APPENDIX 2

Summaries of additional research done at the University of Wollongong on the interactions between potential herbivores and *C. taxifolia*.

Appendix 2A

Responses of common SE Australian herbivores to three invasive *Caulerpa* spp.

A.R. Davis, K. Benkendorff [1] and D.W. Ward[2]

Institute for Conservation Biology
School of Biological Sciences,
University of Wollongong,
NSW 2522, AUSTRALIA

[1.] Current Address: School of Biological Sciences,
The Flinders University of South Australia,
GPO Box 2100, Adelaide, SA 5001, Australia.

[2.] Current Address: NSW Fisheries,
PO Box W47, Tamworth, NSW 2340, Australia.

Corresponding author: AR Davis (phone 61 2 4221 3432)
(fax 61 2 4221 4135)
adavis@uow.edu.au

ABSTRACT

We sought to determine whether common intertidal and shallow subtidal zone grazers would consume extracts or fronds of three invasive *Caulerpa* spp. all of which are now resident in southern New South Wales, Australia. We examined the responses of herbivorous fishes, echinoderms and molluscs to *C. filiformis*. The responses of a subset of these organisms to extracts of the highly invasive *C. scalpelliformis* and *C. taxifolia* were also examined. Most feeding trials were conducted in the field using palatable agar discs containing extracts to prevent any chance of spreading these algae. Algal extracts were produced by macerating algal fronds in ethanol or seawater. Polar extracts of *C. filiformis* deterred a single herbivore, *Aplysia sydneyensis*, but confirmed that the biological activity reported from some *Caulerpa* spp. is not restricted to the lipophilic fractions. The large turbinid *Turbo torquatus* was dissuaded from feeding on agar discs containing ethanol extract of *C. filiformis*, while in contrast the small congener *T. undulatus* demonstrated a significant preference for ethanol extracts of *C. filiformis* relative to controls. However, when *T. undulatus* were offered a choice of fronds from six algal species in a laboratory experiment they readily consumed *Ulva* spp. and *Sargassum* sp., showing the lowest preference for *C. filiformis*. Solvent extracts of *C. scalpelliformis* and *C. taxifolia* did not significantly dissuade any grazers. However, the overall trend was for deterrence by the discs containing solvent extracts of these seaweeds. Indeed, for the large urchin *Centrostephanus rodgersii* and in the fish trials these effects were very near significant ($P<0.06$). We conclude that common herbivores associated with hard substrata are highly unlikely to intercede in the spread or control of these invasive algae.

Appendix 2B

Plant – herbivore interaction in an estuary invaded by *Caulerpa taxifolia*…..
Estimating the impacts of native herbivores on their food resources

By John Gollan

This thesis is submitted in partial fulfilment of the requirements for the degree of Bachelor of Science (Honours)

Department of Biological Sciences
University of Wollongong, NSW, Australia
October 2003

ABSTRACT

Invasive species are among the greatest threats to ecosystems worldwide. Frequently invasive species occur in very high densities in the invaded regions and one theory as to why these species do so well is that they suffer less from the effects of natural enemies in their new environments. Herbivory is an important ecological force shaping most plant communities, altering plant abundance, species diversity and/or species distribution. Consequently, herbivory or its absence, can facilitate invasion by exotic plants. Herbivory is a particularly important ecological force in most marine communities and is likely to have an important role in the invasion of exotic marine plants.

One of the most notorious marine invasive plants is the tropical macroalga *Caulerpa taxifolia*, which is suspected to experience low levels of herbivory in recipient communities. In this study I examined the entire assemblage of herbivores in Lake Conjola, NSW, which is probably the location most heavily infested by *C. taxifolia* in temperate Australia. Specifically, I examined patterns of distribution and abundance of herbivores in Lake Conjola, their feeding rates, habitat choice and their survivorship on native plants vs. *C. taxifolia.*

Surveys during the year revealed that there were only four abundant herbivores in Lake Conjola: the fish, *Girella tricuspian;* the macrograzer, *Aplysia dactylomela*; and two mesograzers, *Platynereis dumerilii antipoda* and *Cymadusa setosa*. Densities of both *G. tricuspidate* and *A. dactylomela* varied significantly in space and time and there was no relationship between their abundance and the abundance of *C. taxifolia*. Densities of both mesograzers also varied significantly in space and time and among five host plants. Most notably, there were consistently low densities of both mesograzers on *C. taxifolia* and a significant negative relationship between the total number of these grazers and biomass of *C. taxifolia*. Highest densities of these mesograzers mostly occurred on two brown algae; *Cystophylum onustum* and *Sargassum* sp. although at some times and sites other hosts had similar or greater densities. Feeding trials to examine the consumption rates of these herbivores on native plants vs. *C. taxifolia* failed to gain useful data for both G. tricuspidate and *A. dactylomela*. However, food selectivity by *A. dactylomela*, assessed by comparing gut content with field abundance, indicated a strong preference for the red alga, *Laurencia* spp. and strong avoidance of *C. taxifolia*. A no-choice feeding experiment comparing native plants vs. *C. taxifolia* showed feeding by *C. setosa* was lowest on *C. taxifolia* and highest on *C. onustum* and *Sargassum* sp. The aversion for *C. taxifolia* displayed by *C. setosa* was further examined using starved and unstarved animals and indicated this species will only eat *C. taxifolia* when hunger stressed.

Conversely, *P. antipoda* showed no aversion for *C. taxifolia* and had similar feeding rates on *C. taxifolia* to all other native seaweeds. Estimated impacts of both mesograzers (calculated by combining field densities with feeding rates on different hosts) were lowest for *C. taxifolia* and highest for *C. onustum* and *Sargassum* sp. Both mesograzers strongly avoided *C. taxifolia* in feeding preference experiments and preferred the two brown algae. Survivorship of *C. setosa* was lower on *C. taxifolia* vs. *C. onustum* but there was no difference between those fed *C. taxifolia* and those that were fed no food. In contrast, the survivorship of *P. antipoda* to 41 days was 100% on *C. taxifolia, C. onustum* and no food.

Overall, the results from this study support the suggestion that *C. taxifolia* is experiencing weak grazing pressure from native herbivores. However the absence of feeding data for two of these herbivores, in particular for *Girella tricuspidata*, constrain this conclusion and future research on the feeding and impacts of this herbivore will contribute to understanding its role in the invasion of *C. taxifolia* in temperate Australia.

Appendix 2C

Fauna associated with *Caulerpa* spp.; potential Biological Control of *C. taxifolia*

Amanda Edwards BSc

This thesis is submitted in partial fulfilment of the requirements for a Bachelor of Science degree

(Honours) from the University of Wollongong

Department of Biology
December 2002

ABSTRACT

Marine ecosystems worldwide are being altered by the invasion of non-indigenous species. *Caulerpa taxifolia* is an alga that has invaded the Mediterranean, California and now Australia. There is great concern about its potential impacts and consequently there is a need to understand more on its ecology to be able to manage or control it.

This study had 2 main aims: 1) to determine patterns of variation in species richness, abundance and community structure in the fauna associated with 4 *Caulerpa* spp. (particularly herbivores) commonly found along the eastern coastline of NSW, Australia. They were: *Caulerpa filiformis*, *C. taxifolia, C. flexilis* and *C. cactoides*. One particular area of interest in the study was the presence of the native herbivores occurring on *Caulerpa* in south eastern Australia and their potential to act as a biological control on *C. taxifolia*. The 4 species were compared across 3 locations and sites within locations. Two species (*C. filiformis* and *C. taxifolia*) were examined 3 times to assess temporal patterns. 2) To examine the feeding of 4 common gastropod herbivores on *C. filiformis* and the feeding of a common sacoglossan on *C. taxifolia*.

The hierarchical sampling design revealed significant differences in species richness and abundance of fauna on small scales: between locations and between sites within locations ($F = 3.13$, $p = 0.0143$; $F = 4.97$, $p<0.001$; respectively for species richness). This data suggests that 'patchiness' in fauna species richness and abundance occurs on small scales. No differences in species richness or abundance occurred between *Caulerpa* spp. Temporal variation between times for different sites (*C. filiformis* and *C. taxifolia*) were also detected, hence, patchiness on temporal as well as spatial scales.

Although there was no variation in fauna numbers between *Caulerpa* spp., the community structure for each was not the same. In total, 61 species were found on the 4 *Caulerpa* spp. *C. filiformis* was comprised mainly of herbivorous gastropods (eg. *Canthrindella picturata* and *Oxynoe viridis*), while the other three species contained mainly amphipods and bivalves (>50% contribution). The fact that samples for each *Caulerpa* spp. were taken from different locations in different habitats may be an important factor contributing to differences in the composition of fauna.

The 4 most abundant herbivores found on *C. filiformis* were used to examine which herbivores consumed it. Of the 4 herbivores, only *Oxynoe viridis* consumed *C. filiformis*. This was based on 3 different measurements of consumption: weight loss, percentage bleached fronds and the photosynthetic ability of the alga. *O. viridis* also consumed the invasive *C. taxifolia* (based on weight loss and percentage bleached fronds). However, consumption of *C. taxifolia* by *O. viridis* as weight loss was relatively low when compared to percent bleaching measurements. *O. viridis* are suctorial feeders and this may affect frond health, shown by large percentage bleaching of fronds following grazing, but may not have an impact on frond weight. The fact that *O. viridis* consumes the invasive *C. taxifolia* at several locations is encouraging when considering the sacoglossan as a potential biological control agent against *C. taxifolia* in Australia.