3. POTENTIAL IMPACTS OF DEGRADED WATER QUALITY ON DUGONG

3.1 Potential Direct Impacts of Water Quality on Dugong Health

There are several potential direct effects of terrestrial runoff on dugong health. Contaminants can cause several symptoms in marine mammals that are reported by Boon et al. (1992) and Garcia Hartmann (1997) to include:

- hormonal effects caused by a range of contaminants known to act as endocrine disruptors, in particular organochlorines, pesticides, and tri-butyl-tin;
- reproductive disorders such as reduced reproductive rate and success, especially caused by PCBs and DDT;
- tumor development such as development of benign and malignant tumors, probably caused by a range of contaminants;
- development of adrenal hyperplasia and cysts related to organochlorines and to stress; and
- immune deficiency related to PCBs and increased stress levels.

Other symptoms reported include reproductive and immunological dysfunction, due to accumulation of pesticides and herbicides (Kuiken et al. 1994; Johnston et al. 1996), and chemical inactivation of cellular enzymes (Förstner 1989) that interfere with growth, reproduction and behaviour (Langston 1990) due to elevated levels of heavy metals.
Three dugong carcasses from animals that were suspected to have drowned in fishing nets at Magnetic Island, Bowen and Mackay were sampled in 1996. The samples collected were analysed for several contaminants and elevated levels of arsenic, chromium and nickel were found (D. Haynes, GBRMPA, pers. comm.). The levels of total dioxins, in particular OCDD, in these dugongs were high, compared to other marine mammals from temperate regions (Haynes et al. 1999). To date, the source of these dioxins is unknown and is the subject of current research (Müller et al. 1999). There is no information on the implications of elevated contaminant levels for dugong health however due to the presence of measurable quantities of contaminants in coastal sediments the potential risk of these contaminants to the health of dugongs and other marine organisms inhabiting the GBRWHA cannot be excluded.

Detailed pathological examinations of stranded or recovered dugong carcasses from the GBRWHA have been conducted (P. Corkeron, JCU, pers. comm.), but results are not available from these examinations. Hence, the incidence of pollutant-related disorders or deaths of GBRWHA dugongs is currently not known.

3.2 Potential Impacts of Terrestrial Runoff on Dugong Habitats

The temporal and spatial effects of terrestrial runoff on GBR ecosystems are difficult to determine and define, and consequently problematic when it comes to mitigating their impact on DPAs. Three significant problems are:

- the frequent natural disturbance of GBRWHA coastal ecosystems by cyclones and floods;
- the short duration of accurate water quality and ecosystem monitoring data (approximately 15 years of data); and
- the lack of unambiguous pristine controls for comparison, because many of the major changes in land use occurred before monitoring of coastal and reefal ecosystems was initiated.

The close proximity of seagrass meadows to the coast means that they are likely to be affected by material originating from land and are vulnerable to changes in coastal processes. Seagrass decline, which is a global problem, has been linked to anthropogenic activities in coastal areas (Sheperd et al. 1989; Walker & McComb 1992; Dennison et al. 1993; Short et al. 1996). Seagrass and corals along the GBR coast have recruited, grown and evolved in the presence of natural freshwater,

terrestrial nutrient and sediment inputs. Coral reefs are found in similar coastal areas as seagrass meadows and have been found to be damaged and even killed by extended periods of freshwater inundation (e.g. Van Woesik 1991; Jokiel et al. 1993). Over longer periods, high sediment and nutrient loads are also known to smother or otherwise affect coastal reefs (e.g. Smith et al. 1981; Rogers 1990). Short and Wyllie-Echeverria (1996) suggest that human activities are now the most serious cause of seagrass habitat loss. These include nutrient and sediment loading from agricultural runoff and sewage disposal, dredging and filling, urban stormwater, and land development. Seagrasses are also at risk of physical damage caused by human activities, such as trawling, certain fishing practices and anchor damage (Clarke & Kirkman 1989).

The distribution and growth of seagrasses is dependent on a variety of factors such as temperature, salinity, nutrient availability, substratum characteristics, and underwater light availability (turbidity). The causes for the extensive mortality of seagrass after flood events in the GBRWHA and in Hervey Bay have not been clearly established, but it is most likely that the causes were a combination of low salinity, sedimentation, turbidity and nutrient stress (Pringle 1989; Preen et al. 1995). Reduced light availability is the most significant cause for the decline of seagrass meadows and for the decrease in seagrass depth distribution and is caused by either increased concentrations of phytoplankton, (as a result of more nutrients being available), or by increased loads of suspended solids (Abal & Dennison 1996; Dennison 1987; Dennison & Kirkman 1996; Duarte 1991).

3.2.1 Increased Nutrients

Approximate ranges for (non-flood) inshore water nutrient concentrations have been measured between non-detectable and 2 μM for dissolved inorganic nitrogen (predominantly ammonia) and non-detectable and 0.2 μM for phosphate (Furnas et al. 1995; Furnas & Brodie 1996; Devlin et al. 1997; Schaffelke et al. in press). Inshore seagrass systems are episodically subjected to high dissolved nutrient and suspended loads, more typical of a eutrophic system, during monsoonal flood conditions. Water samples taken in flood plumes have consistently recorded elevated dissolved inorganic nitrogen concentrations of 0.6 to 10 μM and phosphate levels of 0.13 to 1.98 μM (Brodie & Mitchell 1992; Steven et al. 1996; Brodie & Furnas 1996; Devlin et al. 2001). These nutrient levels have remained high in the inshore lagoon for periods of several days to weeks.

Direct effects of higher nutrient availability on seagrass have been observed. Moderate levels of nitrate additions (3.5 to 7.0 μM) promoted the decline of the temperate seagrass species *Zostera marina* (Burkholder et al. 1992; Short et al. 1995). Increased levels of ammonia (1.85–5.41 μM) and phosphate (0.22–0.50 μM) lead to a reduction in shoot density and biomass of *Z. marina* (Short et al. 1995). Research into nutrient effects on GBR seagrasses is currently underway (J. Mellors, DPI, pers. comm.).

There is increasing evidence from temperate waters that anthropogenic nutrient enrichment of coastal areas stimulates higher abundance of seagrass epiphytes (Borum 1985; Cambridge et al. 1986; Williams & Ruckelshaus 1993; Short et al. 1995). Epiphytes are important components in the seagrass ecosystem, however, high epiphytic biomass reduces the light availability to seagrass, inhibits the gas exchange, competes for nutrients and imparts physical drag that may lead to seagrass leaves and shoots being torn off (Borowitzka & Lethbridge 1989). In sheltered environments, epiphytic macroalgae respond quickly to water-column enrichment and may outgrow grazing pressure, leading to a decline of the underlying seagrass (Sand-Jensen 1977; Harlin & Thorne-Miller 1981; Orth & Moore 1983; Burkholder et al. 1992).

Increased nutrients can also enhance the growth of fleshy macroalgae, which coexist with seagrass in shallow tropical ecosystems. This effect has been demonstrated in

Kaneohe Bay, Hawaii (Smith et al. 1981) and, perhaps less dramatically, at other sites (e.g. Grigg 1994; Grigg & Dollar 1990; Tomascik & Sanders 1985, 1987a, b). In the GBR lagoon this has occurred as a result of pulses of dissolved inorganic nutrients, such as those experienced during cyclonic floods (Schaffelke & Klumpp 1998; Schaffelke 1999). This indicates that certain species of macroalgae in the GBR benefit from increased nutrients and may have a competitive advantage over seagrasses.

Higher nutrient availability in a seagrass system may also enhance phytoplankton growth that also decreases the light availability to seagrass (Lin et al. 1996). Nitrogen and phosphorus are often limiting nutrients for the growth of phytoplankton, especially in warm, clear tropical waters where light is unlikely to be limiting. Evidence of eutrophication in the GBR phytoplankton record is unclear. Comparing present chlorophyll *a* data with historic data, Bell (1991, 1992), and Bell & Elmetri (1995) concluded that the inner GBR lagoon is becoming eutrophic. This argument has been abated by the long-term data of Brodie et al. (1997) which show very high temporal variability in chlorophyll *a* data. However, higher chlorophyll *a* concentrations in coastal waters compared to waters further offshore (Brodie et al. 1997) indicates that more nutrients are available in coastal waters.

3.2.2 Increased Sedimentation

Seagrasses are susceptible to sedimentation damage, suffering from both the lack of light caused by more turbid water and direct smothering from deposited mud (Hatcher et al. 1989; Robertson & Lee Long 1991). In recent times large areas of seagrass meadow have been lost during flood events that discharged terrigenous sediment into the inner lagoon. Over 1000 km^2 of seagrass meadows were lost in Hervey Bay in February 1992, following two large floods of the Mary and Burrum rivers (Preen 1993b; Preen et al. 1995). As a result, the population of dugongs in the area, dependent on the seagrass for food, decreased from an estimated 1466 animals in 1988 to 92 in November 1992. In particular a decrease in the numbers of dugong calves was observed (Marsh & Corkeron 1997). A similar loss of seagrass appears to have occurred around Townsville in the early 1970s (Pringle 1989), possibly associated with cyclone Althea (1971), but this was not fully studied at the time and the sequence of events is not as clear as in the Hervey Bay case.

A large scale decline of Moreton Bay seagrass meadows that occurred during the 1970s was also attributed to increased sedimentation (Kirkman 1978). Fungi was found in all seagrass samples sampled from Moreton Bay at this time, however, it was suggested that this was a natural phenomenon. In other parts of the world, fungi and slime moulds have been significant factors in the decline of seagrass meadows. The catastrophic breakdown of North Atlantic eelgrass meadows in the 1930s has been attributed to the 'wasting disease' caused by the pathogenic slime mould *Labyrinthula zosterae*. Recent studies showed that most seagrass species have their specific *Labyrinthula* species (Vergeer & Den Hartog 1994). Den Hartog (1996) suggests that *Labyrinthula* is omnipresent in senescent seagrass leaves of otherwise healthy plants and that disease outbreaks are rather triggered by environmental factors such as high temperatures and low light, which may be caused by human activities.

3.2.3 Contaminants

Impacts on nearshore environments by contaminants is an additional stressor for seagrass meadows (Walker & McComb 1992; Ralph 1999, 2000). However, the significance and the potential impacts of contaminants in seagrass meadows in Queensland waters is largely unknown. The herbicides atrazine and diuron are used extensively by the sugar industry in Queensland (Hamilton & Haydon 1996). Preliminary investigations of the toxicity of atrazine and diuron to *Halophila ovalis*, which is the preferred food source of dugongs, indicated that short-term herbicide exposure resulted in reduced photosynthesis and leaf loss (Ralph 2000).

In recent studies, marine sediment samples were collected from 51 subtidal locations between Torres Strait and Gladstone in 1998 and 1999 and analysed for a range of herbicides. All sampling sites were located in shallow water in major estuaries and northward facing bays along the northern and central Queensland coast. The herbicide diuron was detected at all sampling sites between Townsville and Cairns (Haynes et al. 2000a) and in Repulse Bay, Whitsundays, and at the mouth of the Fitzroy River. Highest concentrations of diuron were detected adjacent to the mouths of the Herbert and Johnstone Rivers.

Subsequent diuron toxicty trials on three tropical seagrass species (*Halophila ovalis*, *Cymodocea serrulata* and *Zostera capricorni*) using Pulse-Amplitude-Modulated (PAM) fluorometry indicated that environmentally relevant levels of diuron (0.1-1.0 μg/l) exhibited some degree of toxicity to one or more of the tested seagrass species (Haynes et al. 2000b). Seagrasses are known to accumulate heavy metals, but appear to be moderately resistant to the direct effects of metals. However, the fauna associated with seagrass meadows is considered to be at great risk (Ward 1989).

3.2.4 Other Considerations

Recovery and recolonisation of seagrass meadows can be very slow, or nonexistent, because of chronic environmental pressures and poor dispersal capabilities of most seagrass species (Preen et al. 1995; Dennison & Kirkman 1996). It was 10 years after the seagrass meadows in Cockle Bay, Magnetic Island, were destroyed by a cyclone, before the pioneer genus *Halophila* reached a steady state and was then slowly replaced by a presumed climax community of *Halodule* species (Birch & Birch 1984).

The chronic decline of seagrasses may lead to an ecosystem shift from seagrass meadows to a lagoonal system with high turbidity and abundant growth of filamentous algae or with bare, silty substratum (Cambridge & McComb 1984).

3.3 Other Pressures to Water Quality and Dugong Habitat Quality

Although terrestrial runoff is considered to be the most significant impact on water quality and dugong habitat quality in the GBR, other activities such as shipping, oil spills and trawling may influence dugong populations.

3.3.1 Shipping

A number of significant ports line the GBR coast. Access channels to many of these ports need to be regularly maintained by dredging, which leads to problems caused by increased concentrations of suspended solids and nutrients released from dredged material. Other impacts associated with ports and shipping activities result from increased levels of petroleum hydrocarbons and anti-fouling residues in coastal waters and significant amount of ship-borne litter.

3.3.2 Oil Spills

Oil spills represent a significant threat to the viability of GBR environments. Prediction of the effects of an oil spill is difficult, because of a wide range of potential impacts depending on the specific conditions under which the spill occurred (Commonwealth Department of Transport 1995). For the purposes of impacts upon DPAs, the following effects need to be considered:

- direct impacts upon the animals and key habitats within the DPA;
- effects of response actions, e.g. use of dispersants; and
- chronic pollution from oil trapped in mangrove and saltmarsh communities.

Marine mammals, apart from sea otters, have not been demonstrated to be vulnerable to large oil spills. This may be a result of an ability of these animals to avoid oil, or just because no large spills have occurred under conditions that might cause significant impacts.

Direct impacts on critical habitats for dugong may be of greater concern, particularly on intertidal seagrasses. Areas of most concern are the mid-upper intertidal zone where oil will settle. On shorelines and bays with gentle slopes, more extensive effects may occur. Deeper water habitats may be impacted through direct response actions such as the use of dispersants. The GBRMPA's policy on dispersant use clearly states that dispersants may be used in waters over seagrasses to protect mangrove habitats downstream. Other response actions such as shoreline washing where oil is washed off the shore into the water may also cause similar impacts should the oil mix into the water column.

In general research has indicated that seagrass communities recover well from single oiling events, but that chronic contamination may have a greater effect on the long-term viability of the seagrass community. Many of the DPAs are fringed by mangrove systems, which are significant traps for oil that can remain there for many years. Seepage of this oil into the marine environment represents a chronic source of contamination (Commonwealth Department of Transport 1995).

3.3.3 Trawling

Seagrasses are susceptible to damage from trawling activities in the GBR. Although seagrasses are listed as protected marine plants in section 51 of the *Queensland Fisheries Act 1994*, they are often disturbed or removed by trawl fisheries. Most seagrasses in shallow, coastal bays and inlets are in water too shallow for trawlers to operate, and damage to these meadows should be minimal under the fisheries management policy of strip closures (Lee Long & Coles 1997a, b). Dense meadows in deeper water (> 10 m) are usually avoided by trawlers, however, sparse meadows are more at risk. Many of these areas are dugong feeding habitats (Lee Long et al. 1989), but receive no special protection from trawling.