Adapting to change: minimising uncertainty about the effects of rapidly-changing environmental conditions on the Queensland Coral Reef Fin Fish Fishery

Fisheries Research & Development Corporation Project No. 2008/103

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Contents

Acronyms used throughout this report

AIMS ....Australian Institute of Marine Science

CapReef...................Community based monitoring program for the Great Barrier Reef in central Queensland

CPUE ....Catch per unit effort

CRFFF......................Coral Reef Fin Fish Fishery

CSIRO......................Commonwealth Scientific and Industrial Research Organisation

CT ....Coral Trout

DEEDI ....Department of Employment, Economic Development and Innovation (Queensland)

FFRC........................Fishing and Fisheries Research Centre

FQ ....Fisheries Queensland

GBR ....Great Barrier Reef

GBRMP....................Great Barrier Reef Marine Park

GBRMPA ....Great Barrier Reef Marine Park Authority

GBRWHA.................Great Barrier Reef World Heritage Area

LTMP........................Long Term Monitoring Program (AIMS)

MTSRF ....Marine and Tropical Sciences Research Facility

OS ....Other Species

QRAA.......................Queensland Rural Adjustment Authority

QSIA ....Queensland Seafood Industry Association

RQ............................Reef fish quota

RTE ....Red Throat Emperor

RQ............................Reef Quota

RRRC ....Reef and Rainforest Research Centre

SM............................Spanish mackerel quota

TAC..........................Total allowable catch

TC ....Tropical Cyclone

Non-Technical Summary

2008/103	**Adapting to change: minimising uncertainty about the effects of rapidly-changing environmental conditions on the Queensland Coral Reef Fin Fish Fishery**

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OBJECTIVES:

1. Use fishery independent UVC methods to estimate reef structural damage and fish abundance on the frequently sampled Effects of Line Fishing reefs.
2. Determine the real time effects of Tropical Cyclone (TC) *Hamish* on the catch composition and catch rates of each fishing sector within the Coral Reef Fin Fish Fishery (CRFFF).
3. Investigate correlations of variant catch composition and CPUE with archived abiotic data and AIMS LTMP structural damage surveys.
4. Determine the socio-economic effects of TC *Hamish* on the commercial and charter CRFFF, including adaptability of the fleet, vulnerability to future environmental events, and steps for reducing or mitigating this vulnerability.
5. Describe retrospectively the changes in the CRFFF catch composition and CPUE resulting from an unusually long duration storm event (TC *Justin*, March 1997) compared with a short duration but high severity storm event (TC *Larry*, March 2006).

OUTCOMES ACHIEVED TO DATE:

The project has demonstrated, through fishery independent assessment (underwater visual assessment), that although emergent coral reef may suffer extensive structural damage as a result of tropical cyclones, in the short-term (three months post-TC *Hamish*, March 2009) the associated fish community structure and species abundances are not adversely affected.

The project has demonstrated perversive factors affect significant decreases in the catch rates of primary target species, common coral trout and red throat emperor in response to some ‘unique’ tropical cyclone events such as TC *Hamish* (March 2009) and TC *Justin* (March 1997). Despressed catch rates may lag for up to twelve months following cyclone influence. The response from industry has been one of relief; relief that their experiences of depressed catch rates and associated economic hardship have been formally quantified and documented.

The causal factors of these perversive effects of these 'unique' cyclones on catch rates remain uncertain, though may significantly depress (by up to 50%) catch rates of primary target species. Despite attempts to relate the decreased catch rates of the fishery to recorded abiotic data (such as sea surface temperature, degree of coral reef degradation), no consistent link between the observed changes in catch rates and abiotic factors were evident.

An anomalous cool water event that followed the passage of TC *Justin* (March 1997) appears to be the most likely driver of the initial depression of catch rates of coral trout; a response accompanied by an increase in catch rates of red throat emperor. Confusingly though, the anomalous cool water event had a maximum duration of two months, yet the changed catch rates lagged for 12 months and 24 months for coral trout and red throat emperor respectively.

The commercial fishing sector has utilised the outcomes of the project to approach state and federal government departments to investigate options for financial assistance (similar to terrestrial business disaster relief funding) for industry to 'ride-out' adverse weather impacts such as those that result from unique cyclone events.

In comparison to the commercial sector, recreational and charter sectors appear relatively immune to tropical cyclone impacts. This immunity is likely reflecting the unconscious adaptive nature of both fishing sectors. Fishers from these sectors are rarely focused on landing reasonable quantities of a single species and can adapt their fishing efforts and targeting behaviours at very short notice.

Fisheries Queensland (FQ), in response to the early and preliminary indications of depressed commercial sector catch rates identified by the project lifted restrictions on the at-sea filleting and skinning of quota monitored reef. This proactive approach by the FQ is anecdotally reported to have met with limited success due to a lack of marketing opportunities. The opportunities of domestic fillet markets need to be explored.

Fisheries Queensland, has acknowledged the outcome identifying present logbook recording arrangements for this fishery are inadequate for measuring in a timely manner the impacts of severe weather events on CRFFF productivity. The outputs also suggest that commercial fishers themselves need to adopt a share of the responsibility for improved reporting to allow for timely data interrogation as required.

The project findings demonstrate an urgent need for the commercial sector of the CRFFF to consider options for building adaptive capacity and resilience into their businesses. Unique cyclone events will continue to impact the CRFFF. The project outputs demonstrate the difficulties associated with predicting the spatio-temporal characters of each tropical cyclone. Fishers need to be prepared for an uncertain future.

SUMMARY:

With the severity and intensity of tropical cyclones predicted to increase with global climate change (Webster *et al.* 2005), the need to understand the effects of these events on fisheries production is paramount. The northern tropical margin of the Australian continent is subject to tropical cyclone influence each monsoon season. Although the increased rainfall that accompanies these events may have positive benefits for some fisheries production (e.g. Halliday *et al.* 2008; Staunton-Smith *et al.* 2004), the influence of the many other biophysical changes that accompany tropical cyclones (eg: habitat alteration and water temperature fluctuations) is less certain. One fishery for which anecdote reports negative influences of tropical cyclone impact is the Queensland Coral Reef Fin Fish Fishery (CRFFF). Prior to the impacts of severe TC *Hamish* in March 2009, popular anecdote reported that the influence of TC *Justin* (March 1997) on catch rate of the primary target species of the commercial sector, common coral trout (*Plectropomus leopardus*), were particularly negative and long lasting (up to twelve months). Somewhat surprising, the depressed catch rate of trout was accompanied by a noticeable increase in catch rates of red throat emperor (the secondary target species of the CRFFF) that was acknowledged though not quantified by Leigh *et al.* (2006).

The influence of tropical cyclones on the performance of the CRFFF is an annual event, though mostly restricted to loss of potential fishing days due to the inclement and unpredictable weather that accompanies the monsoon season. The ‘average’ cyclone that impacts the Great Barrier Reef World Heritage Area (GBRWHA), within which the CRFFF operates, is generally short lived and crosses the reef structure rapidly in an east to west direction. With the last two decades, most tropical cyclones impacting the GBRWHA have been low intensity systems (category 1 or 2). The influence of these types of systems on reef structure (coral coverage and diversity) and associated small-bodied reef fish communities has been well documented (e.g. Wilson *et al.* 2009; Emslie *et al.* 2008). However, as the monitoring used for these reports focuses initially on corals and secondarily small-bodied fish communities, the ability to measure changes in large-bodied reef fish communities is either not attempted, or compromised. As such, no robust assessment has been completed to understand the changes in abundance and availability of CRFFF primary target species in response to cyclone impacts.

TC *Hamish* impacted the southern section of the GBRWHA in March 2009, and quickly galvanised fishers, managers (both fisheries and Marine Park) and research scientists with a common need to

understand the initial impacts, as well as possible lagging influences of this truly unique event. TC *Hamish* was the most severe storm system to impact the GBRWHA in recent decades, rated a category 5 system when first crossing emergent reef structure east of Bowen before a slight dissipation into a category 4 system that tracked southeast neatly bisecting the southern emergent reef structure that supports the majority of fishing effort and catch of the CRFFF. Commercial fishers were the first to witness and verbally document the wide spread structural damage caused by TC *Hamish*. The destruction, scouring and displacement of reef habitat were significant and widespread covering 3° of latitude (19° to 21° inclusive). In addition to the structural reef damage, commercial fishers were also quick to report depressed catch rates of all species throughout the directly impact areas.

The need for this project was clear, a recent unique cyclone event with significant impacts on fisheries productivity and reef structural integrity; an historic cyclone event whose impacts have been acknowledged (Leigh *et al.* 2006) though not quantified; claims of associated socio-economic hardship; and difficulty for resource managers to appropriately assess and address the situation due to a lack of robust data and assessment methods. As a result the objectives of the project were formulated during two crisis workshops, during which helpful cash contributions from the Great Barrier Reef Marine Park Authority (GBRMPA) ($18,000) and James Cook University (JCU) Fishing & Fisheries Research Centre (FFRC) ($22,500) were offered.

Objective 1, to use a fishery-independent survey technique (UVC) to assess and quantify reef structural damage as well as any changed reef species abundances and community structures, was completed three months following TC *Hamish* impact. Structural reef damage, unsurprisingly, was documented to be as high as 66%. Surprisingly, in contrast to the anecdotal reporting from commercial fishers of poor overall (but particularly coral trout) catch rates, the UVC methods revealed nominal increases in coral trout abundances and no measurable change in fish community structure on TC *Hamish* impacted reefs.

The outputs of Objectives 2 and 3 however presented a quandary by quantitatively documenting greater than 30% reductions in catch rates of coral trout and red throat emperor throughout all fishery grids in southern GBRWHA waters impacted by Hamish (spanning 3° of latitude). This pattern of depressed catch rates lagged for at least nine months (until December 2009 and possibly beyond), effectively confusing any attempts to relate these changed catch rates to abiotic factors including structural damage and SST. The fish were still on the reef (Objective 1), but were not interacting with the fishery. Some uncertain factor(s) were responsible for changing the ecological behaviours of targeted reef fishes, particularly coral trout.

Objective 5 identified historical event TC *Justin* (March 1997), as having even more pronounced effects on catch rates within the CRFFF than TC *Hamish* (March 2009). TC *Justin* was a unique system being long-lived (24 days), though low severity. Structural reef damage was not adequately measured, but was likely minimal relative to TC *Hamish*. This system was however responsible for a defined and unique cool water anomaly that is considered the likely driver of depressed catch rates of coral trout (greater than 50%) and increased catch rates (up to 200%) of red throat emperor. Some uncertainty exists though, as the spatio-temporal effects of the cool water anomaly and the changed coral trout and red throat emperor catch rates were not aligned.

Effort shift was the only adaptive tactic demonstrated by full-time CRFFF commercial fishers. Larger vessels moved more than smaller vessels, though decisions in moving needed to consider lower beach prices in unaffected northern waters as well as the secondary affect of effort congregation. An option existed for fishers to diversify their fishing by targeting other species, however few vessels are appropriately equipped and market price differentials between export live coral trout and domestic fresh fish are too wide to provide sufficient economic returns.

The socio-economic surveys of commercial fishers conducted for objective 4 highlighted two relatively consistent themes. Mitigation of the negative impacts on the CRFFF caused by severe tropical cyclones would be best achieved either by government assistance (similar to terrestrial based drought or disaster relief funding) or reviewing the zoning arrangements of the GBRWHA with a view to accessing some reefs currently closed to fishing. The likelihood of either suggestion being enacted is highly uncertain. Some fishers and working group suggestions included removing unnecessary and impeding management controls, as well as the availability of low interest loans. Working groups formed during the life of the project continue to deliberate over suitable options.

The project outputs clearly demonstrate catch rates within the CRFFF can be significantly and adversely affected by some cyclone events. Understanding the biophysical drivers of these changed catch rates is difficult due to the variable and unique nature of each cyclone event. However, it is clear from project outputs that the negative effects of a cyclone may significantly alter catch rates and that these effects may linger for at least twelve months post-event. The gradual dominance and reliance for economic viability of the commercial sector on live coral trout, has stifled pre-existing adaptive capacity. The infrastructure investments and fishing behaviours of fishers targeting live coral trout are not amenable to changing market places; an ability that may well offer some adaptive capacity to the commercial sector of the CRFFF. In contrast, recreational and charter fishing sectors with their diversified fishing and targeting practices are immune to cyclone influence.

A suggested pro forma for an action plan to track, adaptation plan and possibly mitigate the negative influences of future unique cyclone events is a draft proposal at this time, and will need to be strengthened based on the outcomes from two working groups formed during the last six months. Considerations for further research should include: (1) Identifying the most appropriate data recording system for the CRFFF that will allow timely interrogation of catch data that is not available currently; (2) Canvassing options for building adaptive capacity into a fishery that is currently highly vulnerable to change due to economic reliance on a single species destined for a single market place; and (3) Better understanding the possible drivers of the sustained changes in ecological behaviours of reef fish following cyclone passage.

KEYWORDS:
Coral Reef Fin Fish Fishery, tropical cyclones, coral trout, red throat emperor, depressed catch rates, effort displacement, causal factors, vulnerability, adaptability, socio-economic, indicators, fisheries management.

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The primary acknowledgement must go to the proactive approach of Fisheries Queensland (FQ) of Queensland's Department of Employment, Economic Development and Innovation (DEEDI), as well as the Great Barrier Reef Marine Park Authority (GBRMPA) in heeding advice received from the Queensland Seafood Industry Association (QSIA) and commercial fishers of the Coral Reef Fin Fish Fishery (CRFFF) that catch rates within the fishery were significantly and adversely affected by the impacts of TC *Hamish* (March 2009). In particular, Neil Green, Peter McGinnity and Jim Groves were instrumental in organising and facilitating crisis workshops and meetings. Significant funding for the project was provided by the Australian Government via the Fisheries Research & Development Corporation (FRDC), with further cash contributions from the GBRMPA and the Marine and Tropical Sciences Research Facility (MTSRF), who acknowledged the value in investigating the physical, ecosystem and socio-economic effects of severe and unique tropical cyclones on the CRFFF.

The project staff also thank the many commercial fishers of the CRFFF that provided data, advice and feedback. Their feedback and trust was critical to the instigation and success of the project.

Chapter 1: General Introduction

A. J. Tobin

1.1 Overview

Global climate change is predicted to alter marine habitats and faunal communities at multiple levels via the single action of, or simultaneous combined effect from, a large number of changing physical processes and environmental variables. Within the worlds oceans, numerous physical processes (coastal and oceanic upwellings and currents, terrestrial freshwater and ice-melt discharge, sea-level rise) and abiotic characters (temperature, salinity, pH, dissolved oxygen, turbidity) are predicted to change (Hughes 2003, Jennings and Brander 2009, Munday *et al.* 2009). As these changes are realised, the vulnerability of fishery exploited species to continued human harvesting are also likely to change through altered spatial distributions, migratory patterns, productivity levels, trophic interactions and population connectivities (McIlgorm *et al.* 2009). Attempting to predict these potential changes and effects can be a harrowing experience, with attempts possibly leading to overcomplicated or unfocussed outputs (Cury *et al.* 2008). Although the effects of changed abiotic variables may be measured either via *in situ* (McKinnon *et al.* 2003; Balston 2009) or *in vitro* (De Vries *et al.* 1995, Tsuchida 1995, Green and Fisher 2003, Alavi and Cosson 2005) experimentation, implementing experiments for measuring the effects of large scale unpredictable events such as severe tropical cyclones is more difficult.

The intensity of tropical cyclones is predicted to increase as a result of climate change (Webster *et al.* 2005, Emanuel 2005). Tropical cyclones can develop anywhere within the 10° and 30° latitudinal band both to the north and south of the equator and have long been recognised as a potential agent for severe structural disturbance on emergent tropical reefs. Many examples of tropical cyclone mediated reef damage are available both for the Great Barrier Reef World Heritage Area (GBRWHA) (Cheal *et al.* 2002; Emslie *et al.* 2008; Fabricius *et al.* 2008) as well as globally (Fenner 1991, Adjeroud *et al.* 2002; Gardner *et al.* 2005; Robbart *et al.* 2009). In addition to causing physical damage to the reef, tropical cyclones have been shown to alter coral reef fish community structure (Wilson *et al.* 2009), species-specific distributions (Walsh 1983) and population viability (McIlwain, 2002). However, the level of these impacts often varies markedly and the controlling factor(s) of these changed community structures often difficult to identify. A tropical cyclones brings with it severe storm surge and turbulence (Fabricius *et al.* 2008), dramatic decreased (Schiller *et al.* 2009) or increased (McKinnon *et al.* 2003) water temperatures, and lowered barometric pressures (Heupel *et al.* 2003). Understanding that marine organisms may change their ecological behaviours in response to tropical cyclones is a primary need, however as equal importance is to understand what changing variable(s) forced the change.

Data describing the effects of tropical storms on resident marine species are often obtained fortuitously when a storm disrupts an existing study that is focused on an unrelated objective. This was the case when Tropical Cyclone (TC) *Gabrielle* formed in the Gulf of Mexico during September 2001 and disrupted a movement and spatial distribution study of juvenile blacktip sharks (*Carcharhinus limbatus*) within a shallow water nursery habitat, Terra Ceia Bay, Florida (Heupel *et al.* 2003). Fine scale spatiotemporal data were available from passive acoustic monitoring methods that clearly demonstrated significant increased rate of movement in the hours leading up to the storm, with all monitored individuals (n = 13) fleeing the bay just prior to the storm making landfall not to return for at least five days. The results of this study suggest that the sharks responded to rapidly falling barometric pressure as the storm system approached, and is a rare example of the inherent value incorporated in continuous long-term data sets that include both pre-, during and post- event measures. The logistical and budgetary constraints associated with the collection of long-term datasets that include substantial monitoring within both *a priori* and *a posteriori* periods, is acknowledged as a current constraint that needs to be solved (Wilson *et al.* 2006; Maynard *et al.* 2009).

Despite these constraints on research methodology and design as applied to unpredictable cyclone events, important patterns in ecological responses of coral reef fish communities have been described. Unfortunately however the majority of these studies focus on the community of small bodied reef obligate species such as the pomacentrids, chaetodonts, labrids, acanthurids, scarids, pomacanthids (Cheal *et al.* 2002; Jones *et al.* 2004; Emslie *et al.* 2008). Larger bodied more mobile coral reef fish such as the Serranids and Lethrinids are often not represented, most notably because the survey techniques required for the concomitant monitoring of coral and small bodied reef fish communities are not amenable to monitoring large bodied more mobile reef fish. This area of depurate data and understanding needs addressing as many of these larger bodied reef fish are subject to fisheries exploitation throughout global tropical reef systems, and their removal may have severe cascading or phase shifting effects (Hughes 1994; Graham *et al.* 2007), as well as impact negatively on the socio-economic viability of fisheries that target such larger-bodied fishes.

The Coral Reef Fin Fish Fishery (CRFFF) operates within the waters of the GBRWHA spanning 14° of latitude, northeast Australia (Williams 2002, Welch *et al.* 2009). The fishery is multi-sectoral (commercial, charter and recreational), and multispecies with over 125 species of coral reef fin fish harvested. Historically, common coral trout (*Plectropomus leopardus*) and red throat emperor (*Lethrinus miniatus*) have been the primary target species of all sectors in most regions (Higgs 1996, Mapstone *et al.* 2004). Within the last decade commercial fishery landings have been reduced from around 4,000 t to 2,000 t per annum. This reduced production is largely the result of direct fishery re-structure through management intervention by the Fisheries Queensland (FQ), Department of Employment, Economic Development and Innovation (DEEDI), and the Great Barrier Reef Marine Park Authority (GBRMPA). In July 2004, FQ introduced a Total Allowable Catch (TAC) and Individual Transferable Quota (ITQ) in response to concerns of growing effort and catch being driven by the lucrative live export market and demand for common coral trout. At the same time (July 2004), the GBRMPA introduced the Representative Areas Program, expanding protected ‘no fishing’ zones within the Marine Park from 24% to 33% (GBRMPA 2004).

Coral trout, *Plectropomus leopardus*, dominates catches taken from the CRFFF. Coral trout is also the economic mainstay of the fishery, historically sourcing premium economic return within the domestic dead market that is now outstripped by the premium prices offered for live coral trout by international marketplaces (Figure 1.1). The biology and ecology of the species has been well documented (Davies, 1996; Samoilys 1997a and 1997b; Adams *et al.* 2000; Adams 2002), and a large-scale manipulation experiment on the effects of fishing completed (Mapstone *et al.* 2008). Coral trout are strongly coral reef associated with movements between the isolated emergent reefs of the GBR highly restricted (Davies, 1996).

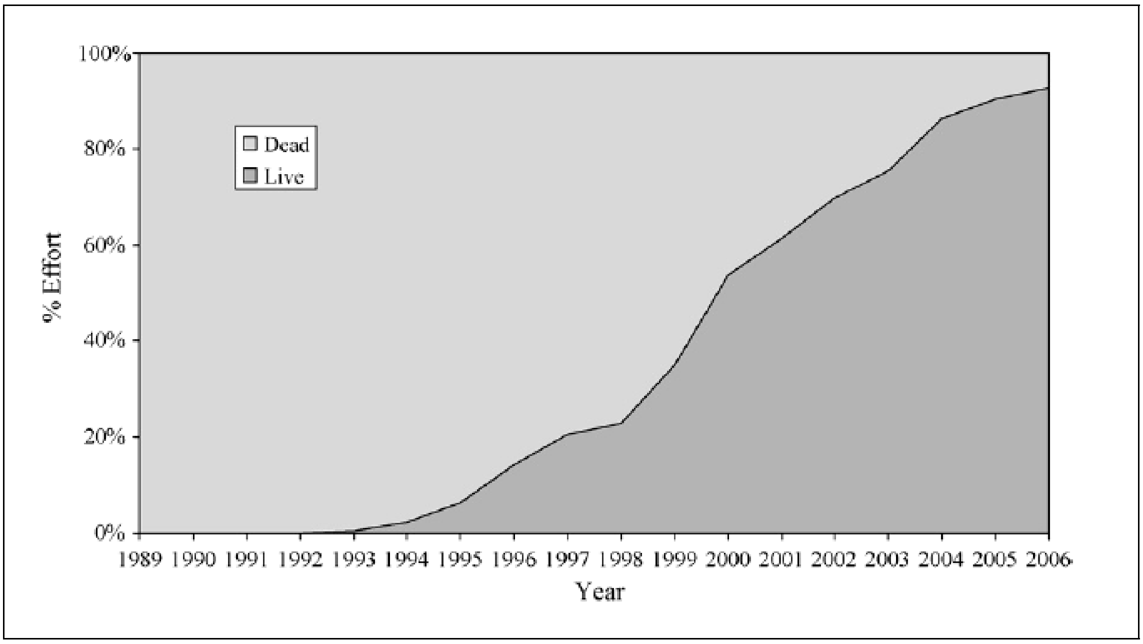


Figure 1.1. In recent history, effort of the commercial fishing sector of the CRFFF has changed from targeting and marketing a dead product to domestic markets to a live product destined for the lucrative southeast Asian market (reproduced from Welch *et al.* 2008).

Red throat emperor is the second most dominate species in catches taken in the CRFFF, with the product sold within the Australian domestic market as ‘whole chilled’ or frozen fillet. The biology and ecology of red throat emperor has also been well documented (Williams *et al.* 2003, Williams *et al.* 2007). In contrast to the reef attached coral trout, red throat emperor inhabits a diversity of offshore habitats in addition to emergent coral reefs including deepwater inter-reef shoals and continental shelf waters. Even though directed but limited tag-release experiments have failed to reveal large scale movement patterns of red throat emperor, the meta-population theory proposed by Williams *et al.* (2003) and their presence across a diverse range of habitat types suggests free movement among locations.

Following TC *Justin* (March 1997), a 24-day storm that wandered throughout the southwest Coral Sea (Figure 1.1), an anomaly of depressed landings of coral trout concomitant with increased landings of red throat emperor (RTE) within the mid to northern sections of the GBRWHA was reported anecdotally by commercial fishers. Although the apparent changed catch rates of coral trout and red throat emperor have never been quantitatively explored, Leigh *et al.* 2006 did note an anomalous increased landing of red throat emperor during 1997. Interestingly, another anomalous event was recorded for the GBRWHA within the same year as the anomalous catch rates were reported by fishers. Schiller *et al.* (2009) has demonstrated that TC *Justin* brought with it a uniquely anomalous event of unseasonably cooler sea surface temperatures that surged through the emergent reef structure of the central section of the GBRWHA. The spatio-temporal link between these two anomalous events has never been explored.

The recent impacts of TC *Hamish* have provided a new incentive for examining the impacts of cyclone systems on coral reefs, their associated fish faunas and the fisheries which target them. This project report completes a robust assessment of the impacts of three cyclone systems on the GBRWHA, the fish that inhabit emergent coral reef, the fisheries that operate and are dependent on a healthy reef, and the socio-economic issues attached to these significant events.

1.2 Need

TC *Hamish* (Category 5) traversed the southern Great Barrier Reef (GBR) in early March 2009, surpassing all previous storms in intensity, duration and maximum track length over reef structure. Hamish neatly bisected the major line fishing grounds of the CRFFF, crossing the GBR east of Bowen then drifting southeast through the GBR southern section. The section of the GBR affected historically produces 70% of the annual landings taken by the commercial fleet as well as supports significant charter businesses and recreational fishing opportunities.

Commercial fishers were first to witness structural damage caused by TC *Hamish* with many reefs reported as receiving extreme damage (loss of live coral). Swift response by the Australian Institute of Marine Science (AIMS) Long Term Monitoring Program (LTMP) confirmed these reports showing some Mackay reefs suffering reductions from >75% to <10% live coral cover.

TC *Hamish* may have also caused marked decreases in Sea Surface Temperature (SST) similar to TC *Justin* (March 1997). TC *Justin* was a long-lived (24 days) system with an unusually large cloud mass, which cooled SST by 4°C. Anecdotally, the unseasonal water cooling depressed CPUE of coral trout, and was responsible for an anomalous northward shift in the distribution of red throat emperor.

Within two weeks of TC *Hamish*, the commercial CRFFF fleet began adapting to the poor fishing and low CPUE in southern GBR waters, with some vessels relocating to northern unaffected fishing grounds (thereby causing potential indirect consequences for northern fishers) and others choosing to remain 'tied-up' to the wharf.

A significant threat of global climate change is that the frequency of intense storms may increase. Investigating the effects of extreme weather events on fishing and associated industries is a high priority. The need also extends to exploring the adaptive ability of all stakeholder groups in circumventing the negative impacts of such events.

1.3 Objectives

1. Use fishery independent *UVC* methods to estimate reef structural damage and fish abundance on the frequently sampled Effects of Line Fishing reefs.
2. Determine the real time effects of TC *Hamish* on the catch composition and catch rates of each fishing sector within the CRFFF.
3. Investigate correlations of variant catch composition and CPUE with archived abiotic data and AIMS LTMP structural damage surveys.
4. Determine the socio-economic effects of TC *Hamish* on the commercial and charter CRFFF, including adaptability of the fleet, vulnerability to future environmental events, and steps for reducing or mitigating this vulnerability.
5. Describe retrospectively the changes in the CRFFF catch composition and CPUE resulting from an unusually long duration storm event (TC *Justin*, March 1997) compared with a short duration but high severity storm event (TC *Larry*, March 2006).

1.4 Methods

To complete the stated objectives, three methodologies – fishery independent underwater visual census, fishery dependent catch data and abiotic data analysis, and active fisher dependent socio-economic methods – were utilised.

More detailed methodologies are given in the specific chapters of the report. In accordance with the data requirements, methods and analytical techniques used, the report includes three chapters. Chapter 1 reports on objective 1 that utilised fishery independent underwater visual census techniques; Chapter 2 reports on objectives 2,3 and 5 that utilised fishery dependent catch data and existing abiotic data archives; while Chapter 3 reports on objective 4 that utilised fisher dependent socio-economic interview methods.

Chapter 2: Fishery independent assessment of tropical cyclone effects on coral reef structure and associated fish communities

T. Ayling, A. Ayling, A. J. Tobin and A. Schlaff

2.1 Introduction

The physical effects of tropical cyclones on coral reef structure and coral assemblages are well documented in the literature. Overwhelming, most studies show extensive damage to occur on reefs that fall within fifty kilometres of the cyclone's path (Done 1992), with the worst destruction typically concentrated on the exposed reef flats and/or reef fronts (Walsh 1983; Letourneur *et al.* 1993). Damage is inflicted not only by violently moving water but also by the solid objects that it dislodges: rolling corals, suspended fragments, and scouring sand (Woodley *et al.* 1981). The extent of damage often varies with reef location, depth and topography (Bythell *et al.* 1993) as well as the type of substratum present and the shape, size, and mechanical properties of the corals found on the reef (Woodley *et al.* 1981; Done 1992).

Delicate branching and plate-like corals such as *Acropora* appear to be the most vulnerable, with documented high mortalities and/or dislodgement immediately following a cyclone (Knowlton *et al.* 1981; Rogers *et al.* 1982; Mah and Stearn 1986; Fenner 1991; Cheal *et al.* 2002). In contrast, sturdier, mound-like corals tend to show better survivorship, most likely due to their compact morphology which allows them to better withstand the high-energy of cyclone-generated waves (Mah and Stearn 1986; Edmunds and Witman 1991; Cheal *et al.* 2002). Some studies have shown the destruction of rapidly growing branching corals such as *Acropora* to ultimately increase coral diversity by providing more light for slower-growing massive corals and by opening up new substrate for juvenile coral settlement (Rogers *et al.* 1982; Done and Potts 1992).

The effects of tropical cyclones on the abundance and species richness of coral reef-associated fish assemblages are also well-documented in the literature, although most studies tend to focus on the more survey amenable small bodied fishes that are more easily observed and counted (e.g. Halford *et al.* 2004; Emslie *et al.* 2008) than larger bodied more mobile apex predators that are often species targeted by coral reef based fisheries. Most studies show the extensive loss of coral associated with cyclones to cause heavy localised declines in coral-dependent fishes, particularly highly-specialised species (Graham *et al.* 2006; Wilson *et al.* 2006; Cheal *et al.* 2008; Wilson *et al.* 2009). However, this loss of diversity is often more than compensated for by commensurate increases in the number of herbivorous fishes feeding on the increased growth of epilithic algal matrix (EAM) found on newly stripped substratum and dead corals (Walsh 1983; Van Woesik *et al.* 1991; Letourneur *et al.* 1993; Wilson *et al.* 2006; Cheal *et al.* 2008; Wilson *et al.* 2009). Therefore, although the large declines in coral cover associated with tropical cyclones may have a limited short-term impact on overall species richness, there may be an associated fundamental change in the community structure of those fishes (Cheal *et al.* 2008; Wilson *et al.* 2009). More pertinently, the existing body of literature does not offer any insights into the effect of cyclones on large bodied reef serranid or lehtrinid species the same or similar to those targeted by the CRFFF.

TC *Hamish* formed off the Queensland coast to the north of Cooktown on 5 March 2009. The storm tracked south parallel to the coast over the next six days and slowly intensified to Category 5. On the morning of 8 March, *Hamish* moved amongst the Great Barrier Reef (GBR) southern emergent reef structure east of Bowen and tracked down through the Pompey and Swain Group reefs for the next 26 hours (Figure 2.1). This track took the cyclone 25-40 km east of the offshore Mackay and southern Pompey Effects of Line Fishing (ELF) experiment survey reef clusters (Mapstone *et al.* 2004).

Within days of the passing of TC *Hamish*, commercial fishers visiting the southern GBR reported extreme reef damage and depressed catch rates, particularly of the primary fishery targets coral trout and red throat emperor, on affected reefs. Sea Research resurveyed three of the six reefs in each of the southern ELF reef clusters using the same Underwater Visual Census (UVC) techniques used during the ELF surveys (see Mapstone *et al.* 2009) and the same survey personnel. A day was spent surveying each of the six reefs during the period 7-15 June 2009, approximately three months after the passage of the cyclone.

This chapter reports on the results of that survey and compares fish abundance and coral structure with UVC results from the last three years (2003-2005) of surveys from the ELF experiment. The specific objective of this methodology was to gather evidence to refute or support the anecdote collected from the fishing fleet that the fish communities of the southern GBR had been adversely affected by the passage and resultant reef structural damage caused by TC *Hamish*.

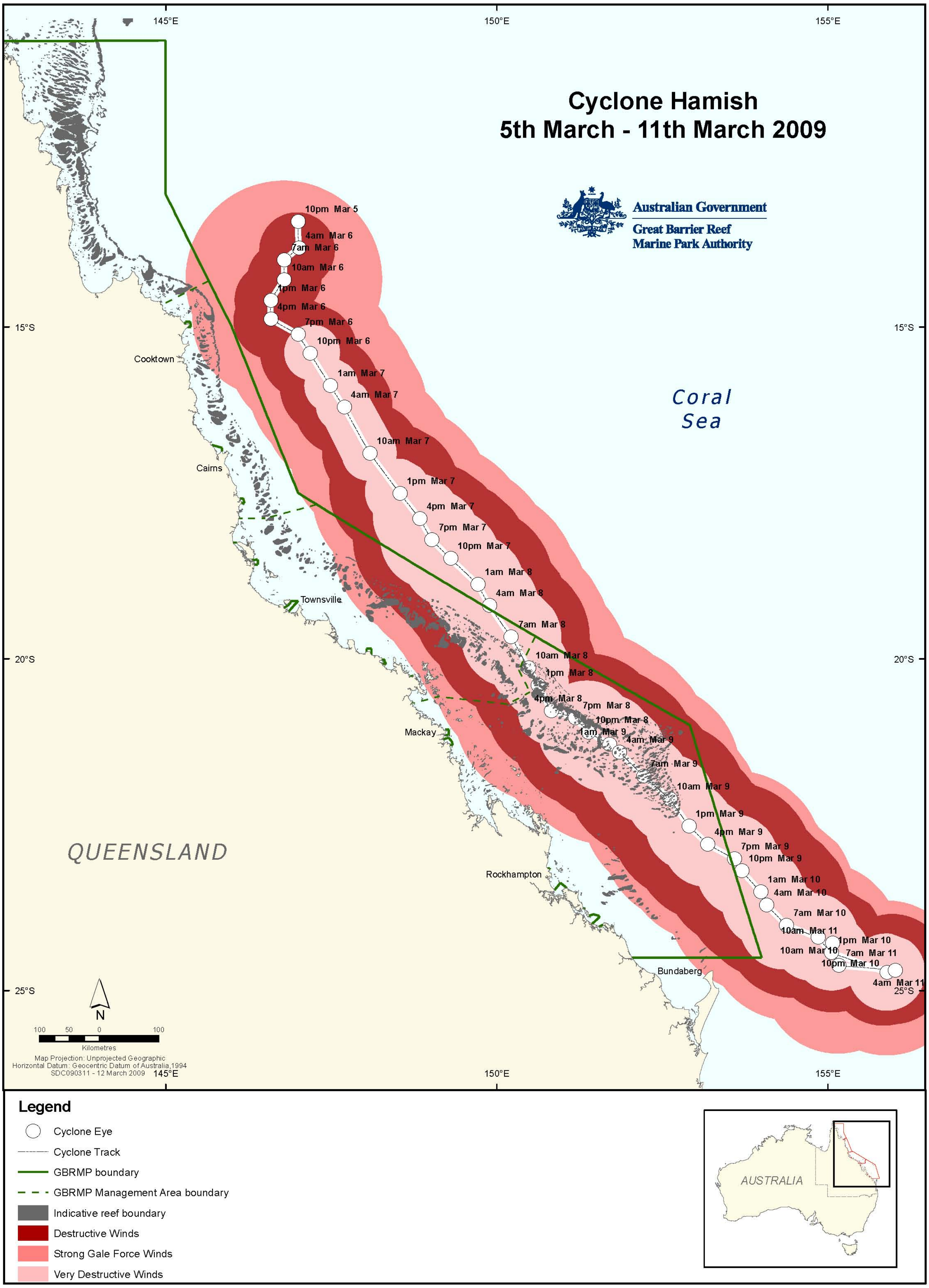


Figure 2.1. Cyclone *Hamish* track showing passage through the GBR region.

2.2 Methods

2.2.1 Survey reefs

The ELF experiment used four groups of six survey reefs between Lizard Island and the southern Pompey reefs (Mapstone *et al.* 2004). For the post- TC *Hamish* survey, three of the reefs in each of the two southern ELF clusters were surveyed using the same techniques employed during the ELF UVC counts, giving a total of six survey reefs (Table 2.1).

Table 2.1. Post-Tropical Cyclone *Hamish* survey reefs.

ELF Cluster/Reef	Reef ID #	Zoning	Size (km)	Distance to cyclone track (km)	Comments
Mackay					
Bax	20-138	Green	12.2 x 5.4	30	
Robertson # 2	20-136	Green	3.7 x 1.6	42	
Liff	20-296	Blue	2.0 x 1.4	40	
Pompey					
21-124	21-124	Blue	2.7 x 1.8	30	protected by Storm Cay reef to south
21-132	21-132	Green	3.9 x 2.5	30	
21-139	21-139	Green	4.4 x3.9	28	previously blue

2.2.2 UVC survey techniques

The ELF UVC survey design used six survey sites on each reef, three on the exposed southeast reef face and three on the sheltered northwest face. At each survey site, five haphazardly positioned belt transects run approximately parallel to the reef edge were used to quantify target fish populations as well as those of their major prey groups. The centre of each transect was positioned at a depth of six to eight metres below low tide level. The first diver (AMA) counted all target fish in a 50 m x 5 m belt, keeping just in front of a second diver deploying the transect tape as close to the substratum as possible. This strategy ensured that wary fishes were not scared off by the tape layer before being counted by the observer. Fish species counted included all species of coral trout *Plectropomus* spp., all other large serranid species, all lutjanid and lethrinid species, all caesionid species grouped together and all large (>25 cm TL) and small (<25 cm TL) scarids grouped together. Baitfish abundance was scored between 0-5 depending on the number of ten-metre segments of each transect where baitfish schools were observed within five metres of the tape. Sharks and large, rare fishes such as the Maori wrasse *Cheilinus undulatus* were counted by the first diver in a single 400 m x 20 m belt transect that incorporated all five transects at each site and included the space between the transects. On the return swim along each transect the first diver (AMA) counted all pomacentrids in a 50 m x 1 m belt, separating out the three common species *Pomacentrus moluccensis, Amblyglyphidodon curacao* and

Chrysiptera rollandi and grouping all other pomacentrid species. Caesionids, small scarids, baitfish and pomacentrids were all considered prey for predators such as coral trout.

While winding in the transect tape the second diver summed the total intercepts of live hard coral beneath the 50-30 m section of the tape in 10 cm increments, summed total soft coral intercepts beneath the 30-10 m section and summed sponge intercepts beneath the final ten metres of each transect. Representative photos were taken at each site to document the reef community and any cyclone damage.

2.2.3 Analysis

Counts from the post-*Hamish* survey were compared with the final three ELF surveys carried out in late 2003, 2004 and 2005 respectively using repeated measures analysis of variance (Table 2.2). The factors of most interest in the analysis were *Time* and the *Time* x *Habitat* interaction. If the *Time* factor was significant it could indicate an increase or decrease in the abundance of that species or group between the reference ELF surveys and the post-Hamish survey. Major damage from the cyclone was restricted to the exposed front reef on the west side of the track and hence changes could be expected to be greater on the front reef compared to the back giving a significant *Time* x *Habitat* interaction.

Table 2.2. Repeated measures ANOVA design for testing of benthic cover and fish density changes between the pre- and post-*Hamish* surveys.

Source of variation	df	Denominator
Between Transects:		
Reef	5	Reef x Site(H)
Habitat	1	Site (Habitat)
Site (Habitat)	4	error (transects)
Reef x Habitat	5	Reef x Site(H)
Reef x Site(H)	20	error (transects)
Error (transects)	576	
Within Transects:		
Time	3	Site (Habitat) x Time
Reef x Time	15	Reef x Site(H) x Time
Habitat x Time	3	Site (Habitat) x Time
Site (Habitat) x Time	12	error (transects x Time)
Reef x Habitat x Time	15	Site (Habitat) x Time
Reef x Site(H) x Time	60	error (transects x Time)
Error (transects x Time)	576	

2.3 Results

The effects of TC *Hamish* on benthic communities on the exposed front of the survey reefs was dramatic with a reduction in hard coral cover from a mean of 50% during the three reference ELF surveys to only 16% three months after the cyclone (Figure 2.2). Although coral cover also decreased on the back reef the decrease on the front was more severe and the *Habitat* x *Time* interaction was also significant (Table 2.3, Figure 2.2). Soft corals also showed a nominal decrease on reef fronts from three percent during the reference surveys to less than one percent in the post-cyclone survey but this change was not significant due to the strong site differences (Table 2.3).

Despite the huge changes in benthic communities caused by the cyclone shark and fish abundances were remarkably similar after the cyclone to those recorded during the three reference surveys (Figures 2.3, 2.4, 2.5; Table 2.3). The density of adult coral trout was nominally *higher* post-cyclone than during any of the reference surveys and was significantly higher than the 2003 and 2004 surveys (Figure 2.4). The abundance of scarids increased markedly following the cyclone, in both the front and the back reef habitats, presumably due to an increase in suitable grazing habitat caused by hard coral damage. The only fish group that showed significant population reductions post-Hamish was total pomacentrids. Small damselfishes had their habitat destroyed by the cyclone on the exposed reef fronts but their density was only reduced by about 24%. Although densities were nominally lower in the back reef habitat the Habitat x Time interaction was significant for this important prey group (Table 2.3, Figure 2.6). Six of the species or groups analysed had significant reef effects. Numbers of these groups were higher on Bax and/or Robertson #2 reef. Although abundance of many species or groups was nominally higher on the exposed front reef habitat than the back reef these differences were only significant for stripeys and pomacentrids (Table 2.3).

One distinctive feature of these southern high-current reefs is the irregular presence of large schools of atherinids, commonly referred to as baitfish (Figure 2.7). Although baitfish were not common during the post-Hamish survey the recorded mean abundance index was within the range of normal fluctuations in abundance of this species (Figure 2.6, Table 2.3).

Table 2.3. ANOVA results for comparison of the three reference surveys with the post-*Hamish* survey.

Hab = habitat; NS = not significant; * = 0.05>p>0.01; ** = 0.01>p>0.001; *** = p<0.001;
Interactions not of interest have been left out.

Species/group	Reef	Hab	Site(H)	**Time**	R x T	**H x T**	RxHxT
Total hard coral	NS	NS	***	***	*	**	NS
Total soft coral	NS	NS	***	**NS**	NS	**NS**	NS
Total sponges	NS	NS	***	**NS**	NS	**NS**	NS
Plectropomus leopardus	NS	NS	***	**NS**	NS	**NS**	NS
P. leopardus adults	***	NS	***	**	NS	**NS**	NS
P. laevis	***	NS	**	**NS**	NS	**NS**	NS
Lethrinus miniatus	NS	NS	***	**NS**	NS	**NS**	NS
Lutjanus carponotatus	NS	*	***	**NS**	NS	**NS**	NS
Scarids	NS	NS	*	***	NS	**NS**	NS
Pomacentrids	*	*	***	**	NS	**	NS
Whitetip shark	NS	NS	NS	**NS**	NS	**NS**	NS
Grey shark	***	NS	NS	**NS**	NS	**NS**	NS
Maori wrasse	***	NS	NS	**NS**	NS	**NS**	NS
Baitfish	**	NS	NS	**NS**	NS	**NS**	NS

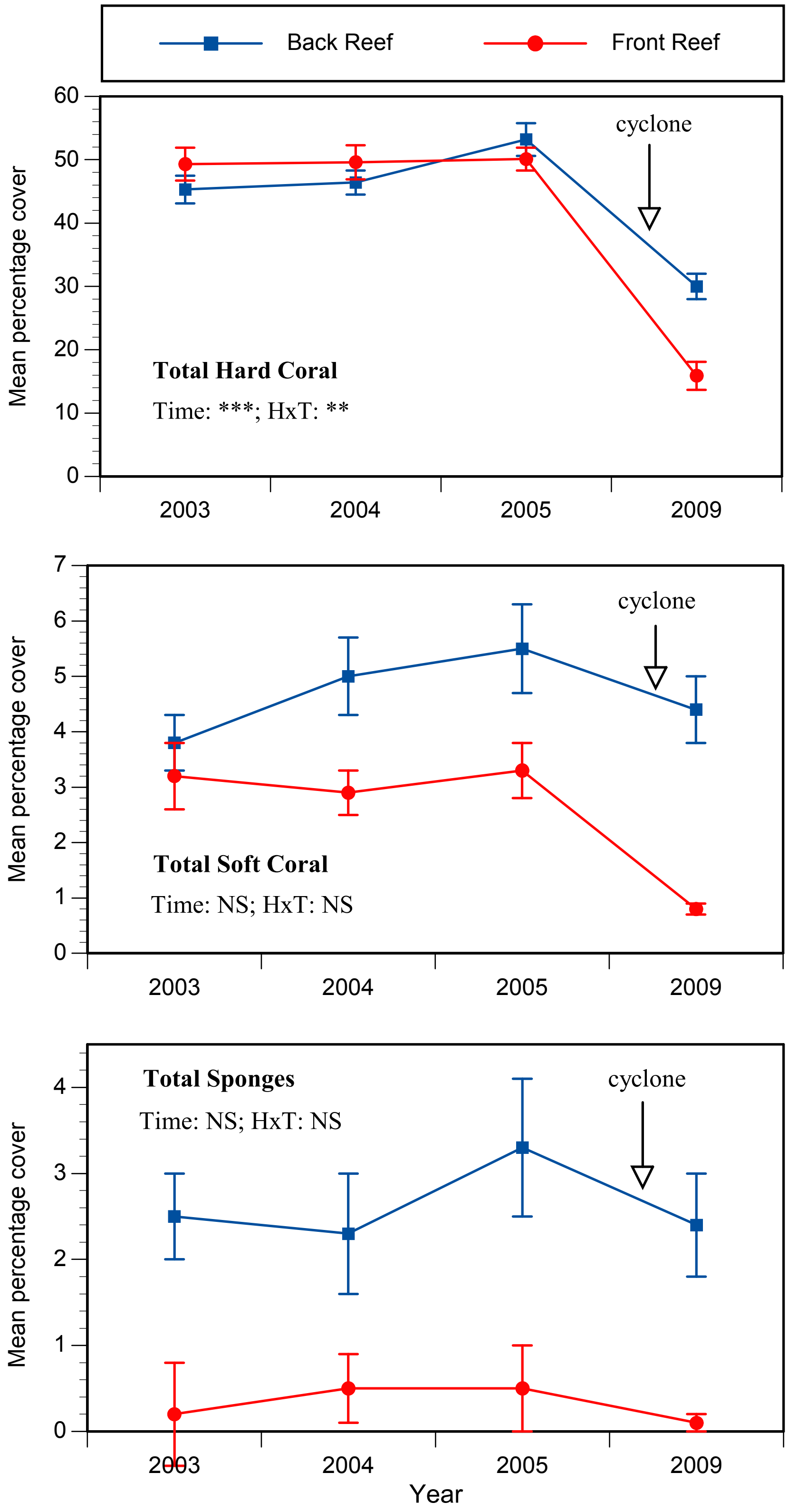


Figure 2.2. Changes in the abundance of benthic organisms on the survey reefs. Figures show grand mean percentage cover from six reefs with three sites of five transects in each habitat. Error bars are standard errors.

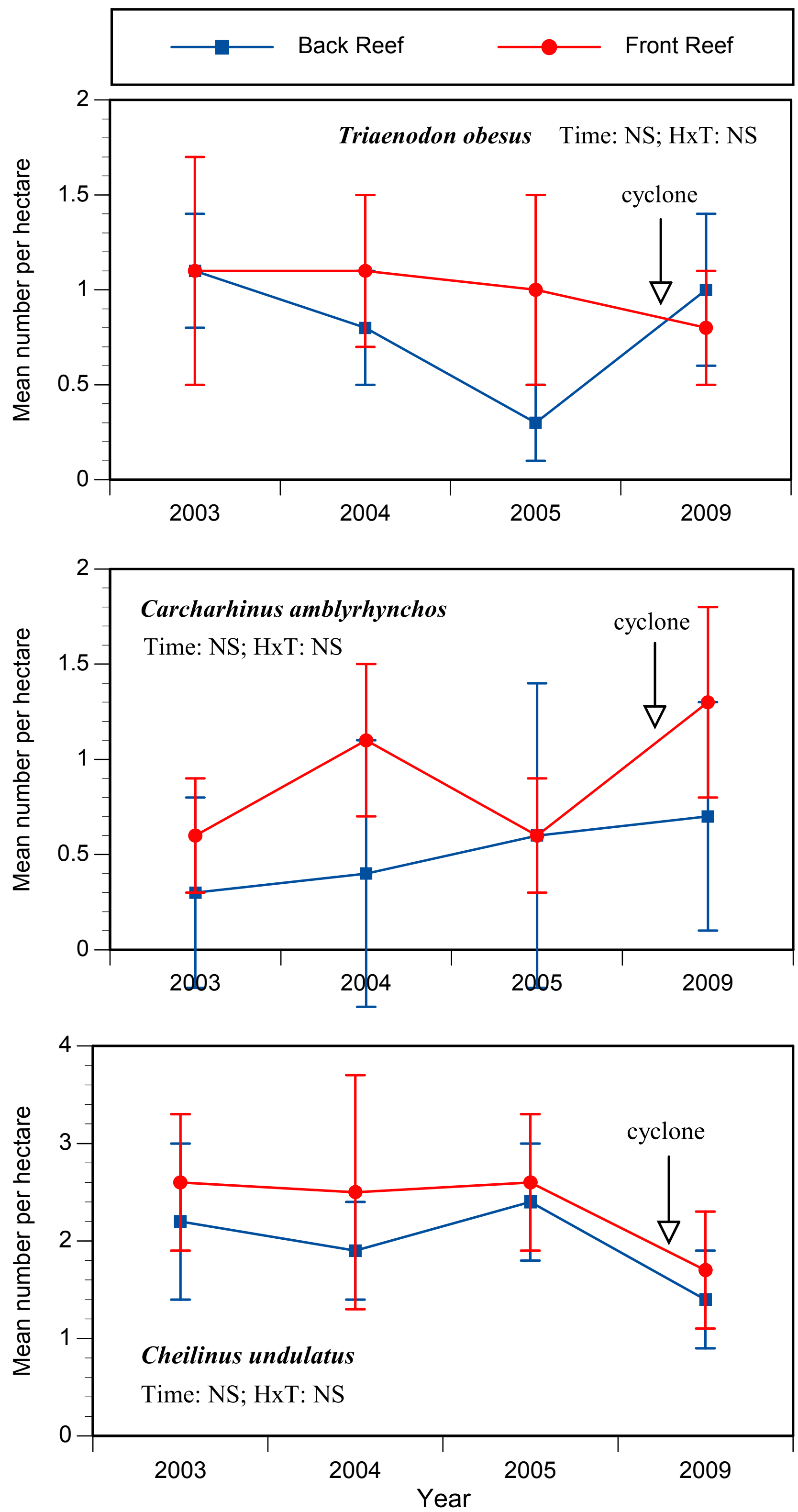


Figure 2.3. Changes in the abundance of sharks and Maori wrasse on the survey reefs. Figures show grand mean abundance per hectare from six reefs with three 400 m x 20 m transects in each habitat. Error bars are standard errors.

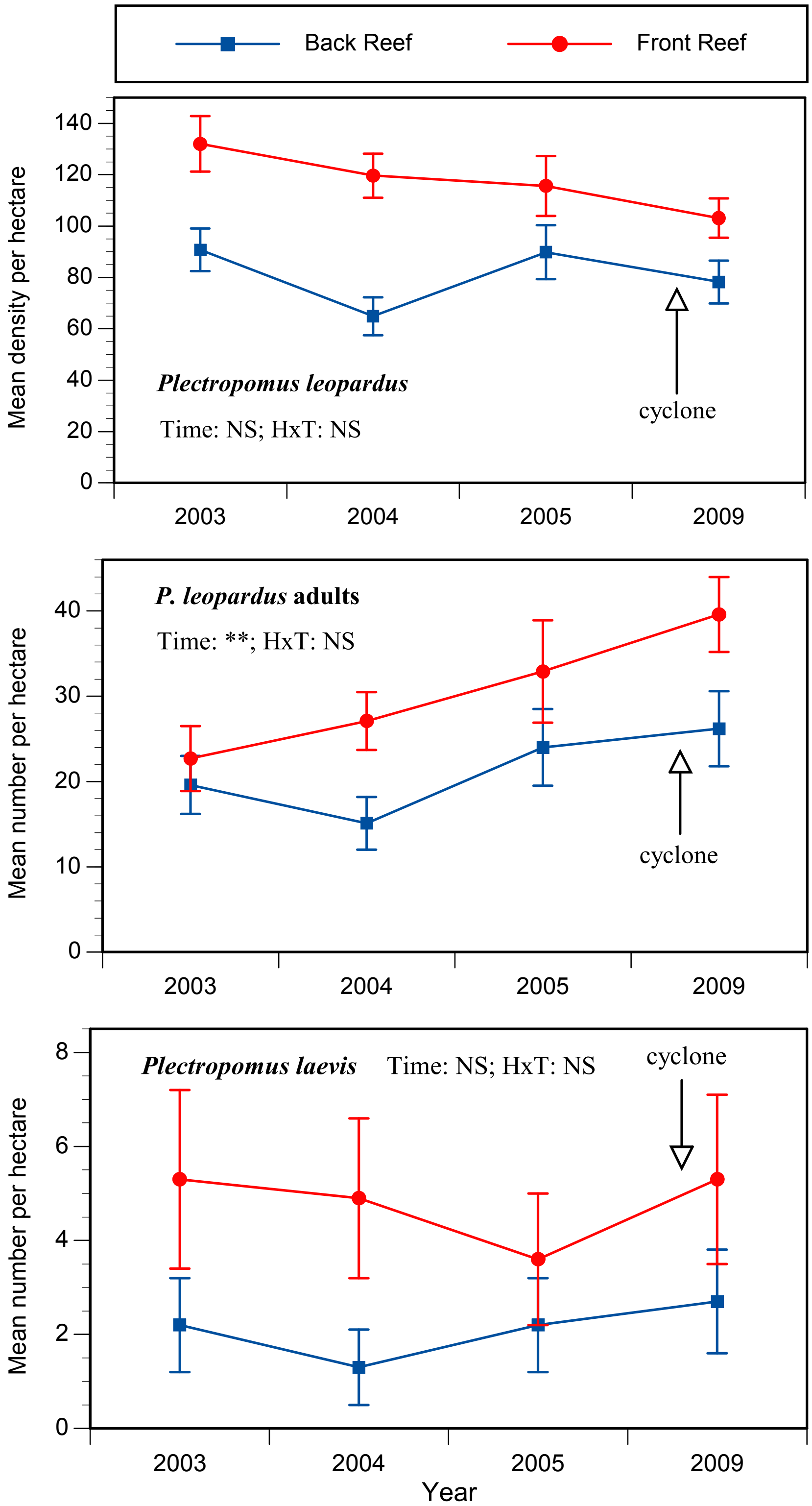


Figure 2.4. Changes in the abundance of coral trout on the survey reefs. Figures show grand mean abundance per hectare from six reefs with three sites of five transects in each habitat. Error bars are standard errors.

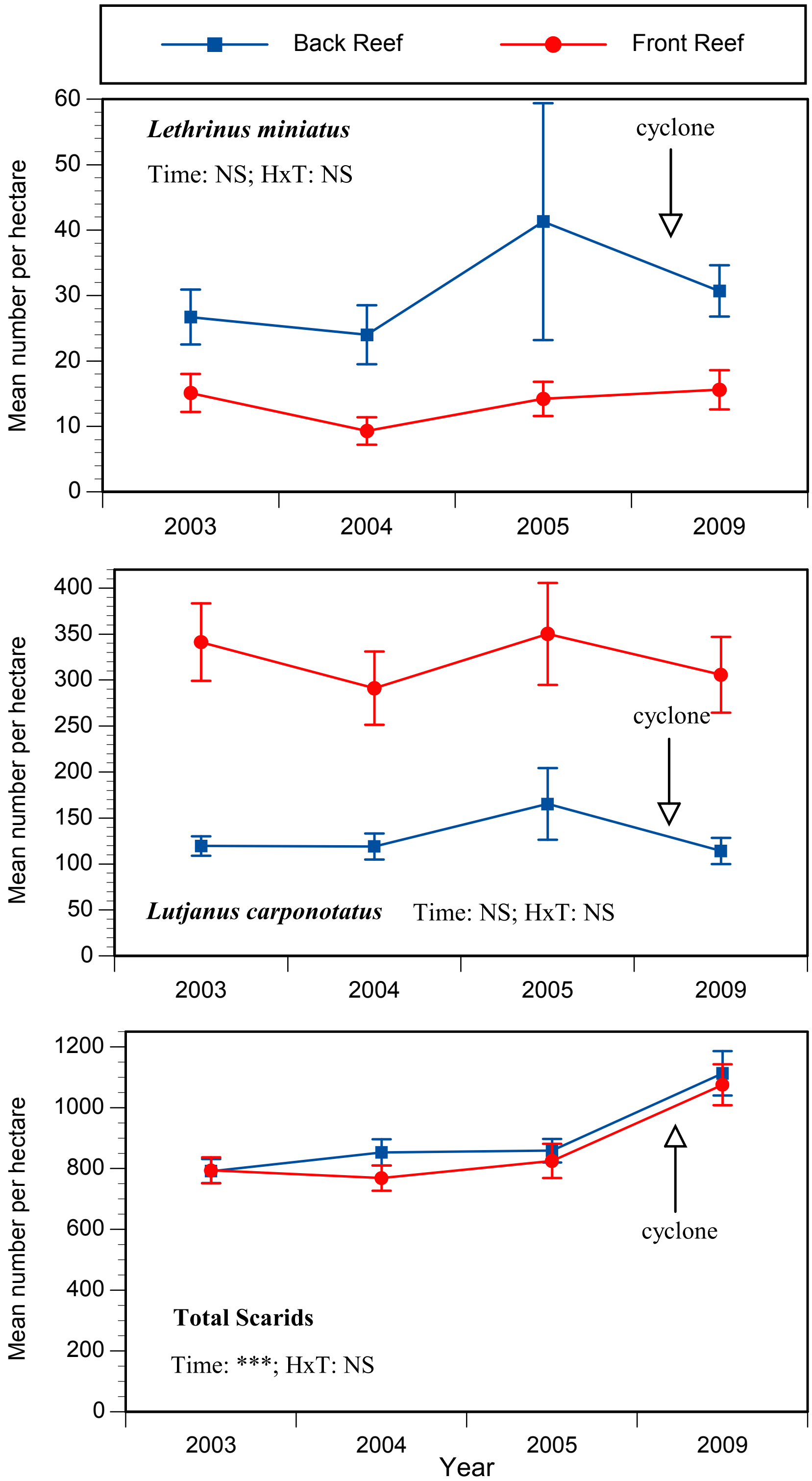


Figure 2.5. Changes in the abundance of 'Other' fishes on the survey reefs. Figures show grand mean abundance per hectare from six reefs with three sites of five transects in each habitat. Error bars are standard errors.

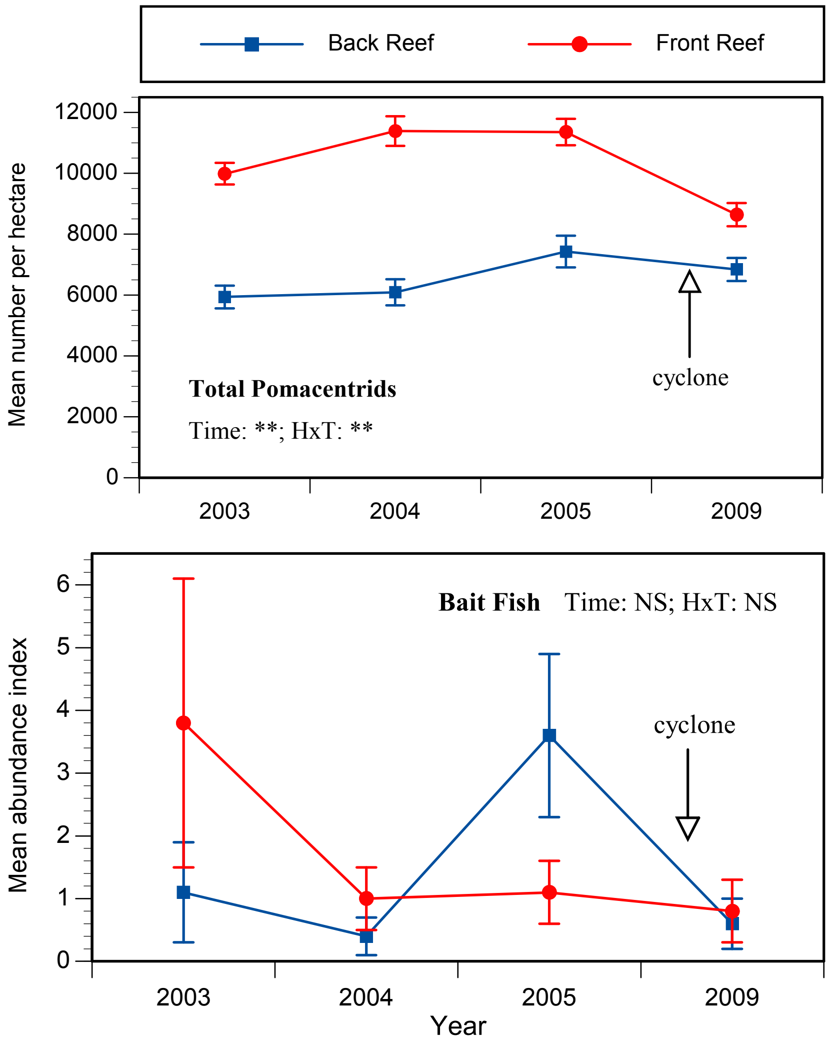


Figure 2.6. Changes in the abundance of prey species on the survey reefs. Figures show grand mean abundance per hectare or for baitfish mean abundance index per site (0-30) from six reefs with three sites of five transects in each habitat. Error bars are standard errors.

Figure 2.7. One of the few large schools of baitfish seen during the post-*Hamish* survey.

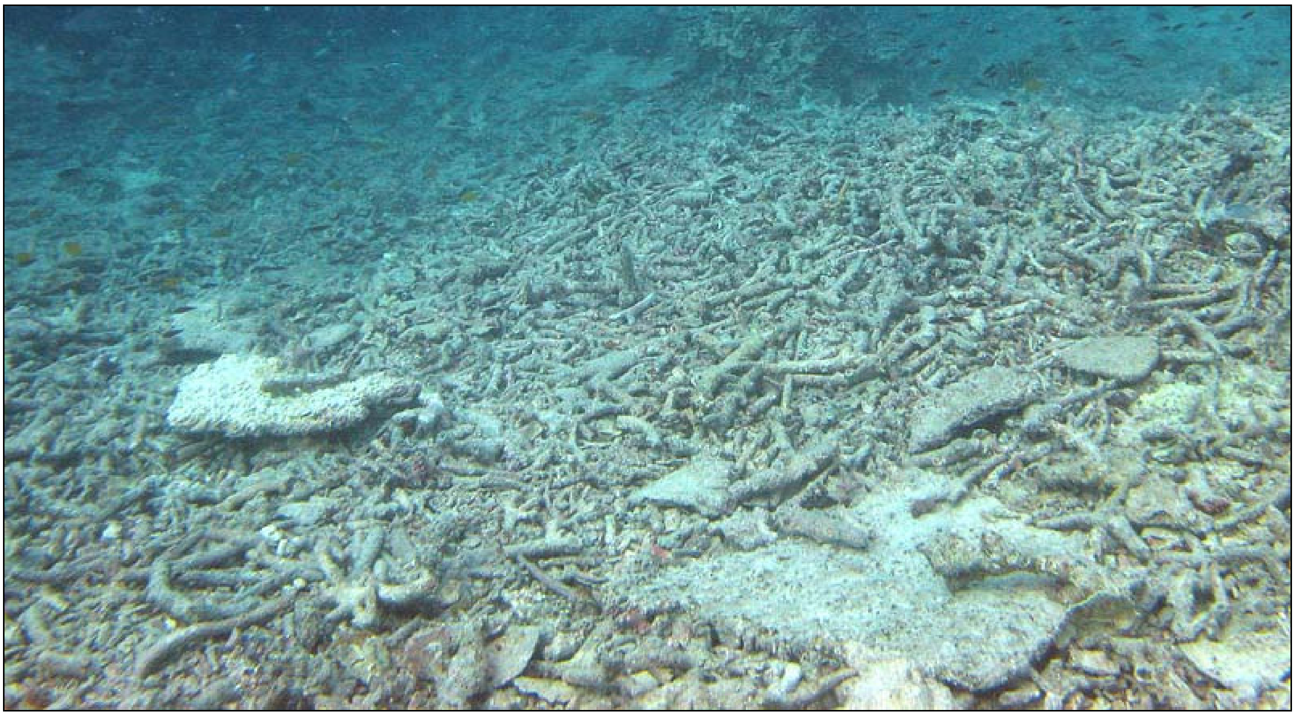


Figure 2.8. Some exposed areas of front reef were almost completely devastated, with little remaining benthic cover: Reef 21-139, front.

Figure 2.9. Some areas of exposed front reef slope showed 'peeling' of reef matrix, exposing layers of old dead coral: Reef 21-132, front.

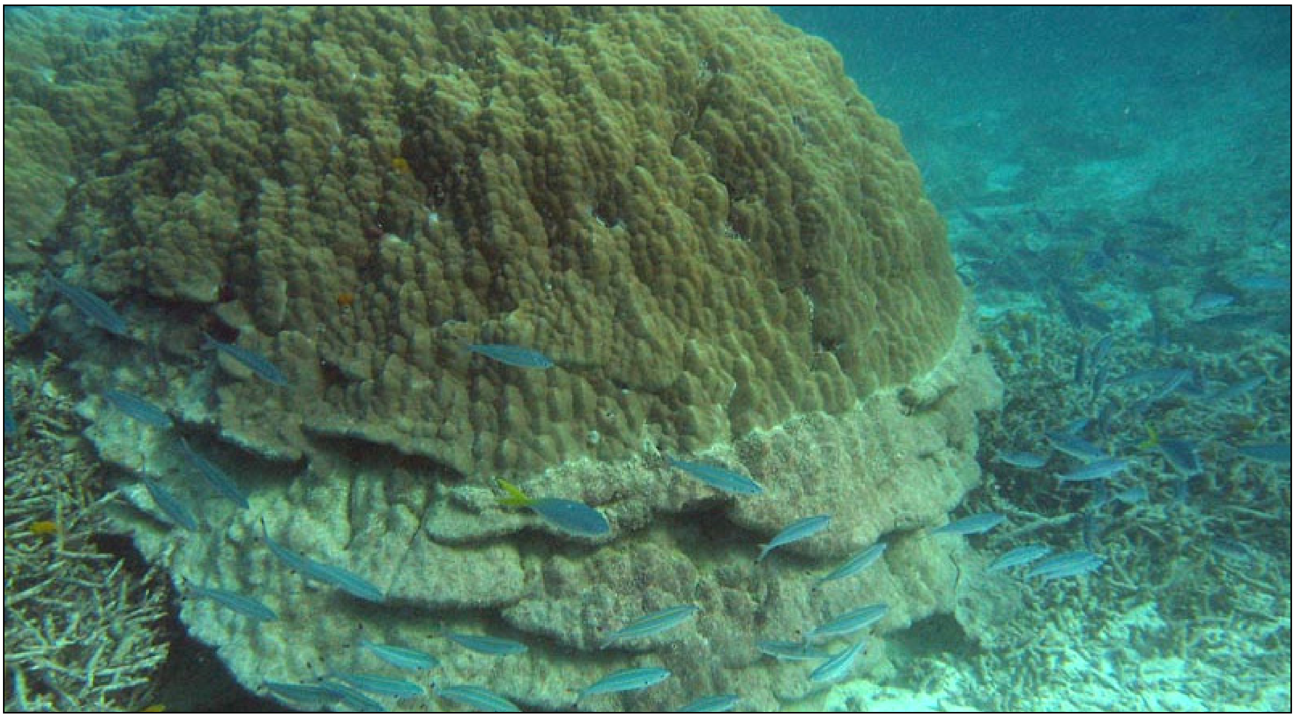


Figure 2.10. Removal of sediment, rubble and staghorn thickets had exposed the dead band on the lower part of this massive *Porites* colony.

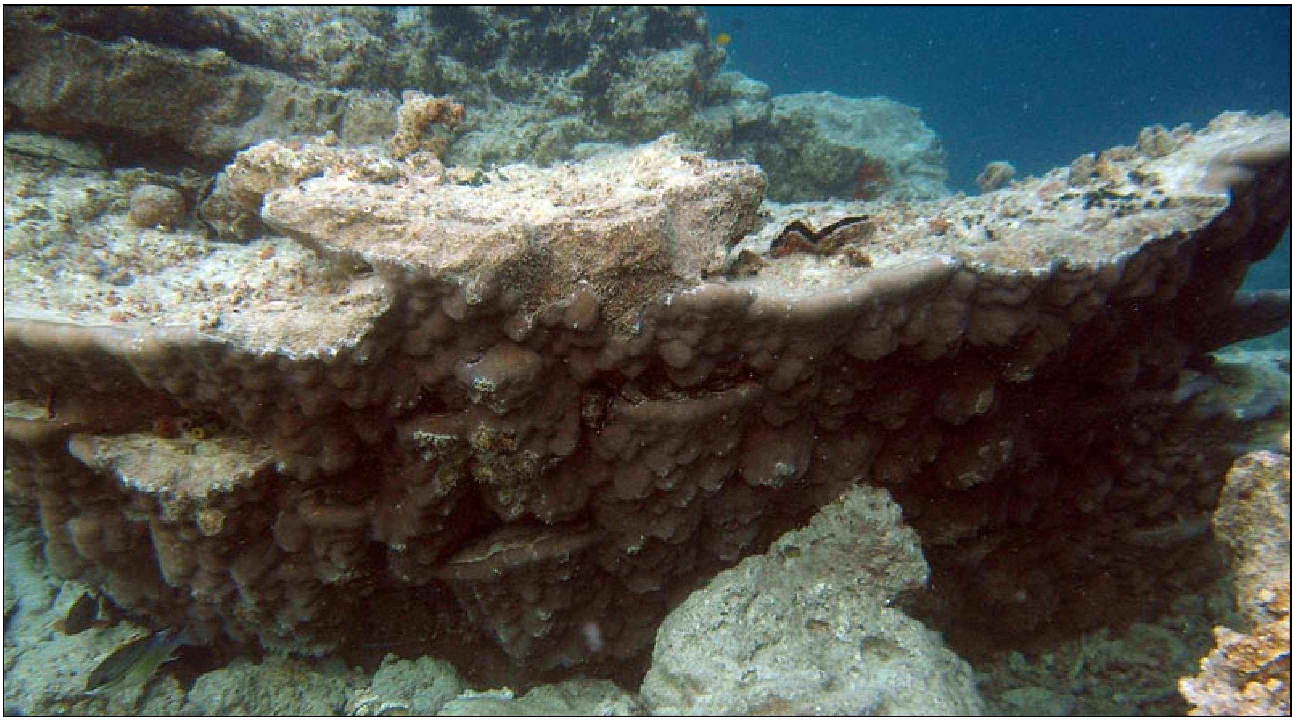


Figure 2.11. Many massive corals had been dislodged and overturned, including this 3 m diameter *Porites* on the front of Bax Reef.

Figure 2.12. Extensive *Acropora* stadhorn thickets on the back flank of Liff Reef in October 2005.

Figure 2.13. The back flank of Liff Reef, post-*Hamish*, with extensive damage to the *Acropora* thicket but lots of live coral remaining.

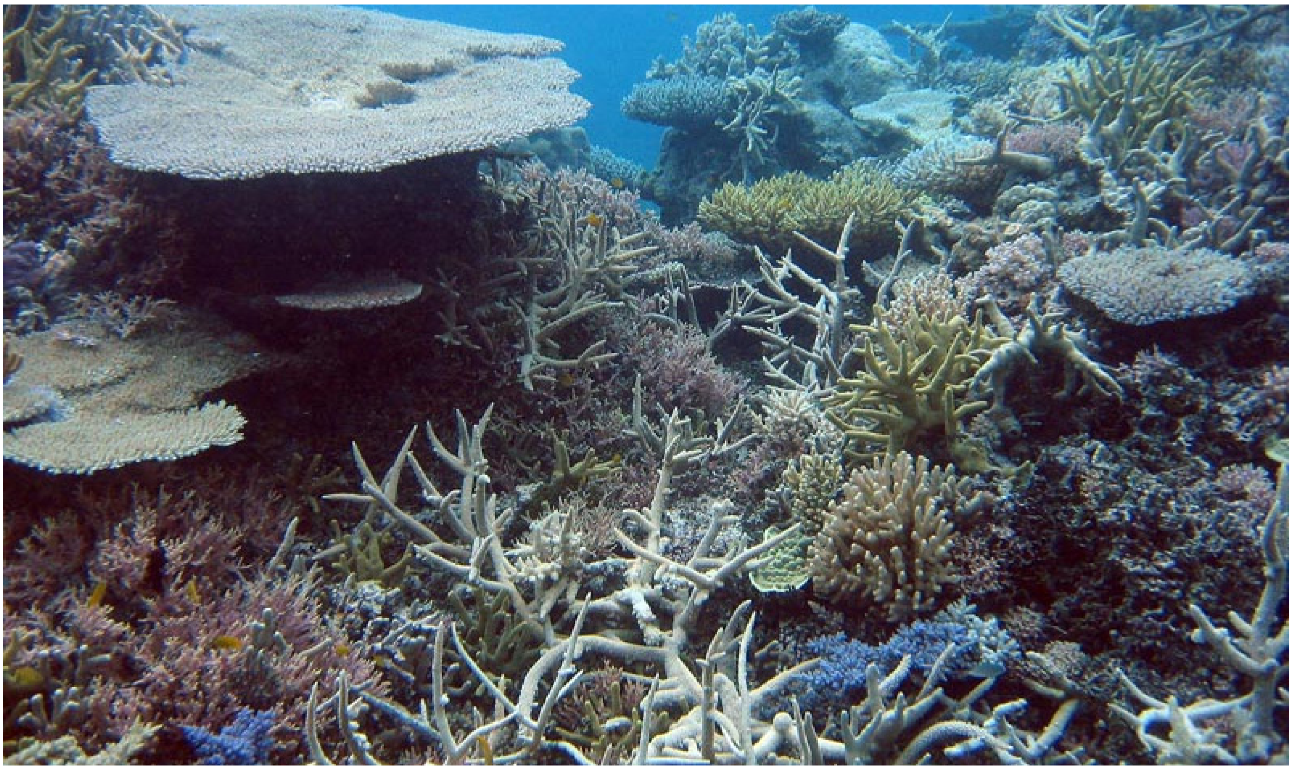


Figure 2.14. Rich coral community on the front flank of Reef 21-132 during the 2005 reference survey.

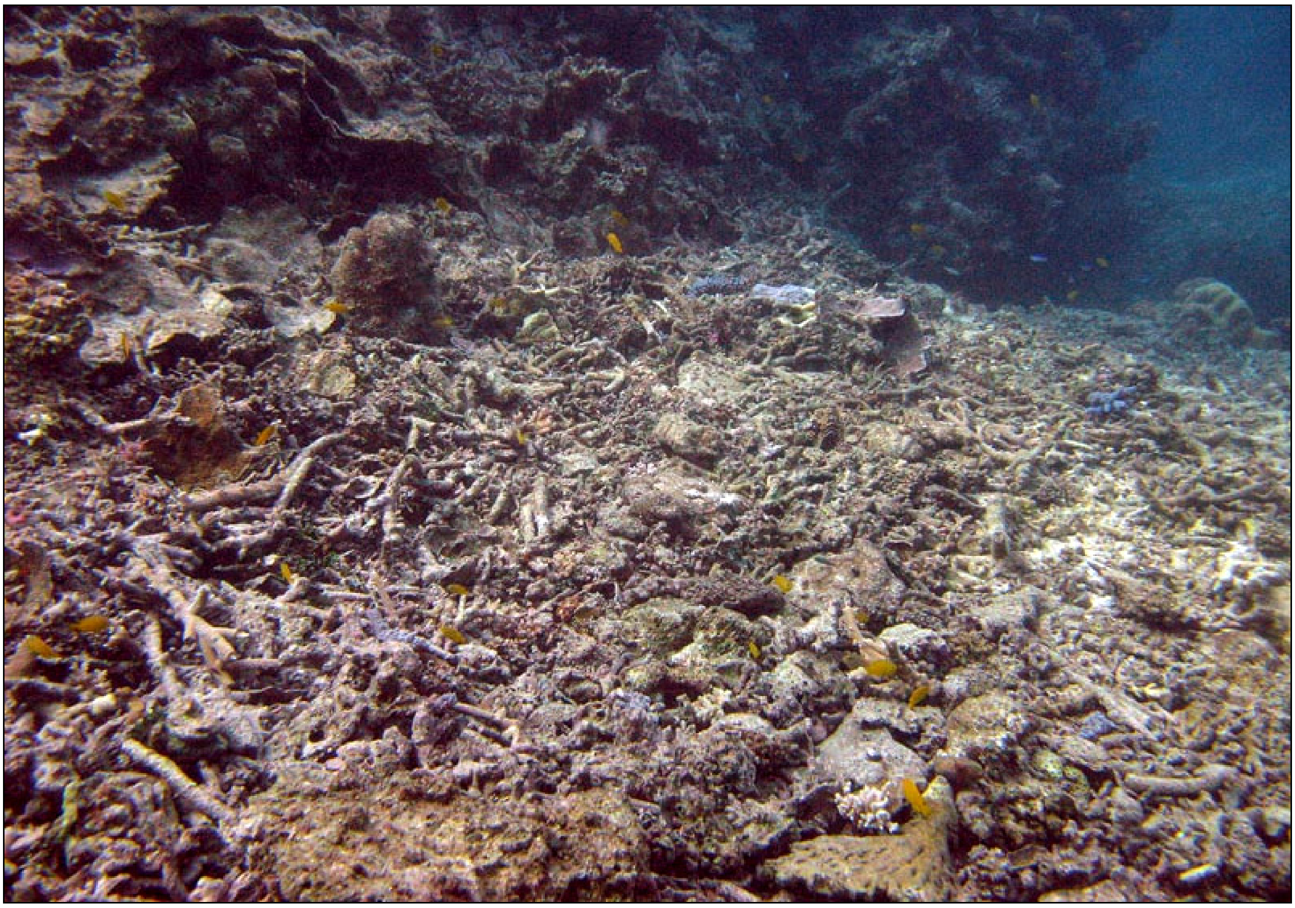


Figure 2.15. Reefs on the front flank of Reef 21-132 badly damaged post-*Hamish*.

2.4 Discussion

2.4.1 Reef structural disturbance

The fully exposed front reef sites visited during this survey had been devastated by TC *Hamish* (Figure 2.8). Coral cover had been reduced to a third of that recorded during the three reference surveys and other benthic groups had also been reduced. In some badly damaged sites no benthic organisms were recorded along entire 50 m transects. Much of the staghorn *Acropora* fields that were characteristic of these reefs had been reduced to rubble with only occasional live fragments remaining. Many surviving live corals were badly damaged, and may be prone to delayed mortality similar to that reported by Guillemot *et al.* 2010. In many sites there had been considerable peeling of the reef matrix to expose long-dead coral substratum (Figure 2.9) and movement of rubble and sand (Figure 2.10). Massive corals up to three metres across had been dislodged or turned completely over (Figure 2.11). All the damage types recorded by Done *et al.* (1991) in their survey of damage after TC *Ivor* were commonly encountered on the exposed front sites of the survey reefs. It is estimated that full recovery of many of these badly damaged sites will take five to ten years (Ayling and Ayling 2006).

Many of the protected back reef sites had minimal damage but those that were partially exposed on reef ends or flanks had sustained minor to moderate damage and coral cover was reduced by over 35% compared to the reference surveys (Figures 2.12, 2.13). In many of these sites much of the damaged staghorn *Acropora* was still alive and recovery should only take a few years.

2.4.2 Fish community disturbance

In spite of this extreme physical damage to the reef structure and the benthic community (Figures 2.14, 2.15) most of the fish populations were unaffected by this cyclonic event. Most notably, coral trout abundances were nominally higher three months after TC *Hamish* than they were during the reference surveys of 2003, 2004 and 2005. This result was most surprising considering the anecdote received from fishers during this same time continued to report depressed catch rates throughout the surveyed regions. The abundance estimates of red throat emperor were also unchanged between the cyclone year and the reference years. One plausible hypothesis of red throat emperor response to cyclone mediated reef damage could be increased presence and abundance. Assuming cyclone mediated reef damage may increase the exposure of zoo-benthos, a major component of red throat emperor diet (Walker 1978) increased survey abundances may be expected. However, the survey data do not support such a notion.

It is likely that populations of coral-feeding chaetodontids would have been markedly impacted but this fish group had not been part of the ELF UVC surveys and this theoretical decline was not documented. The only negative effect on fish numbers recorded here was the 24% decline in small damselfish densities in the exposed front reef habitat. In many front reef sites the normal coral habitat of these species had been completely destroyed but many of the damselfishes were still present, sheltering amongst the dead coral rubble fields.

As would be expected given the increase in available herbivorous fish grazing substratum the numbers of parrotfish recorded on the shallow reef slope was higher following the cyclone than had been recorded during the reference surveys. These fishes had probably gathered to feed in this damaged shallow habitat from other areas of the reef as there had been insufficient time for a population increase of 35% to occur.

It is likely that further declines in the populations of some fish species will occur that are an on-going and lagging effect of TC *Hamish* damage. Damselfishes sheltering in rubble banks rather than live branching corals may undergo higher than normal predation mortality. The reduction and absence of hard coral may limit future recruitment of species that prefer to settle into live coral and there may be other indirect influences of the severe damage to the reef benthic community. However, it is clear that the effect of the cyclone on fish populations was far less dramatic than the impact on benthic communities. Further, the fish community and abundance patterns described do not support the anecdotal reports from fishers that abundance of coral trout and red throat emperor had declined throughout the cyclone impact region.

Chapter 3: Fishery dependent assessment of tropical cyclone effects on coral reef structure and associated fish communities

A. J. Tobin, A. Schlaff, B. Krause, D. Welch, B. Sawynok and J. Maynard

3.1 Introduction

Tropical cyclones can be significant agents of disturbance on coral reef structure and reef fish communities within the Great Barrier Reef World Heritage Area (GBRWHA) (Lough 2007). Further global evidence suggests that the severity of tropical cyclones (aka hurricanes and typhoons) has increased in recent decades (Emanuel, 2005) and are likely to continue to increase in future decades (Webster *et al.* 2005). Projections suggest that tropical cyclones will continue to have an aperiodic affect within the GBRWHA, however systems of increased severity similar to TC *Larry* (March 2006) and TC *Hamish* (March 2009) may be more indicative of future climate than the recent past (Lough 2007).

In recognising more severe cyclones may impact the GBRWHA in future years, substantial knowledge gaps in the understanding of how ecosystem functioning may be altered or disrupted by cyclones still exists. In particular the response of large-bodied reef fishes, which are often valuable target species of fisheries, to cyclone influences is poorly understood. This lack of knowledge hampers any attempt to understand what changes coral reef based fisheries may be subject to in the face of increasing cyclone disturbance. Although the affects of cyclones on small-bodied reef fish communities have received some attention (e.g. Emslie *et al.* 2006), these reports provide little insight into the possible effects of cyclones on the performance of fisheries such as the CRFFF that target large-bodied reef fishes. This lack of knowledge prevents any robust assessment of the vulnerability of reef fishery productivity to cyclone impacts.

This chapter specifically assesses the impacts of three cyclones on the performance of the CRFFF. Chronologically, TC *Justin* (March 1997) was anecdotally reported by active commercial fishers as being responsible for a severe depression in catch rates of coral trout accompanied by a concomitant increase in catch rates of red throat emperor. TC *Larry* (March 2006) was one of the most severe storms to impact the GBRWHA in recent decades, though did not result in any anecdotal reporting of changed catch rates from commercial fishers. TC *Hamish* (March 2009) anecdotally resulted in widespread depressions of catch rates within the CRFFF, and was the system that precipitated this project.

In assessing the impacts of these storms on the performance of the CRFFF, two fishery data sets were analysed – the Fisheries Queensland (FQ) commercial line fishery database; and the CapReef community monitoring dataset. The historical records of the FQ commercial line fishery dataset was of sufficient quality and spatio-temporal coverage to analyse the effects of all three cyclones on catch rates and catch composition of the commercial sector of the CRFFF. The CapReef dataset was of sufficient quality and spatio-temporal coverage to analyse the effects of TC *Hamish* only on catch composition of recreational and charter fishing sectors.

3.2 Methods

3.2.1 Tropical cyclones of interest

The objectives of this project specifically name three tropical cyclones for investigation; a recent passing event, TC *Hamish* (March 2009), and two historical events, TC *Justin* (March 1997) and TC *Larry* (March 2006).

TC *Hamish* was a unique event due to its severity (Category 4/5) and extensive path over emergent reef structure of the GBRWHA. Rather than cross the Queensland east coast in an east to west fashion as most cyclones do, TC *Hamish* approached the coast northeast of Bowen where it first crossed into the emergent reef structure, turned southeast and tracked neatly through the southern section of the GBRWHA (Figure 3.1). In spatio-termporal context, Hamish formed in the Coral Sea on 5 March 2009 and dissipated five days later northeast of Fraser Island.

TC *Justin* was also a unique storm, though in this case for an extended life of 24 days that saw the system track erratically through the Coral Sea (Figure 3.2), though mostly as a Category 1 system. The system spent 18 days in the Coral Sea before finally crossing the Queensland coast near Cairns. *Justin* then tracked back to the southeast and across inner waters of the GBRWHA before dissipating in the Coral Sea on 27 March.

TC *Larry* was an event with a more standard behaviour, having a short life (three days) and an east to west movement that saw the system cross the coast near Innisfail (Figure 3.3). The uniqueness of TC *Larry* was its intensity, Category 4, a category of cyclone that not often makes landfall on the Queensland east coast.

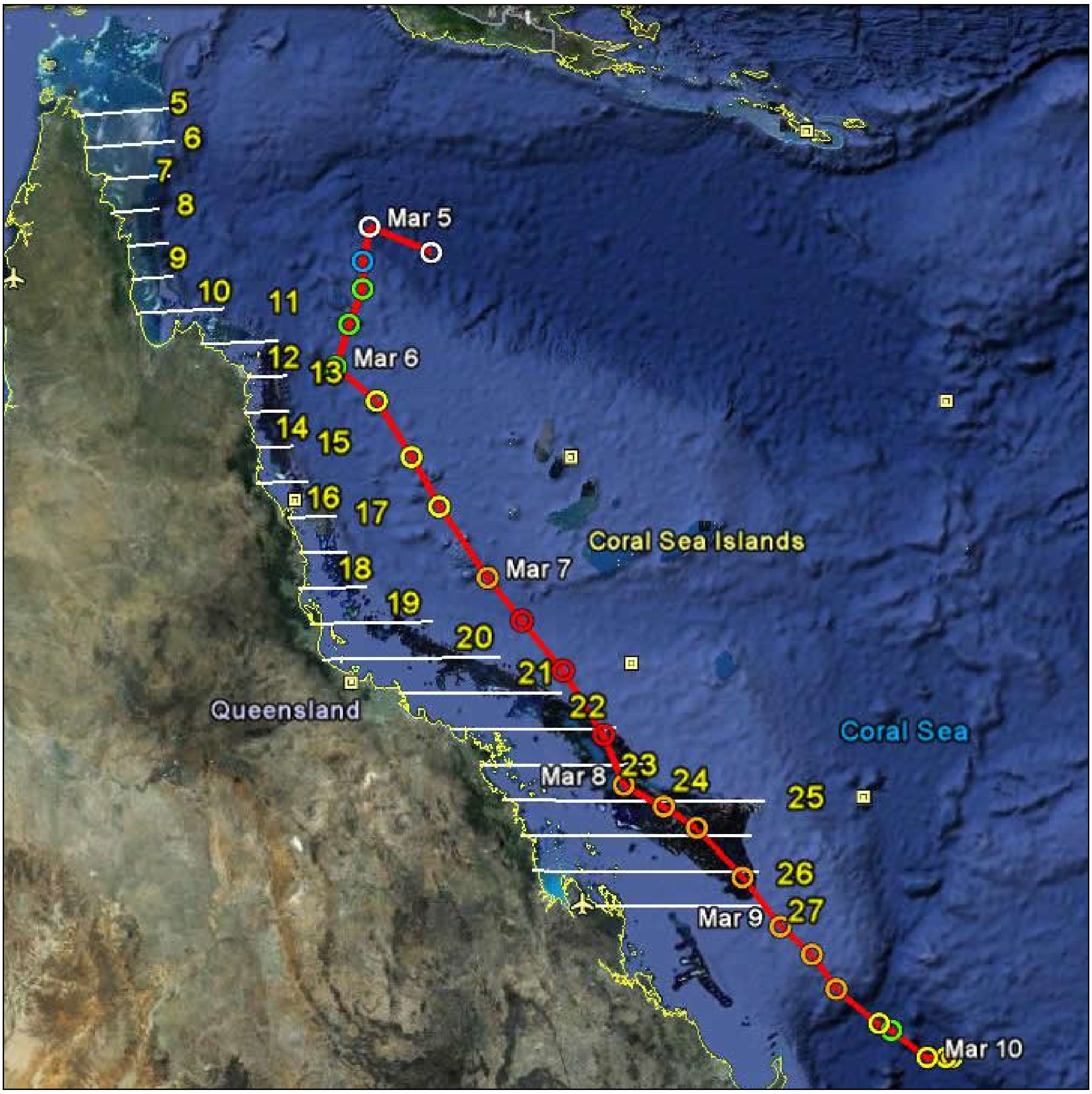


Figure 3.1. The path, intensity and duration of Tropical Cyclone *Hamish*, March 2009, overlaid on the structure of the Great Barrier Reef and the fishery reporting grids of commercial fishers. Six-hourly recordings of the cyclone's position are shown. Coloured circles represent cyclone category: white = Tropical Low system; blue = Category 1; green = Category 2; yellow = Category 3; orange = Category 4; red = Category 5.

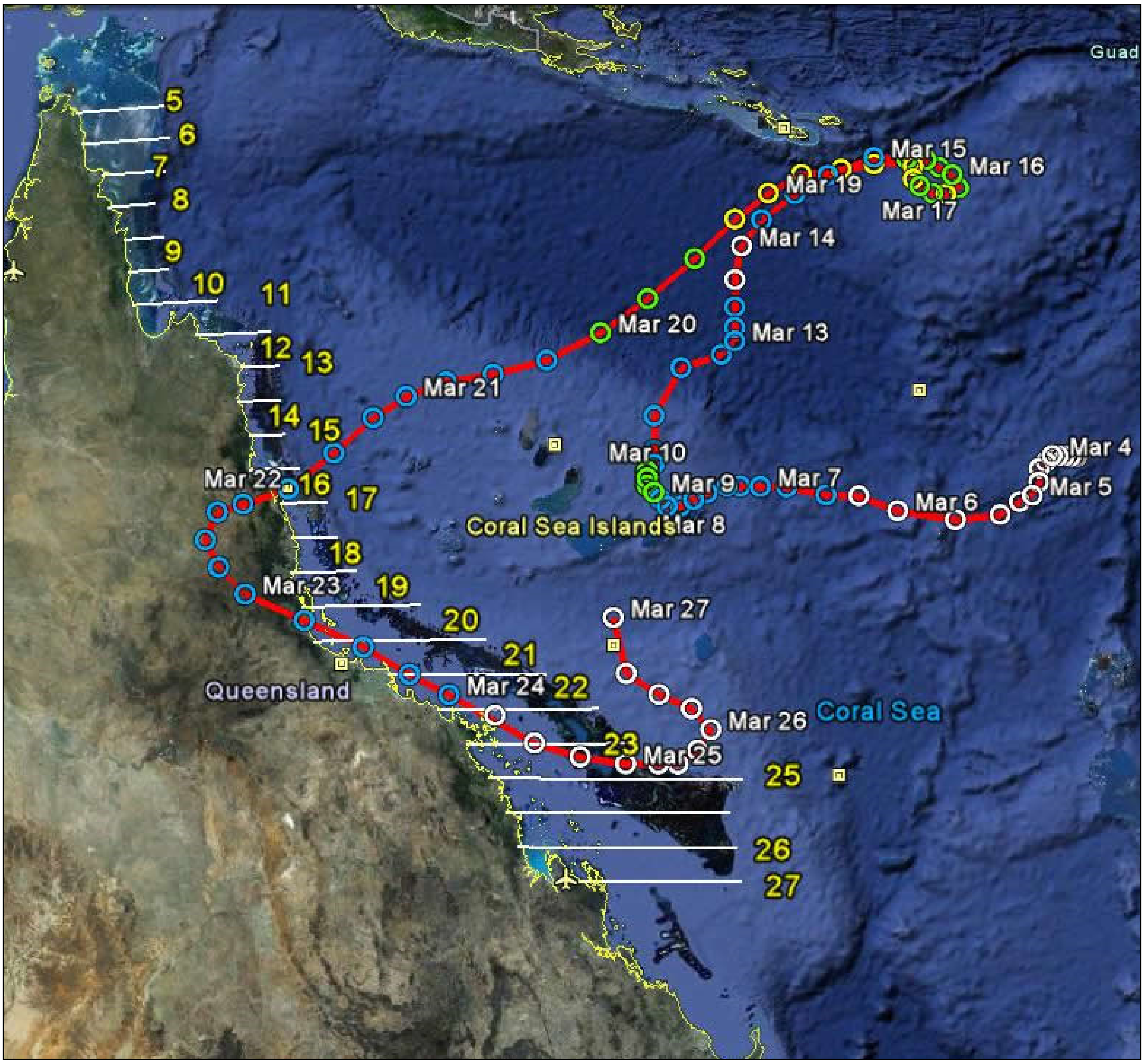


Figure 3.2. The path, intensity and duration of Tropical Cyclone *Justin*, March 1997, overlaid on the structure of the Great Barrier Reef and the fishery reporting grids of commercial fishers. Six-hourly recordings of the cyclone's position are shown. Coloured circles represent cyclone category: white = Tropical Low system; blue = Category 1; green = Category 2; yellow = Category 3; orange = Category 4; red = Category 5.

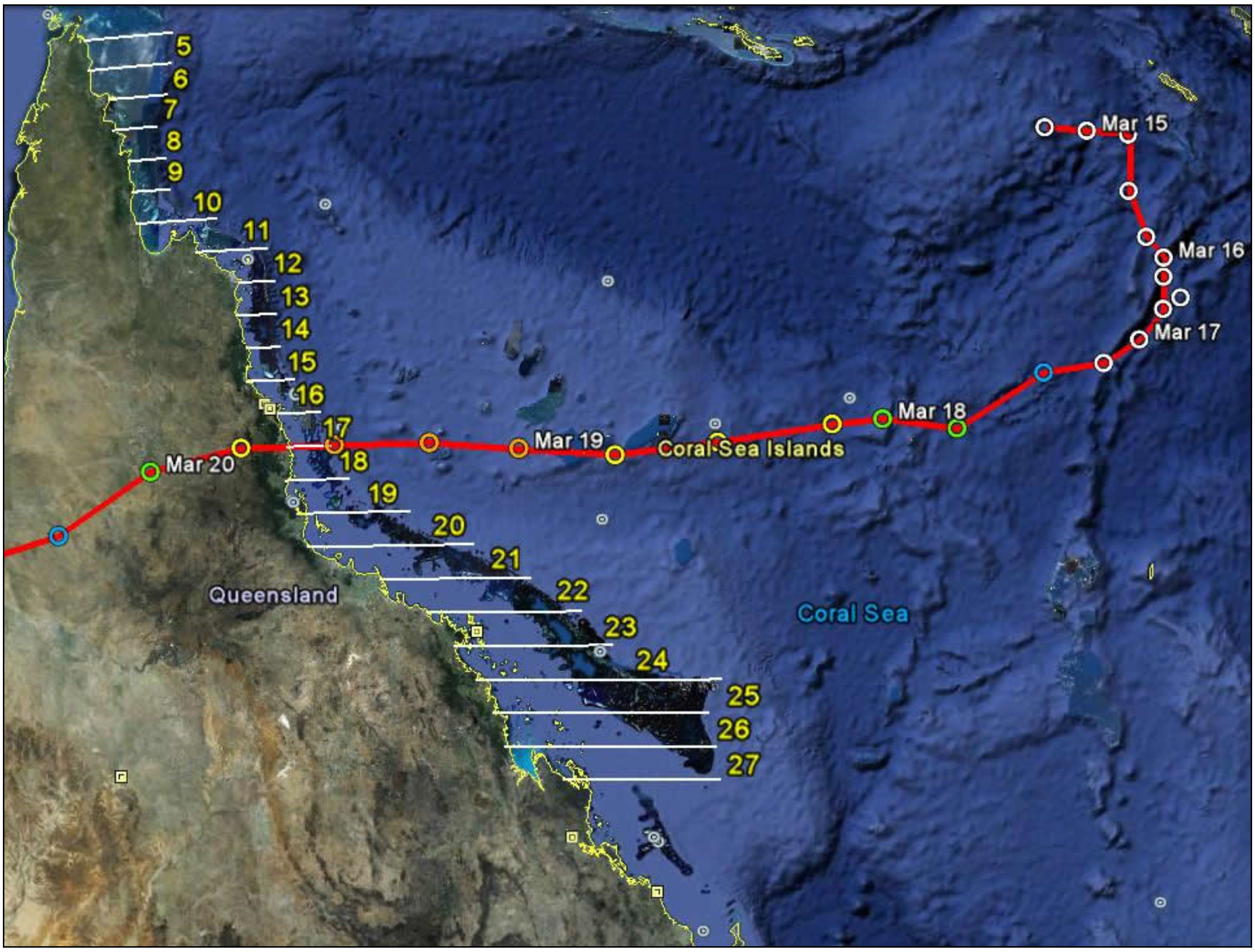


Figure 3.3. The path, intensity and duration of Tropical Cyclone *Larry*, March 2006, overlaid on the structure of the Great Barrier Reef and the fishery reporting grids of commercial fishers. Six-hourly recordings of the cyclone's position are shown. Coloured circles represent cyclone category: white = Tropical Low system; blue = Category 1; green = Category 2; yellow = Category 3; orange = Category 4; red = Category 5.

3.2.2 Commecial fisher logbook records

Initial focus of this research was to document the real-time reaction of catch rates within the commercial sector of the CRFFF to the impact of TC *Hamish*, March 2009. To do this, data from the commercial fishery was initially collected directly from individual commercial fishers' logbooks due to the time lag issues associated with sourcing data through the Fisheries Queensland (FQ) logbook database. Initial collection of data directly from individual fishers' logs and subsequent analysis indicated large spatial scale coverage of detrimental impacts on the catch rates of at least the two dominant species, coral trout and red throat emperor. The extent of the spatial coverage of impact, determined that the most robust approach for investigating, analysing and describing the impacts of TC *Hamish* on catch rates and catch composition of the CRFFF would be to analyse the entire and complete fishery logbook dataset. In recognition that the lag period between fishers recording their daily catches within logbooks, supply of logbook copies to FQ, entry of data by FQ staff into the primary database, extraction of that data from the database and supply to an independent third party (FFRC) for analysis and description; the analysis of commercial fishery data switched focus to an investigation of the validity of anecdote reporting similarly depressed catch rates associated with the historical event of TC *Justin* (March 1997). At a time when a complete database for the entire timeframe of interest (1 January 1994 to 31 December 2009) was available, the research team returned their attention to TC *Hamish*.

Pre-analysis data handling

Data sourced through the compulsory logbook program via the FQ database required significant pre-analysis interpretation and treatment. An *a priori* determination was made that the most informative data point was that of kilograms of catch per tender per day fished. Previous reporting and utility of catch-per-unit-effort (CPUE) for the CRFFF by FQ has included erroneous use of CPUE calculated at the primary vessel level (eg: PMS Anon, 2008). This approach is nonsensical as primary vessels in the fishery have varied fishing capacity and may operate between 0 and 8 attendant tenders. The fishing power of a vessel operating within the CRFFF is directly linked to the number of attendant tenders from which fishing occurs. Further, commercial fishers themselves will discuss catches in this standardized form. In acknowledging the need of the analysis and resultant outputs to be in a form that ensures statistical validity and robustness in examining spatiotemporal trends of tropical cyclone impacts, as well as presenting data in a form that is easily identifiable and interpretable by commercial fishers and other stakeholder groups, standardizing the logbook catch data at the kilograms per tender per day level was the priority task once the data was received from FQ.

Interrogation of commercial catch data sourced from the FQ primary database is complicated by a lack of appropriate effort fields for each catch field that is recorded in the primary database. To achieve standardised data, two FQ databases were required to be married. Database A recorded acceptable catch descriptors that were recorded against course level effort descriptors, but critically no record of the numbers of tenders fishing each day from the primary vessel. Finer scale effort information (in particular, tenders fished per day) is not recorded with the catch descriptors in the FQ primary database (A), though indirectly recorded in database B that keeps track of the number of tenders attached to each primary license throughout the history of individual licenses' structure. As tenders are tradable between primary licenses, database B keeps record of tender movements between primary licenses.

To calculate the standardised CPUE data, the appropriate fields within database A and B were married to produce a single line of catch and effort information for each primary license for each day fished. For example, database A may record the date, location and kilograms of catch of coral trout and red throat emperor, however no record of the number of tenders fishing. A necessary assumption was required that every tender legally attached to that license on that date (as recorded in database B) actually fished. From this marriage of databases, daily CPUEs were then calculated for each quota / species group reported in the CRFFF compulsory logbooks; coral trout (CT), red throat emperor (RTE) and other coral reef species (OS).

Spatial and temporal aggregation of data

Due to the enormity of the working database, between 12,000 and 18,000 daily catch records for primary fishing vessels have been recorded each year between 1994 and 2009 (inclusive) in combination with a spatial distribution across 22.5° of latitude, grouping data into manageable units within both time and space was mandatory. In grouping this data, the process was mindful of not compromising the resolution required to elucidate the effects of tropical cyclones on the CRFFF if they did if fact occur.

Spatial effort is recorded by fishers at sea with catches recorded within 30 nm^2 grids. Given there are 65 such grids spanning the emergent reef structure of the CRFFF area, individual 30 nm^2 grids were grouped within each 0.5° band of latitude (Figure 3.1), from here on termed a fishery 'grid'. The grouped catch and effort information are herein reported at the cumulative grid level. For example the five individual 30 nm^2 catch grids (R25, S25, T25, U25, V25) that are longitudinal neighbours within the 0.5° of latitude 20°00 and 20°30 S, are cumulatively reported as 'grid 25' (Figure 3.1).

Following an intensive period of descriptive statistic and trend searching, grouping data at the spatial scale of latitudinal fishery grid and temporal scale of month, presented the data in a format sufficient to describe spatiotemporal trends in CPUE and catch composition data while remaining logistically feasible and analysable.

3.2.3 Recreational and charter fish data via CapReef

The recording of accurate catch and effort information for recreational fisheries is recognised as a global problem (McPhee *et al.* 2002; Cooke and Cowx, 2006), largely due to the eclectic nature of the individual participants and their diverse motivations for undertaking fishing as a recreation. CapReef is a community run monitoring program based in the Capricornia region of the Great Barrier Reef (approximately bounded by the latitudes 19.26 and 19.28), whose primary goal is collecting catch and effort information from recreational fishers. This dataset is being accumulated to better understand the dynamics of this fishery sector, and how management, anthropogenic or environmental factors may impact on fisheries resources utilized by the recreational fishing sector. Recreational fisher catch and effort information for the period 2006 to 2009 (inclusive) were supplied to the project for inclusion in analyses and interpretation.

3.2.4 Sea-surface temperature (SST) data

Sea surface temperature data was initially sourced through the Australian Institute of Marine Science (AIMS) permanent weather stations (http://www.aims.gov.au/docs/data-centre/weatherstations.html) that monitor water temperatures at various depths on some select emergent reefs within the GBRWHA. However due to significant time gaps in data availability of the AIMS data, satellite derived SST was sourced through the CSIRO (see Griffin *et al.* 2005 for data description).

3.3 Data Analysis

3.3.1 Commercial fishery – catch rates, total catch, effort

All exploratory graphing, statistics and analyses were conducted using the S PLUS statistical package. Initially, annual trends in CPUE, total landed catch and total effort for the three major catch reporting groups (CT – coral trout, RTE – red throat emperor, and OS – other reef species) were investigated via graphical interpretation of mean annual and mean monthly CPUE values fitted with a smoothing spline (df = 6) function. This initial broad level investigation allowed for a qualitative identification of years were catch rates appeared anomalous, and these anomalous years referenced against cyclone presence or absence.

Where specific analysis of catch rate (CPUE) and fishery effort changes in response to cyclones were conducted, two-way full factorial analysis of variance explored the effects of stage (pre-cyclone and cyclone,) and seasonality (month) on mean monthly CPUE, total catch and total effort. Although the descriptive graphical presentation of TC *Justin* effects include pre-cyclone, cyclone and post-cyclone periods, statistical analysis of the impacts of TC *Justin*, *Larry* and *Hamish* on the catch rates and characteristics addressed pre-cyclone and cyclone stages only. The graphical presentation of all three stages for TC *Justin* allowed for some visual interpretation of the temporal extent of effects where they were identified

As the commercial sector of the CRFFF incorporates some part-time participants as well as dedicated full-time fishers, all analyses of commercial sector data included a ‘whole of fishery’ assessment as well as an ‘active boats’ assessment. This approach was adopted to ensure that the effort and catch characteristics of part-time fishers did not interfere with the appropriate analysis and description of tropical cyclone impacts on dedicated CRFFF participants. An arbitrary decision tool was used to identify 'active boats' as any vessel landing at least 1,000 kgs of coral trout per year for each year of the temporal context of that analysis.

For each analysis combination of cyclone and fishery statistic (e.g. TC *Justin* * Coral trout CPUE), bonferroni correction was applied to adjust the significance value and reduce type II errors. Further, where the interaction terms were uninformative ($p > 0.25$) (Winer *et al.* 1992), the term was removed from the analysis to increase the power of tests of the primary factors of interest (stage, season). The season term was included in all analyses, in recognition that seasonal variation in fishery performance may confound the abilities of the analyses to detect cyclone (stage) effects when they occur.

3.3.2 Recreational and charter fisheries

Unfortunately, the reliability of CPUE data was considered via expert opinion to be insufficiently robust due to unacceptable levels of uncertainty in effort measures. Accordingly, this data set was analysed for catch composition characteristics only (see Section 3.3.3).

3.3.3 Fishery catch composition

To determine if any shifts in species composition of catch occurred as a result of cyclone impacts, differences in catch composition between years and seasons were investigated using non-parametric multivariate analyses from the PRIMER package (Clark and Warwick, 1994), as well as standard chi-square analyses.

Commercial Fishery Catch Composition

TC *Justin*: Only three species groupings (CT – coral trout; RTE – red throat emperor; OS – other reef species) were definable for the analysis of TC *Justin* impacts on the catch composition of the commercial fishery due to the inaccuracy of how other reef species where recorded in logs. Data from the three pre-cyclone years (1994, 1995, 1996), as well as the cyclone year (1997) were grouped into nominal seasons: spring (March, April, May), winter (June, July, August), spring (September, October, November) and summer (December, January, February). This nominal grouping was considered most appropriate as the ability to detect changes where they occurred would not be compromised by March being included in a nominal season that included pre-cyclone months (such as February, March, April).

TC *Hamish*: Five species groupings (CT – coral trout; RTE – red throat emperor; REM – red emperor; SNA – reef snappers/lutjanids; SPE – spangled emperor) were possible for the analysis of TC *Hamish* impacts on the catch composition of the commercial fishery due to improvements during this time period in species specific log book recordings. Again, data from three pre-cyclone years (2006, 2007, 2008) as well as the the cyclone year (2009) were grouped into the same nominal seasons.

Recreational Fishery Catch Composition via CapReef

TC *Hamish*: The accuracy of species specific catch recording allowed seven species or species groups to be identified: BCT – bar cheek trout; CCT – common coral trout; RTE – red throat emperor; REDS – small and large mouth nannygai; REM – red emperor; HUS – hussar; SPE – spangled emperor. To complete a robust analysis, catch composition of three years prior to TC *Hamish* (2006, 2007, 2008) were compared against the cyclone year (2009). Due to a paucity of reef fish data during summer and autumn months, only winter months (June, July, August) of each year were included in analyses.

Data sets were fourth-root transformed and standardised before testing season and/or year influenced the proportions in which coral reef fish were represented in retained catches. Bray-Curtis similarity matrices were generated and seasonal and annual effects assessed visually with non-metric multidimensional scaling (nMDS) generating two-dimensional ordination plots. The *a priori* hypothesis that catch composition would not vary in response to cyclone impacts was tested with two-way (*year* * *season*) analysis of similarities (ANOSIM). Significance or dissimilarity was measured by Global R values ($R < 0.05$), and the species responsible for any identified dissimilarity revealed by similarity percentage analyses (SIMPER).

3.3.4 Sea-surface temperature

To allow valid comparisons between the CPUE trends and SST trends, analyses were performed at the same spatiotemporal scale. The analysis of SST did however focus on the identity of anomalous events, particularly as Schillier *et al.* (2009) served as an *a priori* warning that a significant cool water anomaly accompanied the presence of TC *Justin* in March 1997. Although Schillier *et al.* (2009) identified the presence of a cool water anomaly the spatiotemporal characteristics of the event were not defined. With this background, the potential presence of anomalous SST events correlating with cyclone years were investigated by treating the SST patterns of the three years prior to cyclone passage as indicative of usual or average SST patterns, against which the presence or absence of anomalous temperature events in the cyclone years was investigated.

3.4 Results

3.4.1 Prelude

The mass of analyses completed in determining trends in commercial catch data in particular necessitated the use of tabulated summaries of statistical outputs that were easily interpretable by a broad range of stakeholders. Two project progress workshops (reported in Appendices 4 and 5) presented preliminary analysis outputs in formats mirrored here in this final project report.

3.4.2 Broadscale visual assessment – commercial catch data

Initial spatio-temporal exploration of monthly CPUEs (grouped by year) via descriptive graphical methods revealed some marked though nominal responses of mean monthly CPUE of both CT and RTE in response to TC *Hamish* (March 2009) and *Justin* (March 1997), though no clear impact of TC *Larry* (March 2006). Figure 3.4 demonstrates a clear visual signal of downward trends in monthly CPUE of coral trout in both 1997 and 2009, years of TC *Justin* and *Hamish* influence respectively, within some fishery grids. Outside of these years, fishery performance appears relatively stable. Similarly, Figure 3.5 demonstrates some clear visual signals of upward trends in monthly CPUE of RTE in both 1997 and 2009, years of TC *Justin* and *Hamish* influence respectively. Again outside of these years, fishery performance appears relatively stable. In the case of TC *Larry*, no clear trend is evident across multiple fishery grids as is the case with TC *Justin* and *Hamish*. However, coral trout catch rates show a slight depression in grid 17, 2006; and red throat emperor catch rates show a slight increase across grids 17, 18, 19 in 2006 (Figures 3.4 and 3.5 respectively).

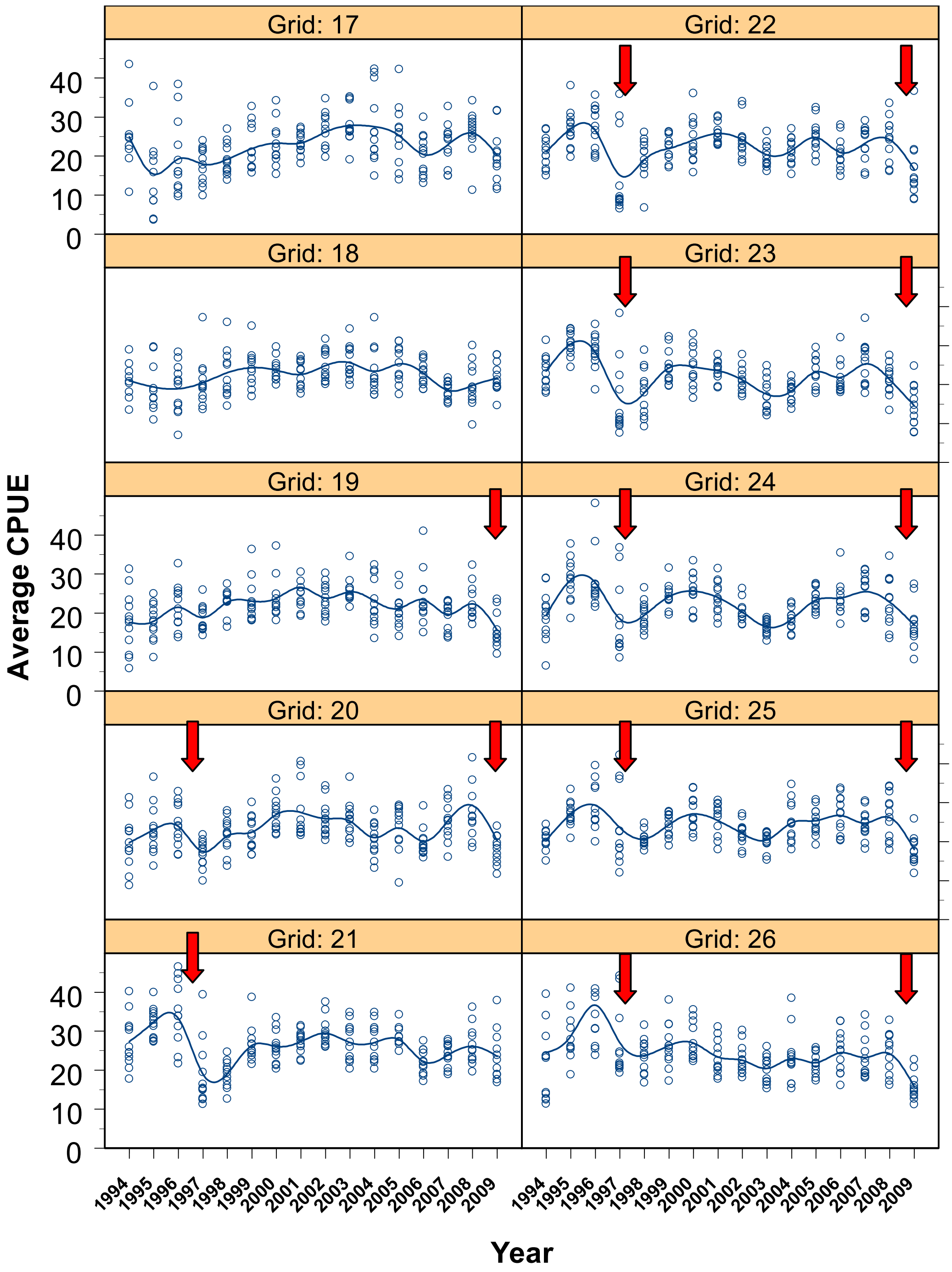


Figure 3.4. Monthly CPUE for **coral trout** throughout the complete time series of database investigated and interrogated (1 January 1994 to 31 December 2009), grouped by year for each fishery grid of the CRFFF. Smoothing splines are fitted to the data with ten degrees of freedom. Negative though nominal impacts of Tropical Cyclones *Justin* (March 1997) and *Hamish* (March 2009) are observable in some grids as highlighted by the arrows.

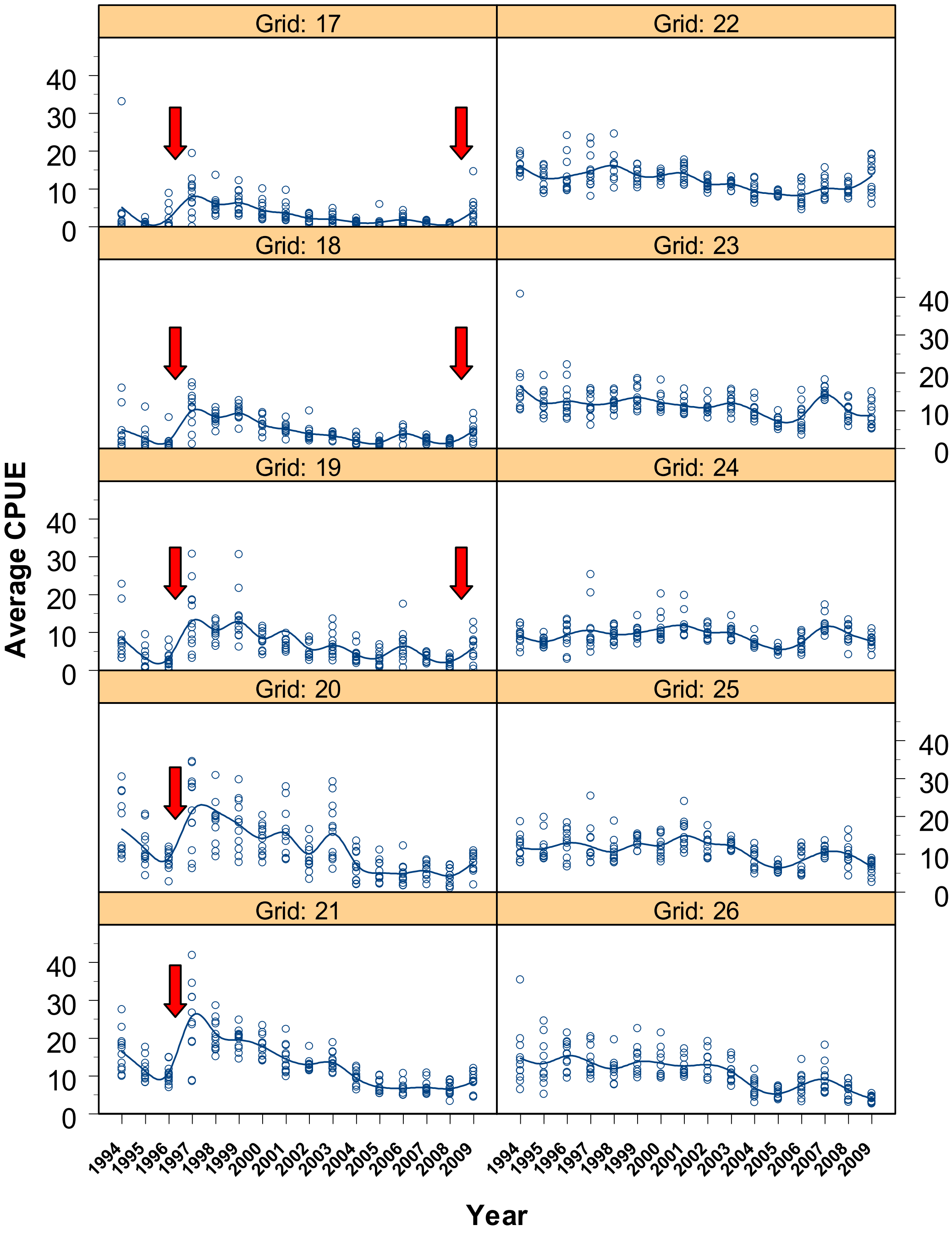


Figure 3.5. Monthly CPUE for **red throat emperor** throughout the complete time series of database investigated and interrogated (1 January 1994 to 31 December 2009), grouped by year for each fishery grid of the CRFFF. Smoothing splines are fitted to the data with ten degrees of freedom. Negative though nominal impacts of Troical Cyclones *Justin* (March 1997) and *Hamish* (March 2009) are observable in some grids as highlighted by the arrows.

3.4.3 Tropical Cyclone *Justin* – Impacts on catches and catch composition

Commercial fishery – broadscale patterns

Clearer indications of TC *Justin* impacts on the performance of the CRFFF were evident when descriptive data summarisation and visual graphical interpretation was undertaken for yearly average CPUE and landed catch of both CT and RTE across fishery grids 17 to 27 (inclusive). Figures 3.6 and 3.7 represent annual mean CPUE and total landed catch for coral trout and red throat emperor respectively.

Figure 3.6 demonstrates substantially depressed CPUE for coral trout occurred across numerous fishery grids in the year TC *Justin* impacted (1997), and was more evident in 'active' tender effort than all tender effort. Correspondingly, landed catch volumes were also reduced across numerous grids (Figure 3.7) and again more evident for volumes of coral trout landed by 'active' tender effort compared with all tender effort. Interestingly, average annual CPUEs were lower in post-cyclone (1998, 1999, 2000) years as compared with pre-cyclone (1994, 1995, 1996) years, likely reflecting the changing targeting behaviour of the fleet as more vessels preferentially targeted live coral trout.

Figure 3.7 demonstrates substantially increased CPUE for red throat emperor occurred across numerous fishery grids in the year TC *Justin* impacted (1997), though notably these increased CPUEs occurred in different fishery grids than the depressed coral trout CPUEs. The CPUE of red throat emperor was relatively unchanged within those fishery grids that demonstrated depressed coral trout CPUEs. Although CPUEs of red throat emperor were relatively unchanged in fishery grids 22, 23, 24 the landed volumes of catch in these grids were noticeably lower in 1997. Interestingly, landed volumes of red throat remained higher in post-cyclone years as compared with pre-cyclone years, most notably in northern fishery grids.

Figure 3.8 demonstrates a strong reaction of fishing effort in response to the changed harvest rates experienced following TC *Justin*. Most notably in the active vessels within the fleet was a movement away from fishery grids 22, 23, 24 with a concomitant increase in effort in more northern and southern fishery grids.

No obvious trends in harvest rates or volumes of the 'other reef species' group were evident, and no graphical representation is shown.

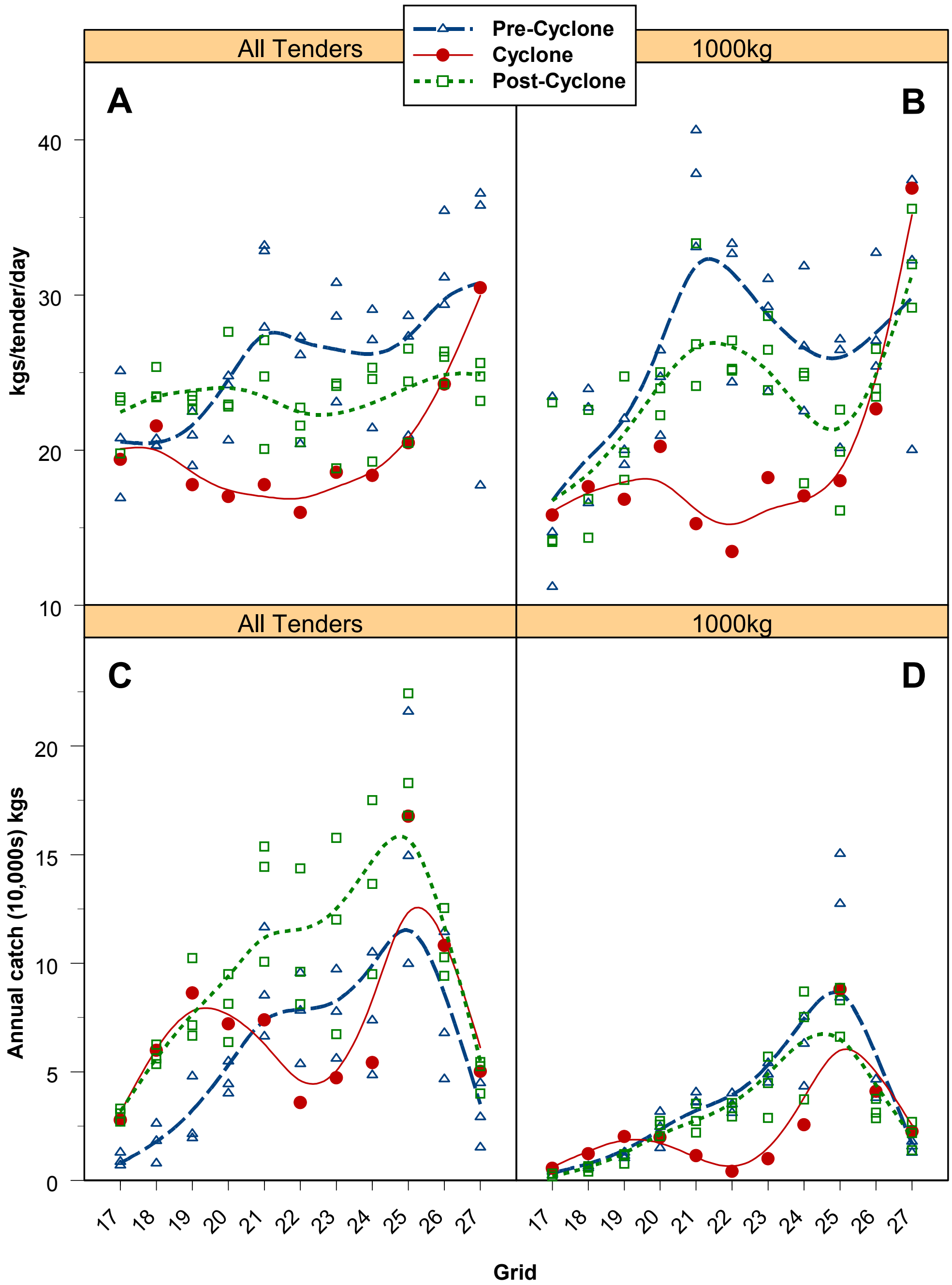


Figure 3.6. Coral trout annual CPUE and landed catch for all tenders and 'active' tenders within the commercial sector of the CRFFF. CPUE trends across fishery grids and through time are shown for (A) all tender effort; and (B) 'active' tender effort. Landed catch trends across fishery grids and through time are shown for (C) all tender effort; and (D) 'active' tender effort.

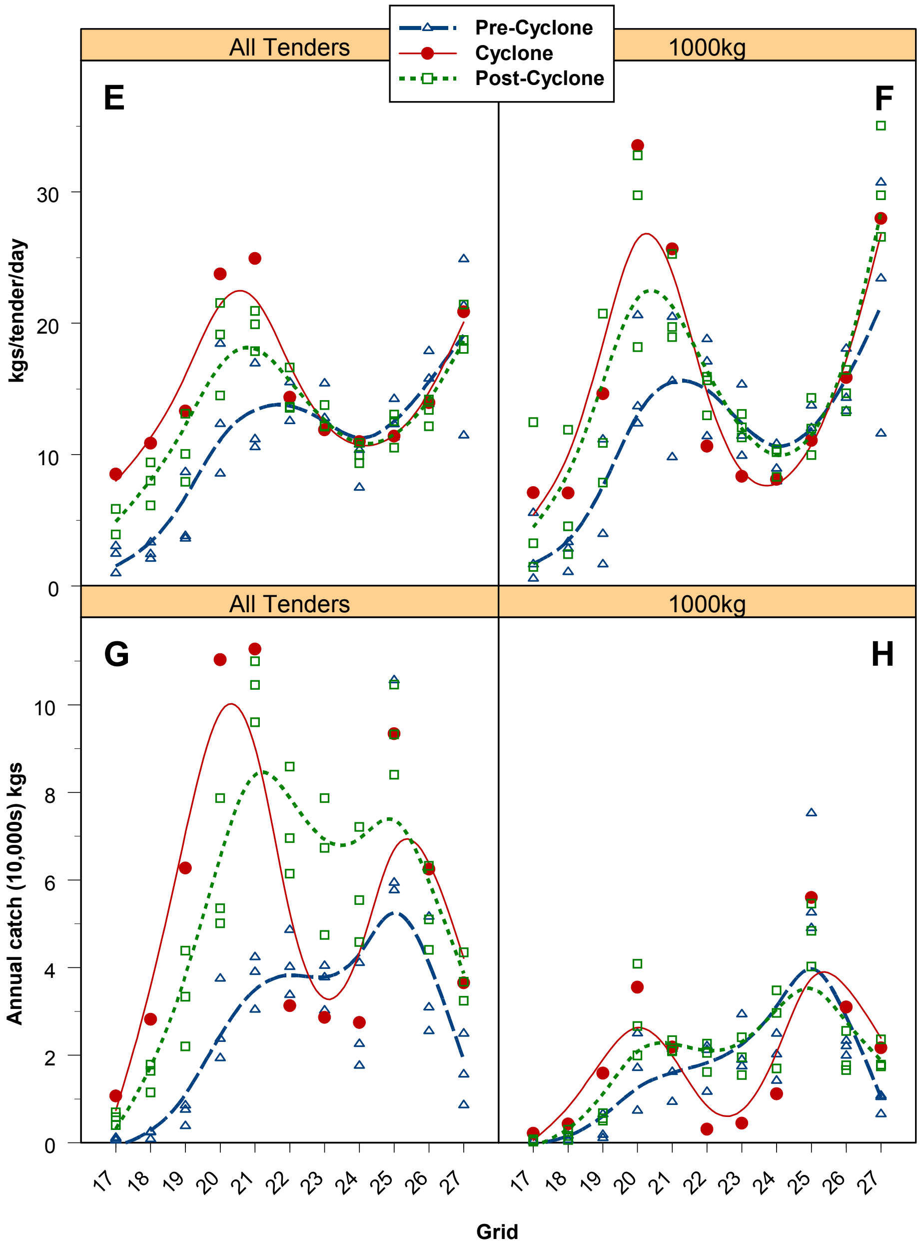


Figure 3.7. Red throat emperor annual CPUE and landed catch for all tenders and 'active' tenders within the commercial sector of the CRFFF. CPUE trends across fishery grids and through time are shown for (E) all tender effort; and (F) 'active' tender effort. Landed catch trends across fishery grids and through time are shown for (G) all tender effort; and (H) 'active' tender effort.

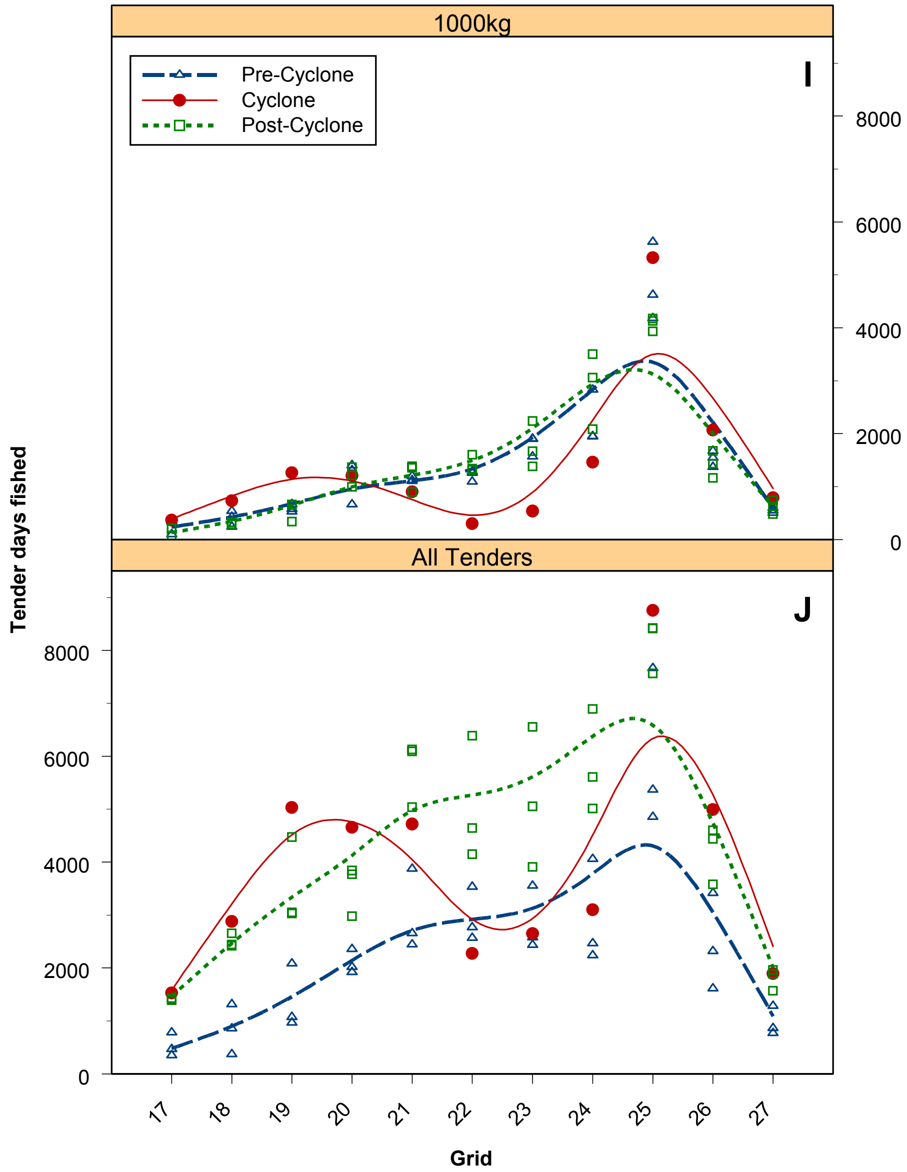


Figure 3.8. Annual days for (I) 'active' tender; and (J) all tender effort within the commercial sector of the CRFFF. Annual effort trends among fishery grids and through time are shown.

Commercial fishery – finescale patterns

Finer scale interpretation of the changed catch rates as experienced by the ‘active’ vessels within the fishery is initially demonstrated via visual assessment of average monthly CPUE trends between pre-cyclone (1994, 1995, 1996), cyclone (1997) and post-cyclone years (1998, 1999, 2000) for coral trout (Figure 3.9) and red throat emperor (Figure 3.10). The patterns in catch rates through these times periods are overlaid with identified cool water anomalous events that impacted some areas of the emergent coral reef structure in 1997. Significance of the changed catch rates and location of effort are summarised in Table 3.1, for both the active fishery and whole fishery.

Coral trout

For the active fishery, notable depression of coral trout catches rates were observed (Figure 3.9) in fishery grids 21, 22, 23, 24 with analysis demonstrating these impacts to be significant and resulting in a maximum depression of 1997 CPUE of 56.4% (grid 22) compared with reference years (1994, 1995, 1996) CPUE (Table 3.1). With the exception of fishery grid 18, the 1997 CPUEs for both the whole and active fishery subcomponent were either nominally or significantly depressed across all grids (Table 3.1).

Notably, the fishery grids where CPUE was significantly depressed were not evenly impacted by the anomalous cool water event. In fishery grid 20 where the temporal extent of the cool water was most evident (two-month duration) no concomitant depression of coral trout CPUE was observed. Further, those fishery grids where depressed catch rates did temporally align with the cool water anomaly, the depressed CPUEs were much more temporally sustained than the cool water event (only one month duration). Similarly, only three of the fishery grids where significant depressions of CPUE were detected (Table 3.1) were within the path of TC *Justin*.

On the basis of annual CPUE averages, grids 21, 22 and 23 sustained at least 50% reductions (Table 3.1) in 1997 compared with pre-cyclone years (1994, 1995 and 1996). From visual interpretation of Figure 3.9, the temporal extent of the reduced CPUEs was at least nine months, a period considerably longer than immediate effects of cyclone influence.

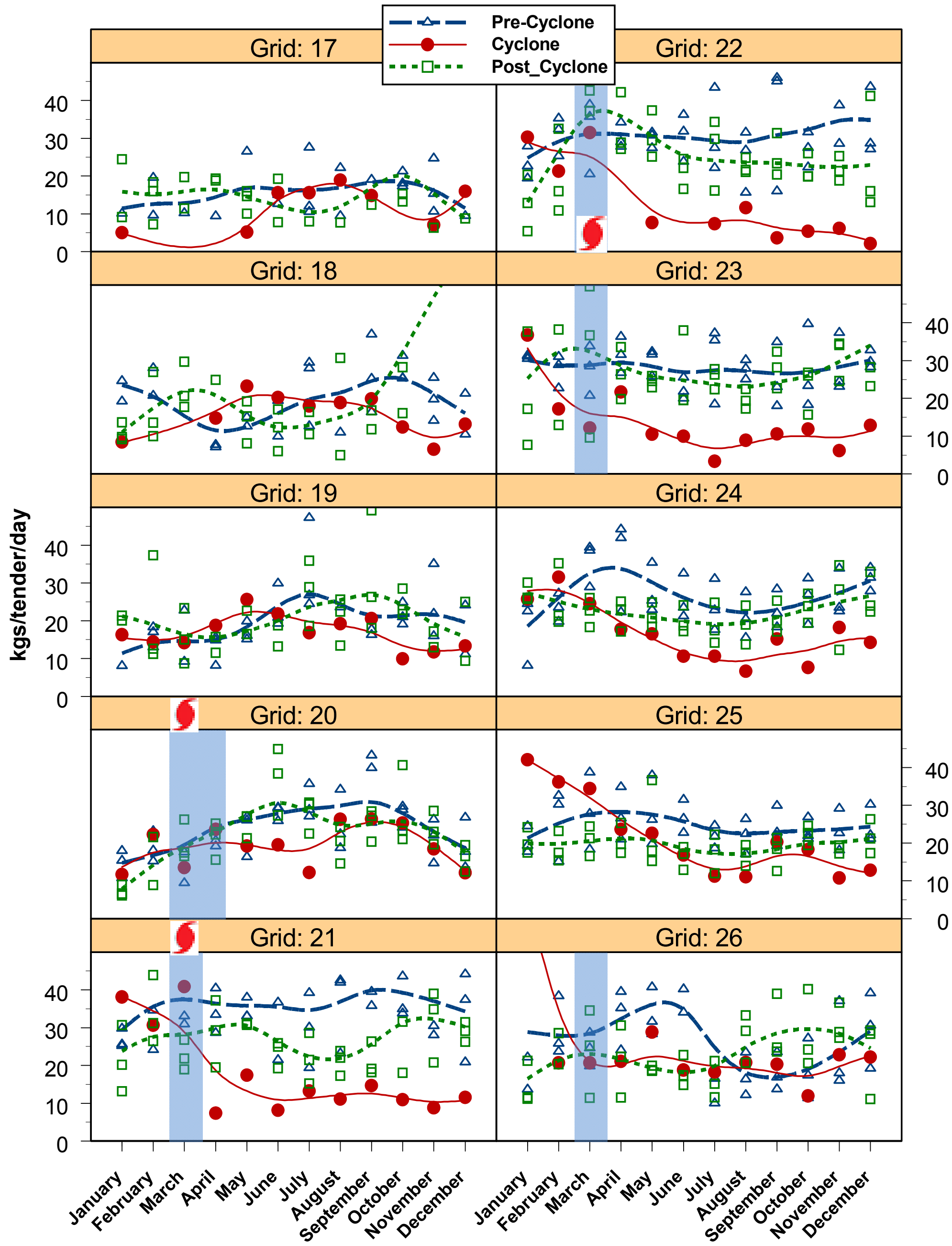


Figure 3.9. Monthly average CPUE for **coral trout** taken by 'active' fishery effort. Pre-cyclone, cyclone and post-cyclone trends are demonstrated for each grid with smoothing splines (df = 6). Location and duration of cool water anomalies are identified with shading, and fishery grids within the cyclone path indicated by the symbol .

Table 3.1. Diagrammatic representation of the significant effects of Tropical Cyclone *Justin* on coral trout, red throat emperor and 'other species' catch rates as well as effort in the fishery. The analysis treated years 1994, 1995 and 1996 as standard or average years of catch and effort against which 1997 was compared. From this comparison, the symbol ▼ represents significant decreases in catch rates or effort, while the symbol ▲ represents significant increases in catch rates or effort and the empty symbols represent nominal changes. Analyses were completed for all data as 'whole' fishery and for only 'active' boats (top 59) within the fishery.

Fishery Grid	Coastal Township	Coral trout		Red throat emperor		Other species		Fishery effort	
		Whole	Active	Whole	Active	Whole	Active	Whole	Active
17	Cairns (south)	▽ 7.9	▽18.6	△166.4	△114.1	▲130.8	△ 4.1	▲157.8	△27.5
18	Mission Beach	△ 5.6	▽16.2	▲223.0	▲139.9	▽ 5.9	△22.6	▲201.1	△54.2
19	Cardwell	▽ 3.2	▽12.2	▲175.5	△219.7	△111.7	▲172.3	▲266.6	▲94.4
20	Ingham	▼24.2	▽20.0	▲80.4	▲114.9	▲72.8	△87.9	▲122.0	△ 7.1
21	Townsville	▼40.4	▼50.7	▲110.0	▲112.7	▲105.2	▲80.8	▲57.8	▽20.7
22	Bowen (north)	▼42.2	▼56.4	△ 4.4	▽37.6	△ 6.6	△94.4	▽23.1	▼61.4
23	Bowen (south)	▼42.4	▼52.1	▽15.4	▽44.6	△51.3	▽11.8	▽ 7.1	▼69.9
24	Mackay(north)	▼28.2	▼37.4	△100.0	▽ 7.2	▲72.5	△ 2.3	△ 6.2	▽34.8
25	Mackay(south)	▽ 8.4	▽11.9	▽0.04	▽ 6.0	△34.8	△26.1	▲46.9	△10.8
26	Carmilla	▽11.5	▽ 5.9	▽ 5.8	△14.9	▲267.6	▲79.8	▲103.8	△35.0
27	Broad Sound	▽ 3.1	△28.5	△13.0	△56.8	△77.6	▽22.7	▲91.0	△47.9

Red throat emperor

For the active fishery, notable increased red throat emperor CPUEs were observed (Figure 3.9) in fishery grids 18, 19, 20, 21, with analysis demonstrating most of these impacts to be significant (Table 3.1). Each of the significant increases in CPUE were at least double (>100%), the CPUE recorded for the reference years (1994, 1995, 1996). Further, although a non-significant increase in CPUE was found for grids 17 and 19, the nominal increases in both these grids were substantial (114% and 219% respectively). Given the northern distributional extent of red throat emperor is anecdotally reported to be around Townsville (grid 20), the general infrequent catches of red throat emperor above this area is likely to be responsible for a loss of statistical power in analysing CPUE trends through this space.

Again, the positive response of red throat CPUE to TC *Justin* does not appear linked to the presence or absence of the cool water anomaly. The cool water anomaly aligns well with the increased CPUE in grids 20 and 21, but not grids 17, 18, 19. Grids 22 and 23 were also impacted by the cool water anomaly, though CPUEs within these grids were nominally depressed (Table 3.1).

Notably, although some nominal depression of red throat emperor CPUE was recorded (grids 22, 23, 24, 25) (Table 3.1), no significant CPUE depressions were recorded.

Seasonal significance was detected in grids 20, 21, 25 though could only be clearly visually interpreted in grids 20 and 21 (Figure 3.10). These seasonal effects made it difficult to visual interpret the temporal extent of the increased CPUEs detected, that was possible with coral trout. However, visual interpretation still clearly indicated that red throat CPUEs were consistently higher in cyclone and post-cyclone years as compared with pre-cyclone year. Substantial lag effects of the increased CPUE of red throat emperor may have occurred similarly to the depressed CPUE of coral trout, though interpretation is confounded by seasonal variation of catch rates.

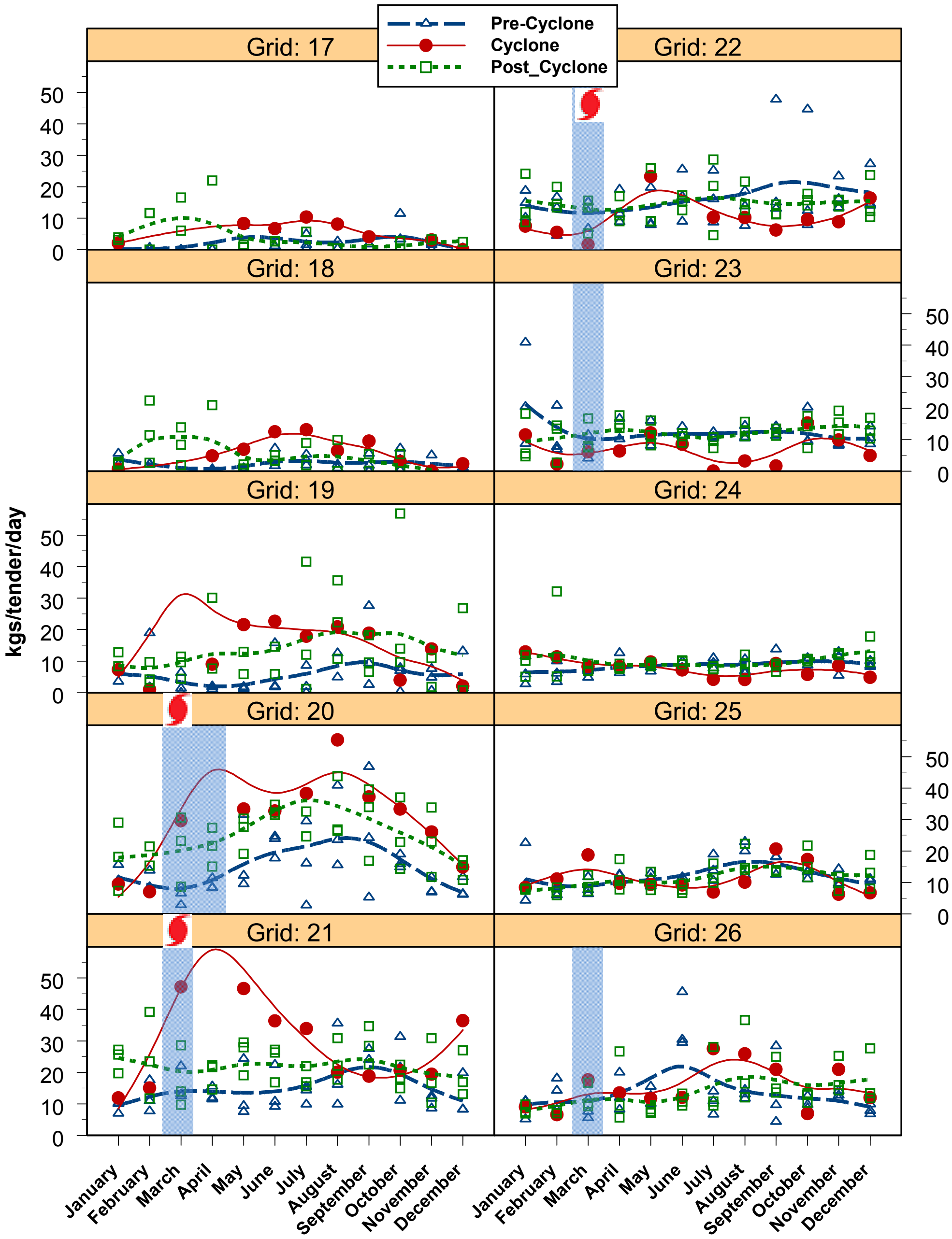


Figure 3.10. Monthly average CPUE for **red throat emperor** taken by 'active' fishery effort. Pre-cyclone, cyclone and post-cyclone trends are demonstrated for each grid with smoothing splines (df = 6). Location and duration of cool water anomalies are identified with shading, and fishery grids within the cyclone path indicated by the symbol

Other species group

Some significant increases in CPUE of the other species group were recorded (Table 3.1), though these effects were not as temporally organised as the effects detected for coral trout and red throat emperor. As the other species group is an eclectic mix of many tens of species captured by the fishery relatively infrequently, interpreting trends in this data is considered folly, with the likelihood of assigning effects where there is likely none (type II error) considered sound reason for not pursuing the outputs further.

Effort patterns

Unsurprisingly, the active boats within the fishery demonstrated a marked avoidance of fishery grids 22 and 23 in 1997, in response to the rapid drop in coral trout CPUE (Table 3.1). This avoidance behaviour was marked enough that not a single tender day of fishing effort was recorded in grid 22 in April and June 1997 (Figure 3.9). Fishing grids where effort increased included – southern grids 25, 26, 27 that received nominally increases in effort; northern grids 17, 18, 20 also received nominally increases in effort; and only grid 19 showed a significant increase in effort. Some effort moved further north into the upper Cape York region, though due to the infrequency of fishing effort within this area (particularly in pre-cyclone years), the statistical significance of this moved effort (and associated catch) was not testable.

Catch composition

Chi-square analysis of catch composition was uninformative with all fishery grids returning a significant effect of year ($p << 0.05$). Graphical representation identified species composition shifts occurring between years where no cyclones were present (Figure 3.11). However, Figure 3.11 does reveal a substantial reduction in the relative landings of coral trout within fishery grids 19, 20, 21 like as the combined result of depressed coral trout catch rates and increased red throat emperor catch rates that were common across these grids (Table 3.1). Further, visual interpretation suggests greater temporal stability of catch composition occurs in southern grids as compared with northern grids.

Non-parametric testing demonstrated catch composition significantly influenced by stage (cyclone presence/absence) only in grouped grids 19-21 (Figure 3.11). In this instance, SIMPER identified that in all years with the exception of 1996, coral trout was the most discriminant species. Interestingly, the other species group was the most similar within the seasons of 1997. Surprisingly, ANOSIM analysis of grouped grids 22-24 that cumulatively recorded the most significant depression in coral trout CPUE and no significant change in red throat emperor CPUE did not return a significant effect of stage on catch composition.

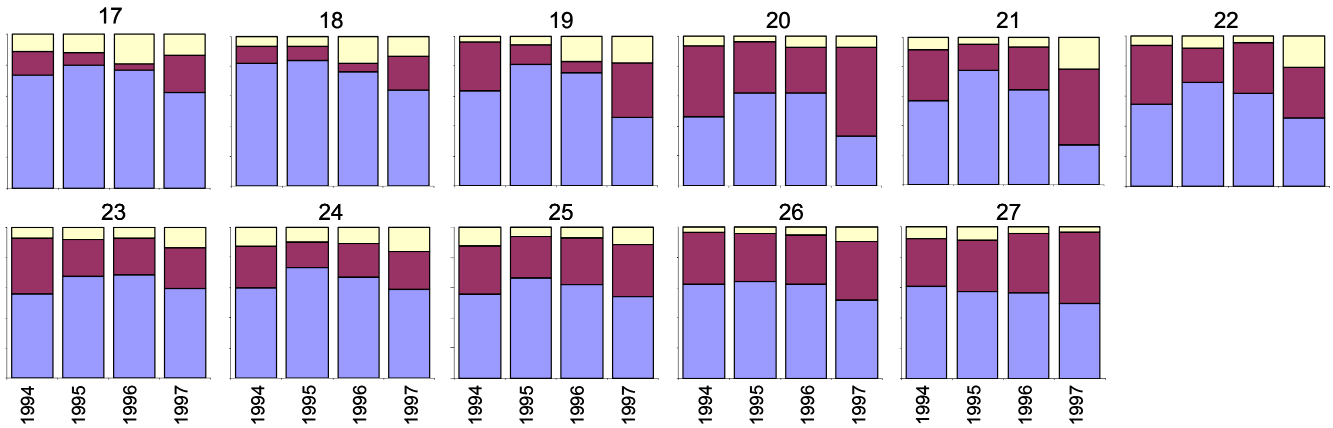


Figure 3.11. Changes in the catch composition of the commercial sector of the CRFFF in response to the impact of Tropical Cyclone *Justin* were explored by examining changes in relative frequency of landed coral trout (purple), red throat emperor (red) and other reef species (yellow). The effect of year on catch composition was significant for all fishery grids (chi-square analysis, bonferroni corrected p = 0.0045).

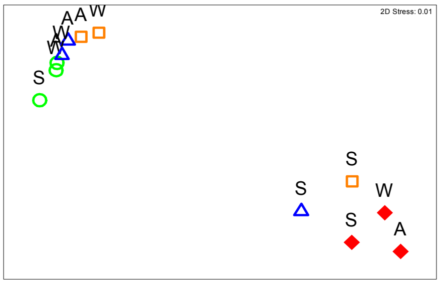
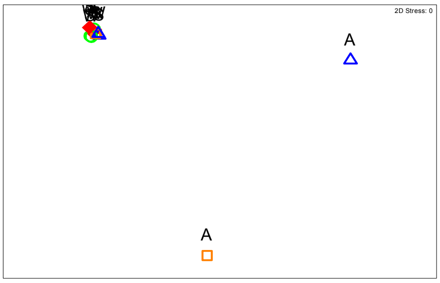
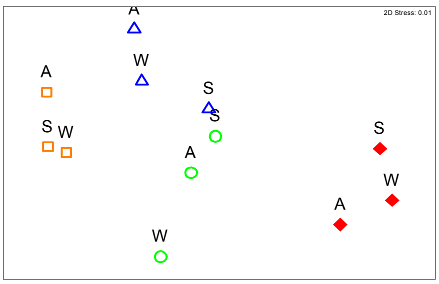
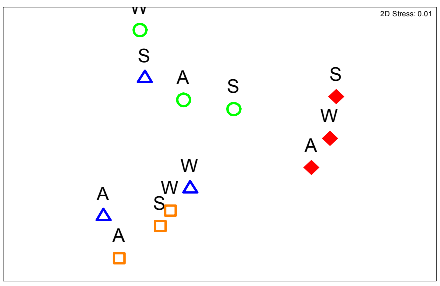
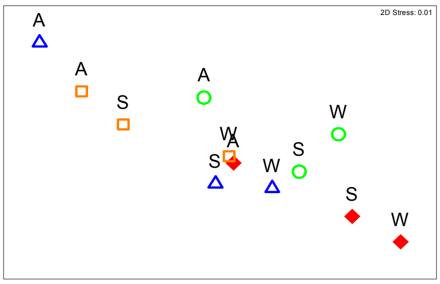
Fishery grids	Primer Outputs	MDS plot
11-14	ANOSIM Season : p = 0.40 Stage : p = 0.10 SIMPER: na	
15-18	ANOSIM **Season : p = 0.01** Stage : p = 0.16 SIMPER: na	
19-21	ANOSIM Season : p = 0.94 **Stage : p = 0.01** SIMPER: 94 – CT, OS, RTE 95 – CT, OS, RTE 96 – OS, CT, RTE 97 – CT, RTE, OS	
22-24	ANOSIM Season : p = 0.24 Stage : p = 0.92 SIMPER: na	
25-27	ANOSIM Season : p = 0.04 Stage : p = 0.03 SIMPER: 94 – CT, RTE, OS 95 – RTE, OS, CT 96 – CT, RTE, OS 97 – CT, RTE, OS	

Figure 3.12. The impact of Tropical Cyclone *Justin* on commercial catch composition presented with MDS plots and ANOSIM and SIMPER analyses. The effects of stage (pre-cyclone years: ○ = 1994; □ = 1995; Δ = 1996) and cyclone year (● = 1997) and season (S = spring, W = winter, A = autumn) were tested.

3.4.4 Tropical Cyclone *Hamish* – Impacts on catches and catch composition

Commercial fishery – broadscale patterns

Clearer indications of TC *Hamish* impacts on the performance of the CRFFF were evident when descriptive data summarization and visual graphical interpretation was undertaken for yearly average CPUE and landed catch of both CT and RTE across fishery grids 5-7 to 27 (inclusive). Figures 3.12 and 3.13 represent annual mean CPUE and total landed catch for coral trout and red throat emperor respectively.

Figure 3.12 demonstrates substantially depressed CPUE for coral trout occurred across numerous fishery grids in the year TC *Hamish* impacted (2009), and was similarly experienced by both 'whole' and 'active' tender effort. Correspondingly, landed catch volumes were also reduced across multiple grids (Figure 3.12) and again similarly experienced by 'whole' and 'active' tender effort. Notably, the spatial extent of the depressed catch rates and hence landed volumes were most obvious in the six most southern fishery grids (22 to 27 inclusive), those grids directly impacted by TC *Hamish*. Interestingly, landed catch increases in northern fishery grids were not accompanied by increased CPUE (Figure 3.12), likely reflecting an increase in fishing effort in these grids by southern vessels moving north to escape cyclone impacted areas where lower catch rates were being experienced.

Figure 3.13 demonstrates substantially decreased as well as increased CPUE for red throat emperor occurred across some fishery grids in the year TC *Hamish* impacted (2009). Similar to the reduced catch rates of coral trout, noticeable depression of red throat emperor catch rates occurred in some southern fishery grids (25, 26, 27) directly impacted by *Hamish*. Interestingly, increased catch rates of red throat emperor occurred in some grids (22, 23, 24) directly impacted by TC *Hamish* and where coral trout were depressed. Some northern grids (17, 19, 20) experienced noticeable increases in red throat emperor catch rates.

Figure 3.14 demonstrates a strong reaction of fishing effort in response to the changed harvest rates experienced following TC *Hamish*. Most notably in the 'whole' fishery effort was a movement away from fishery grids 22, 23, 24 with a concomitant increase in effort in more northern fishery grids.

No obvious trends in harvest rates or volumes of the 'other reef species' group were evident, and as such no graphical representation is shown.

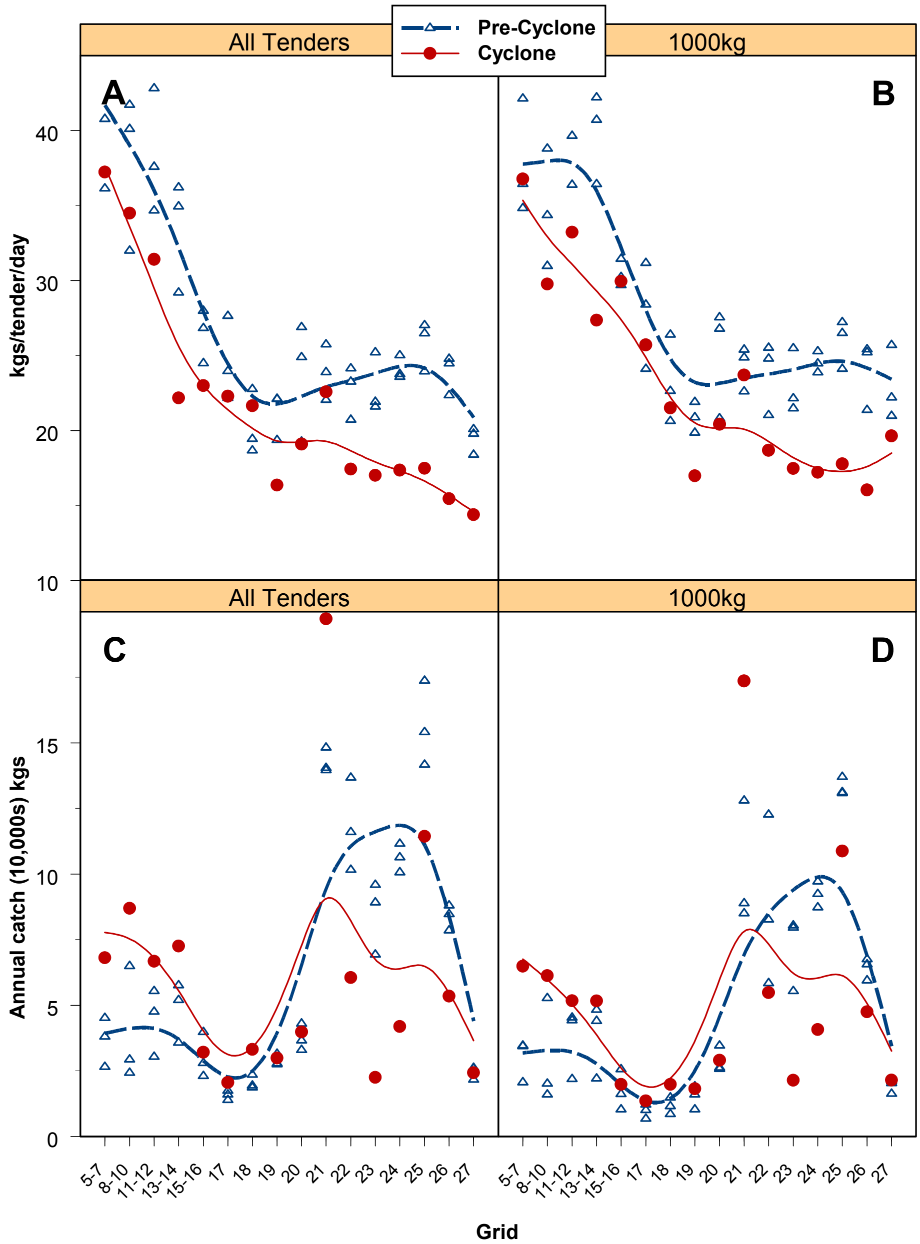


Figure 3.13. Coral trout annual CPUE and landed catch for all tenders and 'active' tenders within the commercial sector of the CRFFF. CPUE trends across fishery grids and through time are shown for (A) all tender effort, and (B) active tender effort. Landed catch trends across fishery grids and through time are shown for (C) all tender effort, and (D) active tender effort.

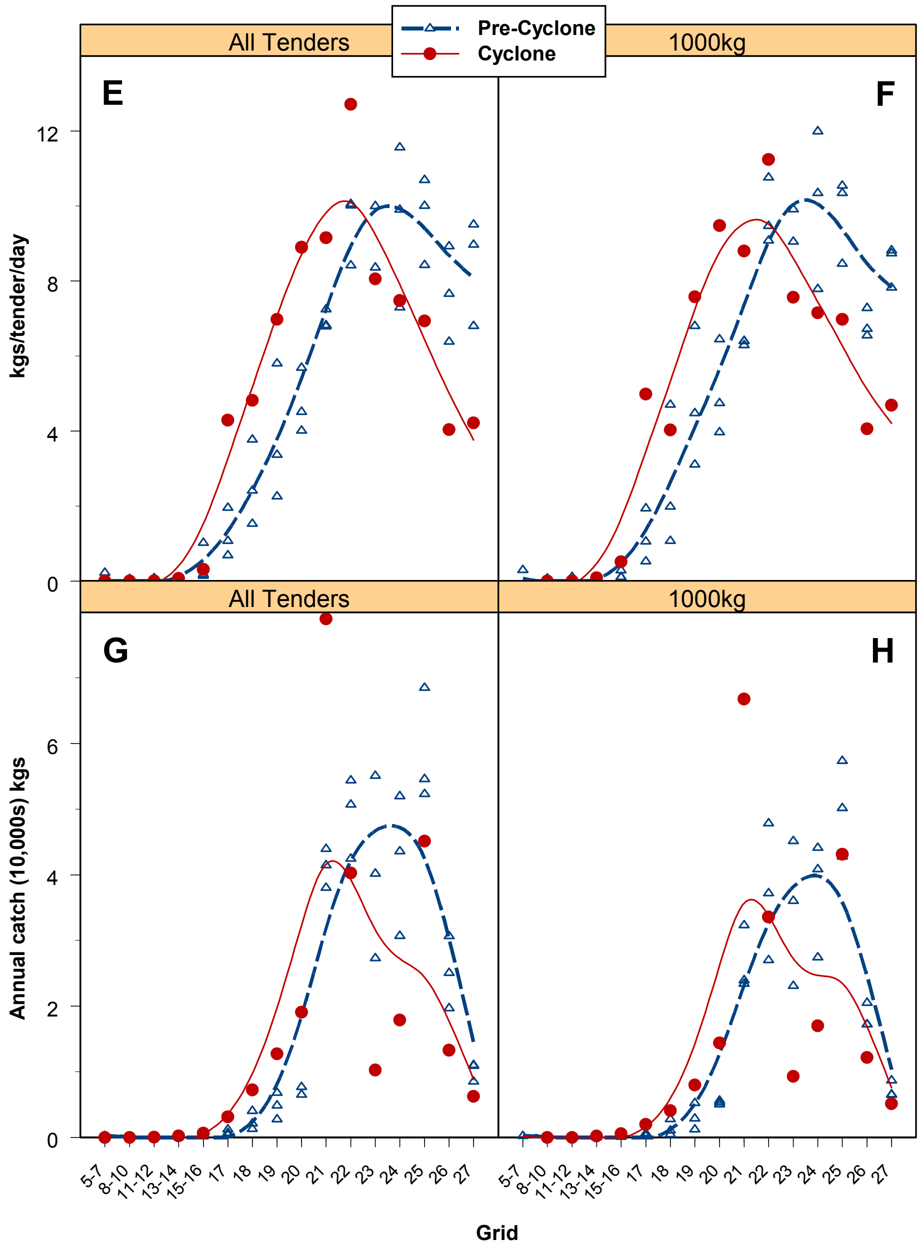


Figure 3.14. Red throat emperor annual CPUE and landed catch for all tenders and 'active' tenders within the commercial sector of the CRFFF. CPUE trends across fishery grids and through time are shown for (E) all tender effort, and (F) active tender effort. Landed catch trends across fishery grids and through time are shown for (G) all tender effort, and (H) active tender effort.

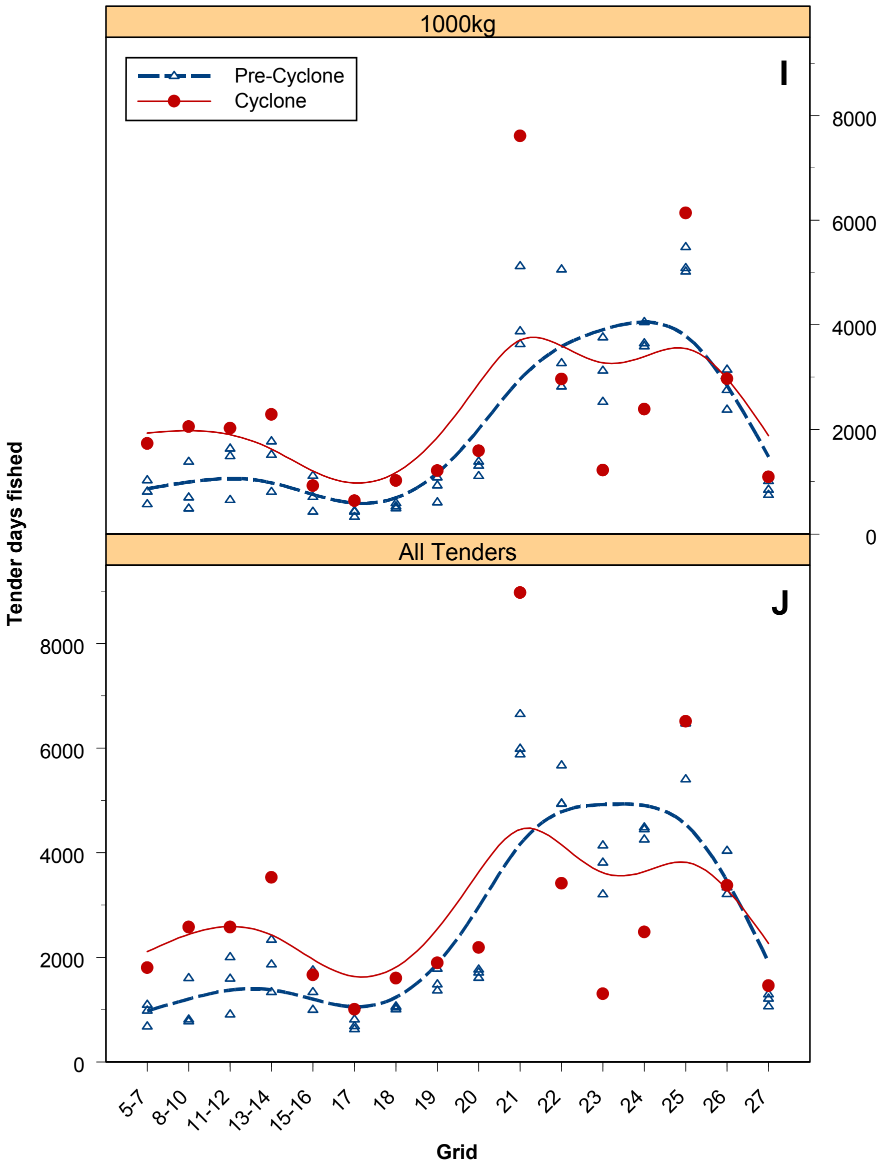


Figure 3.15. Tropical Cyclone *Hamish* annual effort (tender days) fished by the commercial sector during 2006 and 2009 inclusive. Total annual effort is displayed for (I) all primary vessels, and (J) active primary vessels only. Blue triangles are annual data points for pre-cyclone years (2006, 2007, 2008), red circles are annual data points for cyclone year (2009).

Commercial Fishery – fine scale patterns

Finer scale interpretation of the changed catch rates as experienced by the 'active' vessels within the fishery is initially demonstrated via visual assessment of average monthly CPUE trends between pre-cyclone (2006, 2007, 2008), cyclone (2009) for coral trout (Figure 3.15) and red throat emperor (Figure 3.16). The patterns in catch rates through these times periods are overlaid with identified warm water anomalous events that impacted some areas of the emergent coral reef structure in mid-2009. Significance of the changed catch rates and location of effort are summarised in Table 3.2, for both the active fishery and whole fishery.

Coral trout

For the active fishery, notable depression of coral trout catches rates were observed (Figure 3.15) in fishery grids 22, 23, 24, 25, 26 with analysis demonstrating these impacts to be significant and resulting in a depression of 2009 CPUE of at least 30% compared with reference years (2006, 2007, 2008) CPUE (Table 3.2). With the exception of fishery grid 18, the 2009 CPUEs for both the whole and active fishery subcomponent were either nominally or significantly depressed across all grids (Table 3.2).

Notably, the fishery grids where CPUE was significantly depressed were those grids directly impacted by the path of TC *Hamish*. SST analysis exposed the presence of a warm water anomaly in winter months (July, August, September), though no anomalous event associated with the passing of TC *Hamish* (March, April). Interestingly, the warm water anomaly appeared to result in a temporary 'recovery' of the depressed catch rates in some grids (Figure 3.15). Most evident in grid 22, where catch rates decreased following the cyclone impact, recovered during the warm water anomaly, and decreased again later in the year.

From visual interpretation of Figure 3.15, the temporal extent of the reduced CPUEs was at least nine months, a period considerably longer than immediate effects of tropical cyclone presence and influence. In each of the effected fishery grids, catch rates had not recovered nine months post-TC *Hamish*.

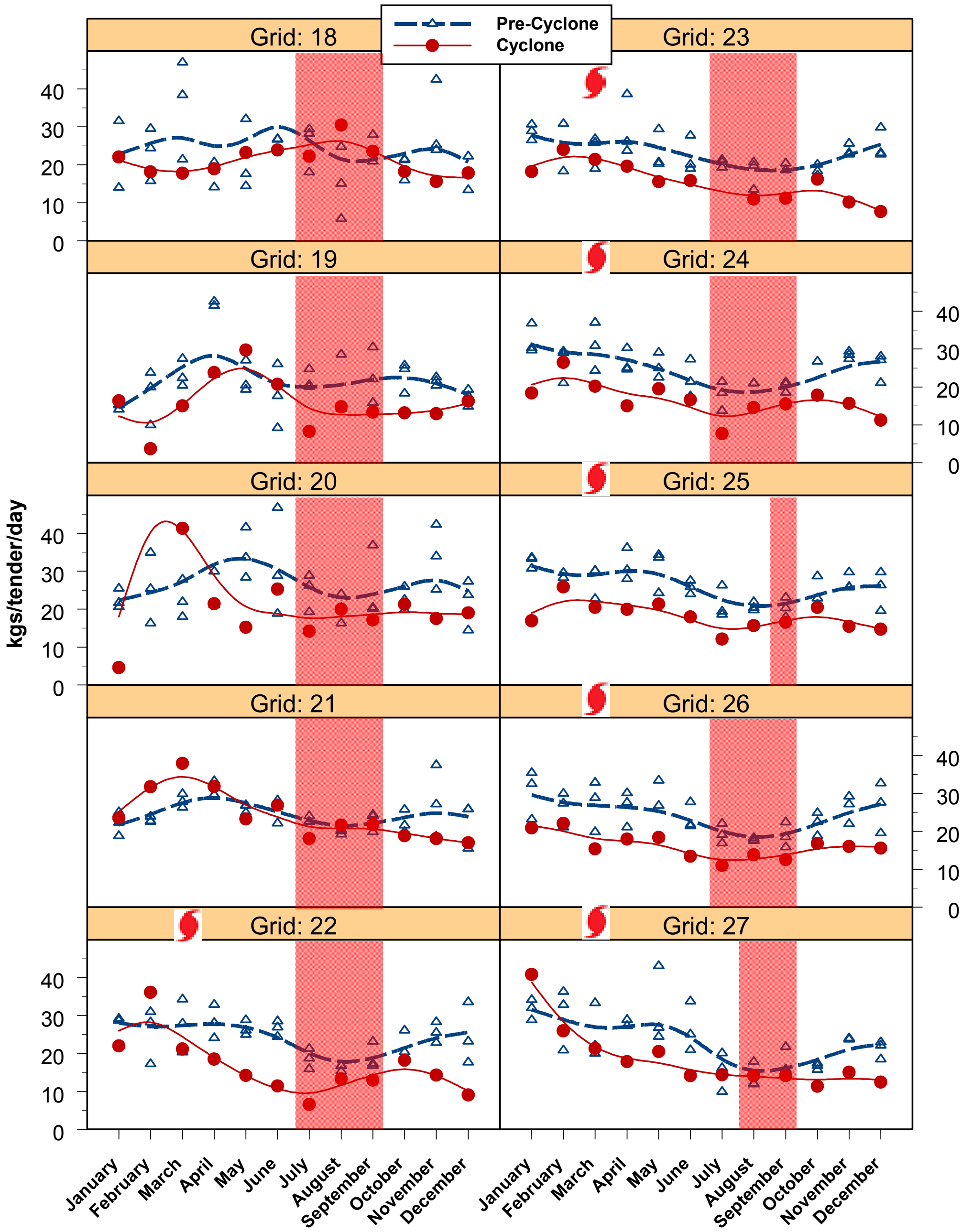


Figure 3.16. Tropical Cyclone *Hamish* monthly CPUE of coral trout for each fishery grid for the active fishery boats only. Trends in CPUE are compared between the three control years (2006, 2007, 2008) and Tropical Cyclone *Hamish* impact year (2009). The control year monthly CPUE data is represented by the open blue triangles, while the impact year is represented by the solid red circles. Trend lines are fitted to each data set using a smoothing spline (df = 6).

Table 3.2. Diagrammatic representation of the significant effects of Tropical Cyclone *Hamish* on coral trout, red throat emperor and 'other species' catch rates as well as effort in the fishery. The analysis treated years 1994, 1995 and 1996 as standard or average years of catch and effort against which 1997 was compared. From this comparison, the symbol ▼ represents significant decreases in catch rates or effort, while the symbol ▲ represents significant increases in catch rates or effort and the empty symbols represent nominal changes. Analyses were completed for all data as 'whole' fishery and for only 'active' boats (top 59) within the fishery.

Fishery Grid	Coastal Township	Coral trout		Red throat emperor		Other species		Fishery effort	
		Whole	Active	Whole	Active	Whole	Active	Whole	Active
5-7	Far North	▽11.2	▽3.8	-	-	▲75.9	▲82.0	▲92.2	▲111.1
8-10	Lockhart River	▽11.5	▽13.9	-	-	▲94.7	▲90.6	▲143.9	▲134.1
11-12	Ribbon Reefs	▽20.1	▽19.5	-	-	▲188.0	△24.6	▲72.3	▲55.8
13-14	Cooktown	▼33.6	▼32.4	△85.7	△9.4	△17.5	▽11.7	▲91.6	▲68.3
15-16	Cairns (north)	▽17.5	▽9.2	△32.2	△125.7	△21.1	▽16.3	△22.7	△24.2
17	Cairns (south)	▽13.1	▽8.8	▲266.1	▲339.4	▽7.4	▽4.9	△43.8	△73.4
18	Mission Beach	△6.6	▽14.2	▲81.3	△42.0	▽1.6	△7.9	▲54.9	▲91.7
19	Cardwell	▼29.1	▽26.7	△48.8	△23.4	△27.6	▽44.7	△23.2	△39.6
20	Ingham	▽19.2	▽13.1	▲62.7	▲66.8	▲110.4	△48.6	△29.5	△26.3
21	Townsville	▽21.2	▽1.0	▲24.7	▲34.9	△3.0	▽21.0	▲45.5	▲81.0
22	Bowen (north)	▼27.7	▼31.5	▲41.5	△31.8	▽16.1	▽30.3	▼34.0	▽20.1
23	Bowen (south)	▼36.1	▼33.1	▽18.3	▽20.5	▲47.3	▽16.4	▼64.9	▼58.1
24	Mackay (north)	▼30.0	▼32.5	▽18.9	▽25.7	△22.5	▽8.4	▼43.4	▼36.4
25	Mackay (south)	▼31.2	▼30.9	▼31.7	▼31.5	△20.0	△9.8	△6.6	△18.3
26	Carmilla	▼34.9	▼33.1	▼49.0	▼41.2	△7.0	△25.4	▽4.2	△7.8
27	Broad Sound	▼28.0	▽20.0	▼87.6	▼43.9	△9.9	△6.4	△23.1	△26.7

Red throat emperor

For the active fishery, notable increased red throat emperor CPUEs were observed (Figure 3.9) in fishery grids 18, 19, 20, 21, 22 with analysis demonstrating most of these impacts to be significant (Table 3.2). Most notable was an increase in catch rate of over 300% in fishery grid 17.

A clear spatial demarcation between increased and decreased catch rates were observed, with all grids north of Bowen (13-14 to 22) having either nominal or significant increases in catch rates, while all grids south of Bowen (23 to 27) had either nominal or significant increases in catch rates (Table 3.2). This northern and southern split roughly corresponds to grids not impacted versus grids impacted by the path of TC *Hamish*.

The warm water anomaly that occurred in winter 2009 does not appear to be temporarily linked to the patterns observed in red throat emperor catch rates.

'Other species' group

Some significant increases in CPUE of the other species group were recorded (Table 3.2), most notably in the most northern fishery grids. For all other grids, a mix of nominal increases and decreases were observed with no clear spatial organisation. As the other species group is an eclectic mix of many tens of species captured by the fishery relatively infrequently, interpreting trends in this data is considered folly, with the likelihood of assigning effects where there is likely none (type II error) considered sound reason for not pursuing the outputs further.

Effort patterns

The active boats within the fishery demonstrated a marked avoidance of fishery grids 23 and 24 in 2009, though surprisingly effort in grids 25, 26, 27 was nominally higher even though decreased catch rates of both coral trout and red throat emperor were being recorded (Table 3.2). All grids north of the TC *Hamish* affected area (21 and north), had increased levels of fishing effort (Table 3.2). Significant increases were recorded in grids 17, 21 and the four most northerly grids.

Catch composition

Chi-square analysis of catch composition was uninformative with all fishery grids returning a significant effect of year ($p << 0.05$). Graphical representation identified species composition shifts occurring between years where no cyclone impacts were present (Figure 3.17). There is some visual evidence of increased relative contribution of red throat emperor within fishery grids 17, 18, 19, 20 that is likely a result of the increased catch rates recorded for these grids (Table 3.2)

Non-parametric testing demonstrated catch composition significantly influenced by stage (cyclone presence/absence) only in grouped grids 15-18 (Figure 3.18). In this instance, SIMPER identified that in years 2006, 2007 and 2008 coral trout was the most discriminate species; while in 2009 tropical snappers (Lutjanids) were the most discriminate species. Surprisingly, ANOSIM analysis did not detect a significant change in catch composition within the southern two grid groupings where catch rate changes were most evident and consistent.

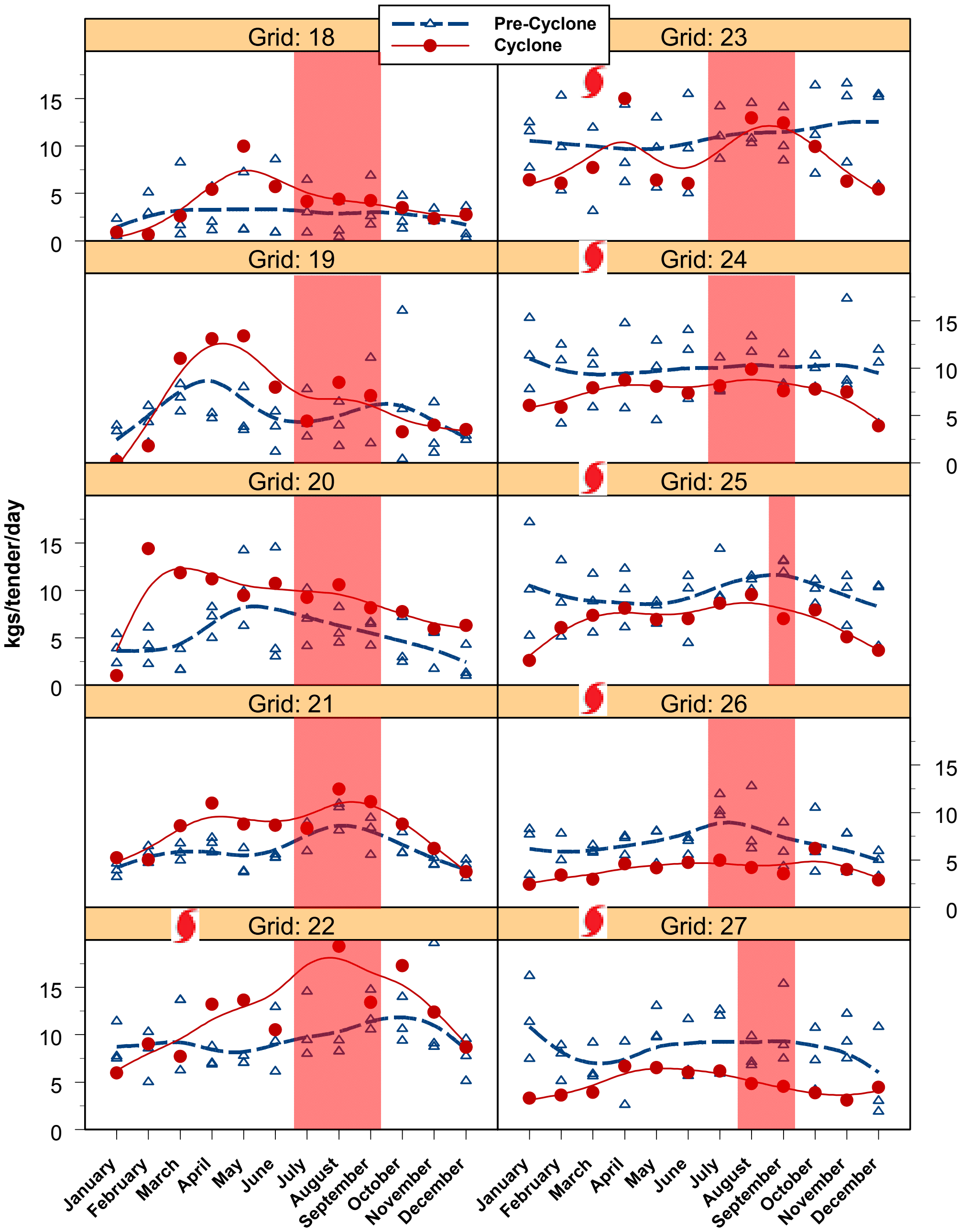


Figure 3.17. Tropical Cyclone *Hamish* monthly CPUE of **red throat emperor** for each fishery grid for the active fishery boats only. Trends in CPUE are compared between the three control years (2006, 2007, 2008) and Tropical Cyclone *Hamish* impact year (2009). The control year monthly CPUE data is represented by the open blue triangles, while the impact year is represented by the solid red circles. Trend lines are fitted to each data set using a smoothing spline (df = 6).

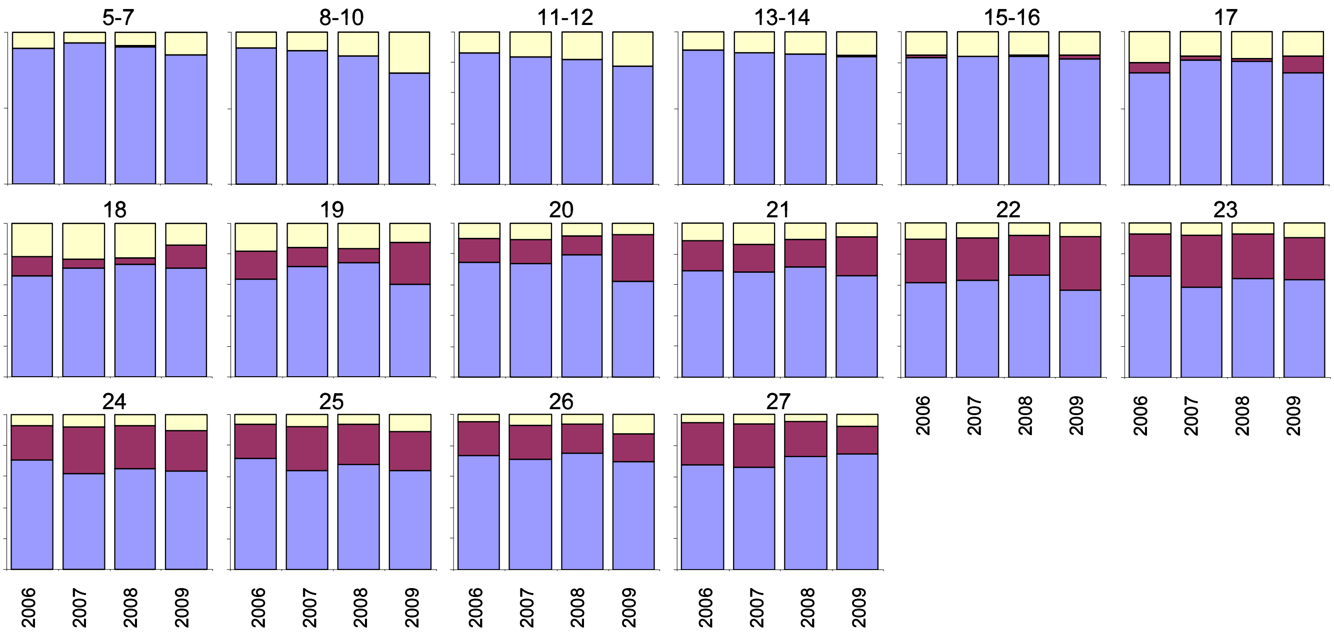


Figure 3.18. Changes in the catch composition of the commercial sector of the CRFFF in response to the impact of Tropical Cyclone *Hamish* were explored by examining changes in relative frequency of landed coral trout (purple), red throat emperor (red) and other reef species (yellow). The effect of year on catch composition was significant for all fishery grids (chi-square analysis, bonferroni corrected p = 0.003).

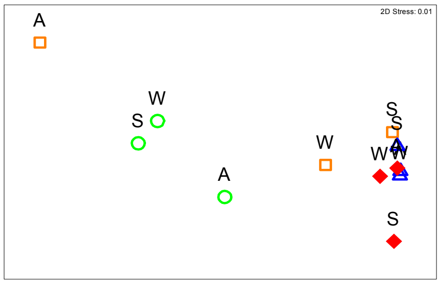
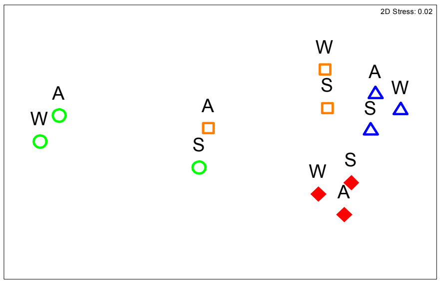
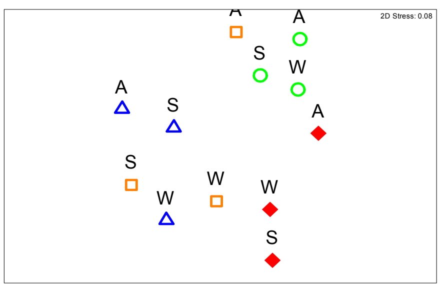
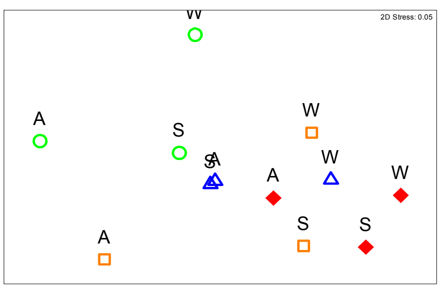
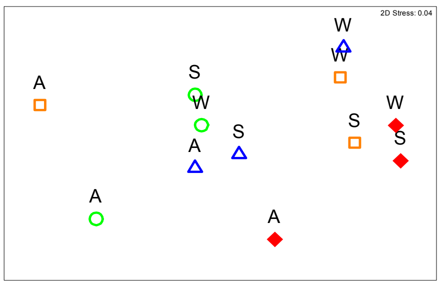
Fishery grids	Primer Outputs	MDS plot
11 – 14	ANOSIM Season : p = 0.64 Stage : p = 0.28 SIMPER: na	
15 – 18	ANOSIM Season : p = 1.00 **Stage : p = 0.01** SIMPER: 06 – CT, RTE 07 – CT 08 – CT, RTE, SNA, REM 09 – SNA, CT	
19 -21	ANOSIM Season : p = 0.28 Stage : p = 0.52 SIMPER: na	
22 – 24	ANOSIM **Season : p = 0.04** Stage : p = 0.25 SIMPER: na	
25 - 27	ANOSIM Season : p = 0.39 Stage : p = 0.41 SIMPER: na	

Figure 3.19. The impact of Tropical Cyclone *Hamish* on the catch composition of the commercial sector of the CRFFF are presented with multi-dimensional scaling (MDS) plots and subsequent ANOSIM and SIMPER analyses. The effects of stage (pre-cyclone years: ○ – 2006; □ – 2007; Δ – 2008) and cyclone year (● – 2009) and season (S – spring, W – winter, A – autumn) were tested.

Recreational and Charter Fisheries – Catch Composition

Chi-square analysis revealed year as a significant factor affecting the relative contributions of coral trout, red throat emperor, red fish and hussar. However no evidence is observed for 2009 being unique from the control years (Figure 3.20). Large lutjanids as well as red throat emperor were more common component of catches in both 2008 and 2009.

Similarly, non-parametric testing did not reveal any effect of year on the catch composition landed by recreational and charter fishers (ANOSIM p = 0.54) (Figure 3.21).

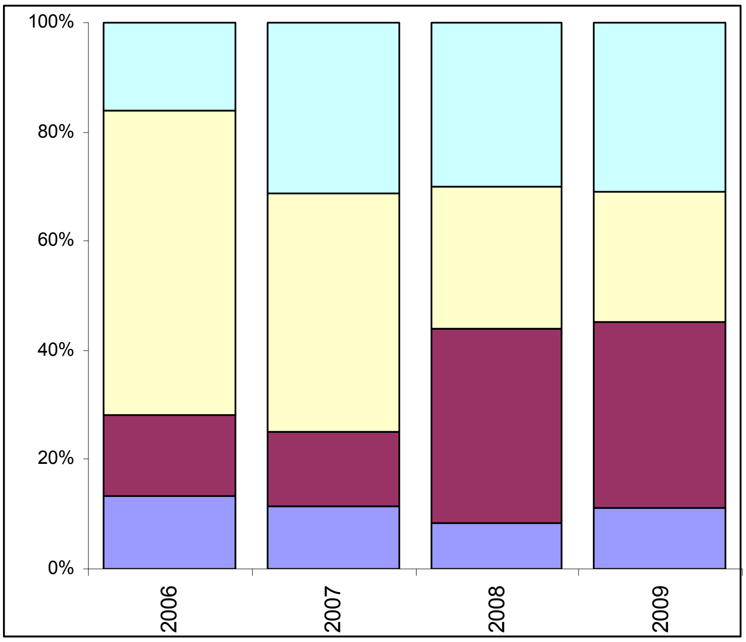


Figure 3.20. The impact of Tropical Cyclone *Hamish* on catch composition of recreational and charter fishers catches as reported by CapReef. The species composition of winter catches (May, June, July) were compared between three reference years (2006, 2007, 2008) and the year (2009) *Hamish* impacted the area. The relative contributions of coral trout (purple), red throat emperor (maroon), large lutjanids (*L. erythropterus, L. malabaricus, L. sebae*) (yellow) and hussar (aqua) are shown.

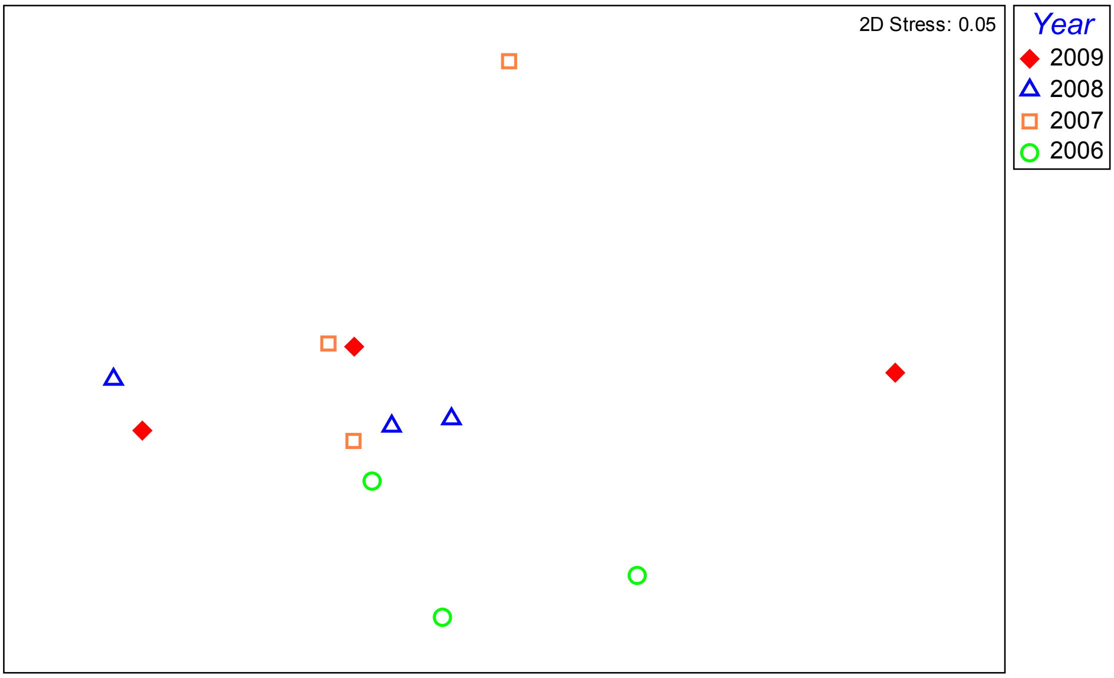


Figure 3.21. The impact of Tropical Cyclone *Hamish* on the catch composition of recreational and charter fishers as reported by CapReef. The multi-dimensional scaling (MDS) plot and subsequent ANOSIM analysis demonstrate no obvious effect of year on catch rates. Nominal winter months of June, July, August are replicate data points within each year.

3.4.5 Tropical Cyclone *Larry* – Impacts on catches and catch composition

Contrasting the marked impacts of TC *Justin* and TC *Hamish* on catch rates within the commercial sector of the CRFFF, TC *Larry* had little impact on the performance of the fishery. Table 3.3 summarises the analyses that compared catch rates and effort levels between the three reference years (2003, 2004, 2005) and the cyclone year (2006). A significant depression of coral trout catch rate was observed in fishery grid 16 only. Only nominal decreases in catch rates were observed in grids 17 and 18, the two fishery grids directly impacted by TC *Larry*. Red throat emperor catch rates were significantly higher in two spatially displaced grids (15 and 18), while other species catch rates were higher in only one grid (18), and effort levels demonstrated no significant changes. SST analyses did not identify any anomalous events.

The lack of any patterns in this data precludes any further analysis or discussion.

Table 3.3. Diagrammatic representation of the significant effects of Tropical Cyclone *Larry* on coral trout, red throat emperor and 'other species' catch rates as well as effort in the fishery. The analysis treated years 2003, 2004 and 2005 as standard or average years of catch and effort against which 2006 was compared. From this comparison, the ▼ symbol represents significant decreases in catch rates or effort, while the ▲ represents significant increases in catch rates or effort and the empty symbols represent nominal changes. Analyses were completed for all data as 'whole' fishery only as relative levels of fishing effort within these fishery grids is very low.

Fishery Grid	Coastal Township	Coral trout	Red throat emperor	Other species	Fishery effort
15	Port Douglas	▲31.0	▲223.0	△21.2	△15.6
16	Cairns (north)	▼27.0	▽ 11.8	▽ 57.8	▽ 8.5
17	Cairns (south)	▽24.9	△35.6	△28.7	▽17.4
18	Mission Beach	▽ 7.6	▲78.0	▲78.4	▽ 3.9
19	Cardwell	△ 2.5	△28.7	△40.3	△ 22.0

3.5 Discussion

The data handling and analysis completed demonstrate that some tropical cyclones have uniquely negative impacts on the productivity of the CRFFF operating within the GBRWHA. These significant negative and disruptive affects are pronounced within the catch rates realised by at least the commercial fishing sector of the CRFFF. The catch rate trends described by the project validate the anecdote of commercial fishers, whose claims of hardship in the months following both TC *Justin* and TC *Hamish* (reduced catch rates) have until now been uncertain. The project has provided certainty in demonstrating catch rates can be depressed by as much as 50% following cyclone influence. Further, these depressed catch rates can occur across large spatial areas (up to 3° of latitude), and lag for significant temporal periods (up to twelve months).

3.5.1 Tropical Cyclone Justin (March 1997)

Although popular commercial fisher anecdote reported severe effects of TC *Justin* on coral trout catch rates across large spatial and temporal scales within the CRFFF, and Leigh *et al.* (2006) noted increased presence of red throat emperor in 1997 catches, no previous research has provided a robust quantitative assessment and description of these claims. This project has demonstrated significant depression of coral trout catch rates occurred across 2.5° of latitude, while red throat emperor catch rates significantly increased across 2° of latitude, in response to TC *Justin* influences.

The likely biophysical driver of these changed characteristics of fishery performance is an anomalous cool water event that accompanied TC *Justin* and impacted the central section of the GBRWHA emergent reef structure. TC *Justin* was unique in its large physical size even though the system was relatively weak (category 1 and 2) and caused little structural damage to emergent reef structure (Sweatman *pers comm.*). A further unique character of *Justin* was its stalling and holding position for three days on the southeast corner of the north Queensland plateau (Figure 3.2). Schillier *et al.* (2009) hypothesised, that the stalling of this very large storm system at this location resulted in an advection of deep cold off-shelf waters up onto the continental shelf and through the emergent reef structure of the central GBR. This plug of cool water (up 2°C cooler than long-term seasonal averages) may have slowed the metabolism of coral trout enough that feeding behaviours and hence catch rates were quickly depressed. Concomitantly, the cool water anomaly encouraged red throat emperor residing within deeper shelf and shoal waters to move up into the shallow waters of emergent reef structure, with catch rates within the fishery quickly increasing.

Interestingly, the contrasting catch rate reactions between red throat emperor and coral trout did not occur across the same spatial areas. Increased catch rates of red throat emperor occurred to the north of those latitudes where coral trout catch rates were severely depressed. Further, the catch rates of red throat emperor throughout the area where coral trout catch rates were lowest were nominally though not significantly depressed. This observation suggests that increased catch rates of red throat emperor occurred as a result of deep shelf and shoal water sub-populations usually free from fishing effort becoming available to the fishery via immigration into the shallow emergent reef habitats preferentially fished by the CRFFF. The immigration encouraged by the cool water anomaly. The alternate explanation of increased northern catch rates is that red throat emperor distributed throughout southern emergent reefs moved north. However, the relative stability of southern catch rates indicates no emigration from these areas. It seems most likely then, that the increased catches occurring in northern waters is a result of fish becoming available from other not usually fished habitats.

The temporal extent of the negative impacts of TC *Justin* on coral trout catch rates is remarkable. In fishery grids 22 and 23 where impacts were most severe, catch rates of coral trout remained depressed for twelve months following the passage of TC *Justin* (Figure 3.22). This result is confusing and difficult to understand. Although some logic applies to interpreting the initial depression of coral trout catch rates – the cool water anomaly effectively slowed the metabolism of coral trout to such an extent that feeding and usual behaviour was depressed and hence catch rates were similarly depressed – the significant temporal lagging of depressed catch rates is unexplainable. Logic suggests that once the cool water anomaly had receded from the emergent reef structure (two month maximum extent), catch rates should have returned to normal or at least near-normal. This did not happen and the reason(s) why catch rates remained depressed for such a long time period remain uncertain.

3.5.2 Tropical Cyclone Hamish (March 2009)

Quickly following the passage and influence of TC *Hamish*, commercial fishers reported wide spread depressed catch rates of both coral trout and red throat emperor throughout the southern section of the GBR. The analyses of logbook data completed by the project again confirmed these initial anecdotal reports. Interestingly, even though TC *Hamish* was a much more severe storm event than TC *Justin* with a much longer path over emergent reef structure, catch rates of coral trout were not as adversely affected. Coral trout catch rate was depressed across a slightly larger area (3° of latitude), though by an average of 30% compared with the 50% recorded for TC *Justin*.

TC *Hamish* was also different to TC *Justin* in being responsible for significant depressions (by 30-40%) in red throat emperor catch rates across 1.5° of latitude. The impact of TC *Justin* did not result in a significant depression of red throat emperor within any fishery grid. Again similar to TC *Justin*, the changed catch rates of coral trout and red throat emperor did not occur across the same spatial scale. Although significant depressions of coral trout catch rates occurred across the southern 3° (latitude) of emergent GBR, the significant depressions of red throat emperor catch rates occurred across the southern 1.5° (latitude) of emergent GBR. The reasons for these contrasting patterns are uncertain.

Identifying the driver(s) of the changed catch rates is again problematic. No cool water anomaly accompanied the passage of TC *Hamish*. A warm water anomaly occurred in late winter/early spring, however this is likely related to the mild 2009 winter experienced through north-eastern Australia rather than a lagging effect of the cyclone. The ecological behaviours of both coral trout and red throat emperor may have been changed by the passage of such a destructive storm, however again the significant lagging effects on both coral trout and red throat emperor confuse any ability for confidence in such a conclusion.

3.5.3 Tropical Cyclone Larry (March 2006)

In comparison to TCs *Justin* and *Hamish*, TC *Larry* impacted a very small section of the GBRWHA. *Larry* crossed the emergent reef structure east of Innisfail, a point within the GBR where the continental shelf is very short and hence the number of emergent reefs is low. Given this, relatively little fishing effort (less than 3% of annual effort) occurs within the fishing grids (17 and 18) directly impacted by this system. The swiftness with which the system moved through is likely related to the lack of impacts similar to those reported for *Justin* and *Hamish*. This contrast suggests that fast moving systems that cross the emergent reef structure on an east to west track may be less likely to cause disruptions to fisheries productivity even if the systems are quite powerful.

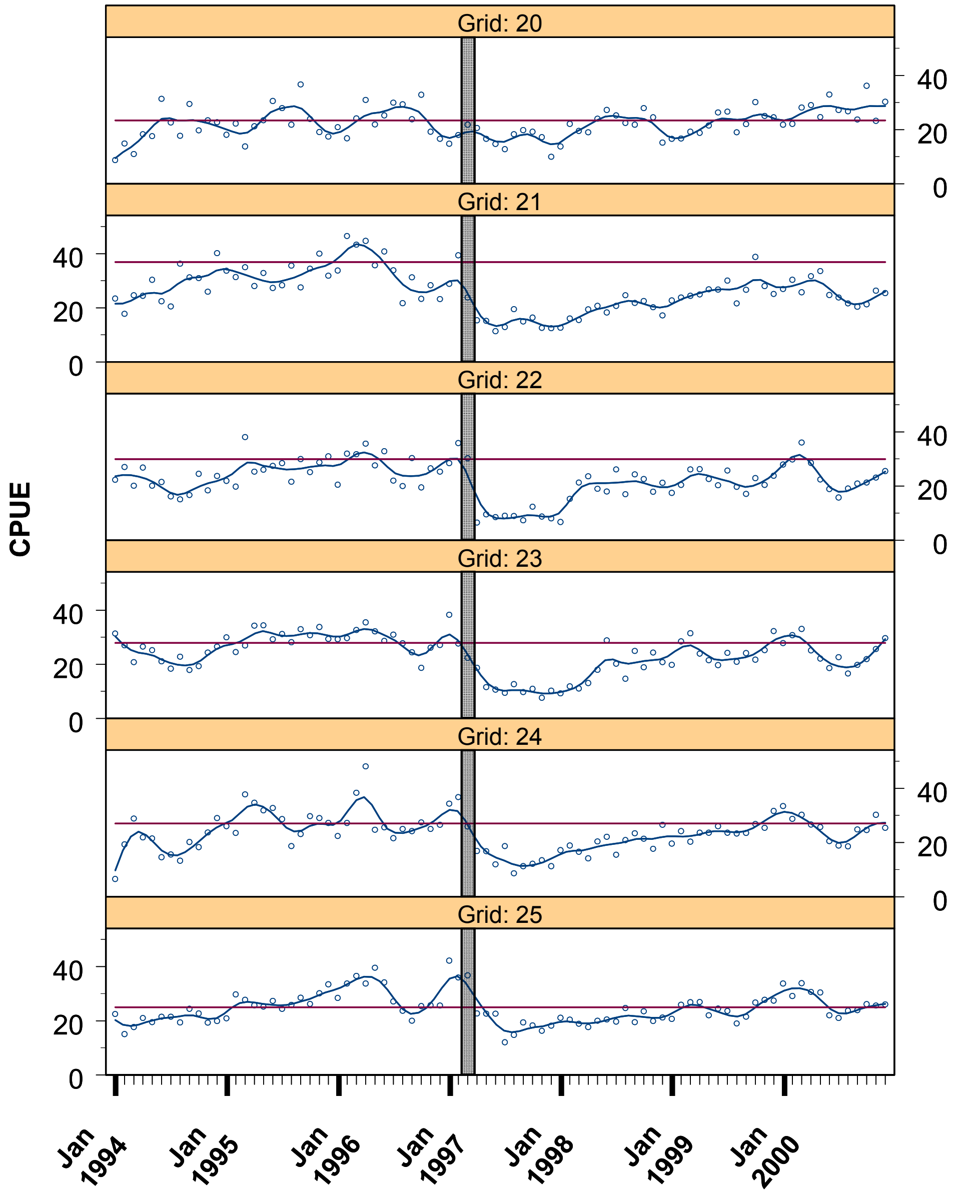


Figure 3.22. The lingering effect of Tropical Cyclone *Justin* influence on the catch rates of coral trout recorded by the commercial fishing sector between 1 January 1994 and 31 December 2000. Previous analysis (see Table 3.1) determined significant negative effect of cyclone year (1997) on catch rates in grids 21, 22, 23, 24; no significant effects were detected in grids 20 and 25. Reference lines highlight the average catch rate in pre-cyclone reference years (1994, 1995, 1996). The month of cyclone influence is highlighted by shaded box.

Commercial fishery adaptive capacity

Most significant of the changed catch rates identified is the substantial reduction in the catch rates of the primary target coral trout. Given the tight association between coral trout and economic profitability within the fishery, the active movement of fishing effort away from affected areas is a strong though not surprising reaction of the commercial fleet. Increased catch rates of red throat emperor, that may occur in some areas where coral trout catch rates are depressed are not sufficient to replace the economic losses realised through the depressed catch rates of coral trout. Although the CRFFF is multi-species in nature, the commercial sectors directed focus on landing coral trout for the live export market severely limits any adaptive capacity for changing target species and/or markets.

Some adaptive capacity is evident within the commercial sector with fishing effort consciously moved away from those areas of the GBR where the worst catch rates are experienced. Unfortunately however, the latitudinal gradient in coral trout abundance does complicate the decision process of businesses to move fishing effort north. Although catch rates may be up to 60-70% higher in the northern most fishery grids of the GBR, the quality of coral trout landed in these areas is poor for live export. Northern GBR trout are on average larger as well as generally of dark green and brown hues. The live export market preferentially takes small red hued trout, and can only handle a limited percentage of other colour and size morphs. Unfortunately for the fishery, the highest quantities of the best quality trout morphs for live export are landed from southern GBR waters; those waters or fishery grids adversely impacted by both TC *Justin* and *Hamish*. Price differentials offered between southern and northern ports can be as much as 30% higher for vessels fishing southern waters. Accordingly, a massive shift of effort away from southern to northern waters of the GBR may appear to be an acceptable adaptive response; however the marketing and economic consequences are likely to be unfavourable.

Recreational and charter fisheries

In contrast to the commercial sector, the recreational and charter sectors response to these unique cyclone events appears to be indifference. This indifference is likely linked to the different motivations, targeting behaviours and expectations of these fisheries sectors. Traditionally within the CRFFF, these sectors have targeted an array of species across an array of habit types represented throughout the GBRWHA. Where the commercial fishery shows a strong preferential targeting of coral trout from the shallow waters (generally less than 25 m depth) of emergent reefs, participants in the recreational and charter fisheries target many species from shallow as well as deep emergent reef waters, and from shoals scattered across the GBRWHA lagoon and shelf waters. This generalised targeting behaviour reflects a unconscious adaptive capacity, as a fisher from these sectors may depart on a reef trip with the expectation of targeting and catching coral trout, however if success is low these fishers are often adaptive enough to target other species from other habitats. The current focus of the commercial sector on live coral trout does not permit such adaptive capacity.

Challenges

The challenges that face the CRFFF are not unique within the global fisheries arena. With the production and distribution of many fisheries exploited species dependent upon fluctuating environmental conditions, the uncertain future of environmental conditions within many ecosystems suggests future fisheries productivity may be difficult to predict (e.g. Beaugrand *et al.* 2004; Stenseth *et al.* 2004).

The relatively stable performance and productivity of the CRFFF is likely its biggest weakness in the face of increasing environmental change. Though many tropical Australian fisheries exploited species may have productivities that fluctuate considerably between years (e.g. barramundi – Staunton-Smith *et al.* 2004; king threadfin – Halliday *et al.*- 2008; banana prawns – Halliday and Robins 2007; mud crabs – Meynecke, 2009), the CRFFF is comparatively a much more stable fishery in terms of daily, monthly and annual production. This long-term relative stability is likely to be an impediment for stakeholders when unique and unexpected events like TC *Justin* and *Hamish* 'rock' the boat'. The socio-economic issues associated with these events are addressed in the following chapter.

Chapter 4: Exploring the socio-economic response and implications of the Coral Reef Fin Fish Fishery to a major environmental event (Tropical Cyclone *Hamish*)

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4.1 Introduction

On the east coast of Queensland, tropical cyclones are relatively frequent and the industries operating in the region generally accept and adapt to them. However, with predictions of an increase in frequency of intense cyclones (Walsh *et al.* 2004; Nicholls 2008), fishers' ability to adapt to such events becomes increasingly important. With the likelihood that events like Cyclone *Hamish* may increase in the future due to climate change, this event provided a timely case study to explore adaptive capacity of the industry to significant environmental events and resilience to climate change in general.

Hennessy *et al.* (2007) warn that many industries in Australia are ill suited to adapting to changes brought on by climate change. Knowledge of the adaptive capacity and hence resilience of resource users, such as commercial fishers, to change can assist in the design and implementation of policies and legislation that maximise ecosystem and industry sustainability while minimising the impacts on people (Marshall and Marshall 2007).

Adaptive capacity is the ability to cope with change without 'losing options in the future' (Adger *et al.* 2003; Brooks *et al.* 2005). Those individuals with greater adaptive capacity are more resilient or less vulnerable to change. Adaptive capacity refers to the ability of individuals to re-organise themselves, be flexible, or learn, and cope with adverse situations (Levin *et al.* 1998; Gunderson 1999; Adger *et al.* 2005; Marshall 2008). Fishers' ability to adapt may be affected by fishers' attitude towards, or perception of, the particular situation (Marshall 2007; Marshall 2008), such as climate change or cyclones more specifically. Other important factors include how dependent fishers are on a particular resource or species, their business structure (e.g. large vs. small operations) and other demographic factors such as education level outside of the fishing industry (Marshall *et al.* 2007; Bohensky *et al.* 2010; Marshall 2010). Management agencies may also increase the adaptive capacity of fisheries through active and timely adaptive management, i.e. experimenting with different strategies and learning from feedback from the industry (Folke *et al.* 2002; Howden *et al.* 2007; Armitage *et al.* 2008; Marshall 2008).

Commercial Coral Reef fin fish fishers have a number of adaptation options, or ‘choices’ available to them following TC *Hamish*. Depending on their ability and limitations, they would likely respond to such events in three ways:

1. Stop fishing, at least temporarily while the catches are low;
2. Continue to fish in the affected area; or
3. Move to fish areas unaffected by the cyclone.

These responses have consequences both for the fishers *directly* affected by the cyclone (i.e. those originally fishing in the area affected), and those *indirectly* affected by fishers moving into their common fishing areas which were unaffected by the cyclone. The response and effects of these responses will likely vary according to characteristics of the business, fishers’ ability to move and/or adapt (e.g. by fishing other species) and their perceptions of their capacity to adapt.

Fisheries Queensland responded actively to TC *Hamish* with an adaptive management option in an attempt to increase adaptive capacity of the industry: they temporarily removed the filleting restrictions which prevented many fishers from filleting and skinning coral reef fish at-sea in order to supply a premium product to domestic markets. This change was intended to improve access to the ‘skin off fillet’ market, allowing fishers to increase profits on product lines domestically marketed by the fishery.

The aim of this research was to explore behavioural changes of fishers following TC *Hamish*, and identify the current adaptability of Coral Reef fin fish commercial fishers to environmental events such as *Hamish*. The research also aimed to explore fishers’ views of the management options to assist industry adapt to this event, fishers’ perceptions of the threat of intense cyclones and climate change on their industry, and fishers’ perceptions of the linkage of environmental events like TC *Hamish* with climate change.

4.2 Methods

Multiple agencies (FQ, GBRMPA, QSIA) and stakeholders (commercial and charter fishers) expressed a keen interest in examining fishers’ response to any impacts from TC *Hamish*, and to determine if/how management can help industry remain viable through future environmental events. A working group was formed including representatives from FQ, GBRMPA, QSIA, and scientists from the Fishing and Fisheries Research Centre, the Australian Institute of Marine Science (AIMS) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). This working group advised on the priorities and methods for the social and ecological aspects of the overall project and reviewed fisher survey drafts.

4.2.1 Questionnaire development

A survey was developed by the project team in consultation with the working group.

Twenty three face to face surveys of commercial fishing owner/operators were conducted along the GBR coast to explore the immediate effects of the cyclone on commercial fisher behaviour and how these responses differed between different types of fishing operations. Eighteen of these surveys were targeted to fishers *directly* affected by the cyclone (those fishing in the area TC *Hamish* traversed) and five surveys of those *indirectly* affected by the cyclone (those who fish outside the area but are potentially impacted by fishers moving into their area). A further two fishers contacted felt there were not impacted and hence did not complete a survey and three declined to do the survey.

The project initially also aimed to include reef line charter fishers. Three charter fishers *directly* affected by the cyclone were surveyed; however it was especially difficult to survey charter fishers due to their limited time on shore between extended trips during the survey period. The three completed charter fisher surveys were not analysed.

Fishers were contacted initially by phone via numbers provided by Fisheries Queensland, GBRMPA Regional Liaison Officers and the QSIA. Face to face interviews were organised prior to meeting in most cases. Some surveys were obtained opportunistically while survey staff were in each port.

Surveys collected basic demographic and business information, opinions about the impact of the cyclone, changes in behaviour following the cyclone, and opinions and perceptions of cyclones, climate change, and fishers' resilience to change. Resilience questions were adapted from Marshall and Marshall (2007). Fishers' opinions were noted regarding whether the management changes (i.e. changes to filleting restrictions) assisted in adaptation. Further, potential barriers to adaptation and solutions available via management were explored and ranked. Questions also explored fishers' opinions regarding the linkage of environmental events like TC *Hamish* with climate change, and fishers' opinions about climate change in general, including in relation to other threats to commercial fishing. Surveys differed slightly between *directly* and *indirectly* impacted fishers reflected the differences in impact from the cyclone (see Tobin *et al.* 2010 for surveys).

The project followed the 23 surveyed fishers over a twelve-month period, within which three surveys were carried out:

1. The initial survey in May-June 2009, as close to the cyclone as possible;
2. A follow-up survey in November-December 2009, six months after the initial survey; and
3. A final survey in February-March 2010, approximately one year after the cyclone.

These three surveys differed slightly to each other to give an overall picture in change in behaviour, perception and resilience in the year following the cyclone. The follow-up surveys allowed a rare opportunity to explore the longer term effects of the cyclone on fisher behaviour and attitudes, and to more accurately quantify responses from initial qualitative questions.

4.2.2 Analyses

Results from *direct* and *indirect* impact surveys were analysed separately. Results for the initial, follow-up and final surveys are also presented separately, in order of surveys. Some comparisons are made between surveys where possible.

All data were initially subject to exploratory analysis and graphed in Microsoft Excel. All five-point scales (e.g. 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, etc.) were collapsed to three-point scales (e.g. disagree, neutral, agree) to describe or present in tables.

Results are presented in broad topics, as follows.

Demographics and business structure

These data are presented descriptively for the initial survey to give an overview of the surveyed fishers. These were later correlated with ability to adapt and resilience level.

Effects of TC Hamish

Fishers' perceptions of the impact of TC *Hamish* on the reef structure and the reef line fishery were explored. Fishers were asked general questions about the effects of the cyclone, and more specific details about the first four trips they completed following the cyclone in the initial survey. For these trips results focus on coral trout given the focus of this species for the fishery and the project. All trips provided by all fishers were combined, and each trip was treated as an individual data point.

Management options

In an attempt to assist fishers in adapting to TC *Hamish*, filleting restrictions had been lifted by the commencement of these surveys. Fisheries Queensland and the fishing industry were interested in knowing is this change assisted fishers, or what other options could be considered in the future.

In the initial survey, fishers were asked to suggest management options to help them better adapt to, or cope with, environmental events like TC *Hamish* in the future. Suggestions given were then tallied and divided into broad categories. In the follow-up survey, fishers were asked to focus on solutions apart from changes to Marine Park zoning in their answers. In the final survey, many of the options listed by fishers in the initial and follow-up surveys were listed, with fishers asked to rate their level of support for each potential solution (aside from Marine Park changes which were not considered feasible), and to list their preferred option. This provided more quantitative information for solution preferences.

Fishery impacts

We explored fishers' perceptions of impacts on the fishery in the initial and final surveys, to gauge fishers' relative perception of cyclones and climate change as threats to the fishery. These were compared between surveys to see if opinions changed over the time of the project.

Climate change

Fishers' opinions of climate change, and the link between cyclones like TC *Hamish* and climate change, were explored descriptively in the initial survey. These were compared with opinions in the final survey to see if opinions changed over the time of the project.

Resilience

Fishers were asked their level of agreement with various statements relating to their resilience according to four dimensions: i.e. (1) Risk perception and management, (2) Planning, learning and reorganisation, (3) Coping with change, and (4) Interest and flexibility. These were developed based on expert opinion and previous research (see Marshall and Marshall 2007). Combined statements were subjected to reliability analysis based on a calculation of the correlation among statements, using Cronbach's α (Chen and Popovich 2002). A value of 0.7 or greater was accepted as indicating a reliable scale (Nunnally 1978; Marshall and Marshall 2007).

When an appropriate Cronbach's α was determined, resilience scores for each fisher were calculated by taking the average of the responses to all statements which were recorded on a 1-5 scale (where a statement was worded negatively, the response was reversed, i.e. 1 = 5, 2 = 4, and so on). Values of 2.5 or lower were considered to indicate low resilience, 2.6-3.5 indicated medium resilience levels, and values greater than 3.5 were indicative of high resilience. Changes in the level of resilience between the initial and final survey were examined as a means to assess fishers' perception of their resilience over the year following the cyclone.

The overall resilience scores (from the initial survey) were tested for correlation in SPSS via linear regression for all independent continuous factors or one-way ANOVA for categorical factors. Factors included were age, marital status, fishing experience, education level, whether fishers had other training, business ownership status, current satisfaction with fishing, revenue, proportion of income from live coral trout vs. other products, debt level, and home port. Similar variables were found to influence fisher resilience in Marshall and Marshall (2007).

For those fishers that stopped fishing prior to the follow-up survey, attributes related to resilience (business structure, demographics, etc.) were described.

4.3 Results

4.3.1 Directly impacted fishers

(a) Initial survey

Demographics and business structure

All of the 18 commercial fishers that were *directly* impacted by TC *Hamish* were male. Age of respondents ranged from 29-63 years, with an average age of 46 years. Most fishers (67%) were married, and two people lived in their household, i.e. without dependents under the age of 18 years in their household.

The largest proportion of fishers (56%) achieved an academic education of Year 10 or lower. The remainder had an education level up to Year 12 (none were higher). However, over half of the surveyed fishers (67%) had other training which included trades (83% of those with training) such as carpentry, boat building, professional chef, motor mechanics, explosives, and mining. There were also a few fishers who listed boating related certificates, transport, or farming (8% each). Most respondents (89%) stated fishing was their sole source of *individual* income and 76% of fishers stated fishing accounted for 100% of their *household* income as well. Eighty three percent stated that they would still be fishing in the current fishery in three years' time.

Respondents had been in the fishing industry for 25 years on average (minimum of 11 years), from as early as 1968. Home ports for directly impacted fishers were split amongst Bowen (22%), Gladstone (39%) and Mackay (39%), with 71% of fishers using a single port throughout the year. Most surveyed fishers (72%) were owner-operators, as opposed to contract skippers (22%) or operators leasing licenses (6%), and half (50%) operated large vessels (>14 m) (Figure 4.1) usually with five dories (Figure 4.2).

Sixty-nine percent of fishers received more than $300,000 in total revenue for their license over the previous financial year (ending 30 June 2008) (Figure 4.3). This was variable between vessels sizes. Debt levels were high for most vessels – 69% had debt levels within $50-100,000 of their revenue. This was also variable between vessel sizes. Live coral trout was the main revenue for 72% of fishers as opposed to live and frozen product (11% of fishers) or multiple endorsements (17%). Live coral trout provided most of the fishing income for most fishers (0-96%, average 70%, median 80%) (Figure 4.4), although this varied between vessel size (Figure 4.5). Note that those large vessels who stated their income came from live and frozen product still received 70-75% of their income from live coral trout.

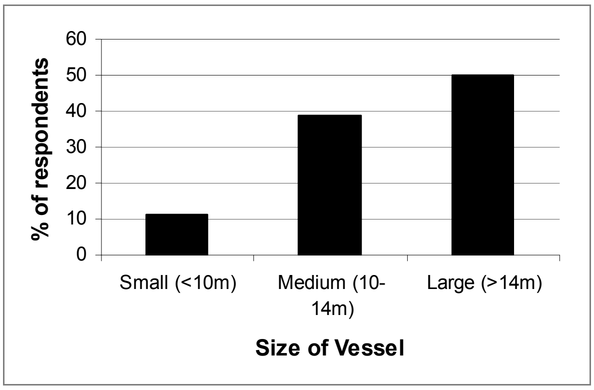

Figure 4.1. Vessel type of surveyed commercial fishers.

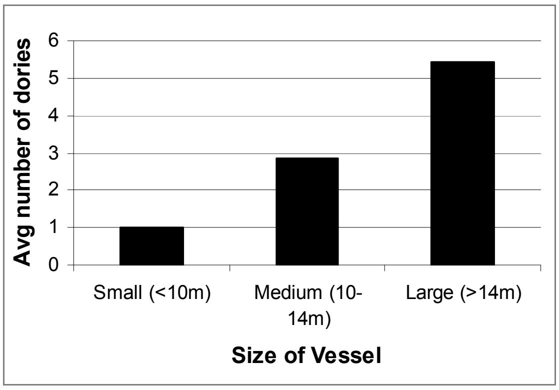

Figure 4.2. Number of dories operated according to vessel type of surveyed commercial fishers.

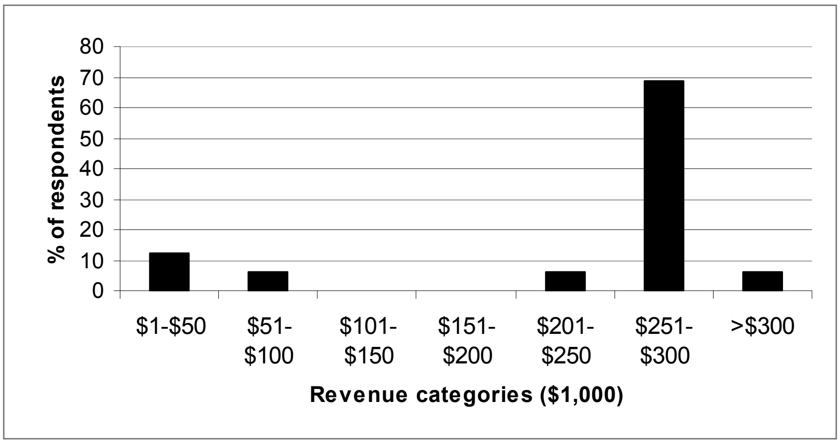

Figure 4.3. Fishers' total revenue received for their selected CRFFF licence over the previous financial year (period ending 30 June 2008).

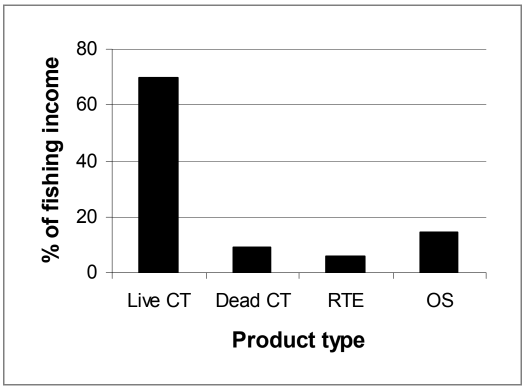

Figure 4.4. Fishers' average fishing income from each CRFF product type for their selected licence.

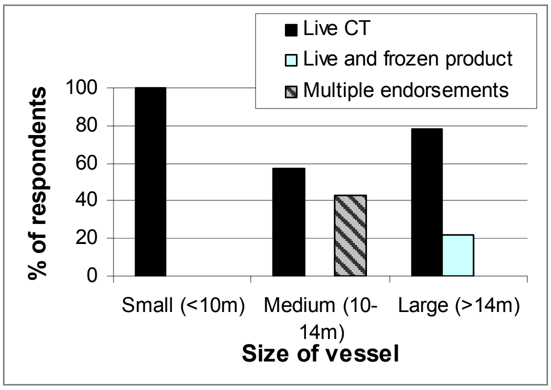

Figure 4.5. Fishers' main source of fishing income according to vessel size.

Effects of TC Hamish

Ninety-three percent of surveyed fishers reported seeing physical damage to the reef in the area affected by TC *Hamish*. Damage reported included (in their words), “lots of coral reduced to rubble”, “dead patches”, “large boulder corals thrown up onto the reef flat”, “overturned plate corals“, and “damage down to twenty metres, particularly on the weather face“. One fisher also noted that “good anchorage was now difficult to find” due to damage caused by the cyclone.

We asked fishers to describe up to the first four trips they completed after the cyclone. Sixty-three percent of respondents stopped fishing for between two and eight weeks (average of four weeks) after TC *Hamish*. This was highly related to vessel size, with all small vessels stopping fishing at some point between the cyclone and the initial survey, and less than 40% of large vessels stopping fishing (Figure 4.6); 80% of the fishers who stopped had returned to fishing by the time of this survey.

On fishers’ first trips after the cyclone, 29% of fishers were not fishing in their common area. By the fourth trip after the cyclone, 50% of fishers were no longer fishing in their common area. Treating each trip provided by all of the surveyed fishers as an individual data point, larger vessels (>14 m) were more likely to move from their fishing area than either smaller or medium-sized vessels (Figure 4.7). All vessels over 14 m had a minimum of five dories. Even if they were within their common area, many fishers mentioned that they were fishing in a different area to what they would normally be at that time of year (not quantifiable in survey).

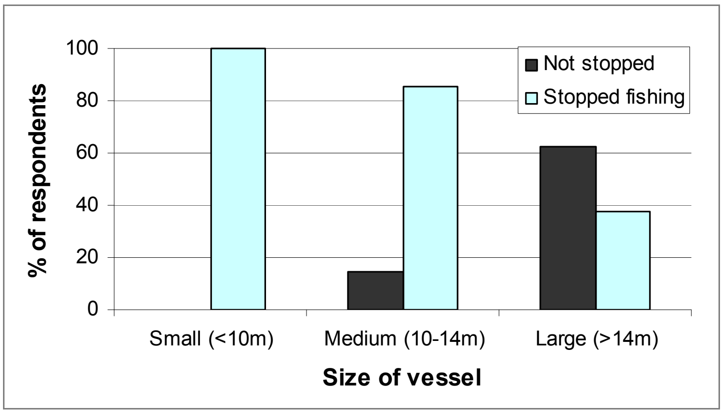

Figure 4.6. Proportion of each vessel size that had stopped fishing for a period of time between the cyclone and the initial survey.

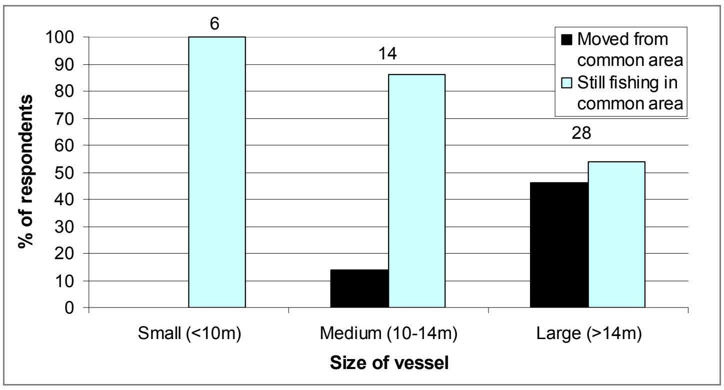

Figure 4.7. Proportion of trips from vessels in each size category that moved from, or remained in, their common fishing area over the first four trips after the cyclone. n = Total number of trips reported for each vessel size category (shown above each size category).

Considering fishers operating both within and outside of their common area, most (87%) stated they noticed lower catches of CT immediately after the cyclone with the remainder reporting no change (Figure 4.8). Forty percent of respondents reported lower catches of red throat emperor and half of the fishers reported lower catches of ‘other species’.

Fishers gave more specific details of up to four trips following the cyclone. Results here focus on coral trout only, given it is the focal species for this fishery and project and answers were more consistent from fishers for this species. Considering each trip from all fishers combined as an individual data point, approximately seventy percent of trips both within and outside of fishers common area returned a lower catch rate of coral trout than fishers expected for that time of year in their common area (Figure 4.9). Despite expectations and anecdotal reports of size and price declines, results showed most trips resulted in coral trout of the same or higher size (for those outside common area) than expected (Figure 4.10) and most received the same price compared to the same time of year previously in fishers' common area (Figure 4.11).

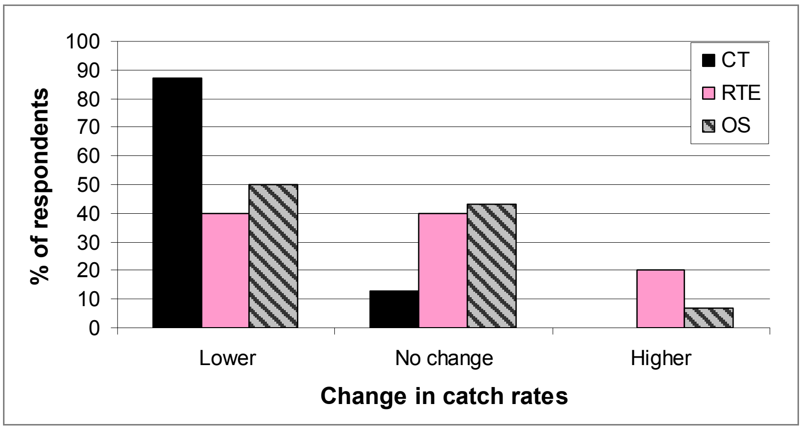

Figure 4.8. Perceived change in catch rates of coral trout (CT), red throat emperor (RTE) and other species (OS) immediately following the cyclone for all fishers, i.e. operating both within and outside of their common area.

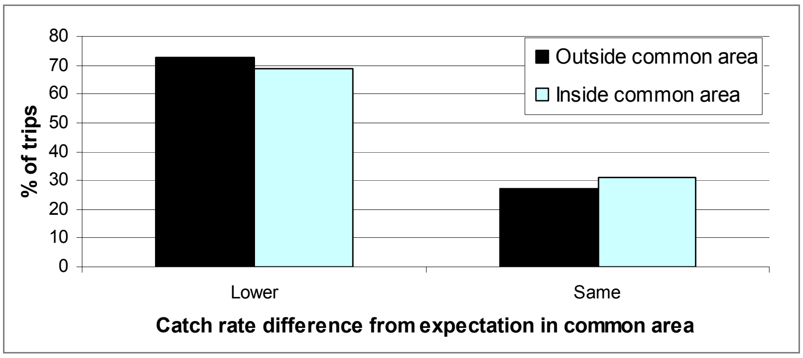

Figure 4.9. Perceived change in catch rates of coral trout (CT) for all trips (within first four) following the cyclone within and outside of fishers' common fishing area (compared to what would normally be expected in their common area at that time of year).

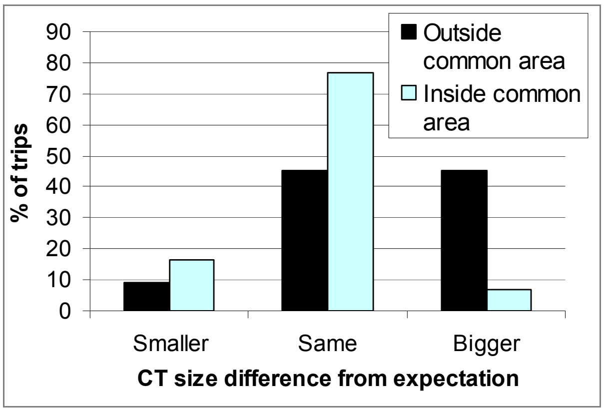

Figure 4.10. Perceived change in size of coral trout (CT) caught in the first four trips following the cyclone both within and outside of fishers' common area (compared to what would normally be expected in their common area at that time of year).

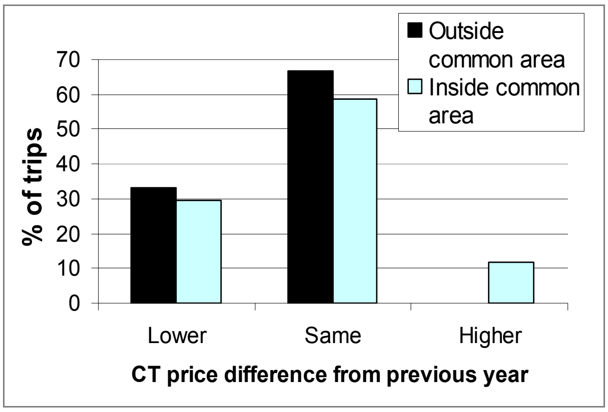

Figure 4.11. Perceived change in price received for coral trout (CT) in the first four trips following the cyclone both within and outside of fishers' common area (compared to the previous year at the same time).

Eighty-eight percent of fishers believed that the cyclone would affect their ability to catch their targeted tonnage of annual reef quota. Also, 83% of respondents stated that they believed they would also miss their targeted turnover as a result of the cyclone.

Eighty-one percent of surveyed fishers said that their running costs were impacted by TC *Hamish*, reportedly increasing from 10-30% per trip. Reasons given included:

- **Travel costs:** increase in fuel/food needed for longer running times (n = 8);
- **Gear costs:** increase in bait/tackle needed for longer running times (n = 4); and
- **Effort costs:** increase in time spent searching for new areas – "twice the time for less fish" (n = 5)

In response to a series of impact statements, the majority of fishers (88%) stated that TC *Hamish* had significantly reduced the profitability of their fishing operation, with 81% of all respondents believing that because of the cyclone they would no longer be able to catch their annual reef fish quota (RQ) (Table 4.1). Most fishers (76%) also believed that TC *Hamish* had disrupted the continuity of reef fish supply to markets. However, the majority of fishers (82%) did *not* believe that the price they were receiving for landed reef fish had been reduced because of the cyclone (as supported by the more detailed trip data in Figure 4.11).

When fishers were asked how else TC *Hamish* had affected their normal operations, responses included:

- **Fishing pressure:** increase in fishing pressure (i.e. lot of boats in a small area) – pulls fish size down; less area to fish;

- **Social pressure:** more stress; hard to be away from family due to longer trips; and
- **Financial pressure:** less fish; more money needed for longer trips; more maintenance; more tackle needed to fish deeper water; demand from restaurants reduced as buyers were after some fish, not others.

Table 4.1. Fishers' response to impact statements regarding Tropical Cyclone *Hamish* and its affect on their fishing business. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'TC *Hamish* has significantly reduced the profitability of my fishing operation'	0	12	**88**
'TC *Hamish* has affected my ability to maintain crew'	29	18	**53**
'Because of TC *Hamish* I will not be able to catch my annual RQ'	13	6	**81**
'TC *Hamish* has not disrupted the continuity of reef fish supply to markets'	**76**	6	18
'The price I receive for landed reef fish has been reduced because of TC *Hamish*'	**82**	12	6

Management options

At the time of this survey, all fishers stated that they were aware that the filleting restrictions had been temporarily lifted in an attempt to help fishers adapt to the impacts of TC *Hamish*. However, only 17% of fishers (n = 3) believed that this would help them to adapt to the impacts of the cyclone. Alternative suggestions for management fell broadly into three categories: area changes throughout the fishery, financial assistance, and 'other' answers. The most common responses related to changes to green zones (Table 4.2).

Table 4.2. Fishers' suggestions for management options to assist with adaptation to Tropical Cyclone *Hamish*.

Category	Suggestion	n (No. of fishers)
Area changes	Close down damaged areas (i.e. Southern fishery) to let them heal, open up new areas	1
	Rotate green zones: relieves fishing pressure by spreading fishery	4
	Open/relax green zones: spreads effort out over larger area (i.e. less impact)	4
Financial help	Disaster/emergency relief	3
	Loan assistance	1
	Drop the price of quota	1
Other	More prevention before tropical cyclone events	1
	Remove/adjust spawning closures	1
	Lift the size of boat restrictions	2

Fishery impacts

When asked to rank potential threats to commercial fishing, most respondents ranked over fishing by commercial fishers as no (67%) or minor (22%) threat (Table 4.3). Most fishers (56%) also considered climate change no threat. The only threat which most fishers considered a 'major' threat was events like cyclones, floods, and droughts.

Table 4.3. Proportion of fishers who view various potential threats to commercial fishing as either 'no threat', 'minor threat' or 'major threat'. Categories chosen by the most respondents are shown in bold for each threat.

Statement	No Threat	Minor Threat	Major Threat	Don't Know
Land-based pollution or run-off from the land	28	**39**	28	6
Coastal development	28	**44**	22	6
Over fishing by recreational fishers	**39**	22	33	6
Over fishing by commercial fishers	**67**	22	6	6
Events like cyclones/floods/drought	22	28	**44**	6
Climate Change	**56**	17	17	11

Climate change

Most fishers (72%) believed that human activity was having an effect on the Earth's climate and the largest proportion (39%) stated this effect was large (Figure 4.12). Likewise, 72% of respondents were concerned about climate change, although most only moderately so (Table 4.4). Seventy-two percent of surveyed fishers were also concerned about the potential effects of climate change on the GBR, but were divided regarding the level of concern. A slight majority (41%) of respondents thought it was *very* necessary to take steps to reduce human activities that are thought to cause climate change.

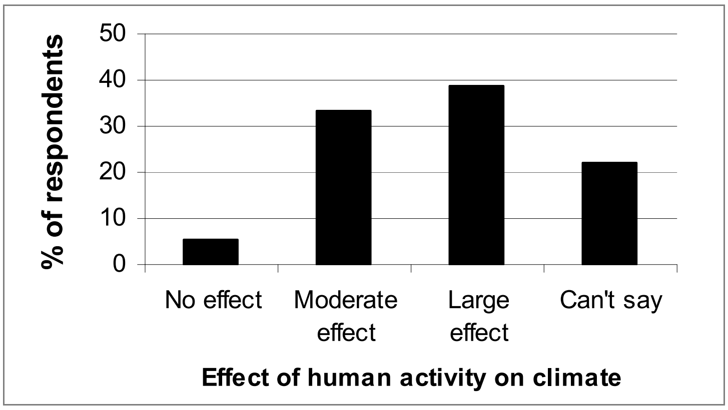

Figure 4.12. Fishers' perceptions of the level of effect human activity is having on the Earth's climate.

Table 4.4. Proportion of fishers concerned about climate change issues and it's affect on the GBR. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Not at all	Moderately	Very	Can't say
How concerned are you about climate change?	22	**44**	28	6
How concerned are you about the potential effects of climate change on the GBR?	28	**39**	33	0
How necessary do you think it is to take steps to reduce human activities that are thought to cause climate change?	12	35	**41**	12

Most fishers (66%) believed that climate change would have either no or minor impact on the GBR in the short term (i.e. over the next twelve months), but were divided as to what the long-term impacts may be (within five vs. 25 years) (Table 4.5).

Table 4.5. Proportion of fishers ranking the level of impact climate change will have on the GBR in the short and longer term. Categories chosen by the most respondents are shown in bold for each statement.

Statement	No impact	Minor impact	Major impact	Can't say
Over the next twelve months?	**33**	**33**	**11**	22
Over the next five years?	28	11	**33**	28
Over the next 25 years?	11	17	**39**	33

Despite concern about climate change, most fishers (72%) did not believe that TC *Hamish* was related to climate change and were divided as to whether or not events like TC *Hamish* will become more intense or more frequent in the future because of climate change (Table 4.6). Many fishers (44%) were concerned about the effects of climate change on the reef line fishery, but half of the respondents did not believe that climate change would decrease the ability of the GBR to support sustainable fisheries.

Table 4.6. Response to impact statements regarding climate change links with cyclones, the Great Barrier Reef and the reef fishery. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am concerned about the effects of climate change on the reef fishery'	22	33	**44**
'I don't think TC *Hamish* is related to climate change'	17	11	**72**
'Events like TC *Hamish* will happen more often now because of climate change'	**33**	**33**	**33**
'Cyclones are likely to be more intense in the future as a result of climate change'	28	**44**	28
'Climate change will decrease the ability of the GBR to support sustainable fisheries'	**50**	17	33

Resilience

Responses to impact statements made in direct relation to cyclones showed that most fishers (59%) believed that TC *Hamish* had made them think that they were more vulnerable to future cyclones and 65% of respondents stated that they plan for cyclones each cyclone season (Table 4.7). Over half (53%) of the respondents stated that if there was another cyclone they would not survive much longer. Despite this, most (53%) surveyed fishers did not agree they were becoming more worried about the risk of cyclones each season.

Table 4.7. Response to impact statements regarding resilience to cyclones. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am becoming more worried about the risk of cyclones each season'	**53**	18	29
'If there is another cyclone I will not survive much longer'	29	18	**53**
'I plan for cyclones each season (before *Hamish*)'	24	12	**65**
'TC *Hamish* has made me think that I am very vulnerable to future cyclones'	35	6	**59**

Fishers were asked to rate their level of agreement with various statements measuring the importance of fishing to them and their intention to remain in the industry (Table 4.8). Overall importance of fishing rated very high with most respondents (76%) stating that they would rather be at sea than on land, were proud to be a commercial fisher (78%), and were likely to always be a fisher (94%). However, a slight majority (56%) stated that they were not as happy with being a fisher now as when they first started.

Table 4.8. Level of agreement with statements regarding the importance of fishing to respondents. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I prefer to be at sea rather than on land'	12	12	**76**
'I am likely to always be a fisher'	0	6	**94**
'The fishing industry to me is a lifestyle – it is not just my job'	11	6	**83**
'I feel proud to tell people that I am a commercial fisher'	11	11	**78**
'I am not as happy with being a fisher now as I was when I first started'	44	0	**56**

Fishers were asked their level of agreement with various statements relating to their level of resilience (Table 4.9). All statements, when considered together, received a Cronbach's α value of 0.688, which we considered to be reliable for an overall measure of resilience. Fishers' average 'resilience score' was calculated by taking the average response of all statements (where a statement was worded negatively, the response was reversed, i.e. 1 = 5, 2 = 4, and so on). Most fishers (50%) had a 'Medium' resilience score, with an overall average resilience score of 3.08, i.e. medium resilience. Linear regression revealed significant interaction between resilience score and education level ($p = 0.041$). Only fishers who completed Year 12 or technical college had a high resilience level (Figure 4.13). No other demographic or business related variables showed significant correlation.

Table 4.9. Fishers' responses to resilience statements. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am confident things will turn out well regardless of whether there is another cyclone'	28	11	**61**
'I am confident I could get work elsewhere if I needed to'	**50**	6	44
'I am more likely to cope with an additional cyclone compared to other fishers I know'	33	11	**56**
'I have many career options available to me if I decide to no longer be a fisher'	67	6	28
'I can cope with a small cyclone in the region'	11	6	**83**
'I am too young to retire and too old to find work elsewhere'	11	22	**67**
'I have planned for my financial security'	22	11	**67**
'I am not competitive enough to survive another cyclone'	**81**	6	13
'I am interested in learning new skills outside of the industry'	**50**	17	33
'It is not easy for me to find new fishing grounds compared to other fishers I know'	33	28	**39**

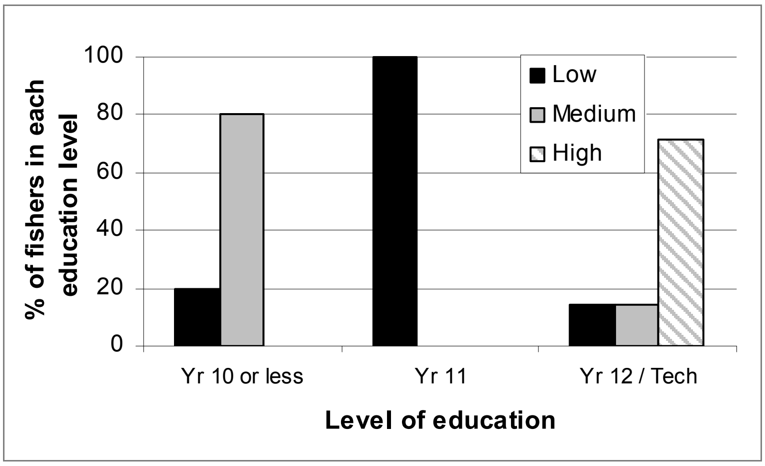

Figure 4.13. Resilience level (low, medium, high) of fishers in each education category. While resilience level is shown here, regression was carried out on resilience score.

(b) Follow-up survey

All 18 fishers from the initial survey agreed to let us contact them again in three months to do a follow-up survey. From these, 16 follow-up surveys were completed, which included 14 fishers still currently fishing in the current fishery and two fishers that had stopped fishing at the time of this survey. Two fishers declined to do the follow-up survey. We will explore the opinions of the fishers who stopped fishing first.

1. Stopped fishing

Effects of TC Hamish

Both fishers listed TC *Hamish* as the main reason that they had left the fishing industry. One of these fishers had stopped fishing for three weeks immediately after the cyclone, returned to fishing for a short period of time, and re-stopped two months prior to this survey. The other fisher had continued fishing after TC *Hamish* up to two weeks prior to this survey but stopped due to stress caused by decreased catches from TC *Hamish*.

Both fishers initially noticed physical damage to the reef in the area affected by the cyclone and both stated that they still noticed damage the last time they fished. Both respondents believed that it would take “years” for the reef to recover.

Both fishers fished in a different area than what they normally would for their first four trips after the cyclone. Compared to their normal area, both respondents stated that fishing quality was initially lower in the new area and that this did not change while they were fishing there. One fisher never returned to the normal area; the other fisher returned two weeks prior to this survey and stated that, although initially catch rates within the normal area were lower for CT, RTE, and OS, the catch rates for CT and RTE were now higher overall, but still lower than what would normally be expected for this time of year.

Both fishers believed that the cyclone had affected their ability to catch their targeted tonnage of annual reef quota in the LAST quota year (ending last June) and both stated that they had missed their targeted turnover LAST financial year as a result of the cyclone – one by an estimated $75,000 per month. Both believed that their running costs were impacted as a result of TC *Hamish*.

Management actions

One of the fishers stated in the initial survey that the filleting restrictions did help them in the short term, and they harvested more 'other species' as a result. In this survey, fishers' suggestions for management options to improve adaptation to the cyclone included both a short-term solution:

- Rotation of green zones;

and two long-term solutions:

- Shutting down affected areas;
- Control effort (tie up boats in affected area) so that it doesn't shift north.

Both fishers believed that financial assistance was necessary in order to help fishers adapt to an event like TC *Hamish*. Suggestions for mode of delivery of financial assistance included:

- Low interest loans;
- Help to meet payments (i.e. so fishers can go on unemployment benefits until the fishery improves).

They stated financial assistance would have made things easier. One fisher stated if he had financial assistance he might have made it through to keep fishing; the other stated if he had a low interest loan he could have stopped fishing temporarily until the fishery recovered instead of having to sell the business.

Resilience

From the initial survey, these fishers had resilience scores of 2.5 (low) and 2.6 (medium). Both of these Mackay based fishers operated large vessels with five and six dories, received 90% and 70% of their income from live coral trout, respectively, and received a total revenue of over $300,000 p.a. Their debt repayments were very high, however ($251-$300,000 for the previous financial year). The fishers were 45 and 50 years of age, had been fishing for 20 years and 38 years, respectively, and each had a low level of education (Year 10 or less). One fisher had other training, and had other sources of family income: This fisher was able to find other employment, although the income was not equivalent ($150,000 less) to what he had been making in the fishing industry. Unfortunately the other fisher, with no other training and with 100% of the family income from fishing, was not able to find other employment (despite having not fished for two months). This fisher stated he intended to buy a smaller boat and return to the industry. Both respondents stated that were sad and disappointed to have to leave, but they maintained links to the fishing industry and intended to return.

2. Still currently fishing

Effects of TC Hamish

In this survey, 86% of responding fishers stated that they had initially noticed physical damage to the reef in the area affected by the cyclone and, of these fishers, all stated that they STILL noticed damage. When asked how long they thought it would take the reef to recover:

- 38% of fishers believed it would take many years (i.e. 4-5);
- 23% of fishers believed it would take at least one year;
- 15% of fishers believed it would take until the next spawning season (October); and
- 23% of fishers didn't know.

In this survey, 57% of fishers fished in a different area than what they normally would for their first four trips after the cyclone. Of those fishers that moved, 75% stated that there was initially no difference in fishing quality between normal and new areas, but 75% stated that catches had changed since then and are now lower. Half had returned to their normal area by the time of this survey, citing:

- Too much fishing pressure (i.e. too many boats) in a small area; and
- Higher costs for longer trips north with lower total catch.

Perceived trends in *initial* catch rates of coral trout, red throat emperor and 'other species' in fishers' normal areas immediately after the cyclone showed most fishers believed catches were lower for all species groups, particularly coral trout (Figure 4.14). This was similar to what was reported in the initial survey (see Figure 4.8), although there was a *increase* (18%) in the proportion of fishers who noticed lower initial catch rates of red throat emperor as well as 10% *decrease* in the proportion of fishers who noticed lower initial catch rates of other species. This change in perception may be partly due to the omission of fishers now not fishing, or change in perception over time.

We asked fishers how the catch rates in their normal area compare NOW compared to immediately after the cyclone; While most fishers stated no change in catch rates for coral trout (50% of fishers) and other species (70% of fishers), 40% of fishers stated coral trout catch rates had declined further, and 50% of fishers stated red throat emperor catch rates had increased since immediately after the cyclone

(Figure 4.15). However, all fishers believed that catch rates of coral trout were lower than what would be expected in the normal area for that time of year (Figure 4.16). Fishers were divided in their perceptions of catch rates for red throat emperor and other species.

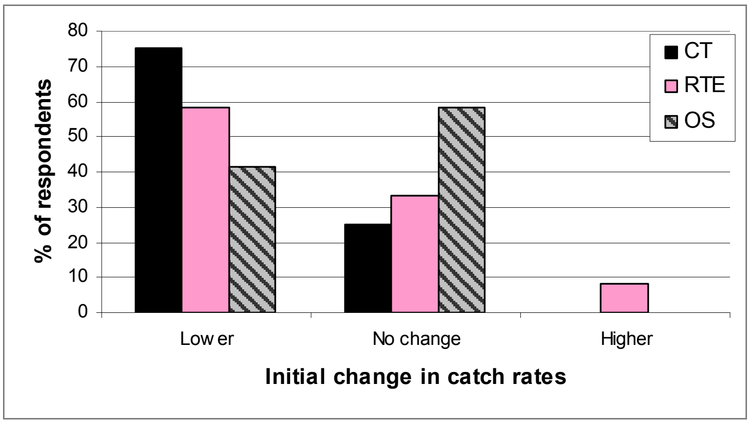

Figure 4.14. Perceived change in initial catch rates of coral trout (CT), red throat emperor (RTE) and other species (OS) immediately following Tropical Cyclone *Hamish* in fishers' common area.

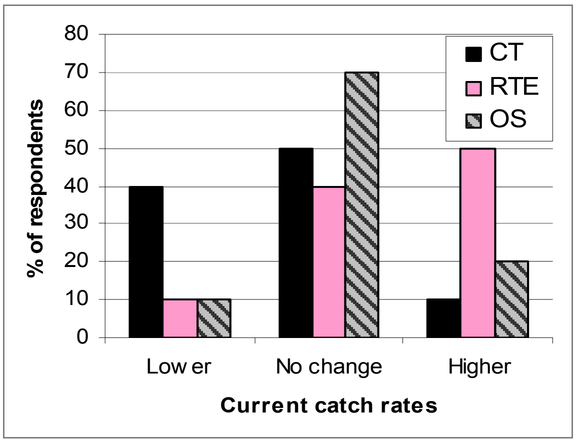

Figure 4.15. Perceived current catch rates of coral trout (CT), red throat emperor (RTE) and other species (OS) compared to immediately following Tropical Cyclone *Hamish* for fishers' common area.

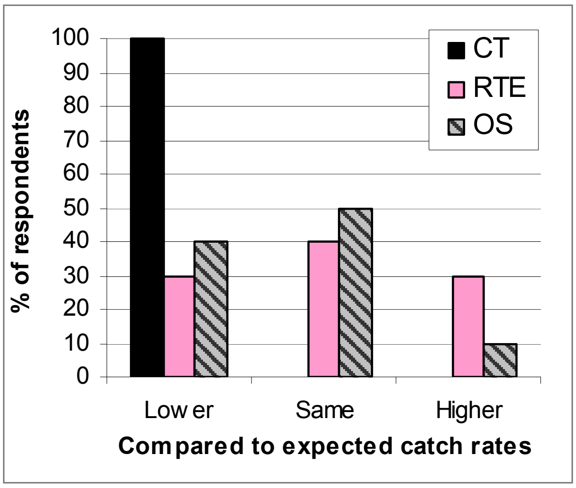

Figure 4.16. Perceived current catch rates of coral trout (CT), red throat emperor (RTE) and other species (OS) compared to expected catch rates in fishers' common area.

Although most fishers (88%) in the initial survey stated that they believed the cyclone *would* affect their ability to catch their targeted tonnage of annual reef quota, this turned out not to be the case; in this follow-up survey 62% of respondents stated that they did not believe that the cyclone had affected their ability to catch their targeted tonnage of annual reef quota in the LAST quota year (ending last June). However, 92% of fishers did believe that the cyclone would affect their ability to catch their targeted tonnage of annual reef quota THIS quota year.

Similarly, in the initial survey, most fishers (83%) stated that they would miss their targeted turnover as a result of the cyclone; however, in this survey most (67%) respondents stated that they did *not* miss their targeted turnover LAST financial year as a result of TC *Hamish*. On the other hand, 62% of fishers *did* believe that they were likely to miss their targeted turnover THIS financial year by an estimated 20-50% as a result of the cyclone.

Most (71%) fishers believed that their running costs had been impacted as a result of TC *Hamish*, reportedly increasing from 15-50% per trip; most reasons for this included the increased amount of fuel, stores, and bait needed for longer trips catching less fish.

The ratios of responses given to impact statements in the follow-up survey were similar to those given in the initial survey (shown in grey in Table 4.10). There was a marginal increase in the proportion of respondents who believed that TC *Hamish* had affected their ability to maintain crew. As well, there was a 17% increase in the proportion of fishers that felt that the cyclone had disrupted the continuity of reef fish supply to markets.

Table 4.10. Fishers' response to impact statements regarding Tropical Cyclone *Hamish* and its affect on their fishing business. Categories chosen by the most respondents are shown in bold for each statement. Proportions for the initial survey are shown in grey in parentheses.

Statement	Disagree	Neutral	Agree
'TC *Hamish* has significantly reduced the profitability of my fishing operation'	0 (0)	14 (12)	**86** (88)
'TC *Hamish* has affected my ability to maintain crew'	14 (29)	21 (18)	**64** (53)
'Because of TC *Hamish* I will not be able to catch my annual RQ'	7 (13)	21 (6)	**71** (81)
'TC *Hamish* has not disrupted the continuity of reef fish supply to markets'	**93** (76)	0 (6)	7 (18)
'The price I receive for landed reef fish has been reduced because of TC *Hamish'*	**79** (82)	21 (12)	0 (6)

When asked in what other ways TC *Hamish* had affected normal operations, responses fell roughly into the following three categories:

- **Fishing pressure:** increase in fishing pressure (i.e. lot of boats in a small area);
- **Social pressure:** hard to be away from family due to longer trips north; social negativity between dorymen, especially in Bowen (i.e. tension/fights); and
- **Financial pressure:** less fish; crew difficult to maintain; had to take out loans.

Management options

In this survey, 69% of respondents stated that they did not believe that filleting restrictions had helped them to adapt to the impacts of the cyclone – a similar result to what was reported in the initial survey; reasons given included:

- Not worth the extra time it takes to do it; and
- No market; easier to sell fillet on the black market, but this does not help the fishery.

All fishers (n = 4) who stated that filleting restrictions *did* help them to adapt to the impacts of the cyclone stated that they stayed primarily focused on coral trout after TC *Hamish*, but were now also selling some red throat emperor and 'other species'.

Fishers offered short- and long-term suggestions for management to assist in fisher adaptation to TC *Hamish* (Table 4.11). Fishers were asked to focus on solutions apart from changes to Marine Park zoning in their answers; however some did include such suggestions.

Most (71%) respondents believed that financial assistance was necessary in order to help fishers adapt to an event like TC *Hamish*. Suggestions for mode of delivery included:

- Low interest loans (n = 5);
- Freeze interest on existing/new loans (n = 4);
- Payouts/license buy backs (n = 3); and
- Pay some boats to sit out, i.e. smaller boats that can't move as much (n = 1).

Table 4.11. Fishers' suggestions for management options to assist with adaption to Tropical Cyclone *Hamish*.

Time-frame	Category	Suggestion	n (No. of fishers)
Short-term	Financial	Fuel subsidies	1
		Loans	1
		Compensation for those in affected areas: declare it a natural disaster	2
	Area	Open green zones: spreads out effort/reduces conflict	2
	Other	Remove/control effort: zone boats so they have to stay in their own areas	2
		Fix the weather station on Gannet Cay	1
		Change of government	1
Long-term	Financial	Make WWF buy our licenses	1
	Area	Rotate green zones	3
		Farm the whole area and close it each year when quota is caught	1

Resilience

The ratios of responses given to impact statements in direct relation to cyclones in the follow-up survey were somewhat different to those given in the initial survey (shown in grey in Table 4.12). Notably, the proportion of fishers who stated that they were becoming more worried about the risk of cyclones each season more than doubled. As well, there was an approximate decrease in the proportion of fishers who believe they plan for cyclone each season, and a 20% increase in the number of respondents who stated that TC *Hamish* had made them think that they were very vulnerable to future cyclones.

Table 4.12. Response to impact statements regarding resilience to cyclones. Categories chosen by the most respondents are shown in bold for each statement. Proportions for the initial survey are shown in grey in parentheses.

Statement	Disagree	Neutral	Agree
'I am becoming more worried about the risk of cyclones each season'	29 (53)	7 (18)	**64** (29)
'If there is another cyclone I will not survive much longer'	29 (29)	29 (18)	**43** (53)
'I plan for cyclones each season (before *Hamish*)'	**43** (24)	14 (12)	**43** (65)
'TC *Hamish* has made me think that I am very vulnerable to future cyclones'	7 (35)	14 (6)	**79** (59)

(c) Final survey

All continuing fishers (14) from the follow-up survey agreed to let us contact them again to do a final follow-up survey, of which 14 surveys were completed in February-March 2010 (approximately one year after TC *Hamish*). One of these fishers left the industry since the follow-up survey, but still answered most questions on the final survey. This fisher stated he left the industry because the catch rates were not very good and he had legal issues. He had found other employment (although at half the income), and will likely return to fishing in the future.

Effects of TC Hamish

Similar to the initial survey, in this final survey 93% of fishers stated that they initially noticed physical damage to the reef in the area affected by the cyclone; of these, all but one fisher stated that they still noticed damage. Of those who responded, most (n = 5, 56%) believed that it would take many years (anywhere from three to fifteen years) for the reef to recover, and 1 fisher stated they didn't think it could recover. Others were unsure (n = 1) or thought the fish were starting to return (n = 2).

Sixty nine percent of fishers in this final survey stated that they fished in a different area than what they normally would for their first four trips after the cyclone. This is slightly higher the number of respondents that said they were fishing outside their common area in the initial survey, a discrepancy that can possibly be accounted for if fishers did not complete four trips prior to the initial survey but moved after, and when fishers that stopped fishing are taken into consideration.

Of those fishers that stated they had moved, most (56%) stated that, compared with what they had expected for their normal area, fishing quality was initially *lower* in new areas (Figure 4.17). Most (78%) fishers stated that catches were now even lower than what they were initially in these areas (Figure 4.17); a similar response to what was seen in the last survey (75%). Eighty-nine percent of respondents had returned to their normal area by the time of this final survey – this was a nearly 40% increase in the number of fishers that had returned to their normal area by the time of the second survey. Of those who gave useable reasons why (n = 7), 85% (n = 6) stated it was because of crowding resulting in declining catch rates. The remaining responding fisher stated the weather in the new area made it difficult with the size of boat they had.

Of those fishers that remained or had returned to their normal areas after TC *Hamish*, 92% reported lower *initial* catch rates of coral trout directly after the cyclone (Figure 4.18); this is a slightly higher proportion than was seen in both the initial (87%) and follow-up (70%) surveys. Compared to the initial survey, there was a 35% increase in the proportion of fishers who reported lower initial catches of RTE and a 25% increase in the proportion of fishers who reported lower initial catch rates of 'other species'. This may be attributed to recall bias or changes in proportions due to the omission of fishers no longer participating.

Current trends in catch rates at the time of this final survey show an improvement in catch rates for all species groups compared to immediately after TC *Hamish* (Figure 4.19). Despite this improvement, all respondents stated that they believed catch rates of coral trout to be lower than what would be expected in fishers' normal area for this time of year and 75% of fishers believed that catches of red throat emperor and 'other species' were also lower than what would be expected in their normal area for this time of year.

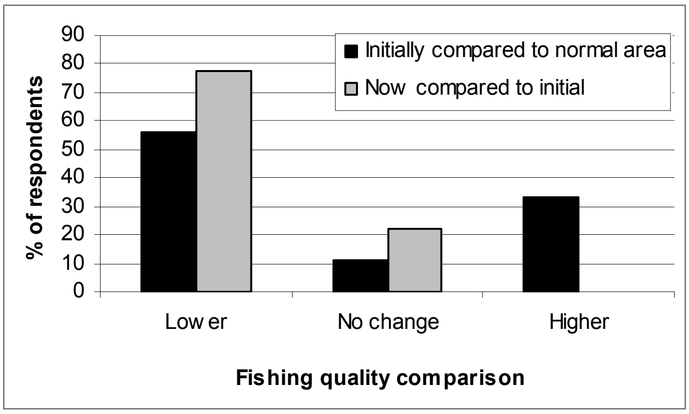

Figure 4.17. Perceived change in fishing quality for fishers operating outside of their common area immediately following the cyclone compared to their expectations for their common area, and in comparison to their initial catch rates.

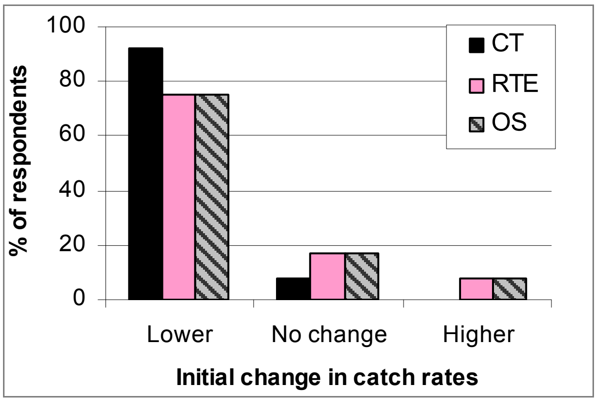

Figure 4.18. Perceived change in initial catch rates of coral trout (CT), red throat emperor (RTE) and other species (OS) immediately following Tropical Cyclone *Hamish* for fishers operating within their common area.

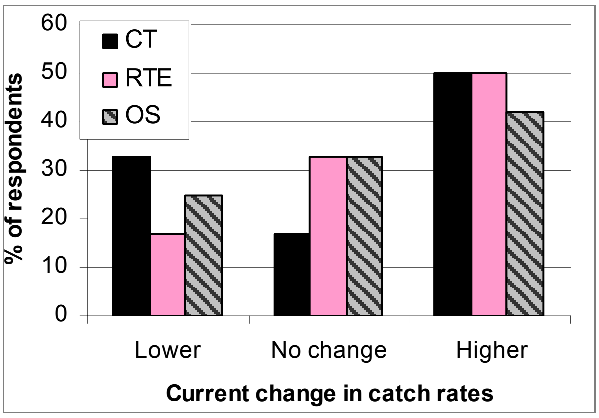

Figure 4.19. Perceived change in current catch rates of coral trout (CT), red throat emperor (RTE) and other species (OS) immediately following Tropical Cyclone *Hamish* for fishers operating within their common area.

Similar to the follow-up survey, in this final survey 92% of fishers stated that they still believed that the cyclone would affect their ability to catch their targeted tonnage of annual reef line quota THIS quota year. Seventy-seven percent of fishers also stated that they believed they were likely to miss their targeted turnover THIS financial year, which was a 15% increase in the proportion of respondents that reported this in the previous survey. Estimates of how much fishers were likely to miss their targeted turnover by as a result of TC *Hamish* also went up from an estimated 20-50% in the previous survey to 30-60% in this final survey.

Most fishers (69%) still believed that their running costs had been impacted as a result of TC *Hamish*; this was similar but slightly lower than what was seen for both the initial (81%) and follow-up (71%) surveys. Reasons given were the same to those listed in the previous survey, specifically the increased amount of fuel, stores, and bait needed for longer trips catching less fish.

The ratios of responses given to impact statements regarding TC *Hamish* in this final survey were similar to those given in the initial survey (shown in grey in Table 4.13), although with an increase in proportions for those answers given by the most respondents, i.e. more fishers believed TC *Hamish* reduced the profitability of their business, affected their ability to maintain crew and catch their annual RQ, and disrupted continuity of reef fish supply. More fishers disagreed that the price they received for reef fish was affected.

Table 4.13. Fishers' response to impact statements regarding TC *Hamish* and its affect on their fishing business. Categories chosen by the most respondents are shown in bold for each statement. Proportions for the initial survey are shown in grey in parentheses.

Statement	Disagree	Neutral	Agree
'TC *Hamish* has significantly reduced the profitability of my fishing operation'	0 (0)	8 (12)	**92** (88)
'TC *Hamish* has affected my ability to maintain crew'	8 (29)	23 (18)	**69** (53)
'Because of TC *Hamish* I will not be able to catch my annual RQ'	8 (13)	8 (6)	**85** (81)
'TC *Hamish* has not disrupted the continuity of reef fish supply to markets'	**92** (76)	0 (6)	8 (18)
'The price I receive for landed reef fish has been reduced because of TC *Hamish*'	**85** (82)	15 (12)	0 (6)

When asked how TC *Hamish* has affected normal operations, responses included:

- **Fishing pressure:** increase in fishing pressure (i.e. lot of boats in a small area);
- **Social pressure:** hard to be away from family due to longer trips north; more stress; less time off;

- **Financial pressure:** less fish; crew difficult to maintain; have had to retrain crew to work damaged areas;
- **Increase in poaching:** boats working in Green areas; and
- **Becoming more dangerous:** working in rougher weather to make pay.

At the suggestion of the working group for the project we asked fishers specifically if they had noticed tension increasing between fishers due to crowding particularly around the Bowen region. Seven of 14 fishers responded affirmatively; the others did not respond.

Management options

Opinions on suggested management options (adapted from fishers' open responses in previous surveys) to help fishers better adapt to, or cope with, environmental events like TC *Hamish* in the future showed that most respondents (79%) preferred the option of allowing fishers in affected areas to receive income support, but be allowed to continue fishing (Table 4.14). All fishers also indicated that they would support a management option that would declare the cyclone a natural disaster, making disaster relief available. Of the options that were strongly supported, most respondents (45%) preferred the former. All fishers disagreed the affected area should be closed without compensating affected fishers.

Additional management options suggested by respondents included:

- Low-interest loans, rebates, or freezing of existing loans;
- Provide more financial counselling services;
- Zone boats to control fishing effort;
- Rotate/open Green zones;
- Pay a limited number of fishers to sit out;
- Have a three-month closure and get paid for it; and
- More information on what price to expect from exporters.

Again at the suggestion of the working group for the project we asked fishers how much compensation they think they would need, if it were available. Two fishers listed $50-$100,000, one fisher stated $300,000, and another $500,000. Others were unsure of exact figures, but stated they would need enough to "pay the crew to sit out", or "help with debt".

This project aimed to assess the usefulness of lifting the filleting restrictions as a short-term adaptation option. Previous surveys suggested low support or usefulness of this option. In this survey we asked fishers if the relaxation of filleting restrictions would help more in the future if the markets for the product were allowed to develop: five fishers responded, two affirmatively and three negatively.

Table 4.14. Fishers' opinions on suggested management options to assist with adaptation to Tropical Cyclone *Hamish*. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree	% preferred
'Close the affected area to allow it to recover, without compensation for affected fishers'	**100**	0	0	
'Provide income support to fishers in the affected area provided they stop fishing, hence reducing the impact on the area and stopping displacement of effort'	21	21	**57**	
'Provide income support to fishers in the affected area but allow them to continue fishing'	7	14	**79**	**45**
'Remove spawning closures at least for the affected year'	36	21	**43**	
'Relax filleting restrictions, as they did for TC *Hamish*'	14	**43**	**43**	18
'Declare a natural disaster so disaster relief is available to fishers'	0	0	**100**	36

Fishery impacts

When asked to rank potential threats to commercial fishing, trends in the ratios of responses provided by fishers in the final survey were similar to those given in the initial survey (shown in grey in Table 4.15), with a few notable exceptions. There was a 25% decrease in the proportion of fishers that considered over fishing by recreational fishers to be a major threat, with most (75%) now considering it to be only a minor threat. There was also a 39% decrease in the proportion of fishers that believed climate change to be no threat. Events like cyclones/floods/droughts were still listed as a major threat by the majority of fishers – now listed by over half.

Table 4.15. Proportion of fishers that view various potential threats to commercial fishing as no, minor or major threats. Categories chosen by the most respondents are shown in bold for each statement. Proportions for the initial survey are shown in grey in parentheses.

Statement	No Threat	Minor Threat	Major Threat	Don't Know
'Land-based pollution or run-off from the land'	25 (28)	**50** (39)	25 (28)	0 (6)
'Coastal development'	33 (28)	**42** (44)	25 (22)	0 (6)
'Over fishing by recreational fishers'	17 (39)	**75** (22)	8 (33)	0 (6)
'Over fishing by commercial fishers'	**75** (67)	25 (22)	0 (6)	0 (6)
'Events like cyclones/floods/drought'	25 (22)	17 (28)	**58** (44)	0 (6)
'Climate change'	17 (56)	**33** (17)	25 (17)	25 (11)

Climate change

In this final survey, all fishers believed human activity was having an effect on the Earth's climate. However, more fishers in the final survey believed this was a moderated effect rather than a large effect, compared to the initial survey (Figure 4.20).

There was an increase in the proportion of fishers who were not at all concerned about climate change and its potential effect on the GBR (Table 4.16). Likewise there was a decrease in the proportion of fishers who though it was very necessary to take steps to reduce human activities that are thought to cause climate change – many of these fishers now thought it was moderately necessary.

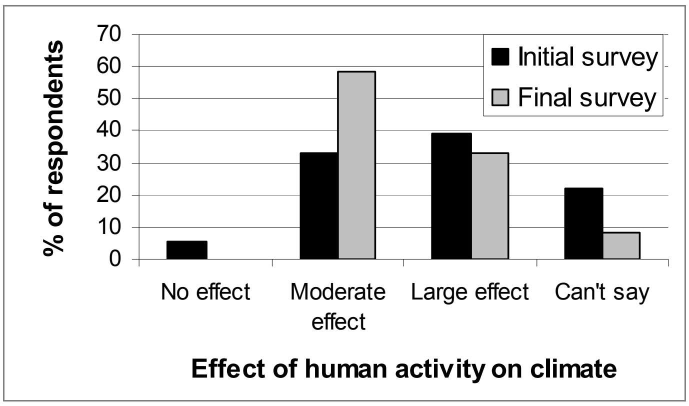

Figure 4.20. Fishers' perceptions of the level of effect human activity is having on the Earth's climate. Comparison of opinions in the initial and final survey.

Table 4.16. Proportion of fishers concerned about climate change issues. Categories chosen by the most respondents are shown in bold for each statement. Proportions for the initial survey are shown in grey in parentheses.

Statement	Not at all	Moderately	Very	Can't say
How concerned are you about climate change?	**42** (22)	33 (44)	17 (28)	8 (6)
How concerned are you about the potential effects of climate change on the GBR?	**42** (28)	33 (39)	17 (33)	8 (0)
How necessary do you think it is to take steps to reduce human activities that are thought to cause climate change?	17 (12)	**58** (35)	17 (41)	8 (12)

Compared to the results from the initial survey (shown in grey in Table 4.17) there was an overall decrease in the concern about climate change impacts on the GBR in the short- and long-term. There was an increase in the proportion of fishers who believed that climate change would have no impact on the GBR in the next twelve months (58% of fishers) or five years (42%). While most fishers believed there would be an impact in the next 25 years, a higher proportion stated this would be minor.

Table 4.17. Proportion of fishers ranking climate change impacts on the GBR in the short and longer term. Categories chosen by the most respondents are shown in bold for each statement. Proportions for the initial survey are shown in grey in parentheses.

Statement	No impact	Minor impact	Major impact	Can't say
Over the next 12 months?	**58** (33)	25 (33)	0 (11)	17 (22)
Over the next 5 years?	**42** (28)	25 (11)	8 (33)	25 (28)
Over the next 25 years?	17 (11)	**33** (17)	25 (39)	25 (33)

Compared to the initial survey (shown in grey in Table 4.18) despite division regarding concern about climate change effects on the reef fishery, there was a 37% increase in the proportion of fishers who believed that TC *Hamish* was related to climate change. Regardless, most respondents (46%) did not believe that events like TC *Hamish* would become more frequent or more intense in the future because of climate change (fishers were divided in their agreement with these statements in the initial survey). Fishers were divided as to their concern about the effects of climate change on the ability of the GBR to support sustainable fisheries.

Table 4.18. Response to impact statements regarding the climate change links with cyclones, the Great Barrier Reef and the reef fishery.Categories chosen by the most respondents are shown in bold for each statement. Proportions for the initial survey are shown in grey in parentheses.

Statement	Disagree	Neutral	Agree
'I am concerned about the effects of climate change on the reef fishery'	**38** (22)	23 (33)	**38** (44)
'I don't think TC Hamish is related to climate change'	**54** (17)	31 (11)	15 (72)
'Events like TC Hamish will happen more often now because of climate change'	**46** (33)	15 (33)	38 (33)
'Cyclones are likely to be more intense in the future as a result of climate change'	**46** (28)	15 (44)	38 (28)
'Climate change will decrease the ability of the GBR to support sustainable fisheries'	31 (50)	**38** (17)	31 (33)

Resilience

The ratios of responses given to impact statements in direct relation to cyclones in this final survey were different to those given in both the initial survey (shown in grey in Table 4.19) and follow-up survey (not shown here). In the current survey, fishers were divided as to whether they were becoming more worried about the risk of cyclones each season as well as to whether or not they would survive much longer given another cyclone; in contrast, in the initial survey most (53%) fishers were not worried about the former, but were concerned about the latter. In the current survey, respondents were divided as to whether or not they would NOW plan for cyclones each cyclone season – a difference from the initial survey where most (65%) fishers agreed that they now would. Interestingly, 63% of fishers who agreed TC *Hamish* affected their profitability (Table 4.13) also agreed they will now plan for cyclones each season. Similar to the initial survey, most respondents (54%) stated that TC *Hamish* had made them think that they were very vulnerable to future cyclones. Regardless, 85% of fishers said they would still be fishing in the current fishery in three years' time.

Fishers were asked their level of agreement with various statements relating to their resilience (Table 4.20), based again on statements modified from Marshall and Marshall (2007). Considering all statements together to give an overall 'score' of resilience, most fishers (50%) had a 'Medium' resilience score (Figure 4.21), with an overall average resilience score of 3.14, i.e. medium resilience – this was similar to the initial survey.

Table 4.19. Response to impact statements regarding resilience to cyclones. Categories chosen by the most respondents are shown in bold for each statement. Proportions for the initial survey are shown in grey in parentheses.

Statement	Disagree	Neutral	Agree
'I am becoming more worried about the risk of cyclones each season'	31 (53)	31 (18)	**38** (29)
'If there is another cyclone I will not survive much longer'	31 (29)	31 (18)	**38** (53)
'I will NOW plan for cyclones each season'	46 (24)	0 (12)	**54** (65)
'TC *Hamish* has made me think that I am very vulnerable to future cyclones'	23 (35)	23 (6)	**54** (59)

Table 4.20. Response to resilience statements. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am confident things will turn out well regardless of whether there is another cyclone'	33	17	**50**
'I am confident I could get work elsewhere if I needed to'	**50**	8	42
'I am more likely to cope with an additional cyclone compared to other fishers I know'	25	**42**	33
'I have many career options available to me if I decide to no longer be a fisher'	67	17	17
'I can cope with a small cyclone in the region'	0	0	**100**
'I am too young to retire and too old to find work elsewhere'	25	8	**67**
'I have planned for my financial security'	8	8	**83**
'I am not competitive enough to survive another cyclone'	**75**	8	17
'I am interested in learning new skills outside of the industry'	42	0	**58**
'It is not easy for me to find new fishing grounds compared to other fishers I know'	**50**	8	42

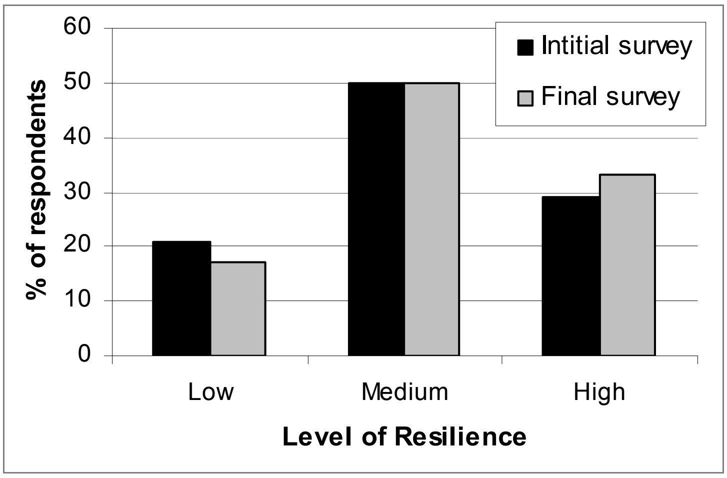

Figure 4.21. Resilience level of fishers as measured by the set of resilience statements. Initial survey compared to final survey.

There were three fishers whose level of resilience changed between the initial and final survey:

1. The first fisher decreased from High to Medium resilience level mostly due to a *decrease* in confidence concerning his ability to find work elsewhere and the number of career options available to him should he decide to no longer be a fisher.
2. The second fisher increased from Medium to High resilience level due to an *increase* in confidence concerning his ability to cope with a small cyclone in the region.
3. The third fisher increased from Low to High resilience level mostly due to an *increase* in confidence concerning his ability to find work elsewhere, the number of career options available to him, his interest in learning new skills, and ability to survive another cyclone.

Why these fishers' responses to these statements changed over the time of the project is unknown.

Fishers were asked specifically what they would do in the event of another cyclone. Most fishers appear to intend to remain in the reef line fishery, but to move to other grounds unaffected by the cyclone, as they did with TC *Hamish* (Table 4.21).

Table 4.21. Fishers' likely response to future cyclones.

Choice	Detail	n
Keep fishing in reef fishery	Move to other grounds	4
	Sell inshore boat to supplement reef fishing	1
Diversify into other fishery	Try crabbing / deepwater	1
Leave industry	Work elsewhere	2
	Stop until it has recovered	1

4.3.2 Indirectly impacted fishers

(a) Initial survey

Demographics

Of the five commercial fishers that were *indirectly* impacted by TC *Hamish*, all were male. Age of respondents ranged from 35-58 years, with an average age of 42 years. Most (80%) fishers were married and had three people in their household, i.e. with dependents under the age of 18 years in their household.

The largest proportion of fishers (60%) achieved an academic education of Year 10 or lower. The remainder had an education level up to Year 11 (none were higher). However, 80% of surveyed fishers had other training which included trades (75% of those with training) such as building, transport, pastry chef, motor mechanics, and locomotive driving and one fisher had experience running a business. All respondents stated that fishing was their sole source of *individual* income and accounted for an average of 86% of their *household* income as well. All fishers stated that they would still be fishing in the current fishery in three years time.

Respondents had been in the fishing industry for 26 years on average (minimum of nine years), from as early as 1969. Mourilyan was the home port for most (60%) indirectly impacted fishers, as opposed to Cairns (20%) and Innisfail (20%), although 80% of respondents stated that they used alternate port(s) (c.f. directly impacted fishers who all used one port). All surveyed fishers were owner-operators and most (80%) operated small vessels (<10 m) with one or two dories (Figure 4.22).

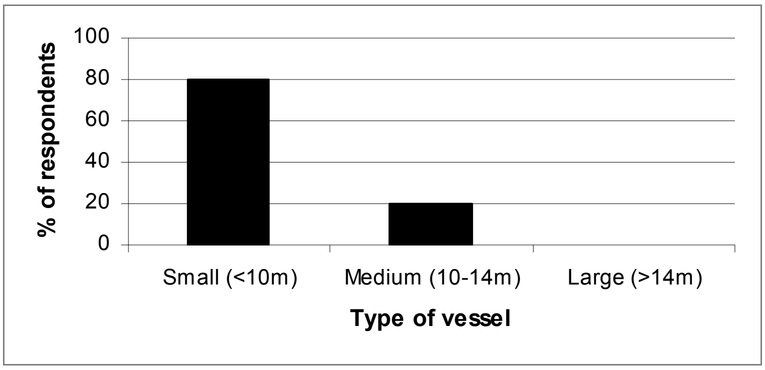

Figure 4.22. Vessel type of surveyed commercial fishers indirectly impacted by TC *Hamish*.

Most fishers (60%) received less than $50,000 in total revenue for their license over the previous financial year (ending 30 June 2008), which is much less than that received by the fishers in the direct impact surveys (most received >$300,000). All fishers had fishing-related debt repayments (i.e. gear, vessel, license, and quota) that were equivalent to their estimated total revenue. In contrast to the directly impact fishers, both live coral trout and multiple endorsements were listed as the source of main revenue for most (80%) indirectly impacted fishers, with live and frozen product comprising the remainder. Only two of the five fishers surveyed were reliant on live coral trout, with 95% and 80% of fishing income from live coral trout for these two fishers. The others relied on multiple species and multiple endorsements

Effects of TC Hamish

Over the first four trips after the cyclone, all of the indirectly impacted fishers were still fishing in their common fishing area. All respondents noticed other fishers from southern reefs moving into their common area after TC *Hamish*, with between three and eight additional boats reported. Most fishers indirectly affected had mixed feelings about the impacts of fishers moving into their area:

- “Doesn't worry me too much, I know the area so I can still catch fish. Have been able to avoid them so far but might be a problem over winter period. Net here long enough yet to have an impact.”
- “Direct impact on how much I catch but I can't blame them. They have to change and go somewhere else.”
- “Displaced effort has an impact. Not their fault, government could have done something more.”
- “Mixed feelings. Traditionally, Swains boats are bigger. Really visual up here because the reef is closer to the coast. Recreational fishers will conflict with commercial fishers. Also feel for them.”
- “Every right to do it”.

Forty percent of the fishers reported lower catch rates of coral trout immediately after the cyclone with the rest reporting no change (Figure 4.23). No effects on catch rates were observed for either red throat emperor or ‘other species’.

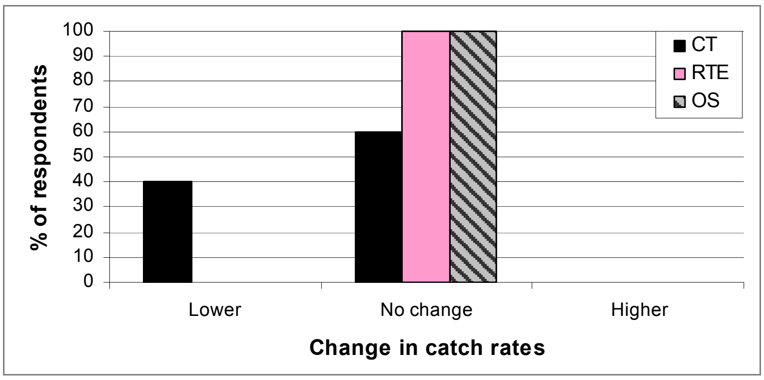

Figure 4.23. Perceived change in catch rates of coral trout (CT), red throat emperor (RTE) and other species (OS) immediately following the cyclone in the indirectly impacted area.

One fisher indirectly impacted had stopped fishing because of fishers moving into their area due to TC *Hamish* and had not returned by the time of this survey. One other fisher felt that their running costs had been impacted as a result of TC *Hamish*, citing the need to travel further to avoid the larger boats.

Two of four responding fishers believed that the cyclone would affect their ability to catch their targeted tonnage of annual reef quota this year and one of these fishers believed he was likely to miss his targeted turnover as well.

In response to impact statements, the majority of fishers (80%) stated that TC *Hamish* had *not* significantly reduced the profitability of their fishing operation, all fishers stated the cyclone had not affected their ability to maintain crew, and only one fisher believed that because of the cyclone he would no longer be able to catch his annual reef fish quota this quota year (Table 4.22). Most fishers (60%) believed that TC *Hamish* had disrupted the continuity of reef fish supply to markets, but did *not* believe that the price they were receiving for landed reef fish had been reduced because of the cyclone.

Table 4.22. Fishers' response to impact statements regarding TC *Hamish* and its affect on their fishing business. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'TC *Hamish* has significantly reduced the profitability of my fishing operation'	**80**	0	20
'TC *Hamish* has affected my ability to maintain crew'	**100**	0	0
'Because of TC *Hamish* I will not be able to catch my annual reef fish quota'	**60**	20	20
'TC *Hamish* has not disrupted the continuity of reef fish supply to markets'	**60**	40	0
'The price I receive for landed reef fish has been reduced because of TC *Hamish*'	**60**	40	0

When fishers were asked how else TC *Hamish* had affected their normal operations, responses included:

- **Fishing pressure:** displaced effort, including larger boats in this area.

Management options

At the time of this survey, all fishers stated that they were aware that the filleting restrictions had been lifted in an attempt to help fishers adapt to the impacts of TC *Hamish*. However, only one fisher believed that this had helped them to adapt to the impact of the cyclone and they had increased the quantity of red throat emperor or 'other species' they kept as a result. Alternative suggestions for management fell broadly into two categories:

- **Area changes:** rotate green zones; open proportion of green zones; and
- **Financial assistance**

Fishery impacts

When asked to rank potential threats to commercial fishing, all respondents ranked coastal development as the biggest major threat (Table 4.23). Land-based pollution or run-off from the land was listed as a major threat by most fishers (80%). Eighty percent of respondents considered over fishing by commercial fishers to be of no threat and most fishers (60%) considered climate change to be only a minor threat. Most fishers (80%) considered events like cyclones etc. as a threat, but were divided in the level of threat they posed.

Table 4.23. Proportion of fishers that view various potential threats to commercial fishing as 'no threat', 'minor threat' or 'major threat'. Categories chosen by the most respondents are shown in bold for each statement.

Statement	No Threat	Minor Threat	Major Threat	Don't Know
Land-based pollution or run-off from the land	0	20	**80**	0
Coastal development	0	0	**100**	0
Over fishing by recreational fishers	0	40	**60**	0
Over fishing by commercial fishers	**80**	0	20	0
Events like cyclones/floods/drought	20	**40**	**40**	0
Climate Change	20	**60**	0	20

Climate change

Fishers were unsure about whether or not human activity was having an effect on the Earth's climate (Figure 4.24), and were divided as to whether it is necessary to take steps reduce human activities that are thought to cause climate change (Table 4.24). Most fishers were not at all concerned (40%) or only moderately concerned (40%) about climate change, and most (60%) were not at all concerned about the potential effects of climate change on the GBR.

Most fishers either couldn't say (40%) or believed that climate change would have no impact (40%) on the GBR in the short term (i.e. over the next twelve months), but were divided as to what the long-term impacts may be (within five vs. 25 years) (Table 4.25).

The majority of fishers (60%) were concerned about the effects of climate change on the reef line fishery, but most fishers (80%) did not believe that TC *Hamish* was related to climate change and most either disagreed (40%) or were neutral (40%) as to whether or not events like TC *Hamish* will become more intense or more frequent in the future because of climate change (Table 4.26). None of the respondents believed that climate change would decrease the ability of the GBR to support sustainable fisheries.

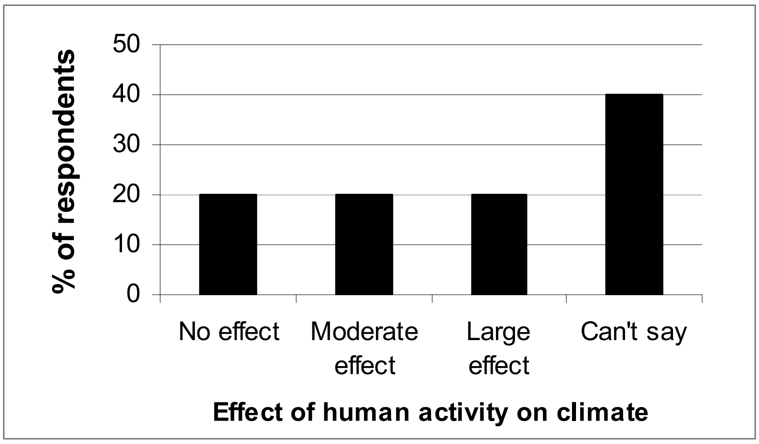

Figure 4.24. Fishers' perceptions of the level of effect human activity is having on the Earth's climate.

Table 4.24. Proportion of fishers concerned about climate change issues. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Not at all	Moderately	Very	Can't say
How concerned are you about climate change?	**40**	**40**	20	0
How concerned are you about the potential effects of climate change on the GBR?	**60**	0	40	0
How necessary do you think it is to take steps to reduce human activities that are thought to cause climate change?	**40**	0	**40**	20

Table 4.25. Proportion of fishers ranking climate change impacts on the GBR in the short and longer term. Categories chosen by the most respondents are shown in bold for each statement.

Statement	No impact	Minor impact	Major impact	Can't say
Over the next twelve months?	**40**	0	20	**40**
Over the next five years?	20	20	20	**40**
Over the next 25 years?	20	20	20	**40**

Table 4.26. Response to impact statements regarding the climate change links with cyclones, the Great Barrier Reef and the reef fishery. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am concerned about the effects of climate change on the reef fishery'	40	0	**60**
'I don't think TC *Hamish* is related to climate change'	0	20	**80**
'Events like TC *Hamish* will happen more often now because of climate change'	**40**	**40**	20
'Cyclones are likely to be more intense in the future as a result of climate change'	**40**	**40**	20
'Climate change will decrease the ability of the GBR to support sustainable fisheries'	40	**60**	0

Resilience

Responses to impact statements in direct relation to cyclones showed that most fishers (60%) are *not* becoming more worried about the risk of cyclones each season (Table 4.27). Most (60%) believe they will survive if there is another cyclone, and stated that they do plan for cyclones each cyclone season. Despite this, most (75%) fishers believed that TC *Hamish* had made them think that they were more vulnerable to future cyclones.

Table 4.27. Response to impact statements regarding resilience to cyclones. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am becoming more worried about the risk of cyclones each season'	**60**	0	40
'If there is another cyclone I will not survive much longer'	**60**	0	40
'I plan for cyclones each season (before TC *Hamish*)'	25*	0	**75**
'TC *Hamish* has made me think that I am very vulnerable to future cyclones'	25*	0	**75**

*Only four fishers responded to these statements.

Fishers were asked to rate their level of agreement with various statements measuring the importance of fishing to them and their intention to remain in the industry. Overall importance of fishing rated very high, with all fishers stating that they were proud to be a commercial fisher, that the fishing industry was a lifestyle choice and not just a job, and that they were likely to always be a fisher (Table 4.28).

However, the majority (80%) stated that they were not as happy with being a fisher now as when they first started and disagreed with the statement that they would rather be at sea than on land.

Table 4.28. Level of agreement with statements regarding the importance of fishing to inshore commercial fishing respondents. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I prefer to be at sea rather than on land'	**80**	20	0
'I am likely to always be a fisher'	0	0	**100**
'The fishing industry to me is a lifestyle – it is not just my job'	0	0	**100**
'I feel proud to tell people that I am a commercial fisher'	0	0	**100**
'I am not as happy with being a fisher now as I was when I first started'	20	0	**80**

Fishers were asked their level of agreement with various statements relating to their resilience (Table 4.29). All statements, when considered together, received a Cronbach's α value of 0.645, which we considered to be reliable for an overall measure of resilience. Fishers' average 'resilience score' was calculated by taking the average response of all statements (where a statement was worded negatively, the response was reversed, i.e. 1 = 5, 2 = 4, and so on). Most fishers (60%) had a 'Medium' resilience score (none were 'Low'), with an overall average resilience score of 3.26, i.e. medium resilience. Linear regression revealed significant interaction between resilience score and education level ($p = 0.019$), as for the directly impacted fishers. No other variables showed significant correlation.

Table 4.29. Response to resilience statements. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am confident things will turn out well regardless of whether there is another cyclone'	**40**	20	**40**
'I am confident I could get work elsewhere if I needed to'	20	0	**60**
'I am more likely to cope with an additional cyclone compared to other fishers I know'	20	0	**80**
'I have many career options available to me if I decide to no longer be a fisher'	**40**	20	**40**
'I can cope with a small cyclone in the region'	20	0	**80**
'I am too young to retire and too old to find work elsewhere'	**60**	0	40
'I have planned for my financial security'	20	0	**80**
'I am not competitive enough to survive another cyclone'	**60**	20	20
'I am interested in learning new skills outside of the industry'	20	0	**80**
'It is not easy for me to find new fishing grounds compared to other fishers I know'	0	40	**60**
Most fishers (60%) stated that they had spoken to the QSIA representative for their area or Fisheries Queensland about fisheries-related issues more than ten times.			

(b) Follow-up survey

All five fishers from the initial survey agreed to let us contact them again in 3 months to do a follow-up survey. From these, all five follow-up surveys were completed.

Effects of TC Hamish

All indirectly impacted fishers stated that southern boats that had moved into their common area after TC *Hamish* were still fishing there, with an average of five to twelve additional boats operating at a given time. Most fishers stated that some of these boats stay and some appeared to be just passing through. Although feelings were mixed in the initial survey, in this follow-up survey *all* fishers indirectly affected felt that the southern boats were having a large effect on the reefs and catch rates in their common area.

The one indirectly impacted fisher who stated in the initial survey that he had stopped fishing because of fishers moving into his area due to TC *Hamish* had returned to fishing by the time of this survey; however, 40% of fishers, himself included, stated that they had moved areas for the same reason. They had since returned to their normal area to be closer to home.

In this follow-up survey all responding fishers (n = 4) now reported lower catches of coral trout in their area in the six months since the cyclone (Figure 4.25). Fishers were divided as to the effects on red throat emperor and other species with 50% reporting lower catches for both and the rest reporting either no change (other species) or higher catches/no change (red throat emperor). This differs from the initial survey where 40% of fishers reported lower catches of coral trout and no fishers observed changes in catch rates for either red throat emperor or other species (Figure 4.23).

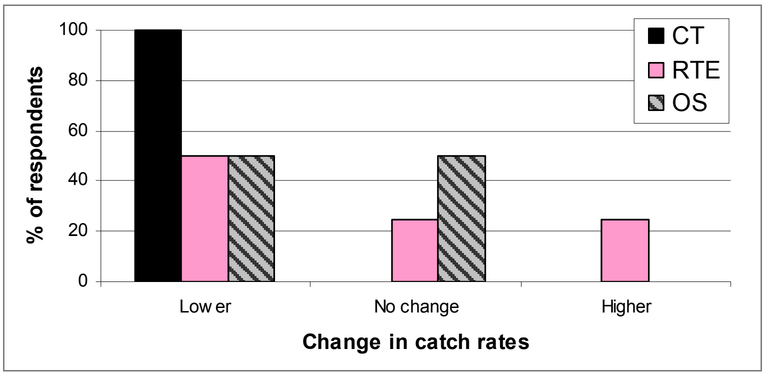

Figure 4.25. Perceived change in catch rates of coral trout (CT), red throat emperor (RTE) and other species (OS) for the six months following the cyclone.

Although 50% of fishers in the initial survey stated that they believed TC *Hamish* would affect their ability to catch their targeted tonnage of annual reef quota, in this follow-up survey none of the indirectly impacted fishers felt that the cyclone had affected their ability to do so in the previous financial year. However, 80% of fishers believed that TC *Hamish* would affect their ability to catch their targeted tonnage of annual reef quota THIS quota year.

None of the indirectly impacted fishers missed their targeted turnover LAST financial year because of TC *Hamish*. However, in the current survey 60% of respondents were concerned about missing their targeted turnover THIS financial year due to the cyclone.

Similar to what was seen in the initial survey, in this follow-up survey most fishers (60%) did *not* feel that their running costs had been impacted as a result of TC *Hamish*; the two fishers that stated their running costs *had* been impacted by the cyclone cited:

- Depressed catch rates
- Need to travel further to avoid the large boats

Compared with the initial survey (shown in grey in Table 4.30) there was a 40% increase in the proportion of respondents who stated that TC *Hamish had* significantly reduced the profitability of their fishing operation as well as a 60% increase in the proportion of fishers who believed that because of the cyclone they would no longer be able to catch their annual reef fish quota this quota year. Similar to the initial survey, most fishers (60%) still believed that TC *Hamish had* disrupted the continuity of reef fish supply to markets, but the majority (80%) did *not* believe that the price they were receiving for landed reef fish had been reduced because of the cyclone.

When fishers were asked how else TC *Hamish* had affected their normal operations, responses included:

- **Fishing pressure:** increase in fishing pressure (i.e. lot of boats in a small area); multiple dory boats on small reefs.
- **Financial pressure:** have to move further afield; less area to work; false sense of security due to increased prices (global market).
- **Social pressure:** tension about the price the southern boats are receiving; traditionally, southern fishers get more because fish are smaller and redder, but doesn't make sense when they are getting fish from the same reefs; potential conflict due to high visibility of large vessels.
- **Loss of time:** waiting for additional boats to get fuel, ice and bait; small loading facility at Mourilyan Harbour not designed for all the big boats.

Table 4.30. Fishers' response to impact statements regarding TC *Hamish* and its affect on their fishing business. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'TC *Hamish* has significantly reduced the profitability of my fishing operation'	20 (80)	20 (0)	**60** (20)
'TC *Hamish* has affected my ability to maintain crew'	**60** (100)	40 (0)	0 (0)
'Because of TC *Hamish* I will not be able to catch my annual reef fish quota'	0 (60)	20 (20)	**80** (20)
'TC *Hamish* has not disrupted the continuity of reef fish supply to markets'	**60** (60)	20 (40)	20 (0)
'The price I receive for landed reef fish has been reduced because of TC *Hamish'*	**80** (60)	20 (40)	0 (0)

Management options

As with the initial survey, all fishers stated that they were aware that the filleting restrictions had been lifted, however, none believed it had helped them to adapt to the impacts of the cyclone; reasons cited for this included:

- Fillet doesn't sell; no demand; and
- Permitting requirements too complex.

Fishers offered short- and long-term suggestions for management to assist in fisher adaptation to TC *Hamish* (Table 4.31). Fishers were asked to focus on solutions apart from changes to Marine Park zoning in their answers; however some did include such suggestions.

Table 4.31. Fishers' suggestions for management options to assist with adaptation to Tropical Cyclone *Hamish*.

Time-frame	Suggestion	n (No. of fishers)
Short-term	Increase minimum size limit of coral trout	1
	Immediate reduction in recreational bag limit of all reef fish	1
	Provide good estimates of catch/dory/day	1
Long-term	Rotate green zones	1
	Remove yellow zones altogether	1

All fishers believed that financial assistance was necessary to help fishers adapt to an event like TC *Hamish*. Suggestions for mode of delivery included:

- Low interest loans (n = 3); and
- Cash payments (n = 2).

Resilience

Responses to impact statements made in direct relation to cyclones showed that the majority (60%) still state they are not becoming more worried about the risk of cyclones each season (Table 4.32). Comared to the initial survey, slightly fewer fishers in the follow-up survey agreed they won't survive another cyclone, and fewer fishers (40%) think they will now plan for cyclones each season. Most fishers (60%) still believed that TC *Hamish* had made them think that they were very vulnerable to future cyclones.

Table 4.32. Response to impact statements regarding resilience to cyclones. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am becoming more worried about the risk of cyclones each season'	**60** (60)	0 (0)	40 (40)
'If there is another cyclone I will not survive much longer'	**40** (60)	**40** (0)	20 (40)
'I will NOW plan for cyclones each season'	**60** (25)	0 (0)	40 (75)
'TC *Hamish* has made me think that I am very vulnerable to future cyclones'	40 (25)	0 (0)	**60** (75)

(c) Final survey

All continuing fishers (5) from the follow-up survey agreed to let us contact them again in three months to do another follow-up survey, of which five surveys were completed close to one year after TC *Hamish*.

Effects of TC Hamish

In this final survey only 60% of the indirectly impacted fishers stated that southern boats that had moved into their common area after TC *Hamish* were still fishing there. They stated there were now only one or two additional operators in their common area, a significant reduction from previous surveys. Most fishers indirectly affected felt that the southern boats *did* have a right to be fishing in there. Some felt there wasn't much they could do. Some stated the vessels that are there now are different to the previous vessels. Some fishers stated the vessels were just moving through, either fishing on their way elsewhere (e.g. to Cooktown) or not.

As in the previous follow-up survey, all responding fishers (n = 4) perceived the coral trout catch rates had declined in the year since TC *Hamish* (Figure 4.26). Most respondents also now reported lower catches of red throat emperor (80%) and other species (100%) – a substantial increase since the previous survey (see Figure 4.25).

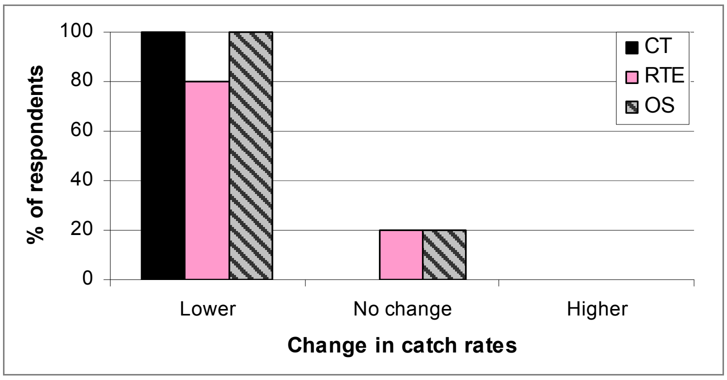

Figure 4.26. Perceived change in catch rates of coral trout (CT), red throat emperor (RTE) and other species (OS) in the year since the cyclone.

Only 40% of the indirectly impacted fishers stated that they felt the cyclone had affected their ability to catch their targeted tonnage of annual reef line quota THIS quota year – half the proportion that had stated such in the second survey. As well, whereas in the previous survey respondents were divided as to whether or not they would miss their targeted turnover THIS financial year due to the cyclone, in this final survey 40% (n = 2) of fishers stated that they would miss it, and one fisher did not know.

Similar to what was seen in both the initial and follow-up surveys, in this final survey most (60%) fishers still did *not* feel that their running costs had been impacted as a result of TC *Hamish*. The two fishers that stated their running costs *had* been impacted by the cyclone cited:

- Depressed catch rates; and
- Increase in effort to find fish.

Compared with the initial survey (shown in grey in Table 4.33) in the current survey there was a 60% increase in the proportion of respondents who stated that TC *Hamish had* significantly reduced the profitability of their fishing operation. Only 40% of respondents believed that because of the cyclone they would no longer be able to catch their annual reef fish quota this quota year – double what was reported in the initial survey, but half that seen in the second survey. Similar to the previous two surveys, most (60%) fishers still believed that TC *Hamish had* disrupted the continuity of reef fish supply to markets, but the majority (80%) did *not* believe that the price they were receiving for landed reef fish had been reduced because of the cyclone. All fishers disagreed that TC *Hamish* had affected their ability to maintain crew.

Table 4.33. Fishers' response to impact statements regarding Tropical Cyclone *Hamish* and its affect on their fishing business. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'TC *Hamish* has significantly reduced the profitability of my fishing operation'	20 (80)	0 (0)	**80** (20)
'TC *Hamish* has affected my ability to maintain crew'	**100** (100)	0 (0)	0 (0)
'Because of TC *Hamish* I will not be able to catch my annual reef fish quota'	20 (60)	**40** (20)	**40** (20)
'TC *Hamish* has <u>not</u> disrupted the continuity of reef fish supply to markets'	**60** (60)	0 (40)	40 (0)
'The price I receive for landed reef fish has been reduced because of TC *Hamish'*	**80** (60)	0 (40)	20 (0)

When fishers were asked how else TC *Hamish* had affected their normal operations, responses included:

- **Fishing effects:** lower catch rates; fishing different or fewer species;
- **Financial pressure:** need to take a second job due to lower/unstable catches; changed to Spanish mackerel quota instead of reef fish quota, affected brokerage business

Management options

Opinions on suggested management options to help fishers better adapt to, or cope with, environmental events like TC *Hamish* in the future showed that all fishers would support a management option that declared the cyclone a natural disaster, making disaster relief available (Table 3.34). Most (80%) respondents also agreed with the option that provided income support to fishers in affected areas provided they *stop* fishing. No fishers supported the idea of closing the affected area without compensating affected fishers, or removing spawning closures. Of the options that were strongly supported, fishers preferred the declaration of a natural disaster, making disaster relief available to affected fishers.

Table 4.34. Fishers' opinions on suggested management options to assist with adaptation to Tropical Cyclone *Hamish*. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree	% preferred*
'Close the affected area to allow it to recover, without compensation for affected fishers'	**100**	0	0	
'Provide income support to fishers in the affected area provided they stop fishing, hence reducing the impact on the area and stopping displacement of effort'	0	20	**80**	25
'Provide income support to fishers in the affected area but allow them to continue fishing'	20	20	**60**	25
'Remove spawning closures at least for the affected year'	**100**	0	0	
'Relax filleting restrictions, as they did for TC *Hamish*'	0	40	**60**	
'Declare a natural disaster so disaster relief is available to fishers'	0	0	**100**	**50**

* Four fishers responded to the preference question.

Fishery impacts

Similar to the initial survey (shown in grey in Table 4.35) when asked to rank potential threats to commercial fishing, most respondents (80%) ranked coastal development as a major threat along with land-based pollution or run-off from the land; however, 80% of fishers now also ranked over fishing by recreational fishers as a major threat – a 20% increase from the previous survey. There was also a 40% increase in the proportion of fishers who stated that they considered climate change to be a major threat, although there was significant division in opinions. Overfishing by commercial fishers was again ranked as the least threatening, although there was an increase in the proportion of fishers who considered it at least a minor threat.

Table 4.35. Proportion of fishers that view various potential threats to commercial fishing as no, minor or major threats. Categories chosen by the most respondents are shown in bold for each statement.

Statement	No Threat	Minor Threat	Major Threat	Don't Know
Land-based pollution or run-off from the land	0 (0)	20 (20)	**80** (80)	0 (0)
Coastal development	0 (0)	20 (0)	**80** (100)	0 (0)
Over fishing by recreational fishers	0 (0)	20 (40)	**80** (60)	0 (0)
Over fishing by commercial fishers	40 (80)	**60** (0)	0 (20)	0 (0)
Events like cyclones/floods/drought	0 (20)	**60** (40)	40 (40)	0 (0)
Climate Change	20 (20)	20 (60)	**40** (0)	20 (20)

Climate change

There was no change in the proportion of fishers who considered human activity was having an effect on the Earth's climate (see Figure 4.24). Similar to the initial survey (shown in grey in Table 4.36) in this final survey most fishers were either not at all concerned (40%) or only moderately concerned (40%) about climate change. Fishers were also divided as to the potential effects of climate change on the GBR as well as the necessity of reducing human activities that are thought to cause climate change.

Table 4.36. Proportion of fishers concerned about climate change issues. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Not at all	Moderately	Very	Can't say
How concerned are you about climate change?	**40** (40)	**40** (40)	0 (20)	20 (0)
How concerned are you about the potential effects of climate change on the GBR?	**40** (60)	20 (0)	20 (40)	20 (0)
How necessary do you think it is to take steps to reduce human activities that are thought to cause climate change?	**40** (40)	20 (0)	20 (40)	20 (20)

Similar to the initial survey, in the current survey most fishers either couldn't say (40%) or believed that climate change would have no impact (40%) on the GBR over the next twelve months to five years (Table 4.37). However, similar to the initial survey, respondents were still divided as to what the long-term impacts may be (within 25 years).

Table 4.37. Proportion of fishers ranking climate change impacts on the GBR in the short and longer term. Categories chosen by the most respondents are shown in bold for each statement.

Statement	No impact	Minor impact	Major impact	Can't say
Over the next twelve months?	**40** (40)	20 (0)	0 (20)	**40** (40)
Over the next five years?	**40** (20)	20 (20)	0 (20)	**40** (40)
Over the next 25 years?	20 (20)	20 (20)	20 (20)	**40** (40)

As seen in the initial survey, the majority of fishers (60%) were concerned about the effects of climate change on the reef line fishery (Table 4.38). Most (80%) still did not think TC *Hamish* was related to climate change, and disagreed (60%) that events like TC *Hamish* would become more frequent or more intense in the future because of climate change, or that climate change would decrease the ability of the GBR to support sustainable fisheries.

Table 4.38. Response to impact statements regarding the climate change links with cyclones, the Great Barrier Reef and the reef fishery. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am concerned about the effects of climate change on the reef fishery'	40 (40)	0 (0)	**60** (60)
'I don't think TC *Hamish* is related to climate change'	0 (0)	20 (20)	**80** (80)
'Events like TC *Hamish* will happen more often now because of climate change'	**60** (40)	20 (40)	20 (20)
'Cyclones are likely to be more intense in the future as a result of climate change'	**60** (40)	20 (40)	20 (20)
'Climate change will decrease the ability of the GBR to support sustainable fisheries'	**60** (40)	20 (60)	20 (0)

Resilience

Responses to impact statements made in direct relation to cyclones showed that, more fishers were becoming worries about the risk of cyclones each season compared to the initial survey (Table 4.39). Fishers were divided regarding whether they would survive another cyclone, and whether they now plan for cyclones each season. Similar to the initial survey, however, most fishers (80%) believe TC *Hamish* had made them think that they were very vulnerable to future cyclones. Eighty percent of fishers stated that they would still be fishing in the current fishery in three years' time.

Table 4.39. Response to impact statements regarding resilience to cyclones. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am becoming more worried about the risk of cyclones each season'	20 (60)	20 (0)	**60** (40)
'If there is another cyclone I will not survive much longer'	**40** (60)	20 (0)	**40** (40)
'I will NOW plan for cyclones each season'	**40** (25)	20 (0)	**40** (75)
'TC *Hamish* has made me think that I am very vulnerable to future cyclones'	20 (25)	0 (0)	**80** (75)

Fishers were asked their level of agreement with various statements relating to their resilience (Table 4.40). Overall resilience levels did not change from the initial survey (see Figure 4.27). However, two fishers 'swapped' resilience level. The first fisher changed from 'High' to 'Medium' resilience level mostly due to a *decrease* in confidence that things will turn out well and in his interest to learn new skills. The second fisher changed from 'Medium' to 'High' resilience level due to an *increase* in confidence concerning his ability to find work elsewhere and the number of career options available to him.

Table 4.40. Response to resilience statements. Categories chosen by the most respondents are shown in bold for each statement.

Statement	Disagree	Neutral	Agree
'I am confident things will turn out well regardless of whether there is another cyclone'	60	20	20
'I am confident I could get work elsewhere if I needed to'	0	20	80
'I am more likely to cope with an additional cyclone compared to other fishers I know'	0	0	100
'I have many career options available to me if I decide to no longer be a fisher'	60	0	40
'I can cope with a small cyclone in the region'	0	40	60
'I am too young to retire and too old to find work elsewhere'	60	20	20
'I have planned for my financial security'	0	20	80
'I am not competitive enough to survive another cyclone'	60	20	20
'I am interested in learning new skills outside of the industry'	20	20	60
'It is not easy for me to find new fishing grounds compared to other fishers I know'	20	40	40

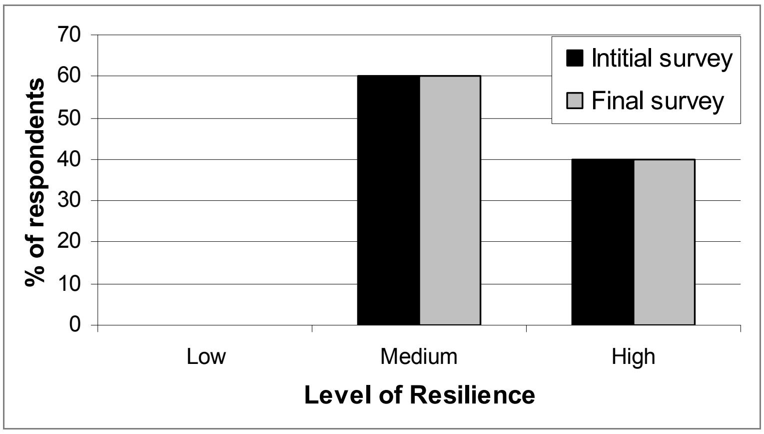

Figure 4.27. Resilience level of fishers indirectly impacted by Tropical Cyclone *Hamish* (comparison of initial and final survey).

4.4 Discussion

It is clear from the social surveys outlined here and the analysis of the catch data from the ecological component of the project that TC *Hamish* had a significant effect of damaging reef structure and depressing catches of the main target species, coral trout and red throat emperor, of the commercial CRFF. These impacts affected both fishers in the area directly impacted by the cyclone, and those in areas outside of the impacted zone, affecting fishers' ability to catch their quota, running costs, profits, and continuity of reef fish supply to markets. Most fishers believe it will take many years for the reef to recover from this event.

4.4.1 Adaptive capacity of fishers

For the directly impacted fishers, how they adapted to the effects of the cyclone depended mostly on the size of fishers' vessels: those with large vessels (>14 m) were able to move to other fishing grounds. A few of the medium vessels (10-14 m) moved to other grounds, but most stopped fishing temporarily. Almost half of the medium vessels did, however, receive most of their income from multiple endorsements so are able to harvest other species including in other fisheries (e.g. the East Coast Inshore Finfish Fishery) in the event of depressed coral trout catches. For those with small vessels (<10 m), their choices were limited in that they were less equipped to move. Further, the small vessels surveyed received most of their revenue from live coral trout, also limiting their ability to diversify. All of the small vessels stopped fishing temporarily immediately after the cyclone. When they did return, they returned to their common fishing grounds, and persevered despite lower catches (up to 30% reduced catch rates, see earlier chapters).

It is common in primary industries for those with larger businesses to be more adaptable to change. Larger businesses can buffer themselves from unpredictable events, can take bigger risks and experiment with their options (Marshall 2008). Although revenue and profit were not correlated with vessels size in this case study, vessel size could be used as a proxy for business size. For example, in agriculture, property size is a key determinant of adaptive capacity (Abel and Langston 2001 in Marshall 2008): the same perhaps could be applied to the commercial CRFF. Unfortunately, however, for those vessels that moved catch rates in the new areas were lower that what fishers expected for the same time of year in their normal area, and these catch rates continued to decline due to concentration of effort. Given this lower catch rate coupled with increased costs due to increased travel from their usual home port to new grounds that they needed to 'explore', whether this option of moving 'paid off' is questionable. Certainly by the final survey, almost a year after the cyclone, most fishers (90%) had returned to their normal grounds, despite the perception that fishing quality was still lower than what they would expect for that time of year (although they had improved since the cyclone). Further, of the three vessels that stopped fishing completely by the follow-up and final surveys, all owned and operated large vessels – for these fishers the 'risk' they took did not allow them to adapt successfully.

Most of these large vessels (80%) were primarily dependent on live coral trout for their revenue, restricting their ability to diversify.

The movement of large vessels from the cyclone affected area had flow-on consequences for fishers outside of the affected area. All *indirectly* impacted fishers noticed large, multi-dory vessels moving into their area after the cyclone, and believed that this impacted on their own catches over the time of the project. For some fishers this had the cascade effect of making them stop fishing temporarily or move to other fishing grounds during the survey period. Despite the impact on their catches, most fishers believed the mobile vessels had every right to move and didn't begrudge them that.

4.4.2 Adaptive management

Fisheries Queensland was proactive in their attempt to assist adaptation of fishers by removing filleting restrictions for the commercial CRFF. Unfortunately, this adaptive management option did not work in the short-term. Very few fishers supported the change as a helpful option and few were encouraged to adapt by diversifying their harvest and targeting other species. Of those that did increase their harvest of fillet product, they had trouble selling it – sufficient market for the product did not exist given the length of time since significant volumes of reef fillet product has been sold on the domestic market (given the dominance of live coral trout in the fishery). Perhaps this adaptation option would improve if the market were given time to develop. The long-term success of this option is inconclusive at this point.

Fishers' other suggested management options focussed on opening or rotating green zones, perhaps to help spread out effort which was concentrated in unaffected areas following the cyclone. Apart from changing area closures, most fishers believed financial assistance was necessary, either through disaster relief (e.g. allowing them to access low interest loans) or through income support for fishers in the affected area to compensate for depressed catches.

4.4.3 Perceptions of climate change

Most fishers were concerned about climate change, including its affect on the GBR at least in the long-term, and felt that human activity is having an affect on the Earth's climate. They did not see it as the greatest threat to commercial fishing, which contrasts to findings of other research which indicate the general community view climate change as the largest threat to the long-term health of the GBR (Nilsson *et al.* 2009).

Most fishers also viewed events like cyclones as a major threat to commercial fishing. In the initial survey, however, very few fisheries believed that events like TC *Hamish* are linked to climate change, and were divided in their opinion regarding whether cyclones will become more frequent or intense as a result of climate change. Further, they did not think climate change would decrease the ability of the

GBR to support sustainable fisheries. These opinions changed a year after TC *Hamish*, with more than half of the fishers then stating that TC *Hamish* was related to climate change. Despite this change, more fishers disagreed that cyclones will become more intense or frequent as a result of climate change. Hence, fishers' views of the likely changes resulting from climate change, at least in the frequency of intense cyclones, are unclear.

The Australian Government's *Great Barrier Reef Climate Change Action Plan* (Action Plan) aims to counter the climate change threat by ensuring that the GBR social-ecological system is resilient to climate change impacts (GBRMPA 2007). For the commercial fishing industry to be able to adapt to change they need to be aware of expected changes and plan for them (Marshall 2007). Initially fishers were not becoming more worried about the risk of cyclones each season: the converse was true a year after TC *Hamish*. Most fishers agreed that TC *Hamish* made them feel more vulnerable to cyclones, and that they will now plan for cyclones each season (although the proportion of fishers decreased from the initial to the final survey). When asked what they will do in the event of another cyclone, few fishers listed new behavioural changes (most would move grounds again). We did not, however, ask if fishers had planned for their financial security for such an event. Further exploration would be beneficial.

4.4.4 Adaptation for the future

Currently fishers appear to rely on financial support from external sources to help them through hard times, rather than invest in and develop their own adaptive capacity. Certainly larger vessels attempted to adapt by moving to unaffected fishing grounds, however lower catches (which continued to decline due to crowding) coupled with increased costs made this option unsuccessful – to the point where some of these fishers left the industry. An attempt to diversify catches was unsuccessful due to the lack of markets – perhaps this is something that should be addressed to increase the long-term adaptation and hence resilience, given severe tropical cyclones such as TC *Hamish* will become more characteristic of the future climate than the recent past (Lough 2007). Fishers need to be able to diversify their operations and adapt to change on their own volition, without the need to rely on government assistance. Perhaps the only saving grace in this instance is the fact that the market price for live coral trout reached record levels at $78-$80/kg with the end of the 2009 Chinese New Year due to low supply from Australia and the Philippines (Martin Perkins, QMSA, pers comm., 18/06/10): if this did not occur perhaps more fishers would have been forced to leave the industry due to being economically unviable.

Given fishers state they will plan for cyclones each season, there is potential for fishers to improve their adaptive capacity and hence resilience to cyclones and potentially climate change. What is needed now is guidance from industry representatives and managers to help determine the best ways to adapt in the future.

4.4.5 Recommendations

Commercial CRFF fishers need some assistance and collaborative work to help them improve their adaptive capacity. At the moment most are highly specialised and most rely on external markets and external sources of financial support to survive the negative impacts of extreme events such as TC *Hamish*. Given intense cyclones are likely to increase in frequency with a changing climate (Lough 2007) fishers need to be better personally prepared for such events. Perhaps fishers should be encouraged to take advantage of financial services provided for primary industries to explore insurance or investment options so fishers do not have to rely on government assistance which is unlikely to be available.

Markets for reef fillet product also need to be developed, with good quality control to ensure optimal economic return for the industry. Currently, much of the available red throat emperor, other reef species and Spanish mackerel total allowable catch remains unused each year. Fishers should be encouraged to diversify their operations into markets developed for these species before the next extreme event occurs. Industry and managers can take on important roles in encouraging diversification, but individual fishers need to be convinced it is worthwhile, particularly given the current difference in profit between exported live coral trout and domestically marketed whole fish and fillet product.

In this case study the most common adaptation response was for fishers in large vessels to move to unaffected areas. Clearly this option is important and needs to remain available. While indirectly impacted fishers felt the consequences in terms of reduced catch rates, they supported fishers' ability to do this. There are issues of effort concentration when effort shifts, however, for which solutions should be explored.

In this study we focussed on fishers impacted by TC *Hamish*. Future research should aim to explore adaptation of more of the commercial fleet, to determine if there is any relationship between adaptation and business size, resilience attributes, diversity of operation, and perceptions of climate change.

Regarding fishers' perceptions of climate change, some improved communication is required informing industry what climate change will likely mean for commercial fisheries. While fishers agreed climate change is an issue and are concerned about long-term impacts, they are unconcerned about short-term consequences, and do not see the link between climate change and the increased frequency of intense cyclone which threaten the viability of their industry. Research similar to Nilsson *et al.* (2009) would be beneficial, focusing specifically on the commercial fishers, exploring perceptions of climate change and it's impact on the GBR and associated fisheries, willingness of fishers to engage in mitigation strategies, and information needs and sources relating to climate change

Chapter 5: General conclusions

5.1 Benefits and adoption

The critical need for this project to be conducted is reflected in the numerous benefits that have been demonstrated as well as adoption and consideration of the results.

1. The project has identified marked ecological responses of common coral trout and red throat emperor to the impacts of some ‘unique’ tropical cyclones. These outputs are relevant to the improved management benefit highlighted in the pre-proposal. No robust quantitative assessment and description of the effects of tropical cyclone passage on the performance of the CRFFF has been available previously. The project has provided robust data analysis and description that removes the uncertainty that previously existed in understanding the quantitative effects some tropical cyclones may have on CRFFF productivity.

   Further, the project has had some success in identifying the possible biophysical drivers of these altered catch rates. A significant cool water anomaly appears to be the most logical driver of changed catch rates following TC *Justin*, although the spatio-temporal consistency of changed catch rates and the cool water anomaly are imperfectly aligned. The shear severity of TC *Hamish* appears to be responsible for the changed catch rates following TC *Hamish*. Interestingly, the cool water anomaly associated with the less severe TC *Justin* had greater negative effects on change catch rates that than impressively destructive TC *Hamish*.

2. The demonstrated catch changes as well as the uncertain causal factors responsible for the long-term lag effects of tropical cyclones passage need to be well heeded by all stakeholders. The relief of commercial fishers that their experiences of tropical cyclones impact have been quantitatively documented needs to be tempered with the great uncertainty that still exists about why these changes in productivity occur. The uncertain ability to predict the response of CRFFF productivity in response to tropical cyclones should be considered a timely warning for businesses invested in this fishery that rapid change can occur with little or no warning.

3. The tight economic dependence of the commercial sector on supplying coral trout for the live export market makes this sector of the fishery highly vulnerable to changed catch rates of coral trout. Although some vessels can move away from affected areas, the latitudinal gradient in live fish prices (20-30% higher in southern than northern waters), may work against a mitigation strategy of

moving to more northern waters if depression of catch rates are experienced in southern waters (eg TC *Hamish*).

4. The current logbook processes of Fisheries Queensland are inadequate for timely tracking of changes in catch rates within the CRFFF. Project workshops identified this shortfall early within the project (September 2009) and in response Fisheries Queensland are examining options for implementing an electronic reporting system. Such a system will allow for real time interrogation of the performance of the commercial sector of the CRFFF. Given the marked impacts on fishery CPUE variable environments are capable of inflicting on the CRFFF, such a system will allow stakeholders and managers a greater level of certainty when dealing with future events.

5. Despite the demonstrated impacts of unique tropical cyclones on the CPUE of the commercial sector of the CRFFF, similar impacts are not measurable within the recreational and charter fishing sectors of this fishery. Importantly, fisheries managers may not be so concerned with the abilities of these sectors to 'ride out the storms'. This finding is likely related to the varied measures of 'trip success' under which these two fishing sectors operate. The expectations of fishers from these two sectors are likely to be less focused than compared to those of commercial fisher expectations. Recreational and charter fishers consider multiple social as well as economic values (location, company, species diversity and catch rate) before valuing the 'success' of a fishing trip. In contrast, commercial fishers are solely focused on economic outcomes, which are strongly influenced by CPUE of common coral trout.

6. The Queensland Seafood Industry Association has used the project outputs to explore potential government assistance options similar to those offered to land-based businesses and primary producers affected by tropical cyclones and other extreme weather events.

7. The socio-economic surveys demonstrated a mindset within the commercial fishery that as a result of severe tropical cyclone impacts on the productivity of their businesses, external government assistance is required. This belief is encouraged by the existence of disaster reflief packages made available to terrestrial based primary industries.

8. The uncertain likelihood of government financial assistance, fishers within the CRFFF need to explore other options available to them to survive. Some suggestions from fishers and the working group (see Appendices 4 and 5) included low-interest loans as well as re-assessing the need for the complex set of input and output controls under which they operate

5.2 Further development

Recommendations for further research and development into the CRFFF include:

HIGH IMPORTANCE:

- Identify diversification strategies to temper the disproportionate reliance of the commercial sector of the CRFFF on export of live coral trout for economic profitability. These may include - looking for other species landed in the CRFFF that may be acceptable in the live export market place; developing domestic markets for high-quality fresh and frozen products; exploring new and novel harvesting gears that may be more efficient than the traditional line fishing gears, particularly when coral trout 'shut down' following passage of unique tropical cyclones.
- Identify adaptation strategies to improve socio-economic resilience within the CRFFF. Encourage fishers to plan ahead for these unpredictable events, particularly in the area of financial security to allow diversification or 'riding-out' these extreme events. Encouragement to develop formal business plans, as this forethought has been demonstrated to significantly improve businesses' adaptive capacity and resilience to change.
- The logbook recording system for the commercial fishery of the CRFFF is in urgent need of re-development. Currently there is no ability to track real-time changes in catch rates of the CRFFF. The introduction of an electronic database system should be explored at the earliest opportunity.

MEDIUM IMPORTANCE:

- The biophysical drivers of the changed catch rates are uncertain. Understanding these processes is of interest, however this need should be considered of medium importance because of two factors. Firstly, *in situ* infrastructure to record biophysical parameters is sparse, and haphazardly distributed throughout the fishery range (GBR). Tropical cyclones often destroy this equipment and useful historical datasets do not currently exist. Secondly, the determination by this project that biophysical drivers of change are difficult to identify should be viewed as much as a successful outcome as a confident determination of biophysical drivers.

LOW IMPORTANCE:

- Should better data fields become available, a more exhaustive examination of the effect of tropical cyclones on the catch rates and catch composition of recreational and charter fishing sectors should be undertaken. Given the stark responses of coral trout and red throat emperor catch rates to some cyclone events as mapped by commercial fishers logbooks, it would be perhaps surprising should no similar signal be observed in recreational and charter fishing sectors.

5.3 Planned outcomes

The project outputs meet the planned outcomes listed in the proposal by:

- Providing a robust quantitative description of tropical cyclone effects on the performance of the CRFFF across the spatio-temporal scale of the GBRWHA, demonstrating significant negative effects on the major target species coral trout;
- Identifying changed productivity of the fishery may lag for significant time periods following the initial influence and passage of cyclones;
- The socio-economic consequences of cyclone impacts have been described, and highlight a lack of adaptive capacity and hence high vulnerability particularly for the commercial sector of the CRFFF. This outcome demonstrates an urgent need for adaptation and resilience planning within the CRFFF; and
- The project has provided a draft action plan (Figure 5.1) for all stakeholders to consider in future events. The response of stakeholders to historical cyclone events has been uncertainty of what to do. This draft action plan will allow for a formal assessment of each cyclone and its associated impacts on the CRFFF. Further, the action plan if followed will build a knowledge base of cyclone impacts better positioning stakeholders to respond to future events from more informed positions.

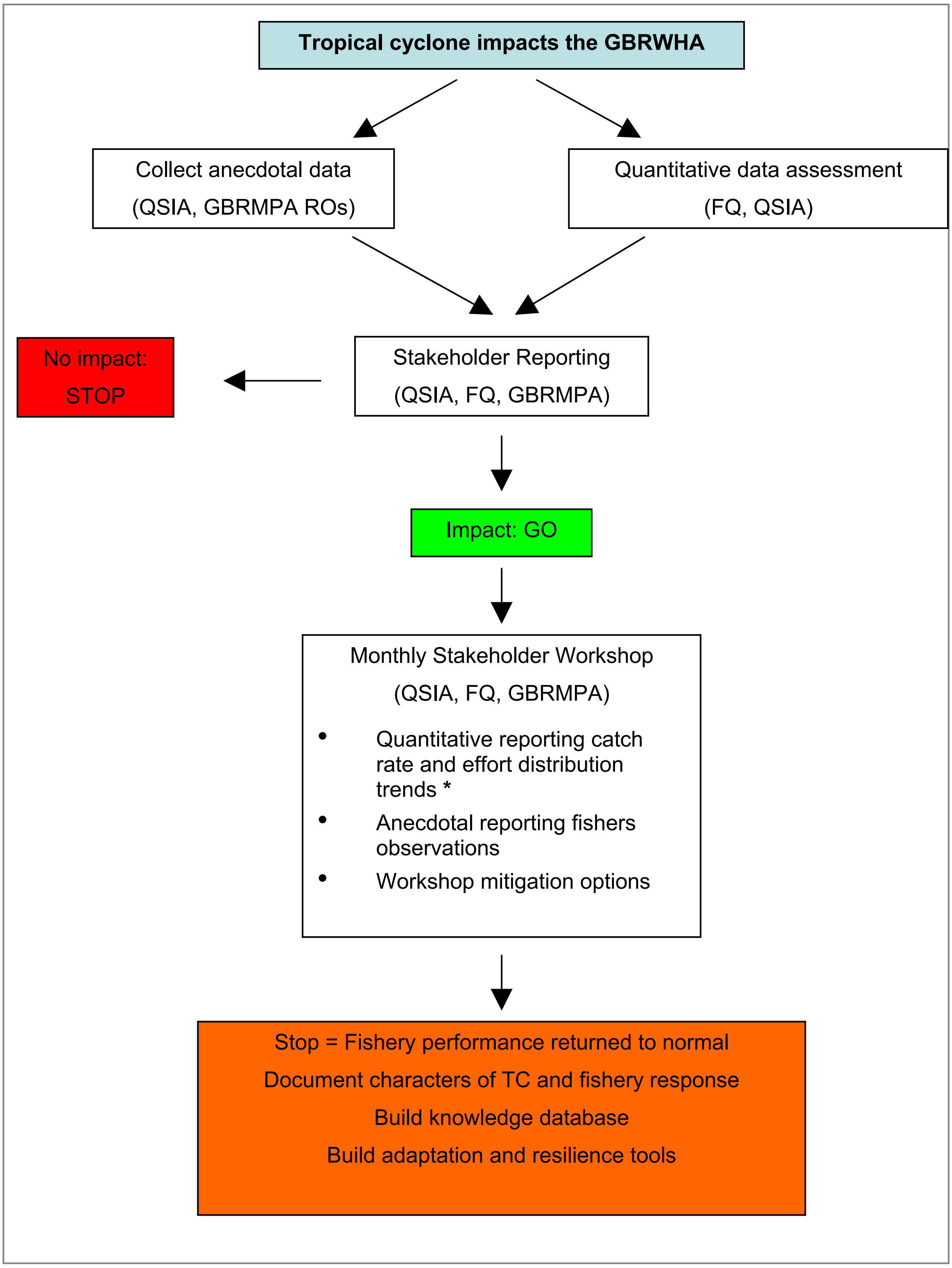

Figure 5.1. A draft action plan for the future assessment of tropical cyclones that impact the GBRWHA and CRFFF. This draft may be updated through the continuing meeting of working groups formed during the last twelve months. Timely quantitative data assessment is reliant on an overhaul of the current logbook reporting arrangements for the CRFFF.

5.4 Conclusion

The goal of this project was to document the impacts of tropical cyclones on the performance of the CRFFF. This report quantifies the negative impacts of two unique cyclone events (TC *Hamish* and *Justin*) on the catch rates of the commercial sector of the fishery. The report also includes a synopsis of the limited-success attempts to understand what biophysical drivers may be responsible for significantly changed catches following cyclone impact.

Each objective of the project was completed successfully and now provides a basis for understanding the possible impacts of tropical cyclones on the CRFFF. The impacts are varied between fishing sectors and target species. An inconsistent dynamic of spatio-temporal influence is also was documented. The contrast between commercial and charter/recreational fisheries highlight a sector highly vulnerable and with limited adaptive capacity against a sector much less vulnerable and highly adaptive.

Although in the short-term, the passage of tropical cyclones does not alter functional reef fish communities or target species abundance, some perversive factor(s) is responsible for significant depressions of catch rates. Although some possible causal factors have been identified, significant further research may be needed to begin to identify these factors. Given the uncertain periodic influence as well as the dynamic and unique nature of each cyclone, future research should prioritise building adaptive capacity within the CRFFF for uncertain change.

A suggested pro forma for an action plan to track, adaptation plan and possibly mitigate the negative influences of future unique cyclone events is relatively simple at this time, and will need to be strengthened based on the outcomes from two working groups formed during the last six months

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Appendix 1: Intellectual Property arising from the research

No patentable or marketable products or processes have arisen from this research. All results will be published in scientific and non-technical literature. The raw data from compulsory fishing logbooks remains the intellectual property of Fisheries Queensland, Department of Employment, Economic Development and Innovation (DEEDI). Raw catch data provided by individual fishers remains the property of the fishers. Intellectual property accruing from the analysis and interpretation of raw data rests jointly with James Cook University, Sea Research Pty Ltd, Fisheries Queensland (DEEDI), the Great Barrier Reef Marine Park Authority and the Queensland Seafood Industry Association.

Appendix 2: Project Personnel

Andrew Tobin	Fishing & Fisheries Research Centre, James Cook University
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Avril Ayling	Sea Research Pty Ltd
Besse Krause	Fishing & Fisheries Research Centre, James Cook University
David Welch	Fisheries Queensland, DEEDI
Stephen Sutton	Fishing & Fisheries Research Centre, James Cook University
Nadine Marshall	Commonwealth Scientific and Research Organisation
Paul Marshall	Great Barrier Reef Marine Park Authority
Jeffery Maynard	Maynard Marine Pty Ltd

Appendix 3: Summary of Survey Abundance of the Benthic Groups and Fishes

Figures show means from six sites on each reef, along with the standard deviation (sd) in italics.

Location	**Bax**	**20-136**	**Liff**	**21-124**	**21-132**	**21-139**
Group or species	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**
2003						
Total Hard Coral	41.1 *16.6*	30.7 *14.0*	61.8 *24.7*	49.8 *25.4*	54.7 *23.8*	45.8 *16.5*
Total Soft Coral	3.4 *3.6*	4.9 *6.7*	1.1 *1.7*	1.1 *1.3*	5.9 *6.4*	4.6 *6.2*
Sponges	0.6 *1.3*	1.2 *2.2*	0.0	0.9 *2.2*	5.2 *8.6*	0.2 *0.7*
Triaenodon obesus	1.3 *1.4*	0.8 *1.3*	2.9 *3.7*	0.4 *1.0*	0.8 *1.3*	0.4 *1.0*
Carcharhinus amblyrhynchos	1.7 *1.3*	0.0	0.4 *1.0*	0.0	0.0	0.4 *1.0*
Cheilinus undulatus	2.9 *2.9*	5.0 *5.0*	1.3 *2.1*	0.4 *1.0*	3.3 *2.2*	1.7 *2.0*
Plecropomus leopardus	156.0 *92.4*	94.7 *84.4*	61.3 *45.5*	120.0 *105.6*	132.0 *123.9*	104.0 *65.3*
P. leopardus adults	42.7 *43.2*	34.7 *45.5*	2.7 *10.1*	8.0 *16.3*	20.0 *27.3*	18.7 *37.0*
Plectropomus laevis	6.7 *18.4*	12.0 *26.1*	1.3 *7.3*	0.0	2.7 *10.1*	0.0
Lethrinus miniatus	42.7 *50.3*	21.3 *27.3*	13.3 *28.4*	6.7 *15.2*	24.0 *30.8*	17.3 *37.4*
Lutjanus carponotatus	236.0 *290.0*	126.7 *254.1*	369.3 *432.3*	210.7 *160.3*	276.0 *290.0*	164.0 *120.8*
Total scarids	602.7 *245.4*	870.7 *486.5*	709.3 *300.6*	954.7 *343.7*	712.0 *442.2*	908.0 *382.0*
Total pomacentrids	11153 *3586*	7681 *3886*	6679 *3567*	7501 *3690*	6339 *3956*	8419 *3691*

Location	Bax	20-136	Liff	21-124	21-132	21-139
Group or species	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**
Baitfish	7.9 *14.2*	6.7 *9.7*	0.0	0.0	0.0	0.0
2004						
Total Hard Coral	40.5 *19.3*	35.9 *14.9*	62.9 *25.3*	50.1 *24.0*	48.4 *20.8*	50.5 *16.4*
Total Soft Coral	4.6 *5.1*	5.7 *4.7*	0.8 *0.9*	1.4 *1.4*	5.9 *5.0*	5.2 *8.5*
Sponges	0.9 *1.7*	2.5 *2.8*	0.0	1.1 *3.1*	3.9 *5.3*	0.1 *0.4*
Triaenodon obesus	1.3 *1.4*	0.8 *1.3*	0.8 *1.3*	1.3 *2.1*	0.8 *1.3*	0.8 *1.3*
Carcharhinus amblyrhynchos	1.7 *2.0*	0.4 *1.0*	0.4 *1.0*	0.0	0.8 *1.3*	1.3 *2.1*
Cheilinus undulatus	2.1 *2.9*	5.8 *7.2*	1.3 *1.4*	1.7 *2.0*	1.7 *3.0*	0.8 *2.0*
Plecropomus leopardus	121.3 *78.2*	114.7 *90.2*	53.3 *52.9*	98.7 *100.6*	80.0 *66.4*	85.3 *72.6*
P. leopardus adults	44.0 *45.0*	30.7 *32.7*	9.3 *17.2*	9.3 *22.7*	22.7 *27.2*	10.7 *20.8*
Plectropomus laevis	8.0 *16.3*	6.7 *21.2*	0.0	0.0	2.7 *10.1*	1.3 *7.3*
Lethrinus miniatus	34.7 *51.2*	17.3 *29.1*	10.7 *23.3*	0.0	22.7 *44.2*	14.7 *24.6*
Lutjanus carponotatus	232.0 *460.3*	118.7 *191.3*	372.0 *403.6*	138.7 *99.0*	224.0 *211.3*	145.3 *167.2*
Total scarids	793.3 *329.2*	1074.7 *397.3*	681.3 *389.4*	848.0 *397.8*	705.3 *350.4*	764.0 *441.5*
Total pomacentrids	12415 *5029*	8940 *5184*	7232 *5664*	7575 *4321*	6916 *4637*	9365 *3771*
Baitfish	7.9 *14.2*	6.7 *9.7*	0.0	0.0	0.0	0.0
2005						
Total Hard Coral	50.1 *20.0*	37.0 *13.2*	61.8 *21.9*	50.0 *21.7*	54.7 *21.6*	56.4 *21.2*

Location	Bax	20-136	Liff	21-124	21-132	21-139
Group or species	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**
Total Soft Coral	5.2 *5.6*	4.2 *3.4*	1.0 *1.4*	0.8 *1.5*	9.0 *8.2*	6.1 *8.6*
Sponges	2.1 *3.1*	0.9 *1.5*	0.7 *2.2*	1.2 *3.3*	6.2 *14.0*	0.2 *0.6*
Triaenodon obesus	0.4 *1.0*	0.8 *1.3*	0.4 *1.0*	0.4 *1.0*	0.4 *1.0*	1.3 *3.1*
Carcharhinus amblyrhynchos	1.3 *3.1*	0.4 *1.0*	0.4 *1.0*	0.0	0.4 *1.0*	0.8 *2.0*
Cheilinus undulatus	5.0 *2.7*	5.0 *2.7*	2.1 *1.9*	0.8 *1.3*	0.4 *1.0*	1.7 *2.0*
Plecropomus leopardus	157.3 *106.1*	105.3 *78.9*	38.7 *37.1*	102.7 *150.3*	120.0 *109.3*	92.0 *84.8*
P. leopardus adults	68.0 *69.8*	44.0 *62.5*	9.3 *17.2*	10.7 *31.4*	28.0 *43.5*	10.7 *27.7*
Plectropomus laevis	5.3 *17.4*	6.7 *15.2*	0.0	1.3 *7.3*	1.3 *7.3*	2.7 *10.1*
Lethrinus miniatus	22.7 *38.9*	18.7 *27.3*	76.0 *291.6*	1.3 *7.3*	30.7 *42.9*	17.3 *29.1*
Lutjanus carponotatus	286.7 *631.2*	153.3 *340.2*	490.7 *705.8*	273.3 *405.8*	217.3 *187.2*	125.3 *139.6*
Total scarids	728.0 *482.9*	814.7 *379.3*	941.3 *465.5*	884.0 *402.8*	753.3 *286.2*	932.0 *626.6*
Total pomacentrids	13519 *5475*	10339 *5021*	7085 *4131*	8725 *3714*	7419 *4505*	9267 *4113*
Baitfish	4.6 *7.1*	1.7 *3.0*	2.1 *5.1*	0.0	5.0 *4.7*	0.8 *2.0*
2009						
Total Hard Coral	16.7 *10.2*	14.0 *10.7*	21.1 *27.0*	37.1 *23.8*	19.5 *16.2*	29.4 *23.1*
Total Soft Coral	2.4 *2.7*	3.4 *3.4*	1.1 *2.1*	2.2 *3.1*	2.1 *2.2*	4.3 *8.9*
Sponges	0.7 *1.1*	1.4 *2.5*	0.2 *0.6*	1.2 *1.4*	3.7 *7.2*	0.3 *0.8*
Triaenodon obesus	1.3 *1.4*	0.0	0.0	1.7 *2.0*	2.1 *1.9*	0.4 *1.0*

Location	Bax	20-136	Liff	21-124	21-132	21-139
Group or species	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**
Carcharhinus amblyrhynchos	3.3 *3.8*	0.8 *1.3*	0.0	0.0	0.8 *2.0*	0.8 *1.3*
Cheilinus undulatus	4.6 *3.7*	2.9 *1.9*	0.0	0.0	0.8 *1.3*	0.8 *2.0*
Plecropomus leopardus	120.0 *100.8*	118.7 *87.6*	62.7 *44.2*	108.0 *68.2*	69.3 *68.0*	65.3 *58.0*
P. leopardus adults	52.0 *51.6*	56.0 *52.1*	24.0 *29.0*	14.7 *22.2*	25.3 *34.0*	25.3 *41.3*
Plectropomus laevis	9.3 *17.2*	9.3 *25.0*	0.0	0.0	2.7 *10.1*	2.7 *10.1*
Lethrinus miniatus	41.3 *38.6*	16.0 *22.5*	21.3 *36.0*	6.7 *18.4*	41.3 *41.3*	12.0 *23.8*
Lutjanus carponotatus	218.7 *252.0*	125.3 *301.1*	260.0 *369.1*	180.0 *203.4*	249.3 *372.4*	226.7 *311.5*
Total scarids	1038.7 *665.4*	1058.7 *617.8*	766.7 *384.8*	1166.7 *613.0*	1298.7 *769.0*	1237.3 *773.5*
Total pomacentrids	8855 *3958*	9576 *3899*	6519 *3115*	6491 *2710*	6208 *3377*	8804 *3853*
Baitfish	1.7 *3.0*	1.3 *3.1*	0.0	0.0	0.8 *2.0*	0.4 *1.0*

Appendix 4: Minutes of Project Workshop 1 – Delivering preliminary results

LINE FISHERY – IMPACTS OF TROPICAL CYCLONE *HAMISH*
WORKING GROUP

MEETING 3/09: 23 September 2009
By Videoconference and Teleconference

Draft Meeting Summary

Participants

Agency/ Sector	Name
Brisbane Videoconference Node (Primary Industries Building – Level 6)	
QPIF	Ian Yarroll (Chair)
QPIF	John Kung (Harvest Management)
QPIF	Tom Roberts (Industry Development)
QPIF	Robin Hansen (Industry Development)
QPIF	Zena Dinesen (Strategic Directions)
QSIA	Winston Harris
Townsville Videoconference Node (GBRMPA – Level 2)	
GBRMPA	Jon Day
GBRMPA	Randall Owens
GBRMPA	Paul Marshall
GBRMPA	Fergus Molloy
GBRMPA	Roger Beeden
AIMS	Hugh Sweatman
JCU	Andrew Tobin
JCU	Renae Tobin
JCU	Ann Penny
Teleconference	
Marketing	Jay Clark (Sydney)

QSIA	Shaun Hansen (Innisfail)
QSIA	Mick Galligan (Mackay)
Apologies	
QPIF	Brigid Kerrigan (Harvest Management)
QPIF	Jim Groves (DD-G Fisheries)
Marketing	Martin Perkins
QSIA	Michael Gardner

Meeting opened 1.15pm

1. The Chair confirmed the following documents received for the meeting:
    - AIMS survey summary – Hugh Sweatman
    - FRDC 2008/103 - Social Survey preliminary results – Renae Tobin
    - CFish (logbook) region and individual boat catch and effort summaries – John Kung
    - FRDC 2008/103 - Tony Ayling fish surveys and CFish summaries – Andrew Tobin
2. An industry update was added to the agenda to follow the updates from AIMS, JCU and QPIF.

Update on AIMS surveys

3. Reef arrays surveyed were in the northern part of TC *Hamish* path – northern Swains, Pompey Rf and Whitsunday sector. Fish surveys only on 3 reef communities in the Whitsundays. Swains area surveys planned for late January.
4. Major disturbances observed: formation of new cays, overall reduction in reef cover (down to 10% in some areas), proliferation of filamentous green algae.
5. Discussion on concerns about decreases in fish numbers a result of coral cover. In relation to productivity of the weather aspects of each reef, Shaun Hansen advised that while the leeward side can be productive, the windward side generally is more productive and fishes better.
6. Discussion in relation to coral trout numbers in LTMP regions generally being low and variable making statistical significance unlikely. What about for other species? – there is a potential concern with loss of structure for species such as butterflyfish, which could increase in predation levels for these species.

Update on social survey on adapting to change

7. Preliminary results presented from initial social survey. Surveys were conducted in May/June. Follow up surveys with participating fishers to be conducted.
8. Discussion on impact of lifting filleting restrictions. Reasons flagged for the lack of benefit in assisting fishers adapt to CT Hamish impacts were attributed to fishers not being set up for filleting and that the price and market were not geared for filleted and skinned product.

9. Discussion on data collected and information that can be derived from the different data sources:
   - Agreement that it would be useful to match up catch and effort information from logbooks (and other datasets) with responses from surveyed fishes

ACTION 1
Renae Tobin and John Kung to liaise on matching up individual boat data and surveyed fishers

Post Meeting Note: Completed

   - Key points to pull out from the data are redistribution of effort to other areas and concentration of effort to specific areas.
   - What this exercise has pointed out is that the type of information collected in logbooks is not sufficient to ascertain impacts. Need to look at other means of collecting data that does provided the information required.

10. Discussion on the type of management changes required. Fishers surveyed have suggested changes. What would be useful would be industry requirements for short term relief followed by the long term strategy for adapting to change and the dynamics for implementing change.

Update on logbook summaries

11. From an overall fishery perspective, catch in the last quota season ending June 2009 have been the highest since quota inception. Landings by regional areas/ports (i.e. Mackay and Gladstone) show reduced catch and effort. Boats have either chosen to remain fishing in the impacted regions, others have chosen to relocate. Catch, effort and catch rates by individual vessels have been variable with some vessels maintaining or improving catch rates and others showing lower catch rates in the months following TC *Hamish*.

12. Discussion on management and marketing factors affecting catch effort and catch rates.
   - This year has seen exceptionally good weather – boats able to fish more often.
   - Fishers are using extra dories – extra dory increases vessel catch by 20-25%.
   - Boats moving to Cooktown driven by expectations of higher catch (lower price compared with down south but will catch more by volume. Will be committed to fishing Cooktown for a longer period.
   - TC *Hamish* has also driven more boats from Bowen/Townsville to move to the Innisfail area. Innisfail is attractive as closer to fishing grounds. Observations of 4-5 additional boats now landing in Innisfail following the cyclone.
   - Very little fishing occurs out of Cairns – not much to catch in this area.

ACTION 2
Update spatial map of CPUE (2008 and 2009) provided to include Innisfail data (John Kung).

Post Meeting Note: Completed

13. Discussion on impacts of cyclone/weather on catches:
    - What is the impact of the cyclone on the fishery? AIMS report indicated recovery of corals will take 8-15 years. However in relation to impacts, there is generally less fluctuation observed in fish numbers then with coral cover.
    - Good stretch of weather also has an impact on catch rates. Fish an area harder resulting in lower CPUE. Fishers agree, areas have been fished hard due to good weather and recent high prices.

14. Discussion on quality of data collected.
    - Data required ascertaining impacts would need to be drilled down to kg/day/dory.
    - Agreed that fishers should take more responsibility in providing better data.

Update on underwater visual surveys and CFish analysis

15. Tony Ayling's observations from the underwater visual surveys are similar to the AIMS observations – significant reductions in coral cover. Data has not been analysed yet however, there does not seem to be a significant change in fish numbers other than an increase in scarid numbers.
16. The CFish data provides a number of scenarios to explore including impacts from TC *Justin* in 1997 and CT Larry (Category 4-5). TC *Justin* remained for 3.5 weeks pulling up deep water up onto the shelf resulting in reduced water temperatures. Affected catch rates with the fleet moving in response to depressed catch rates. TC *Larry* was destructive at its core. Intend to explore impacts on Spanish mackerel quota as well.

Industry Update

17. Shaun Hansen reported that the good weather this year has resulted in more effort put in. Boats are also using their additional dories as it increases the boats turnover. Last few months have been bad. Expect lower catches to continue over the next few months. Consensus from Mackay is that boats are working harder and doing longer trips. Expect this trend to continue.

General Discussion – Short Term Strategy

18. Discussion on what information/data needs to be collected/analysed to determine level of impact. Winston Harris reported that QSIA intend to meet with Minister Burke to seek relief funding. Avenues of relief funding sought at this meeting will be guided by what the data advises. Does the data we have now clearly outline an impact?

19. Andrew Tobin cautioned against making a call that there is an impact now, i.e. 'crying wolf':
    - Would like better data and to complete the FRDC project analysis first.
    - Can't ignore reports that the fish are there but not biting.
    - If the TC *Hamish* data show a fishery response as per the scenarios for TC *Justin* and *Larry*, then there is a case for seeking emergency relief funding.
    - Advised that he is not on this working group as an advocate for industry but in his capacity as a scientist leading FRDC Project 2008/103.
    - See no issues with QSIA initiating engagement with the Australian Government on emergency relief funding and funding avenues for industry based monitoring (i.e. similar to the Queensland Government's Green Army Funding) now and flag that analysis will be completed later).
    - Advised that the FRDC project is due for completion in April 2010 with Analysis of TC *Justin*/*Larry* impacts completed by December 2009. By October would like four to six months of post TC *Hamish* logbook data.

ACTION 3
QSIA/QPIF to contact line fishers to facilitate timely return of logsheets.

Post Meeting Note: QPIF have sent out logsheet return reminder letters in the last week to all line fishery licence holders. Quota Monitoring Unit staff in contact with fishers will also flag reminders to submit outstanding logsheets to assist analysis of impacts.

20. Discussion on responses from social surveys – what other avenues of relief funding do fishers have in mind?
    - Shaun Hansen suggested the PIPES scheme (Primary Industries Productivity Enhancement Scheme) that was available for banana farmers
    - Zena Dinesen advised that PIPES was administered through QRAA. There are other funding avenues available under QRAA that are not disaster related.

Post Meeting Note – PIPE Scheme includes development loans and resource management loans. Eligibility guidelines are available via the QRAA website http://www.qraa.qld.gov.au/.

21. Discussion on input controls that could assist in providing relief to fishers:
    - Shaun Hansen advised that the Filleting Permits were helpful but not many fishers close to take this up

General Discussion – Long Term Strategy

22. Andrew Tobin identified developing real time reporting/electronic catch reporting as a priority and reviewing management arrangements to facilitate replacement of coral trout in some markets (e.g. filleting and minimum size limit for cods).

Where to next?

23. The Chair summed the actions arising:
- Reality is we need to come up with a response strategy, don't have one yet.
- Short term, need QSIA and QPIF to follow up with fishers regarding return of logsheets, data entry needs to occur followed by analysis of logbook data.
- Look at reconvening the working group in November/December once Andrew Tobin's group have completed their data analysis.
- John Kung and Renae Tobin to liaise on sharing of data to match up individual boat data and survey responses and identifying bats for follow up surveys.
- John Kung to redo spatial maps of catch rates to include Innisfail.
- Renae Tobin to summarise key points for consideration arising from this meeting to include in follow up surveys and circulate to working group for comment (*Post Meeting Note – completed*).

Meeting closed 3:15pm

Appendix 5: Minutes of Project Workshop 1 – Delivering CFISH analysis outcomes

LINE FISHERY – IMPACTS OF TROPICAL CYCLONE *HAMISH*
WORKING GROUP

MEETING 1/10: 16 February 2010

Board Room, Museum of Tropical Queensland Board Room, Townsville

Meeting Summary

Participants

Agency/ Sector	Name
Fisheries Queensland	Ian Yarroll (Chair)
Fisheries Queensland	John Kung (Harvest Management)
Fisheries Queensland	Tom Roberts (Industry Development)
Fisheries Queensland	Colin Shelley (Industry Development)
GBRMPA	Randall Owens
GBRMPA	Paul Marshall
GBRMPA	Tyrone Ridgeway
JCU	Andrew Tobin
JCU	Renae Tobin
JCU	Ann Penny
JCU	Audrey Sharpe
Industry	Shaun Hansen
Industry	Terry Must
Industry	Tony Vass
Industry	Carl D'Aguiar
Industry	David Pidduck
Industry	Peter Brayshaw
Industry	Greg Smith
Apologies	

DEEDI	Zena Dinesen (Strategic Directions)
QSIA	Winston Harris
GBRMPA	Peter McGinnity
QSIA	Michael Garrahy
Marketing	Martin Perkins
GBRMPA	Jon Day
GBRMPA	David Wachenfeld
Industry	Gareth Andrew

Meeting opened 10.15am

1. The Chair welcomed participants to the workshop. Winston Harris, Michael Garrahy and Martin Perkins were not able to join the workshop due to teleconferencing facilities being unavailable.
2. The following item was added to the agenda - An update of the socioeconomic survey results by Renae Tobin.
3. Apologies were noted and recorded.

JCU Analysis of CFish data

4. Andrew Tobin presented an analysis of results from FRDC Project 2008/103. Tony Ayling's Underwater fish counts of the reefs from the Effects of Line Fishing Project (7-15 June 2009) (using the last surveys from 2003, 2004 and 2005 as controls) and analysis of results from the CFish (commercial logbook) data examining the impacts to TC *Justin* in 1997 and TC *Hamish* in 2009.
5. The underwater survey recorded significant decreases in hard coral in 2009:
    - Hard corals in exposed front reefs reduced by a third
    - Minimal damage to protected back reefs
    - Most fish populations unaffected
    - No change to coral trout numbers (slight increase in adults)
    - The fish are present but not interacting with the fishery
6. Analysis of CFish data was initially hampered by difficulties associated with data availability in formats appropriate for interrogation. The lack of real time or timely availability of reported catch is also an impediment to assessing impacts. Key trends in CPUE, catch and effort as follows:
7. Data was evaluated as follows:
    - TC *Hamish* impacts on CPUE, and effort using 2009 compared with pre-cyclone years (2006-2008).
    - Data presented for three quota groups – CT, RTE, OS
    - All data (1994-2009) standardised to kg/dory /day

- Data evaluated for whole fishery and active boats (the latter subjectively using a 1000kg (1994-2000) criteria ~ 50-80% of fleet)
- Standardised datasets grouped at two time levels (month and year) and spatially into reporting latitudes (30nm grids).

8. Key trends from TC *Hamish* impact:
   - CT CPUE – depressed across all grids in 2009, in some grids by 30%+.
   - RTE CPUE – CPUE depressed from Bowen south (by 30% – 80% in southern grids), and increased from Bowen north
   - OS – No clear trends.
   - Effort – significant effort shift away from grids 22, 23 and 24 (roughly Bowen to Mackay). Effort displaced to Townsville (grid 21), Mission Beach (grid 18) and all grids Cooktown north (5-14).
   - Generally, boats have shifted north as a result of depressed catch rates. Boats toughing it out in southern grids are putting up with lower catch rates and boats that moved north are finding higher catch rates though lower than previous years.
9. Key trends from TC *Justin* impact (1994-2000 data):
   - Effort moved away north of grid 17 (roughly Innisfail-Cairns) however, infrequent effort in this region makes trends difficult to interpret. In some affected areas, effort decreased by 60% - 70%.
   - CPUE decrease in Bowen by 56%.
   - Recovery evident post cyclone + significant changes in fishery – fishing less.
10. Discussions were as follows:

    Recovery

   - In 1997 when Justin hit the CRFFF was mainly a dead fishery. Now all live and fishing shallow – recovery will be longer.
   - Andrew Tobin advised caution in predicting recovery. Can't say from the dataset when recovery will occur. Now waiting for water temperature data from CSIRO – possible that mass of cold water pushed up by TC *Hamish* onto reef and slowed metabolism of coral trout (plus limited movement) therefore stopping interaction with fishery. Red throat emperor more mobile therefore increasing interaction with fishery.
   - Advice from industry that in Torres Strait after a hard westerly blow, coral trout is caught in trawl nets on sand i.e. coral trout could be more mobile than we thought.
   - Need to look at relationship between water temp and behaviour of the fish. There are differences in water temp effect between TC *Hamish* and Justin therefore the responses to both cyclones may be different. Assuming that coral trout stay on the reef – fish are around but not interacting – impacts on recruitment are uncertain. No one knows – could mean a good recruitment in future. Even if coral reduced to rubble, still hold an operational fish community (e.g. damsels, etc.).
   - What will happen to future recruitment?
   - Peter Doherty's and work from others show recruitment three weeks after spawning and recruitments settle on coral rubble.

Physical impacts on fish

- Was there any evidence of fish dying?
- Fishers reported algae (green slime) immediately after Hamish and some CT with blisters.
- Paul Marshall – From photos available, the algae is probably blue-green algae and possibly toxic to touch

Summary of discussions from Chair

- There is physical damage to area, fish are there but not responding to fishery, don't know what will happen to future spawning, good data available on response of fleet.
- Data is sufficiently robust to use in support/funding applications

Data management

- How can data management be improved i.e. how it is collected from fishers, stored and manipulated?
- This exercise has demonstrated that it is a big task to get a handle on effort given the current data management process.
- Have a quota reporting system that works quite well – how can we modify this system to provide immediate data and ensure that the data is provided in a format that can be interrogated?
- Chair – improving data management is a key message to take away – need to work with industry on how data management could be improved and how we use the data – could be part of industry development work.
- Colin Shelly – access to fishery statistics is generally poor. This is major opportunity for web based data access so that fishers and investors have a portal to access information. Opportunity to revamp DEEDI Information Technology in line with new departmental focus.

Impacts

- Chair – we do not have a foreseeable recovery time and can not predict when.
- Data does not point to a stock sustainability problem but to a profitability concern
- Some fisher observations contradictory to Tony Ayling survey (i.e fish are not there)
- After Cyclone Justin, there was a lot of effort shift north – Bowen is going to cop it.
- This is an emotional issue affecting geographics of the fishery (i.e. effort shifting into areas and affecting local fishers).

Socioeconomic update

11. Renae Tobin presented results of the two surveys (in May 2009 and again six months later). Summary of results were provided in the handout.
12. Discussions were as follows:

Views of filleting policy in the long term

- General response to filleting from survey is that the market for fillets does not exist and crew don't want to fillet. Need to give market time to develop. As an immediate assistance, this has probably not helped yet.
- Fishers at the workshop agreed that the market was lost when filleting restrictions came in 2004 and that time was needed for market to recover. Prohibiting skinning is a problem and doesn't help safe food practice.

Reliance on single species, single market

- Industry rides on the back of the live trout industry. But this not a fall back position to deal with future event. In the longer term - ideally industry will position itself to take up the RTE quota

Infrastructure capabilities and effort shift impacts

- Are there infrastructure impediments to some ports being able to handle more boats?
- Mackay is limited in its facilities as catch is being landed on private facilities.
- Allowing carrier boats in the fishery could assist expanding the fishery into other areas i.e. north of Cooktown. Opposing fisher view was raised that local boats in Cooktown are complaining about lower CPUE due to influx of 4-5 additional boats
- In terms of managing effort movement and gauging the level of concern by local fishers of new boats moving in, the responses from the survey do not indicate concern with boats moving from port to port and is accepting of this practice. However, the level of concern could increase 12 months down the track.

Quantum of assistance sought by fishers

- One of the management responses suggested by surveyed fishers was to compensate fishers to stop fishing.
- Amount of compensation fishers expected was of interest. Renae Tobin agreed to ask the fishers in the final survey.
- Chair - Have to be careful about grants or low interest loans (as these are based on infrastructure or productivity loans as a result of impacts) – there are no provisions for compensation as industry have access to income protection from private institutions.

Industry development

13. Colin Shelley provided an update on the line fishery industry development plan:
    - Need to identify 5-6 key issues for the industry development plan to focus on.
    - Aside from their specific purpose, the industry development plans are useful in leveraging funds for new initiatives and development (especially when have several funding agencies involved).
    - Line fishery plan expected for completion mid 2010.

14. Discussions were as follows:

<u>Risk assessments</u>

- Do the industry development plans include risk assessment i.e. climate change and its impacts on stocks. Fuel use and industry carbon footprint should be taken into consideration.
- Colin Shelley – Can incorporate climate change or carbon footprint in planning. But if these issues are not part of top 5 or 6 issues then would not be a key focus. Key focus are marketing, product development and supply chain analysis

<u>Data management</u>

- Fishers should have more access to their catch data and in a reasonable time and format.
- Colin Shelley – Data management is a key message for industry planning

<u>Single market, single species approach</u>

- Colin Shelley – TC *Hamish* has highlighted the risks of a single market single species approach based on live trout. This is good money as fishers at this workshop have pointed out and will be an issue for the industry plan to address. Issue also to be addressed by Industry Development Reference Group.

<u>Communication and fishery information availability</u>

- Fishery information is an issue e.g. who has what quota – many fishers are not aware of FishNet.
- Colin Shelley – Communication/information improvements to be dealt with by industry development plan.

15. Colin Shelley, Tom Roberts and Tony Vass left the meeting at this point for the industry development port meetings.

Where to from here?

16. Chair advised that following telephone conversation with Winston Harris during the lunch break, the department will work with industry to develop an application for funding/support arrangements to the State/Federal government – ***ACTION ITEM***
17. Discussions were as follows:

<u>Nature of funding/support</u>

- Applications can be put to the Queensland government for emergency declaration provisions to be enacted or to the Federal government for exceptional circumstance support.
- Viewpoint put forward that it is difficult to see exceptional circumstance being granted. This could take up to a year.

- Chair advised that applications to the Federal government for exceptional circumstance would need to be supported by the State. There is robust information that can be used and recovery can not be predicted. There could be other avenues other than funding applications. Other areas of DEEDI and Treasury will need to be consulted as other fisheries may be impacted as well, therefore a system needs to be in place for other fisheries as well. For example, the trawl fishery could be impacted too.

<u>Availability of QRAA productivity loans</u>

- Advice received that most fishers tend not to use QRAA even though the loans offered are 50% lower than lending institutions. QRAA loans currently ~4.5%. Reason for this being the time and frustration it takes to deal with a government body.
- Chair advised that he will provide this feedback to DEEDI as QRAA reports to the Minister – ***ACTION ITEM***
- DEEDI also offers financial counselling through their farm financial counsellors. Feedback received that the officer in Bowen provides good service.

<u>Revision of input controls in relation addressing TC *Hamish* impacts</u>

- Chair advised that outcome of conversation with Winston Harris was to review input controls in relation to efficiency. The issue of filleting and markets development/diversification can be dealt with by the industry development planning process. The issue of expanding the fishery using carrier boats has been raised. –are there others to table for discussion?
- Allowing trapping and multiple hooks was suggested – gear use could be reviewed as part of overall review of Coral Reef Fin Fish Management Plan
- General discussion occurred on needing to position the industry to address future events as these were likely to occur again.

<u>Need to reduce effort</u>

- The need for both output and input controls was questioned. However fishers raised the issue of excessive fishing effort even with a quota in place.
- General discussion on needing to manage recreational and charter catches (in relation to potential for future devaluation of quota as a result of effort growth and resulting insecurity/uncertainty stifling investment and employment) i.e. a need to manage the fishery across all sectors.
- Report that many crew do not want to work on 4 dory boats as they will be in competition with each other and problems with numbers on tenders on reefs.
- General discussion on numbers of tenders used. Andrew Tobin advised that data was available to evaluate vessel catch efficiency in relation to number of tenders.

- Fisher view that there was potential to double the amount of effort now for the same amount of catch if price remained high.

Implementing TAC buffers

- Implementing a TAC buffer was suggested to manage catch and catch rate following severe events. Issues considered were:
  - The need to have catch throughout the year to maintain the Hong Kong market
  - Removal of quota must be accompanied by removal of effort otherwise CPUE will be driven down. The issue was highlighted from the CFish analysis (42943 dory days in 2008 v 46377 dory days in 2009).
  - Business will make their own decisions on how much effort to expend to take their quota. If beach price is high (e.g. $80), more effort will be expended, if price is low (e.g. $30), less fishing will occur. Current management arrangements do not impede individual decisions and therefore nothing fundamental wrong with management arrangements as they exist.
  - Chair summarised discussions so far – not reasonable to expect Government to lease back quota. However, buffers are required, whether formal or informal.
  - Impact of any buffer on quota value need to be considered
  - Current quota levels are adequate to satisfy the Hong Kong market.
  - Use of TAC triggers was raised with discussion then following on how to set the trigger given different operations based on live or dead product and productivity of different fishing grounds.
  - Suggestion made for treating the fishery as two different cultures based on live trout and another on OS. Catch reporting on day boats would be an issue.
  - Suggestion to set quotas with a reserve level e.g. using full quota in good years but setting a 25% buffer level (reserve) and triggering this after an event like Hamish.
  - Mechanism for implementation was raised – voluntary (not likely to be supported by fishers) v legislate
  - Combine TAC buffer with effort controls i.e. dory limitations

Marketing and spreading risk

- To increase adaptive capacity industry needs to diversify markets to include multiple species. High reliance on a single species makes the industry very vulnerable to change.
- Increase profile of GBR fish and increase return to fishers
- The Queensland Catch initiative will promote the quality seafood message. Need to include quality control of filleted product to ensure quality / reliable market.
- Increased availability of fillet product on the local market will also help image of industry – returning product to community rather than just export.
- Perception of lack of security in RTE and OS quota due to uncapped recreational effort needs to be addressed.

- Diversification to other species could include use of more than 6 hooks
- Improving technology for holding and transporting live trout

18. The Chair summarised suggestions raised as follows:
    - Expanding fishery area e.g. by allowing carrier vessels
    - Implementing a TAC buffer (fishing a proportion of quota) – in-principle support to evaluate this option and how it would be implemented. Need to be industry driven. Government will not lease back quota.
    - Complement a TAC buffer with effort management
    - There are no obvious short term changes that can be made. Some of these reviews could be part of the review of the Coral Reef Fin Fish Fishery Management Plan due by 2013 and likely to commence as early as 2011/12

Where to next?

19. The Chair summarised the actions and outcomes arising from this workshop:

<u>Data Management</u>

i) Review data management. Smaller group (including key data management staff from Fisheries Queensland) to address this issue. Group to be separate from review of management arrangements

<u>Advise DEEDI on fisher views on accessing QRAA services</u>

ii) Chair to advise DEEDI of fisher views on QRAA operations and impediments to higher uptake of QRAA services

<u>Industry development plan</u>

iii) Improving OS uptake and marketability and return – part of Colin Shelley's Industry development work

iv) Communication initiatives to improve confidence in quota security and investor confidence in fishery (part of industry development plan)

<u>Industry responsibility – fish holding and transport logistics</u>

v) Improving existing live trout holding and transport logistics (industry responsibility)

<u>DEEDI management planning</u>

vi) Medium term – explore avenues of managing the fishery across all sectors.

Response – quota management strategy and applications for financial support

vii) Develop response strategy based on quota control and review constraints on area expansion

viii) Establish a small working group to address quota control and building confidence in quota management. Chair to discuss with Michael Gardner how QSIA would like to be engaged. Peter Brayshaw to be included in working group.

ix) Application/system for financial/support arrangements to be developed using data analysis by JCU. DEEDI to work with QSIA.

Meeting closed 2:40pm