CSIRO Marine Laboratories Report

Effects of Cyclones on seagrass Communities and penaeid prawn stocks of the Gulf of Carpentaria

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Final Report

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SECTION 2: SUMMARY

Seagrass beds are important habitats for juvenile commercial prawns. Since the start of the CSIRO seagrass and cyclone program in 1984, there have been four cyclones in the western Gulf of Carpentaria. Of these, only two have affected seagrass beds, and only one of these, cyclone 'Sandy', had a severe effect. The extent of damage to the seagrass beds is probably the result of a combination of factors, including the path of the cyclone, the strength of the winds and the currents associated with the cyclone, the height of the tide at the time of the cyclone and whether the storm surge associated with the cyclone is positive or negative. Cyclone 'Sandy' removed about 183 km^2 of seagrass from the Gulf of Carpentaria, which has resulted in the juvenile prawn populations in the area changing from commercially important tiger and endeavour prawns to non-commercial species. The catch of tiger prawns in this area has been consistently lower than in unaffected areas.

Seagrasses have begun to grow in the area again. However, it is a very slow process and small species that do not provide a suitable habitat for juvenile prawns are the first to colonise. In addition, the sediment in some areas may now be unsuitable for seagrass. Seagrass revegetation and recolonisation by juveniles of commercially important prawns is likely to take at least 10 to 15 years.

SECTION 3: BACKGROUND

Seagrasses are grass-like marine angiosperms (flowering plants) that complete their life cycle underwater. They generally grow in shallow coastal water from the intertidal zone to 10m deep, but have been found as deep as 90m. In tropical Australia, they range in size from *Enhalus acaroides*, which has strap-like leaves up to a metre long, to very small species such as *Halophila ovalis*, which has small oval leaves about 15 mm long (Poiner *et al.* 1987).

Seagrass communities are important habitats for many marine animals, providing shelter from predators and strong currents, and playing a vital role in the food cycle of coastal ecosystems. Studies by CSIRO have shown that seagrass communities are the major nursery grounds for juvenile tiger *(Penaeus esculentus* and P. *semisulcatus)* and endeavour *(Metapenaeus ensis* and M. *endeavouri)* prawns (Fig. 1) (Staples *et al.* 1985; Loneragan *et al.* in press). Post-larvae of both tiger and endeavour prawns settle out from the water column into the shallow inshore seagrass beds and, as they grow, move into and through the deeper water beds. The productivity of the off-shore tiger and endeavour prawn fisheries of Australia is dependent on the presence of near-shore seagrass nursery grounds. To .manage these fisheries it is important to monitor and protect the seagrass resources, and to know the factors that affect the distribution and quality of the seagrass nursery grounds.

At least 10 species of seagrass grow in the· Gulf of Carpentaria, but the dense inshore beds of long leaved seagrasses such as *Cymodocea serrulata, Cymodocea rotundata,Syringodium isoetifolium* and *Thalassia hemprichii* are more important for the prawns than beds of smaller species such as *Halodule uninervis* and *Halophila ovalis* which grow intertidally and in deeper water.

In 1984, the CSIRO Division of Fisheries Research surveyed the seagrass communities of the western Gulf of Carpentaria between the Wellesley Islands and Cape Amhem (FIRDTA 1983/13). The number of species, density of shoots, and leaf area of the seagrass beds were recorded, as well as the sediment type, water temperature, salinity and water clarity. Extensive seagrass beds were found between the Sir Edward

Pellew Group of Islands and the Limmen Bight River, and between Edward Island and Rantyirrity Point (Fig. 2; Poiner *et al.* 1987).

Cyclones

On average, five cyclones reach the Australian-coastline each year, with one .or two of these in the Gulf of Catpentaria. The effects of cyclones on the extensive seagrass communities of the western Gulf of Carpentaria have been monitored since 1984 (Poiner *et al.* 1989). Four cyclones of different intensities have reached the Western Gulf since then (Fig. 2). There is no relation between the strength of a cyclone and its effect on seagrass beds (Poiner *et al.* 1987, 1989). Neither high-intensity 'Cathy' nor low-intensity 'Irma' affected total area of seagrass cover or the above-ground biomass. In contrast, high-intensity cyclone 'Sandy' and low-intensity cyclone 'Jason' had significant effects.

Cyclone 'Jason'

In 1987, the low-intensity cyclone Jason affected a small area of seagrass on the west coast of Groote Eylandt. The above-ground biomass of approximately ten hectares of the seagrass bed was reduced, but in deeper water almost all the above-ground parts were removed, and the rhizomes were buried by sediment. However, growth was visible less than three weeks after the cyclone and the total area of seagrass did not change.

Cyclone 'Sandy'

In March 1985, cyclone 'Sandy' swept through the Westem Gulf of Carpentaria. Unlike most cyclones, which cross more or less at right angles to the coast, tSandyt travelled parallel to the coast. 'Sandy' came close to the coast near the Sir Edward Pellew Group of Islands and travelled northwest along the coast, crossing it north of the Raper River, a distance of about 200' km. Cyclone 'Sandy' hit at low tide and had a negative storm surge, which further decreased the water depth. Consequently, extensive areas of seagrass were exposed to, and damaged by, the currents and winds associated with the cyclone.

SECfION 4: OBJECTIVES

- Quantitatively map and re-sample the seagrass communities and juvenile penaeid prawn populations of the portion of the western Gulf of Carpentaria between the Sir Edward Pellew Group and Cape Barrow.
- Compare the results with maps and samples collected one year before, two weeks after and annually until 1990 since Cyclone 'Sandy' destroyed the seagrass communities between the Sir Edward Pellew Group and the Limmen Bight River.
- Assess the rate of, and the nature of, the recolonisation and recovery of the seagrass communities and their associated juvenile prawn populations.
- Assess the impact of the nursery ground removal on the adjacent prawn fishery.

SECfION 5: RESEARCH PROBLEM

The coastline of the western Gulf of Carpentaria was re-surveyed in April 1985, immediately after cyclone 'Sandy' (NTFIRDTF 1985-86). The inshore beds of seagrass between West Island and the Limmen Bight River had completely disappeared. Dead seagrass was found on adjacent beaches in mounds a metre high. The seagrasses in deeper off-shore water had been severely disturbed, and in some areas only a third had survived, though with damaged leaves. A thick layer of fine mud covered the seagrass in many areas. In all, about 151 krn^2 of the original 183 krn^2 of seagrass between West Island and the Limmen Bight River had been removed, undermined or smothered. In contrast, the seagrass beds between Edward Island and Rantyirrity Point were not affected by the cyclone (Poiner *et al.* 1989).

When the area was surveyed again a year later (1986) a dramatic long-term effect was apparent. There was still no sign of seagrass inshore and the remaining deep-water seagrass beds between West Island and the Limmen Bight River had disappeared. In all, 183 km^2 of seagrass (18-20%) of the seagrass in the Gulf of Carpentaria had been removed by cyclone 'Sandy'.

The aim of this project was to monitor the seagrass and juvenile prawn populations annually, and to undertake a logbook analysis of the offshore fishery, so as to understand the impact of large scale nursery habitat loss on the Northern Prawn Fishery (NPF) tiger prawn fishery.

SECTION: RESEARCH METHODS

In 1984, the seagrasses of the Western Gulf of Carpentaria were mapped by a combination of techniques: aerial survey, diver observation, and field collections of seagrass (Poiner *et al.* 1987). The species composition, density and biomass of seagrasses were recorded along transects perpendicular to the shore during this study. In 1985, immediately after cyclone 'Sandy', the coast of the Western Gulf of Carpentaria from the Sir Edward Pellew Group of Islands to Rantyirrity Point was resurveyed (NTFIRDTF 1985-86) along the same transects as those sampled in 1984 (Fig. 3). These transects were then classified as;

- "Control" - no loss of seagrass following the cyclone;
- Total loss - virtually all seagrass lost after the cyclone
- Partial loss - some loss of seagrass following the cyclone.

The same transects were resurveyed in February 1986, February 1987, January 1988, February 1989, December 1989 and February 1992 to monitor the state of the seagrass beds following cyclone 'Sandy'. On each of these surveys, samples were collected from the same transects as those sampled in the seagrass surveys between 1984 and 1987.

The species composition and density of seagrass were recorded along each transect (qualitative sampling). Water depth, distance from shore, sediment depth, sediment type, water temperature, and water salinity were also recorded for each site. In addition, quantitative samples of seagrass, seagrass seed, sediment and juvenile prawns were collected from twelve transects: four in the "Control" area; six in the Total loss area; and two in the Partial loss area (Fig. 3). The seagrass, sediment, seed and juvenile prawn samples were frozen immediately after collection and freighted to the CSIRO's laboratory at Cleveland.

Seagrass, algae and sedintents

The seagrasses were separated into species: *Cymodocea serrulata*, *Cymodocea rotundata*, *Enhalus acaroides*, *Thalassia hemprichii*, *Halodule uninervis* (broad), *Halodule uninervis* (thin), *Halodule pinifolia*, *Syringodium isoetifolium*, *Halophila ovalis* and *Haiophila spinulosa*. The number of shoots were counted and the length of each leaf, "maximum leaf width, stem length and sheath length for 10 randomly selected shoots were measured for each species in each sample. The material for each species was divided into above and below ground components, which were dried at 60°C until they reached a constant dry weight (approximately 8 h), and" weighed to the nearest 0.1 g. The shoot density, leaf area, and the above and below ground biomass per square metre for each species at each site were calculated. A seagrass cover index (number of sites with seagrass/total number of sites in the area) was also calculated for each transect that was quantitatively sampled.

Algae were separated. into five broad taxonomic groups: *Caulerpa* spp.; *Halimeda* spp.; Chlorophyta;

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Phaeophyta and Rhodophyta. Each of these groups was then dried at 60°C for 8 h, and weighed to the nearest 0.1 g.

The grain size composition of the sediment samples was determined using the mechanical and pipette analyses described in Folk (1968). Organic matter was removed by adding 30 011 of 6% hydrogen peroxide to 25 g of each sample, and heating to 70°C for 24 h in a water bath. Each sample was then dispersed with 1% (w/v) Calgon solution and washed through 63 µm nylon mesh to separate the sand and mud fractions. The sand fraction was then dried and sieved through 4, 2, 1, 0.5, 0.25, 0.125 and 0.063 mm sieves, and each fraction weighed. The total mud content of each sample was quantified by pipette analysis. From these figures, the percent cobble (> 10 mm), pebble (> 4 mm), granule (> 2 mm), very coarse sand (> 1 mm), coarse sand (> 0.5 mm), medium sand (> 0.25 mm), fine sand (> 0.125 mm), very fine sand (> 0.063 mm) and mud « 0.063 mm) of each sample was calculated. The seed samples were sieved through a 1 mm mesh and the species composition and density of seeds recorded.

Juvenile prawn sampling

Juvenile prawn trawl sites were selected and trawled in February 1988, and sampled again in each of the subsequent surveys. Two 200 m beam trawls were made during the night at three sites (inshore, rnidshore and Offshore) in each of the twelve transects (Fig. 3), except in 1992, when only the inshore and midshore sites were trawled for prawns. The beam trawl measured 1 x 0.5 m at the mouth and was fitted with 2 mm mesh in the body of the net and 1 mm mesh in the codend.

Prawns were identified from the characteristics in Grey *et al.* (1983), counted and measured to the nearest 1 mm carapace length (CL). Electrophoretic techniques were used to identify small tiger « 3 mm CL) *(Penaeus semisulcatus, P. esculentus),* king « 3 mm CL) *(P. latisulcatus),* and greasyback « 6 mm CL) prawns.

The total number of juvenile prawns (≥ 3 mm CL) was calculated and the proportion of each major species group of juvenile prawns in the total juvenile catch was determined for the three areas (Le. "Control", Total loss and Partial loss). The proportions for the major species groups of the total catch of juveniles were also calculated for each zone (i.e. inshore, midshore and offshore) and year of sampling. The species groups for these analyses were: king *(P. latisulcatus),* tiger *(P. 'semisulcatus* and *P. esculentus),* endeavour *(M. endeavouri)* and greasyback prawns (non-commercial prawns of the genus *Metapenaeus,* mainly M. *moyebi).*

Commercial catch data

The annual catches in the off-shore commercial fishery were obtained through the collation of official landing statistics (Australian Fisheries Service) and fishermen's logbooks (Somers, in press). Log book data and landing statistics from 1980 to 1992 were analysed to determine whether there was a decline in the catch of tiger prawns after the destruction of the seagrass beds. Only inshore areas where brown tiger prawns *(Penaeus esculentus)* are the dominant species in the catch, were considered in this analysis. Catch data were selected from three areas: one adjacent to the Total loss area; one adjacent to the "Control" area, and one south-east of the partially impacted area (Fig. 4). Mean catches were calculated for the years before (1980-1984) and after the cyclone (1986-1992) for the Total loss and two control areas.

SECTION 7: RESULTS

Effect of cyclone 'Sandy' on seagrass beds

A comparison of the extent of seagrass beds in 1984 with those immediately after cyclone 'Sandy' showed that the inshore beds of seagrass between West Island and the Limmen Bight River had completely disappeared. Dead seagrass was found on adjacent beaches in mounds of material up to one metre high (Poiner *et al.* 1989). The seagrasses in deeper off-shore water were also severely disturbed, and in some areas only a third of the existing seagrasses survived. Seagrass cover in the Total loss area declined markedly at this time in the Total impact area (Fig. 3). Furthermore, much of the surviving seagrass in this area had damaged leaves. A thick layer of fine mud covered the seagrass in many areas. In all, about 151 km^2 of the original 183 km^2 of seagrass between West Island and the Limmen Bight River was removed, undermined or smothered immediately following cyclone 'Sandy'. In contrast, the seagrass beds and the seagrass cover index for the ttContror' area, between Edward Island and Rantyirrity Point, did not change following the cyclone (Fig. 3, Poiner *et al. 1989).*

A dramatic long-term effect was apparent in the Total loss area in 1986. There was still no sign of inshore seagrass beds, and the remaining deep-water seagrass beds between West Island and the Limmen Bight River had disappeared (Fig. 3). In all, 183 km^2 of the seagrasses (18-20%) in the Gulf of Carpentaria were removed by cyclone 'Sandy'.

Recolonisation was first recorded in 1987, when a few shallow inshore areas were sparsely covered with patches of *Halodule uninervis.* Both the number of species of seagrass and the cover index started to increase at this time (Figs. 5, 6).

By 1988, about 20% of the area affected by cyclone 'Sandy' had been recolonised by seagrass. *Halodule uninervis* and *Halophila ovalis* were the predominant species of recolonisers. A few isolated seedlings of the larger species, *Cymodocea serrulata* and *Syringodium isoetifolium*, were also recorded and this is reflected in the increase in the number of seagrass species in the Total loss area (Fig. 5). Recolonisation by these four species was probably from seeds that had been stored in the sediment. In 1989, the real extent of seagrass had not changed significantly; however, there was a slight increase in shoot density and the number of seagrass species (Fig. 5), and the area colonised by C. *serrulata* and S. *isoetifolium* expanded (Fig. 6). Two more species *(C. rotundata* and H. *spinulosa)* and a broad-leaved form of H. *uninervis* were recorded in the Total loss area (Fig. 5).

Halodule uninervis, C. *serrulata* and S. *isoetifolium* first flowered in the Total loss area in 1989. Following the production of seeds in these areas, the recolonisation of seagrass was expected to increase noticeably. By 1990, recolonisation in the Total loss area was entering a phase of rapid expansion; the area of seagrass, the cover index in each transect (Fig. 6), and the cover and density of S. *isoetifolium* and C. *serrulata* all increased. However, in 1990 there was still an area south of the Limmen Bight River about 40 km long that had not been recolonised. The sediment here had been severely disturbed by the cyclone, and was composed of unconsolidated shifting sand, with few seeds in the sediment.

In 1992, large, almost monospecific, beds of S. *isoetifolium* were found in much of the cyclone affected area. The rapid recolonisation of this area by *5. isoetifolium* was probably due to flowering and seed production of the S. *isoetifolium* plants that had recolonised from seeds stored in the sediment. Studies around Groote Eylandt (Poiner *et al.* 1989, CSIRO Division of Fisheries, unpublished. data) indicate that H. *ovalis* and H. *uninervis* (thin) produced the..most seed per square metre, followed by S. *isoetifolium,* C. *serrulata* and C. *rotundata,* and *Thalassia hemprichii.* This ranking of seagrass species by the amount of seed they produce parallels the order in which the seagrasses recolonised in the cyclone affected areas.

The area recolonised by seagrass in the Total loss area has continued to expand. By 1992, there was some seagrass in the area south of the Limmen Bight River that was bare in 1990.

Effect of cyclone 'Sandy' on the juvenile prawn communities

A total of 4715 juvenile prawns were collected in 278 beam trawls from all the surveys between February 1988 and February 1992 (Table 1). The non-commercial group of greasy back prawns *(Metapenaeus* spp.) was the dominant species group, comprising 34.2% of the total juvenile catch and more than 31.8% of the catch in each of the areas (Table 1). Endeavour prawns *(Metapenaeus endeavouri)* were the second most abundant taxa, followed by brown tigers, western king and grooved tiger prawns. These five taxa accounted for at least 86.2% of the catch in each area and all areas combined (Table 1).

Unlike greasyback and endeavour prawns, the proportion of juvenile brown tiger *(P. esculentus)* and king prawns *(P. latisulcatus)* in the total juvenile catch varied among the three areas. Brown tiger prawns contributed at least 17.0% to the total juvenile catch in the "Control" and Partial loss areas, compared with only 9.2% in the Total loss area (Table 1). By contrast, western king prawns comprised 22.6% of the total juvenile catch in the Total loss area, but contributed less than 1.1% to the total catch in the "Control" and Partial loss areas (Table 1).

The trends in the ranking of the major species groups, and their contributions to the total juvenile catch, for the inshore, midsho.re and offshore zones (Table 2), were virtually the same as those for the different areas, pooled across zones (Table 1).

In the "Control" inshore zone, juvenile tiger prawns increased their contribution to the total catch from about 10% in 1988 and 1989, to 35-40% in 1990 and 1992 (Fig. 7). This increase in importance of tiger prawns was associated with a decrease in the contribution of greasyback prawns. King prawns in this zone were only caught in 1990 (Fig. 7). Like the "Control" inshore zone, tiger prawns in the Partial inshore zone increased in their importance to the total juvenile catch in 1990 and 1992 (c 40%) compared with 1988 and 1989 (5-22%). King prawns were not caught in this zone.

In the Total loss inshore zone, the highest proportion of king prawns (57%) was recorded in 1988 and declined to values of 10 - 20% between 1989 and 1992 (Fig. 7). The lowest contribution of king prawns (10%) was found in 1992. The contribution of tiger prawns in this zone did not exceed 15% in any year.

The results for "Control" and Total loss areas in the midshore zone were similar to those for the inshore zone: tiger prawns were important in the "Control" area, particularly in 1990 and 1992 and king prawns were only caught in one year (1989); in contrast, in the Total loss region king prawns contributed to the total catch in each year and were the dominant species in 1988. Few prawns were caught in the Partial midshore or offshore zones.

Effect of cyclone 'Sandy' on offshore conunercial prawn catches

The catch of tiger prawns in the south-western_Gulf of Carpentaria fluctuates widely from year to year (Fig. 8). Prior to 'Sandy', catches in the area adjacent to the Total loss of seagrass region ranged from about 150 T (1982, 1983) to 450 T (1981) (Fig. 8). Catches in the Total loss area were greater than those adjacent to the Partial loss area in 1981 and 1984. However, following 'Sandy', catches in the Total loss area were lower than those adjacent to the Partial and Control areas in all years, except 1985 and 1986 (Fig. 8).

The average annual commercial catch of tiger prawns before the cyclone (1980-1984) offshore from the Total and Partial areas was about 250 tonnes, compared with 370 tonnes adjacent to the "Control" area. After-cyclone 'Sandy' (1986-1992), catches in all areas decreased significantly with the greatest decrease being recorded in the Total area (248 to 63.4 T; Partial = 255 to 158 T; and "Control" = 369 to 167 T).

These results from three regions of the NPF, need to be considered in light of trends in the tiger prawn fishery as a whole (Fig. 9). Catches in the NPF were relatively stable between 1980 and 1983 (c 5000 - 6000 T) before declining to 3000 T in 1986. Since then, tiger prawn catches in the NPF have sta-bilised at levels of 3-4 000 T (Fig. 9). Commercial tiger prawn catches from the Total loss region represented 2-10% of the NPF tiger catch prior to the cyclone (average = 5%) but since 1986 have comprised on average 2% of the NPF catch (Fig. 9).

SECTION 8:
DISCUSSION

Prawns of the major commercial species use inshore areas as nursery grounds during the juvenile phase of their life cycle. The nursery grounds differ between species: banana prawns use mangrove-lined estuaries;

tiger prawns use seagrass beds and king prawns use shallow sandy bays. These nursery grounds are essential for the completion of the life cycle of prawns and loss of nursery grounds would have negative impacts on prawn stocks. Staples *et al.* (1985) for example, showed that the production of banana prawns in regions of the Gulf of Carpentaria could be related to the length of mangrove shoreline.

North-eastern Australia is one of the richest areas in the world with respect to seagrasses. Coles *et a1. (1987)* and Lee Long *et a1.* (.1993) for example identified 14 species and mapped about 4 000 km2 of seagrasses on the east coast of Queensland. Poiner *et a1.* (1987) and Long and Poiner (1993) found 11 species in the Gulf of Carpentaria and Torres Strait with an estimated total coverage of 900 km2 in the Gulf and 17,500 km^2 in Torres Strait. Virtually nothing is known about the distribution of seagrass communities of the north west Australian coast between Cape Arnhem and Cape Leveque - a distance of around 6,500 km.

Despite the extensive area and species diversity of tropical Australian seagrasses, they can be destroyed. This can occur through both natural and anthropogenic events. In 1985, cyclone 'Sandy' swept along the south western coast of the.Gulf of Carpentaria destroying extensive areas of shallow inshore seagrass beds. The loss of these nursery grounds led to a significant drop in brown tiger prawn stocks in the area. Surveys by CSIRO have shown that after 5 years, only around 10% of the seagrass beds had recovered while around 10 km^2 of former seagrass beds were still at an early stage of recovery. After 7 years, recolonisation was relatively rapid but there are still large areas devoid of seagrass that previously supported seagrass communities. This ranking of seagrass species by the amount of seed they produce parallels the order in which the seagrasses recolonised in the cyclone-affected areas and reflects their seed production capacity.

In 1992-93, an estimated 900 km^2 of seagrass in Hervey Bay in Queensland disappeared. the cause of this loss is not known although it is thought that high turbidities, resulting from flooding of the Mary and Burrum Rivers and runoff from cyclone 'Fran' three weeks later, were responsible (Preen 1993). Similarly, large areas of seagrass in Torres Strait have been lost, probably due to high turbidities, resulting from flooding of the Mai River and a subsequent population explosion in sea urchins.

Seagrass systems do not readily recover. The plants require special conditions in the substrate and these are not present in disturbed or most sandy substrates. Consequently, once an area has been denuded of seagrass, it may not recover or, if it does, the time frames are long. There is a need to protect and monitor the health of prawn nursery habitats in northern Australia. The fragility and importance of seagrass as a habitat for juvenile prawns led the managers of all three tropical prawn fisheries in Australia to close seagrass beds to trawling. Members of the fishing industry supported these closures and were instrumental in identifying seagrass beds to supplement the data collected by scientific surveys. The result is a series of closures that protect seagrass areas in northern Australia.. Nevertheless, managers are concerned at the low level of knowledge of the extent and condition of seagrasses in northern Australia.

The effect of the cyclone on the juvenile prawn communities appears to have been to replace tiger prawns with western king prawns, both of which are commercially important. The contribution of the commercially important endeavour prawns to the juvenile prawn communities did not appear to be affected by the cyclone. Although no samples of juvenile prawns were taken before cyclone 'Sandy', our results probably reflect a real change in the juvenile prawn communities rather than differences in composition due to differences in prawn communities between the three regions. This conclusion is _ supported by the results of extensive sampling for juvenile prawns around Groote Eylandt (FIRTA 82/13; Loneragan *et al.* in press), Momington Island (Coles and Lee Long 1985) and in the Embley River Estuary (Staples *et al.* 1985, Vance and Staples 1992). These studies show that juvenile tiger prawns are found when seagrass is present in these regions and that king prawns are located on sandy, unvegetated substrate (see also Oall *et al.* 1990, Potter *et al.* 1991). It is further supported by the declines in the catch of tiger prawns offshore from the seagrass affected compared to unaffected areas.

SECTION 9: IMPLICATIONS AND RECOMMENDATIONS

1. Despite the extensive area and species diversity of tropical Australian seagrasses, they can be destroyed. This can occur through both natural (e.g. cyclones) and anthropogenic events.
2. Once destroyed, seagrass systems do not readily recover. The plants require special conditions in the substrate and these are not present in disturbed or most sandy substrates. Consequently, once an area has been denuded of seagrass, it may not recover or, if it does, the time frames are long.
3. The seagrass communities of northern Australia should be mapped as a matter of urgency. There is presently virtually no information about this important habitat along some 6,500 km of coastline.
4. Because of the very large scale changes that can occur in the extent of seagrass communities, their condition needs to be assessed on a five year cycle.

5. The possibility of developing cost-effective methods of monitoring prawn nursery habitats should be investigated.
6. The possibility of developing cost-effective methods of intervening in the seagrass recolonisation.process to speed it up should be investigated.
7. The loss of critical seagrass nursery habitat changed the associated juvenile prawn communities and caused declines in the offshore commercial catch of tiger prawns.

SECTION lO: INTELLECTUAL PROPERTY

Nil

SECTION11: NEW METHODS AND TECHNOLOGIES

There were no new methods or equipment developed as a result of this project.

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Table 1. Proportion (%) of juvenile penaeid prawns (≥ 3 mm carapace length) and the total catch of juvenile prawns from beam trawls in three areas of the Gulf of Carpentaria with different impacts of cyclone 'Sandy.

Species	Impact on seagrass			All areas
	No loss	Total loss	Partial loss	
Greasy back	36.6	31.8	37.2	34.2
Endeavour	27.2	19.1	19.1	21.8
Brown tiger	17.0	9.2	17.4	13.0
Western king	1.1	22.6	0.12	12.0
Grooved tiger	4.7	4.7	12.4	5.8
Trachypenaeus spp.	1.0	0.01	26	0.74
Metapenaeopsis spp.	0.49	0	0.81	0.28
Red endeavour	0.18	0	0.58	0.14
Parapenaeopsis spp.	0	0.04	0	0.07
Total catch	1787	2039	889	4715
(nos of trawls)	(94)	(143)	(41)	(278)

Table 2. Proportion (%) of juvenile penaeid prawns (≥ 3 mm carapace length) for the five most abundant species and the total catch of juvenile prawns from beam trawls in three areas and zones of the south-western Gulf of Carpentaria with different impacts of cyclone 'Sandy'.

Species	Impact on seagrass			All areas
	No loss	Total loss	Partial loss	
INSHORE				
Greasy back	42.1	42.1	50.5	43.2
Endeavour	25.7	15.2	13.8	18.4
Brown tiger	16.5	6.2	22.2	12.2
Western king	1.5	24.4	0	12.8
Grooved tiger	6.2	4.3	7.6	5.5
Total catch	939	829	777	2545
(nos of trawls)	(34)	(52)	(17)	(103)
MIDSHORE				
Greasy back	36.0	24.6	19.2	27.5
Endeavour	31.4	24.0	29.4	27.2
Brown tiger	21.7	9.7	19.3	14.9
Western king	0.94	21.7	0.37	12.0
Grooved tiger	6.8	6.6	20.6	8.7
Total catch	741	596	86	1423
(nos of trawls)	(32)	(53)	(14)	(99)
OFFSHORE				
Greasy back	30.6	27.7	39.6	30.3
Endeavour	24.3	17.5	13.7	19.5
Brown tiger	12.3	12.5	6.7	11.7
Western king	0.7	21.3	0	10.9
Grooved tiger	0.4	26	92	2.7
Total catch	106	614	26	746
(nos of trawls)	(28)	(38)	(10)	(76)

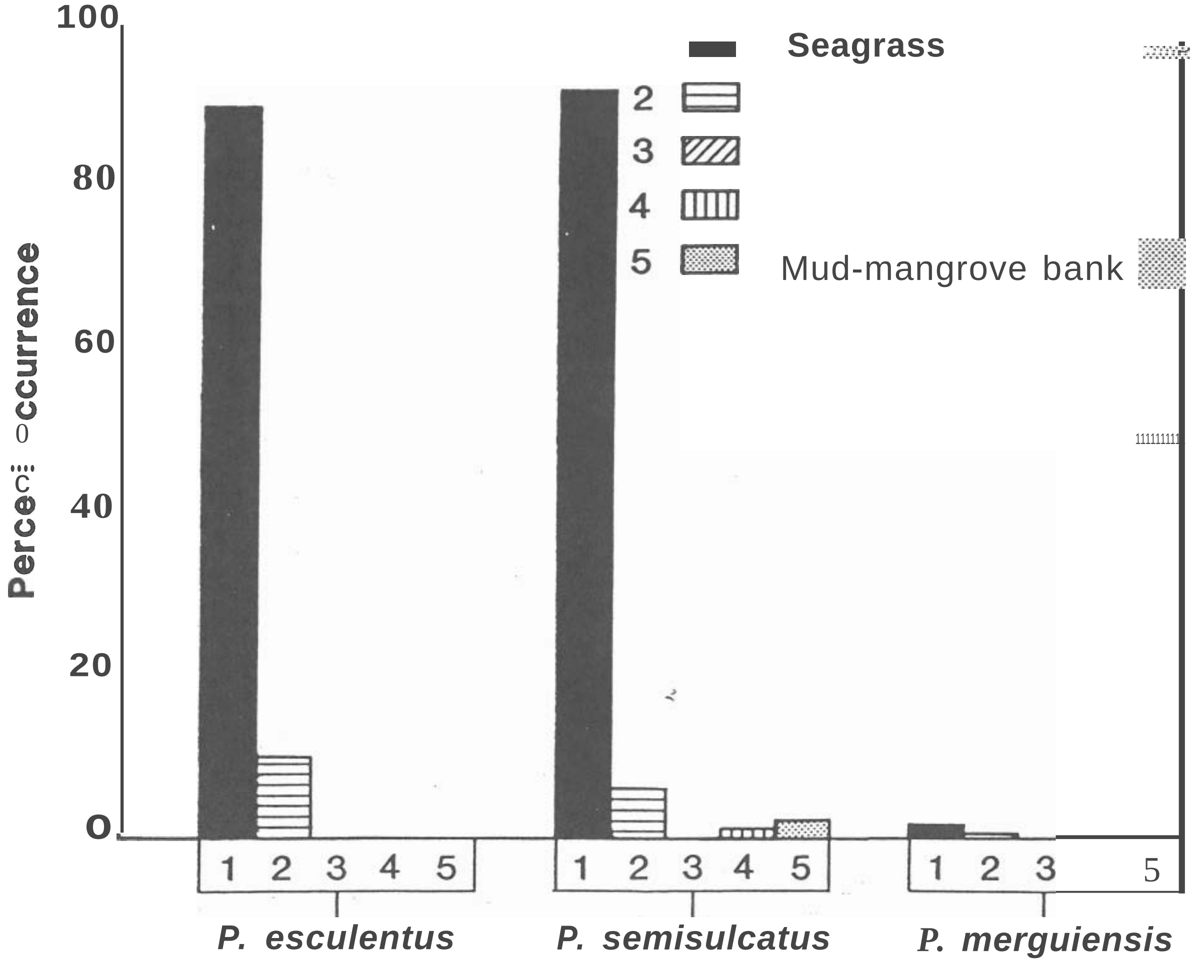

Figure 1. Percentage of juveniles of *Penaeus esculentus*, *P. semisulcatus* and *P. merguiensis* in each of five habitats in the Embley Estuary, Gulf of Carpentaria.

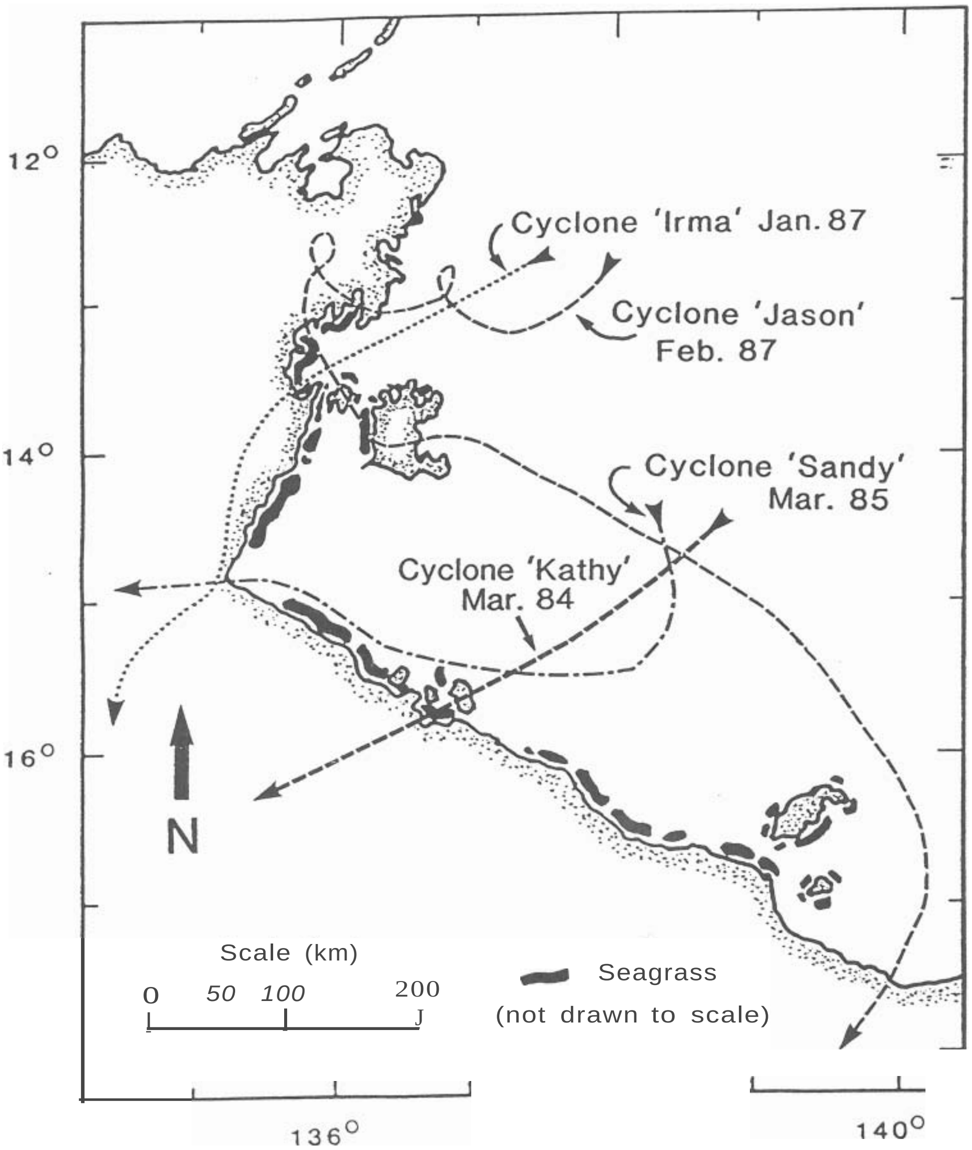

Figure 2. Distribution of seagrass in the western Gulf of Carpentaria/ Australia in 1984, and tracks of the four cyclones that hit seagrass areas in the gulf between 1984 and 1993.

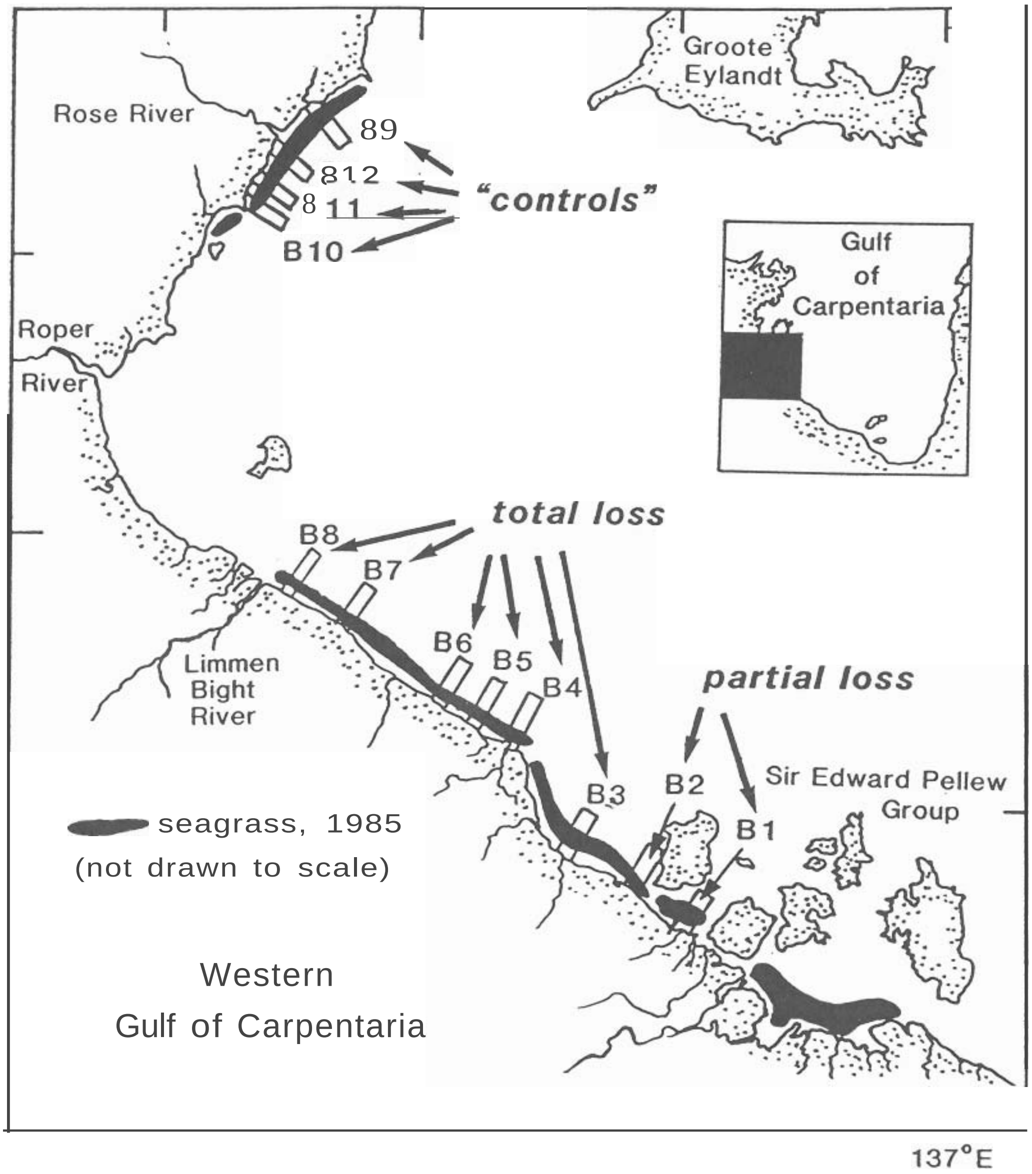

Figure 3. The western Gulf of Carpentaria showing the location of the 12 transects sampled to measure the impact of cyclone 'Sandy' on the seagrass communities. "Control" no loss of seagrass following the cyclone; 'Total loss' - virtually all seagrass lost after the cyclone; 'Partial loss' - some loss of seagrass following the cyclone.

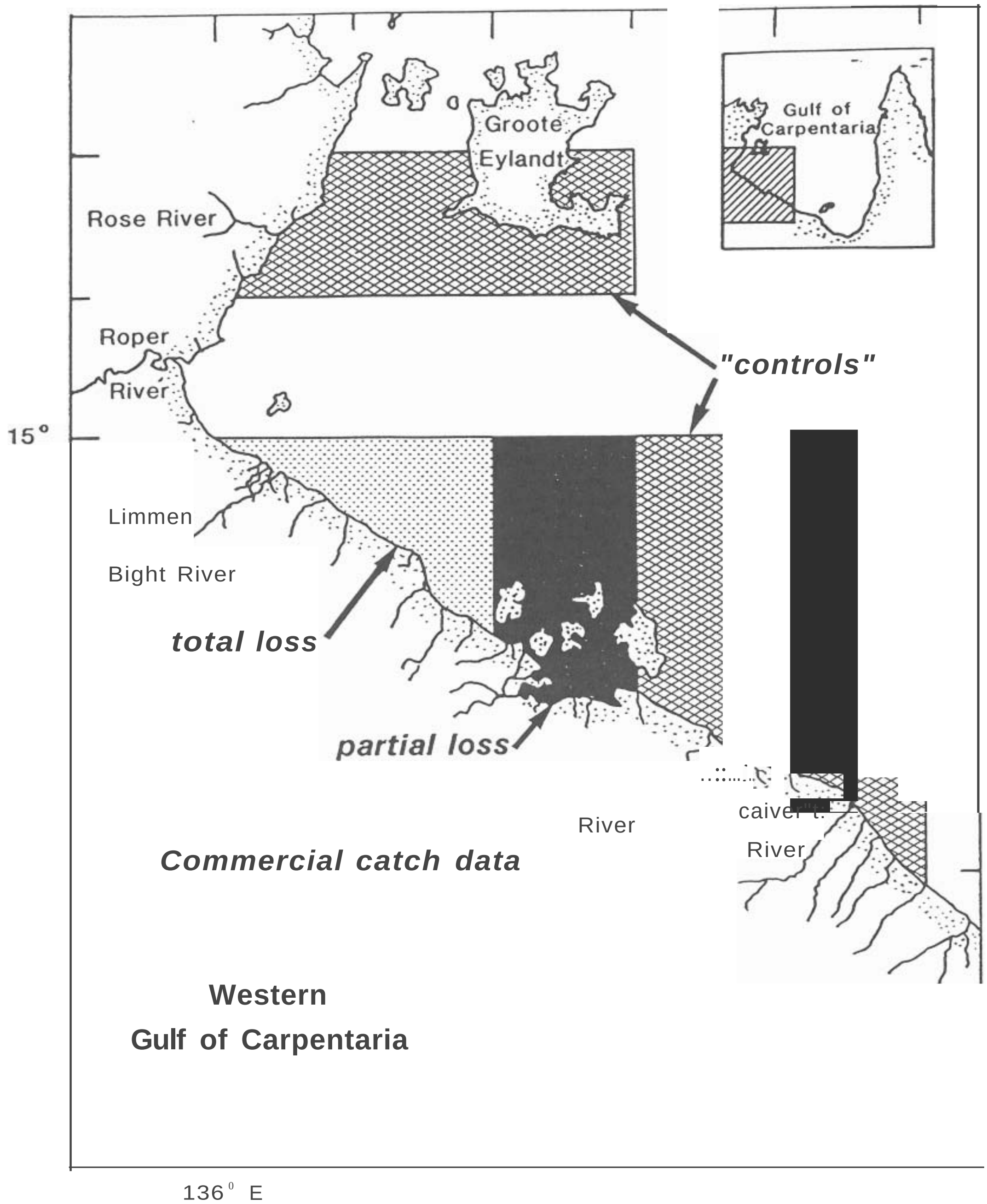

Figure 4. The western Gulf of Carpentaria showing the trawl grounds selected for comparing the tiger prawn catch. "Control" is the area unaffected by cyclone 'Sandy'; 'Partial loss' and 'total loss' are the areas affected by cyclone 'Sandy'.

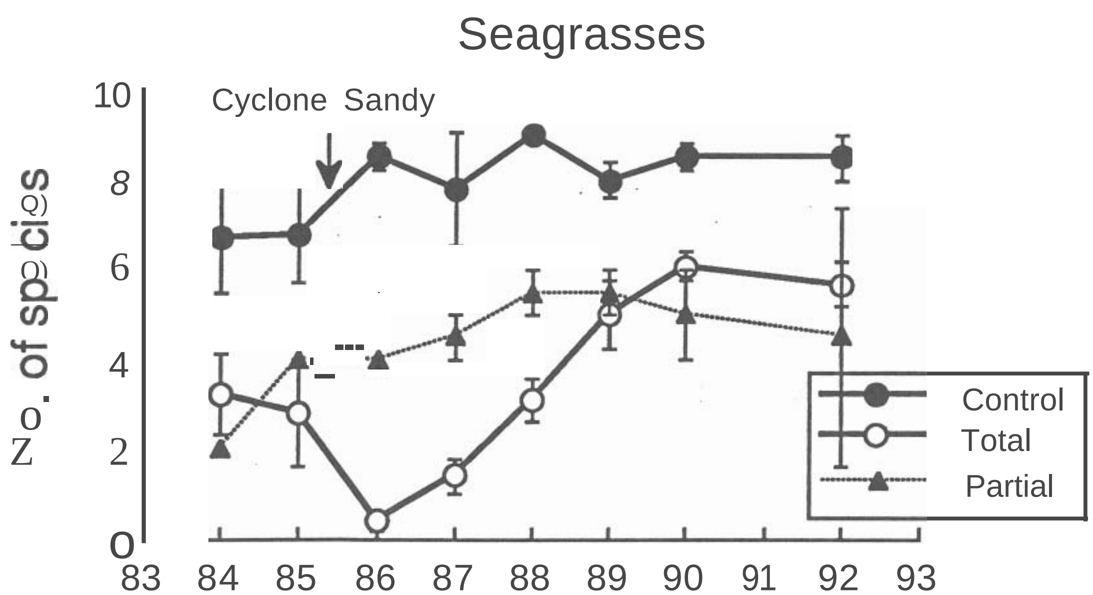

Figure 5. Number of seagrass species, before and after cyclone 'Sandy', in the impacted, partially impacted and control areas. In the impacted areas the lowest number of seagrass species was in 1986, a year after the cyclone, and the number of species has been steadily increasing since then, whereas the number of species in the control area has remained constant.

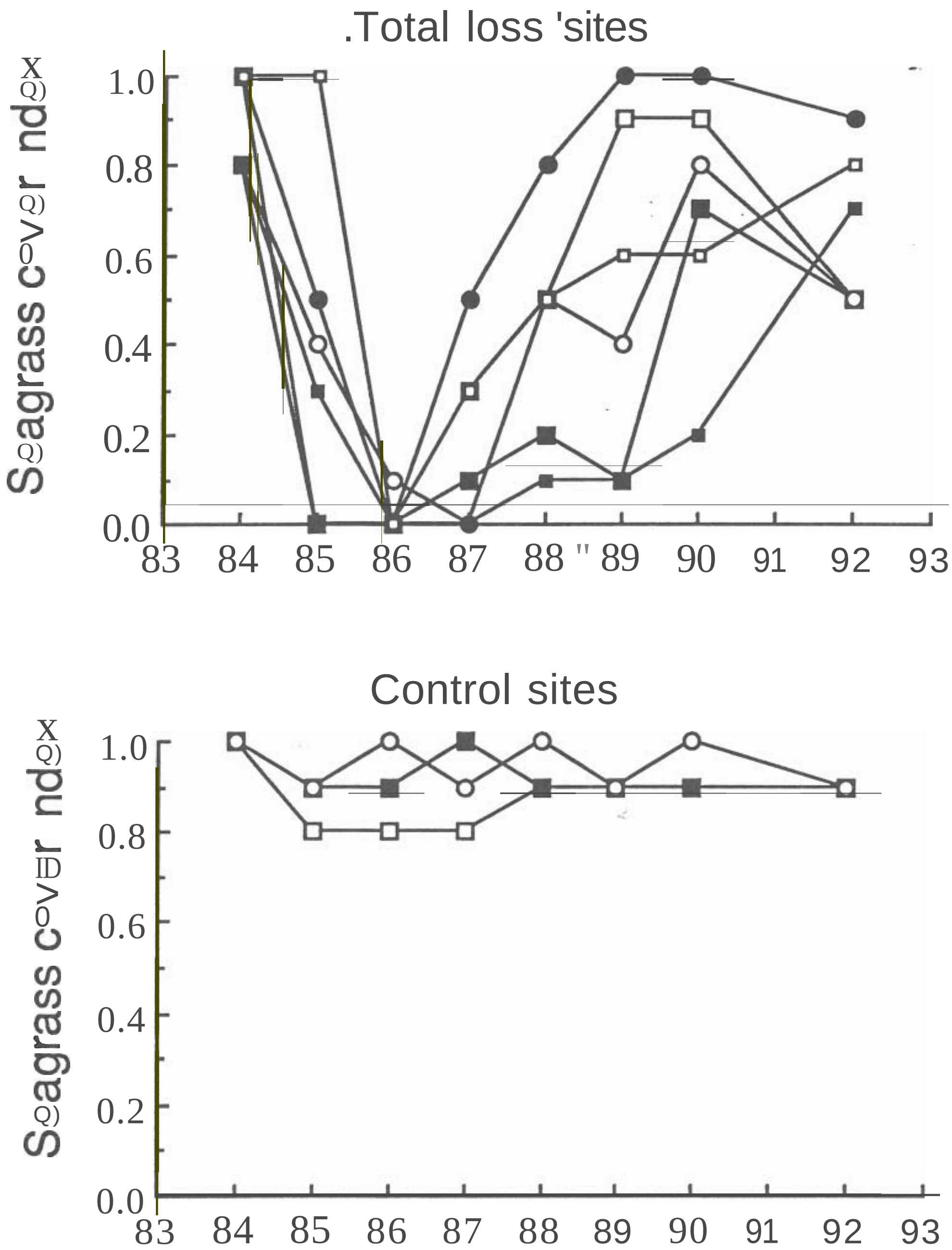

Figure 6. Cover of seagrass before and after cyclone 'Sandy' in the impacted and control areas. The cover of seagrass in the impacted sites was lowest in 1986, a year after the cyclone, and has been steadily increasing since, whereas the cover of seagrass in the control areas has remained fairly constant.

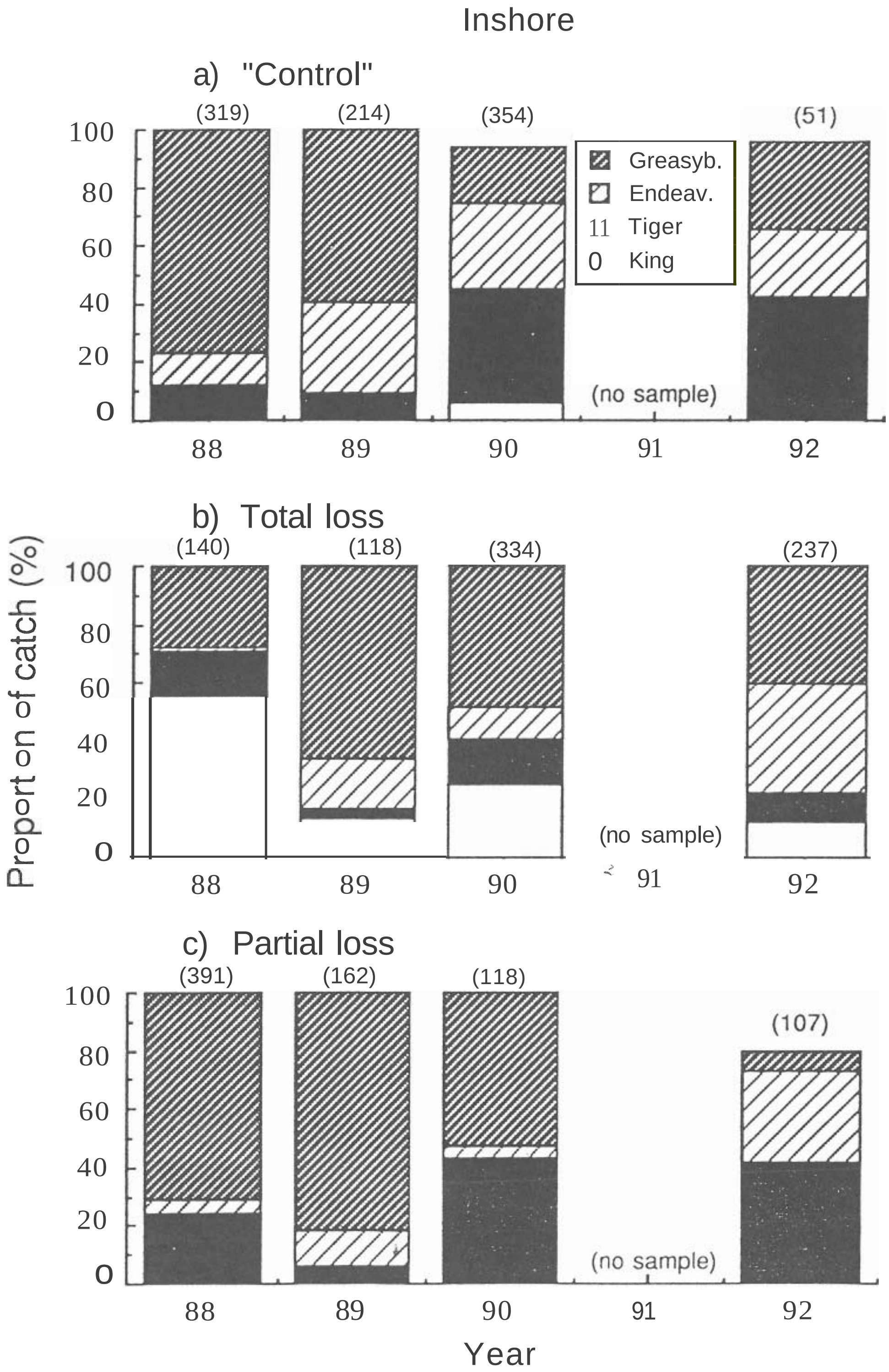

Figure 7. Proportion of major species groups of juvenile prawns in total juvenile prawn catch in the inshore zones of three areas with different impacts on seagrass of cyclone 'Sandy'. Numbers in parentheses are the total catch. Greasyb. = greasybacks, endeav. = endeavours.

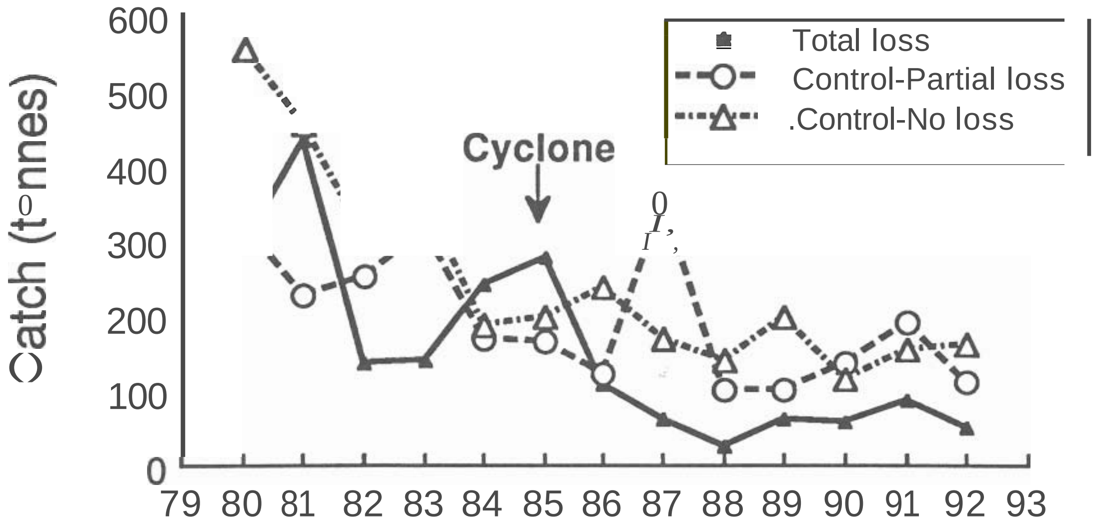

Figure 8. Catch of tiger prawns before and after cyclone 'Sandy' in the impacted, partially impacted and control areas.

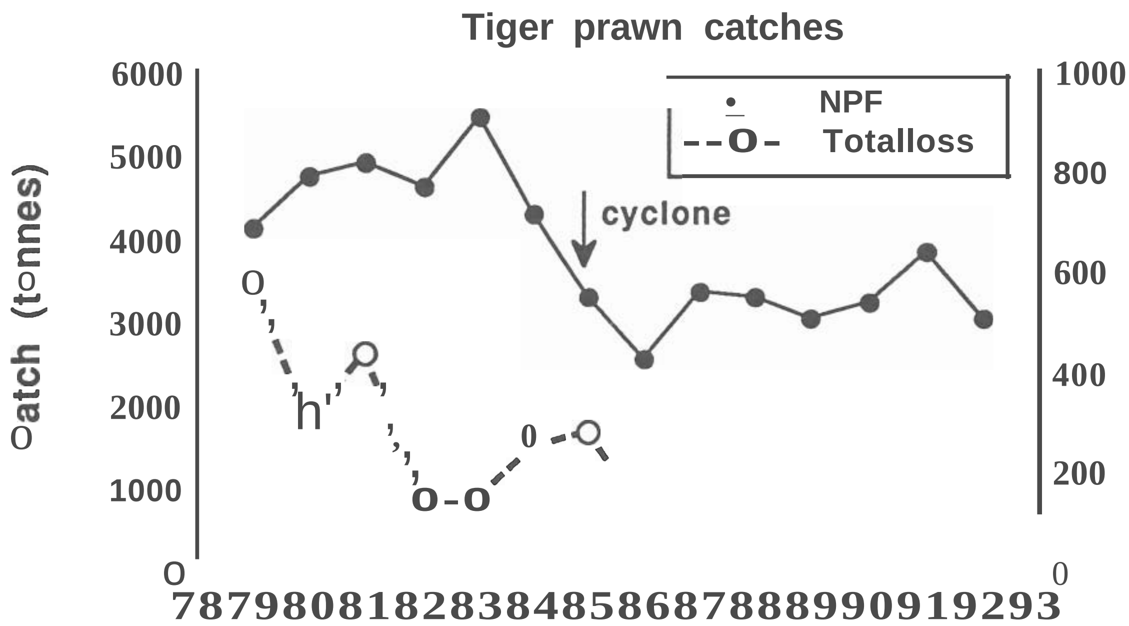

Figure 9. Catch of tiger prawns before and after cyclone 'Sandy' in the Gulf of Carpentaria, and in the impacted area.