Appendix I Ecological Values of Reef Habitat

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I.1 Introduction

Estuarine systems are amongst the world's most productive ecosystems, owing to the high level of nutrient cycling that occurs where fresh waters meet the sea. Estuaries provide valuable habitat and food sources for a variety of vertebrate and invertebrate species including. Many of these are conservationally significant (e.g. dugong, wader birds and turtles) whilst others are of recreational and commercial importance, with the majority of commercially and recreationally important species of fish from eastern Australia dependent upon estuarine environments (Quinn 1992; Pollard 1976; Zeller 1998). Shallow water and intertidal habitats are amongst the most productive environments for fisheries (Quinn 1992).

Generically, the term 'habitat' can be applied to any spatial element of the environment necessary for the survival, growth and reproduction of fishes, with each habitat being a complex of physical and chemical interactions (Zeller 1998). Whilst the fundamental elements of habitat are typically abiotic, biotic features of habitat, such as macrophytes and sessile macro benthos, also provide suitable substrates for other plants and animals, and in effect contribute to microhabitats.

The functions of habitat are varied, including the provision of physical living space, corridors for movement, spawning and feeding sites, and the provision of material (food) to consumers. The way and extent to which a particular habitat contributes to productivity is often complex and difficult to elucidate. For example, often superficially similar habitats support significantly different abundances of fishes (Robertson and Duke 1987).

Vegetated versus Bare Habitat

As a generalisation, vegetated habitat supports more fish and benthic invertebrates than unvegetated substrates (Bell and Pollard 1989; Larkum *et al.* 1989; Poiner, 1980; Warburton and Blaber 1992; Laegdsgaard and Johnson 1995; West and King 1996; FRC Environmental, 2000). However, it is often the combination of vegetated and bare substrates that provide for the complete habitat needs of a species.

I.2 Mangroves

Typically, mangroves are restricted to sheltered shorelines occupying the intertidal shallows between the sea and land. The 'soil' or sediment upon which mangroves grow may be clean coarse sand, but is more commonly fine silt and mud, high in nutrients but essentially anaerobic (lacking in oxygen).

Estuarine mangrove forests are important nursery grounds for many species of juvenile fishes (Halliday and Young 1996; Laegdsgaard and Johnson 1995; Robertson and Blaber 1992; Robertson and Duke 1990). Characteristically mangroves support greater abundances of fish than either seagrass areas or unvegetated tidal flats (Laegdsgaard and Johnson 1995; Blaber *et al*. 1992; Robertson and Duke 1987). Sub-tidal habitats characterised by mangrove-lined channels support a variety of fish with habitat-specific distributions according to each species requirements for food and shelter from predation (Zeller 1998). For example, mangrove prop roots and fallen timber snags support a higher abundance of estuarine snappers (such as *Lutjanus argentimaculatus*), rabbit fishes and bream than unvegetated banks and mid-channel habitat.

Mangroves are an important component of the estuarine habitat because they:

- input significant amounts of vegetable matter into the food chain. Leaves, fruits, wood and bark fragments fall either directly into the water or to the ground. As these components decompose, they provide both soluble nutrients and detrital fragments, which are eaten by crustacea such as prawns and crabs and some fish. Bacteria and fungi also feed on the decomposing matter and in turn are eaten by larger organisms (West 1985);
- trap, accumulate and release nutrients (and in some cases pollutants) and particulate matter (silt) from surrounding land, thus acting as a buffer to the direct effects of runoff (West 1985);
- provide a habitat or shelter to a range of fauna and flora (e.g. Morton *et al*. 1987). Mangroves are recognised as important bird rookeries (e.g. Driscoll 1992), and the sediment in which they grow typically supports both a high diversity and abundance of fauna. Many species of algae and 'terrestrial' epiphytes are commonly found in association with mangrove communities. Mangrove fruit are eaten by the green turtle (*Chelonia mydas*), which is conservationally significant The creeks which wind through large mangrove forests are also important as fish habitat (West 1985); and because they
- protect the shoreline from erosion emanating either from the water (waves, boat wash) or the land (runoff) (Blamey 1992) and contribute to the establishment of islands and the extension of shorelines (Blamey 1992).

I.3 Saltmarsh / Claypan

Saltmarsh plants grow on tidally inundated ground to landward of mangroves. Herbs, grasses and low shrubs commonly dominate saltmarshes (Adam 1990). Saltmarsh communities and the role they play in the broad ecology of estuaries are perhaps the least well understood of the intertidal communities, particularly in Australia. However, they are thought to have the following important roles:

- stabilisation of bare mud flats. Algae frequently colonise first forming mats over the bare mud. The mucilaginous nature of the algae stabilises the sediment surface, enabling colonisation by other (saltmarsh) plants. Sediment is then trapped by the leaves of these plants, causing a gradual buildup of sediment. The binding of sediment by plant roots also probably confers some resistance to erosion (van Erdt 1985; cited in Adam 1990);
- remineralisation of terrestrial and marine debris: saltmarshes contribute to the nutrient cycling of estuaries, and may buffer the water bodies from excess nutrients from the land (Adam 1990);
- provision of a direct food source for terrestrial, avian and marine fauna; and
- provision of habitat for terrestrial, avian and marine fauna, including migratory species and species protected under international treaties such as JAMBA and CAMBA. The false water-rat (Xeromys myoides) is found in areas of saltmarsh dominated by reeds and rushes.

Our understanding of the direct use of saltmarshes by finfish and nektonic crustaceans is comparatively poor. Recent studies indicate that some Queensland saltmarsh / claypan areas are commonly frequented by fish species of significance to commercial and recreational fishers (Connolly 1999).

Saltmarshes may support dense mats of algae, which are important contributors to local fisheries productivity through providing an alternative source of food to detritus (Adam 1995). Shallow pools topped up intermittently by rainfall support a variety of invertebrates (including crabs, other small crustaceans and insects) that are consumed by fishes following the rising tide. In particular, on the rising tide juvenile bream enter tidal drains in saltmarsh habitat to feed, moving back into deeper water as the tide recedes (Morton *et al.* 1987).

I.4 Seagrass

Seagrass meadows, like mangroves, also provide important nursery habitat, particularly for a range of crustacean species (West and King 1996; Laegdsgaard and Johnson 1995; Connolly 1994; McNeill *et al*. 1992; Coles and Lee Long 1985; Young 1978). The distributions of juvenile tiger prawns (*Penaeus semisulcatus and P. esculentus*), eastern king prawns and endeavour prawns are strongly correlated with inshore seagrass meadows (Staples *et al*. 1985). Seagrass leaves provide physical cover for juvenile prawns and fish and provide a substrate for both epiphytic algae and minute grazing animals, which form a major component of the prawns' diet. Seagrasses also provide a direct source of food for dugong, some turtle species (Lanyon *et al*. 1989), and some species of fish and crustacea other than prawns. Juvenile tiger prawns eat the seeds of eelgrass (*Zostera capricorni*).

As significant primary producers (Hillman *et al*. 1989), seagrasses have been recognised as playing a critical role in coastal marine ecosystems (Hyland *et al*. 1989; (Poiner and Roberts 1986; Pollard 1984).

Seagrasses have the following functions (from Poiner *et al*. 1992):

- trap, stabilise and hold bottom sediments (Poiner and Peterken 1995; Fonseca and Kenworthy 1987);
- decrease water movement promoting sedimentation of particulate matter and inhibiting resuspension of organic and inorganic matter (Philips and Menez 1988);
- supply and fix biogenic calcium carbonate (den Hartog 1970);
- produce and trap detritus and secrete dissolved organic matter that tends to internalise nutrient cycles within the system (Moriarty et al. 1984); and
- provide large amounts of substrate for encrusting animals and plants (Klumpp et al. 1989; Harlin 1975).

Seagrasses form dynamic marine plant communities that may undergo substantial change in response to changing seasonal factors (e.g. Coles *et al.* 1997). Light intensity, turbidity, sediment and water column nutrient concentrations and availability, temperature, depth, salinity and substrate characteristics may each be important determinants of both seagrass distribution and primary productivity. In the extreme, entire meadows may be lost (e.g. Abal and Denison 1996; Kirkman 1978); or may regenerate (FRC 1999).

Not all seagrasses have the same value as fish nurseries. Different seagrass species may support differing abundances of an essentially similar community of fishes. Even the same species of seagrass may have greatly differing habitat value. Ultimately, *where* a particular expanse of habitat is located may be more relevant to patterns of recruitment, than the characteristics of habitat structure (Bell *et al.* 1988; Jenkins *et al*. 1998; Bell and Pollard 1989; Bell *et al*. 1987; Young and Carpenter 1977).

I.5 Macroalgae

Macroalgae are a commonly overlooked component of the marine environment, which may significantly contribute to a localities ability to support marine life, in particular fish and crustacea. The macroalgal component of estuarine floral communities may consist of several elements: loose lying or drift algae, rhizophytic or benthic macroalgae, and epiphytic algae on seagrass or other algae (den Hartog 1979).

The ecological significance of macroalgae and its role in nurturing and feeding fish and crustacea of importance to commercial and recreational fisheries has only recently been investigated. Macroalgal communities can play a role similar to other macrobenthic plants, providing oxygen, food and habitat for small fauna. An understanding of the seasonal occurrence and standing crop dynamics is necessary to evaluate this community's role in the ecosystem (Benz *et al*. 1979).

Macroalgae are likely to perform the following functions:
- provide shelter and refuge for resident and transient adult and juvenile animals, many of which are of commercial and recreational importance (Zeller 1998; Jenkins and Wheatley 1998);
- trap, stabilise and hold bottom sediments;
- slow and retard water movement promoting sedimentation of particulate matter and inhibiting resuspension of organic and inorganic matter;
- supply and fix biogenic calcium carbonate;
- produce and trap detritus and secrete dissolved organic matter that tends to internalise nutrient cycles within the system; and
- provide food for many species including the green turtle (*Chelonia mydas*), an endangered species.

Macroalgae are major primary producers within coastal waters, with 10% (kelp communities) to 60 – 97% (algal turf communities) of algal production entering grazing food chains (Carpenter 1986; Klump and McKinnon 1989 – each cited in Phillips, 1998). Even in seagrass meadows, 20 – 62% of the primary productivity of algal epiphytes on seagrass leaves compared to a maximum of 10% of seagrass primary productivity, are consumed by herbivores (Klumpp *et al.* 1992; Orth 1992 – both cited in Phillips 1998).

I.6 Unvegetated Soft Substrate

Unvegetated sandy and muddy sediment, whilst commonly considered to be not as productive as areas supporting seagrass are also important to the ecosystem. Bare substrate is rarely bare. Where sediments are stable, microalgae communities become established within both the intertidal and shallow subtidal. The microalgae support an associated community of small benthic invertebrates (for example polychaete and nematode worms, cumaceans, copepods and soldier crabs), which in turn are an important source of food for fishes that include juvenile mullet (Hollaway and

Tibbetts 1996), bream and whiting (Weng 1983). Mudflats may be transitional zones between juvenile and adult habitats (Laegdsgaard and Johnson 1995). Bare substrates in shallow waters may also provide shelter from larger predators and the opportunity to employ camouflage: whiting, flathead and flounder are each examples of species positively associated with bare substrate habitat.

Intertidal and shallow subtidal sand flats support a variety of fish species. Fish such as whiting and flathead feed in sandy areas, whereas other such as bream and mullet prefer the fauna associated with muddy areas.

The fauna associated with soft sediment habitats is typically determined by the character of the sediment: its grain size and stability; and with the presence or absence (Humphries *et al.* 1992b; Poiner 1980), *or* proximity of seagrass (Ferrell and Bell 1991). Grain size influences the ability of organisms to burrow, and the stability of 'permanent' burrows. Unstable sediments support less diverse benthic communities than those that are relatively stable.

Shallow water, bare sediment communities are characterised by widely fluctuating abundances, species richness and diversity. These fluctuations are correlated with severe abiotic disturbances (such as wind and wave activity). During calmer months, shallow bare sand developed similar communities to deep water bare sand habitats (Poiner 1980).

I.7 Rocky Reefs

Rocky substrates such as emergent platform reefs, boulders and marine cliffs support a diversity of floral and faunal communities, such as limpets, barnacles, soft and hard coral and macroalgae. The high habitat diversity (including rock pools, gullies and ledges) found in these environments may support a high species diversity. These habitat types are of importance to many species that require hard substrate for colonisation.

I.8 Coral Reefs

Coral reef ecosystems occur throughout the tropical and sub-tropical seas of the world. Whilst the most diverse hard coral communities occur in clear, tropical offshore waters, extensive inshore coral communities are found along much of Australia's northern coastline, and within the Indo-Pacific region. Hard coral communities are often complimented by soft corals, sponges, macroalgae and a host of other invertebrate taxa. Coral reefs are the most diverse marine ecosystem types, supporting a wide range of species including fishes, reptiles (such as sea snakes and turtles), echinoderms, polychaetes and crustaceans.

I.9 The Waters

As many species of inshore fish and invertebrates rely on tidal and wind-driven currents to disperse their planktonic larvae, the waters in which fish live must themselves be considered as an important element of habitat. In particular, water quality and movement are two characteristics that may be both critical to the survival, growth and reproduction of particular species; and that may be significantly altered by both natural and anthropogenic influences.

Artificial Habitat

Both inadvertently and deliberately, man creates habitat within the coastal environment. Each structure, even those that move (like boats) contribute to the range of habitat available. Simple examples of man-made habitat include jetties and harbours, canals, tidal lakes and breakwaters. Each provides a characteristic combination of hard surfaces, voids and shading. These structures may alter water quality and sediment characteristics in their immediate vicinity. Each may contribute to a habitat that favours some species over others, or some life history stages over others. Artificial habitat may support faunal communities that are both similar to, yet different from nearby natural habitats.

I.10 Habitat, Environmental Influences and Fisheries Production

The relationships between habitat and fisheries production are often complex and confounded by environmental influences. Few habitats exist in isolation: each may contribute to and benefit from the characteristics of adjoining and in some cases distant habitats. Each living component of the system consumes and releases energy or nutrients for others to use. The cycles of energy transference and webs that connect organisms are often complex and changeable: few species are linked to the one habitat. The integrity of habitats, of habitat diversity and of the links between habitats is critical to maintaining trophic relations, and the abundance and diversity of fish stock.

I.11 References

Abal, E. G. & Dennison, W. C. 1996, 'Seagrass depth range and water quality in Southern Moreton Bay, Queensland, Australia', *Marine and Freshwater Research* 47(6).

Adam, P. 1990, *Saltmarsh Ecology*, Cambridge University Press, Cambridge.

Adam, P. 1995, 'Saltmarsh', In: *State of the Marine Environment Report for Australia Technical Annex: 1 The Marine Environment*, eds Zann, L. P. and Kailola, P., Department of the Environment, Sport and Territories, Canberra, pp. 97-105

Bell, J. D., Westoby, M. & Steffe, A. S. 1987, 'Fish larvae steeling in seagrass: do they discriminate between beds of different leaf density?' *Journal of Experimental Marine Biology and Ecology*, 111:1133-44.

Bell, J. D., Steffe, A. S & Westoby, M. 1988, 'Location of seagrass beds in estuaries: effects on associated fish and decapods', *Journal of Experimental Marine Biology and Ecology* 122:127-46.

Bell, J. D. & Pollard, D. A. 1989, 'Ecology of fish assemblages and fisheries associated with seagrasses', in: *Biology of seagrasses: a treatise on the biology of seagrasses with special reference to the Australian region*s eds Larkum, A. W. D., McComb, A. J., Shepherd, S. A., Elsevier Science Publishers, Amsterdam, p565-609.

Benz, M. C., Eiseman, J. J. & Gallaher, E. E. 1979, 'Seasonal occurrence and variation in standing crop of a drift algal community in the Indian River, Florida'. *Botanica Marina*, 22: 413 - 420.

Blaber, S. J. M., Brewer, D. R., Salini, J. P., Kerr, J. D. & Conacher, C. 1992, 'Species composition and biomasses of fishes in tropical seagrasses at Groote Eylandt, Northern Australia,' *Estuarine, Coastal and Shelf Science*, 35:605-20.

Blamey, R. 1992, *Economics and the evaluation of coastal wetlands*. Queensland Department of Primary Industries QI92015. pp. 141.

Clough, B. F. 1992, 'Primary productivity and growth of mangrove forests', In: *Tropical Mangrove Ecosystems*, eds Robertson, A. I. & Along, D. M. American Geophysical Union, Washington DC. pp. 225-249.

Coles, R. G. & Lee-Long W. J. 1985, 'Juvenile prawn biology and the distribution of seagrass prawn nursery grounds in the south-eastern Gulf of Carpentaria', eds Rothlisberg, P. C., Hill, B. J. & Staples, D. J. *Second Australian National Prawn Seminar*. NPS2: 55-60, Cleveland, Australia.

Coles, R.G., Lee Long, W.J. & McKenzie, L.J. 1997, *Distribution and abundance of seagrasses at Oyster Point, Cardwell – Spring (November) 1995 and Winter (August) 1996*, DPI Information Series QI7055, pp. 36.

Connolly, R. M. 1994, ‘A comparison of fish assemblages from seagrass and unvegetated areas of a southern Australian estuary’, Australian Journal of *Marine and Freshwater Research*, 45:1033-44.

Connolly, R. M. 1999, ‘Saltmarsh as habitat for fish and nektonic crustaceans: Challenges in sampling designs and methods’, *Australian Journal of Ecology*. 24:422-30.

den Hartog, C. 1979, ‘Seagrasses and seagrass ecosystems: An appraisal of the research approach’, *Aquatic Botany*:105-17.

den Hartog, C. 1970, *The seagrasses of the world*, North Holland, Amsterdam.

Driscoll P. V. 1992, ‘Assessment of bird populations of the environs of Fisherman Islands’, *Brisbane’s Port Environmental Study, Volume 1 - Baseline Data 1991-1992*, Port of Brisbane. pp. 137-64.

Ferrell, D. J. & Bell, J. D. 1991, ‘Differences among assemblages of fish associated with *Zostera capricorni* and bare sand over a large spatial scale’, *Marine Ecology Progress Series*, 72:15-24.

Fonseca, M. S. & Kenworthy, J. 1987, ‘Effects of current on photosynthesis and the distribution of seagrass’, *Aquatic Botany* 27: 59-78.

FRC Coastal Resource & Environmental, 1999, *Bells Creek Aquatic Flora (Seagrass) Survey, October/November 1999*, Final report in a monitoring program series, undertaken on behalf of Soprey Pty Ltd.

FRC Environmental, 2000, *Pioneer Bay Environmental Monitoring Program, Fifth Monitoring Event, June 2000*, Undertaken on behalf of Whitsunday Shire Council.

Halliday, I. A. & Young, W. R. 1996, ‘Density, Biomass and species composition of fish in a subtropical *Rhyzophora stylosa* mangrove forest’, *Australian Journal of Marine and Freshwater Research*, 47:609-15.

Harlin, M. M. 1975, ‘Epiphytes - host relationships in seagrass communities’, *Aquatic Botany*, 27:59-78.

Hillman, K., Walker, D. I., Larkum, A. W. D. & McComb, A. J. 1989, ‘Productivity and Nutrient Limitation’, eds Larkum, A. W. *et al*. 1993, *The Biology of Seagrasses - An Australian Perspective,* Australian Fisheries Resources. Bureau of Resources Sciences and the Fisheries Resources and Development Corporation, Elsevier, Amsterdam, pp. 635-685.

Hollaway, M. and Tibbetts, I. 1995, ‘Meiobenthos of the Brisbane River and Moreton Bay: evidence of mullet as potential consumers’, *International Larval Fish Conference and Australian Society for Fish Biology Abstracts*, University of Sydney. pp. 57.

Humphries, P., Potter, I. C., & Loneragan, N. R. 1992b, 'The fish community of the shallows of a Western Australian estuary: relationship with the density of the seagrass *Ruppia megacarpa', Estuarine Coastal and Shelf Science*, 34:325-46.

Hyland, S. J., Courtney, A.J. & Butler, C. T. 1989, *Distribution of Seagrass in the Moreton Region from Coolangatta to Noosa*, Queensland Department of Primary Industries QI89010, pp. 42.

Jenkins, G. P., Keough, M. J. and Hamer, P. A. 1998. The contributions of habitat structure and larval supply to broad-scale recruitment variability in a temperate zone, seagrass-associated fish. *Journal of Experimental Marine Biology and Ecology*. 227:259-78.

Jenkins, G. P. & Wheatley, M. J. 1998, 'The influence of habitat structure on nearshore fish assemblages in a southern Australian embayment: Comparison of shallow seagrass, reef algae, and unvegetated habitats, with emphasis on their importance to recruitment', *Journal of Experimental Marine Biology and Ecology*, 221:147-172.

Kirkman, H. 1978, 'Decline of seagrass beds in northern areas of Moreton Bay, Queensland' *Aquatic Botany*, 5:63-76.

Klump, D. W., Howard, R. K., & Pollard, D.A. 1989, 'Trophodynamics and nutritional ecology of seagrass communities. In. *Biology of seagrasses: a treatise on the biology of seagrass with special reference to the Australian region'*, eds Larkum, A. W. D., McComb, A. J. & Shepherd, S.A., Elsevier, Amsterdam, Netherlands. pp. 394-487.

Laegdsgaard, P. & Johnson, C. R. 1995. Mangrove habitats as nurseries: unique assemblages of juvenile fish in subtropical mangroves in eastern Australia. *Marine Ecology Progress Series*. 126:67-81.

Lanyon, J. *et al*. 1989, 'Dugongs and turtles; grazers in the seagrass system', eds Larkum, A. W. D., McComb, A. J. & Shepherd, S. A. *The Biology of Seagrasses - An Australian Perspective*, Elsevier, Amsterdam, pp. 610-34.

Larkum, A. W. D., McComb, A. J., Shedherd, S. A. 1989, *Biology of seagrasses*. Elsevier Science Publishers, Amsterdam.

Lenanton, R. C. J. & Potter, I. C. 1987, 'Contribution of estuaries to commercial fisheries in temperate Western Australia and the concept of estuarine dependence', *Estuaries*. 10(1):28-35.

McNeill, S. E., Worthington, D. G., Ferrell, D. J. & Bell, J. D. 1992, 'Consistently outstanding recruitment of five species of fish to a seagrass bed in Botany Bay, NSW', *Australian Journal of Ecology* 17:359-65.

Moriarty, D. J. W. *et al*. 1984, 'Microbial biomass and productivity in seagrass beds', *Geomicrobiology Journal*. 4:21-51.

Morton, R. M., Pollock, B. R. & Beumer, J. P. 1987, ‘The occurrence and diet of fishes in a tidal inlet to a saltmarsh in southern Moreton Bay, Queensland’, *Australian Journal of Ecology* 12: 217-37.

Morton, R. M., Beumer, J. P. & Pollock, B. R. 1988, ‘Fishes of a subtropical Australian saltmarsh and their predation upon mosquitoes’, *Environmental Biology of Fishes* 21(3):185-94.

Philips, R. C. & Menez, E. G. 1988, ‘Seagrasses’, *Smithsonian Contributions to the Marine Sciences*. 34:1-104.

Phillips, J. A. 1998, ‘Macroalgae of Moreton Bay: Species diversity, habitat specificity and biogeography’, *Moreton Bay and Catchment*, eds Tibbetts, I. R., Hall, N. J., Dennison, W. C., School of Marine Science, University of Queensland, Brisbane, pp. 279 – 290.

Poiner, I. R. 1980, ‘A comparison between species diversity and community flux rates in the macrobenthos of an infaunal sand community and a seagrass community of Moreton Bay, Queensland’, *Proceedings of the Royal Society of Queensland*. 91:21-36.

Poiner, I. R., Staples, D. J & Kenyon, R. 1987, ‘Seagrass communities of the Gulf of Carpentaria, Australia’, *Australian Journal of Marine and Freshwater Research.* 38:121-32.

Poiner, I. R., Conacher, C. A., Staples, D. J. & Moriatry, J. W. 1992, ‘Seagrasses - why are they important?’, ed Crimp, O. N., *Moreton Bay in the Balance*, Australian Littoral Society and the Australian Marine Science Consortium, Brisbane, Australia. pp. 41-53.

Poiner, I. R, & Peterken, C. 1995, ‘Seagrasses’, eds Zann, L. & Kailola P, *The State of the Marine Environment Report for Australia Technical Annex: 1. The Marine Environment*, Great Barrier Reef Marine Park Authority, Townsville, Qld pp. 107-17.

Poiner, I. R. & Roberts, G. 1986, *A brief review of seagrass studies in Australia. Proceedings of the National Conference on Coastal Management*, Coffs Harbour, pp. 243–49.

Pollard, D. A. 1984, ‘A review of ecological studies on seagrass – fish communities, with particular reference to recent studies in Australia’, Aquatic Botany. 18:3-42.

Robertson A. I. & Blaber S. J. M. 1992, ‘Plankton, Epibenthos and Fish Communities’, eds Robertson, A. I. and Alongi, D. M., *Tropical Mangrove Ecosytems.: Coastal and Estuarine Studies*, American Geophysical Union.

Robertson, A. I. & Duke, N. C. 1987a., ‘Insect herbivory on mangrove leaves in north Queensland’, *Australian Journal of Ecology*. 12:1-7.

Robertson, A. I. & Duke, N. C. 1987b, 'Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia', *Marine Biology*, 96:193-205.

Robertson, A. I. & Duke, D. C. 1990, 'Recruitment, growth and residence time of fishes in a tropical Australian mangrove system', *Estuarine*, *Coastal and Shelf Science*, 31:723-43.

Smith, K. A. & Suthers, I. M. 2000, 'Consistent timing of juvenile fish recruitment to seagrass beds within two Sydney estuaries', *Marine and Freshwater Research.* 51:765-76.

Staples, D. J., Vance, D. J. & Heales, D. S. 1985, 'Habitat requirements of juvenile penaeid prawns and their relations to offshore fisheries', eds Rothelsberg, P. C., Hill, B. J. & Staples, D. J. *Second Australian National Prawn Seminar*. NPS2:47-54, Cleveland, Australia.

Vance D. J., Haywood, M. D. E. & Staples, D. J. 1996, 'Use of mangrove estuary as a nursery area for postlarval and juvenile banana prawns, *Penaeus merguiensis* de Man, in northern Australia', *Estuarine, Coastal and Shelf Science*. 31:689-702.

Warburton, K. & Blaber, S. J. M. 1992, 'Patterns of recruitment and resource use in a shallow-water fish assemblage in Moreton Bay, Queensland', *Marine Ecology* Progress Series. 90:113-26.

Weng, H. T. 1983, 'Identification, habitats and seasonal occurrence of juvenile whiting *(Sillaginidae)* in Moreton Bay, Queensland', *Journal of Fish Biolog*, 23:195-200.

West, R. J. 1985, *Mangroves*, Agfact F2.0.1, Department of Agriculture New South Wales. pp. 15.

West, R. J. & King, R. J. 1996, 'Marine, brackish, and freshwater fish communities in the vegetated and bare shallows of an Australian coastal river', *Estuaries*. 19:31-41.

Young, P. C. 1978, 'Moreton Bay, Queensland: a nursery area for juvenile penaeid prawns', *Australian Journal of Marine and Freshwater Research*. 29:55-75.

Young, P. C. & Carpenter, S. M. 1977, 'Recruitment of postlarval prawns to nursery areas in Moreton Bay, Queensland', *Australian Journal of Marine and Freshwater Research*, 28:745-73.

Zeller, B. 1998, *Queensland's Fisheries Habitats: Current Condition and Recent Trends*. Queensland Department of Primary Industries (QDPI), Information Series Q198025, pp. 211.

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