6. GENERAL DISCUSSION

To date, *C. taxifolia* in NSW has been found only in relatively sheltered embayments in water ~ 0.5–10 m deep and never on exposed coasts. Comprehensive water quality data are not available for the various waterways and depths in which *C. taxifolia* is present, but based on data from numerous sources, salinity in these areas (at depths > 0.5 m) may range from ~ 27–36 ppt and temperature ranges can be from ~ 12–25 ^{o}C. In all waterways, *C. taxifolia* is growing primarily on soft sediments, adjacent to or in beds of seagrass or in previously unvegetated sediments. In only a few places is the alga found on hard surfaces such as pier pilings, concrete mooring blocks or shallow rocky reef.

During winter, the cover of *C. taxifolia* in NSW waterways generally decreases and the alga is typically much smaller, which is consistent with findings in other countries (Meinesz *et al*. 1995, Ceccherelli and Cinelli 1999a). Large-scale die-off occurs in shallow water (0.5–2 m) in most waterways during the cooler months and this has been particularly evident after heavy rainfall. Thus, it is possible that die-back may be a consequence of decreased temperature, decreased salinity, increased turbidity or some combination of these factors. This information, and a better understanding of the basic biology of the species in NSW, has been used to help determine when control work is likely to be most effective.

Eliminating or controlling the spread of *C. taxifolia* with osmotic shock techniques (application of salt in NSW or the use of freshwater in South Australia) has been shown to be reasonably effective and cost-efficient. Any control technique, however, will be scale dependent – things that work well at small scales may not be feasible at larger scales. Thus, in NSW, the application of salt can be very effective at scales up to a few hectares. Limited resources have meant that many outbreaks have not yet been treated and the results of large-scale salting have been mixed. For example, in Lake Macquarie, single applications of salt to numerous outbreaks have resulted in the apparent removal of almost 5200 m^2 of *C. taxifolia*, whereas repeated salting of a 3000 m^2 infestation in Careel Bay in Pittwater has led to a considerable reduction in the density of the alga, but no overall change in the boundaries of the infestation. If natural phenomena assisted with the removal of *C. taxifolia* from Lake Macquarie, as seems likely, a focus of future research needs to be on patterns of change in established populations of *C. taxifolia* and the causes of those fluctuations. *Caulerpa* spp. worldwide often undergo patterns of rapid expansion followed by dramatic declines (Jaubert *et al*. 2003 and references therein), and it may be that *C. taxifolia* will show the same phenomenon in NSW. Until the reasons for any 'natural' fluctuations are known, however, work on elimination or controlling the further spread of the alga is imperative.

For larger infestations such as those in many NSW estuaries, salt treatment can only be used in localised sites. Additional technologies such as species-specific biocides may provide one avenue for further investigation. The development of such technologies, however, will take a considerable time (R. Thresher, pers. comm.) and their utility will still then have to be evaluated in field situations. Given this time frame, it is unlikely that any technology will be able to completely eradicate *C. taxifolia* from NSW waterways in the near future. This realisation means that no single approach to the management of this marine invader will suffice. Rather, an integrated plan incorporating multiple approaches is required.

The investigations described in this report have informed the process of developing a statewide control plan for invasive *C. taxifolia* in NSW. This plan, officially released in February 2004, contains a preliminary risk assessment that considers the risks of transport of *C. taxifolia* to new estuaries or areas within estuaries, the risks of environmental and socio-economic impacts of the alga and the process by which priorities are set for control activities. This plan is available on the NSW Fisheries website at http://www.fisheries.nsw.gov.au/thr/species/fn-caulerpa.htm

Future directions

A great deal more research is needed on natural fluctuations in abundance of *C. taxifolia* and on correlations between various biotic and abiotic parameters and abundances of *C. taxifolia*. Research of this kind is likely to be more effective for managing the species than is continued control work which is expensive and often logistically difficult. Importantly, it is not yet known whether *C. taxifolia* is having negative impacts on estuarine ecosystems and thus it is unclear whether vast resources should be allocated to the control of the species. Future research, therefore, should be more directed towards understanding the potential impacts of *C. taxifolia* and investigating natural fluctuations in abundance of the alga. Control work will continue, but efforts will be prioritised because the treatment of *C. taxifolia* with salt in all invaded estuaries in NSW is not logistically feasible and prohibitively expensive. Key priority areas for control have been identified in the NSW Fisheries *Caulerpa* control plan and include seagrass beds (which may be vulnerable to invasion), boat ramps and popular fishing spots (from where *C. taxifolia* may be spread) and outbreaks close to the open coast. Some resources should also be devoted to investigating other methods for control.

Various research projects on the potential impacts of *C. taxifolia* are currently underway in collaboration with universities. These include comparisons of *C. taxifolia* and native seagrasses as habitats for fishes and invertebrate epifauna and infauna. NSW Fisheries has also begun investigating the interactions between *C. taxifolia* and seagrasses in an attempt to determine how vulnerable beds of seagrass are to invasion. As described in this report, research at the University of Wollongong has focussed on the life history characteristics, growth and spread of *C. taxifolia*, in addition to associations between marine herbivores and the alga and more research is planned along these lines. Future research by NSW Fisheries may include studies of the invasiveness of *C. taxifolia* in different waterways in NSW versus that of native *C. taxifolia* in Queensland. Given that results of genetic studies regarding the affiliations of different populations of *C. taxifolia* are still inconclusive, research on the invasive characteristics of populations may be an indirect way of determining whether different populations of *C. taxifolia* are related whilst addressing one of the most important issues, namely the ability of different strains to invade. Additional effort will also be devoted to identifying the types of places that *C. taxifolia* is most likely to invade so that preventative action can be made more effective.

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