresponds to a ratio between gametophytes and tetrasporophytes (G:T ratio) of 1.6.

Frond samples of *Chondrus crispus* collected at the same site in Tor Bay in June, July, and August 1991 also indicated that gametophytes were predominant (Scrosati et al., 1994). Monthly relative abundances were, then, 72–78% of gametophytes and 22–28% of tetrasporophytes. Since habitat conditions, particularly the substrate, are relatively stable in this shore on a long-term basis (as opposed, for example, to the Gulf of St. Lawrence sandstone substrate; Lazo et al., 1989), few changes in the proportion of life-history phases were expected for *Chondrus crispus* since 1991. Our findings in 2003 confirmed this hypothesis. At a finer quantitative scale, explaining the mild differences observed after 12 years is not possible with the existing information. The complete explanation of the proportion of life-history phases for any algal population must consider demographic traits for each phase simultaneously (Scrosati & DeWreede, 1999). Such traits depend on species and habitat, which therefore calls for demographic research at the study site. By combining detailed, short-term studies with observations on changes (or persistence) of patterns after several years, our understanding of factors affecting the abundance of life-history phases in the Gigartinaceae should improve. This will not only impact fundamental ecology for this group of organisms, but also applied ecology, as important departures from expected trends might indirectly indicate that some relevant component of the environment is changing.

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References

Barry, J. P., C. H. Baxter, R. D. Sagarin & S. E. Gilman, 1995. Climate-related, long-term faunal changes in a California rocky intertidal community. Science 267: 672–675.

Bjørnstad, O. N. & B. T. Grenfell, 2001. Noisy clockwork: time series analysis of population fluctuations in animals. Science 293: 638–643.

Bolton, J. J. & M. A. P. Joska, 1993. Population studies on a South African carrageenophyte: *Iridaea capensis* (Gigartinaceae, Rhodophyta). Hydrobiologia 260/261: 191–195.

Craigie, J. S. & J. D. Pringle, 1978. Spatial distribution of tetrasporophytes and gametophytes in four maritime populations of *Chondrus crispus*. Canadian Journal of Botany 56: 2910–2914.

DeWreede, R. E. & L. G. Green, 1990. Patterns of gametophyte dominance of *Iridaea splendens* (Rhodophyta) in Vancouver Harbour, Vancouver, British Columbia, Canada. Journal of Applied Phycology 2: 27–34.

Dyck, L. J. & R. E. DeWreede, 1995. Patterns of seasonal demographic change in the alternate isomorphic stages of *Mazzaella splendens* (Gigartinales, Rhodophyta). Phycologia 34: 390–395.

Dyck, L., R. E. DeWreede & D. Garbary, 1985. Life history phases in *Iridaea cordata* (Gigartinaceae): relative abundance and distribution from British Columbia to California. Japanese Journal of Phycology 33: 225–232.

Garbary, D. J. & R. E. DeWreede, 1988. Life history phases in natural populations of Gigartinaceae (Rhodophyta): quantification using resorcinol. In Lobban, C. S., D. J. Chapman & B. P. Kremer (eds), Experimental Phycology. A Laboratory Manual. Cambridge University Press, Cambridge: 174–178.

Haddad, N. M., D. Tilman & J. M. H. Knops, 2002. Long-term oscillations in grassland productivity induced by drought. Ecology Letters 5: 110–120.

Hansen, J. E. & W. T. Doyle, 1976. Ecology and natural history of *Iridaea cordata* (Rhodophyta; Gigartinaceae): population structure. Journal of Phycology 12: 273–278.

Hughey, J. R., P. C. Silva & M. H. Hommersand, 2001. Solving taxonomic and nomenclatural problems in Pacific Gigartinaceae (Rhodophyta) using DNA from type material. Journal of Phycology 37: 1091–1109.

Inchausti, P. & J. Halley, 2001. Investigating long-term ecological variability using the global population dynamics database. Science 293: 655–657.

Lazo, M. L., M. Greenwell & J. McLachlan, 1989. Population structure of *Chondrus crispus* Stackhouse (Gigartinaceae, Rhodophyta) along the coast of Prince Edward Island, Canada: distribution of gametophytic and sporophytic fronds. Journal of Experimental Marine Biology and Ecology 126: 45–58.

Lindgren, A. & P. Åberg, 1996. Proportion of life cycle stages of *Chondrus crispus* and its population structure: a comparison between a marine and an estuarine environment. Botanica Marina 39: 263–268.

May, G., 1986. Life history variations in a predominantly gametophytic population of *Iridaea cordata* (Gigartinaceae, Rhodophyta). Journal of Phycology 22: 448–455.

McLachlan, J. L., J. Quinn & C. MacDougall, 1989. The structure of the plant of *Chondrus crispus* Stackhouse (Irish moss). Journal of Applied Phycology 1: 311–317.

Morley, T. L., J. J. Bolton & R. J. Anderson, 2003. Phase dominance and reproductive characteristics in two co-occurring Rhodophyta from the west coast of South Africa. In Chapman, A. R. O., R. J. Anderson, V. J. Vreeland & I. R. Davison (eds), Proceedings of the XVIIth International Seaweed Symposium, Cape Town, South Africa, 28 January–2 February 2001. Oxford University Press, Oxford: 365–371.

Mudge, B. & R. Scrosati, 2003. Effects of wave exposure on the proportion of gametophytes and tetrasporophytes of *Mazzaella oregona* (Rhodophyta: Gigartinales) from Pacific Canada. Journal of the Marine Biological Association of the United Kingdom 83: 701–704.

Otaíza, R. D., S. R. Abades & A. J. Brante, 2001. Seasonal changes in abundance and shifts in dominance of life history stages of the carrageenophyte *Sarcothalia crispata* (Rhodophyta, Gigartinales) in south-central Chile. Journal of Applied Phycology 13: 161–171.

Phillips, B., 1994. Ecological differences between the isomorphic phases of *Mazzaella lilacina* (Rhodophyta, Gigartinaceae): 1) spore production, 2) recruitment specialization, 3) resistance to removal by wave action. M.Sc. thesis, University of British Columbia, Vancouver, 113 pp.

Scrosati, R., 2002. An updated definition of genet applicable to clonal seaweeds, bryophytes, and vascular plants. Basic and Applied Ecology 3: 97–99.

Scrosati, R. & R. E. DeWreede, 1999. Demographic models to simulate the stable ratio between ecologically similar gametophytes and tetrasporophytes in populations of the Gigartinaceae (Rhodophyta). Phycological Research 47: 153–157.

Scrosati, R., D. J. Garbary & J. McLachlan, 1994. Reproductive ecology of *Chondrus crispus* (Rhodophyta, Gigartinales) from Nova Scotia, Canada. Botanica Marina 37: 293–300.

Scrosati, R. & B. Mudge, 2004. Effects of elevation, wave exposure, and year on the proportion of gametophytes and tetrasporophytes in *Mazzaella parksii* (Rhodophyta, Gigartinaceae) populations. Hydrobiologia 520: 199–205.

Sousa, W. P., 2001. Natural disturbance and the dynamics of marine benthic communities. In Bertness, M. D., S. D. Gaines & M. E. Hay (eds), Marine Community Ecology. Sinauer Associates, Sunderland: 85–130.

Taylor, A. R. A. & L. C.-M. Chen, 1994. *Chondrus* Stackhouse. In Akatsuka, I. (ed.), Biology of Economic Algae. SPB Academic Publishing, The Hague: 35-76.

Thornber, C. S. & S. D. Gaines, 2003. Spatial and temporal variation of haploids and diploids in populations of four congeners of the marine alga *Mazzaella*. Marine Ecology Progress Series 258: 65–77.

Tveter-Gallagher, E. & A. C. Mathieson, 1980. An electron microscopy study of sporeling coalescence in the red alga *Chondrus crispus*. Scanning Electron Microscopy 3: 571–579.

Underwood, A. J., M. G. Chapman & S. D. Connell, 2000. Observations in ecology: you can't make progress on processes without understanding the patterns. Journal of Experimental Marine Biology and Ecology 250: 97–115.