

# Macroalgae

## By: Dr. Brian E. Lapointe

### Summary

Marine macroalgae (seaweeds) are a diverse group of organisms (Taylor, 1957 & 1972; Littler & Littler, 2000; Dawes & Mathiesen, 2008) important to the productivity, structure and function of estuarine and coastal ecosystems. Ryther (1963) estimated that global benthic seaweed production approaches 10% that of phytoplankton, even though macroalgae occupy an area only 1% as large. Macroalgal productivity and abundance are controlled by a variety of physical, chemical, and biological factors (Dawes, 1998), including irradiance (Dring, 1981; Ramus, 1981; Nielsen et al., 2002), temperature (Lapointe et al., 1984), nutrient availability (Mann, 1973; Hanisak, 1979; Wheeler & North, 1981; Lapointe, 1987), grazing (Lubchenco, 1978), water movement, and dessication (Surif and Raven, 1990). Macroalgae are considered ecosystem engineers (Jones et al., 1994), providing habitat for invertebrates (Marx & Herrkind, 1985) and fishes (Holbrook et al., 1990; Perez-Matus et al., 2007), and supporting coastal food webs as nutrition sources for herbivores (Sammarco et al., 1974; Lewis, 1986) and detritivores (Tenore, 1977).

Macroalgae are involved in the biogeochemical cycling of nitrogen and phosphorus in coastal ecosystems (Atkinson & Smith, 1983; Lapointe et al., 1992) and respond to nutrient pollution and eutrophication (Valiela et al., 1992; Lapointe et al., 1994; Howarth et al., 2000). Nutrient-enrichment of macroalgae can produce “harmful algal blooms” (HABs) when excessive biomass causes hypoxia/anoxia, reduced biodiversity and alteration of nutrient cycles and food webs (ECOHAB, 1995; Lapointe, 1997; Valiela et al., 1997). Increasingly problematic are non-native species introductions, such as *Caulerpa taxifolia* in the Mediterranean Sea (Meinesz et al., 1993), *Sargassum muticum* in Europe (Critchley et al., 1990), *Acanthophora spicifera* and *Hypnea musciformis* in Hawaii (Russell, 1992), and *Caulerpa brachypus f. parvifolia* in southeast Florida, USA (Lapointe et al., 2006; Lapointe & Bedford, 2009). Because they are attached and assimilate nutrients directly from the water column, macroalgae can be useful for monitoring nutrient availability using tissue C:N:P ratios, and for identifying nutrient input sources using elemental stable isotope ratio signatures (e.g.  $\delta^{15}\text{N}$ , ‰; Costanzo et al., 2001; Lapointe et al., 2005; Risk et al., 2009).

### References Cited

[Atkinson, M. J., and S. V. Smith. 1983. C:N:P ratios of benthic marine plants. \*Limnol. Oceanogr.\* 28\(3\): 568-574.](#)  
[Costanzo, S. D., M. J. O'Donohue, W. C. Dennison, N. R. Loneragan, and M. Thomas. 2001. A new approach for detecting and mapping sewage impacts. \*Marine Pollution Bulletin.\* 42: 149-156.](#)

- [Critchley, A. T., W. F. Farnham, T. Yoshida, and T. A. Norton. 1990. A bibliography of the invasive alga \*Sargassum muticum\* \(Yendo\) Fensholt \(Fucales; Sargassaceae\). \*Bot. Marine\* 33\(6\): 551-562.](#)
- Dawes, C. J. 1998. *Marine Botany*, 2nd Ed. John Wiley & Sons, New York.
- Dawes C. J., and A. C. Mathieson. 2008. *The Seaweeds of Florida*. University Press of Florida, Gainesville.
- [Dring, M. J. 1981. Chromatic adaptation of photosynthesis in benthic marine algae: an examination of its ecological significance using a theoretical model. \*Limnol. Oceanogr.\* 26: 271-284.](#)
- ECOHAB, 1995. *The ecology and oceanography of harmful algae blooms: a national research agenda*. Anderson, D.M. (Ed.), WHOI.
- [Hanisak, M. D. 1979. Nitrogen limitation of \*Codium fragile\* ssp. \*tomentosoides\* as determined by tissue analysis. \*Marine Biol.\* 50: 333-337.](#)
- Holbrook, S., M. H. Carr, R. S. Schmitt, and J. A. Coyer. 1990. [Effect of giant kelp on local abundance of reef fishes: the importance of ontogenetic resource requirements](#). *Bulletin. Marine Science* 47: 104-114.
- [Howarth, R., D. Anderson, J. Cloern, C. Elfring, C. Hopkinson, B. Lapointe, T. Malone, N. Marcus, K. McGlathery, A. Sharpley, and D. Walker. 2000. Nutrient pollution of coastal rivers, bays, and seas. \*Issues in Ecology\* 7: 1-5.](#)
- [Jones, C. G., J. H. Lawton, and M. Schachak. 1994. Organisms as ecosystem engineers. \*Oikos\* 69:373-386.](#)
- Lapointe, B. E. 1987. [Phosphorus- and nitrogen-limited photosynthesis and growth of \*Gracilaria tikvahiae\* \(Rhodophyceae\) in the Florida Keys: An experimental field study](#). *Marine Biol.* 93: 561-568.
- Lapointe, B. E. 1997. [Nutrient thresholds for bottom-up control of macroalgal blooms on coral reefs in Jamaica and southeast Florida](#). *Limnol. Oceanogr.* 42: 1119-1131.
- Lapointe, B. E., and B. J. Bedford. 2009. [Ecology and nutrition of invasive \*Caulerpa brachypus\* f. \*parvifolia\* blooms on coral reefs off southeast Florida, U.S.A.](#) *Harmful Algae*, *in press*.
- Lapointe, B. E., B. J. Bedford, and R. Baumberger. 2006. [Hurricanes Frances and Jeanne Remove Blooms of the Invasive Green Alga \*Caulerpa brachypus\* forma \*parvifolia\* \(Harvey\) Cribb From Coral Reefs Off Northern Palm Beach County, Florida, USA](#). *Estuaries and Coasts* 29: 966-971.
- Lapointe, B. E., P. J. Barile, M. M. Littler, and D. S. Littler. 2005. [Macroalgal blooms on southeast Florida coral reefs: II. Cross-shelf discrimination of nitrogen sources indicates widespread assimilation of sewage nitrogen](#). *Harmful Algae* 4: 1106-1122.
- Lapointe, B. E., M. M. Littler, and D. S. Littler. 1992. [Nutrient availability to marine macroalgae in siliciclastic versus carbonate-rich coastal waters](#). *Estuaries* 15: 75-82.
- Lapointe, B. E., D. A. Tomasko, and W. Matzie. 1994. [Eutrophication and trophic state classification of seagrass communities in the Florida Keys](#). *Bulletin. Marine Science* 54: 696-717.
- Lewis, S. M. 1986. [The role of herbivorous fishes in the organization of a Caribbean reef community](#). *Ecological Monographs* 56(3): 184-200.

- Littler, D. S., and M. M. Littler. 2000. Caribbean Reef Plants. Offshore Graphics, Washington, D.C.
- Lubchenco, J. 1978. [Plant species diversity in a marine intertidal community: importance of herbivore food preference and algal competitive abilities](#). Am. Nat. 112: 23-39.
- Mann, K. H. 1973. [Seaweeds: Their productivity and strategy for growth](#). Science 182: 975-981.
- Marx, J. M., and W. Herrnkind. 1985. [Macroalgae \(Rhodophyta: \*Laurencia\* spp.\) as habitat for juvenile spiny lobsters, \*Panulirus argus\*](#). Bulletin. Marine Science 36: 423-431.
- Meinesz, A., J. de Vaugelas, B. Hesse, and X. Mari. 1993. [Spread of the introduced tropical green alga \*Caulerpa taxifolia\* in northern Mediterranean waters](#). J. App. Phycol. 5: 141-147.
- Nielsen, S. L., K. Sand-Jensen, J. Borum, and O. Geertz-Hansen. 2002. [Depth colonization of eelgrass \(\*Zostera marina\*\) and macroalgae as determined by water transparency in Danish coastal waters](#). Estuaries 25(5): 1025-1032.
- Perez-Matus, A., L. A. Ferry-Graham, A. Cea, and J. A. Vasquez. 2007. [Community structure of temperate reef fishes in kelp-dominated subtidal habitats of northern Chile](#). Marine and Freshwater Research 58: 1069-1085.
- Ramus, J. 1981. The capture and transduction of light energy. In: Lobban, C. S., and M. J. Wynne (eds.), The Biology of Seaweeds. Blackwell, Oxford, pp. 458-492.
- Russell, D.J. 1992. The ecological invasion of Hawaiian reefs by two marine red algae *Acanthophora spicifera* (Vahl) Boerg. and *Hypnea musciformis* (Wulfen) J. Ag., and their association with two native species, *Laurencia nidifica* J. Ag. and *Hypnea cervicornis* J. Ag. Int. Coun. Explor. Sea Marine Science Symp. 194:110-125.
- Risk, M. J., B. E. Lapointe, O. A. Sherwood, and B. J. Bedford. 2009. [The use of  \$\delta^{15}\text{N}\$  in assessing sewage stress on coral reefs](#). Marine Pollution Bulletin. 58: 793-802.
- Ryther, J. H. 1963. Geographic variations in productivity. In: Hill, M.N. (Ed.), The Sea. John Wiley and Sons, New York, pp. 347-380.
- Sammarco, P. W., J. S. Levington, and J. C. Ogden. 1974. Grazing and control of coral reef community structure by *Diadema antillarum* Phillipi (Echinodermata:Echinoidea): a preliminary study. J. Marine Res. 32: 47-53.
- Surif, M. B., and J. A. Raven. 1990. [Photosynthetic gas exchange under emersed conditions in eu littoral and normally submersed members of the Fucales and the Laminariales](#). Oecologia 82: 68-80.
- Taylor, W. R. 1957. Marine algae of the northeastern coast of North America. University of Michigan Press, Ann Arbor
- Taylor, W. R. 1960. Marine algae of the eastern tropical and subtropical coasts of the Americas. University of Michigan Press, Ann Arbor.
- Tenore, K. 1977. [Growth of \*Capitella capitata\* cultured on various levels of detritus derived from different sources](#). Limnol. Oceanogr. 22: 936-941.
- Valiela, I., K. Forman, M. LaMontagne, D. Hersh, J. Costa, P. Peckol, B. Demeo-Andreson, C. D'Avanzo, M. Babione, C. H. Sham, J., Brawley, and K. Lajtha. 1992. [Couplings of watersheds and coastal waters:sources and consequences of nutrient enrichment in Waquoit Bay, Massachusetts](#). Estuaries 15(4): 443-457.

- Valiela, I., J. McClelland, J. Hauxwell, P. Behr, D. Hersh, and K. Forman. 1997. [Macroalgal blooms in shallow estuaries: controls and ecophysiological and ecosystem consequences](#). *Limnol. Oceanogr.* 42: 1105-1118.
- Wheeler, P. A. and W. J. North. 1981. [Nitrogen supply, tissue composition, and frond growth rates for \*Macrocystis pyrifera\* off the coast of southern California](#). *Marine Biol.* 64: 59-69.

### Other References

- Chapman, A. R. O. and J. S. Craigie. 1977. [Seasonal growth of \*Laminaria longicuris\*: relations with dissolved inorganic nutrients and internal reserves of nitrogen](#). *Marine Biol.* 40: 197-205.
- Clifton, K. E. 1997. [Mass spawning by green algae on coral reefs](#). *Science* 275: 1116-1118.
- Duarte, C. M. 1995. [Submerged aquatic vegetation in relation to different nutrient regimes](#). *Ophelia* 41: 87-112.
- Fong, P., J. B. Zedler, and R. M. Donohoe. 1993. [Nitrogen vs. phosphorus limitation of algal biomass in shallow coastal lagoons](#). *Limnol. Oceanogr.* 38: 906-923.
- Fong, P., K. E. Boyer, K. Kamer, and K. A. Boyle. 2003. [Influence of initial tissue nutrient status of tropical marine algae on response to nitrogen and phosphorus additions](#). *Marine Ecol. Prog. Ser.* 262: 111-123.
- Fujita, R. M., P. A. Wheeler, and R. L. Edwards. 1989. [Assessment of macroalgal nitrogen limitation in a seasonal upwelling region](#). *Marine Ecol. Prog. Ser.* 53: 293-303.
- Hanisak, M. D. and S. M. Blair. 1988. [The deep water macroalgal community of the East Florida continental shelf \(USA\)](#). *Helgolander Meeres.* 42: 133-163.
- Hardwick-Witman, M. N., and A. C. Mathieson. 1986. [Tissue nitrogen and carbon variations in New England estuarine \*Ascophyllum nodosum\* \(L.\) \*Le Jolis\* populations \(Fucales, Phaeophyta\)](#). *Estuaries* 9(1): 43-48.
- Hauxwell, J., J. Cerbrian, C., Furlong, and I. Valiela. 2001. [Macroalgal canopies contribute to eelgrass decline in temperate estuarine ecosystems](#). *Ecology* 82(4): 1007-1022.
- Holbrook, S. J., M. H. Carr, R. J. Schmitt, and J. A. Coyer. 1990. [Effect of giant kelp on local abundance of reef fishes: the importance of ontogenetic resource requirements](#). *Bulletin. Marine Science* 47(1): 104-114.
- Hudson, H. J. 1985. Growth rate and carbonate production in *Halimeda opuntia*: Marquesas Keys, Florida. In: Toomey, D. F., and M.H. Nitecki (eds.), *Paleoalgology: Contemporary Research and Applications*. Springer-Verlag, Berlin, pp. 257-263.
- Huisman, J. M., I. A. Abbott, and C. M. Smith. 2007. Hawaiian Reef Plants. Report # UNIHI-SEAGRANT-BA-03-02, University of Hawaii Sea Grant College Program, Honolulu, Hawaii.
- Lapointe, B. E. 1995. [A comparison of nutrient-limited productivity in \*Sargassum natans\* from neritic versus oceanic waters of the Western North Atlantic Ocean](#). *Limnol. Oceanogr.* 40: 625-633.
- Lapointe, B. E. 1999. [Simultaneous top-down and bottom-up forces control macroalgal blooms on coral reefs \(reply to the comment by Hughes et al.\)](#). *Limnol. and Oceanogr.* 44(6): 1586-1592.

- Lapointe, B. E., P. J. Barile, C. S. Yentsch, M. M. Littler, D. S. Littler, and B. Kakuk. 2004. [The relative importance of nutrient enrichment and herbivory on macroalgal communities near Norman's Pond Cay, Exumas Cays, Bahamas: a "natural" enrichment experiment.](#) J. Exp. Marine Biol. Ecol. 298(2): 275-301.
- Lapointe, B. E., P. J. Barile, M. M. Littler, D. S. Littler, B. J. Bedford, and C. Gasque. 2005. [Macroalgal blooms on southeast Florida coral reefs I. Nutrient stoichiometry of the invasive green alga \*Codium isthmocladum\* in the wider Caribbean indicates nutrient enrichment.](#) Harmful Algae 4: 1092-1105.
- Lapointe, B. E. and B. J. Bedford. 2007. [Drift rhodophyte blooms emerge in Lee County, FL, USA: evidence of escalating coastal eutrophication.](#) Harmful Algae 6: 421-437.
- Larned, S. T. 1998. [Nitrogen versus phosphorus limited growth and sources of nutrients for coral reef macroalgae.](#) Marine Biol. 132: 409-421.
- Littler, M. M., and D. S. Littler (eds.). 1985. Handbook of Phycological Methods, Ecological Field Methods: Macroalgae. Cambridge University Press, Cambridge.
- Littler, M. M., and D. S. Littler. 1980. [The evolution of thallus form and survival strategies in benthic marine macroalgae: field and laboratory tests of a functional form model.](#) American Naturalist 116: 25-44.
- Lobban, C. S., and P. J. Harrison (eds.). 1994. Seaweed Ecology and Physiology. Cambridge University Press, Cambridge.
- McGlathery, K. J. 1995. [Nutrient and grazing influences on a subtropical seagrass community.](#) Marine Ecol. Prog. Ser. 122: 239-252.
- McGlathery, K. J., D. Krause-Jensen, S. Rysgaard, and P. B. Christensen. 1997. [Patterns of ammonium uptake within dense mats of the filamentous macroalga \*Chaetomorpha linum\*.](#) Aquat. Bot. 59: 99-115.
- Orris, P. K. 1980. [A revised species list and commentary on the macroalgae of the Chesapeake Bay in Maryland.](#) Estuaries 3(3): 200-206.
- Peckol, P., and J. S. Rivers. 1996. [Contribution by macroalgal mats to primary production of a shallow embayment under high and low nitrogen loading rates.](#) Est. Coast. Shelf Science 43: 311-325.
- Rodgers, S. K. and E. F. Cox. 1999. Rate of spread of introduced rhodophytes *Kappaphycus ahwarzii*, *Kappaphycus striatum*, and *Gracilaria salicornia* and their current distributions in Kaneohe Bay, Oahu, Hawaii. Pac. Science 53: 232-241.
- Ryther, J. H. 1956. The Sargasso Sea. Science Amer. 194(1): 98-104.
- Sfriso, A., B. Pavoni, A. Marcomini, and A. A. Orio. 1992. [Macroalgae, nutrient cycles, and pollutants in the Lagoon of Venice.](#) Estuaries 15: 517-528.
- Smith, J. E., C. L. Hunter, and C. M. Smith. 2002. [Distribution and reproductive characteristics of nonindigenous and invasive marine algae in the Hawaiian Islands.](#) Pac. Science 56: 299-315.

- Vadas, R. L., and B. Beal. 1987. [Green algal ropes: a novel estuarine phenomenon in the Gulf of Maine.](#) Estuaries 10(2): 171-176.
- Virnstain, R. W., and P. A. Carbonara. 1985. [Seasonal abundance and distribution of drift algae and seagrasses in the mid-Indian River Lagoon, FL.](#) Aquat. Bot. 23: 67-82.
- Williams, S. L. 1984. [Uptake of sediment ammonium and translocation in a marine green macroalga \*Caulerpa cupressoides\*.](#) Limnol. Oceanogr. 29: 274-279.
- Williams, S. L. and T. R. Fisher. 1985. [Kinetics of nitrogen-15 labelled ammonium uptake by \*Caulerpa cupressoides\*.](#) J. Phycol. 21: 287-296.

### **Web Resources**

[www.algaebase.org](http://www.algaebase.org)

## Image Gallery

Image 1. *Caulerpa brachypus* f. *parvifolia* blooming off southeast Florida, USA; this is a non-native invasive from the western Pacific. (Photo: Brad Bedford '08)



Image 2. *Cladophora liniformis* bloom covering dead coral heads and seagrasses at “The Rockpile” reef, north of the Content Keys, southern Florida Bay, USA, June 2008. (Photo: Brian Lapointe '08)





Image 3. Intertidal *Ascophyllum nodosum* and *Fucus* sp., coastal Maine, USA. (Photo: Brian Lapointe '09)

