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Examining Sources of Energy and Nutrient Input From Different Microhabitats Within
Matapouri Estuary (New Zealand)

ABSTRACT

In order to determine relative importance of different environments within an ecosystem, sources of energy and nutrient input were collected and quantified from four microhabitats within Matapouri Estuary, New Zealand: *Hormosira banksii* environments, sand flats, *Avicennia marina* pneumatophores, and *A. marina* shoots. Nutrient sources were divided into four categories: diatoms (microalgae), macroalgae, fecal pellets, and plant matter. After total individual abundances were obtained, they were set against a ranked scale, based on preexisting literature (Alfaro et al. 2006; Twilley et al. 1986; Haines & Montague 1979). It was found that, in this ecosystem, *A. marina* shoots are the most productive microhabitat by the scaling factor, while beds of *H. banksii* were the least.

INTRODUCTION

Estuarine habitats, particularly those that include mangrove stands, are considered to be ecosystems of high species diversity and abundance (Alfaro et al. 2006). However, it has been revealed that the mangrove species *Avicennia marina*, the exclusive mangrove species found in New Zealand, may not yield as high species diversity and richness as other estuarine habitats (Alfaro 2006).

Matapouri Estuary in the Northland of New Zealand is a site that recently has received some attention due to its microhabitat diversity, which includes mangrove stands (Alfaro 2006; Alfaro et al. 2006; Pohe 2008). Studies of macrofauna and trophic webs have revealed areas of high productivity within estuaries, such as sea grass beds and barren bottoms, and that a large amount of productivity comes from smaller organisms like plankton and microalgae rather than the macroalgae and flora of the area (Alfaro et al. 2006). However, the amount of productivity and nutrient input accounted for strictly by phytoplanktonic organisms, and not entrained benthic microalgae or other sources, is still

unknown. Other studies have revealed that productivity is affected by a wide range of factors, including habitat (Cahoon et al. 1999; Cahoon & Safi 2002; McIntyre et al. 1996; McIntire and Amspoker 1986). Counts of sources of energy and nutrient input to the estuarine environment allow for estimates of total source representation at sites, and from this relative importance and productivity of varying microhabitats may be estimated (Pickney & Zingmark 1993).

The current study examined the presence of four main potential sources of nutrient and energy input: microalgae in the form of diatoms; macroalgae; fecal pellets; and plant matter. Abundances of these energy sources were recorded for the main microhabitats found in Matapouri estuary: environments containing *Hormosira banksii*, commonly known as Neptune's Necklace; sand flat environments; areas containing mangrove (*Avicennia marina*) pneumatophores; and areas containing young *A. marina* shoots. From this, the relative productivity and, thereby, importance, of each microhabitat could be determined.

BACKGROUND

Estuarine habitats are unique in aquatic environments for their high degrees of physical and ecological variation over relatively short distances, as well as their important contribution to aquatic food webs (Alfaro et al. 2006; Ysebaert & Herman 2002). As a meeting of oceanic and fluvial influences, estuaries benefit from having essentially two trophic systems, the phytoplankton based primary productivity system and the detrital system, within their food web structure (Fig. 1; Corell 1978; Lee 1990). The phytoplanktonic system is largely an influence of the oceanic input to the estuary,

where wide open areas allow high access to sunlight for producers within the water column, whereas the detrital system occurs in more shaded environments like the rivers and streams of catchments feeding estuaries where canopy cover shields the water column against sunlight by absorbing it directly into aerial leaves, but inputs this energy into the aquatic system through the decomposition of leaf litter and other detritus. The energy in both systems originates from photosynthetic organisms such as algae and vascular plants, the main difference being that much of the nutrient and energy value present in vascular plant cells is not readily digestible by most estuarine consumers, and as such enters the detrital web, where it is broken down by bacteria then made available to primary consumers, effectively adding in another step in the trophic web not present in the phytoplanktonic web (Corell 1978; Pollard & Moriarty 1991). Digestible forms of productive matter associated with the detrital system include leaf litter and fecal pellets, while algae dominate the available productive sources of the phytoplanktonic food web (Brinson et al. 1981; Corell 1978).

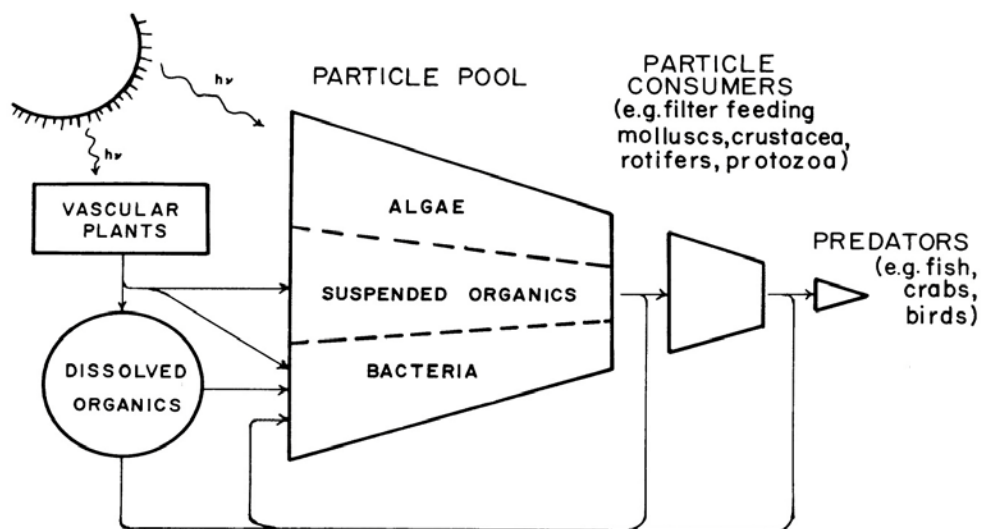


Figure 1. Generalized map of estuarine food web trophic interactions. Adapted from Corell 1978.

Matapouri Estuary is an estuary in the Northland region of New Zealand. The estuary is fed by two main catchments which meet very close to the estuary outlet into Matapouri Bay (Fig. 2). It is largely dominated by mangrove (*Avicennia marina*) habitat, but also includes several other important microhabitats such as sand flats, seagrass beds, and salt marshes. Mangrove stands are of particular interest in New Zealand, as, unlike in tropical variants, it is increasingly believed that *A. marina* creates low diversity and low production habitat, possibly of lesser ecological significance than other microhabitats (Alfaro et al. 2006; Green et al. 2003). Due to increased sedimentation of catchments from agriculture, these mangrove stands are expanding in many New Zealand estuaries, including Matapouri Estuary, creating concern for the other microhabitats that are being overrun, and pressing the question whether or not the continued growth of mangrove habitat is desired. Thus it is important to determine the ecological significance of all the different microhabitats present in New Zealand estuaries, best represented in terms of their productivity potential, which will help support higher organisms and therefore facilitate ecosystems with greater diversities and abundances.



Figure 2. Aerial view of Matapouri Estuary, Northland, NZ. Study locations are marked 1 & 2

METHODS

Two locations within Matapouri Estuary were selected for sample collection – the first landward of the western road bridge extending over an estuary channel, and the second landward of the eastern road bridge that passes over a separate estuary channel, and were designated locations 1 and 2 respectively (Fig. 2). No major environmental differences were observed at these locations, and they were primarily selected for the presence of the four necessary microhabitats (*Hormosira banksii*, sand flats, and *Avicennia marina* pneumatophores and shoots), and to serve as replicates of each other. Sampling occurred during a single low tide on April 5, 2009 in order to minimize variation due to temporal and environmental processes. Two samples were collected from each microhabitat at each location for a total of 16 samples. Samples were immediately placed into capped vials and preserved in enough formaldehyde to entirely cover the individual samples, so that they might be safely transported back to a laboratory for analysis.

In the laboratory, individual samples were filtered through a series of three sieves – 250 μ m, 150 μ m, and 50 μ m in size – to remove inorganics like sand as well as the larger plant and algal material inherent in the samples. After filtration, they were sub-sampled down to two 1.5mL representative samples by means of a standard plastic pipette, each then placed into an individual petri dish. These were examined under a dissecting microscope at 20 times magnification, and abundances of each of the four productivity sources were counted.

Diatoms were recognized in chains of 10 individual cells, with no distinction made between centric and pinnate structures. Macroalgae were primarily identified by red or blue-green coloration of organic matter, again with no distinction being made

between different types. Fecal matter was recognized and counted as smooth pellet aggradations of particulate matter showing minimal to no signs of structural degradation, which could indicate prior utilization within the natural habitat. Plant matter was identified as any particles indicative of vascular plant structure, including leaf bits, roots, and other fragments. It is important to note that most plant and macroalgal matter would have been filtered out during the sieving process. Remaining material within the subsamples largely consisted of fine sand and inorganic silts, silica skeletons, dead plant and algal cells, and small planktonic consumers, though none of these were quantified.

RESULTS

Of the four sources of nutrient and energy input recorded, fecal pellets were the most prevalent, found in every microhabitat (Fig. 3). Quantitatively, macroalgae were represented in the lowest amounts, but were found in more habitats than the microalgal diatoms, which were almost exclusively found in samples of *Hormosira banksii*. Plant detritus was found in widely varying abundances, being most present in the mangrove microhabitats.

For almost every microhabitat, samples taken from location 1 showed higher general abundances of sources of productivity than those taken from location 2 (Fig. 4). The only exception to this was in the *H. banksii* samples, where location 2 dominated. In this microhabitat, a higher abundance of diatoms in the second location pushes productivity source abundances past that of location 1, whereas in the sand flat, pneumatophore, and shoot microhabitats fecal pellets and plant matter contribute to make

yields higher in location 1 (Fig. 4). It is interesting to note that fecal pellet presence was consistently much higher in location 1 than in location 2.

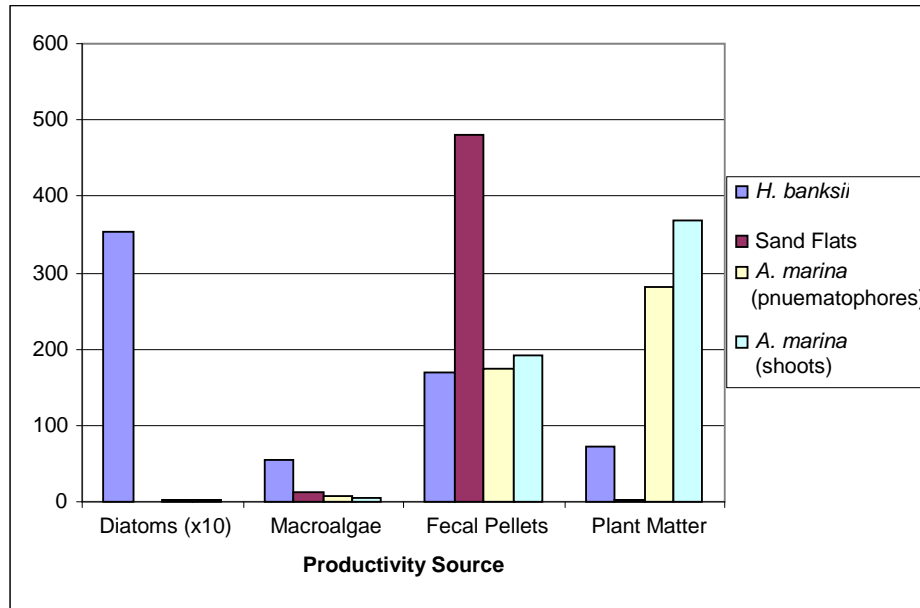


Figure 3. Mean abundances of productivity sources (Diatoms, Macroalgae, Fecal Pellets, Plant Matter) for each microhabitat (*Hormosira banksii*, Sand Flats, *Avicennia marina* pneumatophores, *A. marina* shoots). Diatom abundances are represented as clusters of 10 individual diatomic cells.

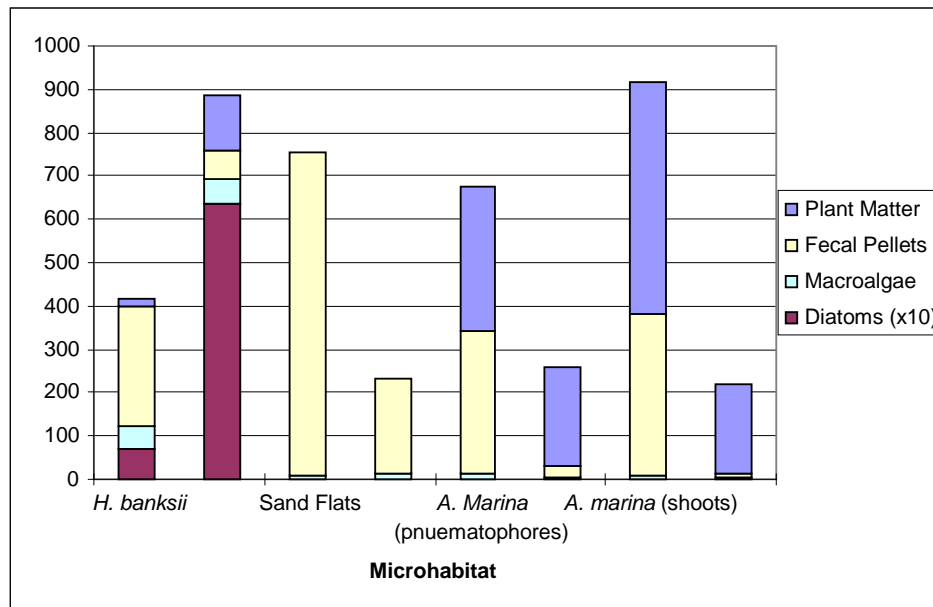


Figure 4. Total abundances of productive matter (Diatoms, Macroalgae, Fecal Pellets, Plant Matter) for each microhabitat (*Hormosira banksii*, Sand Flats, *Avicennia marina* pneumatophores, *A. marina* shoots), showing values for each location. The first bar in each set is the data from Location 1, and Location 2 is the second bar. Diatom abundances are represented as clusters of 10 individual diatomic cells.

DISCUSSION

Each of the microhabitats shows productivity sources being dominated by one to two of the four classes, varying between habitats (Fig. 4). The joint dominance of plant matter and fecal pellets in the mangrove *Avicennia marina* pneumatophore and shoot habitats can be explained as a function of the detrital food web. It is logical that underneath vascular plants, high levels of plant litter would be found. In aquatic, especially estuarine environments, this plant matter is rapidly broken down and converted into more readily usable sources, such as fecal matter and particulates, by various bacteria and grazers (Twilley et al. 1986; Lee 1990; Robertson 1986). Since all microhabitats sampled were present in a relatively confined area, leaf detritus will have also spread to the other environments, explaining its presence and also exerting some influence in these realms as well. The absence of much algal growth in the mangrove habitats can be explained simply as a result of environmental conditions. Here, grown *A. marina* shade out waters below, lowering available light for photosynthetic producers such as algae, and the mangrove roots and pneumatophores trap riverine sediment, creating an anaerobic environment in which the algae cannot survive.

The complete dominance of the sand flat environment by fecal pellets is somewhat more difficult to explain (Fig. 3, 4). Judging on the basis of general algal growth requirements, one might expect the sand flats to be dominated by macroalgal or diatomic production, as there is high exposure to light and an aerobic environment. However, studies have shown total algal productivity input in estuarine environments to be dwarfed by the input of terrestrial and emergent plants in terms of biomass (Alfaro et al. 2006; Haines and Montague 1979; Lee 1990). A study of the benthic macrofauna of

Matapouri Estuary shows the sand flats to be the most abundantly occupied environments, dominated by filter feeding bivalves (Alfaro 2006). This means that any algal productivity, be it macroalgae or diatoms, is readily consumed by filter feeders. Therefore, plant litter and detritus will be the only statically present production source in the environment. Since the litter fall isn't directly into the sand flat environment, what does occur are the fecal pellets, which have been reworked by various grazers into their present form and are more slowly used by the fauna of this environment (Robertson 1986; Twilley et al. 1986).

In the algae *Hormosira banksii*, commonly known as Neptune's Necklace, it is not macroalgae that dominates but rather microalgae, in the form of diatoms, which is most present (Fig. 4). The most obvious explanation for the great abundance of diatoms in this microhabitat, which is most similar to the sand flat microhabitat, is that it receives high levels of light for primary productivity. However, unlike the sand flat environment, the rampant growth of *H. banksii* covers the estuary bed, removing the heavy influence benthic filter feeders have in the barren sand flats, meaning the diatomic presence remains unused for the most part, likely trapped to a degree within the macroalgae. Also, despite the fact that the microhabitat is composed almost entirely of macroalgae, the lab filtration process removes anything over 150µm in size, which is the large majority of macroalgae present.

The only readily observable trend indicating inter-site variation between locations 1 and 2 is the higher level of fecal pellet matter in all microhabitats of location 1 in comparison to location 2 (Fig. 4). Alfaro (2006) found organism densities to be unusually high around location 1, most likely resulting in the high levels of fecal matter

in this area due to the increased abundances. This might also explain the higher levels of diatoms in location 2 for the *H. banksii* microenvironment, as relatively lower consumer abundances would yield higher levels of unused diatoms.

Simply looking at general abundances of the four main sources of productive input in Matapouri Estuary tells nothing of their individual contributions, and therefore, which, if any, of the microhabitats are more productive than the others (Fig. 3, 4). However, preexisting literature can help provide a general rank-order and relative ratio of productivity input for the various sources. Multiple studies have suggested that algal sources, primarily microalgae, to be the dominant producers in estuarine systems, providing up to 90% of total productivity (Corell 1978; Pollard & Moriarty 1991). However, increasing evidence, including a study performed at Matapouri Estuary, suggest dominance by plant matter and detritus/fecal matter, with algal productivity taking a lesser role (Alfaro et al. 2006; Lee 1990; Bustamante & Branch 1996). Most studies consistent with this claim place fecal and detrital input just above that of plant matter (Alfaro et al. 2006; Twilley et al. 1986; Bustamante & Branch 1996). While there are those that suggest the opposite (Lee 1990; Haines & Montague 1979), we will place detritus and fecal matter above plant matter as this is consistent with a previous study at the same location (Alfaro et al. 2006). Macroalgal productivity is least represented in the literature, showing low to moderate degrees of productivity (Lee 1990; Pollard & Moriarty 1991).

Based on these guidelines, the rank-order of importance of productivity sources, with the names used in the present study, would be as such: fecal pellets > plant matter > diatoms > macroalgae. Based on the literature (Alfaro et al. 2006; Twilley et al. 1986;

Haines & Montague 1979), estimates of percent contributions to productivity can be assigned as follows: fecal pellets 40%, plant matter 35%, diatoms 15%, and macroalgae 10%. Despite the low scaling value, this causes the *Hormosira banksii* microhabitat to dominate in terms of gross productivity, simply by nature of the sheer volume of diatoms in the location (it is important to clarify in this instance that diatom values used in the calculation were individual diatoms, though otherwise diatoms are presented in groupings of 10 cells) (Fig. 5). All other microhabitats are relatively close to each other in terms of overall productivity.

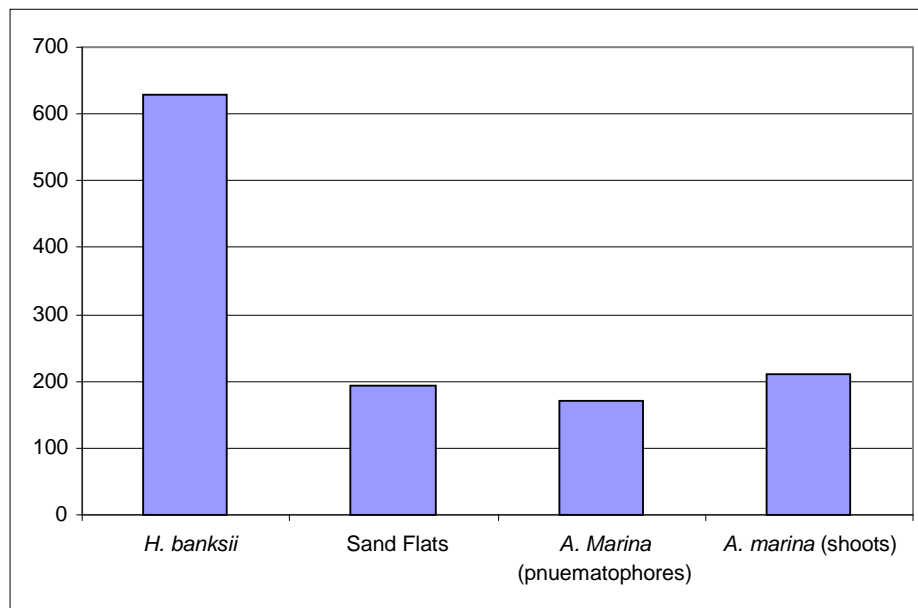


Figure 5. Scaled total levels of productivity for each microhabitat (*Hormosira banksii*, Sand Flats, *Avicennia marina* pneumatophores, *A. marina* shoots). Values are unitless. See text for scaling factors.

It is important to consider as well that different microhabitats may cater to different trophic structures (Pollard & Moriarty 1991), as well as the fact that results are based upon what matter was present at a single time of sampling, and there may be temporal variance (Kemp & Boynton 1984). Other issues include the fact that the smallest sieve size used was 50 μ m in size, whereas it is believe that the greatest

percentage of diatomic productivity is held in cells around 10 μ m in size (Corell 1978). Additional confounding factors that may have influenced results was the high sediment content , even after sieving, in samples from the sand flat microhabitat, which made productivity particulate counts very difficult.

Future effort must be given to identifying what role microalgae not detectable in the current study may play in providing energy and nutrient input into the various microhabitats, as well as rates of uptake of all the sources of productivity by the benthos of Matapouri Estuary. Some effort has been directed this way, but has not been comprehensive of all microhabitats (Alfaro et al. 2006). Additionally, comparing the levels of benthic input and water column input may reveal further linkages or sources of importance within this system. All this knowledge can be used to best estimate microhabitats potentially of greater import to the ecological functioning of Matapouri Estuary, and may help to determine the influence of expanding mangrove habitat on New Zealand coastal environments.

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