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Final Report on FIRTA Grant No. 86/78.

PRODUCTIVITY OF TIGER PRAWN NURSERY AREAS

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INTRODUCTION

Many fisheries around the Australian coast, particularly for mullet, whiting, prawns and lobsters, are dependent on seagrass beds. Tiger and endeavour prawns are largely dependent on seagrass beds as nursery areas for the juvenile life history stages. These prawns are now of major importance in the catch from northern Australia, especially the Gulf of Carpentaria. CSIRO projects funded by FIRTA have shown that seagrass beds are obligatory habitats for the juvenile prawns. The seagrass beds have been mapped in the Gulf of Carpentaria and Torres Strait by CSIRO and very extensive beds have been found (Poiner, Staples and Kenyon, 1987). Data are available on seagrass species composition, density and physical structure of the seagrass beds. Data are also available on the abundance, growth and survival of juvenile prawns in the different types of seagrass communities around Groote Eylandt in the western Gulf of Carpentaria. These studies are being carried out as part of a larger range of investigations into prawn biology and ecology by the Cleveland Laboratory of CSIRO.

It is presumed that the prawns find food and shelter from predators in seagrass beds. In order to better understand the relationships between the seagrasses and prawns, and thus to make more informed judgements on the management of both seagrass beds and prawn fisheries, information is needed on the productivity of the seagrasses and the transfer of seagrass production to animals.

If we wish to predict whether a prawn fishery will be stable in the long term, quantitative information is needed on how and why the ecosystems that include the prawns function. A predictive model based on population dynamics is useful while the status quo is unchanged, for predicting catches or economic yield. But, it cannot work if unspecified conditions should change, e.g. the effects of a loss of seagrass beds or substantial change in seagrass productivity on juvenile prawn numbers and growth. Management decisions to optimise long term exploitation of the prawn fishery will require knowledge of answers to questions such as: what do the various larval prawn species eat in the water column; how do water currents influence their migration to nursery grounds; what effect do cyclonic storms have on nutrient concentrations and thus on phytoplankton or seagrass productivity, and in turn on prawn larval or juvenile growth rates; how important is the bacterial fixation of nitrogen in sediments to the supply of organic nitrogen (i.e. protein) to the food chain leading to prawns.

The aquaculturalists and pastoralists have asked questions of the same broad nature concerning the terrestrial environment in which they work. The large research effort in those spheres over the last century has provided them with general as well as specific answers to most questions. Marine research is a long way behind.

The three year programme proposed for this FIRTA project was designed to provide information about the productivity of seagrass beds used as nursery grounds by juvenile tiger prawns and the role of nitrogen fixation as a source of reduced nitrogen for seagrass growth.

Bacteria play an important role in the food chain to prawns, because they are the essential links between seagrasses and animals. The structural carbohydrates of seagrasses cannot be digested by animals and the carbon to nitrogen ratio of seagrasses is too high to be immediately useful as food for animals. The seagrasses must be decomposed by bacteria first. During this process, bacteria synthesize protein from inorganic nitrogen and thus supply the basic protein needs of the animals that feed on them. An important aspect of the nitrogen cycle in seagrass beds, about which we need more information, is nitrogen fixation, the ultimate source of all nitrogen in the food chain. It is this process that may limit production in seagrass beds.

SPECIFIC OBJECTIVES:

1. Obtain concurrent measurements of seagrass production, epiphyte production and bacterial production.

2. Determine the importance of nitrogen fixation in the nitrogen cycle, and the turnover of ammonia in seagrass sediments.

3. Investigate whether seagrasses and/or epiphytes are the base of the food chain to juvenile prawns.

RESULTS AND DISCUSSION:

1. Primary Productivity

The dominant seagrass in the study site at Weipa was *Enhalus acoroides*. Its productivity per shoot was very high compared to other species of seagrass (Tables 1,2). The values for primary productivity of the whole community were determined from diel and tidal changes in oxygen concentration, and thus include the contributions of other seagrass species as well as algae.

Table 1. Productivity of *Enhalus acoroides* at site 4, Groote Eylandt in February, 1987 and with the whole community in a seagrass bed at Weipa in November, 1986. Values given are means ± standard deviation, (n); standard deviation for areal values is derived from variation in shoot density.

Method		Productivity	
		mg C $shoot^{-1}$ day^{-1}	g C m^{-2} day^{-1}
Groote Eylandt			
Enhalus acoroides	Lacunal gas	45 ± 12 (7)	3.4 ± 1.1 (10)
Weipa			
Enhalus acoroides	Lacunal gas	23 ± 8 (8)	0.9 ± 0.3 (15)
Community	O_2, drogue		2.2 ± 0.9 (5)
Community	O_2, diurnal change		4.2 ± 1.3 (6)

Table 2. Productivity of seagrasses at Groote Eylandt in February 1987. Values are means ± standard deviation, (n). The standard deviation for areal values is based on shoot density variation.

Site, Seagrass	Productivity	
	mg C $shoot^{-1}$ day^{-1}	mg C m^{-2} day^{-1}
Sheltered Bay		
Syringodium isoetifolium	0.5 ± 0.2	1.5 ± 0.6
Cymodocea serrulata	2.7 ± 1.0	3.0 ± 1.6
Reef flat		
Thalassia hemprichii	0.5 ± 0.03	0.3 ± 0.3
Cymodocea rotundata	0.8 ± 0.3	0.5 ± 0.3

The productivity per unit area at the sheltered bay site and in the Enhalus beds was considerably higher than on the reef flat. These results are similar to those found in earlier work. Furthermore, productivity was much greater in summer than in winter (Moriarty, Pollard and Roberts, ms in preparation). Poiner, I.R., Staples, D.J., and Kenyon R. (1987) Seagrass communities of the Gulf of Carpentaria, Australia. Aust. J. Mar. Freshw. Res. **38:** 121-31, pointed out that seagrass beds with highest biomass and shoot density of seagrass supported the greatest density of juvenile tiger prawns. Our work shows that these seagrass beds also have the greatest productivity.

2. Bacterial Productivity

Bacterial productivities were very high in the sediments (Table 3).

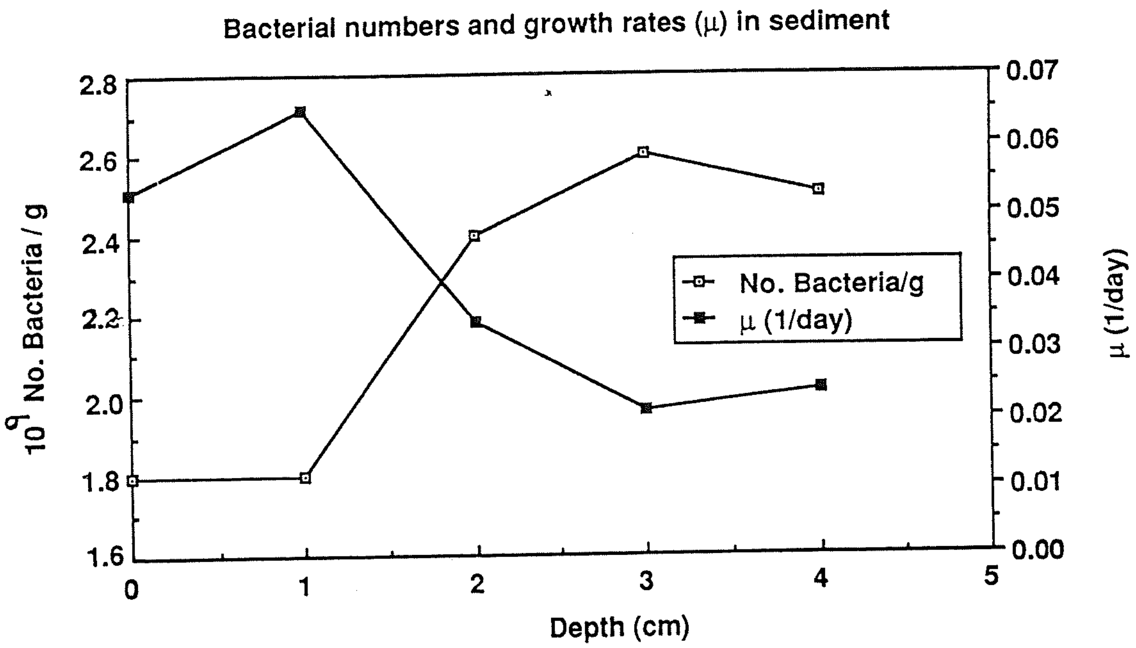
Table 3. Bacterial productivities in sediment of seagrass beds at Weipa, December 1986, and Groote Eylandt, February, 1987. Values are given as g C m^{-2} day^{-1} (mean ± standard deviation).

Site	Seagrass	Productivity
Weipa	Enhalus acoroides	2.7 ± 0.6
Groote Eylandt	Enhalus acoroides	3.3 ± 0.4
	Sheltered Bay	2.4 ± 0.6
	Reef flat	1.2 ± 0.4

These values are similar to those found earlier for summer (January, 1985). In winter productivities of both seagrasses and bacteria were 2 to 5 times lower. These bacterial productivities are 25% to 50% of primary production, which means that at least half and up to all the primary production is cycled through the bacteria (i.e., assuming a value of 50% for bacterial growth efficiency). Thus bacteria are the major consumers of seagrass.

The 2 to 3 g C m^{-2} day^{-1} of new bacterial biomass is grazed at about the same rate, because numbers of bacteria do not vary much on a diel or seasonal scale. In fact, in the surface sediments, numbers of bacteria are generally smaller than at depths greater than 1 cm, whereas the growth rates are faster (Fig. 1). This indicates that grazing is an important factor. The bacterial production in summer is a substantial, high quality, food resource, equivalent to 250 kg fresh weight ha^{-1} day^{-1} of proteinaceous material. This is a minimum amount, because results from the method that was used do not include the productivity of bacteria that reduce or oxidise sulphur. About 20% of the organic matter decomposed by bacteria was lost from the sediment as CO_2 through the activities of the anaerobic sulphate-reducing bacteria.

Figure 1. Change with sediment depth of bacterial numbers and specific growth rate (number of generations per day) of bacteria in a <u>Syringodium</u> bed.



We were not able to determine what proportion of the prawns' food was derived ultimately from seagrasses via bacteria, because the FIRTA grant was not renewed. From others' work elsewhere, it is probable that at least 50% of the organic matter eaten by prawns resulted from seagrass photosynthesis. The remainder would be from epiphytic and benthic algae. It is clear from these results that bacteria are of major significance in seagrass food chains.

3. Nitrogen fixation

Nitrogen fixation by bacteria in the sediments around the seagrasses was substantial (Table 4). The rates are very rapid compared to agricultural land where non-symbiotic fixation occurs (e.g. in grassland). Much of the fixation was closely associated with the seagrasses in the rhizosphere, and some even occurred in washed roots. Thus there is a close association between the nitrogen-fixing bacteria and the seagrasses. Nitrogen fixation is a biochemical process that requires much energy. The energy is supplied to the bacteria in the form of organic matter by seagrasses.

Nitrogen fixation by epiphytic cyanobacteria (blue-green algae) on the leaves of <u>Enhalus</u> was substantial, but on other species was 5% or less than that in the sediment.

Table 4. Nitrogen fixation in seagrass beds. Rates are mg N m^{-2} day^{-1}. (Means and standard deviation shown).

Site, Seagrass	Rate of N_2 Fixation
Weipa, Enhalus acoroides	
Sediment	32 ± 9 (n = 6)
Leaves	4.3 ± 0.2 (n = 4)
Groote Eylandt, sediment	
Syringodium	66 ± 40 (n = 14)
Thalassia, cymodocea	40 ± 10 (n = 6)

Seagrass beds are major sites for nitrogen fixation in coastal habitats. As all animals require protein (fixed nitrogen) in their diet, and nitrogen is generally a limiting nutrient for marine productivity, it is clear that nitrogen fixation is a most important role for seagrass ecosystems. In fact, seagrasses may be more important in this respect than as a source of food for energy (primary production *per se*) or shelter.

GENERAL CONCLUSIONS

Because the work was planned as a three year project, but only one was funded, the objectives could not be fulfilled. The work done has shown that the seagrass beds are most productive in summer, at the time that abundance of juvenile tiger prawns is greatest. Rates of seagrass decomposition are very high, and closely coupled on a seasonal basis to rates of primary production. Our results, showing that bacterial production is substantial in summer, show that much greater animal productivity would result in the summer also. The extent to which algae, particularly epiphytic and benthic microalgae, support food chains is not known, but is probably substantial. Thus these results are not in disagreement with the hypothesis that tiger prawns utilise seagrass beds because an abundant food supply is available, but more work is needed to substantiate a causative argument.

Nitrogen fixation is one aspect of how seagrasses and bacteria have an integral relationship in the sediment. It is an anaerobic process, and occurs mostly in anoxic sediments. Anoxic conditions are generated by the activities of many different types of heterotrophic bacteria during utilisation of organic material supplied by seagrasses. These anoxic conditions may enhance the toxic effect of any heavy metals that may be present, but these effects in turn are lessened by other bacterial activities such as the release of slime. Thus sediment chemistry is considerably altered by the interplay between seagrasses and bacteria. Much more research is needed in this area if predictions are required on the success of any proposals to revegetate denuded seagrass beds or establish seagrasses in new areas.

PUBLICATION OF RESULTS

The above report is a brief summary of work that is being written up in 6 research papers. When complete, a precis will be prepared for "Australian Fisheries".