Northern Australian sharks and rays: the sustainability of target and bycatch species, phase 2

PRINCIPAL INVESTIGATOR: John Salini

Project No. 2002/064

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Northern Australian sharks and rays: the sustainability of target and bycatch fisheries, Phase 2.

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Project Objectives

1. Establishment of long-term collection of catch composition data from target shark fisheries in northern Australia (NT Joint Authority Shark Fishery, NT Coastal Net Fishery, Queensland Joint Authority Shark Fishery, Queensland N9 Shark Fishery, WA Joint Authority Shark Fishery, WA North Coast Shark Fishery, Queensland East Coast Net Fishery), in order to improve stock assessments.
2. To determine the appropriate management scale for the target species of northern Australian shark fisheries, by examining the degree to which stocks are shared across northern Australia and with Indonesia.
3. To evaluate the effect of gillnet fishing on northern chondrichthyans, by determining bycatch composition (Queensland N3 Net Fishery, Queensland East Coast Gillnet Fishery, NT Barramundi Fishery, WA Kimberley Gillnet and Barramundi Fishery).
4. To derive estimates of biological parameters to assess the status of sawfish populations; age structure, reproduction and growth.
5. To re-evaluate the risk assessment of northern chondrichthyans (undertaken in the EA project), based on the new information collected above. This risk assessment will be compatible with the one undertaken in application FRDC 2002/033 (PI Terry Walker) in line with the NPOA-Shark priority for a national approach to risk assessment for chondrichthyans.

Non Technical Summary:

KEYWORDS: Sharks, management, fishery, observer, population structure, sawfish, shark bycatch, risk assessment.

OUTCOMES ACHIEVED TO DATE

The outcomes from the project were direct and indirect results and involved major changes to both the shark catch reporting and the effort by fishers, largely in the form of a reduction in real or latent effort. Most of the outcomes were directed at delivering more detailed fishery information that will contribute to improved stock assessments by improving; i) the species composition information (use of observers) from both target and bycatch shark fisheries, ii) the catch and effort records, iii) fisher awareness of sustainable fishing, iv) fisher acceptance of the impact of fishing on sharks, especially since most shark fin is exported.

Related outcomes include:

- Changes to shark log books to reflect more accurate species composition and effort, management changes to reduce effort on a geographic scale (WA) or capping effort by consolidating licenses (NT) and declaring sawfish protected species (WA). Shark fisher representative bodies have independently demonstrated long-term commitment to sustainable fishing by developing Codes of Conduct to encourage live release of sawfish where possible (NT). These outcomes will provide information that will improve elasmobranch stock assessments and they highlight the reality of shark bycatch from non-target fisheries (as recorded by project observers), even when these sharks are not normally recorded as catch.
- Updated risk assessment that allows management and research to focus on higher risk species.
- Evaluation of the status of northern sawfishes that helps identify management and research priorities.

The importance of the shark fishery has been enhanced by the high public profile of sharks, the sensitivities and value of the shark fin trade and the explosion in illegal foreign shark fishing across northern Australia (also driven by high fin values). The Illegal, Unreported, Unregulated (IUU) shark issue has largely developed within the course of this project and for this reason resource managers need the latest information on the species composition and catch rates for, target shark fisheries, fisheries that take shark as bycatch (mackerel fisheries, barramundi gillnet fishers, trawl fisheries) and illegal (foreign) shark fishing. The consequence of the high value of shark fins means that the effort directed towards shark by Australian and IUU fishers, has increased significantly in recent years. Australia has a responsibility to manage the north Australian shark fishery, and other fisheries that take sharks, in an ecologically sustainable way. This responsibility is driven by several factors, including legal obligations that are linked to the National Plan of Action (NPOA) for the Conservation and Management of Sharks (administered by Department of Agriculture, Forestry and Fisheries, DAFF), the general public and conservation groups.

Since sharks tend to be slower growing and have a lower productivity (reproductive potential) than fin fish, there is concern for their ability to withstand increasing fishing pressure. In order to provide information useful to shark fishery managers, this project set out to:

(1) provide data to enable these fisheries to improve stock assessments,
(2) ensure management is at the appropriate scale for stocks,

(3) address some of the EPBC Act guidelines and
(4) align with the National Plan of Action for the Conservation and Management of Sharks.

The establishment of shark fishery observers in WA, NT and Queensland was successful in terms of the target shark fisheries in each jurisdiction. In the barramundi fisheries (shark bycatch fisheries), there was limited success in gaining observer time with fishers. Future effort to monitor shark bycatch fisheries such as the barramundi fishery, may require cooperative log-book changes to improve the recording of shark bycatch. This outcome was to be included as part of a future FRDC project (unsuccessful proposal) to help Qld and NT jurisdictions introduce the improved log books.

Establishing shark fishery observers was undertaken slightly differently in each jurisdiction. WA Fisheries were able to incorporate an existing shark researcher (Justin Chidlow) for the duration of the observing schedule, as was the case in Queensland Fisheries where the project phase 1 observer continued in that role (Stirling Peverell). Keeping an observer in the NT shark fishery was more challenging with three observers filling the role. The biological data collected by observers was less than expected and remains a limiting factor in the risk assessment calculations for the less abundant species.

Understanding the management scale based on genetic stock structure of the major target species, *C. sorrah* and *C. tilstoni*, was achieved using mtDNA and nuclear DNA (microsatellites) procedures. These revealed that Australian caught and Indonesian caught *C. sorrah* (spot-tail shark) were separate from each other, although both species showed no genetic separation across northern Australia and the east coast. This reflects their bentho-pelagic feeding behaviour and high mobility, although *C. tilstoni* are not recorded from Indonesia waters and are restricted to northern Australia. This implies that uniform management of this species across jurisdictions is needed for sustainable exploitation.

An understanding of the status of sawfish in north Australian waters was enhanced by records from WA, NT and Queensland, although records were less than anticipated. However, small advances in our understanding of their distribution/habitat were made from location of capture data. The main problem in determining trends in sawfish abundance and obtaining biological data was the rarity of sawfish capture (or reporting) in commercial operations. The difficulty in obtaining independent bycatch records from inshore gillnetters such as barramundi fishers was reflected in the lack of sawfish information from these fisheries. Increased biological information was obtained for all four species although life cycle parameters for age and growth were compromised by a lack of large specimens and a lack of validation of ageing data. Their high vulnerability to gillnets and trawling makes further research on their biology and habitat use of paramount importance, if shark fisheries are to mitigate against the threat to sawfish. More data on the habitat utilisation and long term movement patterns are required to mitigate the effects of fishing. Fishery awareness of project research helped stimulate proactive measures to avoid sawfish interactions and to elect to release live sawfish as a 'Code of Practice' measure.

Data on fishery specific species composition as well as new data on the biology of some species were used to update the risk assessment. The original risk assessment methodology was modified to better suit available data and take into account the range of methods (gear) used to capture elasmobranchs. Comparisons between the risk assessment methodology used by Terry Walker (FRDC project 2002/033) and those developed in this project were made to determine the best approach for northern Australian elasmobranchs. The risk was evaluated on a per fishery basis and a cumulative Risk Assessment over all fisheries. This revealed up to 14 high risk species, with susceptibility to gillnets and low productivity the major factors contributing to their 'high risk' status. These included sawfishes (*Pristis clavata, P. microdon, P. zijsron),* giant shovelnose ray (*Rhinobatos typus),* shark ray (*Rhina ancylostoma*), speartooth sharks (*Glyphis* sp. A, *Glyphis* sp. C), the great hammerhead (*Sphyrna mokarran),* the lemon shark (*Negaprion acutidens),* Pig eye (*Carcharhinus amboinensis*) and three whaler species (*C. brevipinna, C. leucas, C. limbatus).*

Keywords: shark fishery, risk assessment, shark fin, code of practice, sawfish, sustainability.

1. CHAPTER 1 INTRODUCTION

1.1 Background

Recent Impacts (not discussed in the original proposal)

One of the overriding influences on the shark fishing industry in north Australian waters over the duration of this phase 2 project, has been the changes in fishing effort brought about by high fin prices. Apart from changes in effort within the north Australian shark fisheries, the great unknown has been the extraordinary surge in illegal foreign fishing, mainly for sharks, from the Memorandum of Understanding (MOU) box in north-western Australia waters, right through to the Torres Straits. The impact of Illegal, Unregulated, Unreported (IUU) shark fishing was starting to be recognised as a significant factor when the current project began. The project was not designed to address IUU shark fishing, although recent surveillance data suggests IUU shark effort and catch may overwhelm the Australian shark effort and catch.

A measure of the estimated foreign catch of sharks has now become a priority for the next FRDC Shark Mitigation project proposal and is an urgent matter for WA, NT, Queensland and the Australian Fisheries Management Authority (AFMA) managers of northern shark resources. In recent months (early 2006), proposals for estimating the effort and catch of sharks by Foreign Fishing Vessels in the north have been submitted to AFMA for funding, with the Effort Estimation project approved in April 2006. Such projects, together with the NAFM strategic and operational plans directed at northern sharks, will eventually place the IUU shark effort in its true perspective in relation to the Australian effort.

Background for the original project (excluding IUU fishing)

There is increasing international and national concern over the sustainable management of elasmobranchs (sharks, rays and sawfishes). This is due to rapidly increasing catches, in part driven by high prices for fins, and the vulnerability of elasmobranchs to overfishing. International concern for elasmobranchs is reflected by the development of an International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) by the Food and Agriculture Organisation (FAO) of the United Nations. In line with the IPOA-Sharks, Australia is developing a National Plan of Action for the Conservation and Management of Sharks (NPOA-Shark, coordinated by AFFA, developed with the assistance of the Shark Assessment Group, SAG). The International Union for the Conservation of Nature (IUCN) is also currently producing a global action plan for the conservation and management of elasmobranchs. These international and national action plans will have implications for Australia’s management of elasmobranchs.

Within Australia, fisheries management is increasing its focus on ecologically sustainable development. The recent Environment Protection and Biodiversity Conservation (EPBC) Act requires fisheries that export any product to be assessed according to guidelines. This assessment examines the ecological impacts of the fishery on target and by-product species, bycatch species, threatened, endangered and protected species, marine habitats and marine food chains. There is also increasing national concern for some groups such as sawfish (Pristidae). The sawfishes are considered by the IUCN Shark Specialist Group to have all species listed as at least vulnerable status, with most endangered or critically endangered (Simpfendorfer, 2000). In Australia, some sawfish are considered vulnerable and there are strong concerns about the long-term viability of tropical species. The bycatch of these species is unknown in most fisheries.

Updated Risk Assessment

The SAG and NPOA-Shark (ratified by the Minister for Fisheries Forestry and Conservation, April 2004) have identified the risk assessment of Australian elasmobranchs, undertaken with a national approach, as a high priority for research. The risk assessment proposed in this project is fundamental to the NPOA-Shark and management agencies' ability to prioritise their actions for the conservation and management of sharks. The risk assessment undertaken in this project will contribute directly to this. In order to achieve a national approach, this project is aligned strongly with Terry Walker's FRDC Project Proposal 'Rapid assessment of sustainability for ecological risk of shark and other elasmobranch bycatch species taken in the Southern Shark Fishery, SSF, Southeast Net and Troll Fishery, SENTF, Southeast Trawl Fishery, SETF (now the Commonwealth Trawl Sector) and Great Australian Bight Trawl Fishery, GABTF' (FRDC 2002/033). Together, the two projects will produce compatible risk assessments of elasmobranchs in line with the recommendations of the NPOA-Shark.

Several initiatives have been taken to ensure close alignment between the two projects. One is for the Principal Investigator of each of the two projects to serve as a Co-Investigator on the other project. Each year, the Principal Investigator from the Northern Australian Project Team will meet with members of the Southern Project Team and, conversely, the Principal Investigator from the Southern Australian Project Team will meet with members of the Northern Australian Project Team. John Stevens is also a co-investigator on both projects. Another major initiative is for the national SAG to serve as a steering committee for both projects. The SAG will assess progress against project objectives, ensure alignment with NPOA-Shark objectives and have the authority to direct changes to the research as part of its functions of review and steerage. Milestone reports and other progress reports for the present project will be submitted to FRDC via initially the SAG, and subsequently the FRDC Sub-program, if it is formed. All publications, media releases, radio interviews, conference abstracts, magazine articles will be submitted to initially the SAG, and subsequently the FRDC Sub-Program, for approval in writing prior to distribution or release. The SAG will also provide another mechanism for facilitating the uptake of project outputs by the relevant management agencies.

Ilona Stobutzki (*now with Bureau of Rural Sciences, BRS*), Terry Walker and John Stevens were also involved in the AFMA funded project 'Ecological Risk Assessment for Commonwealth Fisheries' (ERA Project) which aims to develop appropriate methods and undertake ecological risk assessment for fisheries. The risk assessment methodologies developed in the ERA Project will feed directly into this proposal and FRDC Project Proposal 2002/033 (PI Terry Walker). The Final Report for the EA project *The Sustainability of Northern Australian Sharks and Rays*, which used the relative risk assessment method, was submitted in March 2002.

Project link to management

This project will address important local and regional fisheries management issues in northern Australia. For target shark fisheries within Queensland, Northern Territory and Western Australia the project aims to enable effective and sustainable fisheries management. This will be achieved through providing the data necessary to

(1) enable these fisheries to improve stock assessments,

(2) ensure management is at the appropriate scale for stocks,

(3) address some of the EPBC Act guidelines and

(4) align with the NPOA-Shark and NAFM strategic and operational plan

Across the northern Australian region this project will examine the impact of fishing on elasmobranchs therefore:

(1) enabling managers to prioritise species for future management,

(2) contributing to the EPBC Act assessment of fisheries that catch elasmobranchs as bycatch, and,

(3) align with the broader issues in the NPOA-Shark and NAFM strategic and operational plan

The National Shark Assessment Report (Draft, prepared by the SAG for AFFA) as part of the NPOA-Shark (ratified April 2004), lists the following as significant issues in regard to the take of shark in Australian waters:

i) a general lack of species identification and quantification of shark taken in target and non-target shark fisheries;

ii) lack of consistent and accurate data collection and reporting of shark catches across all fisheries and jurisdictions;

iii) lack of scientifically defensible stock assessments for some targeted and important by-product species;

iv) management of the overall impact on shark species which are taken in two or more fisheries.

Improved fishery data collection

This proposal directly addresses these issues for northern Australian elasmobranchs. Catch composition data will be collected in the target fisheries (NT Joint Authority Shark Fishery, which has become the NT Offshore Net and Line Fishery, Queensland Joint Authority Shark Fishery (*now merged with the N9*), Queensland N9 Shark Fishery, WA Northern Shark Fishery, Queensland East Coast Net Fishery), based on trials conducted during Phase 1 (FRDC 2001/077). This project will also work towards consistent and continued data collection across all target fisheries.

Bycatch composition will also be collected from northern net fisheries that catch elasmobranchs as bycatch (Queensland N3 Net Fishery, Queensland East Coast Gillnet Fishery, NT Barramundi Fishery, WA Kimberley Gillnet and Barramundi Fishery). There are several northern fisheries for which elasmobranch bycatch information is already available (e.g. Northern Prawn Fishery, Torres Strait Prawn Fishery and East Coast Otter Trawl Fishery) from previous and ongoing FRDC research projects. This information will enable improved stock assessments for the target fisheries that are based on the take not only in the target fisheries but also in the bycatch fisheries.

Management scale for blacktip sharks

The validity of the stock assessments for the main target species will also be ensured by an analysis of the stock structure of the primary target species (*Carcharhinus tilstoni* and *C. sorrah*). This is important for determining the appropriate scale of management. In the 1980s, population genetics analyses using allozyme-based techniques were carried out on these species (Lavery and Shaklee 1989). This study showed little detectable population structure across northern Australia. However genetic techniques have advanced significantly and the issue of shared stocks with Indonesian fisheries has yet to be resolved. This project will take advantage of samples collected in Indonesia by a CSIRO/Murdoch University/Indonesia/ACIAR project to address the issues of shared stocks with Indonesia (ACIAR FIS2003/037).

This project will contribute to the management of the overall impact on shark species that are taken in two or more fisheries by undertaking a risk assessment of all northern elasmobranchs, based on the new information collected above. The project will integrate the catch information from the different fisheries with available biological and ecological knowledge of the species to examine the sustainability of the catches of northern elasmobranchs. This will highlight potentially vulnerable species that may require management action to ensure their sustainability. This risk assessment will be compatible with that undertaken in FRDC Project Proposal 2002/033 (PI Terry Walker) and will feed directly into the NPOA-Shark through the SAG steering committee. Recent developments with the risk assessment have shown that this is most feasible on a fishery by fishery basis.

This project will also collect biological information on the sawfishes. There is very little known about the biology of this group and yet they are the focus of concern. The collection of biological information will contribute directly towards ‘productivity’ parameters in the risk assessment and thereby enable a more robust assessment of the impact of fisheries on this group.

The Northern Australian Fisheries Management (NAFM) Workshop has identified the sustainable management of elasmobranchs in northern Australia as a high priority since 1998 and this was reiterated in 2001. The NAFM workshop is attended by Queensland, WA and NT fisheries management and research organisations as well as Commonwealth agencies (AFMA, BRS and CSIRO). Based on NAFM's requests CSIRO/Qld DPI/NT DPIF/FWA/BRS have been developing and undertaking projects to address this issue. Initially a desktop study was funded by Environment Australia (EA) (1999-2002). The EA project is collating all available information to provide an assessment of the impact of both target and bycatch fisheries on elasmobranchs in northern Australian waters. However the EA project is limited by the lack of catch composition from most fisheries. In 2001 FRDC funded Phase 1 of the current proposal (FRDC 2001/077) to begin to address this issue, by trialling an observer program to collect catch composition information from the target shark fisheries. Phase 2 will ensure this data continues to be collected and will extend this collection to fisheries that take elasmobranchs as bycatch. During Phase 1, workshops with industry were held to determine what issues concerned industry members (October – December 2001); the output of these workshops will be integrated into Phase 2. During the project, NAFM in 2004 and 2005 focussed most of its attention on the growth of IUU fishing that targets sharks in the north and developed a shark strategic and operational plan. New projects that investigate the characteristics of the IUU shark catch have been funded by AFMA and these projects will eventually lead to a scientifically valid estimate of the IUU effort and catch.

This project builds on previous research in the CSIRO Northern Pelagic program, recently completed and ongoing FRDC projects, and the extensive experience of the collaborating agencies. The proposed research will extend the work in FRDC 96/257 (Ecological sustainability of prawn trawl bycatch) where elasmobranchs, particularly sawfishes, were highlighted as a potentially vulnerable group. This project also links with a CSIRO/Murdoch University/ACIAR project examining artisanal shark and ray catch in south-eastern Indonesia. Samples from Indonesia will be used to examine whether the main target species of northern Australian shark fisheries are shared between the two countries. This project will utilize data collected from FRDC 95/049 & 99/125 (TRAP Phase I and II). This project will also take advantage of the high level skills and collaborative links already established among the team members.

1.2 Need

The management of northern elasmobranchs has a strong need for research to address local and regional management issues. The need is fundamental and the Northern Shark Stock Assessment Review Workshop (Queensland, NT, WA and the Commonwealth), Broome 2000, identified the lack of species identification in NT and Queensland catches in target and bycatch fisheries as a major concern. This has been clearly recognised at State/Territory, national (NAFM) and international (FAO, IUCN) levels. The sustainability of these species is also an explicit priority with stakeholders. The Northern Australian Fisheries Management (NAFM) Workshop (Queensland, NT, WA and the Commonwealth) identified research into elasmobranchs as high priority in 1998, 1999, 2000 and 2001. The NAFM Workshop agreed to write to FRDC to reiterate the high priority of this project. Professor Carl Walters, at a Stock Assessment Workshop in Darwin, examining northern shark catches, also highlighted the issue of inadequate data (Walters and Buckworth 1997) while the National Shark Assessment Group (Nov. 2000) also identified similar issues. There is also a clear need to determine the extent of shared stocks, both within Australia and with Indonesia, to ensure the management scale is appropriate.

This project will also address the critical need for information on the biology and catch of sawfishes in northern Australia, research for which Environment Australia have also indicated their support. The first phase of this project (Jul 2001 - Jul 2002) received a high priority from QFIRAC 2000 and was funded by FRDC (FRDC 2001/077). Environment Australia and ACIAR have also funded complementary research on sharks and rays in northern Australia and Indonesia. The current project is critical to ensuring these studies have valid, up to date information on the current catches in northern fisheries. QFIRAC has given this project very strong support, ranking it second of all proposals submitted. This project will align with FRDC Project Proposal 2002/033 (PI Terry Walker) to address the high priority need identified by the NPOA-Shark, for a national approach to risk assessment for elasmobranchs. This risk assessment is required in order to prioritise actions within the NPOA-Sharks.

Developments since the proposal was written
During the course of the project, a desktop study of all available sawfish records in museums, jurisdictional databases and the CSIRO was initiated with FRDC approval and salary contribution from CMAR appropriation funding (see Giles *et al.* 2005, Appendix 3). This became an invaluable resource to the ‘status of sawfish’ objective.

The expanding IUU fishing effort in the north, especially the component targeting shark fins, has highlighted the need for accurate species composition data from the Australian fishery in order to compare with known IUU catch composition. Fins confiscated from apprehended foreign fishing vessels (FFVs) provide a means of identifying the shark species caught (*AFMA Fin Identification - Methods* project currently underway). At a minimum, we need as much species information as possible from the Australian catch, via observers, to at least be able to compare species compositions between the illegal foreign shark catch and the licensed Australian shark fisheries.

1.3 Benefits

Proposal FLOW OF BENEFITS TABLE:

Fishery (including aquaculture) Managed by:	Commercial Sector	Recreational Sector	Traditional Fishing (by Aboriginal & Torres Strait Islander people) Sector
NSW	0	0	**0**
NT	15	0	**0**
Qld	45	0	**0**
WA	25	0	**0**
Australian Fisheries Management Authority			
AFMA - Northern Prawn	15	0	**0**
Total	**100**	**0**	**0**

Summary Flow of Benefits	
Sub Total Commercial Sector	**100**
Sub Total Recreational Sector	**0**
Sub Total Traditional Fishing Sector	**0**
Summary Flow of Benefits	**100**

The original proposal nominated the project benefits flowing 25% to the WA commercial sector, compared to 15% to the NT commercial sector. This was based on the extensive shark fisheries and bycatch of sharks in northern WA (fish trawl, long line and gillnet fisheries). WA has substantially reduced effort in 2005 with the benefit possibly shifting up 5% to 20% for NT and WA benefit at 20%. Although not part of the study, the Western Tuna and Billfish Fishery (long line) provided some tissue samples for this and other projects and the updated risk assessments may have an indirect benefit for that fishery.

Well managed shark target and bycatch fisheries have increased value due to the high price of fins. Managing effort to sustainable levels of exploitation ensures that Australian fishers can continue to take advantage of the legal fin trade, without resorting to ‘gold rush’ exploitation rates or targeting of vulnerable, large species such as shark rays and sawfish. Close scrutiny of catches and the gear selectivity through improved logbook data can provide positive feedback to managers that should ensure Australian fishers have a viable shark fishery in the future, assuming that IUU fishing does not overwhelm any local benefit from well managed shark fisheries.

1.4 Further Development

There appears to be a lack of precision and transparency in reporting of non-flesh product from sharks in both target and bycatch fisheries. Recognition of this weakness in shark catch information by the Shark Assessment Group has led to the recommendation that each fishery taking sharks must aim to report to species (at least for the most common species), regardless of jurisdiction, in order to improve the stock assessments for sharks. Similarly, the true value of the shark fishery can only be enhanced by full reporting of shark flesh and fins landings. Fin convertion ratios vary from 3% for whole weight, 6.5 % for trunk and 13% for fillets (without skin). However, scientific measurements of fin conversion made in the field during this project reveal much lower fin ratios of at least half the currently accepted figures. Although unmarketable trunks may increase these ratios, small quantities of unretained trunks should not affect the ratio to a large extent. The current ratios are therefore likely to allow for significantly higher landings of fins relative to the landings of flesh or trunks.

Ongoing observer assistance to fishers needed to deliver accurate reporting.

The World Trade Organisation (WTO) requirements for shark fisheries are; i) by June 2005 conduct an assessment of the observer coverage needs sufficient to meet sustainability objectives for the fishery and ii) develop a scientifically robust program for implementation from 2006. The accepted observer coverage from NSAG was around 7%, which was largely what the project observer coverage achieved. Although shark logbooks have been improved to incorporate daily (NT) catch records and more detailed species breakdowns, the nature of the fishery requires dedicated monitoring to verify logbook records and landings at the wharf.

The states/territory agencies have agreed to engage dedicated observers for this task; the fishery management (Federal or state/territory) must co-invest to ensure the observers are effective throughout the shark fishery season. At the Northern Shark Assessment Group (NSAG) meeting in April 2005, this commitment to ongoing observer work was supported by NSAG.

Ongoing need to improve species ID in logbooks:

The improvement in logbook records adopted by each jurisdiction will need ongoing observer training and liaison to educate shark fishers in identifying and recording shark species. In the NT, this is recognised as a big problem that can be addressed by delivering skills to the deck-hands who do the gutting, finning, trunking and assign classifications to the catch, rather than to the skippers!

Similarly, Queensland has a commitment to improving shark identification as recorded in log books via their N3/N9 observer.

Verification of shark flesh and fin landings

<u>Port-based observer monitoring of catch landings</u> – this was addressed in the FRDC proposal (unsuccessful) "*Assessing fishing impacts on vulnerable northern Australian Sharks and Rays: adopting long-term research monitoring protocols for high risk species*". The management of the shark fishery would be enhanced with improved accuracy of the catch statistics. This catch verification initiative would add robustness to the current source of catch information via the obligatory logbook system. Appropriate incentives would need to be introduced as a way of gaining fisher cooperation with the landings verification.

Realistic estimate of shark product value –

Ambiguity and uncertainty of true fin landings from target shark fisheries. Latest figures for shark fin landings appear unrealistic compared to the quantity of shark landed and the demand for fin. There appears to be differing fin product reporting between jurisdictions. The above recommendation would be a step in the right direction of removing the uncertainty of product value in each jurisdiction.

Unsatisfactory reporting of shark product from non-target fisheries, eg barramundi fisheries. There needs to be a mechanism to allow verification of the low reporting of shark product in all ‘bycatch’ fisheries. NT has taken steps to address the shark bycatch in the barramundi fishery (see Chapter 4) and similar initiatives may need to be considered in WA and Queensland barramundi and the NPF, long line and fish trawl fisheries.

Close monitoring of catches and of the gear selectivity can provide positive feedback to managers that should ensure that Australian fishers have a viable shark fishery in the future, assuming IUU fishing does not overwhelm the Australian fishery (see below).

Foreign Fishing Vessel (FFV) effort

This issue has expanded in direct proportion to the value of fins. At the start of this project, there was a known, but increasing level of illegal foreign fishing in northern Australian waters. Initially, most of this effort was directed at sharks by largely artisanal Indonesian effort around the MOU box and across the Arafura coastline. Coastwatch sighting records clearly show this spatial distribution for years 2000 and 2001. By 2002, the coastwatch records clearly document a dramatic shift in sightings of ‘shark’ vessels across the north, with effort apparently shifting eastward. By 2004 the FFV sightings increased dramatically and the majority of FFVs were larger ‘type 3’ shark boats, accepting that coastwatch flights were targeting high activity coastal areas more than other less prductive areas within the Australian Fishing Zone (AFZ). More disconcerting for quarantine and fishery managers, fishers and researchers, is the shift in FFV effort (directed at sharks and reef fish) geographically eastwards and southwards well in to the coastal regions of the Gulf of Carpentaria.

Quantifying the extent of the FFV effort and catch is the subject of a current AFMA/Coastwatch project.

1.5 Planned Outcomes

Proposal Planned Outcomes:
Improved stock assessment data for the primary target species of northern shark fisheries due to improved identification of the species caught, information from fisheries that take these species as bycatch and an understanding of the extent to which stocks are shared across the jurisdictions. This will provide managers with an improved estimate of the sustainable exploitation levels, on which to base management decisions. As this will be collaborative across the States/Territory it will assist managers in ensuring management is complementary across jurisdictions where necessary for shared stocks.

The benefits of engaging three observers (WA, NT and Queensland) are that it has facilitated the introduction of more detailed logbooks in NT and Queensland. These new logbooks incorporate more detailed species identifications, although there are limitations in identifications where deckhands do not have the training that has been delivered to some skippers. In the NT shark fishery, the shark species information will improve over time and is not expected to happen in a couple of seasons; rather, it can only benefit from continued liaison with fishery observers. Unfortunately, observer support was planned as an on-going component of the next FRDC Shark project, "*Assessing fishing impacts on vulnerable northern Australian Sharks and Rays: adopting long-term research monitoring protocols for high risk species*" but the proposal was unsuccessful.

The understanding that *C. sorrah* forms genetically separate stocks between Australia and Indonesia is a valuable contribution to future regional stock assessments for blacktip sharks. Similarly, a lack of genetic discrimination across the north for both *C. sorrah* and *C. tilstoni* suggests that these species can be treated as a single stock across jurisdictions within Australian waters.

The project has highlighted the inter-connectivity of the geographic regions, regardless of the independent jurisdictional controls and management strategies. The Northern Shark Assessment Group (NSAG), consisting of the project collaborators and jurisdictional managers, has been instrumental in paving the way for cross-jurisdictional uniformity in shark log books. NT has introduced their new log books in July 2005 (David McKey, NT Fisheries Aquatic Resource Manager, at project Risk Assessment Workshop March 2006), while Queensland is in the process of introducing a similar logbook that will allow more detailed species breakdowns to be made from the data. To assist with this process, there has also been a commitment to provide ongoing observer support in the N3 fishery, which will allow verification of species composition. Details of these logbook improvements are presented in Chapters 2 and 4.

Improved management of the effect of all northern Australian fishing activities on elasmobranchs. This project will provide a risk assessment of northern elasmobranchs that will identify the species that management and research should focus on, due to their level of risk.

Chapter 6 presents the results of the project Risk Assessment, based on the additional biological and fishery catch data collected during the project. The 14 species clearly identified to be at elevated risk are: sawfishes (*Pristis clavata, P. microdon, P. zijsron),* giant shovelnose ray (*Rhinobatos typus),* shark ray (*Rhina ancylostoma*), speartooth sharks (*Glyphis* sp. A, *Glyphis* sp. C), the great hammerhead (*Sphyrna mokarran),* the lemon shark (*Negaprion acutidens),* Pig eye (*Carcharhinus amboinensis*) and three whaler species (*C. brevipinna, C. leucas, C. limbatus).*

In Queensland, project collaborators have used project data on shark biology and catch/effort observer data to produce two substantial reports on the status of sharks in the Gulf of Carpentaria N3 and N9 fisheries and the East Coast finfish gillnet fishery (see Chapter 2 and Appendix 3). These reports were important contributions to the Ecological Risk Assessment of Queensland-managed Fisheries in the Gulf of Carpentaria (Zeller and Snape, 2006).

Alignment of the management practices of northern Australian shark fisheries with the National Plan of Action for the Conservation and Management of Sharks.

All 10 objectives of the NPOA Sharks (italics below) have been addressed either during, or as a consequence of, the project.

Sustainable Harvest of Sharks & Threats to Sharks (NPOA objectives i & ii)

Sustainable fishing has been a high priority for each state/territory and the project has facilitated this awareness to the extent that WA and NT have produced significant changes to the targeted fishing effort, most notably, the reduction in fishing area in north western Australia, the removal of ‘latent’ effort (inactive licences) and restricting long line effort to a single licence equivalent in NT.

To improve recording of shark bycatch from the NT barramundi fishery, an allowable take of 500kg shark per trip exists for the 24 barramundi licences.

The NT Offshore Net and Line fishery, NTONL (formerly the NT Fishery Joint Authority, NTFJA, see Tables 4.2.3, 4.2.5, 4.2.7 for a full list of fishery acronyms) shark fishers elected to adopt a live release of sawfish where possible in recognition of their vulnerability to gillnets.

In WA, legislation has been introduced to make the take of all sawfish illegal, although this status for *Anoxypristis cuspidata* may be subject to review in light of its abundance.

Each jurisdiction (WA, NT, Qld) require landings of fins to conform with a realistic fin/flesh ratio. This measure aims to reduce the incentive to catch as many sharks as possible to increase the fin catch regardless of the fate of the shark flesh.

Special Attention to vulnerable or threatened species (NPOA Objective iii)

WA Fisheries has recently introduced a ban on taking all Pristids (sawfishes) and dusky sharks (*C. obscurus*), in response to their recognised high risk of fishing mortality (as illustrated by the project risk assessment in Chapter 6).

NT shark fishers have introduced a Code of Practice that encourages the release of live sawfish from gillnets, where possible.

QDPI Fisheries has engaged commercial shark fishers in the Gulf of Carpentaria to educate them in the need to release live sawfish from gillnets and have published an extensive departmental leaflet on methods of releasing them (Appendix 3, *Sawfish Release Procedures*).

Improved consultation between all stakeholders (NPOA iv)

The project held annual shark fisher workshops in NT and Queensland, facilitated by project collaborators and the relevant observers. In WA, this direct contact and interaction with shark fishers was achieved through regular observer contact with licensed shark fishers instead of a workshop gathering. Such consultation was a direct cause of the industry cooperation in addressing negative impacts on the shark stocks in each jurisdiction.

Minimise unutilised incidental catch of sharks (NPOA v)

The NT Fisheries management has introduced a maximum take of shark of 500kg per trip from the NT barramundi gillnet fishery. This provides some scope for the retention of incidentally caught sharks during the barramundi season. The secondary benefit is that it provides a measure of the shark bycatch in that fishery. Queensland N3 (Gulf of Carpentaria inshore gillnet fishery) has no regulatory restriction on shark bycatch, although a 'per trip' limit fashioned on the NT proposal is under consideration. The fisher Code of Practice aimed at releasing live sawfish is a positive step towards minimising the incidental catch of these vulnerable sharks (above as *NPOA Sharks iii*).

To minimise waste and discards from shark catches (NPOA vii)

This has been addressed in part by the statutory authorities' obligation that fishers are required to account for fins with the correct fin/flesh ratios (NT, Queensland) or, more stringently, requiring the landing of fins with the trunk (WA).

Controls on landings of shark fins have been tightened by management decisions (e.g. fins landed as % of flesh) as wells as a voluntary code of conduct by the NT shark fishers that encourages live release of sawfish. In the NT, shark fishers complete a monthly landings sheet that allows a cross-check on the fins to flesh ratios landed at the wharf. The proposal to allow 500kg of shark per trip from the barramundi fishery is intended to allow some retention of dead sharks, rather than oblige fishers to discard them.

Encourage full use of dead sharks (NPOA viii)

Fishers in the NT and Queensland N3 with dual entitlements (Crab and Bait licences) utilise low value shark meat as crab bait, although the shark used as bait is not formally recorded in the log books.

Facilitate improved species specific catch data and monitoring shark catches (NPOA ix)

As noted above, the observers in this project provided crew training in species identification both on board vessels and at fisher workshop, held each year. The commitment by all jurisdictions to upgrade shark logbooks to incorporate species identifications has been facilitated by the project. Each jurisdiction now has a commitment to support observers in the fisheries that take sharks as part of the need for improved species specific catch data via the upgraded log books.

Facilitate identification and reporting of species specific biological and trade data (NPOA x)

Although not directly addressed by this project, a related project is currently underway to develop appropriate DNA identification procedures for dried shark fins from the IUU apprehensions in the north. WA collaborators on this project also successfully completed a similar project that identifies shark body parts from nine WA species (FRDC2003/067).

Effective management and conservation of northern sawfishes. This project will provide an evaluation of the status of sawfish populations that can form the basis of effective management of these species.

The results of Objective 4 have, indirectly, already led to WA totally protecting all sawfish (Fish Resources Management Amendment Regulations (No. 7) 2005, Western Australian Government Gazette No. 241, 22 December 2005). The sawfish publications by Peverell (2005) and the draft on age determinations and age/growth parameters for the four sawfish species (Peverell in prep.), have been used extensively in the "*Description of Key Species Groups in the Northern Planning Area – chapter 8*" produced for the National Oceans Office, and in a CSIRO report to DEH on the "Conservation assessment of *Glyphis* sp. A (speartooth shark), *Glyphis* sp. C (northern river shark), *Pristis microdon* (freshwater sawfish) and *Pristis zijsron* (green sawfish)" (Stevens *et al.* 2005, Appendix 3).

Increased industry awareness of the issues regarding northern elasmobranchs and the need for accurate data on their catch rates.

The increased industry awareness has been noted by all collaborators (WA, NT and Queensland) and is a direct consequence of the observer time on board vessels and the fisher workshops held annually. In the NT in particular, the close link between shark fishers, their industry peak body and fishery managers has been the driving force behind their adoption of an industry Code of Conduct, a Code of Practice and an Environmental Management System for the Offshore Net and Line Fishery. In Queensland, the ready cooperation with access for observers to shark vessels by Seafresh Seafoods has been a clear reflection of the understanding of the benefit of project research to the long-term sustainability of the shark fishery.

For fisheries that export their product, recognition within the EA assessment guidelines of their actions taken to improve elasmobranch stock assessment and address elasmobranch bycatch issues.

Improving Catch and Effort Information

All the logbook improvements (species identification, set by set records in NT, move from monthly to daily records) by each jurisdiction is in part a response to the need to provide fishery information that will contribute to future stock assessments for the shark species harvested by those fisheries.

The shark fishery commitment to maintaining observers beyond this project in Queensland and NT is in recognition of the actions required to improve future stock assessments. This includes observer coverage for the N3 (barramundi) fishery in Queensland, which is a shark bycatch fishery.

In the Queensland N9 fishery, there is an ongoing VMS programme that monitors fishing activity (and hence, effort).

A monthly product report by fishers (quantity, value, species groups, who the buyer is, see Appendix 3, *NT Shark Fishery Monthly Summary*) and by Traders/Processors allows for a degree of cross-validation of the NT shark catch.

Containing and Managing Fishing Effort

The recognition by NT shark fishers that fishing impacts on vulnerable species such as sawfishes, needs to be reduced. This is exemplified by their Code of Practice that requires release of live sawfishes where possible (see *NT Shark Fishery Daily Log Sheet* in Appendix 3).

The reduction of effort in WA by area closures in the north acknowledges the vulnerability of some shark species to over-fishing (details in Chapter 2).

The reduction of effort in NT by changing the long line effort back to the equivalent of one long line vessel and the removal of latent effort by reducing licences from 19 to 12.

Industry marketing for non-fin shark product has been stimulated, as have development of a Code of Conduct, a Code of Practice and an Environmental Management System for the Offshore Net and Line Fishery (NTONLF). These are all now in place in the NT fishery.

Some issues remain with reporting of shark catch from bycatch fisheries such as the coastal barramundi fisheries. In the NT, the reported proportion of the total shark catch from ‘bycatch’ fisheries, Barra and Crab Bait netters, is less than 1%, compared to around 15% for the N3 fishery in Queensland. Of the NT Barr and Crab Bait Net fisheries, 60% comes from Bait netters. NT recognises the problem of reporting shark catch from the Bait netters and is moving to remove (or change) this category of licence. The role of crab bait gillnets needs to be resolved to ensure better use of sharks caught by the target and bycatch fisheries (mainly NT barramundi fishery).

In WA there is still a major component of shark catch that comes from ‘bycatch’ shark fisheries, e.g. WAKGBF, WAPFTF, etc. (see details in Chapter 4, Table 4.2.1) and some of this has still not been addressed by the recent changes that reduced the shark gillnet fishery area.

1.6 Conclusion

1. Establishment of long-term collection of catch composition data from target shark fisheries in northern Australia (NT Joint Authority Shark Fishery, NT Coastal Net Fishery, Qld Joint Authority Shark Fishery, Qld N9 Shark Fishery, WA Joint Authority Shark Fishery, WA North Coast Shark Fishery, Qld East Coast Net Fishery), in order to improve stock assessments.

Ongoing observers have been established or will be established in these fisheries beyond the completion date of this project. After the project observers ended their work, the NSAG and jurisdictional managers agreed to initiate long-term observer commitments by all northern shark fishery jurisdictions. This is now an obligation for WA, NT and Queensland and has largely been met or will be met in each case. WA achieves this objective by ongoing contact with shark fishers through research projects. In Queensland, there is a funded observer position to address the coastal net fisheries. The Queensland East Coast Net Fishery is more complex than the equivalent Gulf of Carpentaria fisheries because the number of licensed fishers is large compared to the Gulf of Carpentaria shark licenses. In addition, there has been a difficult relationship between the Great Barrier Reef Marine Park Authority (GBRMPA) and net fishers who have been excluded from GBR protected areas and this has impacted on the amount of East Coast shark observer boat time (and hence, samples) from this region. Conversion ratios for fin-to-trunk/flesh ratios are used to verify landed fins, although some questions remain about the validity of the ratio values currently used.

2. To determine the appropriate management scale for the target species of northern Australian shark fisheries, by examining the degree to which stocks are shared across northern Australia and with Indonesia.

The project results for the population genetics study of *C. sorrah* and *C. tilstoni* across the north and Indonesia (*C. sorrah*) clearly showed that both species mix readily over large geographic ranges. *Carcharhinus sorrah* from Indonesia were genetically separate from the Australian populations, while there was no differentiation among the Australian samples across the north. However, due to the presence of a third indistinguishable blacktip species, *C. limbatus* that is indistinguishable from *C. tilstoni*, this phenotype (*C. limbatus/tilstoni*) must be treated as forming separate stocks between WA, NT (GoC) and Qld (East coast). This population structure will clarify the management scale for these species, especially in the light of increased fishing pressure from both legal and illegal fishing.

3. To evaluate the effect of gillnet fishing on northern chondrichthyans, by determining bycatch composition (Qld N3 Net Fishery, Qld East Coast Gillnet Fishery, NT Barramundi Fishery, WA Kimberley Gillnet and Barramundi Fishery).

The project data clearly shows a significant impact on shark resources from bycatch fisheries, where reasonable observer data was collected. The limitation of this outcome is that for some bycatch fisheries, there was insufficient species composition data collected, but where it was collected, it shows that the current catch records (from logbooks) do not reveal the extent of shark bycatch as recorded by observers.

4. To derive estimates of biological parameters to assess the status of sawfish populations; age structure, reproduction and growth.

The Master's Thesis (Peverell, submitted JCU) and manuscript on age and growth have produced the first estimates of age at size, size at first maturity and reproductive status for all four species. The best information is for the most common species (*Anoxypristis cuspidata*), while there is considerably less information for *Pristis clavata*, *P. microdon* and *P. zijsron*. The lack of large specimens in some species has lead to reduced samples across the size ranges for both age at size and size at reproductive stages.

5. To re-evaluate the risk assessment of northern chondrichthyans (undertaken in the EA project), based on the new information collected above. This risk assessment will be compatible with the one undertaken in application FRDC 2002/033 (PI Terry Walker) in line with the NPOA-Shark priority for a national approach to risk assessment for chondrichthyans.

In consultation with shark experts both collaborators and fishery managers, the updated risk was evaluated on a per fishery basis and a cumulative Risk Assessment over all fisheries. This revealed 14 high risk species with susceptibility to fishing gear and low productivity the major factor contributing to their 'high risk' status. These included sawfishes (*Pristis clavata, P. microdon, P. zijsron)*, giant shovelnose ray (*Rhinobatos typus)*, shark ray (*Rhina ancylostoma*), speartooth sharks (*Glyphis* sp. A, *Glyphis* sp. C), the great hammerhead (*Sphyrna mokarran)*, the lemon shark (*Negaprion acutidens)*, Pig eye (*Carcharhinus amboinensis*) and three whaler species (*C. brevipinna, C. leucas, C. limbatus).*

1.7 Acknowledgments

We wish to make the following acknowledgements:

CMAR appropriation support of $16K to extend a graduate casual position that produced the sawfish desktop study (Appendix 3).

NOO funding (QDPI/CMAR) for sawfish acoustic tracking field work at Mapoon.

DEH funding for Conservation Assessment of Sawfish and Speartooth sharks, including trip to Adelaide River.

Australian Geographic for support to acoustically track sawfish (*P. microdon*) in Daly River as part of the September 2004 Scientific Expedition.

Queensland Fisheries Service (QFS) for N9 shark fishery data (Malcolm Dunning, Mark Doohan, Jason Stapely).

Seafresh Seafoods (Rob Lowden) for generous assistance with allowing observers on company shark vessels and support for the project goals.

All shark fishers who made the effort to attend project workshops and who cooperated by allowing project observers on their fishing boats.

Jenny Giles for her diligent work on the Sawfish Desktop Study (FRDC and CMAR funds).

Toni Cannard expertly formatting and finalising the report.

1.8 Staff

Name	Position	Qualifications	Time
1. Ilona Stobutzki/Steve Blaber	Subprogram Leader	PhD	**20**
2. John Stevens	Principal Research Scientist	PhD	**10**
3. John Salini	Scientist	MSc	**40**
4. Neil Gribble	Senior Fisheries Biologist	PhD	**10**
5. Jenny Ovenden	Research Scientist	PhD	**15**
6. Stirling Peverell	Fisheries Biologist	BSc	**100**
7. Geoff McPherson	Senior Fisheries Biologist	BSc	**10**
8. Rik Buckworth	Senior Fisheries Biologist	PhD	**10**
9. Rod Lenanton	Supervising Scientist – finfish	PhD	**5**
10. Richard Pillans	CSIRO Technician	BSc	**100**
11. see below	NT Observer	BSc	**100**
12. Justin Chidlow	WA Observer	BSc	**100**
13. Terence Walker	Program Leader, Modelling & Data Management	BSc	**5**

1.8.1 Observers:

WA:
Justin Chidlow was funded as the observer in WA.

NT:
Alex Beatty July2002 – March 2003
Nathan Crofts September 2003 – September 2004
Chris Tarca October 2004 – June 2005

Qld:
Stirling Peverell carried over from the one-year phase 1 observer trial.

1.8.2 Other changes during the project:

WA:
Rory McAuley ran the WA observing and coordinating components of the project and attended most meetings (see Annual Project Meetings minutes).

CMR/CMAR:
Mr Richard Pillans appointed as Biological Technician November 2002.

The Principal Investigator, Dr. Ilona Stobutzki resigned from CMAR in November 2002 to take a research position with Worldfish Centre in Penang, Malaysia. She is currently with BRS, Canberra.

John Salini assumed the day-to-day project coordination as Project Leader, November 2002, following Ilona’s departure.

Dr Steve Blaber replaced Dr. Stobutzki as PI, with FRDC approval, December 2002.

John Salini replaced Steve Blaber as PI, with FRDC approval, February 2006.

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2. CHAPTER 2 – OBJECTIVE 1 CATCH DATA FROM TARGET SHARK FISHERIES

Prepared by John Salini and Richard Pillans

Objective 1 *Establishment of long-term collection of catch composition data from target shark fisheries in northern Australia (NT Joint Authority Shark Fishery, NT Coastal Net Fishery, Qld Joint Authority Shark Fishery, Qld N9 Shark Fishery, WA Joint Authority Shark Fishery, WA North Coast Shark Fishery, Qld East Coast Net Fishery), in order to improve stock assessments.*

2.1 Introduction

This work extends the observer work established in the phase 1 project whereby project observers on board shark vessels identified sharks and provided training to the crew. The fisher workshops are planned annually to reinforce the need for accurate catch composition and effort data, as well as to highlight the issues of 'at risk' species in need of special care. In most cases, the observer data provides the only accurate window on the species composition of the commercial shark catch. Another aspect addressed by this project observer work is the use of agreed field data sheets so that biological and catch data can be shared and compared across jurisdictions, as well as between the northern and southern shark fisheries. The longer term aim is to provide the training that will allow the observer (or their replacements) in each jurisdiction to continue fishery observer data collection beyond the life of this project.

2.2 Method

In Phase 1, workshops with industry were held in NT, Qld and WA (October – December 2001). These were designed to involve local shark fishers, fishery managers and other stakeholders. These enabled the fishers, managers and others to raise issues regarding the fisheries and contribute to the development of Phase 2. We successfully sought funding to continue these workshops in Phase 2, with the focus on continued discussion with fishers on:- i) Continued improvement of species identification and quantification of shark taken; ii) consistency and accuracy of data collection and reporting of shark catches; iii) fisher issues with shark assessment and management; iv) results from the pilot observer program undertaken in Phase 1 and the progress in Phase 2.

These workshops and direct discussions with managers will continue to increase the accuracy of data supplied by the fisheries, enhancing the sustainable management of their fisheries. In conjunction with FRDC Project Proposal 2002/033 (PI Terry Walker) we developed, as far as possible, a common data sheet for each species, so that the minimum data collected is the same in both regions.

2.3 Results

Name changes to target shark fisheries
Since the start of this project, some of the fisheries have undergone significant management changes including name changes. The Target Shark fisheries are now referred to as the following:

Region	Original name	Current name	Comment
WA remains same	WANCSF	WANCSF	Target sharks
Qld N9 Gillnet	N9	N9	Target sharks

Qld Joint Authority, beyond N9 25nm	QJASF	N9 (in this report)	Target sharks
NT Joint Authority Gillnet & Longline	NTJASF	NTONLF	Includes grey mackerel

Observer Program

The establishment of shark fishery observers in WA, NT and Queensland was undertaken slightly differently in each jurisdiction. WA Fisheries were able to incorporate an existing shark researcher (Justin Chidlow) for the duration of the observing schedule, as was the case in Qld Fisheries where the project phase 1 observer continued in that role (Stirling Peverell). Keeping an observer in the shark fishery in NT was more challenging with three observers filling the role (Alex Beatty, Nathan Crofts and Chris Tarca). Between Alex and Nathan, there was a period of four months with no observer active in the role. Overall, this led to a reduced level of catch/effort and biological data collection, although the observer role was extended well beyond the original schedule to provide more data before the project completion date.

To help clarify the use of common names across jurisdictions, the Table 2.3.1 lists the current common names used by each authority.

Table 2.3-1: Categories of Chondrichthyans recorded in logbooks in Qld, NT and WA-

Qld	NT	WA
Ray – Sting Unspecified	Black tip (*C. tilstoni and C. limbatus*)	Sandbar shark (*C. plumbeus*)
Shark - Shovelnose Unspecified	Tiger shark (*G. cuvier*)	Lemon shark (*N. acutidens*)
Sawfish - Unspecified	Spot tail shark (*C. sorrah*)	Tiger shark (*G. cuvier*)
Shark - Unspecified	Great hammerhead (*S. mokarran*)	Blacktip shark (Carcharhinus spp.)
Shark - Whaler Unspecified	Hammerhead (all others)	Hammerhead shark (Sphyrnidae)
Shark - Hammerhead	Milk shark (*R. acutus*)	Pigeye shark (*C. amboinensis*)
Shark - Spot Tail (*C. sorrah*)	Pigeye shark (*C. amboinensis*)	Bull shark (*C. leucas*)
Shark - Black Tip Reef (*C. amblyrhynchos*)	Grey reef shark (*C. amblyrhynchoides*)	Bronze whaler (*C. obscurus*)
Shark - Eastern Shovelnose (*R. australiae*)	Lemon shark (*N. acutidens*)	Shovelnose/fiddler rays (Rhinobatidae, Rhynchobatidae)
Sawfish – Green (*P. zijsron*)	Narrow sawfish (*A. cuspidata*)	Other sharks/rays
	Dwarf sawfish (*P. clavata*)	
	Freshwater sawfish (*P. microdon*)	
	Glyphis species	

The common Field Data sheet agreed on at the project startup meeting was adopted and formed the basis of data collection by the observers. The data sheet format is shown in Table 2.3-2, Table 2.3-3 and Table 2.3-4 which show the parameters recorded, where possible.

In general, the best industry cooperation came from larger scale operators, e.g. long line vessel (FV *Thor*), gillnetters run by major operator (Rob Lowden *Seafresh Seafoods,* Cairns), some NT shark gillnetters. This was partly due to the logistics of accommodating a scientific observer on many commercial boats. However, there was considerable difficulty in obtaining cooperation from Queensland East Coast shark fishers in regard to fisheries observers. In Queensland, collaboration with the project by fishers is entirely voluntary and the observers are invited onto cooperating vessels. Phase I of the project set-up potential collaborations through a pilot study and workshop, but since then there has been a number of political developments outside the control of the investigators. There always had been a 'difficult' relationship between net fishers and the Great Barrier Reef Marine Park Authority. An example was that at the Phase I workshop, the shark fishers voted to ask the GBRMPA representative to leave the meeting. The subsequent imposition of an unpopular system of closed Marine Representative Areas has meant that fishers have become highly distrustful and have not been willing to assist any "Government Agency", even if unconnected with the GBRMPA.

The GBRMPA Marine Representative Area consultative process has created considerable anger in the East Coast fisheries over the last three years and our relationship with the fishing industry has suffered as a result. An extreme example was the stoning of the QDPI vehicles in the compound of the Northern Fisheries Centre at the height of the controversy over Marine Representative Areas. Data on shark catch and bycatch in Queensland was supplemented by fishery independent sampling (using commercial gear) and by buying catches from commercial skippers, but is not as complete as originally hoped.

Observer data per fishery

A summary of all observer data from shark target fisheries is presented in Table 2.3-5 as percent contribution by numbers per fishery and numbers of sharks/rays recorded. Figure 2.3-1 gives a geographic perspective to all the observer data collected across the north of Australia, including both shark target and bycatch fisheries. It also clearly illustrates the contrast between the Australian shark fishery (largely a coastal fishery) and the surveillance records of Foreign Fishing Vessels (FFVs) that take shark. The FFVs are sighted throughout the Gulf of Carpentaria and further offshore. Publicly available Coastwatch records do not discriminate between FFVs actively fishing or FFVs moving between regions, so that FFVs in the middle of the GoC may be in transit.

The observer data presented in Table 2.3-5 illustrates whether a species occurs in specific fisheries or is caught over a wide cross section of fishing gears, for example, nine species (*C. dussumieri*, *C. fitzroyensis*, *C. sorrah*, *C tilstoni*, *E. blochii*, *G. cuvier*, *R. acutus*, *S. lewini* and *S. mokarran*) are caught across the entire north by both gillnets and long lines. Other species, such as the narrow sawfish, *Anoxypristis cuspidata*, are caught in 3 of the 4 target shark fisheries listed. Although not caught in the long line WANCSF fishery, it is present in the more coastal bycatch fisheries in WA (see Chapter 4) where *A. cuspidata* is clearly a major component of the WA EMBGF and KGBF northern gillnet fisheries at 12.5% and 13% respectively.

Some species do not occur in the eastern shark fisheries, such as *C. plumbeus*, but occur in the WANCSF fishery. Conversely, 18 species recorded by observers in both target and bycatch shark fisheries, do not occur in the target shark fisheries, but are listed in Table 2.3-5. Most of these 19 species are rays caught mainly in the NPF as bycatch. Blacktip sharks, *Carcharhinus sorrah* and *C. tilstoni*, are caught in most fisheries and reflect their wide distribution and abundance. Species that utilise estuaries and freshwater, such as *C. leucas*, occur in small numbers in the target shark fisheries, mainly because of the geographic location of these fisheries (coastal and offshore). By comparison, *C. leucas* constitutes a major component of the NT barramundi fishery (34.8% of observed sharks and rays) and 10% of the N3 (barramundi) fishery at the start of the barramundi season largely due to their seasonal abundance (post-pupping) at the start of the barramundi season. Similarly, the Speartooth Shark, *Glyphis* sp.A comprised 24.6% of the observed sharks in the NT barramundi fishery.

Seasonal Observer Effort

A more detailed seasonal breakdown of numbers of shots per month per fishery is presented for each state/territory in Table 2.3-7. Although observer shots were sampled in all months, there are significantly less samples in the monsoon months covering November to February. WA and Queensland managed to obtain samples every month but May, June, August and September proved barren months for the NT observers.

Apart from Catch and Effort data, the observers recorded biological parameters such as Total Length, sex, maturity, reproductive stage, which is essential information for the qualitative risk assessment

(Chapter 6). The average total lengths for all species and all fisheries (shark target and bycatch) is presented in Table 2.3-8.

The biological data recorded by observers is presented in summary graph form as Appendix 4 where all species with sufficient data are plotted as Clasper Length versus Total Length for males and Uterine Stage (stages 1-6) vs. Total Length for females. There are 37 species for which there is sufficient reproductive data. This reproductive data is summed across all fisheries and illustrates the difficulties experienced in collecting information from the rarer species. These measures were used to update biological parameters such as size at birth, size at maturity, maximum size, number of pups, reproductive periodicity and gestation period. These biological parameters were then incorporated into the Risk Assessment (Chapter 6) to reduce the number of unknowns in the productivity parameters.

One of the most important additions to the observer data was obtaining the N9 Shark fishery data though the courtesy of Queensland Fisheries Service. This extensive database, including DNA tissues collections for several species, was facilitated by the QDPF N9 observer, Jason Stapley.

Differences between fisheries

The total lengths recorded by the observers illustrate some differences between fisheries that reflect the gear used, geographic area fished and the habitat. For example, Species such as the guitar ray, *Rhynchobatus australiae*, are differentially caught at a larger size by long lines compared to gillnets (Table 2.3-8). The average size over all fisheries is considerably smaller than in the WANCSF or NTFJA because of the predominance of small specimens caught by the fish trawlers in the PFTF, a shark bycatch fishery. Similarly for the spinner shark, *C. brevipinna* where the WANCSF mean TL = 190cm compared to 102.7cm and 96.8cm in the N9 and NTJFA respectively. The latter fisheries are targeting juvenile spinners with gillnets while the WA fishery targets larger spinners.

In the case of the closely related blacktip species *C. limbatus* and *C. tilstoni*, the larger size of the former is clearly illustrated by the observer data for mean TL in all fisheries (154cm) compared to the smaller mean length for the latter (118cm). One distinguishing feature for these species is that *C. limbatus* becomes sexually mature at a significantly larger size than *C. tilstoni*, which is apparent from the project reproductive graphs in Appendix 4. The plot for male *C. tilstoni* clearly shows some probable mis-identification of *C. tilstoni* where the sharks are larger than the majority for sizes equal to or greater than 200cm TL. The maximum recorded size for *C. tilstoni* is 200cm (Last and Stevens 1994).

Temporal Changes in Catch Composition from 1980s

Research sampling of sharks in the 1980s (Stevens and McLoughlin, 1991; Davenport and Stevens 1986; Stevens and Wiley, 1988) provides a useful comparison of catch composition over about 20 years. The research data in Table 2.3-6 allows a direct comparison with the WANCSF, NTONLF and the N9 (shown in brackets) from this project compared to the catch compositions recorded in the mid-1990s. The main species differences are:

C. tilstoni appears to have declined in proportion of the catch in the N9 and WANCSF fisheries, most significantly in the N9 where they now represent less than half the shark catch. The other blacktip species, *C. sorrah* appeared to be almost the same, with an increase from 10.6% to 18.8% of the catch in WA. The hardnose shark, *C. macloti*, shows a large decline in the NTONLF and WANCSF. The leather skin shark, *C. plumbeus*, is not recorded in NT or Qld fisheries but in WA it showed a dramatic rise in importance and now represents over a third of the catch. Other increases occurred in the N9 fishery for the milk shark, *R. acutus* and the hammerhead group (*S. lewini*, *S. mokarran*, *E. blochii*). The increase in *R. acutus* is partially offset by the decline in *R. taylori*, but as a group, the milk sharks (*R. acutus* and *R. taylori*) increased from 7.5% to 19.0%. The hammerheads (*S. lewini*, *S. mokarran*, *E. blochii*) increased from 1.8% to 15.6%.

The increase in proportion of the catch for larger species such as hammerheads and sandbar remains a concern for their long term sustainability. In fact, the WA government has taken steps to reduce the effort and catch of sandbars.

Table 2.3-2: Observer field data sheet: Information about the fishing Method and each operation.

METHODS	
FIELD	**Description**
LOGID	*Unique identifier for each fishing operation (set, shot, trawl etc)*
STATE	*Qld, NT or WA*
FISHERY_ACRONYM	*Acronym for fishery*
SHOTDATE	*Date*
TIME	*Time*
BOAT	*Boat name*
SKIPPER	*Name of skipper*
RECORDER	*Name of observer*
SHOT_LAT_DD	*Latitude in decimal degrees*
SHOT_LONG_DD	*Longitude in decimal degrees*
DEPTH_M	*Water depth (m)*
MESHSIZE_MM	*Mesh size (mm)*
DROP_MESHES	*Drop of net (number of meshes)*
NETLENGTH_M	*Length of net (m)*
NO_HOOKS	*Number of hooks*
STARTSET_TIME	*Time at start of set*
ENDSET_TIME	*Time at end of set*
STARTHAUL_TIME	*Time at start of haul*
ENDHAUL_TIME	*Time at end of haul*
FISHING_TIME	*Fishing time (half of setting time + half of hauling time + (start – end haul times))*
DAILYSHOTNO	*Shot number on the same date*
WATERTEMP_DEGC	*Water temperature (degrees Celsius)*
COMMENTS	*Comments on sea conditions etc*

Table 2.3-3: Observer field data sheet: Biological information about each species collected.

SPECIES BIOLOGICAL DATA

FIELD	Description
FISHID	*Unique identifier for each individual recorded*
LOGID	*Unique identifier for each fishing operation (set, shot, trawl etc)*
SPECIES_name	*Scientific name*
CAAB_CODE	*CAAB code*
SEX_M_F	*Male or female*
TOT_L_CM	*Total length (cm)*
FORK_L_CM	*Fork length (cm)*
PREC_L_CM	*Precaudal length (cm)*
LJTL_SAWFISH_CM	*Length from lower jaw to tip of tail (lower jaw total length) only for sawfish*
TOT_WT_KG	*Total weight (kg)*
TRUNK_WT_KG	*Trunk weight (kg)*
FIN_WT_KG	*Fin weight (kg)*
FILLET_WT_KG	*Fillet weight (kg)*
UMBIL_SCAR_Y_N_P	*Umbilical scar (yes, no or partial)*
CLASPER_L_CM	*Clasper length (cm)*
CLASPER_DIAM_MM	*Clasper diameter (mm)*
CLASPER_CALC_Y_N_P	*Clasper calcification (yes, no or partially calcified)*
TESTIS_STG_1_3	*Testis stage*
RUN_SPERM_Y_N	*Presence of absence of runny sperm in seminal vesicles*
MAX_OVA_DIAM_MM	*Diameter of largest ova*
NO_YOLKY_OVA	*Number of yolky ova*
UTERINE_STG_1_6	*Uterine stage from 1 to 6*
NO_EMBRYO	*Number of embryo's*
MEAN_EMBRYO_TL_CM	*Mean total length of embryo's*
STMCH_FULL_1_4	*Stomach fullness on a scale of 1 to 4*
STMCH_CONT_ITEM	*Food items found in stomach*
STMCH_CONT_COUNT	*Count of food items in stomach*
RELEASE_CONDIT	*Release condition of animal*
STMCH_SAMP_ID	*Stomach sample identification number*
GENETIC_SAMP_ID	*Genetic sample identification number*
VERT_SAMP_ID	*Vertebral sample identification number*
COMMENTS	*Comments on biology of animal*
UTERUS_WIDTH_CM	*Uterus width (cm)*

Table 2.3-4: Observer field data sheet: Information about Embryos in mature females.

EMBRYO DATA	
FIELD	**Description**
FISHID	*Unique identifier for each individual recorded*
LOGID	*Unique identifier for each fishing operation (set, shot, trawl etc)*
EMB_1_TL	*Length of embryo*
EMB_2_TL	*Length of embryo*
EMB_3_TL	*Length of embryo*
EMB_4_TL	*Length of embryo*
EMB_5_TL	*Length of embryo*
EMB_6_TL	*Length of embryo*
EMB_7_TL	*Length of embryo*
EMB_8_TL	*Length of embryo*
EMB_9_TL	*Length of embryo*
EMB_10_TL	*Length of embryo*
EMB_11_TL	*Length of embryo*
EMB_12_TL	*Length of embryo*
EMB_13_TL	*Length of embryo*
EMB_14_TL	*Length of embryo*
EMB_15_TL	*Length of embryo*
NO_MALE	*Number of males*
NO_FEMALE	*Number of females*

Table 2.3-5: Summary of all observer data from shark target fisheries as percent contribution by numbers per fishery. N9= Queensland Gulf of Carpentaria fishery from 7 nautical miles out to 25 nautical miles plus the old QFJA (Queensland Fishery Joint Authority); NTONLF= Northern Territory Offshore Net and Line Fishery (sharks and grey mackerel), WANCSF= WA North Coast Shark Fishery. The shark bycatch fisheries are listed in Chapter 4 of this report.

Species/Fishery	N9	NTONLF	WANCSF
Total elasmobranchs	**2864**	**3689**	**3924**
Number of shots observed	**100**	**46**	**108**
Aetobatus narinari			
Aetomylaeus nichofii			
Anoxypristis cuspidata	1.9	0.2	
Brachaeluridae - undifferentiated			
Carcharhinus albimarginatus			0.8
Carcharhinus altimus			0.1
Carcharhinus amblyrhynchoides	0.5	0.8	
Carcharhinus amblyrhynchos	< 0.1	0.6	2.2
Carcharhinus amboinensis	0.6	1.5	3.5
Carcharhinus brevipinna	0.4	0.5	0.4
Carcharhinus cautus	0.2	0.1	
Carcharhinus dussumieri	1.5	0.6	0.1
Carcharhinus fitzroyensis	0.6	0.5	0.1
Carcharhinus leucas	0.4	0.2	
Carcharhinus limbatus	1.3	0.1	
Carcharhinus macloti	1.8		0.3
Carcharhinus melanopterus	< 0.1	< 0.1	< 0.1
Carcharhinus obscurus			1.8
Carcharhinus plumbeus			34.4
Carcharhinus sorrah	28.9	18.4	18.8
Carcharhinus tilstoni	25.4	63.4	10.9
Carcharias taurus			0.1
Chiloscyllium punctatum			
Dasyatidae – undifferentiated			0.4
Dasyatis annotata			
Dasyatis kuhlii			
Dasyatis leylandi			
Eucrossorhinus dasypogon			
Eusphyra blochii	5.9	2.9	0.3
Galeocerdo cuvier	0.2	1.7	7.4
Glyphis sp. A			
Glyphis sp. C		0.2	
Gymnura australis			
Hemigaleus australiensis	0.1	< 0.1	
Hemipristis elongata	0.5	0.4	
Himantura toshi			
Himantura uarnak			
Himantura undulata			
Loxodon macrorhinus			0.8
Manta birostris	< 0.1	< 0.1	
Mobula eregoodootenkee		0.2	
Mustelus sp. B			< 0.1
Nebrius ferrugineus		1.2	0.5
Negaprion acutidens	< 0.1	0.8	3.5

Species/Fishery	**N9**	**NTONLF**	**WANCSF**
Orectolobus wardi			
Pastinachus sephen			
Pristis clavata			
Pristis zijsron		< 0.1	
Rhina ancylostoma			
Rhinobatidae – undifferentiated			0.2
Rhinobatus typus		< 0.1	
Rhinoptera neglecta	0.1		
Rhizoprionodon acutus	18.7	1.8	7.8
Rhizoprionodon oligolinx			
Rhizoprionodon taylori	0.3	0.1	0.4
Rhynchobatus australiae	< 0.1	0.1	0.7
Sphyrna lewini	7.6	2.9	2.0
Sphyrna mokarran	2.1	1.1	2.0
Sphyrna zygaena			< 0.1
Stegostoma fasciatum		< 0.1	0.3
Taeniura meyeni			
Triaenodon obesus			0.1

Table 2.3-6: Most abundant species as a percentage of numbers recorded in research surveys by Stevens *et al.* (1990) during the 1980s. Eastern GoC approximates to the current N9 Queensland Gulf of Carpentaria fishery from 7 nautical miles out to 25 nautical miles, plus the joint authority beyond 25nm. NT Inshore corresponds with the Northern Territory Offshore Net and Line Fishery (sharks and grey mackerel), Western Australia = WA North Coast Shark Fishery. The shark bycatch fisheries are listed in Chapter 4 of this report. Figures in brackets are the current values taken from Table 2.3-5.

Species	Queensland East Coast	Eastern GoC	Western GoC	NT Inshore	NT offshore	Western Australia
Carcharhinus tilstoni	69.8	60.7 (25.4)	73.5	56.8 (63.4)	23.6	35.4 (10.9)
Carcharhinus sorrah	14.5	25.2 (28.9)	23.6	22.3 (18.4)	6.6	10.6 (18.8)
Carcharhinus macloti	8.8	2.2 (1.8)	0.7	13.8 (0)	64.2	36.2 (0.3)
Carcharhinus amblyrhynchoides		0 (0.5)	0.8	1.2 (0.8)		6.5 (0.0)
Carcharhinus fitzroyensis	0.1	0 (0.6)	0.2	0.6 (0.5)		1 (0.1)
Carcharhinus amboinensis	0.8	0.6 (0.6)		0.4 (1.5)		1.7 (3.5)
Carcharhinus limbatus	0.8	0 (1.3)				
Carcharhinus melanopterus				0.1(0.1)		
Carcharhinus amblyrhynchos			0.1			0 (2.2)
Carcharhinus brevipinna		1.5 (0.4)	0.2	0.3 (0.5)	0.9	0.6 (0.4)
Carcharhinus dussumieri		0.6 (1.5)		0.3 (0.6)		0.3 (0.1)
Carcharhinus plumbeus						0.1 (34.4)
Rhizoprionodon acutus	3.8	1.4 (18.7)	0.1	2 (1.8)	1.9	4.3 (7.8)
Rhizoprionodon taylori		6.1 (0.3)	0.1	0.1 (0.1)	0.9	0.6 (0.4)
Hemipristis elongata			0.1	0.1 (0.4)		
Loxodon macrorhinus						
Galeocerdo cuvier	0.1			0 (1.7)		0 (7.4)
Sphyrna lewini	0.7	0.9 (7.6)	0.4	0.8 (2.9)	1.9	1.3 (2.0)
Sphyrna mokarran	0.4	0.8 (2.1)	0.1	0.4 (1.1)		0.3 (2.0)
Eusphyra blochii	0.1	0 (5.9)	0.1	0.7 (2.9)		0.8 (0.3)
TOTAL NUMBER	**718**	**654**	**1519**	**6457**	**106**	**1544**

Figure 2.3-1: Geographic breakdown of the project's observer data collected across northern Australia.

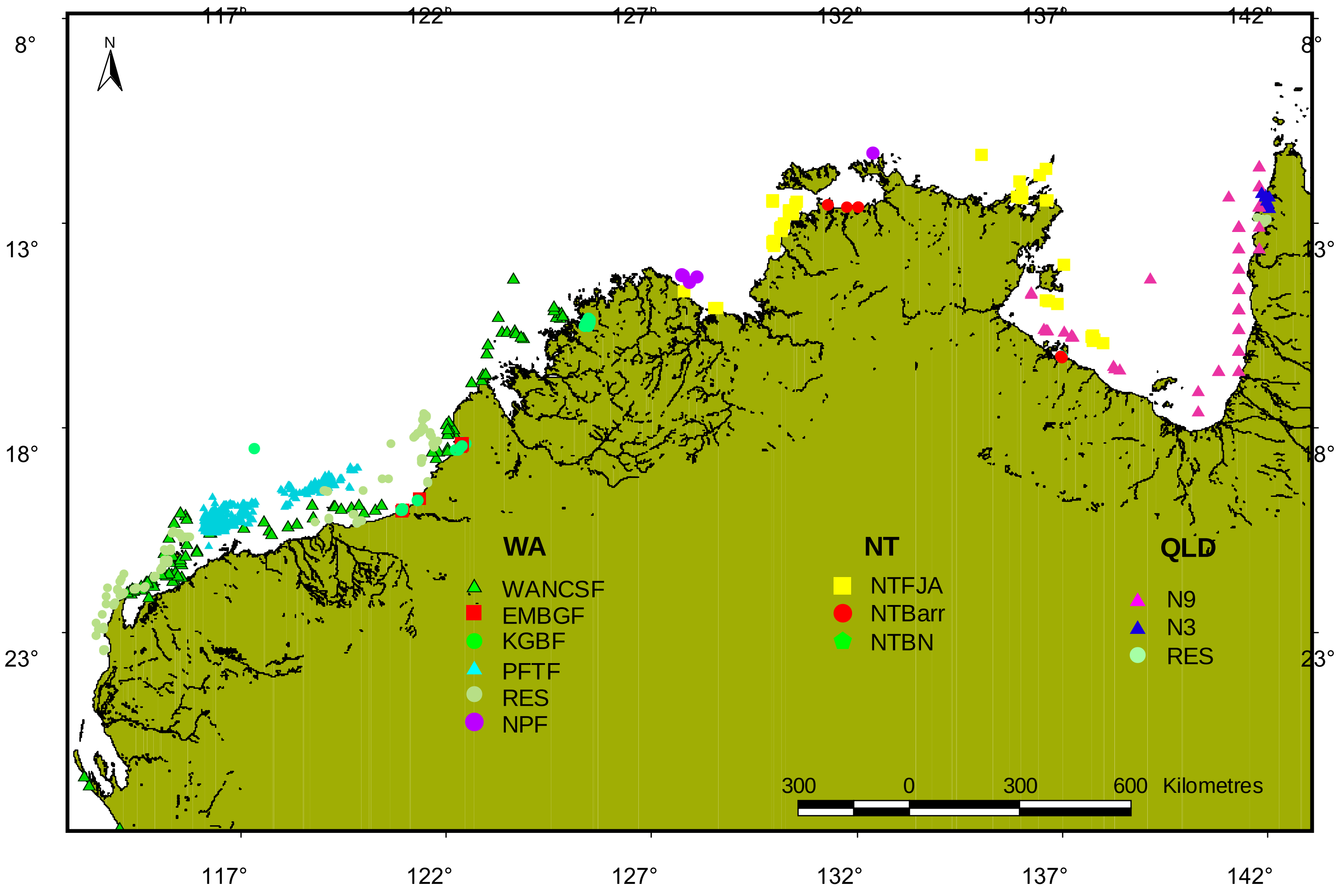

Table 2.3-7: Summary of observer data by month as numbers of shots (gear sets, trawls) per fishery, including target and bycatch* fisheries. Note that QFJA has recently been combined with N9 as the same licences used both regions in the Gulf of Carpentaria.

State	Fishery acronym	TOTAL	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Qld	N9	82					6	30	31	15				
Qld	QFJA	18		18										
Qld	N3	30					12				12			6
Qld	ECN	40				8		3		7	8			14
NT	NTONLF (NTFJA)	50	17		10	9	8	1		4				1
NT	NTBarr	14				11	3							
NT	NTBN	3					3							
WA	WANCSF	109		8	31	30	17		7	12	4			
WA	KGBF	88								5	18	27	19	19
WA	EMBGF	28								13		4	11	
WA	PFTF	426	31	28	31	30	45	60	55	28	26	31	30	31

Table 2.3-8: Average Size (total length in centimetres) and standard deviation (SD) per species per fishery. Species with insufficient records have not been included; a full list of recorded species is presented elsewhere in this report. Fishery acronyms as per list at start of Results. The Average Total Lengths for 'ALL FISHERIES'* includes the shark bycatch fisheries listed in Chapter 4. SD = standard deviation

BIOLOGICAL DATA ALL SPECIES	Average Total Lengths (and SD) per fishery													
	ALL FISHERIES*		QJFA	SD	ECN	SD	NTONL	SD	N9	SD	RES	SD	WANCSF	SD
Carcharhinus albimarginatus	118.1	42.3									169.5	54.4	114	39.7
C. amblyrhynchoides	107.5	30.5	117.4	30.6	141.6	34.0	133.3	11.6	113.7	8.0	107.5	36.6		
Anoxypristis cuspidata	179.4	84.7	227.2	41.6			246.1	46.9	286.5	31.5				
C. amblyrhynchos	116.1	33.4			151.7	24.3	119.6	28.1			76.9	7.8	131	25.1
C. amboinensis	135	57.9					181.4	46.7	218.4	13.1	204.4	14.6	187.6	51
C. brevipinna	120.2	56.8					96.8	10.5	102.7	30.2			189.8	66.1
C. cautus	92.6	25.0	123	34.2	94.5	12.0	148.3	2.3			100.4	20.0	86.5	25.6
C. dussumieri	77.6	10.6	81.8	12.1	88.3	4.2	80.9	11.6	75.4	2.9	57	2.1	71.5	4.8
C. fitzroyensis	91.4	15.0	86.2	19.1	79.8	24.0	99.8	12.7	85	10.9			102.7	12.1
C. leucas	92	32.9	157.5	39.6	122	21.7	95.7	12.1	298.2	11.9	95.3	7.3		
C. limbatus	154.1	39.3	141.1	31.6			195.7	21.4	209.2	10.3				
C. macloti	75.6	6.6			76.5	3.7			76.2	3.6			73	5.0
C melanopterus	95.7	18.6												
C. obscurus	250.7	46.4									262.6	23.1	250	47.9
C. plumbeus	151.2	22.9			201.5	12.0					152.3	30.6	151	22.5
C. sorrah	97.8	12.8	97	15.3	111.6	13.1	98.8	13.4	97.2	9.7	89.6	12.0	95.4	13.7
C. tilstoni	118	32.2	108.5	21.3	130.7	27.6	107.8	24.2	123.9	21.8	127.8	42.1	143.7	35.3
C. altimus	180.6	74.3									210.2	51.8	98	5.7
Carcharias taurus														
Centrohorus granulosus	158.2	4.9												
Chylocillium punctatum	39.7	8.0												
Dasyatis annotata	19.5	3.8												
Eucrossorhinus dasypogon	57.8	33.6												
Eusphyra blochii	125.3	31.1	129	31.0	110.9	34.3	129.9	25.0	140.8	13.8	85	-	127.6	16.5
Galeocerdo cuvier	205.4	77.9					217.9	72.9	292.5	55.6	215.3	64.1	202	78.3
Glyphis sp.A	124.7	34.2					168	-						
Gymnura australis	35.9	13.8												
Hemigaleus microstoma	71	14.7			98.8	-			96.4	1.8	92	6.0		

BIOLOGICAL DATA ALL SPECIES	Average Total Lengths per fishery													
	ALL FISHERIES		QJFA	SD	ECN	SD	NTONL	SD	N9	SD	RES	SD	WANCSF	SD
Hemipristis elongata	133.5	24.1			120.6	23.9	126.2	12.9	143.1	15.9				
Loxodon macrorhinus	74	15.7											73.4	15.6
Mobula eregoodootendee	76.7	15.3					76.7	15.3						
Nebrius ferrugineus	225	35.8					223.8	36.9			256.7	11.5	211.5	57.3
Negaprion acutidens	208.5	60.2					234.5	37.8	228.4	-	136.8	58.8	235	29.4
Pristis clavata	134.9	49.6									210.7	16.4	74.3	3.2
Pristis zijsron	190.6	130.1					310	-			220.2	30.1		
Pseudocarcharias kamoharai	82.4	9.4												
Rhinobatos typus	102.8	46.8					249	-			109.4	13.7		
Rhizoprionodon acutus	81	6.4	65.1	14.1	88.8	4.1	84.2	5.5	81.5	3.5	81.6	6.4	80.3	7.3
Rhizoprionodon taylori	65.2	13.8					99	-	67.8	12.2	42	24.1	52.3	4.4
Rhynchobatus australiae	136	29.5	126.9	-	81.3	1.6	194.3	85.6			143.4	27.1	268.5	35.4
Sphyrna lewini	134.6	52.7	183.6	52.2	181.7	62.1	129.3	35.6	162.1	17.7	200.5	59.0	160	58.0
Sphyrna mokarran	244.9	58.0	294.1	-	184.4	65.7	235.9	63.0	217.4	57.9	242.9	31.2	273	44.5
Stegostoma fasciatum	172.8	17.9					101	-					167	-

Table 2.3-9: Sex Ratios (Females:Males) per species per target shark fishery. Species with insufficient records have not been included; a full list of recorded species is presented elsewhere in this report. The sex ratio for 'ALL FISHERIES' includes shark bycatch fisheries. Fishery acronyms as in pervious tables except RES=Research field samples (Qld).

BIOLOGICAL DATA ALL SPECIES	Sex Ratio F:M per fishery, FEMALES = 1, MALES = M/F						
	ALL FISHERIES	QJFA	ECN	NTONL	N9	RES	WANCSF
Carcharhinus albimarginatus	0.227					0	0.250
C. amblyrhynchoides	1.103	1.5	0	0.19	0	0	
Anoxypristis cuspidata	0.559	4.5		0.2	0.049		
C. amblyrhynchos	1.775		0	1.333	0	1.25	1.778
C. amboinensis	1			1.136	2.5	0	1
C. brevipinna	0.903			1.375	0.714		0.4
C. cautus	1.512	1.5	1	0		3	1
C. dussumieri	2.342	0	0.7	0.444	0	0	0
C. fitzroyensis	0.868	2.333	1	3	2		0.5
C. leucas	0.81	1.667	0	0.5	0	1	
C. limbatus	0.522	0.611		0.5	0		
C. macloti	5.909		0		7.5		10
C melanopterus	1.5						
C. obscurus	0.431					0.25	0.447
C. plumbeus	0.707		1			0.386	0.784
C. sorrah	1.239	1.288	0.869	0.592	2.587	1	1.387
C. tilstoni	0.839	1.186	0.388	0.774	1.355	0.368	0.91
C. altimus	0.696					0.476	1
Carcharias taurus							
Centrohorus granulosus	0						
Chylocillium punctatum	0.87						
Dasyatis annontata	1.33						
Eucrossorhinus dasypogon	0						
Eusphyra blochii	1.103	0.5	0.333	0.492	4	0	1.5
Galeocerdo cuvier	0.688		0	0.436	1	1	0.732
Glyphis sp.A	0.667			0			
Gymnura australis	3.5						
Hemigaleus microstoma	1.645		0	0	0	0.667	
Hemipristis elongata	1.72		2.25	1	1.75		
Loxodon macrorhinus	0.737						0.778
Mobula eregoodootendee	1			1			
Nebrius ferrugineus	0.625			0.483		0	2
Negaprion acutidens	1.53			2.857	0	0.429	1.851
Pristis clavata	1					0.5	0
Pristis zijsron	0.9			0		0.5	
Pseudocarcharias kamoharai	6.333					6.333	
Rhinobatos typus	0.571			0		2	
Rhizoprionodon acutus	1.848	0.8	1	0.9	26.4	0.409	0.581
Rhizoprionodon taylori	2.077			0	1.2	0.8	2.25
Rhynchobatus australiae	0.754	0	0	0.5		2	0
Sphyrna lewini	2.731	2.833	1.571	2.281	17	1.4	0.609
Sphyrna mokarran	1.068	1	0.667	0.667	4	0.667	0.49
Stegostoma fasciatum	0.529			0			2

2.4 Discussion

The initial plan for observer data collection was probably ambitious, given the difficulties encountered in NT and Qld. In particular, obtaining catch composition/effort and biological information from inshore barramundi gillnetters proved very difficult in all jurisdictions. These shark bycatch fisheries are reported in Chapter 4 (Objective 3).

In Queensland, there was considerable difficulty in obtaining cooperation from Queensland East Coast shark fishers in regard to fisheries observers. Collaboration with the project by fishers is entirely voluntary and the observers are invited onto cooperating vessels. Phase I of the project set-up potential collaborations through a pilot study and workshop, but since then a number of political developments outside the control of the investigators have influenced these potential collaborations (see Results for further details). Data on shark catch and bycatch was supplemented by fishery independent sampling (listed as RES in most tables) using commercial gear, and by buying catches from commercial skippers, but is not as complete as originally hoped. As shown in Table 2.3-2 and Table 2.3-3, the blacktip sharks represent the major catch by numbers for the NT and Qld shark fisheries, although there appears to have been a decline in the proportion of *C. tilstoni* in the N9 fishery compared to historical records (Table 2.3-6). In WA, the decline in proportion of *C. tilstoni* and *C. macloti* (60%) is balanced by the increase in proportion of Sandbar (*C. plumbeus*), Tiger (*G. cuvier*) and *C. sorrah* sharks (58%). Whether the increase in proportions of Sandbar and Tiger sharks is related to the value of fins, is not discernable from the project data. Any future research should incorporate observer monitoring of shark fin landings as well as trunks and flesh. Although new logbooks incorporate more detailed species records and interactions with ‘vulnerable’ species (see NT Shark Fishery Daily Log Sheet in Appendix 3), the availability of the fin records needs to be more transparent for any future shark sustainability project.

In general, fisher cooperation with observer was not a hindrance to data collection in the NT shark fishery. The link between researchers and fishers appeared positive and the attitude of the shark fishers in recognizing the impending changes towards more sustainable shark fishing was illustrated by the fishers peak body (NT Seafood Council) taking the initiative in significant changes in fisher attitudes towards sensitive or vulnerable species such as sawfish. The shark fishers Code of Conduct specifies the obligation to release live sawfish where possible. One issue that arose during the project was the status of Glyphis sharks (speartooth sharks) in the NT fishery. A consequence of observer work was that several speartooth sharks were recorded, including 7 specimens on one observer trip. Others specimens have since been recorded and this has raised the issue of their protected status, that is, they are listed as endangered under the EPBC Act. Given the current legislation and listing under the EPBC act, the presence of speartooth sharks in the NTONLF is a serious concern for export markets and Australia’s international obligations to the NPOA-Sharks (Stevens *et al.* 2005).

One reporting issue that requires immediate clarification is the agreement on uniform and appropriate fin/trunk and fin/flesh ratios across all jurisdictions. Current retention values are 3% for wet fin to whole weight 6.5 % for trunk and 13% for fillets (without skin). These values are significantly higher, than actual ratios measured in the field (The phase 1 project fin conversion values are listed in Table 2.4-1). Current fin to whole animal, trunk or fillet ratios are at least double the actual values allowing fishers to effectively fin half their catch and not retain any other portion of the animal.

Reasons for the current allowable ratios of fins to whole animal, trunk or fillets ratios are designed to allow for fishers to use shark flesh for bait in longline fisheries, account for sharks with inedible flesh, flesh being eaten by lice, and parts of sharks being consumed by other sharks. While all these reasons are valid, allowing for more than half the catch to be finned and no other part retained seems excessive when fisheries are trying to maximise the quality of their primary product which is shark flesh. A more conservative approach should be adopted to ensure that large sharks are not just finned and dumped due to inedible flesh, a practice which is known to occur.

Table 2.4-1: Fin conversion ratios derived from the phase 1 observer project (FRDC2001/077).

Species	n	wet fin/whole weight	SE	Dry fin/whole weight %	SE	Dry fin/wet fin %	SE	Weight range
Qld								
C. tilstoni	10	1.64	0.06	0.79	0.04	48.6	1.9	
C. sorrah	8	1.32	0.04	0.56	0.01	42.2	0.07	
NT								
C. tilstoni	40	1.5	0.03	0.63	0.02	42.4	1	1-9.3
C. sorrah	20	1.23	0.04	0.55	0.02	44.2	1.6	2-7.2
C. amboinensis	6	1.68	0.1	0.73	0.05	43.4	1	2.1-11.2
C. fitzroyensis	14	1.71	0.07	0.68	0.04	39.5	0.7	2.3-9
C. dussumieri	18	1.35	0.06	0.61	0.03	46	1.7	1.5-2.4
C. melanopterus	34	1.5	0.04	0.68	0.02	45.6	0.9	1.1-13.5
C. amblyrhynchoides	13	1.47	0.06	0.59	0.01	41.3	1.9	1.1-6.8
C. cautus	1	1.06		0.51		47.5		4.5
R. acutus	1	1.92		1.04		54		1.8
E. blochii	9	2.16	0.17	0.98	0.07	45.8	1.2	3.2-10.5
S. mokarran	3	2.21	0.04	0.99	0.03	44.9	2	5.8-22.2
A. cuspidata	8	1.41	0.06	no data				2.2-3.3
A. cuspidata	1	2.18		0.98		44.9		4.1

In general, the three jurisdictions have taken measures to improve the sustainable harvest of sharks in Australian waters, as noted in Chapter 1, Non-technical summary and Planned Outcomes. However, the overriding issue clouding the good work of shark fisheries management agencies has been the looming impact of IUU shark fishing in the north. It is difficult to discuss shark fishery management needs without qualifying any statements with reference to the overwhelming impact of IUU fishing on Australia's northern shark stocks. However, as real as this issue might be, it does not remove the need for sound management directed towards the long-term sustainable harvest of sharks.

To this end, some projects that are directed at investigating the IUU shark catch have been funded by AFMA. A Shark Fin Identification project (collaboration between CMAR, AIMS and QDPI) commenced in late 2005 and is designed to assist Compliance Officers with identification of shark species from dried fins. A second project is under development to quantify the IUU effort for all categories of foreign fishing vessels (FFVs), including sharks. This collaboration will be between CMAR, AIMS, QDPI, CMIS and funded by Coastwatch and AFMA. At present, there is no valid estimate available of the shark catch by FFVs. In addition, the level of 'on the water' apprehensions cannot keep pace with the level of surveillance. Records of the number of apprehended vessels (both arrests and legislative forfeitures) since 2000 have shown an increasing trend such that there is no clear understanding yet if the complete extend of IUU effort by FFVs is known.

Summary

The project observer work in the target shark fisheries produced significant new species composition, biological samples and data and fishing effort data that was essential for producing the parameter values for the risk assessment. Access to commercial shark boats was not an issue for observers. The shark fisher workshops proved to be a productive method of liaison with fishers and to provide education/extension of project aims and results.

2.5 References

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3. CHAPTER 3 – OBJECTIVE 2 POPULATIONS STRUCTURE OF BLACKTIP SHARKS

Prepared by Jennifer Ovenden

3.1 Introduction

Objective 2 *To determine the appropriate management scale for the target species of northern Australian shark fisheries, by examining the degree to which stocks are shared across northern Australia and with Indonesia.*

This report presents the mtDNA and microsatellite (nuclear DNA) results from the genetic analysis of the two blacktip species that form the major component of the commercial shark catch across northern Australia. The report is presented under Results and Discussion in the form of a scientific paper. The section below deals with the original Methods as proposed in the project document.

3.2 Methods

This section will focus on *Carcharhinus tilstoni* and *C. sorrah*. Samples for genetic analysis will be collected during Phase 1 and in Phase 2 these will be analysed to determine stock structure. The samples from Indonesia will be provided from the CSIRO/Murdoch University/ACIAR project (FIS2003/037). Initially only samples from the extremes of the northern fisheries (WA and Queensland) and Indonesia will be analysed. If these samples do not show separation of stocks, no further analysis will be required. If there is separation of stocks, samples from NT will also be processed to determine where the stocks are distinct. In the 1980s population genetics analyses using allozymes were carried out on the two abundant carcharhinid species to be studied in this project, *C. tilstoni* and *C. sorrah* (Lavery and Shaklee 1989). This study showed little detectable population structure across northern Australia. However, in south-eastern Australia, Ward and Gardner (1997) identified three genetic stocks of gummy sharks *Mustelus antarcticus* using both allozymes and mtDNA, while school sharks, *Galeorhinus galeus*, could not be genetically distinguished over a large range. This project will use recent genetic techniques to re-examine the stock structure and extend the comparison to Indonesia.

The method for shark mtDNA will be the same as those developed by Dr Jenny Ovenden (QDPI Deception Bay) in the ACIAR and FRDC studies on three snapper species and goldband snapper, *Pristipomoides multidens*, respectively. In brief, a region known to be highly polymorphic is amplified using PCR (polymerase chain reaction) from each fish. This fragment of DNA is digested with restriction enzymes to produce a haplotype (genotype) for each fish. Comparing the relative frequencies of haplotypes assesses the degree of spatial genetic subdivision. Few studies using mtDNA have been reported for the species to be investigated in this project and this project provides an ideal opportunity to apply DNA technology to re-examine species studied almost 20 years ago with simpler protein-based methods.

Small sections of highly variable nuclear (not mitochondrial) DNA are targeted by specifically designed ‘primers’. These ~200 bp size DNA fragments behave like Mendelian allozymes and follow the laws of Mendelian inheritance. In general, microsatellite DNA reveals higher levels of genetic variation than other methods and so has a better chance of discriminating populations. The best approach acknowledged in most major studies today is to use both methods to maximise resolution where species are known to be mobile and widely distributed.

3.3 Results and Discussion

Genetic population structure of black-tip sharks (*Carcharhinus tilstoni* and *C. sorrah*) in northern Australia

By JR Ovenden, R Street, D Broderick, T Kashiwagi and J Salini

3.3.1 Summary

Black-tip (*Carcharhinus tilstoni*) and spot-tail (*C. sorrah)* shark are two of seven commercial species that make up a multi-million dollar fishery in Queensland and the Northern Territory. Both species have low reproductive rates and relatively slow growth rates, and being predators, have relatively small population sizes. These features combine to make them vulnerable to over-fishing and likely to have genetically subdivided populations. The aim of this study was to use two DNA-based genetic markers to investigate the population structure of both species in northern Australian waters. At present, both species are considered as single stock units that are largely managed the same way across three jurisdictions. Of the two markers used here, the control region of the mitochondrial genome was shown to be remarkably devoid of polymorphism, which was a characteristic previously reported for allozyme loci. However, microsatellite loci optimised during this study specifically for *C. tilstoni* and *C. sorrah* were highly polymorphic. The degree of genetic population subdivision measured by these loci was similar to that reported for allozyme loci. The microsatellite Index of Fixation, $F_{ST,}$ for *C. tilstoni*, although relatively low at 0.0073, showed that significant genetic subdivision is present with two genetic stocks of *C. tilstoni*; one in Western Australian waters and a second represented by the two samples from the Northern Territory and East coast of Queensland. However, there was no genetic evidence for more than a single stock of *C. sorrah* across northern Australia, although both microsatellite and mtDNA markers revealed significant population genetic structure between Indonesia and northern Australia. We conclude that there is sufficient evidence for the management of *C. tilstoni* as at least two separate stocks along the northern Australian coastline. Although gene flow in *C. sorrah* may be attenuated by deep offshore water, it is likely that gene flow is sufficient along the Australian coastline to allow the management of *C. sorrah* as a single population.

3.3.2 Introduction

Few countries worldwide invest resources to manage shark fisheries, possibly due to the relatively low market value of shark products. However, shark populations are naturally prone to over-harvesting. Their population sizes tend to be smaller than fish populations, their productivity is low due to low fecundity, and their growth rates are slower. Australia has a significant obligation to ensure the sustainable management of shark species in the Australian Fishing Zone, an area of about nine million square kilometres extending 200 nautical miles from the shore including Australia's external territories except the Antarctic Territory. Of the 1025 elasmobranch species found worldwide, approximately 300 are found in Australia and over 50% of these are endemic. They are targeted by commercial, indigenous, recreational and game fishers, and sharks are a by-catch or by-product in at least 70 types of commercial fishing operations. Currently there are numerous types of controls on shark harvest, including individual quotas, limited entry fisheries, minimum legal sizes, trip limits and bans on shark-finning and permissible types of fishing gear (Shark Advisory Group and Lack, 2004). The total value of the Australian shark fishery in 2001/2 was $32 million. Black-tip (*Carcharhinus tilstoni*) and spot-tail (*C. sorrah*) shark are two of seven commercial species that make up this fishery.

The distribution of *C. tilstoni* is restricted to northern Australia, while *C. sorrah* is found in northern Australia and south-east Asia. Females of both species have one to eight pups per year and males and females are sexually mature in two to four years (Last and Stevens, 1994). Movement patterns were studied by Stevens *et al.* (2000) in a long-term study involving the tag and release of 7765 *C. tilstoni* and *C. sorrah* in 1983-5. Over a 12 year period, most of the recaptures were within 50km of the tag and release site, but some individuals of both species moved up to 1000km. *C. sorrah* was demonstrated to be more mobile than *C. tilstoni*. The study concluded that there was sufficient movement to prevent genetic subdivision, but not enough to prevent a reduction in local populations due to heavy fishing pressure.

Lavery and Shaklee (1989) determined the degree of genetic subdivision in *C. tilstoni* and *C. sorrah* in northern Australia using allozyme electrophoresis. They collected 925 *C. tilstoni* and *C. sorrah* from northern Western Australia to Torres Strait in the east. Low levels of genetic variation were found across 47 allozyme (protein-coding) loci and only five loci had sufficient polymorphism for a comparison of allele frequencies among populations. The level of genetic subdivision found was low in both species. The measure of subdivision (F_{ST}) for *C. tilstoni* (0.0094) was larger than *C. sorrah* (0.0076), suggesting that the number of migrants exchanged per generation was higher for *C. sorrah* compared to *C. tilstoni*. These results compared favourably to the tag and release study by Stevens et al. (2000) that also found *C. sorrah* was more mobile than *C. tilstoni*.

The objectives of this study was to use two DNA based genetic markers, microsatellites and mitochondrial DNA control region, to investigate genetic population structure in *C. tilstoni* and *C. sorrah* in northern Australian waters. Microsatellite analysis of *C. limbatus* was included because of its close taxonomic affinities with C. tilstoni and its co-distribution with *C. sorrah* in Indonesia and *C. tilstoni* in Australia. Indonesian populations of *C. sorrah* and *C. limbatus* were included to provide a comparison between the degree of genetic subdivision along the northern Australian coastline and between northern Australia and central Indonesia over the same spatial scale, but across waters of great depth. Based on the work of Lavery and Shaklee (1989) and Stevens *et al.* (2000), our expectation was that the degree of genetic subdivision would be small, but detectable, and that subdivision would be greater in *C. tilstoni* compared to *C. sorrah*.

3.4 Methods

3.4.1 Sampling

Sharks were sampled from commercial catches by on-board observers and fisheries biologists from north-western Western Australia (WA), Western Gulf of Carpentaria (NT) and the north-eastern coast of Queensland (Qld).

C. sorrah and *C. limbatus* was sampled from Muara Angke (western Java) and Tanjung Luar (Lombok) in Indonesia (IND). These samples were taken from landed catch at local markets and the exact collection location was unknown but assumed to be within a 300km radius (Fig. 1).

Approximately 200mg of muscle tissue excluding skin was dissected and preserved in 1ml of 20% dimethyl-sulphoxide solution containing 5M NaCl.

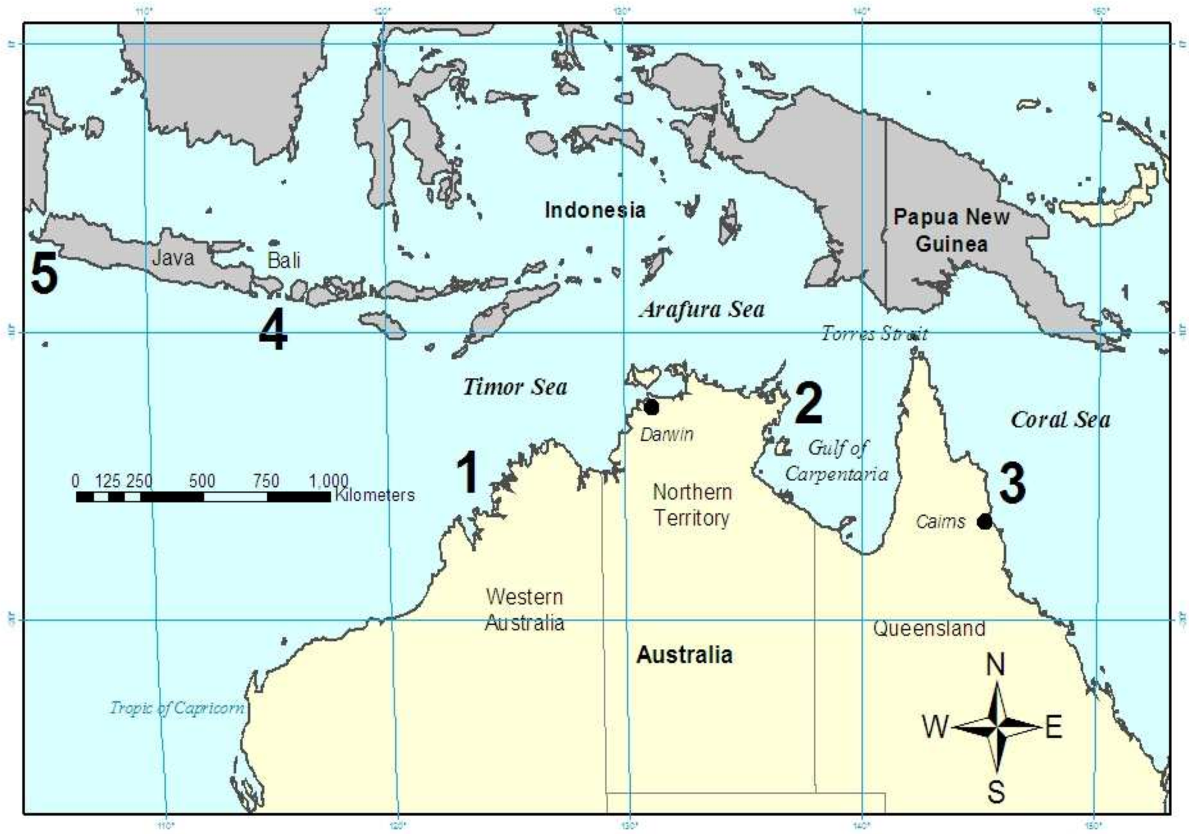


Figure 3.4-1: Collection locations for *C. tilstoni* (1-3) and *C. sorrah* and *C. limbatus* (1-5) in Western Australia (1; WA), Northern Territory (2; NT), Queensland (Qld; 3) and Indonesia (IND; 4, 5).

3.4.2 Species identification

C. sorrah was readily identified in the field, however *C. tilsoni* and *C. limbatus* individuals could not reliably be identified in the field. Precaudal vertebral counts were used to identify four *C. limbatus* and four *C. tilstoni* specimens that were used as reference samples. Species-specific mtDNA control region sequences were identified from these reference samples using primers GWF (CTG CCC TTG GCT CCC AAA GC) and CAR (GGG AAT AGC GAT TTG CTT CA). The PCR conditions were denaturation at 94°C for 10 sec, annealing and extension at 60°C for 4 minutes over 28 cycles with a final extension of 7 minutes at 60° C. Sequence was performed in both directions using 25pmol of either

GWF or CAR primers with 10-20ng of purified PCR product and Applied Biosystems Dye Terminator chemistry. Fragments were resolved by capillary electrophoresis on ABI3100xl under conditions recommended by the manufacturer. Sequence data was edited and aligned with Sequencher (Anon, 2000). All candidate *C. tilstoni* and *C. limbatus* samples were sequenced and identified to species level in this way.

3.4.3 Laboratory

Total genomic DNA extraction
Muscle tissue stored at –70^{o}C was used for total genomic DNA extraction: 10-50mg from each sample was digested in 50□l of a suspension of 5% Chelex-100 (w/v) in 5mM Tris.Cl ph8.0, 0.5mM EDTA. Proteinase K (100mg) was added and the tissue digested to completion at 55^{o}C for 1 hour on a shaking platform. The mixture was boiled for five minutes then centrifuged at 1200g for 5 minutes to precipitate Chelex resin and cellular debris. The supernatant was removed to a fresh tube for subsequent manipulation and storage. A small number of samples were extracted using Wizard method (Promega Corporation, Madison WI USA).

Microsatellite genotyping
Sharks were genotyped with five dinucleotide microsatellite loci (Ovenden *et al.*, 2006). *C. tilstoni* and *C. limbatus* samples were genotyped with loci CS02, CS06, CT05, Cli12 and LS24. *C. sorrah* samples were genotyped with loci LS15, CT05, CS12, Cli100 and CS08.

Microsatellite amplifications were performed in 96-well plates using a Perkin Elmer 9700 thermocycler. Reactions (10μl) contained 1μl of PCR buffer ® (Qiagen P/L) containing Tris-HCl (pH 8.7), KCl and $(NH_4)_2SO_4$; 4mM $MgCl_2$; 0.5μM forward primer; 0.5μM reverse primer; 0.05μM labelled M13 primer; 0.3 units *Taq* DNA polymerase (Qiagen P/L); 63μM dNTP (Pharmacia Biotech); 1% bovine serum albumin and approximately 25ng genomic DNA template. Forward primers had an M13 extension (GAG CGG ATA ACA ATT TCA CAC AG) at the 5' end, enabling fluorescent labelling with M13 (Broderick, Ovenden, MS; Schuelke, 2000). The DNA template and enzyme were denatured at 94^{o}C for 1 min 30 sec, followed by 35 cycles consisting of 94^{o}C for 5 sec, 60^{o}C for 20 sec and 72^{o}C for 30 sec. A final extension at 72^{o}C for 30 min was used to ensure complete addition of adenine to the PCR product, essential for consistent allele calling during genotyping. All loci were amplified in separate reactions and then combined for fragment separation according to label colour and fragment size.
Microsatellite fragment separation and scoring was performed by Gribbles Molecular Science (1/21 Smallwood Place, Murrarie Qld) using capillary electrophoresis on a MegaBACE 1500 (GE Health Care). The running Buffer and capillary matrix (LPA) were supplied by GE Health Care and the GT Dye Set 1 was used. The running conditions included a sample injection voltage of 3KV, sample injection time of 45 secs, run voltage of 10KV with a run time of 75 mins. All other parameters were according to the manufacturers specifications. Before loading, the amplicons were cleaned using the acetate/ethanol method and re-suspended in 10μl, of which 3ul was used to load the capillary. Size standard was made up using 25μl of 400SS and 275μl water; 3μl was added to each sample. The total load volume was 6μl, which was denatured for three minutes and chilled on ice prior to loading.

Microsatellite genotype scoring
The size in base pairs of microsatellite amplicons was calculated to two decimal places. Amplicons were allocated to a 'bin' that represented the mean allele size. Scoring of microsatellite alleles was verified by graphical representation of allele size measured to two decimal places against bin size. Alleles were consistently two base pairs apart, as expected from the di-nucleotide loci used, and there were clear cut-off points between successive allele sizes.

Mitochondrial control region sequencing
The mtDNA control region (D-loop) was amplified using the primers GWF (CTG CCC TTG GCT CCC AAA GC) and GWR (CCT AGC ATC TTC AGT GCC AT) (Pardini *et al.*, 2001). Polymerase chain

reaction amplifications were carried out in 50µl volumes using the following reagent concentrations: dNTP's, 100mM each; primers, 0.5 µM each; and additional 1.5 mM $MgCl_2$. Each reaction contained 0.5 Units of Taq DNA polymerase and the reaction buffer supplied by the manufacturer (®Qiagen P/L)). Thermal cycling conditions consisted of an initial denaturation, 94°C for 1 min 30 secs followed by 35 cycles of 94°C for 5 seconds, 55°C for 30 seconds and 72°C for 30 secs, with a final extension step of 72°C for 5 minutes. Cycling was performed in a PTC200 DNA Engine (MJ Research, USA).
The sequence of mtDNA control region amplicons was performed in one direction using primer GWF. We used Applied Biosystems Dye Terminator chemistry and fragment separation carried out by capillary electrophoresis (Gribbles Molecular Science, MegaBace 1500) under conditions recommended by the manufacturer. Sequence data was edited and aligned with Sequencher (Anon, 2000).

3.4.4 Data analyses

The program Micro-checker (Van Oosterhout *et al.*, 2004) was used to investigate likely causes for possible deviation from Hardy-Weinberg equilibrium. The program calculates probabilities for the observed number of homozygotes of various allele size classes. An overall significant excess of homozygotes over all size classes suggests the presence of null alleles. Deficiencies of individuals heterozygous for alleles differing by one repeat unit, suggests PCR 'stutter' was interfering with the scoring process. Large allele dropout was suggested if excess homozygotes were biased towards the extreme end of the allele size distribution.

The null hypothesis of Hardy-Weinberg equilibrium was tested using GenePop (Morgan, 2000) with the following Markov chain parameters for all tests; dememorization, 10000; batches, 1000 and iterations per batch, 1000.

Microsatellite genetic diversity was characterised by the number of alleles per locus, expected heterozygosity (HE) and observed heterozygosity (HO). Microsatellite data was used to investigate population structure using standard F_{ST} (Weir and Cockerham, 1984) in an Analysis of Molecular Variance (AMOVA) framework implemented in GenAlEx software (Peakall and Smouse, in press). Non-parametric bootstrapping was implemented to estimate p-values. Missing data for individual pairwise comparison was handled by inserting the average genetic distance for the appropriate population level pairwise comparison as recommended in GenAlex (Peakall and Smouse, in press).

Phylogenetic trees were constructed from mtDNA sequence data using Kimura's two-parameter distances (gamma, 0.5) and the neighbour-joining method (NJ, Saitou and Nei, 1987) assuming minimum evolution (ME). Trees were produced and evaluated with 1000 bootstrap replicates in PAUP v. 4.0b10 (Swofford, 1999).

3.5 Results

3.5.1 Species identification

MtDNA control region sequencing identified five shark species and one unknown shark species among the genetic samples collected in the field as *C. tilstoni*. There were 133 *C. tilstoni*, 107 *C. limbatus*, 1 each of *C. brevipinna* and *C. fitzroyensis*, two *C. sorrah*, and one sample that could not be identified to species level using the data collected (Table 3.5-1). One shark specimen could not be assigned to either *C. limbatus* or *C. tilstoni* using the sequence collected (unknown, Table 3.5-1). Species other than *C. limbatus* or *C. tilstoni* were removed from the analyses.

The relative frequencies of *C. limbatus* compared to *C. tilstoni* among the samples collected for genetic analyses varied between states. *C. limbatus* (n = 44) were more frequently collected in Western Australia than *C. tilstoni* (n = 27). In Queensland the proportions of each species were similar (30 *C. limbatus*, 34 *C. tilstoni*). In the Northern Territory, *C. tilstoni* was more common (16 *C. limbatus*, 72 *C.*

tilstoni). The variation could reflect species abundances or parameters involved in their collection as the samples were initially collected to be *C. tilstoni* only. *C. tilstoni* was not recorded among 17 samples collected in Indonesia.

3.5.2 Microsatellites

Scoring errors due to ‘stuttering’ or large allele drop-out were not detected by the software Microchecker for either *C. tilstoni* or *C. sorrah*. There was a significant excess of homozygotes (equivalent to a heterozygote deficit) for locus CS02 for *C. tilstoni* sampled from WA; the expected number of homozygotes was 4.7, yet 16 homozygotes were observed ($p < 0.0025$). There was an excess of homozygotes for this locus at the other two sampling locations (NT and Qld), however it was not significant ($p > 0.05$). No deviations from Hardy-Weinberg genotype proportions were detected with Microchecker for *C. sorrah* samples analysed with five microsatellite loci.

Microsatellite loci for *C. tilstoni* and *C. sorrah* showed a higher allele number and higher per locus heterozygosity than allozyme loci (Lavery and Shaklee, 1989). Three (CS06, Cli12, LS24) *C. tilstoni* loci had up to ten alleles across the three populations. One locus had more than 20 alleles (CS02) and locus CT05 had between 10 and 20 alleles (Table 3.5-1). The statistics were similar for *C. sorrah*; three loci (LS15, CS12 and CLi100) had less than 10 alleles, one locus had between 10 and 20 alleles (CT05) and one locus had more than 20 alleles (CS08, Table 3.5-2).

Table 3.5-1: Identification system used for *C. tilstoni* and *C. limbatus* samples collected for genetic population subdivision analysis using reference samples identified using precaudal vertebrate counts and corresponding control region mtDNA sequence at nine variable base pair positions.

Haplotype Number	Species[1]	Reference Sample[2]	Unique Sequence[3]	N[4]
CT02	*C. tilstoni*	D7	TAAACATCT	47
CT03	*C. tilstoni*	G10, F2, D8	.G.......	78
CT04	*C. tilstoni*	None	.....G...	5
CT05	*C. tilstoni*	None	CG.......	2
CT06	Unknown[5]	None	.....G..C	1
CL02	*C. limbatus*	F3, E10, B7, B3	..T..G.AC	96
CL05	*C. limbatus*	None	..TG.G.AC	8
CL06	*C. limbatus*	None	..T..GCAC	1
CL07	*C. limbatus*	None	..T....AC	1
CL16	*C. limbatus*	None	.GT..G.AC	1

3.5.3 Microsatellites

Scoring errors due to 'stuttering' or large allele drop-out were not detected by the software Microchecker for either *C. tilstoni, C. limbatus* or *C. sorrah*. Deviations from Hardy-Weinberg genotype proportions were detected for four out of 20 population-sample by locus combinations for *C. sorrah* samples. Deviations from Hardy-Weinberg genotype proportions were detected for six out of 35 population-sample by locus combinations for *C. tilstoni* and *C. limbatus* samples. In all cases the deviation was due to heterozygote excess, except for the *C. sorrah* population sample from the Northern Territory for locus CS12 where there was a heterozygote deficit (Table 3.5-2 and Table 3.5-3).

Microsatellite loci for *C. tilstoni* and *C. sorrah* showed a higher allele number and higher per locus heterozygosity than allozyme loci for those species (Lavery and Shaklee, 1989). Three (CS06, Cli12, LS24) *C. tilstoni* loci had up to ten alleles across the three samples. One locus had more than 20 alleles (CS02) and locus CT05 had between 10 and 20 alleles (Table 3.5-2). The statistics were similar for *C. sorrah*; three loci (LS15, CS12 and Cli100) had less than 10 alleles, one locus had between 10 and 20 alleles (CT05) and one locus had more than 20 alleles (CS08, Table 3.5-3). Allele frequencies are available from the senior author on request.

[1] Species identification derived from precaudal vertebral counts (reference samples) or sequence similarity with reference samples.

[2] Precaudal vertebral counts for *C. tilstoni* reference sample were 85. The count varied from 97 to 100 for *C. limbatus* reference samples.

[3] Sequence at variable sites located at base positions 77, 98, 119, 149, 175, 193, 200, 234 and 236 in 375 base pairs of mtDNA control region sequence. Sequence is same as above unless indicated.

[4] Number of specimens reported among 240 sharks sampled for genetic analyses.

[5] Sequence of sample with haplotype CT06 was not diagnostic for either *C. tilstoni* or *C. limbatus.*

Table 3.5-2: Summary statistics for *Carcharinus limbatus* (CL) and *C. tilstoni* (CT) samples analysed from Western Australia (WA), Queensland (Qld), Northern Territory (NT) and Indonesia (IND) for five microsatellite loci. [6]

Pop		Locus CS02	Locus CS06	Locus CT05	Locus Cli12	Locus LS24
C. limbatus						
CLIND	N	17	16	16	15	15
	Na	12	3	10	3	4
	Ho	0.647	0.250	0.875	0.333	0.800
	He	0.882**	0.531**	0.811	0.438	0.660
CLNT	N	14	14	15	11	13
	Na	13	5	7	3	5
	Ho	1.000	0.429	0.533	0.273	0.692
	He	0.893	0.658	0.724*	0.459	0.672
CLQld	N	28	26	26	29	28
	Na	14	5	11	4	5
	Ho	0.679	0.731	0.808	0.414	0.500
	He	0.862**	0.710	0.878	0.461	0.578
CLWA	N	38	41	41	40	44
	Na	16	6	13	4	7
	Ho	0.632	0.659	0.854	0.600	0.591
	He	0.916**	0.653	0.891	0.509	0.634
C. tilstoni						
CTNT	N	62	56	51	39	47
	Na	21	7	13	4	5
	Ho	0.871	0.732	0.686	0.410	0.596
	He	0.886	0.698	0.772	0.533*	0.623
CTQld	N	31	31	29	31	33
	Na	21	4	10	5	5
	Ho	0.871	0.677	0.759	0.452	0.606
	He	0.904	0.683	0.742	0.546	0.618
CTWA	N	23	24	23	22	24
	Na	16	6	8	2	6
	Ho	0.913	0.708	0.783	0.364	0.625
	He	0.921	0.727	0.681	0.496	0.635

[6] The number samples assayed at each sampling location (N), the number of alleles *(*Na), expected number of heterozygotes (He) and the observed number of heterozygotes (Ho) are given for each locus. Significant deviation of heterozygote proportions are shown.

Table 3.5-3: Summary statistics for *Carcharinus sorrah* samples analysed from Western Australia (WA), Queensland (Qld), Northern Territory (NT) and Indonesia (IND) for five microsatellite loci. [7]

Pop		Locus LS15	Locus CT05	Locus CS12	Locus Cli100	Locus CS08
WA	N	53	51	51	46	40
	Na	4	17	7	8	27
	Ho	0.094	0.922	0.608	0.500	0.975
	He	0.125	0.890	0.567	0.452	0.952
Qld	N	56	53	55	51	45
	Na	4	14	8	5	28
	Ho	0.161	0.849	0.564	0.314	0.867
	He	0.152	0.837	0.523	0.359	0.943*
NT	N	38	30	48	44	32
	Na	4	11	5	4	24
	Ho	0.132	0.733	0.667	0.227	0.844
	He	0.125	0.799	0.525**	0.274	0.937*
IND	N	31	25	47	42	28
	Na	2	10	5	4	24
	Ho	0.032	0.760	0.468	0.048	0.857
	He	0.032	0.794	0.552	0.070*	0.944

Hierarchical partitioning using AMOVA revealed significant genetic variation at microsatellite loci between northern Australian and central Indonesian populations of *C. sorrah* (F_{RT} = 0.040). A similar amount of variation was found between the closely related species *C. tilstoni* and *C. limbatus* (F_{RT} = 0.041). One of this species pair (*C. tilstoni*) is only found in northern Australia, while *C. limbatus* is found in northern Australia and worldwide. The pairwise F_{ST} between sympatric *C. tilstoni* and *C. limbatus* population samples in Western Australia, Northern Territory and Queensland was 0.035, 0.014 and 0.031. The pairwise F_{ST} between northern Australian and central Indonesian populations of *C. limbatus* was 0.023, 0.014 and 0.015. The amount of variation in the data that was due only to regional differences between Indonesia and Australia (F_{RT}) was insignificant.

Populations of *C. sorrah* from three locations on the northern Australian coastline (Western Australia, Northern Territory and Queensland) were not significantly different at five microsatellite loci (pairwise F_{ST}'s 0.004, 0.004 and 0.008). Likewise, *C. tilstoni* from the same three locations were also not significantly different (pairwise F_{ST}'s 0.006, 0.008 and 0.009). In comparison, pairwise F_{ST}'s among the three Australian locations for *C. limbatus* samples were larger (0.022, 0.025, 0.008) and significantly larger than zero.

3.5.4 Mitochondrial control region

Nucleotide sequence was obtained from the left domain of the mitochondrial control region of *C. tilstoni*, *C. limbatus* and *C. sorrah*. A small number of polymorphic sites was observed among the *C. tilstoni* sequences; four among 17 sequences of approximately 700 base pairs. One polymorphism involved a transversion – the nucleotide substitution from a purine to a pyramidine (A to T at base 194), which is unusual for intraspecific polymorphisms. The remaining of the substitutions were transitions

[7] The number samples assayed at each sampling location (N), the number of alleles (Na), expected number of heterozygotes (He) and the observed number of heterozygotes (Ho) are given for each locus. Significant deviation of heterozygote proportions are shown.

(A to G, bases 217 and 537) and a one-base pair insertion-deletion event. Three substitutions – all transitions - were observed among 14 *C. limbatus* sequences across 700 base pairs.

Phylogenetic analysis of *C. tilstoni* and C. *limbatus* mtDNA control region sequence data confirmed genetic differentiation between the species observed by the magnitude of microsatellite F_{ST} (Fig 3.5.1). There was no evidence of subdivision between populations in Queensland, Northern Territory and Western Australia for either *C. tilstoni* or *C. limbatus.*

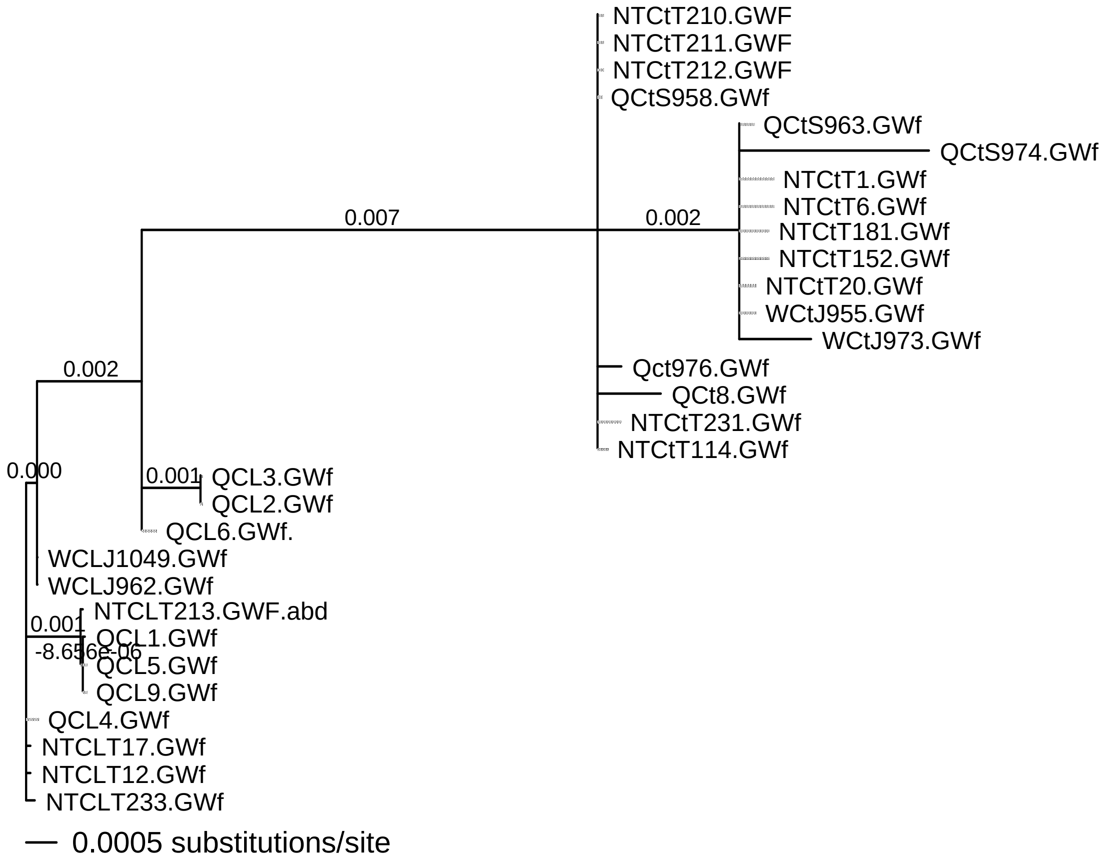


Figure 3.5-1: Consensus bootstrap neighbour joining tree showing similarity between mtDNA control region sequences for *C. tilstoni* (Ct) and *C. limbatus* (CL) from Western Australia (W), Northern Territory (NT) and Queensland (Q). Similarity was measured using the Kimura 2-parameter method. Bootstrap support for the two-clade structure was 98%.

In contrast, 19 polymorphic sites were observed for *C. sorrah* control region sequences of similar length (Table 3.5-4). Phylogenetic analysis of *C. sorrah* mtDNA control region sequence data provided no evidence of subdivision between populations in Queensland, Northern Territory and Western Australia (Fig 3.5.2.), but did provide clear evidence of genetic distinction between Australia and Indonesian populations. The neighbour joining analysis grouped the Australian and Indonesian sequences into two clades that were well supported in bootstrap analyses. The table of character states clearly shows the Indonesian samples possess similar states at seven of the 19 characters (sites 172, 178, 242, 261, 271, 353 and 420) emphasizing their close genetic relationship. One shark sample from Northern Territory (NTCsS1597, Fig. 3.5.2) showed close similarity to the Indonesian group, suggesting that that individual, or its direct maternal ancestor, has migrated from Indonesian to Australian waters.

The amount of polymorphism reported here for the control region of the mitochondrial genome of *C. tilstoni* and *C. sorrah* is low compared to bony fish. Nucleotide diversities for the equivalent region the mitochondrial genome of the narrow-barred Spanish mackerel (*Scomberomorus commerson*) ranged from 0.02 to 0.05 (Ovenden and Street, *Submitted*). These values are one order of magnitude greater than the nucleotide diversities reported in this study for sharks (0.001 to 0.007). Heist (2004) has reported that mtDNA evolves more slowly in sharks compared to mammals.

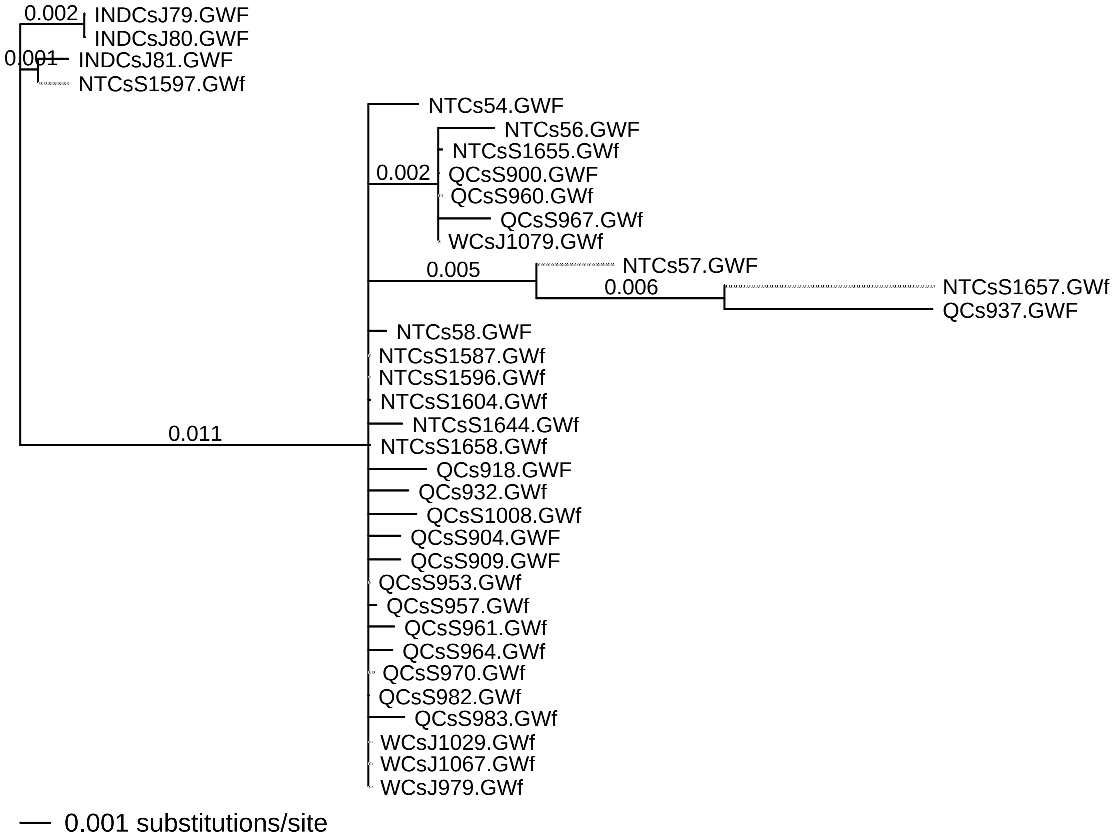


Figure 3.5-2: Consensus bootstrap neighbour joining tree showing similarity between mtDNA control region sequences for *C. sorrah* from Western Australia (W), Northern Territory (NT), Queensland (Q) and Indonesia (IND). Bootstrap support for the separation of the Indonesian clade was 99%.

Table 3.5-4: Character state table for polymorphic sites in mtDNA control region sequences for *C. sorrah*. Characters that are the same as the state above are indicated by ‘ . ‘. Some characters were not determined (N). Characters 167 and 359 had polymorphism with one base pair insertion/deletion (ID).

	site 44	site 67	site 161	site 167	site 172	site 178	site 242	site 261	site 271	site 300	site 353	site 359	site 420	site 431	site 434	site 435	site 436	site 705	site 711
Indonesia																			
INDCsJ79	T	A	T	G	T	C	A	C	A	A	T	A	T	A	A	T	G	N	N
INDCs83	N	N	.	ID	.	.	N	N	N	N	N	N	N	N	N	N	N	N	N
INDCsJ80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	N	N
INDCsJ81	C	.	.	.	.	A	.	.	.	.	.	.	.	.	.	.	.	N	N
Northern Territory																			
NTCs54	.	.	.	A	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
NTCs56	.	.	.	.	C	A	G	T	G	G	C	G	C	.	.	.	.	N	N
NTCs57	.	G	.	.	C	A	G	T	G	.	N	N	N	N	N	N	N	N	N
NTCs58	N	N	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
NTCsS1587	N	.	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
NTCsS1596	N	.	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
NTCsS1597	N	.	.	.	.	A	.	.	.	.	.	.	.	.	.	.	.	A	A
NTCsS1604	.	.	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	G	G
NTCsS1644	.	G	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
NTCsS1655	.	.	.	.	C	A	G	T	G	G	C	.	C	.	.	.	.	G	G
NTCsS1657	.	.	.	A	C	A	G	T	G	.	C	ID	C	N	N	N	N	N	N
NTCsS1658	.	.	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	G	G
Queensland																			
QCs918	.	.	.	.	C	A	G	T	G	.	C	.	.	.	.	.	.	N	N
QCs932	N	N	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
QCs937.	N	N	N	N	N	N	N	N	N	N	C	ID	C	G	G	G	A	N	N
QCsS1008	N	N	.	.	C	A	G	.	G	.	C	.	C	.	.	.	.	N	N
QCsS900	.	.	.	.	C	A	G	T	G	G	C	.	C	.	.	.	.	N	N
QCsS904	.	.	.	.	C	A	G	T	G	.	C	.	.	.	.	.	.	N	N
QCsS909	.	.	.	.	C	A	G	T	G	.	C	.	.	.	.	.	.	N	N
QCsS953	.	.	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
QCsS957	.	.	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
QCsS960	.	.	.	.	C	A	G	T	G	G	C	.	C	.	.	.	.	N	N
QCsS961	.	.	.	.	C	A	G	T	G	.	C	.	.	.	.	.	.	N	N
QCsS964	N	N	.	.	C	A	G	T	G	.	C	.	.	.	.	.	.	N	N
QCsS967	N	N	C	.	C	A	G	T	G	G	C	.	C	.	.	.	.	N	N
QCsS970	N	N	N	N	N	N	G	T	G	.	C	.	C	.	.	.	.	N	N
QCsS982	N	N	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
QCsS983	N	N	N	N	C	A	G	T	G	.	C	.	.	.	.	.	.	N	N
Western Australia																			
WCsJ1029	N	N	N	N	N	N	G	T	G	.	C	.	C	.	.	.	.	N	N
WCsJ1067	.	.	.	.	C	A	G	T	G	.	C	.	C	.	.	.	.	N	N
WCsJ1079	.	.	.	.	C	A	G	T	G	G	C	.	C	.	.	.	.	N	N
WCsJ979	N	N	N	N	N	N	G	T	G	.	C	.	C	.	.	.	.	N	N

3.6 Discussion

The degree of genetic subdivision in two species of northern Australian commercial sharks (*C. tilstoni* and *C. sorrah*) revealed by two types of DNA-based markers (microsatellites and mitochondrial DNA control region) in this study is similar to the previous allozyme study (Lavery and Shaklee, 1989). Both this study and the previous study report overall low levels of genetic subdivision. The measure of population subdivision (F_{ST}) for *C. tilstoni* when measured using allozyme loci was 0.0094. It was 0.006 – 0.009 in this study using microsatellite loci. Similarly, the measure of population subdivision (F_{ST}) for *C. sorrah* when measured using allozyme loci was 0.0076 and it was 0.004 – 0.008 in this study using microsatellite loci. Both studies found that *C. sorrah* was marginally less subdivided than *C.*

tilstoni, which correlates with a tag release study that concluded that *C. sorrah* was more mobile than *C. tilstoni* (Stevens *et al.*, 2000). Interestingly, our microsatellite data suggests significant population subdivision within the Australian distribution of *C. limbatus* – population pairwise F_{ST}'s varied from 0.008 to 0.025. Within their Australian ranges for these shark species, intraspecific mtDNA sequence data was insufficiently polymorphic to provide corroborating evidence for the patterns of subdivision inferred from microsatellite data. However, there is no evidence for separate genetic populations of *C. tilstoni* (Figure 3.6.2) which suggests this species, when considered independently of its sibling species, C. limbatus, forms a single northern stock. However, since they cannot readily be distinguished in the field, they should be treated as a combined species (see discussion below and Figures 3.6.3).

The microsatellite and mtDNA analysis of *C. sorrah* from Australian and Indonesian waters has demonstrated convincingly that while *C. sorrah* may move on a large scale along the northern Australian coast, genetic subdivision is present between Australia and Indonesia (Figure 3.6-1). This implies that the species disperses widely along the Australian continental shelf but does not move offshore into Indonesian waters. The distance between the northernmost extent of the Australian continental shelf, the Sahul Banks, and shallow Indonesian habitat is less than 200 nautical miles suggesting that deep water may be an effective barrier to movement in *C. sorrah*. Despite this, phylogenetic analyses of mitochondrial control region sequences from Australian and Indonesian *C. sorrah* highlighted an individual that was collected from the waters of the Northern Territory, but clearly carries Indonesian mtDNA. Given mtDNA is maternally inherited and clearly distinguishes between Indonesian and Australian populations, it is likely that the individual or its immediate maternal ancestors have immigrated from Indonesia. This shows that movement of *C. sorrah* is possible between the two countries, but is presumably rare as even small amounts of gene flow would homogenize microsatellite allele frequencies. The other alternative, apart from possible laboratory cross-contamination of sample, is that immigrants occur, but do not join the local Australian breeding population. A pattern of one-way movement from Indonesia to Australia was also demonstrated by parasite (Lester *et al.*, 2001) and genetic (Ovenden and Street, Submitted) analysis in narrow-barred Spanish mackerel (*Scomberomorus commerson*).

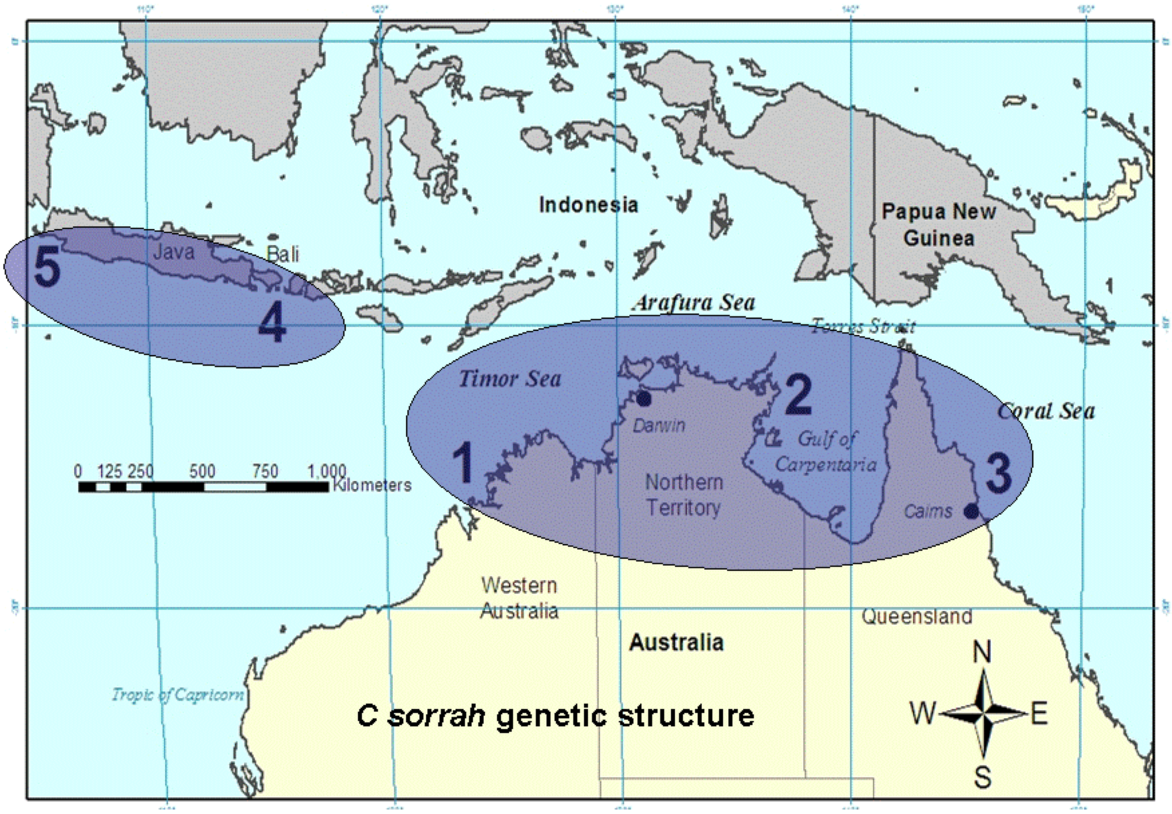
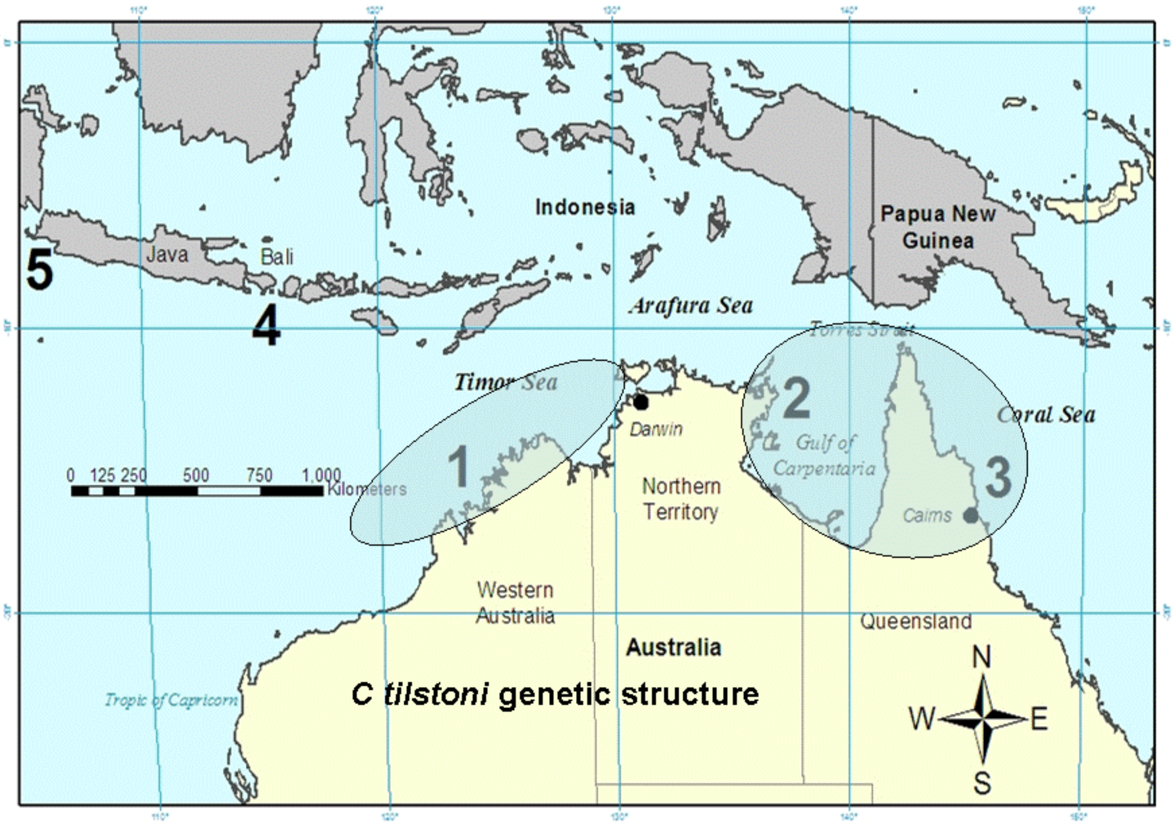


Figure 3.6-1: Graphic representation of proposed population structure of *C. sorrah* as revealed by mitochondrial and microsatellite fragment analyses.

The microsatellite data provides evidence that *C. limbatus* is subdivided between northern Australia and central Indonesia. Additionally, *C. limbatus* may be genetically subdivided within Australian waters. The population pairwise F_{ST}'s for *C. limbatus* from Western Australia, Northern Territory and Queensland ranged from 0.008 to 0.025, which are significantly larger than the corresponding pairwise F_{ST}'s for *C. sorrah* and *C. tilstoni* (0.004 to 0.009). This means all three populations of *C. limbatus* in Australia (sites 1, 2 and 3) are genetically separate and that they are all genetically separate from the Indonesian sites (sites 4 and 5 combined). Therefore, if the sibling species *C. limbatus* and *C. tilstoni* are treated as the same species (true in the field), their real population structure consists of at least four populations as shown in Figure 3.6.3. Dispersal in *C. limbatus* appears to be restricted across the deep waters separating northern Australia from central Indonesia as well as being restricted in the shallow waters of the northern Australian continental shelf. This infers there are significant differences among species in aspects of the biology of three Carcharinid sharks in northern Australian waters: *C. tilstoni*, *C. sorrah* and *C. limbatus*.

Figure 3.6-2: Graphic representation of proposed population structure of *C. tilstoni* as revealed by mitochondrial and microsatellite fragment analyses.



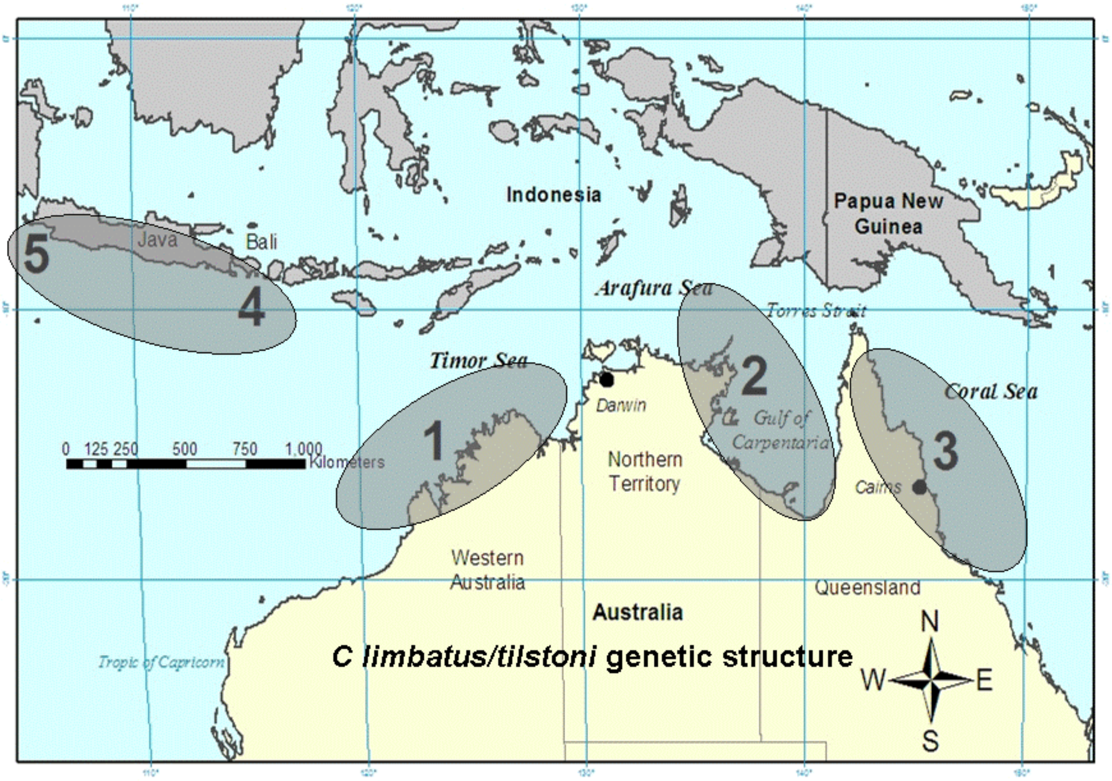


Figure 3.6-3: Graphic representation of proposed population structure of the 'phenotype' represented by both *C. limbatus* and *C. tilstoni* as revealed by mitochondrial and microsatellite fragment analyses.

This study also provided an opportunity to test the taxonomic validity of *C. tilstoni* amd *C. limbatus*. There was considerable confusion between these two species in genetic samples collected for this study by experienced fisheries biologists in Western Australia, Northern Territory and Queensland. A previous allozyme study (Lavery and Shaklee, 1991) found two allozyme loci with nearly fixed allele frequency differences between *C. tilstoni* and *C. limbatus* collected from Australian waters even though the character that they used to distinguish between species – dark colouration of the pelvic fins – is now known to be unreliable. This conundrum, and the apparent increase in the number of *C. limbatus* occurring sympatrically with *C. tilstoni* from 0.33% in Lavery and Shaklee (1991) to about the equal proportions reported here, await further study. The degree of genetic variation between the two species (F_{RT} = 0.041) was similar to the amount of intraspecific variation in *C. sorrah* between northern Australia and central Indonesia (F_{RT} = 0.040). However, the microsatellite data strongly suggests taxonomic validity as well as the absence of hybridization for *C. limbatus* and *C. tilstoni*. Samples of the two species collected from the same geographic location were consistently genetically separated (pairwise F_{ST} from 0.014 to 0.035). As the two species are genetically similar and *C. limbatus* is distributed worldwide while *C. tilstoni* is restricted to Australia, it is likely that *C. tilstoni* has arisen recently from *C. limbatus*. Interestingly, the extensive genetic subdivision reported here for *C. limbatus* from microsatellite data could be related to speciation events such as this.

3.7 Conclusion

Lavery and Shaklee (1989) concluded from their allozyme analysis of the population genetics of *C. tilstoni* and *C. sorrah* that there was no genetic evidence to suggest that the species should not be managed as single populations in Australia. This study, using highly polymorphic microsatellite loci and mtDNA, supports this (Figure 3.6.2). However, this study has found an upper limit to movement in these species; gene flow does not occur across the deep water that separates northern Australia and

Indonesia. This study makes an important additional contribution, however. A third black-tip shark species (*C. limbatus*), which is co-distributed with *C. tilstoni* and *C. sorrah*, in Australian waters has been shown to be genetically subdivided. Based on samples collected for this study, this species is equally abundant as *C. tilstoni* and presumably captured by the same methods. The two species appear the same in the field, except that *C. limbatus* matures at a significantly larger size than *C. tilstoni* (see graphs in Appendix 4). Because of their physical similarity, the combined genetic structure inferred from this study, means that the *C. limbatus/tilstoni* 'phenotype' in effect has separate populations at sites 1, 2, 3 and 4/5 (Figure 3.6.3). Exploitation practices that assume migration from other populations into areas of high harvest pressure may threaten this species when it is captured as part of the multi-species shark fishery. We recommend that existing limits to exploitation are essential for the long-term health of Australian populations of black-tipped sharks given the evidence presented here for finite gene flow.

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4. CHAPTER 4 – OBJECTIVE 3 SHARK BYCATCH IN GILLNET FISHERIES

Prepared by Richard Pillans

Objective 3 *To evaluate the effect of gillnet fishing on northern chondrichthyans, by determining bycatch composition (Qld N3 Net Fishery, Qld East Coast Gillnet Fishery, NT Barramundi Fishery, WA Kimberley Gillnet and Barramundi Fishery).*

This work addressed the lack of species composition information from fisheries that take sharks as bycatch. Current data records almost no shark catch from these fisheries, mainly caused by the sharks not being recorded as part of the catch either because they are discarded or because they are not considered part of the catch from those fisheries, such as the coastal barramundi fisheries. Gaining access to some of these fisheries proved more challenging due to logistical limitations with the vessels, although some useful data was obtained. Clearly, the bycatch of sharks will continue to be an area that lacks species information except where jurisdictions have committed to engaging observers specifically to address this information gap.

4.1 Method

To determine bycatch composition in gillnet fisheries, observers will be deployed in northern fisheries that are likely to catch elasmobranchs in their bycatch. There are some fisheries for which data is already available from previous and ongoing projects such as the Northern Prawn Fishery and the Queensland N3 Net Fishery (FRDC 1995/125 & FRDC 1999/125). This project will focus on inshore gillnet fisheries in QLD, NT and WA. Workshops were held in WA, QLD and NT with local fishers, managers and other stakeholders. At these the proposed observer program and its aims and potential benefits were discussed and agreement from fishers to allow observers to collect elasmobranch bycatch data was obtained.

Trained fisheries observers will attempt to accompany commercial operators in state fisheries that capture elasmobranchs as either target or bycatch fisheries using gill nets, long lines, prawn trawls and fish trawls. Observer effort will attempt to obtain data on the seasonal and temporal variations in catches from the various fisheries; however the primary objective is to describe the catch composition of the fisheries. Observers will record catch and effort data on a shot by shot basis. Data on the location of shots, gear type and fishing time will be recorded for each shot. Species specific catch data will be collected for all shots. Wherever possible, data on the length, sex and maturity status of individuals will also be collected. Maturity data will include uterine condition and number of pups for females and clasper length and degree of clasper calcification for males. These data will be collected to obtain biological data for species where this information is lacking. Table 4.1-1 shows data recorded by observers. Appendix 3 outlines the biological sampling protocol developed during this project to ensure consistency between observers. Genetic samples will be collected for Objectives 2 and 4 and biological samples for Objective 4. The species composition of the bycatch will be used in Objective 5 to assess the sustainability of northern Australian elasmobranchs. In conjunction with FRDC Project Proposal 2002/033 (PI Terry Walker) we will develop a common data sheet for each species, so that the minimum data collected is the same in all regions.

Table 4.1-1: Shot and species specific catch and biological data recorded by fisheries observers.

Shot data	Biological data
Shot ID	Shot ID
State	Species
Fishery acronym	Individual unique ID number
Shotdate	Sex
Start set time	Total length (cm)
Endset time	Fork length (cm)
Start haul time	Precaudal length (cm)
End haul time	Lower jaw total length (sawfish only)
Boat name	Weight (kg)
Skipper	Trunk weight (kg)
Recorder	Fin weight
Start shot latitude	Fillet weight
Start shot longitude	Umbilical scar (yes/no)
End shot latitude	Clasper length (mm)
End shot longitude	Clasper calcification (yes/no/partial)
Water depth (meters)	Runny sperm (yes/no)
Fishing method (gillnet, longline etc)	Maximum ova diameter
Meshsize (inches)	Number of yolky ova
Drop (meshes)	Uterine stage
Net ply	Number of embryo's
Net length (meters)	Number of undeveloped embryo's
Number of hooks	Average embryo length (cm)
Bait	Individual embryo length
Daily shot number	Stomach fullness
Sea conditions	Stomach content
Water temperature (degrees celcius)	Genetic sample ID
Comments	Dart tag number
	Fin tag number
	Release condition if released
	Comments

4.2 Results

Observer Program

The contribution of elasmobranchs to the total catch in target and bycatch fisheries calculated from logbook data in 2004 is shown in Table 4.2-1 and the spatial relationship of observer coverage is represented in Figure 2.2.1 (Chapter 2). We chose 2004 due to the overlap with the observer effort in this project. The highest catches of elasmobranchs in bycatch fisheries were recorded in the ECN (1300 t), N3 (246 t), NTFish Trawl Fishery (161 t), WAPilbara Fish Trawl Fishery (40.3) and the NT Restricted Bait Net (29.7 t).

The number of shots observed in each fishery by month is presented in Table 4.2-2. Observers from Queensland, Northern Territory and Western Australia collected species composition and biological data from bycatch fisheries with varying success. Access to inshore gillnet fisheries in the Gulf of Carpentaria and Northern Territory was difficult due to the remoteness of these areas. Also, fishers often use bush camps as a base for fishing making it difficult to access areas by road. As a result of this, observer coverage of these areas was not as comprehensive as expected. Coverage of the NT Barramundi fishery and NT Restricted Bait Net Fishery had the least observer coverage with only 14 and 3 shots recorded in each fishery, respectively. Anger amongst east coast net fishers as a result of

GBRMPA zoning plan also hindered observer effort in the east coast net fishery with limited opportunities for observers to board vessels. Data was therefore only collected from around Cairns and Princess Charlotte Bay.

Observers in WA collected catch composition and biological data from the Pilbara fish trawl fishery (PFTF) as part of this project. Observer data from the Northern Prawn Fishery (NPF) was determined from 1082 paired shots in the eastern NPF (Gulf of Carpentaria) and 20 paired shots in the western NPF (Joseph Bonaparte Gulf). Species composition data from Queensland Demersal Trawl Fishery (QDTF) were collected by observers involved in other projects. Additional data on the species captured in other non-target fisheries were obtained from state management agencies as well as AFMA.

Fishing methods in the inshore gillnet bycatch fisheries varies between states and fisheries. A summary of the methods, number of licences, depths and areas fished is provided in Tables 4.2.3 and 4.2.4 (Queensland Gulf of Carpentaria and East Coast), Table 4.2-4 and Table 4.2-5 (NT), Table 4.2-6 and Table 4.2-7 (WA)**.**

The number of observed shots and elasmobranchs recorded as well the percentage contribution by number per bycatch fishery is summarised in Table 4.2-1 and Table 4.2-1. Due to the priority of collecting elasmobranch catch data, teleosts were not always counted and therefore direct comparisons between the number of target and bycatch species is not possible with observer data. However, logbook data allows comparisons to be made.

The infrequent nature of data collection, lack of seasonal and spatial replication precludes detailed analysis of catch data; as a result, only broad comparisons between fisheries are made. Elasmobranchs are a major component of the inshore gillnet fishery bycatch and there are only a few species which are captured exclusively in bycatch gillnet fisheries but not in target gillnet fisheries (Table 4.2-9). These species are *Aetobatus narinari*, *Glyphis* sp. A, *Pristis clavata* and *P. microdon*. *Pristis zijsron* is predominantly captured in inshore gillnet fisheries but one specimen was recorded in the NTONL. Apart from *Glyphis* sp. A., all these species contributed less than 4.2 % of total elasmobranch catch in each fishery. In the NT Barramundi fishery, *Glyphis* sp. A made up more than 24 % of the elasmobranch catch.

Although the species composition in the bycatch fisheries was not significantly different to that in the target fisheries, the percent composition by number was markedly different for some species (Table 4.2-9). Of species captured in both inshore and offshore gillnet fisheries, *Carcharhinus amblyrhynchoides*, *C. amboinensis, C. cautus, C. fitzroyensis* and *C. leucas* were more abundant in inshore gillnet than offshore gillnet catches.

Carcharhinus sorrah was recorded in both inshore and offshore gillnet fisheries but contributed less to inshore than offshore catches in both Queensland and Western Australia. *Carcharhinus sorrah* was not recorded in inshore gillnet fisheries in the Northern Territory but this is most likely due to observer sampling effort.

In the N3 fishery, the dominant species were *C. leucas* (59.6 %), *C. tilstoni* (13.1 %) *E. blochii* (9.1 %). In the ECN fishery, *C. tilstoni* (33.1 %), *C. sorrah* (23.6 %), *C. dussumieri* and *R. acutus* (8.9 %) and *S. lewini* (8.4 %) dominated the catches.

In the NTBarr fishery, *C. leucas* (34.8 %), *Glyphis* sp. A (24.6 %) and *C. tilstoni* (18.8 %) were the dominant species. The only species recorded in the NTRBN fishery were *R. acutus* (85.7 %) and *C. tilstoni* (14.3 %).

Table 4.2-1: Total elasmobranch and total catch of teleosts and elasmobranchs (tonnes) from 2004 state and territory logbook data. Elasmobranch catches have been ordered from high to low. Target fisheries are highlighted. The complete listing of the names represented by these fishery acronyms are provided in Table 4.2-3, Table 4.2-5 and Table 4.2-7.

State	Fishery acronym	Total elasmobranch catch 2004 (tonnes)	Total catch (all species) 2004 (tonnes)	Percent (%) contribution of elasmobranchs to total catch
Qld	ECN	1300	6500	20
Qld	N3	246	1674.5	14.7
Qld	*N9*	*189*	*515*	*36.7*
NT	*NTONL*	*1080*	*1600*	*67.5*
NT	NTFTF	161	1000	16.1
NT	NTRBN	29.7	72.4	41.0
NT	NTCL	8.3	312	2.6
NT	NTBarr	3.7	1095	0.3
NT	NTCN	2.8	15.5	18.1
NT	NTDF	No data*	No data*	No data*
NT	NTTRF	0	700	0
WA	*WANSF*	*1293.6*	*1293.6*	*100*
WA	WAPFTF	40.285	2893	1.4
WA	WANCSLF	No data*	No data*	No data*
WA	WAEMBGF	No data*	No data*	No data*
WA	WAKP	3.182	437	7.3
WA	WAKGBF	2.6	136.1	1.9
WA	WAEGPT	2.56	1449	0.17
WA	WAEGBSG	No data*	No data*	No data*
WA	WANBPF	0.234	124	0.18
WA	WAOPF	0.064	215	0.03
WA	WAPTF	0.019		?
WA	WANDSF	0	690	0
WA	WABP	0	124	0

* Less than five vessels so confidentiality agreement prevents use of catch data. No elasmobranchs are retained, however post release mortality has not been evaluated.

Table 4.2-2: Number of shots observed per bycatch fishery per month from 2000 – 2004 for bycatch fisheries. N3= Queensland Gulf of Carpentaria fishery from shore out to 7 nautical miles, ECN = East coast net fishery, NTBarr= NT Barramundi fishery, NTRBN= NT Restricted Bait Net Fishery, WAEMBGF= Eighty Mile Beach Gillnet Fishery, WAKGBF= Kimberly Gillnet Barramundi Fishery, WAPFTF= WAPilbara Fish Trawl Fishery.

State	Fishery acronym	TOTAL	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Qld	N3	30					12				12			6
Qld	ECN	40				8		3		7	8			14
NT	NTBarr	14				11	3							
NT	NTBN	3					3							
WA	WAKGBF	88								5	18	27	19	19
WA	WAEMBGF	28								13		4	11	
WA	WAPFTF	426	31	28	31	30	45	60	55	28	26	31	30	31

Table 4.2-3: Summary of fishery acronym, fishery name, gear type, minimum and maximum mesh and net length restrictions, and closed seasons for Queensland fisheries addressed in this study

Fishery acronym	Fishery type	Fishery name	Gear type	Min mesh size (mm)	Max mesh size (mm)	Max net length (m)	Closed seasons
C1	Pot	Queensland commercial mudcrab fishery	Crab pots, dillies or inverted dillies	NA	NA	NA	NA
L4	Line	Queensland joint authority line fishery (0 to 25 nautical miles)	Hand held fishing lines and fishing rods with hand or mechanically operated reels and lines	NA	NA	NA	NA
L5	Line	Queensland joint authority line fishery (0 to 3 nautical miles)	Hand held fishing lines and fishing rods with hand or mechanically operated reels and lines	NA	NA	NA	NA
N3	Gillnet	Queensland Gulf of Carpentaria inshore finfish fishery	Set mesh nets	162.5	245	600	Sept-Feb
N6	Bait Net	Queensland bait net fishery	Cast, mesh, scoop or seine nets	50	50	NA	NA
N7	Bait Net	Queensland bait net fishery	Mesh or seine nets	50	50	400	NA
N9	Gillnet	Queensland Gulf of Carpentaria inshore finfish fishery (offshore component)	Set mesh nets	162.5	245	1200	Sept-Feb
QDFT	Fish Trawl	Queensland demersal fish trawl fishery	Semi pelagic demersal trawl. Restricted beyond 25 nautical miles from coast & north of 15 degrees South.	110	NA	NA	NA

Table 4.2-4: Summary of target species, gear restriction, access to fishery, fishing area and depth, number of licensed and operational vessels, fishing effort in 2004 and effort units for Queensland fisheries addressed in this study

Fishery acronym	Target species	Gear and catch restrictions	Access to fishery	Min latitude	Max latitude	Min depth	Max depth	Number of licensed vessels	Number of operational vessels	Effort 2004	Effort units
C1	crabs other than spanner crabs	Pot restrictions	Licence, limited entry	137.6	154	0	10	850	66	4943	boat days
L4	Finfish	Apparatus restrictions	Licence, limited entry	137.6	142.3	0	30	43	3	31	boat days
L5	Finfish	Apparatus restrictions	Licence, limited entry	137.6	142.3	0	30	5	1	3	boat days
N3	Barramundi	Area and seasonal closures, mesh size and net length	Licence, limited entry	137.6	142.09	0	15	87	52	2638	boat days
N6	garfish, mullet	Net restrictions	Licence, limited entry	137.6	142.09	0	10	NA	NA	NA	NA
N7	mullet, garfish, blue salmon,	Net restrictions	Licence, limited entry	137.6	142.09	0	30	NA	NA	NA	NA
N9	Shark (*Carcharhinus tilstoni* and *C. sorrah*), grey mackerel	Area and seasonal closures, net mesh size, drop and length, boat length	Licence, limited entry	137.6	142.09	10	30	5	2	460	boat days
QDFT	Red Snapper	Area and seasonal closures, mesh size and net length	2 non-transferable permits	139	142	10	80	2	NA	NA*	boat days

Table 4.2-5: Summary of fishery acronym, fishery name, gear type, minimum and maximum mesh and net length restrictions, and closed seasons for Northern Territory fisheries addressed in this study

Fishery acronym	Fishery type	Fishery name	Gear type	Min mesh size (mm)	Max mesh size	Max net length (m)	Closed seasons
NTONL	Gillnet, Longline	NT Offshore Net and Line (formerly NTFJA)	surface set gillnets, monofilament, drop 50-100 meshes, weighted and a buoyed headline.	160	185	2000	None
NTBarr	Gillnet	NT Barramundi Fishery	gillnet >50 if monofilament; mesh size 150 in most tidal mud flats, 175 in the open rivers; length 1,000 (some licences are restricted to less)	150	175	1000	Oct-Jan
NTRBN	Bait Net	Restricted Bait Net entitlement	gillnet, 65 mm stretched mesh, drop 5m, length 100 (if used as fixed gillnet), 200 m if used as a surround net (usually only in mackerel fishery for garfish)	NA	65	100 (see previous)	None
NTBN	Bait Net	NT Bait Net Fishery	bait net not anchored or staked hand hauled, cast net, scoop net and gaff	NA	65	300	None
NTCN	Gillnet	NT Coastal Net Fishery	gillnet/haulnet; 300 long, 5 drop	NA	65	300	None
NTFTF	Fish Trawl	NT Finfish Trawl Fishery	semi pelagic demersal trawl	110			None
NTM	Line	NT Mackerel Fishery	Any number or combination of troll line, floating handline, rod and line. Restricted bait net to collect bait in coastal waters.	NA	NA	NA	None
NTTRF	Line and Trap	NT Timor Reef Fishery	Droplines, handlines, mechanically assisted haul lines and traps	NA	NA	NA	None
NTCL	Line and Trap	NT Coastal Line Fishery	Line throughout whole fishery, and a maximum of 5 traps per licence may be used in waters outside 2 n mile. Little trap fishing reported to date.	NA	NA	NA	None
NTDF	Line and Trap	NT Demersal Fishery	Handlines, hydraulically powered hauled lines and traps	NA	NA	NA	None

Table 4.2-6: Summary of target species, gear restriction, access to fishery, fishing area and depth, number of licensed and operational vessels, fishing effort in 2004 and effort units for Northern Territory fisheries addressed in this study.

Fishery acronym	Target species	Gear and catch restrictions	Access to fishery	Min latitude	Max latitude	Min depth	Max depth	No of licenses issued	No of operational vessels	Effort 2004	Effort units
NTONL	Mackerel (*Scomberomorus semifasciatus*) and shark (*Carcharhinus tilstoni* and *C. sorrah*)	Net and longline length day effort units	Licence, limited entry with	129.4	138.5	0	80	23	13	1575	Boat days
NTBarr	Barramundi and threadfin salmon	Gillnet units, area and seasonal closures; SHARK CATCH=<500 KG WHOLE/TRIP	Licence, limited entry	130.6	137.6	0	20	24	24	3520	Boat days
NTRBN	Catfish, mullet, salmon and shark	Restrictions on nets to harvest bait	Entitlement attached to a fishing licence to access. All NT licences have this entitlement but mostly used by mudcrab fishers	130.6	137.6	0	10	All NT licences		7006	Boat days
NTBN	Mullets, blue salmon, trevallies and queenfish, shark	Restriction on gear & species taken	Licence, limited entry	130.6	137.6	0	10		2	31	Boat days
NTCN	Blue Salmon, mullet, sharks etc.	Net length, mesh size, area closures; SHARK CATCH=<500 KG WHOLE/TRIP	Licence, limited entry	130.6	137.6	0	10	14	2	197	Boat days
NTFTF	Red snapper (*Lutjanus malabaricus*, *L. erythropterus*)	Net restrictions; NO SHARK PERMITTED	Limited Entry	131	137.4	30	120	1	1	<5 operators: confidential	Boat days
NTM	Narrow-barred Spanish Mackerel (*Scomberomorous commerson*), observed bycatch is low due to fishing technique targetting schools of mackerel	NO SHARK PERMITTED	Licence, limited entry 2 for 1 licence reduction program	129.4	137.6	0	20	19	12	875	Boat days (only troll line fishers)

Fishery acronym	Target species	Gear and catch restrictions	Access to fishery	Min latitude	Max latitude	Min depth	Max depth	No of licenses issued	No of operational vessels	Effort 2004	Effort units
NTTRF	Goldband snapper & sharp tooth snapper	NO SHARK PERMITTED	Licence, limited entry, area restriction	129.4	132.2	30	120	12	8	1479	Boat days
NTCL	Jewfish, snappers etc.	Limits on gear including hooks and traps; SHARK CATCH=<500 KG WHOLE/TRIP	Licence, limited entry; Note can fish out to 15 nm; 2:1 licence reduction	130.6	137.6	0	80	56	34	1186	Boat days
NTDF	Red snapper (*Lutjanus malabaricus*, *L. erythropterus*)	NO SHARK PERMITTED	Licence, limited entry (15 nautical mile out to EEZ)	130.6	137.6	30	120	60	3	203	Boat days

Table 4.2-7: Summary of fishery acronym, fishery name, gear type, minimum and maximum mesh and net length restrictions, and closed seasons for Western Australian fisheries addressed in this study. Note there is a WA Open Wetline fishery but it is outside the managed areas and hence not included (no data).

Fishery acronym	Fishery type	Fishery name	Gear type	Minimum mesh size (mm)	Maximum mesh/hook size	Maximum net length (m)	Closed seasons
WANSF	Demersal Longline	WA Northern shark fisheries (replaces WANCSF & WAFJA)	Gillnet and Longline (to 300 days longline and 600 days gillnet)	n/a	n/a	none	None
WAKGBF	Gillnet	WA Kimberley Gillnet & Barramundi Fishery	gillnet	n/a	n/a	Unrestricted; 600m-1000m in practice	None
WAEMBGF	Gillnet	WA Eighty Mile Beach Gillnet Fishery	demersal gillnet	n/a	n/a	none	None
WAEGBSG	Gillnet	WA Exmouth Gulf Beach Seine & Gillnet Fishery	Seine, gillnet	n/a	n/a	n/a	None
NCSL	Dropline and longline	WA North coast setline	Dropline, longline, handline and unspecified line	No metal snoods in the Pilbara, otherwise unrestricted	n/a	n/a	None
WANDSF	Trap and Line	WA Northern Demersal Scalefish Fishery	trap, dropline, handline	Nylon mono (no metal permitted)	n/a	n/a	None
WAPTF	Trap	WA Pilbara Trap Fishery	trap	n/a	n/a	none	None
WAPFT	Fish Trawl	WA Pilbara Fish Trawl Fishery	Demersal Fish Trawl	n/a	100 mm	n/a	None but some vessels operate in WANBPF so only fish off-season
WABP	Prawn Trawl	WA Broome Prawn Trawl Fishery	Demersal Prawn Trawl	n/a	n/a	n/a	Varies, Aug-May (inclusive in 2000)

Fishery acronym	Fishery type	Fishery name	Gear type	Minimum mesh size (mm)	Maximum mesh/hook size	Maximum net length (m)	Closed seasons
WAEGPT	Prawn Trawl	WA Exmouth Gulf Prawn Trawl Fishery	Demersal Trawl with TED's and BRD's	NA	n/a	n/a	Varies, Nov-Mar (inclusive in 2000)
WAKP	Prawn Trawl	WA Kimberley Prawn Trawl Fishery	Demersal Trawl with TED's and BRD's	NA	n/a	n/a	Varies; May, July-Oct, Jan-Apr (inclusive in 2000)
WANBPF	Prawn Trawl	WA Nickol Bay Prawn Fishery	Demersal Prawn Trawl	NA	n/a	n/a	Varies; Dec-Feb (inclusive in 2000)
WAOPF	Prawn Trawl	WA Onslow Prawn Fishery	Demersal Prawn Trawl	NA	n/a	n/a	Varies; Nov-Feb (inclusive in 2000)

Table 4.2-8: Summary of target species, gear restriction, access to fishery, fishing area and depth, number of licensed and operational vessels, fishing effort in 2004 and effort units for Northern Territory fisheries addressed in this study

Fishery acronym	Target species	Gear and catch restrictions	Access to fishery	Min latitude	Max latitude	Min depth	Max depth	Number of licensed vessels	Number of operational vessels	Effort 2004	Effort units
WANSF	Sharks		Licence	120	129	0	150	14	7	1246	Equivalent hook days (Gillnet effort prior to 2002/03 standardised in longline units, as per McAuley et al., 2005)
WAKGBF	Barramundi, threadfin salmon		Licence	121	129	0	10	7	7	825	boat days
WAEMBGF	Threadfin salmon and shark		Licence	114	121.5	0	8	2	1	112	boat days
WAEGBSG	Whiting and mullet		Licence	114.16	114.75	0	5	6	2	112	boat days
NCSL	Demersal finfish - spangled emperor, red emperor, jobfish, Rankin cod, other cod	No metal trace in Pilbara	Open (Kimberley longline through a loophole caused by OCS)	114	129	0	200			52242	hook days
WANDSF	Reef fish - demersal scalefish		Licence	120	130.6	0	150	11	7	820	boat days
WAPTF	Demersal finfish - spangled emperor, red emperor, jobfish, Rankin cod, red emperor		Licence	114.9	120	30	200	5	5	420	boat days

Fishery acronym	Target species	Gear and catch restrictions	Access to fishery	Min latitude	Max latitude	Min depth	Max depth	Number of licensed vessels	Number of operational vessels	Effort 2004	Effort units
WAPFTF	Blue spot emperor, red snapper, red emperor, flagfish, threadfin bream, Rankin cod			114.9	120	50	200	11	8	971	boat days
WABP	Penaeid prawns	Vessel size, net head-rope lengths and mesh size specifications	Licence, limited entry, time and area closures (input controls)	120	123.75	10	30	5	5	307	boat days
WAEGPT	Penaeid prawns			114.16	114.75	10	30	16	13	2522	boat days
WAKP	Penaeid prawns		Licence, limited entry	123.75	127	10	30	134	22	1168	boat days
WANBPF	Penaeid prawns			116.75	120	10	30	14	17	725	boat days
WAOPF	Penaeid prawns			114.66	116.75	10	30		10	785	boat days

Although the species composition is not significantly different to that in the target fisheries, the percent composition by number is markedly different for some species. Of species captured in both inshore and offshore gillnet fisheries, *Carcharhinus amblyrhynchoides, C. amboinensis, C. cautus, C. fitzroyensis* and *C. leucas* were more abundant in inshore gillnet than offshore gillnet catches.

Carcharhinus sorrah was recorded in both inshore and offshore gillnet fisheries but contributed less to inshore than offshore catches in both Queensland and Western Australia. *Carcharhinus sorrah* was not recorded in inshore gillnet fisheries in the Northern Territory but this is most likely due to observer sampling effort.

In the N3 fishery, the dominant species were *C. leucas* (59.6 %), *C. tilstoni* (13.1 %) *E. blochii* (9.1 %). In the ECN fishery, *C. tilstoni* (33.1 %), *C. sorrah* (23.6 %), *C. dussumieri* and *R. acutus* (8.9 %) and *S. lewini* (8.4 %).

In the NTBarr fishery, *C. leucas* (34.8 %), *Glyphis* sp. A (24.6 %) and *C. tilstoni* (18.8 %) were the dominant species. The only species recorded in the NTRBN fishery were *R. acutus* (85.7 %) and *C. tilstoni* (14.3 %).

In the EMBGF fishery, *C. amboinensis* (42.5 %), *C. cautus* (18.3 %), *Anoxypristis cuspidata* (12.5 %), *C. amblyrhynchoides* (7.1 %) and *C. tilstoni* (6.7 %) dominated the catches. A similar trend was seen in the KGBF fishery with *C. amboinensis* (43.8 %), *A. cuspidata* (13 %), *C. tilstoni* (10 %), *C. cautus* (6.4 %) and *C. leucas* (5.4 %) being the dominant species.

Species composition in the trawl fisheries was different to the target and bycatch gillnet fisheries. Twenty two species were recorded in longline and gillnet but not in trawl gear while eleven species were recorded in fish and prawn trawls but not in gillnet or longline. Species recorded in trawls but not other gear were mainly stingrays and benthic sharks that either do not encounter gillnets and long lines or are not captured due to their size and shape. Smaller Carcharhinid species such as *Carcharhinus tilstoni* and *C. dussumieri* were more common in trawls while larger species were predominantly absent from catches. Benthic species such as stingrays, shovelnose sharks and guitarfish were more commonly captured in trawl gear. *Hemigaleus australiensis* was the most abundant species in the WAPFTF (22.4%) followed closely by undifferentiated Dasyatids and Rhinobatids (13.5 and 14.3 %). *Rhynchobatus australiae* and *Rhizoprionodon acutus* comprised 10.1 and 9.4 % of the elasmobranch catch in the WAPFTF.

In the eastern NPF, *Carcharhinus dussumieri* (19 %), *C. tilsoni* (12.8 %), *Gymnura australis* (13 %), *Himantura toshi* (9.3%), *Rhynchobatus australiae* (9 %) and *Chiloscyllium punctatum* (8.8 %) were the dominant species. In the western NPF, *Dasyatis annotata* (67.3 %), *Gymnura australis* (14.9 %), *Rhizoprionodon acutus* (6.1 %) and *Himantura toshi* (5.1 %) dominated the catches.

Observers did not collect data on the catches in the following fisheries: L4, L5, N6, N7, NTCL, NTTRF, NTDF, NTM, WAEGBSG, WANDSF, WAPTF, WABP, WAEGPT, WAKP, WANBPF, WAOPTF. Apart from the WA prawn trawl fisheries where the species composition was assumed to be similar to the western NPF, all other fisheries capture very few elasmobranchs. Species composition in bait net fisheries (N6, N7) was determined from scientific surveys (Stirling Peverell, QDPIF, *pers. comm.*2006). Catches of elasmobranchs in troll, dropline and trap fisheries targeting teleosts was obtained from state fisheries and were negligible.

Table 4.2-9: **Summary of all observer data as percent contribution by numbers per fishery for bycatch fisheries including total number of elasmobranchs and number of observed shots. N3= Queensland Gulf of Carpentaria fishery from shore out to 7 nautical miles, ECN = East Coast net fishery, NTBarr= NT Barramundi, NTRBN= NT Restricted Bait Net Fishery, EMBGF= Eighty Mile Beach Gillnet Fishery, KGBF= Kimberly Gillnet Barramundi Fishery, PFTF= Pilbara Fish Trawl Fishery, NPF East= NPF Gulf of Carpentaria, NPF West= NPF Joseph Bonaparte Gulf.**

Fishery	N3	ECN	NTBarr	NTRBN	EMBGF	KGBF	PFTF	NPF East	NPF West
Total elasmobranchs	**99**	**907**	**69**	**7**	**240**	**592**	**2497**	**1428**	**369**
Number of shots observed	**18**	**52**	**14**	**3**	**28**	**88**	**404**	**1084**	**23**
Aetobatus narinari	2.0		1.4						
Aetomylaeus nichofii								1.3	
Anoxypristis cuspidata	3.0		1.4		12.5	13.0	0.2	0.3	0.36
Brachaeluridae - undifferentiated							0.5		
Carcharhinus albimarginatus									
Carcharhinus altimus							0.2		
Carcharhinus amblyrhynchoides		0.2			7.1	3.0			
Carcharhinus amblyrhynchos		0.6							
Carcharhinus amboinensis		0.1			42.5	43.8	0.1		
Carcharhinus brevipinna		1.0			1.3		< 0.1		
Carcharhinus cautus		0.2			18.3	6.4			
Carcharhinus dussumieri		8.9					4.1	19.1	0.11
Carcharhinus fitzroyensis		7.5							
Carcharhinus leucas	59.0	0.8	34.8			5.4			
Carcharhinus limbatus	1.0								
Carcharhinus macloti	1.5	1.21			1.3				
Carcharhinus melanopterus						0.2			
Carcharhinus obscurus									
Carcharhinus plumbeus		0.2					3.6		
Carcharhinus sorrah		23.6				0.2	1.0	0.5	
Carcharhinus tilstoni	13.1	33.1	18.8	14.3	6.7	10.0	3.2	12.8	0.71
Carcharias taurus									
Chiloscyllium punctatum							1.7	8.8	0.35
Dasyatidae - undifferentiated					0.4	0.2	13.5		
Dasyatis annotata								6.7	67.34
Dasyatis kuhlii								1.4	
Dasyatis leylandi								5.0	
Eucrossorhinus dasypogon							0.2		
Eusphyra blochii	9.1	0.8	8.7		3.3	5.2	< 0.1		0.80
Galeocerdo cuvier		0.1					0.2		
Glyphis sp. A	0.3		24.6						
Glyphis sp. C									
Gymnura australis								13.0	14.93
Hemigaleus australiensis		0.2					22.4	5.1	3.39
Hemipristis elongata	2.0	1.5					1.1	0.2	
Himantura toshi								9.3	5.13
Himantura uarnak								0.1	
Himantura undulata								0.1	
Loxodon macrorhinus						0.7	< 0.1		
Manta birostris									
Mobula eregoodootenkee									
Mustelus sp. B									

Fishery	**N3**	**ECN**	**NTBarr**	**NTRBN**	**EMBGF**	**KGBF**	**PFTF**	**NPF East**	**NPF West**
Nebrius ferrugineus							0.2		
Negaprion acutidens			1.4		2.5	3.2			
Orectolobus wardi							0.1		
Pastinachus sephen								0.1	
Pristis clavata					2.1	4.2			
Pristis microdon		0.2							
Pristis zijsron	1.0		1.4		1.7	1.4	0.1		
Rhina ancylostoma							0.2		
Rhinobatidae - undifferentiated					0.4		14.3		
Rhinobatus typus	3.0	0.2							
Rhinoptera neglecta									
Rhizoprionodon acutus		8.9	4.3	85.7		2.2	9.5	6.5	6.07
Rhizoprionodon oligolinx		0.1							
Rhizoprionodon taylori		0.2				0.7	4.6		
Rhynchobatus australiae	6.0	1.0	2.9			0.2	10.1	9.0	0.80
Sphyrna lewini		8.4					4.6	0.4	
Sphyrna mokarran		0.6					0.3	0.1	
Sphyrna zygaena							< 0.1		
Stegostoma fasciatum		0.2					4.0		
Taeniura meyeni								0.1	
Triaenodon obesus									

4.3 Discussion

Data from state and territory logbooks was used to determine the total catch of elasmobranchs in bycatch fisheries in 2004 (Table 4.2-1). Limited observer coverage in bycatch fisheries did not allow for detailed analysis or comparison of CPUE and size distribution between fisheries. Fisheries with the highest elasmobranch bycatch were the Queensland East Coast Net fishery (ECN = 1300 t), Queensland Gulf of Carpentaria inshore finfish fishery (N3 = 246 t), Northern Territory Finfish Trawl Fishery (NTFT = 170 t) and the WA Pilbara Fish Trawl Fishery (WAPFT = 40.3 t). Although no data on catch rates of elasmobranchs were available from the Queensland Demersal Fish Trawl Fishery (QDFT), catches of elasmobranches are likely to be comparable to the NTFT given the nature of the gear and the fact that both fisheries target the same species.

The total elasmobranch bycatch in the ECN is significantly higher than the targeted catch of sharks in the N9, WANSF and NTONL fisheries (see section 1). Although the east coast of Queensland is a larger area, these high catches in a bycatch fishery warrant further research with respect to spatial changes in species composition and catch rates. The high catches of elasmobranchs in the N3 fishery are of also of concern and species specific catches should be monitored closely in the future. This should be achievable given the QDPI commitment to placing an observer in the N3 fishery (NSAG 2005 meeting, Darwin).

In comparison to the ECN and N3 fisheries, bycatch of elasmobranchs in the NT Restricted bait net (NTRBN = 29.7 t), WA Eighty Mile Beach Gillnet Fishery (WAEMBGF = 11.6 t), NT Barramundi Fishery (NTBarr = 3.7 t) and WA Kimberly Gillnet and Barramundi Fishery (WAKGBF = 2.6 t) was significantly lower. However due to the inshore nature of these fisheries and the number of threatened and protected species they interact with, monitoring of species specific catch rates is required under the NPOA - Sharks. The level of under reporting in these fisheries is unknown but may significantly underestimate catches.

In the NTBarr fishery, reported elasmobranch catch is very low, representing less than 0.4 % of the total catch. Limited observer coverage in this fishery as well as observations inside river mouths prior to the implementation of the 2005 NT Barramundi Management Plan prevents extrapolation of observed catch data to determine the true elasmobranch catch. Given the similarities between the N3 and the NTBarr fishery and the high percent of elasmobranchs (14.7%) in the N3, it is likely that elasmobranch bycatch in the NTBarr fishery is significantly higher than that reported. Although a 500kg elasmobranch catch limit per trip has recently been implemented for the NTBarr fishery the high contribution species, such as *Glyphis* sp. A and *C. leucas*, (Table 4.2-8) to the catches of observed shots suggests that this fishery needs to be more closely monitored. The catch limit may result in better reporting of catches in this fishery, however independent assessment of catch should be investigated.

Appendix 3 shows level of species specific recording in the state and territory logbooks for fisheries that target elasmobranchs. The Northern Territory has the highest level of detail, with 11 species recorded in the logbooks. Western Australian logbooks record 6 species and Queensland, four species. Although the current NT and WA logbook has categories for recording species specific elasmobranch catch data, species specific catches are not recorded in WA and NT fisheries that capture elasmobranchs as bycatch. Management action is required to introduce species specific catch data in order to meet the objective of the National Plan of Action for the Conservation and Management of Sharks (NPOA – Sharks). The primary objective of the NPOA – Sharks is: "to ensure that shark catches from target and non-target fisheries are sustainable" while objective 9 in the NPOA – Sharks is: "to facilitate improved species specific catch and landings data and monitoring of shark catches". Ecologically sustainable development of fisheries cannot occur if species specific catches of elasmobranchs are not recorded particularly when some of these species are threatened and protected. Introduction of species specific logbooks will require fisher education, both in identification of elasmobranch species, as well the need to report elasmobranch bycatch in order to meet EPBC act requirements. User friendly field guides, specific to northern Australian elasmobranchs are also required to aid fishers in identification of elasmobranchs.

Observer data: Gill net fisheries

The data collected by the observers provides the first insight into the species composition of bycatch fisheries and it is apparent that species composition in bycatch fisheries is significantly different from target fisheries. Also, observer data highlighted the diversity of elasmobranch bycatch and the urgent need for species specific log book data to be collected.

Four species were captured exclusively by inshore gillnet bycatch fisheries. These species were *Aetobatus narinari*, *Glyphis* sp. A, *Pristis clavata* and *P. microdon*. Of these species, *A. narinari* is the only one that is not threatened by fishing activity. Although *A. narinari* has a preference for shallow inshore areas where nets are often placed, there is currently no market for this species in the northern fisheries and as a result, most animals are released alive.

Threatened and protected species interaction with gill net fisheries

The abundance and distribution of *Glyphis* sp. A, *P. clavata*, P. *microdon* and *P. zijsron* in northern Australia is thought to have declined significantly in the past 20 years (Stevens *et al.*, 2005) and as a result, *Glyphis* sp. A and *P. microdon* are listed as critically endangered and vulnerable, respectively, under the EPBC act. *Glyphis* sp. A and *P. microdon* are listed as critically endangered and *P.* clavata, and *P. zijsron* are listed as endangered by the IUCN Red List (Cavanagh *et al.*, 2003). Apart from *Glyphis* sp. A in the NTBarr fishery, all species are captured infrequently. The low capture rates most likely reflect these species rarity rather than low incidence of capture in the gear. All three management jurisdictions have introduced measures to reduce the impact on these species due to requirements of NPOA - sharks. The capture of vulnerable or threatened species falls under object #3 in the NPOA – Sharks: “To identify and provide special attention, in particular, to vulnerable or threatened sharks.” The operational plan for northern Australian shark resources also highlights the need for management action following capture of vulnerable and threatened sharks in action 2 and 12:

2) Assess current management plans for listed threatened species against recovery plans for those species.

12a) Initiate action to identify habitat critical to the survival of shark species and where identified as necessary take action to protect, and minimise threats to these habitats.

12b) Within relevant statutory timeframes protect and minimise threats to habitats critical to the survival of species listed under commonwealth/State/NT legislation.

The management actions introduced by state/territory agencies as well as deficiencies with respect to threatened protected species are outlined below. Queensland has introduced a voluntary code of conduct for handling sawfish and encourages all commercial fishers to release these species alive (Chapter 5 - Objective 4). Recent captures of *Glyphis* sp. A by commercial fishers in N3 fishery has resulted in fishery observers educating fishers on the identification of this species and all fishers are encouraged to release this species. Given the limited distribution of *Glyphis* sp. A in the Gulf of Carpentaria, further research into the abundance of *Glyphis* sp. A in the N3 fishery and Gulf of Carpentaria is required. Research should aim to determine the distribution and critical habitat of this species as well monitor the catch rates in areas of known occurrence such as the Ducie and Wenlock Rivers. Further training of fishers in the identification of this species is also required. Fishers operating in rivers within Princess Charlotte Bay have recently reported *Glyphis* species in their catches, although surveys have failed to catch any *Glyphis* in this area (Stirling Peverell, QDPIF, *pers. comm.* 2006). More research into the occurrence and capture of *Glyphis* in Princess Charlotte Bay is required.

Although the NTONL fishery has introduced a voluntary code of conduct that encourages fishers to release sawfish alive, this code of conduct does not apply to the NTBarr, NTCN and NTRBN fisheries. Sawfish are undoubtedly captured in these fisheries and management actions are required to mitigate their capture and release in order to demonstrate ESD. Seventeen *Glyphis* sp. A ranging in size from 75 – 175 cm TL were recorded in five shots in the NTBarr fishery. These animals were recorded by an observer in the Adelaide River as part of this project during 2004. The number of animals taken was of great concern given the fact that the Adelaide River is one of few rivers *Glyphis* sp. A has been recorded in (Stevens *et al.*, 2005). The impact that the NTBarr fishery has on *Glyphis* sp. A has since been reduced by recent legislation (February 2005), ensuring that commercial barramundi fisheries targeting barramundi are excluded from all rivers in which *Glyphis* sp. A has been recorded in the NT. These Rivers are: Adelaide River, South Alligator River, East Alligator River, West Alligator River and Murganella Creek, and fishing is only allowed seaward of an imaginary line drawn across the mouth of the river (Northern Territory of Australia Barramundi Fishery Management Plan, February 2005; Annette Souter, NTDBIRD, *pers. comm.*, 2005). There have been several unconfirmed reports of *Glyphis* being captured in the NTBarr fishery since the introduction of this management plan. These reports suggest that *Glyphis* are not only restricted to rivers and estuaries but may also utilise shallow coastal areas. Further research into the distribution and habitat requirements of *Glyphis* is therefore required in order to determine the extent of overlap between commercial net fishing and the species distribution in order to mitigate the impact of fishing on this species.

Commercial barramundi fishers using 7 inch mesh net are still allowed to fish in all or part of the rivers such as Cooper Creek, Limmen Bight River, Wearyan River, Robinson River and the Victoria River (see Schedule 6, Northern Territory of Australia Barramundi Fishery Management Plan, February 2005, pp 49 -50). Although *Glyphis* sp. A have not been recorded in these systems, surveys should concentrate on these rivers as any populations within these systems are likely to be impacted by gill net fisheries. Effectively excluding the NTBarr fishery from most rivers and estuaries in the NT will also benefit *P. microdon* which is known to spend its early years in rivers. Although this fishery will still encounter large mature animals, it is likely that most juveniles will escape capture due to their preference for rivers in their early years.

All rivers in the NT are closed to bait net fishing, the small mesh size (2.5 inches) is unlikely to capture even small *Glyphis* sp. A. The small mesh size of the bait net fisheries will however still be able to capture sawfish due to their rostral teeth. As such, the capture of sawfish should be reported in logbooks in order to monitor catches of these species.

In WA, Glyphis have not been recorded in inshore net fisheries but *P. clavata* and *P. zijsron* were recorded by observers in both the WAEMBGF and the WAKGBF. *Pristis microdon* have also been reported by fishers but none were seen during observer trips. Sawfish in these fisheries are mainly small juvenile animals (Table 2.3-8) making them easier to handle. The small size combined with the fact that nets are generally set and checked from the beach means that releasing sawfish is relatively easy. As such, fishers have been encouraged to release sawfish alive in both fisheries. In general, *P. zijsron* and *P. microdon* in both fisheries are large animals and the majority are therefore retained due to their high value and difficulty removing them from the nets. *Pristis clavata* in the WAEMBGF are mostly small animals and are predominantly released alive while in the WAKGBF, approximately half the animals are released.

In Queensland, the narrow sawfish, *Anoxypristis cuspidata* was recorded in the N3 but not the ECN fishery. Although not recorded in the ECN fishery, it is known to occur along the east coast (see Sawfish desktop study – Appendix 3) and has been recorded by observers outside of this study. Peverell (2005) showed that the catch rates of *A. cuspidata* in the N3 were slightly lower than the N9 and that animals in the N3 were significantly smaller than those taken offshore (N9). These data suggest that juvenile *A. cuspidata* are utilising inshore areas as nursery grounds.

One *A. cuspidata* was recorded in the NTBarr fishery in only 14 shots. The catch rates and fate of captured animals in this fishery are unknown but it is likely that catches and mortaility are high. Research into the catch and retention rates of *A. cuspidata* in the NTBarr fishery are urgently required.

Anoxypristis cuspidata were the third and second most abundant species taken in the WAEMBGF and WAKGBF, respectively. Although some animals were released by fishers in these fisheries, post-release survival was very low and fishing mortality was assumed to be 100 % (Rory McAuley, WA

Fisheries, *pers. comm.* 2005). The high capture rates and low survival of *A. cuspidata* in the WAEMBGF and WAKGBF warrants additional research into the population structure, movement and abundance of *A. cuspidata* in North West Australia. *Pristis clavata*, *P. microdon* and *P. zijsron* captured in the WAEMBGF and WAKGBF survived capture and release suggesting that *A. cuspidata* is less resilient to capture and handling. The low survival of released animals in the WAEMBGF and WAKGBF raises questions about the survival of this species in target fisheries in NT and Qld were most animals are released. Further research into the post release survival of this species is required to determine whether the release of animals is an effective management strategy to reduce fishing mortality.

Threatened and protected species, and in particular sawfish are captured as bycatch in nearly all gill net fisheries. While management initiatives, which encourage the release of sawfish have been implemented to reduce the mortality to these species there is a lack of data on the post capture survival of released animals. The effectiveness of these management initiatives is therefore unknown and more research is required to determine their effectiveness. Additional management including spatial closures may be required to mitigate the impact inshore gill net fisheries are having on sawfish populations. Additional research into the habitat requirements of these species is required before alternative management initiatives can be addressed.

Species captured by both target and bycatch fisheries

Observer data has shown that several species are captured in both target and bycatch fisheries. The capture of species in multiple fisheries, particularly in fisheries where species specific catches are not recorded has implications for management of both target and bycatch fisheries. Species specific logbooks, standardised catch per unit effort estimates as well as joint and complementary management initiatives are required to ensure ESD of these species. The Operational Plan for the Sustainable use of Northern Australian Shark Resources (OPSUNASR) highlights the importance of monitoring catches of species across different fisheries in action 11: “Ensure that where a species is taken in two or more fisheries within a jurisdiction or in two or more jurisdictions: a) processes are in place to collect/report data from all fisheries and jurisdictions involved in the management of that species uniformly and are included, when data become available in stock assessments or risk assessments conducted for that species; b) the potential of multi-jurisdictional or across fishery approaches to shark management have been assessed and introduced where possible; c) effective communication and consultation mechanisms between all stakeholders are in place; and d) management measures are complementary and consistent with an ESD approach.” Current log book systems in adjoining state/territories do not record species composition in bycatch fisheries. Cross jurisdictional management of these bycatch species is therefore not possible under the current reporting requirements.

Carcharhinus tilstoni and C. sorrah contribute approximately 54 and 82% to the elasmobranch catch in the target gill net fisheries in Qld. and NT, respectively. The combined contribution of *C. tilstoni and C. sorrah* in a bycatch gill net fishery was highest in the ECN fishery (56.6%) and lowest in the WAEMBGF (6.7 %). The lack of *C. sorrah* in the N3, NTBarr and NTRBN catches is due to sampling effort rather than an absence of this species in these fisheries. *Carcharhinus sorrah* and *C. tilstoni* comprise a significant proportion of the total elasmobranch bycatch in all inshore gill net fisheries. The consistent capture of these two species in inshore bycatch fisheries as well offshore fisheries targeting these species in all three states necessitates careful management of the two species, both of which form a single stock in Australian waters (see Chapter 3).

The high contribution of *C. sorrah* and *C. tilstoni* to the ECN fishery, as shown by observer data, is probably not representative of the entire fishery. The majority of data was collected from the ECN fishery was collected from commercial vessels in Princess Charlotte Bay and off Cairns/Port Douglas (Figure 2.3-1) and the composition of *C. tilstoni and C. sorrah* reflect catches by these boats in this area. Catches from land based operators in inshore, estuarine and riverine areas of the N3 and ECN are likely to contain higher numbers of inshore species such as *C. amboinensis*, *C. amblyrhynchoides*, C. *leucas*, *C. fitzroyensis*, *N. acutidens* as well as *Rhynchobatus australiae*, *Rhinobatus typus*. *Pristis microdon and P. zijsron* are more likely to be taken by fishers operating in inshore estuarine areas and it is well known that juvenile *C. leucas* are targeted by net fishers in rivers throughout Queensland during the pupping season (TRAP Report, Gribble *et al.* 2003).

In the bycatch gill net fisheries, of the species that are captured in both target and bycatch fisheries, species that have a preference for shallow inshore and estuarine areas were more abundant in the inshore gill net fisheries. These species include juveniles of *Carcharhinus amboinensis*, C. *leucas* and *N. acutidens* which make significant contributions to the N3, NTBarr, WAEMBGF and WAKGBF fisheries. These three species are large slow growing species (Last and Stevens, 1994; Branstetter and Styles., 1987; Wintner *et al.*, 2002) whose juveniles utilise shallow inshore nursery areas.

Juvenile *C. leucas* spend their early years in the upper reaches of rivers and estuaries and therefore occupy similar habitat to target species such as barramundi and king salmon. While adult *C.* leucas are too large to be captured in 6-7 inch mesh net, the neonate and juvenile sharks (60 - 90 cm TL, Last and Stevens, 1994) are easily meshed. Although *C. amboinensis* and *N. acutidens* do not live in the freshwater reaches of rivers, the juveniles utilise shallow inshore coastal and estuarine areas as nursery grounds and are therefore susceptible to capture in inshore gill net fisheries. Juveniles of both species are small enough to be captured in gill nets while sub adult and adult sharks are too large to be frequently captured. Additional research into the catch rates and stock assessment of *C. leucas* in the ECN, N3 and NTBarr fishery is warranted given their high contribution to observed catches, anecdotal reports that catches have declined (at least in the N3) combined with this species low productivity (Branstetter and Styles., 1987; Wintner *et al.*, 2002).

Small to medium sized whaler sharks such as *C. cautus*, *C. fitzroyensis* and *C. amblyrhynchoides* are also more common in inshore than offshore gill net fisheries. This is due to their preference for inshore areas and estuaries. Due to the smaller size of these species, both adults and juveniles of these species are captured by gill nets. Catch rates of these species need to be closely monitored to ensure over fishing does not occur. Monitoring catch rates of these species is only possible if logbook data records species specific catch data.

Trawl fisheries

Although not a gillnet fishery, trawl fisheries are described for the sake of shark bycatch completeness. Comprehensive data on the bycatch of trawl fisheries was only obtained from observers in the WAPFT and NPF. A list of species recorded in the QDFT fish trawl fisheries was obtained from an observer in the fishery. Data on catch rates and percent contribution by number were not available. Given the similarity between the QDFT and the NTFT, species composition was assumed to be similar. The main differences between trawl catches and gillnet and longline catches is the presence of stingrays and the higher contribution of Rhynchobatids and Rhinobatids to the catches. With the exception of WAPFTF, in all other trawl fisheries, elasmobranchs have to be released alive. The most important factor in determining the sustainability to captured species is therefore post release survival. We currently know very little about the mortality associated with capture and subsequent release of elasmobranchs in trawl fisheries. Given the high catches of elasmobranchs in both fish trawl and prawn trawl, research is urgently required in order for trawl fisheries to demonstrate the catches of elasmobranchs are sustainable.

The implementation of TED's and BRD's in the NPF has significantly reduced the capture rates of several species of large elasmobranchs in this fishery. The catches of large rays such as *Himantura toshi*, *Rhynchobatus australiae* have been reduced by 42 and 39% respectively, while catches *H. uarnak*, *H. undulata* and *Rhyna ancylostoma* have been reduced by between 90 – 100% (Brewer *et al.*, 2004). Even small species such as *Dasyatis annotata* and *D. leylandi* have been shown to be excluded by 30 – 35 %. Importantly, catch rates of *A. cuspidata* have also been reduced due to TED's and BRD's, however this species is still captured by this and other trawl fisheries. Due to the difficulty in extracting sawfish from trawl gear, most animals brought on deck are not returned alive and the survival of released animals is not expected to be high. Observers in the NPF estimate that mortality of sawfish brought **on deck is approximately 90%.** Additional measures to reduce the capture of this species are therefore required.

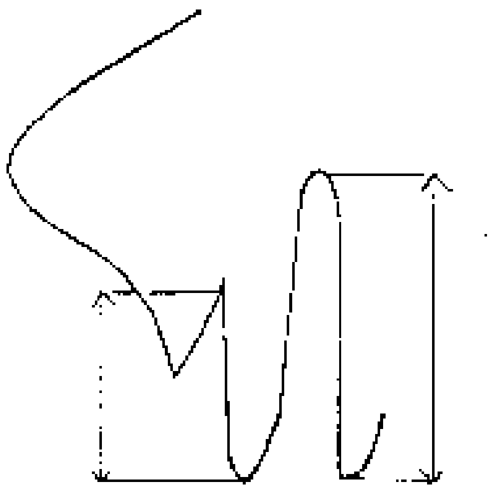
The QDFT and NTFTF fisheries do not have TEDS or BRDS, and while the retention of elasmobranchs in both trawl fisheries is not permitted, post capture mortality of captured species is currently unknown. Given the high catches of elasmobranchs in these fisheries, data on the post release survival of commonly captured species should be assessed in the future. Given the nature of the fishery, benthic species such as sawfish, stingrays, shovelnose sharks and guitarfish are more likely to be at risk from these fisheries. The NTFT fishery operates using short shots and a hopper arrangement that is designed to increase the survival of unwanted and larger species. Turtle exclusion devices (TED's) will also be introduced to the NTFTF in 2007 (David McKey, NT Fisheries, Pers. Comm).

Summary

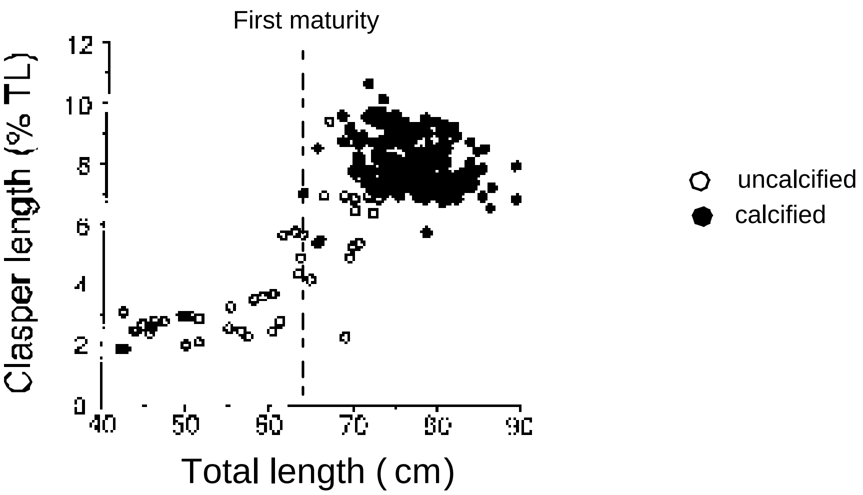
Gill net and trawl fisheries which capture elasmobranchs as bycatch require management initiatives to reduce the incidental capture of threatened and protected species as well as additional research into the survival of released animals to demonstrate ESD and meet the requirements of the NPOA – Sharks. Long term, species specific monitoring of catches is also required to ensure that management initiatives are having the desired effect.

The lack of species specific catch data (log book) from target (chapter 2) and bycatch fisheries (this chapter) combined with a range of target and bycatch fisheries which capture a large variety of elasmobranch species makes it difficult to assess the sustainability of elasmobranchs in all fisheries. The data collected in the current project does however allow for an updated risk assessment of elasmobranchs in northern Australia using information on the catch composition and fishing methods of fisheries that capture elasmobranchs as target and bycatch. Using these data as well as new data on the biology of certain species, risk assessment methods will be used to estimate the relative sustainability of all species of elasmobranchs to northern fisheries. Both the EPBC Act and the NPOA – Sharks requires all fisheries that capture elasmobranchs as target and non-target species to demonstrate that the catches are sustainable.

Sexual maturity in males



(1) Measure claspers
(2) Record whether uncalcified or calcified
(3) Plot relative clasper length against body length



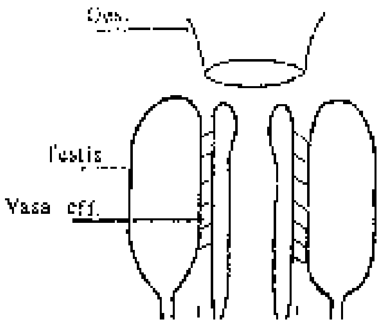
Reproductive Sampling Info from John Stevens **FRDC S&R project**

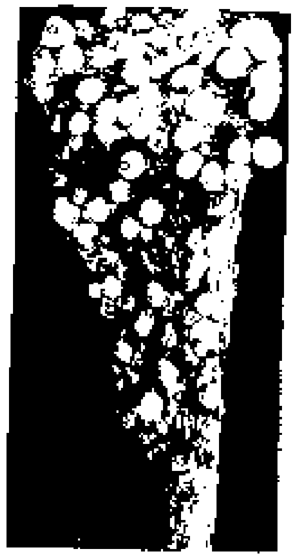
Figure 4.3-1: Measurement required to determine sexual maturity in males. The graph represents the relationship between clasper length and total length.

Table 4.3-1: Female reproductive stages*

Stage 1.	**Immature**	Oviducts and uteri thread-like. Nidamental gland not visible, or present only as slight swelling. Uteri not distinguishable from oviducts. Ovary indistinguish-able from epigonal organ, or very small with minute ova.
Stage 2.	**Mature resting**	Nidamental gland visible as heart-shaped structure. Uteri clearly distinguishable from oviducts. Ovary well formed, ova of about 5 mm in diameter with clear yolk.
Stage 3.	**Pre-ovulatory**	Uteri expanded, thick walled and vascular. Ovary with large, yellow yolked eggs ready for ovulation.
Stage 4.	**Pregnant**	Uteri expanded and containing eggs or embryos.
Stage 5.	**Spent**	Uteri very expanded, thin walled and flaccid. May contain remnants off egg membrane or placental scars. Ovary usually with numerous pale or greeny coloured corpora lutea and mostly with small ova.

Reproductive seasonality





Weigh testis

Measure maximum ova diameter

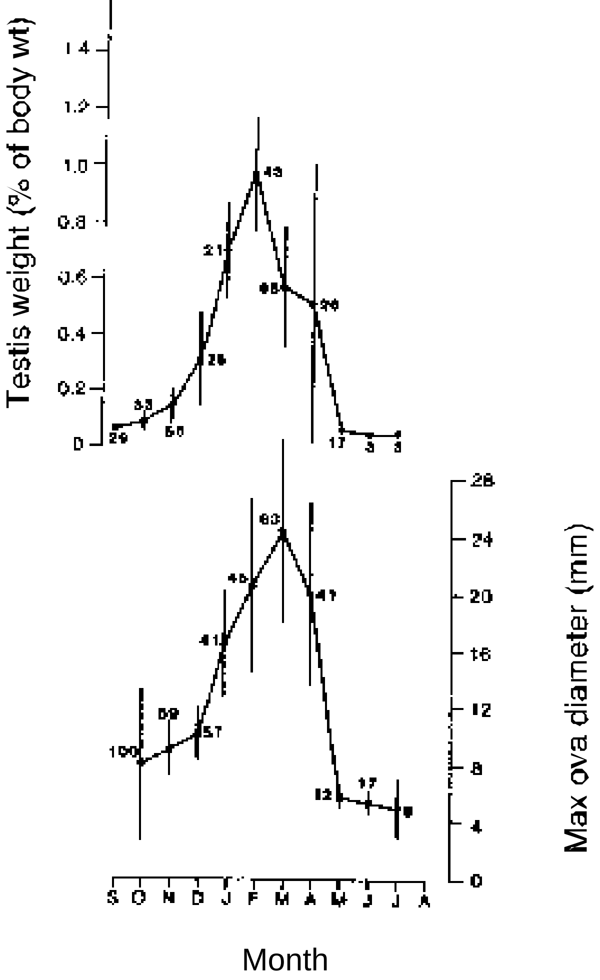


Figure 4.3-2: Representative diagram of the female reproductive system in elasmobranchs. Maturity stages were based on this diagram

Female reproductive system

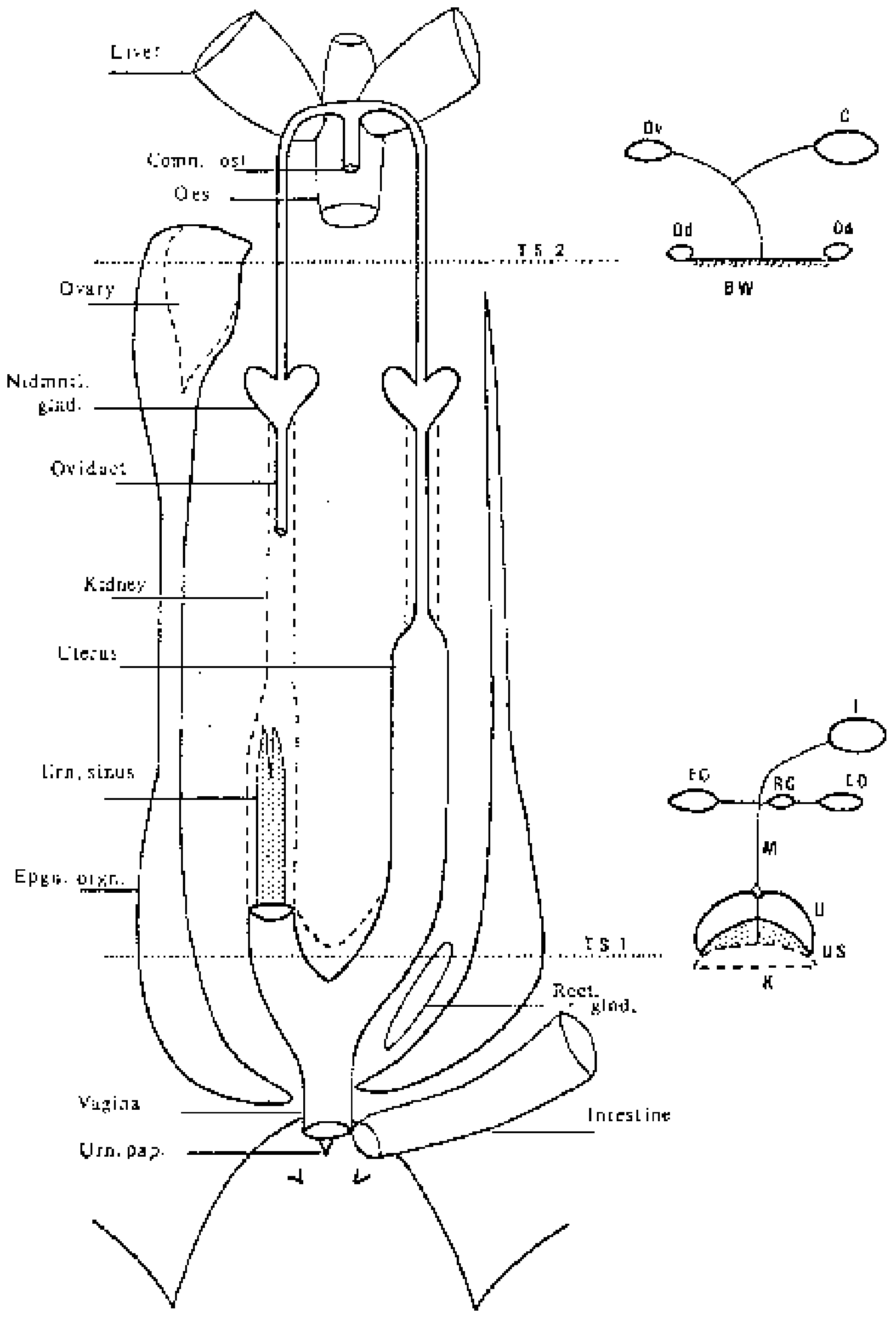


Figure 4.3-3: Representative diagram of the female reproductive system in elasmobranchs. Maturity stages were based on this diagram.

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Male reproductive system

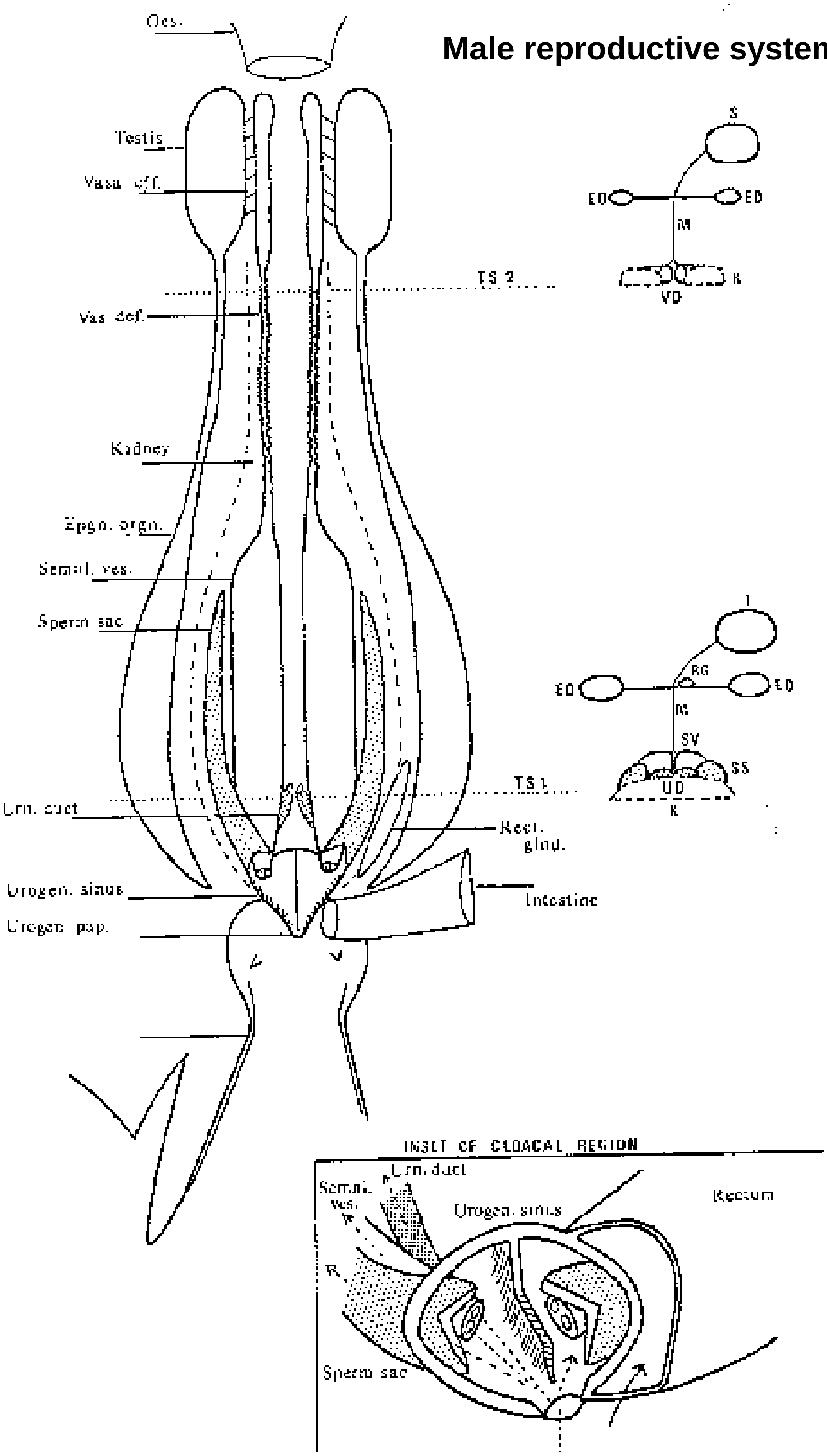
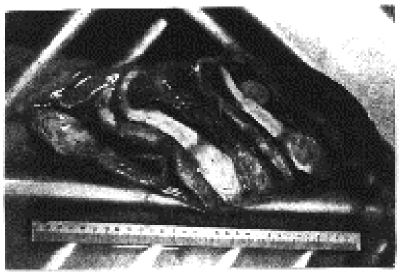
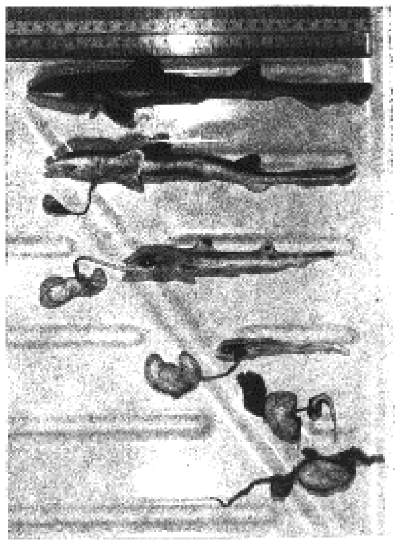


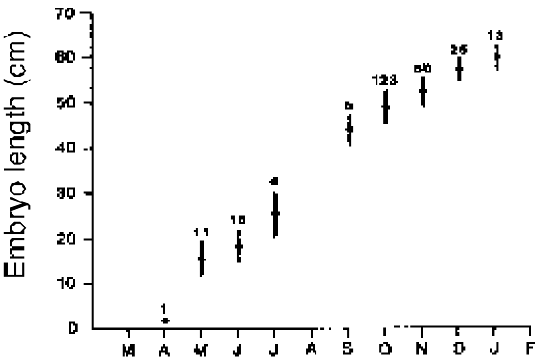
Figure 4.3-4: Representative diagram of the male reproductive system.

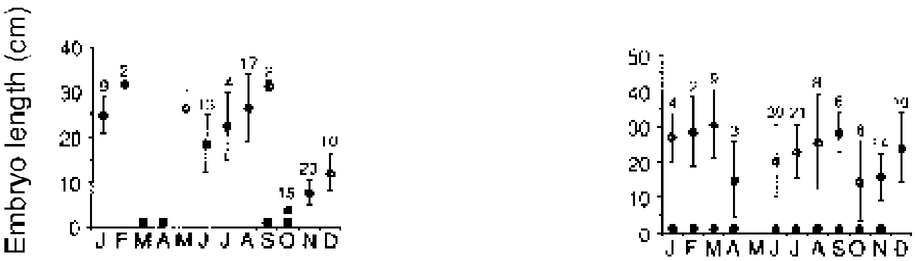
Pregnant females





Record ova in utero
Measure embryos





Month

Figure 4.3-5: Pregnant females

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5. CHAPTER 5 – OBJECTIVE 4 STATUS OF SAWFISH

Information supplied by Stirling Peverell and Neil Gribble

Objective 4 *To derive estimates of biological parameters to assess the status of sawfish populations; age structure, reproduction and growth.*

5.1 Introduction

This objective was developed to collect as much biological information as possible on sawfishes. Internationally and within Australia, there is very little known about the biology of this group and yet they are the focus of concern. An FRDC NPF bycatch project clearly demonstrated the uncertain status of sawfishes in the NPF (Stobutzki *et al.* 2002), while the NHT funded survey of freshwater and estuarine elasmobranchs in northern Australia by Thorburn *et al.* (2003) highlighted the decline in sawfish numbers across northern Australia. More conclusively, the data from the Queensland Shark Beach Protection Programme over the last 40 years shows clear evidence of sawfish population decline on the east coast. The lack of biological knowledge of these species in the light of this decline and in the face of worldwide declines and extinctions, has made this study more urgent as fishing pressure increases in the remote areas of the north.

The collection of new biological information will enable a more robust assessment of the impact of fisheries on this group and Chapter 6 reflects the current Risk Assessment for the sawfishes in northern Australia.

5.2 Methods

This work was undertaken by Stirling Peverell (QDPI) focusing primarily on Queensland but will aim to extend this to NT and WA. This formed part of Stirling's Master of Science with James Cook University. Observers collected samples for sawfish biological parameters. Age and growth studies were conducted at the Northern Fisheries Centre, using vertebrae to estimate the age of individuals. Vertebrae sectioning requires a minimum of six per size class per species. Reproductive staging was conducted on all available specimens and, where possible, the number of offspring estimated. The combination of the reproductive and aging work enables longevity and age-at-maturity to be estimated and compared among the species as are estimates of fecundity and growth rate. Genetic analysis of samples was undertaken to determine or validate species identification. Recent surveys have identified a potential new species and this will be clarified. DNA profiling on 20 individuals per species (where possible) was planned to be undertaken through the JCU electrophoretic lab under the supervision of Professor Howard Choat. However, some processing problems forced some of this work to be re-directed to the QDPI Molecular Fisheries Laboratory at Deception Bay (Jennifer Ovenden, the laboratory has recently re-located to the Queensland Bioscience Precinct, St. Lucia). A tagging program was conducted in conjunction with recreational and commercial fishers through INFOFISH services and will be directed by Bill Sawynok. Fisheries observers plan to tag sawfish using stainless-steel headed dart tags. (Radio and acoustic tracking will be investigated to provide important behavioural information such as survival post captures and movement of released animals - This technology is already available within QFS). The tagging will provide some age and movement information on the species.

5.3 Results & Discussion

5.3.1 Sawfish biology and ecology in the Gulf of Carpentaria.

This work has been carried out as part of a JCU MSc project; the final draft of the dissertation is complete and currently undergoing editing prior to submission. The outcomes so far have been two major reports to the project:

a. The spatial distribution and relative abundance of the four species of sawfish on Queensland coastal Gulf of Carpentaria; *Pristis microdon*; *Pristis clavata*, *Pristis zijsron*, *Anoxypristis cuspidata*. This work has been published in *Environmental Biology of Fishes*, 2005, **73:**391-402 as Peverell, S. C. "Distribution of sawfishes (Pristidae) in the Queensland Gulf of Carpentaria, Australia, with notes on sawfish ecology" (Appendix 5).

b. Age estimation based on vertebral section "ring" counts and age/growth equations of the four species of sawfish on Queensland coastal Gulf of Carpentaria; *Pristis microdon*; *Pristis clavata*, *Pristis zijsron*, *Anoxypristis cuspidate* (draft manuscript, Appendix 3).

These reports have been used extensively in the "Description of Key Species Groups in the Northern Planning Area" produced for the National Oceans Office, and in a CSIRO report to DEH on the conservation status of *Pristis microdon*. (Stevens *et al.* 2005).

At the time of preparation of this report, the thesis had been submitted and some rewriting was expected before final acceptance. A summary of the findings are presented here as derived from a draft Abstract from the thesis document. Italicised headings are included for clarity. Full data details for spatial distribution and the age estimation manuscripts are included in Appendix 5 as referred to in sections a and b above.

5.3.2 Draft MSc Thesis Abstract

The sawfish group Pristidae are relatively rare and are critically endangered in many habitats around the world. Information on their distribution and life history is limited. This study has improved the knowledge of pristid distribution and abundance within the inshore and offshore set net fisheries of the Gulf of Carpentaria (GoC), Queensland (Qld). Complementing this is information on the life history and biology of each of the species with recommendations for future management strategies. *Pristis microdon*, *P. zijsron*, *P. clavata* and *Anoxypristis cuspidata* are distributed throughout the Northern, Southern and Western Qld regions of the GoC, Australia.

Abundance and Distribution

This study showed that *Anoxypristis cuspidata* was the most abundant species and was recorded in both the inshore and offshore set net fisheries in both its mature and immature life stages. *Anoxypristis cuspidata* abundance appeared to be greatest in the Northern region of the Gulf with a maximum catch per unit effort (CPUE) of 0.83 sawfish 500m net day^{-1}. The size distribution and catch locations of *A. cuspidata* suggest that the inshore area to a depth of ten metres may be the preferred habitat for juveniles, while adults primarily occur offshore. *Pristis microdon*, *P. zijsron*, and *P. clavata* were recorded only in the inshore fishery with catches dominated by immature animals. The abundance of *P. microdon* and *P. zijsron* was extremely low with a maximum CPUE of 0.1 and 0.2 sawfish 500m net day^{-1} respectively and their distribution patchy. The maximum CPUE for *P. clavata* was 0.83 sawfish 500m net day^{-1}, however unlike *A. cuspidata,* their distribution was more restricted. The incidental catches of *P. microdon* in the set net fisheries of the GoC appear to be seasonal. This species was predominantly caught in the inshore fishery late in the monsoonal wet season (February to

April) and inhabited both freshwater and estuarine environments. These findings are supported by tag and recapture and microchemistry of vertebrae (LA-ICPMS) analysis.

Tagging

The tag and recapture data demonstrates that *P. microdon* is capable of moving along the coastal foreshore between estuaries and juveniles migrate upstream following the receding freshwater and downstream with the floodwaters. The findings from the LA-ICPMS analysis support the theory that *P. microdon* utilise freshwater, estuarine and marine habitats during different stages of their life history. High Sr/Ca ratios indicative of a marine environment were recorded in the section of vertebrae representative of the mature life stage in *P. microdon*. Low ratios indicative of a freshwater environment were recorded during the juvenile life stages. This habitat preference demonstrated by juvenile *P. microdon* is possibly a 'predator avoidance' behaviour. Although *P. microdon* was not represented in the incidental catch of the offshore gillnet fishery, it is highly likely they do inhabit this fishing area based on the findings of the tag and release information and LA-ICPMS data from this study. Furthermore, *P microdon* is a bycatch species in the Northern Prawn Fishery (NPF) (Stobutzki *et al*., 2002), thereby giving credibility to the hypothesis that this species inhabits deep offshore waters of the GoC. Unlike the commercial catch of *P. microdon*, there appeared to be no seasonal trend in the catches of the other three sawfish species*. Pristis clavata*, *P. zijsron* and *A. cuspidata* were recorded throughout the commercial set net fishing season. Information obtained from tag and recapture of *P. clavata*, and *A. cuspidata* and LA-ICPMS analysis and short term acoustic tracking of *P. zijsron* indicate that these specimens exhibited restricted site fidelity. Observations of the reproductive organs and the capture of neonate specimens suggest that in all four pristids, pupping occurred through the wet season until the beginning of the dry season in May. These findings add credibility to the previously unexplained report by Allen (1982) that *P. microdon* pup at the mouths of rivers during the wet season.

Age and Growth

The age at maturity estimates of the four pristid species in this study were similar between species. The number of growth checks on cross-sectioned vertebrae and observations made of reproductive organs, the age at maturity for *P. microdon*, *P. clavata* and *P. zijsron* was between 8 and 10 years. Similarly, for *A. cuspidata* with age estimates based from growth checks on branchial vertebrae sections and macro-staging of reproductive organs, the age at maturity was 4 years for males and 5 years for females. In this study, size at maturity for female *P. microdon* was 300cm T_L and previously recorded 306cm T_L for males (Tanaka, 1991). The observed size at maturity of *P. clavata* and *P. zijsron* in this study was 295cm T_L and 380cm T_L respectively. However, the observed size at maturity for *A. cuspidata* was considerably smaller at 203cm T_L for males and 225cm T_L for females. In this study the observed maximum size at birth for *P. microdon* of 90cm T_L was considerably longer than 76cm T_L previously reported by Compagno and Last (1999). The litter size of between 1 and 11 pups for *P. microdon* may also be inaccurate and could be as high as 34 pups. This inference is based on the observation of 34 vitilogenic oocytes present in the ovary of a pupping *P. microdon*. The size at birth reported by Compagno & Last (1999) for *A. cuspidata*-61cm T_L and those inferred in this study for *P. clavata* (75cm T_L) *P. zijsron* (75cm T_L) are biologically reasonable given the size frequency of young of the year captured in this study. All GoC pristid species share a rapid growth rate in the first twelve months of development. This first year increase in size in *P. microdon* was 56cm, in *P. clavata* it was 35cm, in *P. zijsron* it was 52cm and in *A. cuspidata* it was 42cm. In all GoC pristids the growth rate in the later mature stages of life decreases to a total growth over the last 10 years of only 14cm in *P. microdon*, 7cm in *P. clavata*, 19cm in *P. zijsron* and 9cm in *A. cuspidata*. A pattern of growth similar to that of GoC pristids was reported by Thorson (1982a) for *P. pectinata*. The longevity estimates for pristid species in this study are slightly higher to those estimated by Simpfendorfer (2000) for *P. pectinata* and *P. perotetti* (both 30 years) and lower than that suggested by Tanaka (1991) for *P. microdon* (>44 years). The maximum ages of GoC pristids ranged from 51 years (*P. microdon*), 48 years (*P. clavata*), 41 years (*A. cuspidata*), to at least 36 years (*P. zijsron*). There is a wide range in the estimates of longevity within the elasmobranch group (Cailliet & Goldman 2004) and the findings reported in this study for GoC pristids concur with Simpfendorfer (2000), Last & Stevens (1994), Tanaka (1991), Thorson (1982a), Pogonoski (2002) Pogonoski *et al*., (2002), in suggesting all pristid species are long lived in comparison to most other elasmobranchs.

Diet

This study is the first documented account of prey items found in the stomachs of pristid species. Prey items found in the stomachs of *P. microdon* included *Macrobrachium spp*., *Penaeus spp*., *Arridae spp*., *Tandanus tandanus*, *Nibea squamosa*, *Polydactylus macrochir* and *Rhinomugil nasutus*. These species are of marine, estuarine and freshwater origin. Prey items found in the stomachs of *P. clavata* included *P. merguiensis*, *Nibea squamosa*, *Clupeidae spp.*, *Mugilidae spp*., and *Leptobrama mulleri*. These prey items are typically found in marine and estuarine habitats. Teleost fishes were the only prey items found in the stomachs of *P. zijsron* and these included *Eleutheronema tetradactylum*, *Engraulidae spp*., *Pomadasys kaakan*, *Nibea squamosa* and *Ambassidae spp*, while captive *P. zijsron* consume pilchard and squid. Prey items found in the stomachs of *A. cuspidata* included Mullidae *spp.*, Synodontidae *spp*., Platycephalus *spp.*, Carangidae *spp.*, *Chirocentrus dorab* and *Photololigo chinensis* suggesting they have a benthopelagic diet. The prey items of *A. cuspidata*. *Anoxypristis cuspidata* are also observed to feed on *Leiognathus spp*. The prey items found in the stomachs of *A. cuspidata* are species typically found in the bycatch of the NPF, another commercial fishery known to capture pristids. *Anoxypristis cuspidata* was more resilient to fishing pressure because it has the ability to reproduce at a smaller size and at a younger age than the other *Pristis* species.

The findings of this study would indicate that the *P. microdon*, *P. clavata*, and *P. zijsron* populations of the GoC may have (1) moved further offshore and not vulnerable to capture or (2) been depleted to levels where few mature specimens are being caught. The life history and biological strategies of the three *Pristis* species are such that they are not capable of sustaining high levels of fishing pressure, as demonstrated in other *Pristis* populations around the world. In the Queensland GoC, pristid populations may have been conserved due to a number of factors including low levels of coastal development and hence habitat degradation, and the existence of a multitude of spatial and temporal fishing closures that help reduce interaction with commercial fishing nets.

5.3.3 Further achievements:

Extension:

- Publication of a species identification sheet and release procedures document for sawfish in the Gulf of Carpentaria set net fishery. These documents have been used to formulate similar publications in the NT and WA by WWF and SEANET.
- A collaborative production between Stirling Peverell and Bill Sawynok of a recreational fishers sawfish release procedures information sheet.
- Regular advice provided to Gulf Mac through briefing by Rod Garrett (DPI & F representative on Gulf MAC) and by an invited presentation of sawfish distribution and biology in 2003.
- Regular seminars given to peak commercial fishing body (Gulf of Carpentaria Commercial Fishermen's Organisation) annual meetings.
- Sawfish added to the Queensland Commercial Fishers Compulsory logbook program "Species of conservation interest (SOCI)", due heightened profile caused by the project.
- Sawfish were added to the Gulf of Carpentaria Commercial Fisherman association shark id guide, as part of an industry driven Enviromental Management System with DPI&F project staff providing technical backup.
- The project carried out shark identification and sawfish live release workshops for commercial set net fishers in the Gulf of Carpentaria (4) and on the East Coast (2).
- Stirling Peverell organised a workshop for Gulf of Carpentaria and East Coast commercial fishermen in Cairns 2004 to present the IUCN National Plan of Action for Sharks (presenter was IUCN Project Officer Rachel Cavanagh).

Community liaison:

- Extensive community liaison was carried out by Stirling Peverell and the Queensland Coast Care Facilitator for the Gulf of Carpentaria, Ms Karen Vidler, on raising the profile of sawfish based on data provided by this component of the FRDC project. Groups targeted included Ecofish on the East Coast; Northern Gulf, Southern Gulf and Cape York regional Natural Resource Management Groups; the Indigenous Fishing Forum; the major land councils for the Cape York and Gulf of Carpentaria region; and Gulf of Carpentaria Catchment Management Groups.
- Based on this community liaison work, a successful bid was made for NHT Phase II funding for a follow-on project, "The development of a Gulf community based natural resource monitoring program, with sawfish as the initial focus".
- The sawfish information was also used in the DEH EPBC Act ecological risk assessment for the Gulf of Carpentaria commercial fisheries (Roleofs, 2003) and will be used to in the DEH Queensland East Coast risk assessment process.
- The FRDC project contributed information on sawfish identification and biology to the IUCN elasmobranch workshop, Brisbane 2003.
- Information on the status of freshwater sawfish provided to Queensland Freshwater MAC to consider increasing the conservation status of the species in Queensland waters by protecting them under state fisheries legislation.
- Based on his sawfish expertise the project Biologist Stirling Peverell was invited to be a member of the Protected Species and Education Project Team for DPI & F

Expansion of the program:

- The project has successfully maintained strong community and industry support for an ongoing sawfish tagging program.
- The Project Biologist, Stirling Peverell, obtained seed money from National Ocean Office to extend the FRDC project by an acoustic tracking study on the green sawfish.
- As an adjunct to the field surveys for sawfish, specimens of the rare Glyphis sp. of shark were identified, which resulted in DPI & F funding extra surveys that have expanded the known range of this shark. The work is currently being published in ZOOTAXA as "*New records of the River Shark Glyphis (Carcharhinidae), reported from Cape York Peninsula, northern Australia*".
- Genetic samples have been taken for over 100 Queensland sawfish. DNA extraction protocols have been developed for all of these species along with D-loop and cytochrome b genetic sequencing methodology. Sequences have been sent to Dr Jenny Ovenden DPI & F Southern fisheries Centre for further analysis.

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5.5 Sawfish Desktop Study

At the second project meeting in August 2003, there was a resolution passed by the meeting to pursue the collection of all available sawfish catch records from existing sources (see Minutes of Second Project Meeting in Appendix 3). This would include museum records, research surveys, Queensland Shark Control Program (QSCP) and foreign fishing records from the 1960s through to the recent past. A six month graduate position was engaged to carry out the study (Jenny Giles). Funding was supported by CMAR and from within the FRDC project. Support was originally requested from DEH and FRDC but extra funds were unavailable.

The complete report is provided as part of Appendix 3 and the tables and figures below are contained in that document. One of the most significant contributions of this study was that it highlighted the decline in abundance of sawfish. Catches of sawfish on the east coast were obtained from the records of the QSCP, where species were not identified and so the data refers to Pristids as a family group. The declines in catches are clearly seen in Chapter 3 of the desktop study report and in particular, Tables 3.9, 3.10, Fig. 3.3 and 3.4. A total of over 1660 sawfish records were represented in the QSCP records.

Catch summary from all sources
The majority of records in the database were obtained from state agencies; primary NT logbooks and Queensland's beach meshing program (Figure 6.1). State observer data made a very small contribution to the overall number of state records, and is presently the only data source for sawfish bycatch in WA and Queensland fisheries. After the state fisheries, the most data was collected from historical

fisheries, the Northern Prawn Fishery and research surveys, followed by collections, a small number from the aquarium trade, and miscellaneous reports. Net fishing accounts for most of the catch records in the database (80.2%), followed by trawling (16.6%), line (9.2%) and recreational gears (0.3%) (Figure 6.2). The majority of data (79.7%) are recorded at the family level (Figure 6.3), largely due to routine recording at this level in the two largest datasets; NT logbooks and QSCP records. Of those recorded at species level, 65.5% were recorded as *A. cuspidata*, 10.0%, 14.8% and 9.3% of *P. clavata*, *P. microdon* and *P. zijsron* respectively. A total of three *P. pectinata* were recorded (0.3%). These records were included in the family level group for other calculations. While *A. cuspidata* and *P. zijsron* records came from a variety of sources, *P. microdon* and *P. clavata* were identified almost exclusively from research datasets. There are few species-specific records with values for sex, length and weight (Figure 6.4).

6. CHAPTER 6 – OBJECTIVE 5 RE-EVALUATE RISK ASSESSMENT – ASSESSING THE RISK TARGET AND BYCATCH FISHERIES POSE TO ELASMOBRANCHS IN NORTHERN AUSTRALIA

Objective 5 *To re-evaluate the risk assessment of northern chondrichthyans (undertaken in the EA project), based on the new information collected above. This risk assessment will be compatible with the one undertaken in application FRDC 2002/033 (PI Terry Walker) in line with the NPOA-Shark priority for a national approach to risk assessment for chondrichthyans.*

6.1 Background

Worldwide, there is increasing concern over the sustainability of elasmobranch fisheries due to these species slow growth, low natural mortality rates and low reproductive potential (Stevens 1997; Walker 1998; Prince 2002; Baum *et al*. 2003). Management of fisheries that capture elasmobranchs as a target or bycatch is further hampered by the lack of species-specific catch and effort data and biological data required for conventional stock assessment models. In Australia, the level of concern is reflected in the high number of species listed in the IUCN Red List of threatened species. Of the species recorded in northern Australian fisheries assessed in this study, 2 species are considered to be critically endangered, 4 species endangered, 1 species vulnerable and 19 species near threatened.

Following the development of an International Plan of Action for Sharks (IPOA – Sharks, FAO 1999a) Australia developed its own National Plan of Action for Sharks (NPOA – Sharks), of which the first objective is to: “ensure that shark catches from target and non target fisheries are sustainable”. An important issue arising from the NPOA – Sharks was the need to collect data on the species-specific catch and landings of elasmobranchs and the need for these data in ecological risk assessments. Ecological risk assessment is becoming an increasingly used approach in fisheries to assess the sustainability of individual species to better guide management.

The system for recording catches of elasmobranchs as a target or bycatch in northern Australian fisheries does currently not allow the sustainability of species captured in these fisheries to be adequately assessed, particularly in Queensland and the Northern Territory (NT) (Gribble *et al.*, 2003). Queensland logbooks only record the weight of shark fillet and trunks with no species-specific data. In NT, commercially important species are only recorded in groups such as “blacktip” and “hammerhead” shark. However, for bycatch even this level of detail is unknown. In WA, there is some information on catch composition of target species in the Western Australian North Coast Shark Fishery (WANCSF). Bycatch composition data from WA fisheries is also largely unknown. The lack of species-specific elasmobranch catch data in northern Australian fisheries does not allow for an assessment of the sustainability of individuals species captured in these multi-species fisheries as a target species or as bycatch using conventional population models.

Due to the lack of species-specific catch data, there are a number of ecological risk assessment techniques that can be useful for assessing the risk of individual species in highly diverse and data poor assemblages impacted by a range of fisheries (Milton *et al.*, 2001; Stobutzki *et al.*, 2001; Stobutzki *et al.*, 2003). Stobutzki *et al*. (2003) produced a preliminary risk assessment of 148 species of northern Australian sharks and rays taken in 28 fisheries based on available data. Although this assessment approach was valid, the catch composition in the fisheries assessed was largely unknown and therefore the results should be viewed with caution. In addition to the lack of fisheries catch data, species-specific biological data were also lacking for many species. For all species, 43 % of the biological parameters were unknown and therefore given the highest possible rank as a precautionary approach. This resulted in the potential for overestimation of the risk to many species.

Using data collected in Chapters 2 and 4, this chapter will assess the sustainability of elasmobranchs in northern Australian fisheries using two semi-quantitative attribute-based risk assessment methods. Risk assessment refers to the relative risk to species from commercial fishing in the region. Risk is dependent on the vulnerability of each species to fishing activities based on their ability to recover from fishing and the amount of a population captured by the fishery/fisheries. Risk is essentially an estimate of sustainability and will highlight priority species for management and research. Species that are classified as high risk are least likely to be sustainable in the long term while low risk species are likely to be sustainable.

6.1.1 Risk Assessment methodology

The risk a fishery poses to a population of animals is dependent on the fishing effort, the catchability and biology of individual species. Recent efforts to qualitatively evaluate risk to individual species in several fisheries that impact high numbers of species have centred on this principle with the term ‘susceptibility’ being used to describe the relative likelihood that a species with particular ecological and biological attributes will be caught using a particular gear type. The potential for a species to recover from fishing has been termed ‘productivity’ or ‘recovery’ and describes the biological attributes of a species relevant to reproductive potential, and therefore, their ability to recover after depletion. Milton (2001) and Stobutzki *et al.* (2001b, c) developed a semi-quantitative attribute-based method for assessing the risk of fishing to seasnakes, teleosts and elasmobranchs in Australia’s Northern Prawn Fishery (NPF). This risk assessment method uses a ranking system to qualitatively assess the risk to individual species based on their ‘susceptibility’ to capture by fishing and their ‘recovery’ capacity once populations are fished. These methods are known as either Productivity - Susceptibility Analysis (PSA) (Hobday *et al.*, 2003) or Recovery – Susceptibility Analysis (RSA) (Griffiths *et al.*, 2006). The overall susceptibility and recovery ranks are plotted to estimate the species that are likely (or least likely) to be sustainable. This method only produces a relative indication of risk, determining the actual risk of extinction (see Ottway *et al.*, 2004) or likelihood of overexploitation is not possible with these methods.

The relative simplicity of this method and its ability to handle hundreds of species with limited data has resulted in it being widely used to assess ecological sustainability of elasmobranchs in a range of Australian fisheries. Gribble *et al.* (2004) used the PSA method on Queensland inshore and offshore gill net fisheries. Stobutzki *et al.* (2001 b) used the PSA method in the (NPF) and Griffiths *et al.* (2006) used the RSA method in the NPF following the introduction of turtle excluder devices (TEDs) and bycatch reduction devices (BRDs). Stobutzki *et al.* (2003) used a similar risk assessment methodology to assess the cumulative risk of 28 fisheries across northern Australia that captured elasmobranchs as a target or bycatch

The overall objective of this chapter was to produce an updated risk assessment for northern Australian elasmobranchs in order to assess their sustainability in northern fisheries. The specific aims were:

1. Update scores for ‘recovery’ attributes using biological data collected by fisheries observers (Chapter 4).
2. Obtain estimates of the ‘susceptibility’ of each species using observer data on the catch composition, species specific post-capture mortality and gear selectivity of different fisheries (Chapters 2 and 4).
3. Compare the multiplicative (Walker 2004) and additive (Stobutzki *et al.*, 2001, 2003) methods of estimating susceptibility and determine the most appropriate method.
4. Assess the risk of individual fisheries on the sustainability of individual elasmobranch species taken as a target or bycatch.
5. Assess the cumulative risk of all northern Australian fisheries on the sustainability of individual elasmobranchs.

6.2 Methods

A total of 29 northern Australian fisheries that have the potential to capture elasmobranchs were included in the risk assessment. These fisheries were chosen on the basis of the fishing gear used and the area fished. A list of the fisheries, methods, area of operation, effort and target species is provided in Chapters 2 and 4. Data from fisheries observers in this project as well as observer data from previous projects were used to produce a list of species captured in these fisheries. A total of 75 species were recorded in 29 fisheries. The risk assessment methodology was based on methods developed by Milton (2001), Stobutzki *et al.* (2001b, c) and Walker (2004). The sustainability of species was considered to be dependant on: 1) the susceptibility of the species to capture and mortality by the fishery, and 2) the capacity of a population to recover after depletion. A range of criteria were used to determine the final susceptibility and recovery values. The 'susceptibility' and 'recovery' of each species was plotted along two axes to estimate the overall risk or sustainability of each species. The overall values of 'sustainability' and 'recovery' were derived from several criteria summarised below.

6.2.1 Susceptibility

Susceptibility of a species to capture and subsequent retention by a fishery is dependent on the ecological interaction of the species with the fishery operation. The likelihood that a particular species is susceptible to capture and mortality is dependent upon the location of the fishery (distribution, habitat and depth) in relation to the species spatial distribution, the type of gear used, fishing effort, and post-capture mortality. The following criteria were used to assess the susceptibility of a species to capture:

6.2.2 Range

Range: The extent of overlap between the fishery and the species' distribution.

This made use of species distribution data from Last and Stevens, 1994; Compagno and Niem, 1998, CAAB database and boundaries of state fisheries.
Rankings were based on the extent of longitudinal overlap between known species distribution and fishery area. Species whose distribution extends well beyond the boundaries of the fishery were considered less susceptible than species whose distribution is encompassed by a fishery.

Rules:
If overlapping area of fishery / area of species distribution <0.33, rank = 1
If overlapping area of fishery / area of species distribution >0.33 and <0.66, rank = 2
If overlapping area of fishery / area of species distribution >0.66, rank = 3

6.2.3 Habitat

Habitat: Irrespective of geographic overlap (range), the extent of overlap between habitats fished (eg reef, soft sediment, oceanic etc) and species habitat preferences will influence susceptibility.

This made use of species habitat data from Last and Stevens, 1994; Compagno and Niem, 1998, CAAB database, Fishbase and boundaries of state fisheries.
6Rankings will be based on the extent of overlap between species' habitat and the habitat each fishery fishes over or on (Table 6.2-1).

6.2.4 Habitat definitions

Estuarine: Species found within estuaries and inside river mouths including freshwater.

Coastal: Species found in coastal inshore areas from mean high water mark to 3 nm from land.

Shelf: Species found between 3 nautical miles offshore and 200 m.

Slope: Species found between 200 and 700 m.

Oceanic: Pelagic species found off the shelf.

Pelagic: Species that spend the majority of their time in upper layers of the water column and are not associated with, or feed on, the sea floor.

Benthopelagic: Species that spend time in the water column but also feed on demersal animals.

Demersal: Species that spend all of their time on the bottom (e.g. *Dasyatis kuhlii*) and do not venture far from the seafloor to feed.

Soft substrate: Demersal species that are primarily associated with soft substrata (sand, mud etc).

Reef: Species that are primarily associated with coral or rocky reefs (eg *Carcharhinus amblyrhynchos*).

Table 6.2-1: Susceptibility in relation to habitats that a fishery interacts with. Species habitat preferences are shown in Table 6.6-1.

Fishery type	Fishery	Low (1)	Medium (2)	High (3)
Prawn trawl	NPF, WABP, WAEGPT, WAKP, WANBPF, WAOPF	pelagic, oceanic, reef	benthopelagic, coastal, shelf	demersal, soft substrate, shelf, coastal
Scampi trawl	NWSTF	pelagic, benthopelagic, demersal, oceanic, coastal, soft substrate, estuarine, reef, shelf	benthopelagic, slope	demersal, soft substrate, slope
Fish trawl	NTFT, QDFT, WAPFTF	pelagic, oceanic, demersal, benthopelagic, coastal, estuarine, reef, slope, soft substrate	demersal, benthopelagic, shelf, coastal	demersal, shelf, soft substrate
Inshore gillnet	N3, N6, N7, QMBF, WAKGBF, WAEMBGF, NTBarr, NTBN, NTCN, NTMBF	pelagic, oceanic, benthopelagic, demersal, shelf, slope	demersal, benthopelagic, reef, shelf	pelagic, benthopelagic, shelf, soft substrate
Offshore gillnet	N9, QFJA	pelagic, oceanic, demersal, coastal, reef, estuarine	pelagic, benthopelagic, slope	pelagic, benthopelagic, off-shore, soft substrate
Inshore and offshore gillnet	NTONL, WAFJA, WANCSF,	oceanic, pelagic, demersal, benthopelagic, reef, slope, shelf	demersal, reef, coastal	pelagic, demersal, benthopelagic, coastal, shelf, soft substrate
Pelagic troll line	NTM, L4, L5	demersal, estuarine, oceanic, slope	pelagic, benthopelagic, coastal	pelagic, benthopelagic, coastal, shelf
Demersal line	WAPDL (WANCSL), NTTRF, NTDF	demersal, benthopelagic, pelagic, estuarine, coastal, shelf, oceanic	pelagic, benthopelagic, coastal, shelf	demersal, benthopelagic, reef, shelf, soft sediment
Fish trap	WANDSF, NTCL, WAPTF, NTTRF, NTDF	demersal, pelagic, oceanic, benthopelagic, estuarine, coastal, soft substrate	demersal, benthopelagic, reef, soft substrate, shelf	demersal, benthopelagic, reef, shelf
Demersal shark longline	WANCSF, WAFJA, NTFJA	estuarine, pelagic, oceanic, demersal, benthopelagic, slope	coastal, reef	demersal, benthopelagic, pelagic, coastal, shelf

6.2.5 Depth

Depth: The extent of overlap between the depth range fished and the vertical distribution of the species.

- Use species depth distribution data from Last and Stevens, 1994; Compagno and Niem, 1998, and Fishbase and depth fished by each fishery.
- Rankings will be based on the extent of overlap between species depth and the depth range each fishery fishes.

Rules:
If overlapping depth of fishery / depth of species distribution <0.33, rank = 1
If overlapping depth of fishery / depth of species distribution >0.33 and <0.66, rank = 2
If overlapping depth of fishery / depth of species distribution >0.66, rank = 3

6.2.6 Selectivity

Selectivity: Selectivity is the relative proportion of a population that are vulnerable to capture in the fishing gear. This takes into account mesh size, speed of gear (e.g. trawl speed), and the size of animals likely to encounter the gear. Although a species may interact with a particular gear type, it does not always result in capture. Additional data from the fishery (average size at capture) and expert knowledge (size of animals in a particular area, mesh selectivity) was therefore used to determine this rank. For example, bull sharks *Carcharhinus leucas* in estuarine and coastal areas are best captured in 6-7 inch mesh gill nets, since the majority of animals in these areas are juveniles and are small enough to be meshed. However, over the shelf, the majority of bull sharks are large adults that are too big to be captured in 6 – 7 inch mesh gill nets. In estuarine gill net fisheries, bull sharks would have a selectivity of 3, whereas in offshore fisheries, the selectivity rank would be 1. The following guidelines were used to determine overall rank.

Low risk (rank = 1): Species that are known to inhabit the area being fished but are not recorded or are recorded infrequently in the gear type eg: stingrays and eagle rays in gill nets. These species may interact with the gear but because of their morphology they are not captured. Less than 33% of animals encountering the gear are captured.

Medium Risk (rank = 2): Species that are captured by the gear type but are not always captured when they interact with it. Between 33 and 66% of animals encountering the gear are captured

High Risk (rank = 3): Species are almost always captured by a gear when they encounter it. For example, black tip sharks and sawfish in gill nets. This largely relates to target fisheries where the gear is specifically designed to capture particular species. Greater than 66% of animals encountering the gear are captured

6.2.7 Post capture mortality

Post capture mortality: Post-capture mortality is the proportion of animals that survive after capture, handling and being returned to the water. For target species, survival is obviously low as most animals are retained. For species that are released, post-capture mortality takes into account the proportion of animals that survive release. Post-capture mortality was determined from observation of released animals by observers and from the expert panel.

Rules:

If more than 66% of animals are released alive following capture and survive release, rank = 1
Between 33 and 66% of animals survive capture and release, rank = 2
Less than 33% survive capture and release, rank = 3

Survival rules for sawfish in Western Australia (WAEMBGF and WAKGBF)

Anoxypristis cuspidata , rank = 3 for both fisheries. Retention and very low post release survival

Pristis clavata

EMBGF, rank = 1. Most animals are small and are released, survival is high.

KGBF, rank = 2. Animals are larger and therefore more difficult to release. However, it is assumed that one operator can release all animals.

Pristis zijsron, rank = 3 for both fisheries
Pristis microdon, rank = 3 for both fisheries

6.2.8 Recorded

Recorded: This criteria uses observer data on species composition to identify whether a species is captured by the fishery or not. Observer coverage in certain bycatch fisheries was probably not representative of the fishery and species composition was not always determined. In these cases, data from similar fisheries was used based on expert opinion at a risk assessment workshop held in Cleveland (February 2006). Workshop participants included: Dr John Stevens (CSIRO), John Salini (CSIRO), Terry Walker (DPI Victoria), Dr Neil Gribble (QDPIF), Mark Doohan (QDPIF), Rory McAuley (WA Fisheries), Dr Rik Buckworth (NTDBIRD), Dave McKey (NTDBIRD) and Dr Richard Pillans (CSIRO).
For example, species composition in the NTCN fishery was not determined but was assumed to be similar to the NTBarr fishery. Differences in the selectivity of the mesh size in these two fisheries are accounted for in the selectivity criteria. Species are either recorded in a fishery or not, therefore the following criteria were used:

Low Risk (rank = 1): Species that are not recorded in the fishery
High Risk (rank = 3): Species that are recorded by the fishery

6.2.9 Weighting of fisheries that use more than one method

Certain fisheries use a combination of gill nets and long lines (eg NTONL, WANCSF) or demersal long lines and traps (eg NTTRF). For these fisheries, the susceptibility for each method was calculated independently and then weighted using the relative effort (number of licences utilising each method) to determine the overall rank. Separate risk assessments for gill net and long line or line and trap components of individual fisheries could not be conducted due to confidentiality issues where fewer than 5 boats were using a particular method.

6.3 Recovery

Recovery is specific to the biology of individual species. Fast-growing, highly fecund species having a greater capacity to recover once the population is depleted than slower-growing species with low fecundity. Scores for recovery criteria were determined from biological data on all species. Estimates of recovery were primarily based on size data due to the general relationship between size, growth rates and population recovery. In general, larger species tend to live longer, have slower growth and older maturation (Roberts and Hawkins, 1999; Jennings *et al.*, 1999). Species with these characteristics have been shown to be significantly more susceptible to population decline under fishing pressure.

Smith *et al.* (1998) studied the rebound potential of 26 species of Pacific sharks using a demographic modelling technique. They use a derivative of the population parameter ‘r’,or λ (intrinsic rate of natural increase) which they termed r_{2M} (intrinsic rate of population increase at MSY). Their results showed: i) smaller sized sharks tended to mature earlier, be shorter lived, and had r_{2M} values than larger species. These species had the highest rebound or r_{2M} and were smaller inshore coastal species (eg *Rhizoprionodon terranovae*), ii) sharks within the mid-range r_{2M} values were mostly large and relatively fast-growing and early-maturing pelagic species. This group included species such as *Galeocerdo cuvier, Carcharhinus limbatus, Prionace glauca*, as well as some benthic species such as *Triaenodon obesus*, and iii) sharks with lowest recovery probabilities (lowest r_{2M}) were medium to large in size, slow growing, late-maturing coastal sharks such as *Carcharhinus leucas, C. obscurus, C. plumbeus* and *Negaprion brevirostris*.

In the absence of age and growth data for most species (49 of 71 spp.), we have utilised a combination of the following characters to score recovery criteria and to determine the overall recovery score.

Size at birth
Smaller species with higher “*k*” values (*sensu* von Bertalanffy growth parameters) are born at a higher proportion of their maximum size than larger, slower growing species (Cortez, 2000). Our data supported this with values of size at birth/max size (expressed as a percentage) between 33-45% for small species such as *R. taylori* and *C. sorrah.* Larger species such as *C. leucas* and *N. acutidens* have values between 8-20%. Species born at a smaller size generally represent faster growing, highly productive species.

Size at maturity
Species with a large size at maturity tend to have a longer generation time and are more vulnerable to over-exploitation since recruitment and population recovery is slow (Jennings, 1998; Roberts and Hawkins, 1999). Frisk *et al.* (2001) also showed that larger species had slower growth rates within the family Carcharhinidae.

Age at maturity
Species that mature later have longer generation times and are therefore less productive.

Age at maturity/max size
Age at maturity/maximum size was used only when data on age at maturity were available. Combining age at maturity and max size ranks species with a small size but slow growth rates (eg *C. plumbeus*) more accurately.

Maximum size
Species that attain a large size are generally longer lived than smaller species, at least in tropical regions. Frisk *et al.* (2001) showed that larger species within the family Carcharhinidae have slower growth rates. In general, larger species tend to live longer and their populations recover more slowly (Roberts and Hawkins, 1999).

Annual fecundity (pups per litter and reproductive periodicity)
Annual fecundity takes into account both number of pups and reproductive periodicity. However, in 30 out of 53 cases within the group of species where TL was used to determine ranks, there was no data available on reproductive periodicity. This would have lead to all of these species being ranked as “high risk” by using the highest precautionary value for any criteria using this value. However, data on number of pups per litter are available for most species. It was therefore considered more informative to use both number of pups per litter and reproductive periodicity and obtain a separate ranking for

each. Species that produce more pups per year are more productive and will have a greater resilience to fishing pressure.

6.3.1 Overall recovery

Recovery was determined by taking the average of all recovery parameters (see Determination of risk from each fishery on individual species under the following conditions.

For species where no age data was available:

Recovery = weighted average of ranks for size at birth, size female maturity, maximum size, number of pups per litter and reproductive periodicity.

For species where age data was available:

Recovery = weighted average of ranks of size at birth, age at maturity, age at maturity/max size, number of pups per litter and reproductive periodicity.

The two different calculations of recovery were made to take into account age data if it was known. In addition, an expert panel assessed each final recovery ranking to determine if there were species that were ranked incorrectly in terms of their biology. There was agreement that all species were ranked accurately with respect to other species.

6.3.2 Determination of recovery:

Each species was ranked 1, 2 or 3 for each recovery criteria. Rankings were determined from biological data of each species (Table 6.6-2). For each criterion, the minimum and maximum values were log transformed and divided into thirds. These boundary points were then back transformed to provide a means of determining criteria ranking (Table 6.3-1, Table 6.3-2). Log transformation was used to reduce the influence of outliers.

Table 6.3-1: Criteria used to determine recovery ranking for size at birth, size at female maturity and maximum size. Size ranges were calculated in total length (TL) for sharks, shovelnose rays, guitarfish and sawfish. Disk width (DW) was used for stingrays and skates. For example, a species with a birth size of 40 cm TL would be given a rank of 2 for the size at birth criteria.

Rank	Size at birth (TL)	Size female maturity (TL)	Maximum size (TL)
1	< 30.69	< 80.13	<137.57
2	between 30.70 and 55.4	between 80.14 and 183.28	between 137.57 and 300.41
3	> 55.4	>183.28	>300.41

Rank	Size at birth (DW)	Size female maturity (DW)	Max size (DW)
1	< 16.167	<32.61	<45.69
2	between 16.17 and 23.75	between 32.62 and 62.55	between 45.69 and 122.78
3	>23.76	>62.56	>122.78

Table 6.3-2: Criteria used to determine recovery ranking for age at maturity (only species where age data were available), litter size, reproductive period and age female maturity/maximum size (only species where age data were available).

Rank	Age at maturity	Litter size	Reproductive period	Age maturity/maximum size
1	<2.71	>11.69	<1	<0.018574
2	between 2.71 and 7.36	between 3.41 and 11.69	>=1	between 0.01857 and 0.03305
3	>7.36	<3.41	> or = 2	> 0.03305

The following decision rules were used to filter the biological data from various sources into Table 6.5-3. In all cases, regional data was used in preference to data from other areas.

Birth size (cm TL) – where more than one credible value was available, the smallest value was used.

Size at female maturity (cm TL) – where more than one credible value was available, the smallest value was used.

Maximum size (cm TL) – where more than one credible value was available, the largest value was used.

Age at female maturity (years) – where more than one credible value was available, the smallest value was used.

Max age (years) – where more than one credible value was available, the largest was used.

Average Litter Size – where average was available it was used, otherwise the mean of maximum and minimum litter sized was used. If only one value was available it was used.

Reproductive Period (years) – where more than one credible value was available, the largest value was used. Adjustments were made for to make gestation period consistent for all species.

6.4 Weighting of criteria

All criteria were weighted to reflect their perceived importance to overall ‘recovery’ or ‘susceptibility’. Recovery weightings mainly reflected the importance of size at maturity, number of pups and reproductive periodicity to overall reproductive output. In contrast, ‘susceptibility’ weightings place more emphasis on criteria such as selectivity, survival and whether a species is recorded in a fishery. Weightings were determined based on expert opinion at a risk assessment workshop held in Cleveland (February 2006). Workshop participants included: Dr John Stevens (CSIRO), John Salini (CSIRO), Terry Walker (DPI Victoria), Dr Neil Gribble (QDPIF), Mark Doohan (QDPIF), Rory McAuley (WA Fisheries), Dr Rik Buckworth (NTDBIRD), Dave McKey (NTDBIRD) and Dr Richard Pillans (CSIRO).

The following weightings were applied to susceptibility and recovery criteria:
Susceptibility: Range = 2, Habitat = 1, Depth = 2, Selectivity = 3, Post capture mortality = 3, Recorded = 3
Recovery: Size at birth = 1, Size at female maturity = 3, Maximum size = 1, Number of pups = 3, Reproductive periodicity = 3

6.4.1 Effort weighting

An effort weighting was used in an attempt to weight the fishing mortality imposed by each fishery. Effort weighting was only applied to the cumulative risk assessment (Objective 5). Intuitively, a fishery that targets elasmobranchs will have a greater impact than a fishery that only captures a few elasmobranchs on rare occasions. The exceptions to this are fisheries that infrequently capture rare species or catch large numbers of elasmobranchs that share the same habitats as as the target species of a fishery, such as prawn trawling . In these cases, the impact from these captures may be equal to or greater than target elasmobranch fisheries. Due to the lack of species-specific catch data in all state logbooks, species-specific catch data could not be used.

The total susceptibility of any species to a particular fishery was therefore weighted according to the total catch of elasmobranchs within that fishery. This approach was required to limit overestimation of risk from fisheries that do not capture large quantities of elasmobranchs.

The total catch of elasmobranchs from all fisheries was determined from 2004 logbook data. Total catch (kg) was used in preference to CPUE due to high effort in fisheries that interact with elasmobranchs as bycatch, which would underestimate the importance of these fisheries.

The minimum and maximum elasmobranch catch in all fisheries were log-transformed and divided into thirds. These boundary points were then back transformed to categorise the catch from each fishery as High (3), Medium (2) or Low (1). Each fishery was assigned a rank of 1, 2 or 3, which was used to calculate the cumulative susceptibility of each species to all fisheries.

Species-specific catch composition for some fisheries was available from observer data, however, it was not used to weight “susceptibility” due to the limited number of shots observed in all fisheries and the large variation within species-specific CPUE within fisheries.

6.4.2 Determination of risk for each species per fishery

Susceptibility was determined using both a multiplicative and a weighted average approach. This was done in order to compare the outcome of each method and determine which method is the most appropriate.

The total susceptibility score using the multiplicative approach was calculated as:

$$S_i = \left(\frac{\prod_{j=1}^{n} R_i}{243} \right) \times 2/3 + 1$$

where S_i = the total susceptibility for species *i*
R_i = the rank (1, 2, or 3) for species *i* for criteria *j*
n = the number of susceptibility criteria

The total susceptibility score (weighted average method) or recovery ranking for each species in each fishery was determined by the following equation:

where S_i = species susceptibility in fishery *i* or recovery rank for species *i*

W_j = the weighting for criteria *j*
R_i = the rank (1, 2, or 3) for species *i* for criteria *j*
n = number of susceptibility or recovery criteria

$$S_i = \frac{\sum_{j=1}^{n} W_j R_i}{\sum_{j=1}^{n} W_j}$$

$$S_i = \frac{\sum_{j=1}^{n} W_j R_i}{\sum_{j=1}^{n} W_j}$$

6.4.3 Determination of cumulative risk of all fisheries on individual species

Total susceptibility combined for all fisheries for individual species was determined by:

Where: S_i = total susceptibility for species *i* in all fisheries
W_j = weighting for fishery *j* (total elasmobranch catch in each fishery)
R_i = susceptibility rank for species *i* in fishery *j*
n = number of criteria on each axis

The total 'susceptibility' and 'recovery' criteria were graphed to determine the relative sustainability of each species across all fisheries. The most sustainable species have the lowest rank in both axes, while the least sustainable (highest risk) species will have the highest values on both axes. Species with a low susceptibility rank and high recovery rank will also be at low risk as these species are not captured by the fishery/fisheries. Species that have low recovery ranks and medium to high susceptibility ranks will be at medium to high risk.

6.5 Results

6.5.1 Recovery

Recovery and susceptibility ranks were determined for 75 species in 29 fisheries. Ranks of recovery criteria and the percentage of species with species-specific biological data available for rank determination are presented in Table 6.5-1 and Table 6.5-2. Final recovery ranks are shown in Table 6.5-3. For species where total length was used (Table 6.5-1), age at maturity and reproductive periodicity had the least amount of species specific biological data. For species where disk width (DW) was used (Table 6.5-2) there were few data on all criteria except maximum size. Lack of biological data resulted in these species having a high recovery rank as all unknown criteria were given a precautionary maximum value of 3. Species that had a high recovery ranking due to a lack of data included *Aetobatis narinari*, *Himantura jenkinsi*, *Mobula eregoodootenkee Pastinachus sephen* and *Urogymnus asperrimus.*

Species with the lowest recovery ranks (highest recovery potential) were primarily smaller species such as *Carcharhinus sorrah*, *C. macloti*, *Hemigaleus microstoma*, *Rhizoprionodon acutus*, *R. taylori*, *Dasyatis kuhlii* and *D. leylandi*. Species with the highest recovery rankings were primarily large species including *Carcharhinus amboinensis, C. leucas, C. obscurus*, *Negaprion acutidens*, *Pristis microdon* and *P. zijsron*.

Table 6.5-1: Species specific recovery criterion ranks for species where total length (TL) was used. Ranks were calculated based on criteria in Table 6.3-2Table 6.3-2. Numbers in parenthesis is the weighting used for each criteria. Species with an asterisk are those only recorded in the NWSTF. Ranks of 3 with an asterisk represent criteria where species specific data was unknown. For species were data was not available, a rank of 3 was assigned. The species specific information (% known) column represents the number of species for which data was available for that criterion.

Scientific name	Size at birth (1)	Size at female maturity (3)	Maximum size (1)	Litter size (3)	Reproductive periodicity (3)	Age at maturity (3)	Age at maturity/maximum size (1)	Percent known for each species
Species specific information (% known)	**98**	**90**	**100**	**84**	**65**	**36**	**36**	
Alopias pelagicus	3	3	3	3	3*	2	2	80
Anoxypristis cuspidata	3	3	3	1	2	1	1	100
Carcharhinus albimarginatus	2	3	2	2	3	3*	3*	100
Carcharhinus altimus	3	3	2	2	3*	3*	3*	80
Carcharhinus amblyrhynchoides	2	2	2	2	2	3*	3*	100
Carcharhinus amblyrhynchos	2	2	2	3	3	3	3	100
Carcharhinus amboinensis	3	3	2	2	3	3*	3*	80
Carcharhinus brevipinna	3	3	2	2	3	2	2	100
Carcharhinus cautus	2	2	2	3	2	3*	3*	100
Carcharhinus dussumieri	2	1	1	3	2	3*	3*	100
Carcharhinus falciformis	3	3	3	2	3	2	2	100
Carcharhinus fitzroyensis	2	2	1	2	2	3*	3*	100
Carcharhinus leucas	3	3	3	2	3	3	3	100
Carcharhinus limbatus	3	3	2	2	3	2	2	100
Carcharhinus macloti	2	1	1	3	2	3*	3*	100
Carcharhinus melanopterus	2	2	2	2	2	3*	3*	100
Carcharhinus obscurus	3	3	3	2	3	3	3	100
Carcharhinus plumbeus	2	2	2	2	3	3	3	100
Carcharhinus sorrah	2	2	2	2	2	1	1	100
Carcharhinus tilstoni	3	2	2	3	2	2	2	100
Carcharias taurus	3	3	3	3	3	2	2	100
Centrophorus granulosus	2	3*	2	3	3*	3*	3*	60
Chiloscyllium punctatum	1	1	1	3*	3*	3*	3*	40
Eucrossorhinus dasypogon	1	3*	1	3*	3*	3*	3*	40

Scientific name	Size at birth (1)	Size at female maturity (3)	Maximum size (1)	Litter size (3)	Reproductive periodicity (3)	Age at maturity (3)	Age at maturity/maximum size (1)	Percent known for each species
Eusphyra blochii	2	2	2	2	2	3*	3*	100
Galeocerdo cuvier	3	3	3	1	3	1	1	100
Glyphis sp. A	2	3	2	2	3	3*	3*	100
Glyphis sp. C	3	2	2	2	3*	3*	3*	60
Hemigaleus australiensis	1	1	1	2	2	3*	3*	100
Hemipristis elongata	2	2	2	2	3	3*	3*	100
Hexanchus griseus	3	3	3	1	3*	3*	3*	80
Hydrolagus lemures *	1	1	1	3*	3*	3*	3*	60
Isurus oxyrinchus	3	3	3	2	3	3	3	100
Loxodon macrorhinus	2	1	1	3	2	3*	3*	100
Mustelus sp. B	1	1	1	2	2	3*	3*	100
Nebrius ferrugineus	2	3	3	1	2	3*	3*	80
Negaprion acutidens	3	3	2	2	3*	3*	3*	80
Orectolobus wardi	3*	3*	1	3*	3*	3*	3*	20
Prionace glauca	2	3	3	1	3*	1	1	80
Pristis clavata	3	3	3	3*	3*	3*	3*	60
Pristis microdon	3	3	3	3*	2	1	1	80
Pristis zijsron	3	3	3	3*	2	1	1	80
Pseudocarcharias kamoharai	2	1	1	2	3*	3*	3*	80
Rhina ancylostoma	2	3*	2	3*	3*	3*	3*	40
Rhinobatos typus	2	3*	2	3*	3*	3*	3*	40
Rhizoprionodon acutus	2	1	1	2	2	3*	3*	100
Rhizoprionodon oligolinx	1	1	1	2	3*	3*	3*	80
Rhizoprionodon taylori	1	1	1	2	2	1	1	100
Rhynchobatus australiae	2	2	2	1	3*	3*	3*	80
Sphyrna lewini	2	3	3	1	2	1	1	80
Sphyrna mokarran	3	3	3	1	3	3*	3*	100
Stegostoma fasciatum	1	2	2	3	3*	3*	3*	80
Triaenodon obesus	2	2	2	3	3*	2	2	80

Table 6.5-2: Species specific recovery criterion ranks for species where disk width (DW) was used. Ranks were calculated based on criteria in Table 6.3-1 and Table 6.3-2. Numbers in parenthesis is the weighting used for each criteria. Species with an asterisk are those only recorded in the NWSTF. Ranks of 3 with an asterisk represent criteria where species specific data was unknown. For species were data was not available, a rank of 3 was assigned. The species specific information (% known) column represents the number of species for which data was available for that criterion. No age data was available for any of these species and therefore not included.

Scientific name	Size at birth (1)	Size at female maturity (3)	Maximum size (1)	Litter size (3)	Reproductive periodicity (3)	Percent known from each species
Species specific information (% known)	**59**	**64**	**100**	**41**	**23**	
Aetobatus narinari	2	3*	3	3*	3*	40
Aetomylaeus nichofii	2	2	2	3*	3*	60
Dasyatis annotata	3*	1	1	3	2	80
Dasyatis kuhlii	1	2	1	3	2	100
Dasyatis leylandi	1	1	1	3	2	100
Gymnura australis	3*	2	2	2	2	80
Himantura jenkinsii	3*	3	2	3*	3*	40
Himantura toshi	2	3	2	3	3*	80
Himantura uarnak	3	3*	3	2	3*	60
Himantura undulata	2	3	3	3*	3*	60
Manta birostris	3	3	3	3	3*	80
Mobula eregoodootenkee	3*	3*	2	3*	3*	20
Narcine sp. A	3*	1	1	3*	3*	40
Pastinachus sephen	2	3*	3	3*	3*	40
Pavoraja alleni *	1	1	1	3*	3*	60
Plesiobatis daviesi *	3*	3	3	3*	3*	40
Raja sp. F *	1	1	1	3*	3*	60
Raja sp. I *	1	2	2	3*	3*	60
Rhinoptera neglecta	3*	3*	2	3*	3*	20
Squatina sp. B *	1	1	1	3*	3*	60
Taeniura meyeni	3	3	3	3*	3*	60
Urogymnus asperrimus	3*	3*	2	3*	3*	20

Table 6.5-3: Final recovery ranking for each species in ascending order. Abbreviated name refers to the species as presented in the sustainability plots. The number of criteria were biological data was available is shown as a percentage.

Family	Scientific name	Abbreviated name	Final Recovery rank	Percent of recovery criteria where data available
Carcharinidae	*Rhizoprionodon taylori*	Rhta	1.55	100
Hemigaleidae	*Hemigaleus microstoma*	Haus	1.55	100
Triakidae	*Mustelus* sp. B	MspB	1.55	100
Carcharinidae	*Carcharhinus sorrah*	Csor	1.64	100
Carcharinidae	*Rhizoprionodon acutus*	Rhac	1.64	100
Sphyrnidae	*Sphyrna lewini*	Slew	1.64	80
Pristidae	*Anoxypristis cuspidata*	Acus	1.73	100
Carcharinidae	*Rhizoprionodon oligolinx*	Rhol	1.82	80
Dasyatididae	*Dasyatis leylandi*	Dley	1.82	100
Carcharinidae	*Prionace glauca*	Pgla	1.91	80
Carcharinidae	*Carcharhinus dussumieri*	Cdus	1.91	100
Carcharinidae	*Carcharhinus fitzroyensis*	Cfit	1.91	100
Carcharinidae	*Carcharhinus macloti*	Cmac	1.91	100
Carcharinidae	*Loxodon macrorhinus*	Lmac	1.91	100
Pseudocarchariidae	*Pseudocarcharias kamoharai*	Pkam	1.91	80
Carcharinidae	*Carcharhinus amblyrhynchoides*	Cambe	2	100
Carcharinidae	*Carcharhinus melanopterus*	Cmel	2	100
Dasyatididae	*Dasyatis annotata*	Dann	2	80
Rhynchobatidae	*Rhynchobatus australiae*	Raus	2	80
Sphyrnidae	*Eusphyra blochii*	Eubl	2	100
Dasyatididae	*Dasyatis kuhlii*	Dkuh	2.09	100
Chimaeridae	*Hydrolagus lemures*	Hlem	2.09	60
Ginglymostomatidae	*Nebrius ferrugineus*	Nfer	2.09	80
Gymnuridae	*Gymnura australis*	Gaus	2.09	80
Hemiscylliidae	*Chiloscyllium punctatum*	Chpu	2.09	40
Rajidae	*Pavoraja alleni*	Pall	2.09	60
Rajidae	*Raja* sp. F	RaspF	2.09	60
Squatinidae	*Squatina* sp. B	SqspB	2.09	60
Carcharinidae	*Galeocerdo cuvier*	Gcuv	2.27	100
Carcharinidae	*Carcharhinus cautus*	Ccau	2.27	100
Hemigaleidae	*Hemipristis elongata*	Helo	2.27	100
Narcinidae	*Narcine* sp. A	NspA	2.27	40
Carcharinidae	*Carcharhinus falciformis*	Cfal	2.36	100
Carcharinidae	*Carcharhinus tilstoni*	Ctil	2.36	100
Hexanchidae	*Hexanchus griseus*	Hexg	2.45	80
Rajidae	*Raja* sp. I	RaspI	2.45	60
Sphyrnidae	*Sphyrna mokarran*	Smok	2.45	100
Stegostomatidae	*Stegostoma fasciatum*	Sfas	2.45	80
Carcharinidae	*Carcharhinus albimarginatus*	Calb	2.55	100
Carcharinidae	*Glyphis* sp. A	GspA	2.55	100
Carcharinidae	*Triaenodon obesus*	Tobe	2.55	80
Myliobatididae	*Aetomylaeus nichofii*	Anic	2.55	60
Pristidae	*Pristis microdon*	Pmic	2.55	80
Pristidae	*Pristis zijsron*	Pzij	2.55	80
Alopiidae	*Alopias pelagicus*	Apel	2.64	80

Family	Scientific name	Abbreviated name	Final Recovery rank	Percent of recovery criteria where data available
Carcharinidae	*Carcharhinus altimus*	Calt	2.64	80
Carcharinidae	*Carcharhinus amboinensis*	Camb	2.64	80
Carcharinidae	*Negaprion acutidens*	Nacu	2.64	80
Carcharinidae	*Carcharhinus brevipinna*	Cbre	2.64	100
Carcharinidae	*Carcharhinus limbatus*	Clim	2.64	100
Carcharinidae	*Carcharhinus plumbeus*	Cplu	2.64	100
Carcharinidae	*Glyphis* sp. C	GspC	2.64	60
Carcharinidae	*Carcharhinus amblyrhynchos*	Cambo	2.64	100
Odontaspididae	*Carcharias taurus*	Ctau	2.64	100
Orectolobidae	*Eucrossorhinus dasypogon*	Edas	2.64	40
Carcharinidae	*Carcharhinus leucas*	Cleu	2.73	100
Carcharinidae	*Carcharhinus obscurus*	Cobs	2.73	100
Dasyatididae	*Himantura uarnak*	Huar	2.73	60
Lamnidae	*Isurus oxyrinchus*	Ioxy	2.73	100
Dasyatididae	*Himantura toshi*	Htos	2.82	80
Orectolobidae	*Orectolobus wardi*	Owar	2.82	20
Rhinobatidae	*Rhinobatos typus*	Rtyp	2.82	40
Rhynchobatidae	*Rhina ancylostoma*	Ranc	2.82	40
Squalidae	*Centrophorus granulosus*	Cegr	2.82	60
Dasyatididae	*Urogymnus asperrimus*	Uasp	2.91	20
Dasyatididae	*Himantura jenkinsii*	Hjen	2.91	40
Dasyatididae	*Pastinachus sephen*	Psep	2.91	40
Dasyatididae	*Himantura undulata*	Hund	2.91	60
Mobulidae	*Mobula eregoodootenkee*	Mere	2.91	20
Myliobatididae	*Aetobatus narinari*	Anar	2.91	40
Rhinopteridae	*Rhinoptera neglecta*	Rneg	2.91	20
Dasyatididae	*Taeniura meyeni*	Tmey	3	60
Mobulidae	*Manta birostris*	Mbir	3	80
Plesiobatidae	*Plesiobatis daviesi*	Pdav	3	40
Pristidae	*Pristis clavata*	Pcla	3	60

6.5.2 Susceptibility

The susceptibility of all species to capture in each fishery was assessed using both the multiplicative and weighted average method. Examples of sustainability plots from selected fisheries calculated using both the multiplicative and weighted average method are shown in Figure 6.5-2 through to Figure 6.5-24. The multiplicative method produces a significantly lower susceptibility ranking for all species unless the species was given a rank of 3 for all six criteria. When using the multiplicative method, even if a species has a rank of 3 for 5 criteria and a rank of 1 for the other, it will only have a susceptibility rank of 1.67 which is classified as low or medium risk depending on the species recovery ranking. If more than one criterion has a value of 1, the final susceptibility will not have a rank above1.22 which results in a species being classified as sustainable.

The multiplicative method works on the principle that if one of the criteria has a low rank (low risk), then the species is not at risk from that fishery. We argue that placing so much emphasis on one low rank is not the best approach when using multiple criteria to assess risk. Instead, weighting each criterion based on its importance to overall susceptibility and averaging all values provides a better reflection of risk and is a more conservative approach which follows the precautionary principle.

The weighted average method was therefore chosen to determine susceptibility of each species in each fishery. Susceptibility values of each species in each fishery are shown in Table 6.5-4. These fishery specific susceptibility values were used to calculate the cumulative susceptibility also shown in Table 6.5-4. The combination of recovery and susceptibility values in each fishery and the overall sustainability of each species are discussed below.

Table 6.5-4: The total susceptibility rank for each species in each fishery as well as the total cumulative susceptibility across all fisheries. To calculate total susceptibility, a weighting factor was applied. The weighting was determined from the total catch of elasmobranchs in each fishery (from state and territory logbook data). The total susceptibility is a weighted mean of the susceptibility ranks from each fishery. The susceptibility of six species only recorded in the NWSTF is shown at the end of the table. These species are marked with an asterisk.

FINAL SUSCEPTIBILITY	N3	N9	ECN	NPF	WAKP	WAEGPT	WABP	WANBPF	WAOPF	NTBarr	NTBN	NTCN	NTRBN	NTONL
Catch weighting	**3**	**3**	**3**	**3**	**2**	**2**	**1**	**1**	**1**	**2**	**1**	**2**	**2**	**3**
Aetobatus narinari	1.57	1.00	1.36	1.71	1.43	1.29	1.21	1.21	1.21	1.71	1.29	1.29	1.29	1.71
Aetomylaeus nichofii	1.43	1.29	1.50	2.00	1.57	1.29	1.36	1.36	1.36	1.50	1.29	1.29	1.29	1.79
Alopias pelagicus	1.43	1.43	1.43	1.64	1.43	1.29	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.21
Anoxypristis cuspidata	2.64	2.64	2.64	3.00	2.64	2.21	2.64	2.64	2.64	2.71	2.71	2.71	2.71	2.43
Carcharhinus albimarginatus	1.79	1.79	1.64	1.57	1.43	1.29	1.43	1.43	1.43	1.79	1.57	1.57	1.57	1.21
Carcharhinus altimus	1.64	1.64	1.64	1.71	1.57	1.29	1.36	1.36	1.36	1.64	1.43	1.43	1.43	1.21
Carcharhinus amblyrhynchoides	2.64	2.14	2.86	1.86	1.64	1.36	1.43	1.43	1.43	2.64	1.93	1.93	1.93	2.43
Carcharhinus amblyrhynchos	1.86	2.07	2.57	1.57	1.43	1.29	1.21	1.21	1.21	2.00	1.57	1.57	1.57	2.00
Carcharhinus amboinensis	2.71	1.71	2.64	1.79	1.57	1.29	1.36	1.36	1.36	2.43	1.93	1.93	1.93	2.00
Carcharhinus brevipinna	2.29	2.14	2.43	1.86	1.57	1.29	1.36	1.36	1.36	2.21	1.57	1.57	1.57	2.21
Carcharhinus cautus	2.64	1.93	2.71	1.86	1.64	1.36	1.64	1.64	1.64	2.43	1.93	1.93	1.93	2.43
Carcharhinus dussumieri	2.43	2.36	2.57	2.43	2.21	1.93	1.79	1.79	1.79	2.21	1.79	1.79	1.79	2.14
Carcharhinus falciformis	1.64	1.93	1.64	1.57	1.43	1.29	1.21	1.21	1.21	1.64	1.43	1.43	1.43	1.21
Carcharhinus fitzroyensis	2.71	2.64	2.71	1.86	1.64	1.36	1.64	1.64	1.64	2.43	1.93	1.93	1.93	2.43
Carcharhinus leucas	2.71	1.64	2.71	1.79	1.57	1.29	1.36	1.36	1.36	2.57	1.93	1.93	1.93	1.64
Carcharhinus limbatus	2.57	2.50	2.71	1.86	1.71	1.43	1.50	1.50	1.50	2.29	1.79	1.79	1.79	2.43
Carcharhinus macloti	2.43	2.57	2.57	2.21	2.00	1.71	1.57	1.57	1.57	2.00	1.57	1.57	1.57	2.07
Carcharhinus melanopterus	2.50	1.86	2.64	1.71	1.43	1.29	1.43	1.43	1.43	2.00	1.57	1.57	1.57	2.43
Carcharhinus obscurus	1.43	1.79	2.07	1.71	1.57	1.29	1.36	1.36	1.36	1.43	1.43	1.43	1.43	1.64
Carcharhinus plumbeus	1.43	1.79	2.07	1.71	1.57	1.29	1.36	1.36	1.36	1.43	1.43	1.43	1.43	1.64
Carcharhinus sorrah	2.50	2.57	2.64	1.86	1.57	1.29	1.36	1.36	1.36	2.43	1.79	1.79	1.79	2.43
Carcharhinus tilstoni	2.57	2.57	2.57	1.79	1.57	1.29	1.36	1.36	1.36	2.43	1.79	1.79	1.79	2.21
Carcharias taurus	1.57	1.50	1.21	1.57	1.43	1.29	1.43	1.43	1.43	1.57	1.14	1.14	1.14	1.29
Centrophorus granulosus	1.64	1.57	1.43	1.64	1.64	1.50	1.86	1.57	1.43	1.43	1.43	1.43	1.43	1.43
Chiloscyllium punctatum	1.21	1.00	1.36	2.00	1.71	1.29	1.93	1.93	1.93	1.14	1.14	1.14	1.14	1.71
Dasyatis annotata	1.36	1.36	1.36	2.57	2.43	2.00	2.43	2.43	2.43	1.43	1.43	1.43	1.43	1.79
Dasyatis kuhlii	1.14	1.00	1.21	2.36	2.07	1.93	2.07	2.07	2.07	1.14	1.14	1.14	1.14	1.50
Dasyatis leylandi	1.36	1.29	1.36	2.43	2.14	1.71	2.14	2.14	2.14	1.29	1.29	1.29	1.29	1.71
Eucrossorhinus dasypogon	1.50	1.29	1.50	1.50	1.29	1.14	1.50	1.50	1.50	1.64	1.14	1.14	1.14	1.71
Eusphyra blochii	2.64	2.64	2.86	1.86	1.64	1.36	1.43	1.43	1.43	2.64	1.93	1.93	1.93	2.50
Galeocerdo cuvier	1.86	1.79	1.71	1.43	1.36	1.07	1.36	1.36	1.36	1.43	1.43	1.43	1.43	1.79

FINAL SUSCEPTIBILITY	NTFT	QDFT	NTM	NWSTF	WA-EMBGF	WA-KGBF	WANCSF	PFTF	NTTRF	NTCL	NTDF	WANDSF	WAPTF	N6	N7	TOTAL
Catch weighting	**3**	**3**	**1**	**2**	**2**	**2**	**3**	**2**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	
Aetobatus narinari	1.71	1.79	1.14	1.21	1.50	1.50	1.43	1.29	1.07	1.14	1.07	1.14	1.07	1.29	1.36	**1.44**
Aetomylaeus nichofii	2.00	1.93	1.43	1.21	1.36	1.50	1.43	1.43	1.07	1.43	1.50	1.57	1.36	1.14	1.21	**1.54**
Alopias pelagicus	1.29	1.29	1.14	1.43	1.43	1.43	2.29	1.57	1.07	1.07	1.07	1.14	1.14	1.43	1.43	**1.51**
Anoxypristis cuspidata	2.43	2.36	1.43	2.43	2.57	2.71	2.07	2.50	1.07	1.43	1.36	1.43	1.21	1.71	1.79	**2.48**
Carcharhinus albimarginatus	1.21	1.21	1.29	1.50	1.79	1.57	2.29	1.43	1.00	1.00	1.50	1.50	1.50	1.57	1.57	**1.59**
Carcharhinus altimus	1.14	1.14	1.29	1.43	1.64	1.21	1.86	1.64	1.00	1.00	1.29	1.29	1.36	1.43	1.43	**1.51**
Carcharhinus amblyrhynchoides	1.29	1.36	1.21	1.36	2.57	2.14	2.43	1.50	1.07	1.14	1.29	1.50	1.29	1.71	1.79	**1.97**
Carcharhinus amblyrhynchos	1.21	1.21	1.29	1.21	2.00	1.79	2.50	1.29	1.00	1.00	1.50	1.57	1.57	1.57	1.57	**1.70**
Carcharhinus amboinensis	1.29	1.29	1.29	1.21	2.57	2.14	2.71	1.71	1.14	1.14	1.14	1.14	1.14	1.71	1.71	**1.92**
Carcharhinus brevipinna	1.43	1.50	1.29	1.21	2.43	1.57	2.71	1.64	1.07	1.14	1.57	1.64	1.57	1.57	1.64	**1.88**
Carcharhinus cautus	1.29	1.36	1.21	1.43	2.57	2.14	2.07	1.50	1.07	1.14	1.07	1.14	1.07	1.71	1.79	**1.92**
Carcharhinus dussumieri	1.86	1.86	1.29	1.43	2.00	1.57	2.07	2.57	1.50	1.29	1.36	1.43	1.43	1.57	1.57	**2.03**
Carcharhinus falciformis	1.00	1.00	1.29	1.29	1.64	1.43	1.86	1.50	1.00	1.00	1.29	1.29	1.36	1.43	1.43	**1.48**
Carcharhinus fitzroyensis	1.36	1.50	1.36	1.43	2.14	1.71	2.71	1.57	1.00	1.14	1.21	1.36	1.21	1.71	1.86	**2.00**
Carcharhinus leucas	1.07	1.07	1.14	1.21	1.93	1.93	2.29	1.36	1.07	1.07	1.07	1.14	1.14	1.71	1.71	**1.77**
Carcharhinus limbatus	1.36	1.50	1.36	1.21	2.21	1.36	2.29	1.36	1.00	1.14	1.50	1.64	1.50	1.57	1.71	**1.92**
Carcharhinus macloti	1.64	1.64	1.29	1.43	2.43	1.57	2.29	2.14	1.07	1.07	1.36	1.43	1.43	1.57	1.57	**1.94**
Carcharhinus melanopterus	1.29	1.36	1.29	1.43	2.00	2.00	2.50	1.50	1.07	1.14	1.36	1.43	1.36	1.57	1.64	**1.83**
Carcharhinus obscurus	1.14	1.14	1.29	1.43	1.43	1.00	2.50	1.43	1.00	1.00	1.29	1.36	1.36	1.43	1.43	**1.53**
Carcharhinus plumbeus	1.36	1.36	1.29	1.36	1.43	1.00	2.50	1.86	1.00	1.00	1.50	1.57	1.57	1.43	1.43	**1.58**
Carcharhinus sorrah	1.43	1.50	1.29	1.21	2.43	2.00	2.50	2.07	1.29	1.14	1.36	1.43	1.36	1.57	1.64	**1.97**
Carcharhinus tilstoni	1.43	1.43	1.29	1.21	2.43	2.00	2.50	1.93	1.29	1.07	1.36	1.43	1.43	1.57	1.57	**1.93**
Carcharias taurus	1.50	1.50	1.29	1.43	1.57	1.57	2.29	1.36	1.07	1.07	1.36	1.43	1.43	1.14	1.14	**1.49**
Centrophorus granulosus	1.21	1.21	1.00	2.93	1.71	1.43	1.86	1.79	1.00	1.00	1.00	1.00	1.14	1.43	1.43	**1.56**
Chiloscyllium punctatum	1.64	1.71	1.29	1.43	1.14	1.14	1.43	1.86	1.50	1.36	1.57	1.64	1.57	1.14	1.21	**1.50**
Dasyatis annotata	1.93	1.86	1.43	1.79	1.29	1.43	1.57	2.21	1.07	1.43	1.36	1.43	1.21	1.29	1.36	**1.74**
Dasyatis kuhlii	2.00	2.00	1.29	1.64	1.14	1.14	1.43	2.00	1.14	1.14	1.43	1.43	1.43	1.14	1.14	**1.57**
Dasyatis leylandi	2.29	2.29	1.29	1.43	1.29	1.29	1.43	2.29	1.14	1.14	1.29	1.29	1.29	1.29	1.36	**1.67**
Eucrossorhinus dasypogon	1.43	1.57	1.36	1.43	1.57	1.57	1.86	1.43	1.00	1.14	1.29	1.43	1.29	1.14	1.29	**1.49**
Eusphyra blochii	1.64	1.71	1.50	1.36	2.57	2.57	2.71	2.29	1.29	1.36	1.29	1.50	1.29	1.71	1.79	**2.13**
Galeocerdo cuvier	1.43	1.43	1.29	1.21	1.21	1.00	2.71	1.93	1.07	1.07	1.57	1.64	1.64	1.43	1.43	**1.62**

FINAL SUSCEPTIBILITY	N3	N9	ECN	NPF	WAKP	WAEGPT	WABP	WANBPF	WAOPF	NTBarr	NTBN	NTCN	NTRBN	NTONL

Catch weighting	**3**	**3**	**3**	**3**	**2**	**2**	**1**	**1**	**1**	**2**	**1**	**2**	**2**	**3**
Glyphis sp. A	2.86	1.64	3.00	1.79	1.50	1.36	1.43	1.43	1.43	2.86	2.14	2.14	2.14	2.00
Glyphis sp. C	1.79	1.50	1.86	1.79	1.50	1.36	1.43	1.43	1.43	2.14	1.86	1.86	1.86	2.07
Gymnura australis	1.36	1.36	1.43	2.43	2.21	1.79	2.43	2.43	2.43	1.36	1.29	1.29	1.29	1.71
Hemigaleus australiensis	2.57	2.57	2.57	2.14	1.93	1.50	1.71	1.71	1.71	2.57	1.93	1.93	1.93	2.14
Hemipristis elongata	2.36	2.36	2.57	1.79	1.57	1.29	1.36	1.36	1.36	2.14	1.71	1.71	1.71	2.21
Hexanchus griseus	1.43	1.57	1.43	1.71	1.71	1.29	2.00	2.00	1.71	1.43	1.43	1.43	1.43	1.00
Himantura jenkinsii	1.14	1.29	1.50	1.93	1.50	1.07	1.93	1.93	1.93	1.14	1.14	1.14	1.14	1.79
Himantura toshi	1.29	1.29	1.29	1.93	1.71	1.29	2.14	2.14	2.14	1.29	1.29	1.29	1.29	1.50
Himantura uarnak	1.36	1.36	1.43	1.79	1.57	1.14	2.00	2.00	2.00	1.36	1.29	1.29	1.29	1.71
Himantura undulata	1.36	1.29	1.50	1.79	1.50	1.07	1.93	1.93	1.93	1.29	1.29	1.29	1.29	1.71
Isurus oxyrinchus	1.64	1.64	1.64	1.43	1.43	1.29	1.43	1.43	1.43	1.64	1.43	1.43	1.43	1.21
Loxodon macrorhinus	2.00	2.14	2.21	2.00	1.79	1.50	1.79	1.79	1.79	2.00	1.79	1.79	1.79	2.29
Manta birostris	1.29	1.43	1.43	1.86	1.71	1.43	1.29	1.29	1.29	1.21	1.14	1.14	1.14	1.71
Mobula eregoodootenkee	1.29	1.43	1.57	1.86	1.71	1.43	1.29	1.29	1.29	1.21	1.14	1.14	1.14	1.71
Mustelus sp. B	1.86	2.00	1.86	1.79	1.64	1.50	1.71	1.71	1.71	1.86	1.43	1.43	1.43	1.43
Narcine sp. A	1.14	1.43	1.29	2.36	1.93	1.50	1.93	1.93	1.93	1.29	1.29	1.29	1.29	1.86
Nebrius ferrugineus	1.43	1.00	1.50	1.57	1.29	1.14	1.50	1.50	1.50	1.36	1.14	1.14	1.14	1.64
Negaprion acutidens	2.07	2.00	2.29	1.86	1.64	1.36	1.64	1.64	1.64	2.29	1.79	1.79	1.79	2.00
Orectolobus wardi	1.71	1.50	1.50	1.50	1.29	1.14	1.50	1.50	1.50	1.64	1.14	1.14	1.14	1.93
Pastinachus sephen	1.36	1.36	1.43	1.79	1.57	1.14	2.00	2.00	2.00	1.29	1.29	1.29	1.29	1.50
Prionace glauca	1.64	1.64	1.64	1.43	1.43	1.29	1.21	1.21	1.21	1.64	1.43	1.43	1.43	1.21
Pristis clavata	2.07	1.79	2.21	2.86	2.71	2.29	2.71	2.71	2.71	2.64	2.57	2.57	2.57	2.36
Pristis microdon	2.50	1.71	2.64	2.86	2.64	2.21	2.64	2.64	2.64	2.64	2.57	2.57	2.57	2.36
Pristis zijsron	2.50	1.71	2.64	2.86	2.64	2.21	2.64	2.64	2.64	2.64	2.57	2.57	2.57	2.36
Pseudocarcharias kamoharai	1.86	1.86	2.00	1.57	1.43	1.29	1.43	1.43	1.43	1.86	1.43	1.43	1.43	1.43
Rhina ancylostoma	1.79	1.79	1.86	1.79	1.57	1.14	2.00	2.00	2.00	1.79	1.71	1.71	1.71	1.86
Rhinobatos typus	2.36	1.93	2.43	1.93	1.71	1.29	2.14	2.14	2.14	2.14	1.71	1.71	1.71	2.14
Rhinoptera neglecta	1.43	1.36	1.71	1.50	1.43	1.14	1.43	1.43	1.43	1.36	1.14	1.14	1.14	1.71
Rhizoprionodon acutus	2.43	2.57	2.57	2.36	2.21	1.93	2.00	2.00	2.00	2.43	2.21	2.21	2.21	2.21
Rhizoprionodon oligolinx	2.50	2.36	2.57	2.64	2.29	2.00	2.07	2.07	2.07	2.36	2.07	2.07	2.07	2.43
Rhizoprionodon taylori	2.43	2.57	2.21	2.43	2.21	1.93	2.00	2.00	2.00	2.43	2.21	2.21	2.21	2.43
Rhynchobatus australiae	2.43	2.14	2.43	1.93	1.71	1.29	2.14	2.14	2.14	2.14	1.93	1.93	1.93	2.14
Sphyrna lewini	2.29	2.43	2.57	1.71	1.57	1.29	1.36	1.36	1.36	2.07	1.64	1.64	1.64	2.00
Sphyrna mokarran	2.50	2.36	2.43	1.86	1.57	1.29	1.36	1.36	1.36	2.00	1.57	1.57	1.57	2.43
Sphyrna zygaena	2.00	2.07	2.29	1.79	1.64	1.36	1.43	1.43	1.43	2.00	1.50	1.50	1.50	1.71
Stegostoma fasciatum	1.43	1.07	1.43	1.57	1.36	0.93	1.79	1.79	1.79	1.21	1.14	1.14	1.14	1.71

FINAL SUSCEPTIBILITY	**N3**	**N9**	**ECN**	**NPF**	**WAKP**	**WAEGPT**	**WABP**	**WANBPF**	**WAOPF**	**NTBarr**	**NTBN**	**NTCN**	**NTRBN**	**NTONL**
Catch weighting	**3**	**3**	**3**	**3**	**2**	**2**	**1**	**1**	**1**	**2**	**1**	**2**	**2**	**3**
Taeniura meyeni	1.21	1.07	1.43	1.50	1.29	1.14	1.71	1.71	1.71	1.14	1.14	1.14	1.14	1.50
Triaenodon obesus	1.36	1.21	1.36	1.36	1.21	1.07	1.43	1.43	1.43	1.36	1.14	1.14	1.14	1.71
Urogymnus asperrimus	1.21	1.36	1.43	1.79	1.57	1.14	2.00	2.00	2.00	1.14	1.14	1.14	1.14	2.00

FINAL SUSCEPTIBILITY	NTFT	QDFT	NTM	NWSTF	WAEMBGF	WAKGBF	WANCSF	PFTF	NTTRF	NTCL	NTDF	WANDSF	WAPTF	N6	N7	TOTAL
Catch weighting	**3**	**3**	**1**	**2**	**2**	**2**	**3**	**2**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	
Glyphis sp. A	1.14	1.07	1.57	1.21	2.00	1.79	2.29	1.43	1.00	1.43	1.14	1.14	1.00	1.93	2.00	**1.68**
Glyphis sp. C	1.36	1.36	1.36	1.50	1.93	1.86	2.57	1.43	1.00	1.43	1.36	1.64	1.21	1.71	1.86	**2.05**
Gymnura australis	2.00	2.07	1.36	1.64	1.29	1.29	1.43	2.00	1.07	1.14	1.43	1.50	1.43	1.29	1.36	**1.95**
Hemigaleus australiensis	2.07	2.07	1.29	1.43	2.14	1.93	2.07	2.36	1.07	1.07	1.21	1.29	1.29	1.71	1.71	**1.58**
Hemipristis elongata	1.93	1.86	1.29	1.50	2.14	1.93	2.29	2.36	1.57	1.29	1.29	1.29	1.29	1.71	1.71	**1.57**
Hexanchus griseus	1.43	1.43	1.00	1.71	1.50	1.29	2.29	1.50	1.00	1.00	1.50	1.79	1.79	1.43	1.43	**1.58**
Himantura jenkinsii	2.29	2.29	1.43	1.79	1.29	1.29	1.79	1.64	1.14	1.14	1.29	1.43	1.29	1.14	1.14	**1.58**
Himantura toshi	2.29	2.21	1.29	1.64	1.29	1.29	1.64	1.64	1.14	1.07	1.29	1.29	1.29	1.29	1.29	**1.60**
Himantura uarnak	2.21	2.29	1.36	1.64	1.29	1.29	1.64	1.57	1.07	1.14	1.21	1.29	1.21	1.29	1.36	**1.53**
Himantura undulata	2.21	2.29	1.29	2.21	1.29	1.29	1.79	1.57	1.07	1.14	1.21	1.43	1.21	1.29	1.36	**1.91**
Isurus oxyrinchus	1.43	1.43	1.29	1.43	1.64	1.64	1.86	1.43	1.00	1.00	1.29	1.29	1.29	1.43	1.43	**1.49**
Loxodon macrorhinus	1.29	1.29	1.29	1.64	1.79	2.00	2.50	2.14	1.14	1.14	1.86	1.86	1.86	1.79	1.79	**1.50**
Manta birostris	1.57	1.71	1.36	1.00	1.79	1.57	1.43	1.36	1.21	1.36	1.29	1.43	1.29	1.14	1.29	**1.68**
Mobula eregoodootenkee	1.14	1.29	1.36	1.57	1.79	1.57	1.57	1.36	1.00	1.14	1.71	2.00	1.71	1.14	1.29	**1.66**
Mustelus sp. B	1.14	1.14	1.00	2.14	1.86	1.43	2.07	2.00	1.00	1.00	1.71	1.71	1.71	1.43	1.43	**1.57**
Narcine sp. A	2.14	2.00	1.29	1.64	1.00	1.00	1.43	2.07	1.36	1.93	1.57	1.29	1.29	1.14	1.14	**1.94**
Nebrius ferrugineus	2.07	2.14	1.29	1.36	1.36	1.36	2.29	1.64	1.29	1.14	1.36	1.57	1.36	1.14	1.21	**1.53**
Negaprion acutidens	1.86	1.93	1.36	1.43	2.43	1.79	2.71	1.43	1.07	1.14	1.36	1.43	1.36	1.57	1.64	**1.54**
Orectolobus wardi	1.43	1.71	1.36	1.43	1.57	1.57	1.64	1.86	1.21	1.14	1.29	1.43	1.29	1.14	1.29	**1.52**
Pastinachus sephen	1.93	1.36	1.14	2.07	1.29	1.29	1.64	1.29	1.29	1.36	1.29	1.36	1.29	1.29	1.36	**2.22**
Prionace glauca	1.43	2.00	1.14	1.21	1.64	1.43	2.07	1.29	1.00	1.00	1.00	1.07	1.07	1.43	1.43	**2.26**
Pristis clavata	2.00	1.43	1.50	1.86	2.36	2.71	2.07	2.00	1.00	1.14	1.21	1.50	1.21	2.14	2.29	**2.31**
Pristis microdon	1.79	2.14	1.36	2.00	1.93	2.57	2.21	2.00	1.00	1.14	1.00	1.29	1.00	2.14	2.29	**1.64**
Pristis zijsron	2.21	1.93	1.36	2.14	2.36	2.57	2.07	2.43	1.00	1.14	1.00	1.29	1.00	2.14	2.29	**1.85**
Pseudocarcharias kamoharai	1.64	1.36	1.14	1.57	1.86	1.64	1.64	1.43	1.00	1.00	1.00	1.14	1.00	1.43	1.43	**1.98**
Rhina ancylostoma	2.00	1.64	1.36	1.64	1.93	1.93	2.07	2.21	1.07	1.14	1.64	1.71	1.64	1.71	1.79	**1.48**
Rhinobatos typus	2.07	2.07	1.29	1.64	2.36	1.93	2.07	1.86	1.14	1.14	1.29	1.29	1.29	1.71	1.71	**2.15**
Rhinoptera neglecta	1.64	2.07	1.29	1.21	1.57	1.57	1.43	1.43	1.07	1.14	1.36	1.43	1.36	1.14	1.21	**2.17**

FINAL SUSCEPTIBILITY	**NTFT**	**QDFT**	**NTM**	**NWSTF**	**WAEMBGF**	**WAKGBF**	**WANCSF**	**PFTF**	**NTTRF**	**NTCL**	**NTDF**	**WANDSF**	**WAPTF**	**N6**	**N7**	**TOTAL**
Catch weighting	**3**	**3**	**1**	**2**	**2**	**2**	**3**	**2**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	
Rhizoprionodon acutus	1.86	1.71	1.29	1.64	2.00	2.00	2.50	2.57	1.07	1.07	1.36	1.43	1.43	1.79	1.79	**2.18**
Rhizoprionodon oligolinx	1.93	1.86	1.64	1.64	2.00	1.57	2.07	2.07	1.29	1.93	1.64	1.43	1.36	1.93	2.00	**2.07**
Rhizoprionodon taylori	1.93	1.86	1.29	1.64	2.00	2.00	2.50	2.57	1.36	1.36	1.43	1.43	1.43	1.79	1.79	**1.86**
Rhynchobatus australiae	2.29	1.86	1.29	1.64	1.93	2.36	2.50	2.29	1.36	1.36	1.29	1.29	1.29	1.71	1.71	**1.92**
Sphyrna lewini	1.57	2.29	1.29	1.21	1.86	1.64	2.50	2.07	1.00	1.00	1.29	1.36	1.36	1.43	1.43	**1.82**
Sphyrna mokarran	1.64	1.57	1.29	1.21	2.00	1.79	2.71	2.07	1.07	1.14	1.57	1.64	1.57	1.57	1.64	**1.47**
Sphyrna zygaena	1.36	1.71	1.43	1.21	1.93	1.71	2.71	2.00	1.00	1.14	1.50	1.64	1.50	1.50	1.57	**1.43**
Stegostoma fasciatum	1.86	1.43	1.36	1.43	1.14	1.14	1.86	1.64	1.07	1.14	1.57	1.64	1.57	1.14	1.21	**1.44**
Taeniura meyeni	1.71	1.93	1.29	1.71	1.14	1.14	1.64	1.29	1.29	1.36	1.21	1.29	1.21	1.14	1.21	**1.49**
Triaenodon obesus	1.43	1.79	1.29	1.43	2.00	1.57	2.29	1.50	1.00	1.00	1.29	1.36	1.36	1.14	1.14	**1.44**
Urogymnus asperrimus	2.21	1.43	1.29	1.79	1.14	1.14	1.64	1.57	1.07	1.14	1.21	1.29	1.21	1.14	1.14	**1.49**
Dipturus sp. F*				2.79												**2.79**
Dipturus sp. I*				2.71												**2.71**
*Hydrolagus lemurs**				2.71												**2.71**
*Pavoraja alleni**				2.79												**2.79**
*Plesiobatis daviesi**				2.43												**2.43**
Squatina sp. B*				2.57												**2.57**

The combination of recovery and susceptibility scores are represented in sustainability plots. Figure 6.5-1 provides an explanation of how to interpret recovery-susceptibility plots which are shown for 14 fisheries (Figure 6.5-2 through to Figure 6.5-24). A summary of the sustainability of species in each fishery is provided below.

Queensland Gulf of Carpentaria inshore finfish fishery (N3)
Twenty species were least likely to be sustainable in the N3 fishery (Figure 6.5-3). Of these, 8 species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species were *Carcharhinus amboinensis*, *C. leucas*, *C. limbatus*, *Glyphis* sp. A, *P. microdon*, *P zijsron* and *Sphyrna mokarran*. Twelve species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and are also least likely to be sustainable. Catches of species with a susceptibility rank between 1.66 and 2.33 were likely to be sustainable in this fishery.

Queensland Gulf of Carpentaria inshore finfish fishery (offshore component) (N9)
Eight species were least likely to be sustainable in the N9 fishery (Figure 6.5-5). Of these, three species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species were *C. limbatus*, *C. tilstoni*, *Hemipristis elongata* and *S .mokarran*. Seven species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable based on this assessment. Of these species, *Anoxypristis cuspidata*, *C. fitzroyensis* and *Eusphyra blochii* are the least sustainable.

East Coast Net fishery (ECN)
Approximately 25 species were least likely to be sustainable in the ECN fishery (Figure 6.5-7). Of these, 14 species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species include *C. amboinensis, C. brevipinna, C. leucas, C. limbatus, C. tilstoni*, *Glyphis* sp. A, *Negaprion acutidens*, *Pristis zijsron*, *P. microdon, S. mokarran*. Eleven species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable. These species include *Carcharhinus amblyrhynchoides, C. cautus, C. melanopterus, C. fitzroyensis*, *Eusphyra blochii* and *Rhynchobatus australiae*.

Northern Prawn Fishery (NPF)
Eleven species were least likely to be sustainable in the NPF (Figure 6.5-9). Of these, three species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species were *P. clavata*, *P. microdon* and *P. zijsron.* Eight species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable based on this assessment. These species include *A. cuspidata, Dasyatis annotata, D. kuhlii, D. leylandi*, *Gymnura australis* and *Narcine* sp. A. Of these species, *A. cuspidata* had the highest susceptibility rank of all species and despite its low recovery ranking it is considered as least sustainable.

Western Australia Kimberley Prawn Trawl Fishery (WAKP)
Five species were least likely to be sustainable in the WAKP. Of these, three species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species were *P. clavata*, *P. microdon* and *P. zijsron. Anoxypristis cuspidata* and *D. annotata* were also classified as least sustainable

Western Australia Exmouth Gulf Prawn Trawl Fishery (WAEGPT)
No species had susceptibility and recovery ranks above 2.33. *Pristis clavata*, *P. microdon, P. zijsron* and *A. cuspidata* were the species least likely to be sustainable in this fishery.

Western Australia Broome Prawn Fishery (WABP), WA Nickol Bay Prawn (WANBPF), WA Onslow Prawn Fishery (WAOPF)
Species in these three fisheries had the same susceptibility ranks. Six species were least likely to be sustainable in the WABP, WANBPF and WAOPF. Of these, three species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in these fisheries. These species were

P. clavata, P. microdon and *P. zijsron.* Three species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable based on this assessment. These species were *A. cuspidata D. annotata* and *G. australis*.

Northern Territory Barramundi Fishery (NTBarr)

Fifteen species were least likely to be sustainable in the NTBarr fishery (Figure 6.5-11). Of these, seven species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species were *C. amboinensis, C. cautus, C. leucas, Glyphis* sp. A, *P. clavata, P. microdon* and *P. zijsron.* Six species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable based on this assessment. These species include *A. cuspidata, C. amblyrhynchoides, C. fitzroyensis, E. blochii* and *C. tilstoni*.

Northern Territory Bait Net Fishery (NTBN), Northern Territory Coastal Net Fishery (NTCN), Northern Territory Restricted Bait Net Entitlement (NTRBN)

Species in these three fisheries had the same susceptibility ranks. Four species were least likely to be sustainable in these fisheries. These species were *A. cuspidata*, *P. clavata, P. microdon* and *P. zijsron.* The small mesh size in this fishery prevents other species being captured; however sawfish are likely to be captured due to their heavily toothed rostrum.

Northern Territory Offshore Net and Line Fishery (NTONL)

Twenty one species were least likely to be sustainable in the NTONL (Figure 6.5-13). Of these, twelve species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species included *C. amboinensis, C brevipinna, C. limbatus, C. tilstoni*, *Glyphis* sp. C, *Negaprion acutidens, S. mokarran, P. microdon* and *P. zijsron.* Nine species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable based on this assessment. These species include *A. cuspidata*, *C. amblyrhynchoides*, *C. cautus*, *E. blochii* and *Rhynchobatus australiae*.

Northern Territory Finfish Trawl Fishery (NTFT), Queensland Demersal Fish Trawl Fishery (QDFT)

Susceptibility to capture in the NTFT and QDFT were similar. Only *A. cuspidata* was least likely to be sustainable in the NTFT and the QDFT (Figure 6.5-14).

North West Shelf Trawl Fishery (NWSTF)

Eight species were least likely to be sustainable in the NWSTF (Figure 6.5-15). Of these, three species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species were *Plesiobatus daviesi*, *Centrophorus granulosus* and *Dipturus* sp. I. Five species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable based on this assessment. These species were *A. cuspidata*, *Dipturus* sp. F, *Hydrolagus lemurs*, *Pavoraja alleni* and *Squatina* sp. B. Species that were only captured by the NWSTF were not plotted on the cumulative assessment due to the fact they are only captured in this fishery. However, they were assessed as being least likely to be sustainable due to the overlap between the NWSTF and the species distribution.

Western Australia Eighty Mile Beach Gillnet Fishery (WAEMBGF)

Nine species were least likely to be sustainable in the WAEMBGF (Figure 6.5-17). Of these, five species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species were *C. amboinensis*, *C. tilstoni, N. acutidens, P. clavata* and *P. zijsron.* Four species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable based on this assessment. These species were *A. cuspidata*, *C. amblyrhynchoides*, C. *cautus* and *E. blochii*.

Western Australia Kimberly Gillnet Barramundi Fishery (WAKGBF)

Six species were least likely to be sustainable in the WAKGBF (Figure 6.5-19). Of these, three species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species were *P. clavata*, *P. microdon* and *P. zijsron.* Three species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable based on this assessment. These species were *A. cuspidata*, *E. blochii* and *R. australiae*.

Western Australia North Coast Shark Fishery (WANCSF)

Seventeen species were least likely to be sustainable in the WANCSF (Figure 6.5-21). Of these, nine species had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. These species were *C. amboinensis, C. amblyrhynchos, C. brevipinna, C. obscurus, C. plumbeus, C. tilstoni, Glyphis* sp. C, *N. acutidens* and *S. mokarran.* Seven species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33 and were also least likely to be sustainable based on this assessment. These species included *C. amblyrhynchoides, C. fitzroyensis,* C. *melanopterus, Galeocerdo cuvier,* E. *blochii* and *R. australiae*.

Pilbara Fish Trawl Fishery (PFTF)

Seven species were least likely to be sustainable in the PFTF (Figure 6.5-22). *Pristis zijsron* and *Hemipristis elongata* had susceptibility and recovery ranks above 2.33 and were the least sustainable species in this fishery. Three species had a susceptibility rank above 2.33 and a recovery rank between 1.66 and 2.33. Of these, only *A. cuspidata* was likely to be the least sustainable. Although *Hemigaleus australiensis* had a low recovery rank, the high susceptibility of this species suggests that its capture in the PFTF is not likely to be sustainable.

Trap and Line Fisheries (NTTRF, NTCL, NTDF, WANDSF, WAPTF, N6, N7)

Trap and line fisheries that target teleosts capture elasmobranchs very rarely and as result, elasmobranchs species captured by these fisheries were considered sustainable. The plots for recovery and susceptibility in the NTTRF fishery are shown to illustrate the lack of high risk species. (Table 6.5-4).

6.5.3 Cumulative risk assessment for all northern Australian fisheries

The cumulative risk assessment is presented in Figure 6.5-25. There was less spread in the susceptibility ranks of the cumulative assessment compared to individual fisheries due to averaging over all fisheries. Sawfishes were the least sustainable group with all four species having the highest susceptibility ranks due to the fact that they are capture by prawn and fish trawls, gill nets and long lines. The only fisheries in which sawfish were likely to be sustainable were those fisheries that did not capture these animals (NT Mackerel fishery, trap fisheries and drop line fisheries targeting teleosts).

Other species that were least likely to be sustainable were *C. amblyrhynchoides, C. amboinensis, C brevipinna, C. leucas, C. limbatus, Glyphis* sp. A, *Glyphis* sp. C, *N. acutidens, S. mokarran,* and *E. blochii*. These species were classified as being least likely to be sustainable due to their high susceptibility in target and bycatch gill net and long line fisheries. Fisheries that contributed to these species high susceptibility ranks were the N3, N9, ECN, NTBarr, NTONL, WAEMBGF, WAKGBF and WANCSF.

The selectivity of the fishing gear combined with the number of species the gear interacts with was reflected in the number of species least likely to be sustainable in each fishery. Inshore gill net fisheries such as the N3, ECN, NTBarr had 20, 25 and 15 species, respectively, that were unlikely to be sustainable. This was due to the fact that these methods operate in inshore areas where species diversity is higher and because they capture juveniles of several species that utilise shallow inshore areas as well as rivers and estuaries as nursery areas. The WAEMBGF and the WAKGBF had 8 and 6 species, respectively, that were least likely to be sustainable. These numbers were lower than the N3, ECN and NTBarr due to the small geographic coverage of these fisheries. The N9 fishery which only uses pelagic gill nets beyond 9 nautical miles had 8 species that were unlikely to be sustainable. This was considerably lower than the NTONL and WANCSF (21 and 17 species least likely to be sustainable, respectively) which operate inshore and offshore and use a combination of gill nets and long lines.

6.5.4 Cumulative risk assessment for all northern Australian fisheries

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Other species that were least likely to be sustainable were *C. amblyrhynchoides*, *C. amboinensis*, *C brevipinna, C. leucas, C. limbatus*, *Glyphis* sp. A, *Glyphis* sp. C, *N. acutidens, S. mokarran*, and *E. blochii*. These species were classified as being least likely to be sustainable due to their high susceptibility in target and bycatch gill net and long line fisheries. Fisheries that contributed to these species high susceptibility ranks were the N3, N9, ECN, NTBarr, NTONL, WAEMBGF, WAKGBF and WANCSF.

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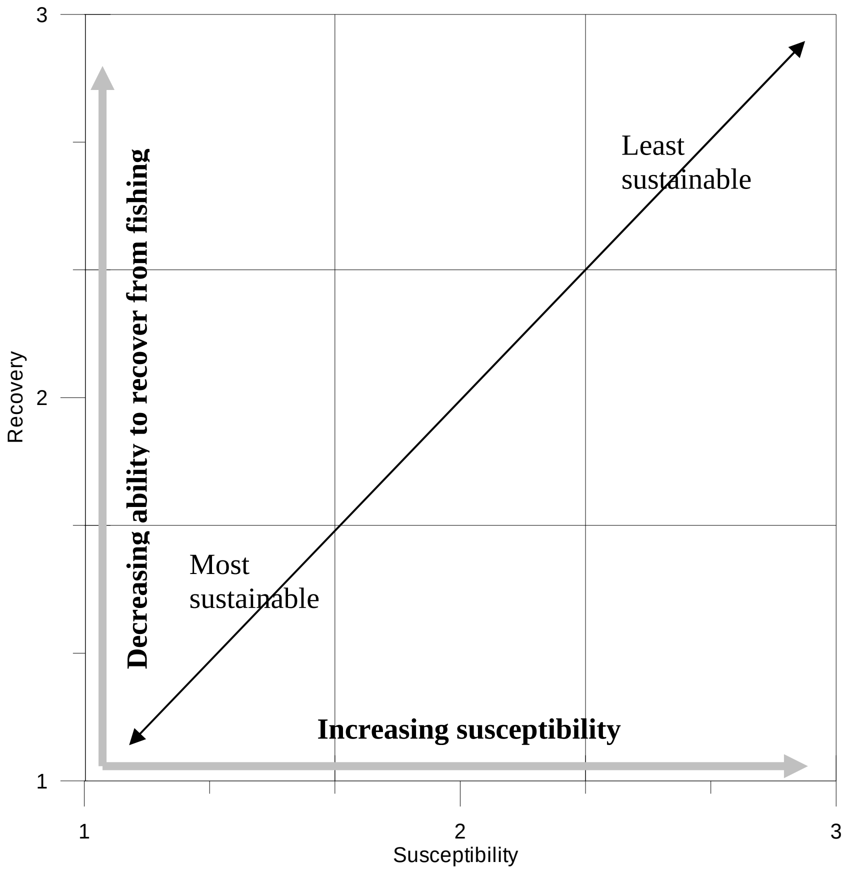
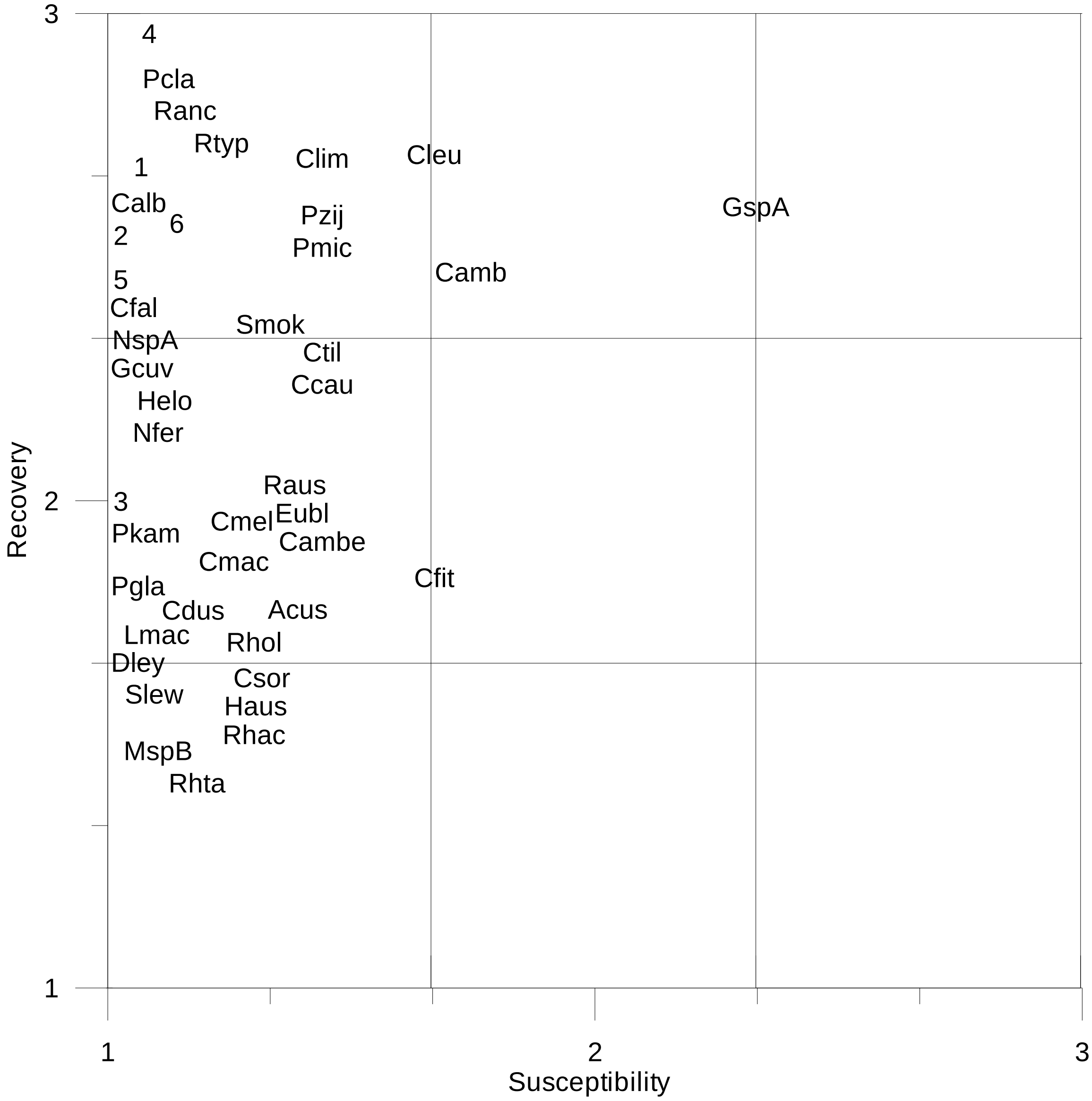


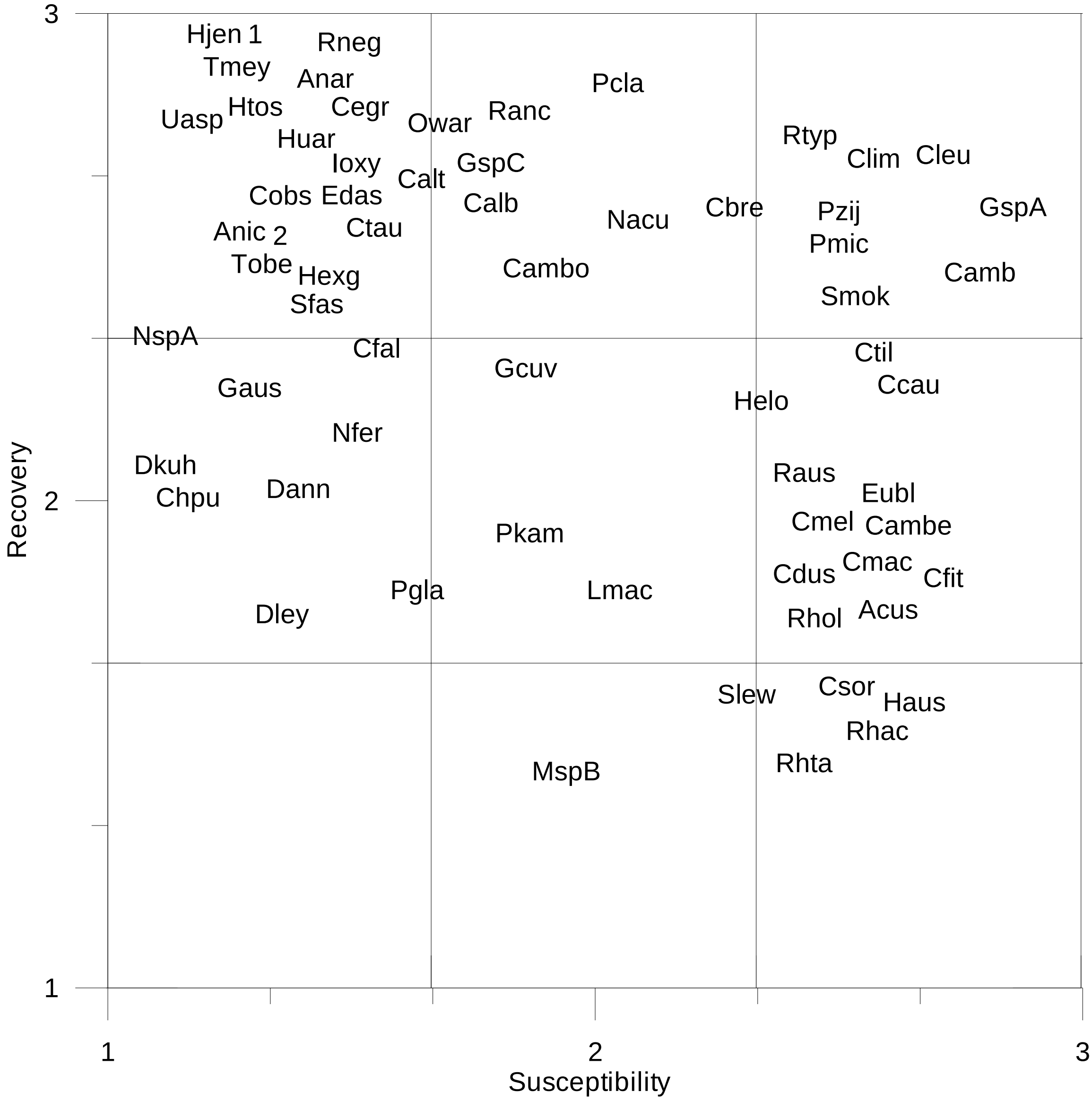
Figure 6.5-1: Representative sustainability plot showing the recovery and susceptibility axes. Each axis is divided into thirds to create nine regions which broadly categorise the level of risk based on the susceptibility and recovery ranks. Species which have a susceptibility rank between 1 and 1.66 are deemed to be at low risk regardless of their recovery ranking as these species do not interact with the fishery. Species that have a susceptibility rank between 1.66 and 2.33 are predominantly at low to medium risk depending on their recovery rank. Although these species are captured by the fishery, the fishery does either not overlap with the species primary habitat or distribution, or the gear is not effective at catching them. Under high fishing pressure, species in this category with a high recovery rank should be monitored closely. Species that have a susceptibility rank between 2.33 and 3 and a recovery rank between 1 and 1.66 are at medium risk. Species fall into the medium risk category due to their ability to recover from fishing. Under high fishing pressure, these species are still highly susceptible to over fishing and should be monitored closely. All species with a susceptibility rank above 2.33 and recovery rank above 1.66 are classed as high risk.



N3 - Multiplicative

1 = Huar, Cobs, Ioxy
2 = Cplu, Apel, Edas, Calt, GspC, Cambo
3 = Dkuh, Chpu, Dann, Gaus
4 = Hjen, Tmey, Uasp, Htos, Mbir, Mere, Hund, Psep, Rneg, Anar, Cegr, Owar
5= Tobe, Anic, Hexg, Sfas
6 = Nacu, Cbre

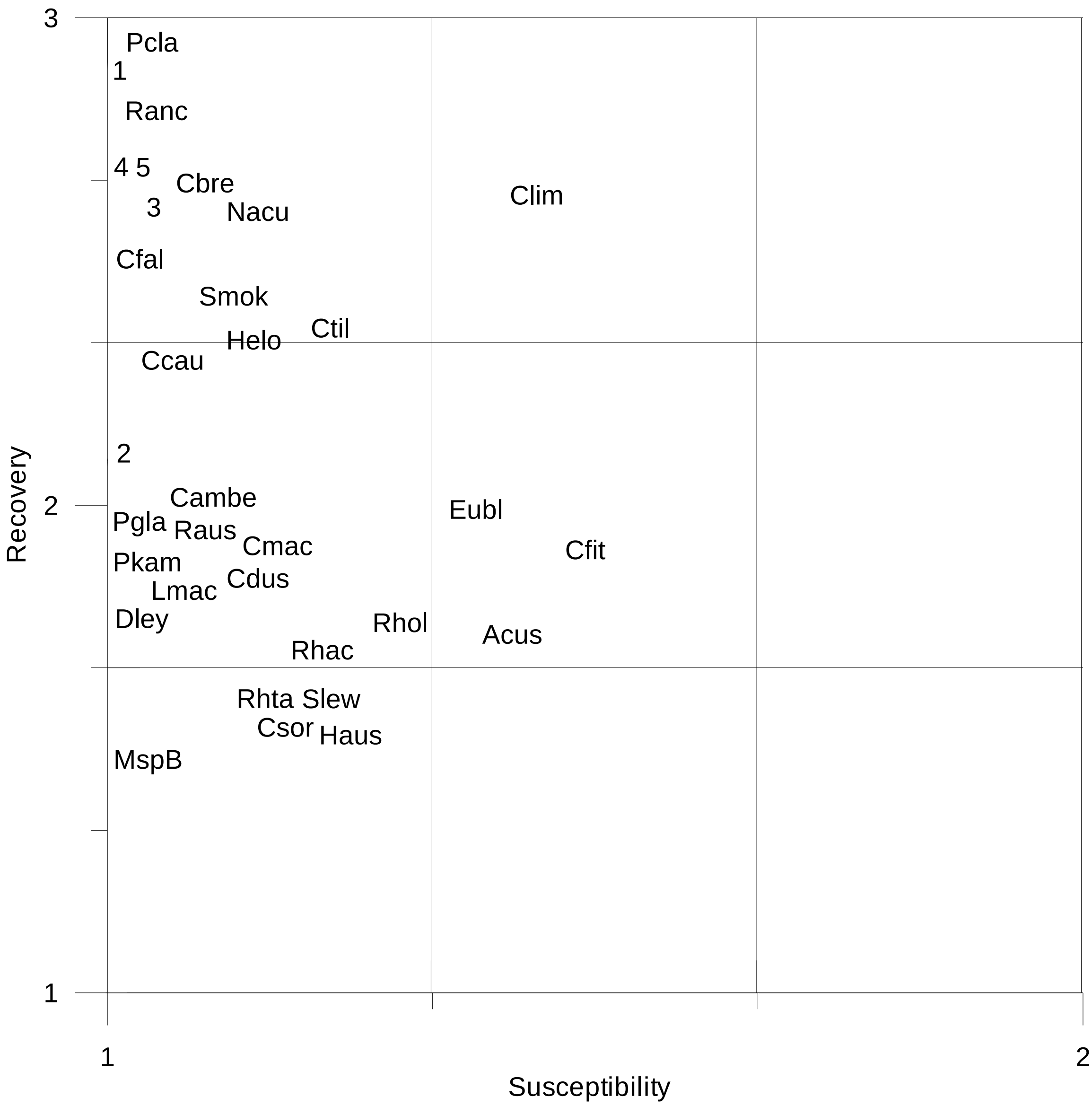
Figure 6.5-2: Sustainability plot for the N3 fishery calculated using the multiplicative method. Refer to Figure 6.5-1 for risk categories.



N3 - Weighted average

1 = Mbir, Mere, Hund, Psep
2 = Cplu, Apel

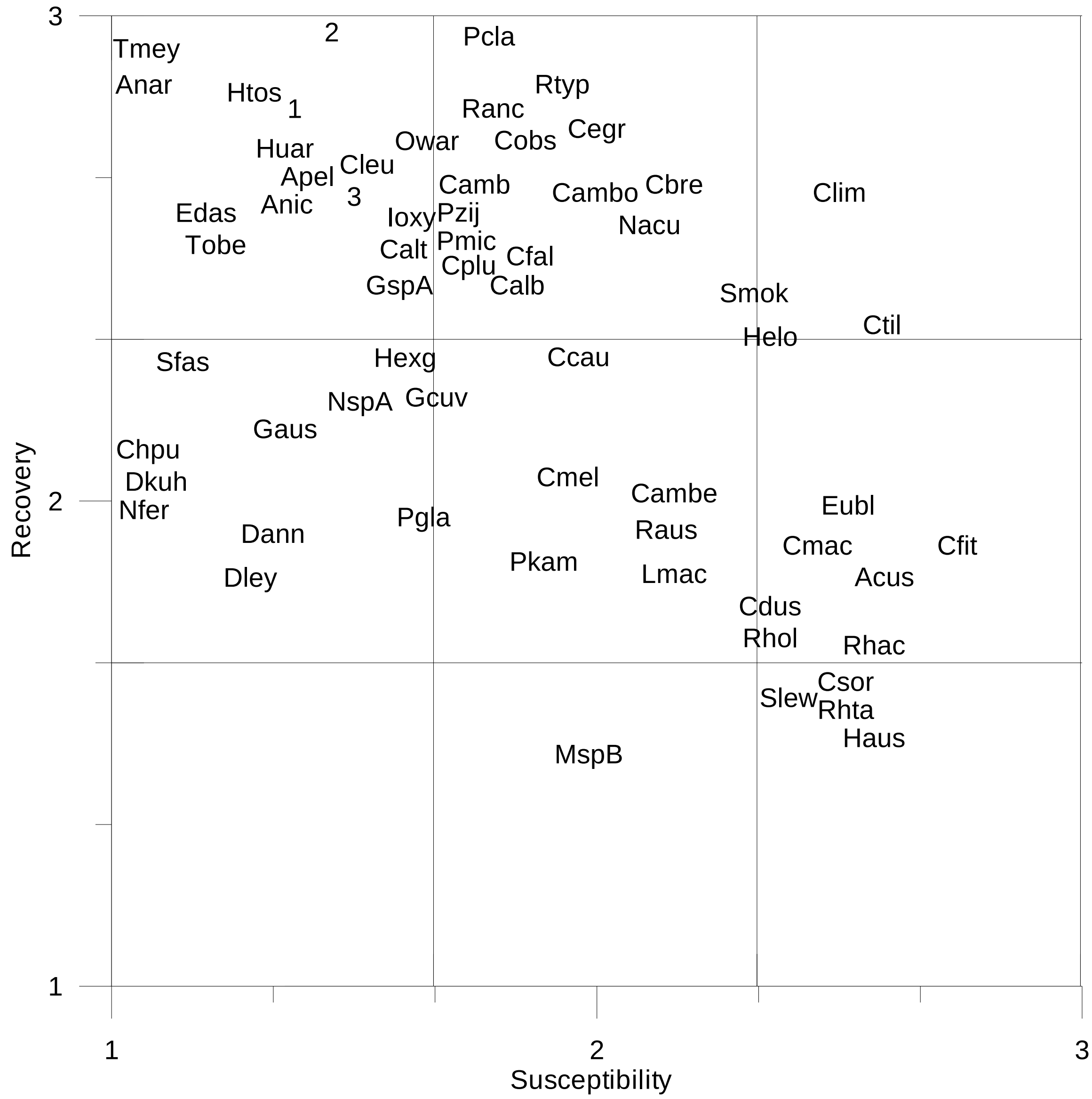
Figure 6.5-3: Sustainability plot for the N3 fishery calculated using the weighted average method. Refer to Figure 6.5-1 for risk categories.



N9 - Multiplicative

1 = Anar, Cegr, Hjen, Htos, Hund, Mbir, Mere, Owar, Psep, Rneg, Tmey, Uasp, Rtyp
2 = Cmel, Chpu, Dann, Dkuh, Gaus, Gcuv, NspA, Nfer
3 = Anic, Calb, GspA, Hexg, Pmic, Pzij, Sfas, Tobe
4 = Apel, Calt, Cambe, Cambo, Cplu, Ctau, Edas, GspC
5 = Cleu, Cobs, Ioxy

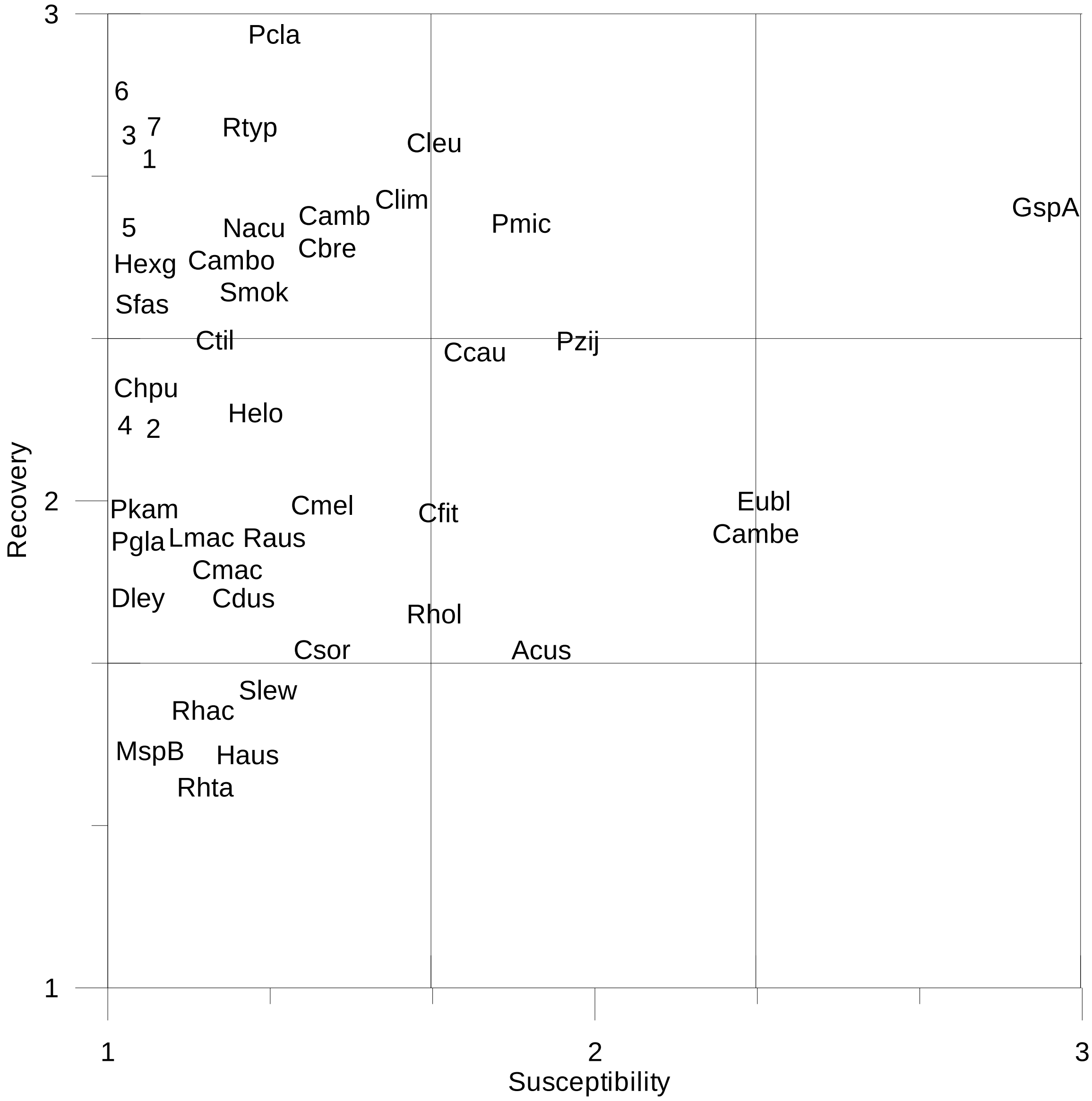
Figure 6.5-4: Sustainability plot for the N9 fishery calculated using the multiplicative method. Refer to figure 1 for risk categories.



N9 - Weighted average

1 = Hjen, Hund, Psep, Rneg, Uasp
2 = Mbir, Mere
3 = Ctau, GspC

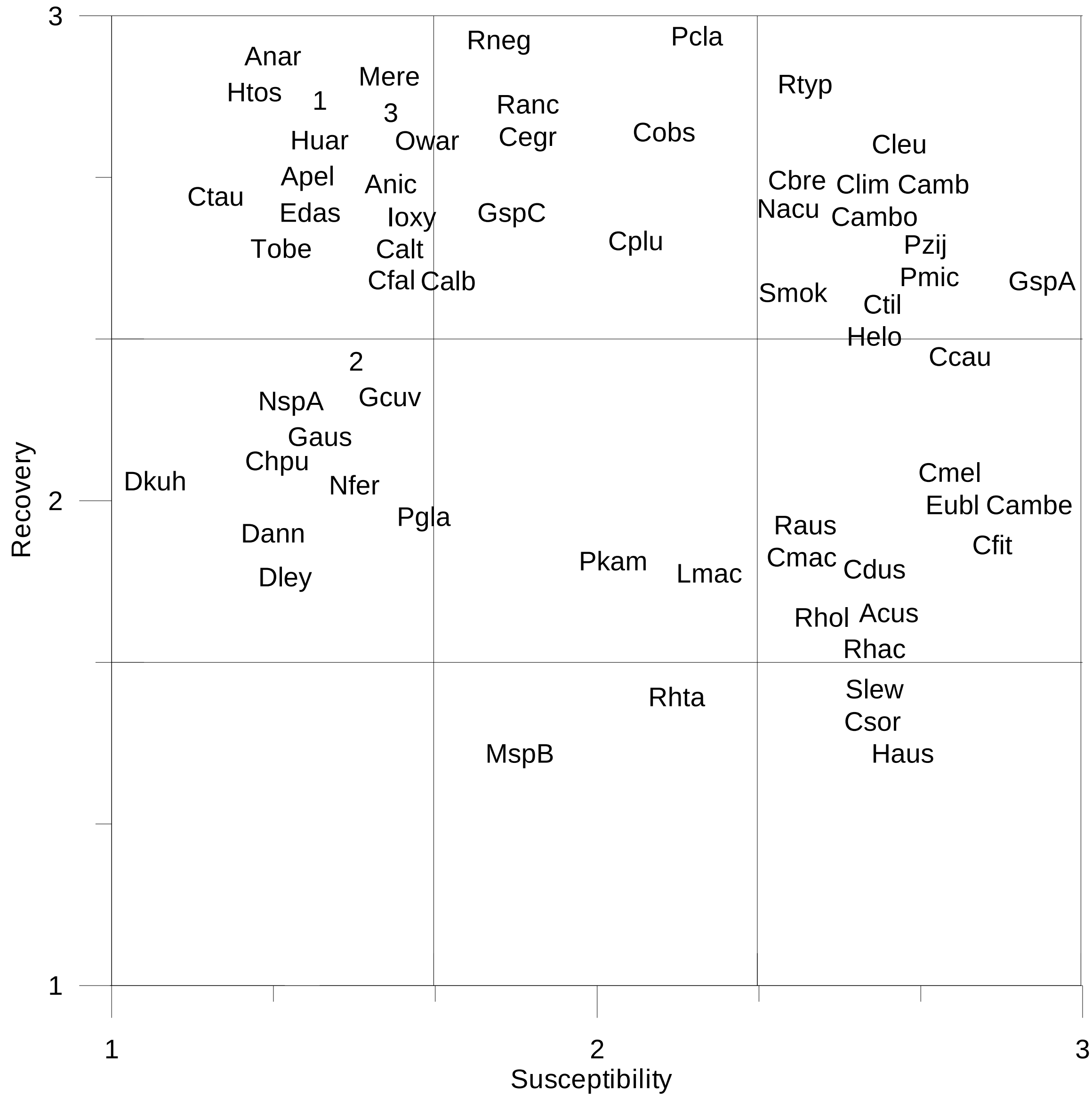
Figure 6.5-5: Sustainability plot for the N9 fishery calculated using the weighted average method. Refer to figure 1 for risk categories.



ECN - Multiplicative

1 = Apel, Cplu, Edas, Ctau, GspC
2 = Cfal, Dkuh, Gaus, Nfer
3 = Cegr, Htos, Owar, Ranc
4 = Gcuv, NspA
5 = Anic, Calb, Tobe
6 = Anar, Hjen, Hund, Mbir, Mere, Psep, Rneg, Tmey, Uasp
7 = Ioxy, Huar, Cobs

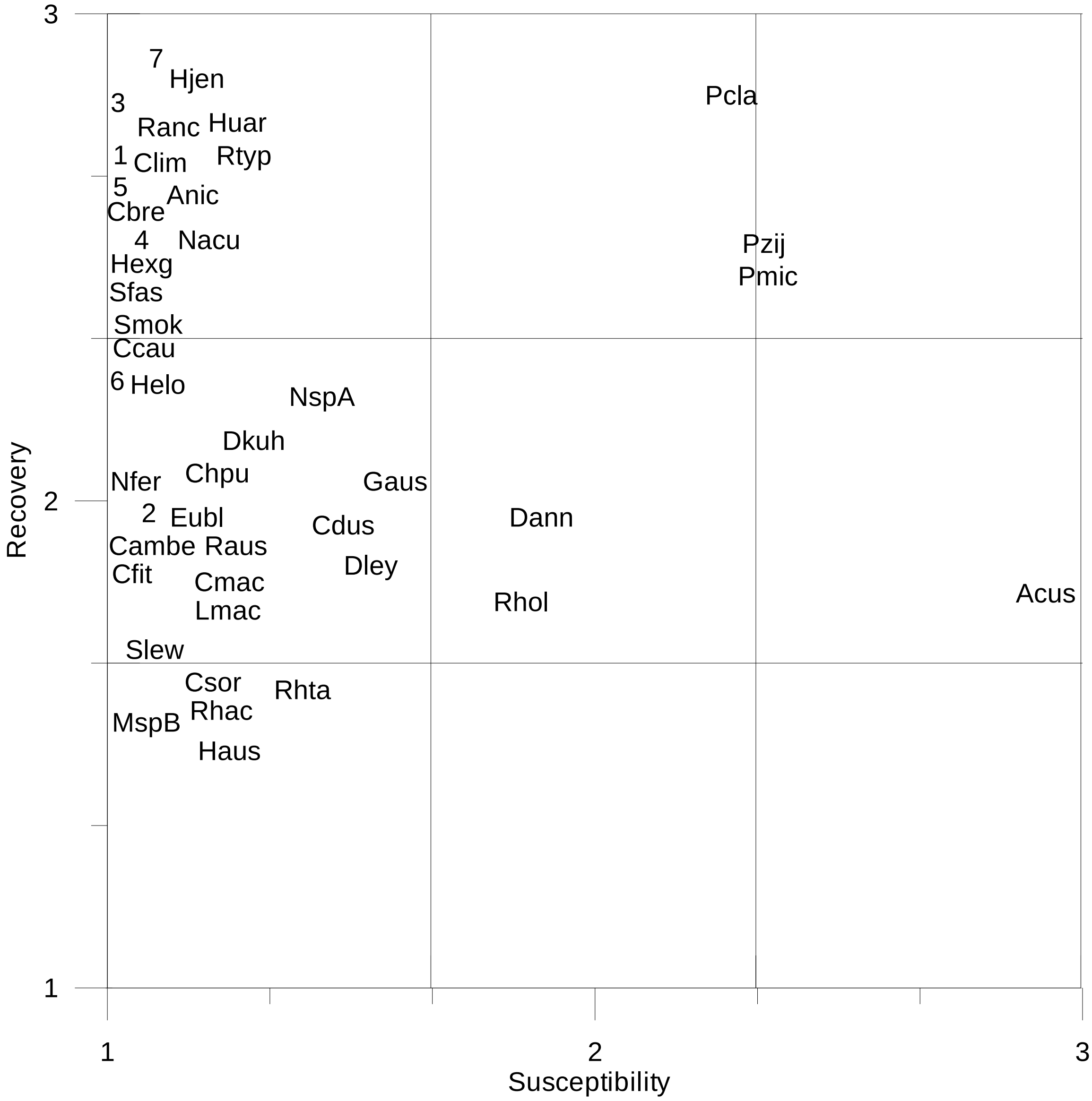
Figure 6.5-6: Sustainability plot for the ECN fishery using the multiplicative method.



ECN - Weighted

1 = Tmey, Uasp, Psep, Mbir
2 = Sfas, Hexg
3 = Hjen, Hund

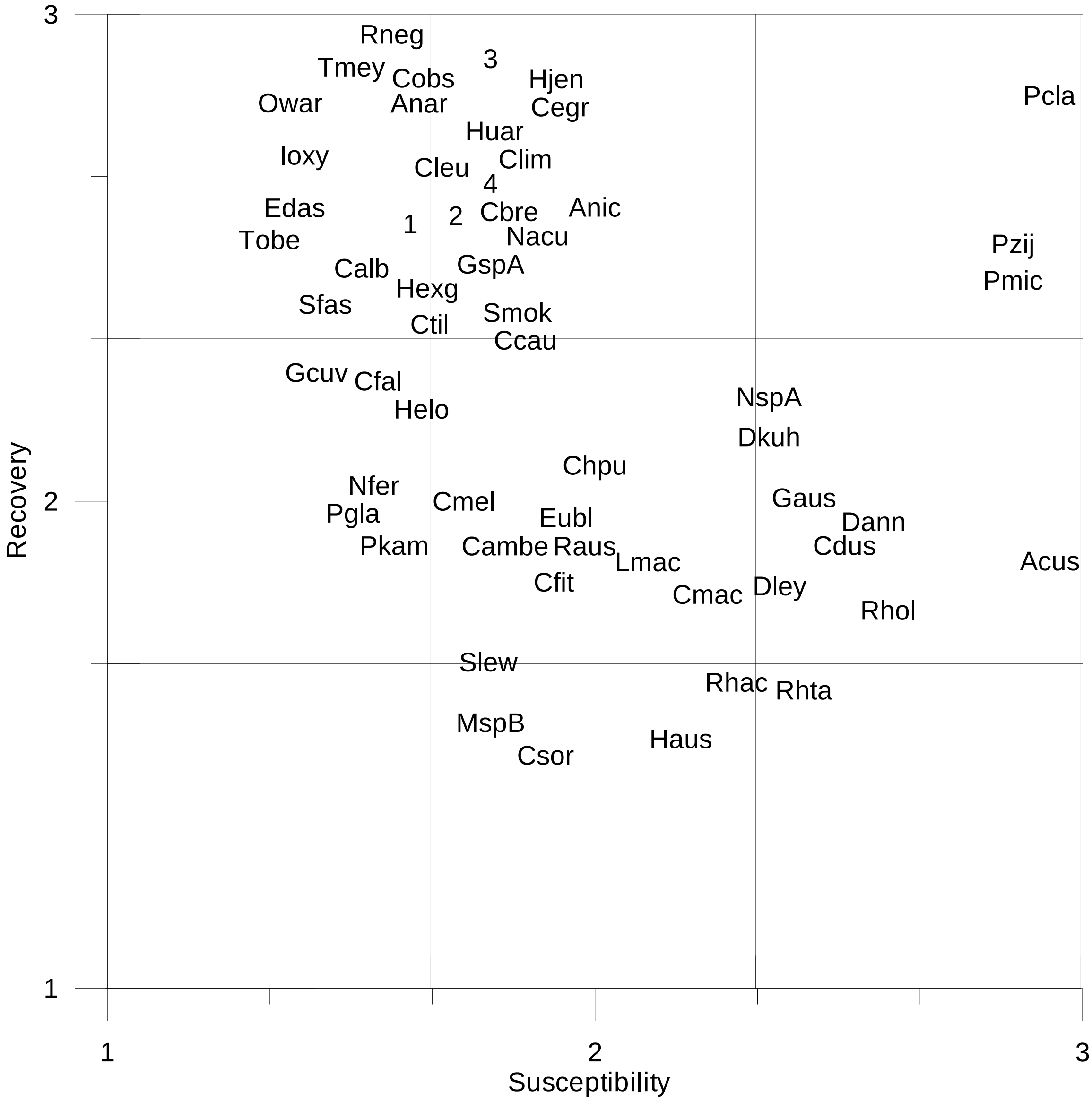
Figure 6.5-7: Sustainability plot for the ECN fishery using the weighted average method.



NPF - Multiplicative

1 = Ioxy, Cobs, Cleu
2 = Pgla, Pkam, Cmel
3 = Owar, Rneg, Tmey, Anar
4 = Cambo, Ctau, Apel, Calt, Cplu, Edas, GspC, Camb
5 = Tobe, Calb, GspA
6 = Cfal, Gcuv, Ctil
7 = Hund, Mbir, Mere, Psep, Uasp, Htos

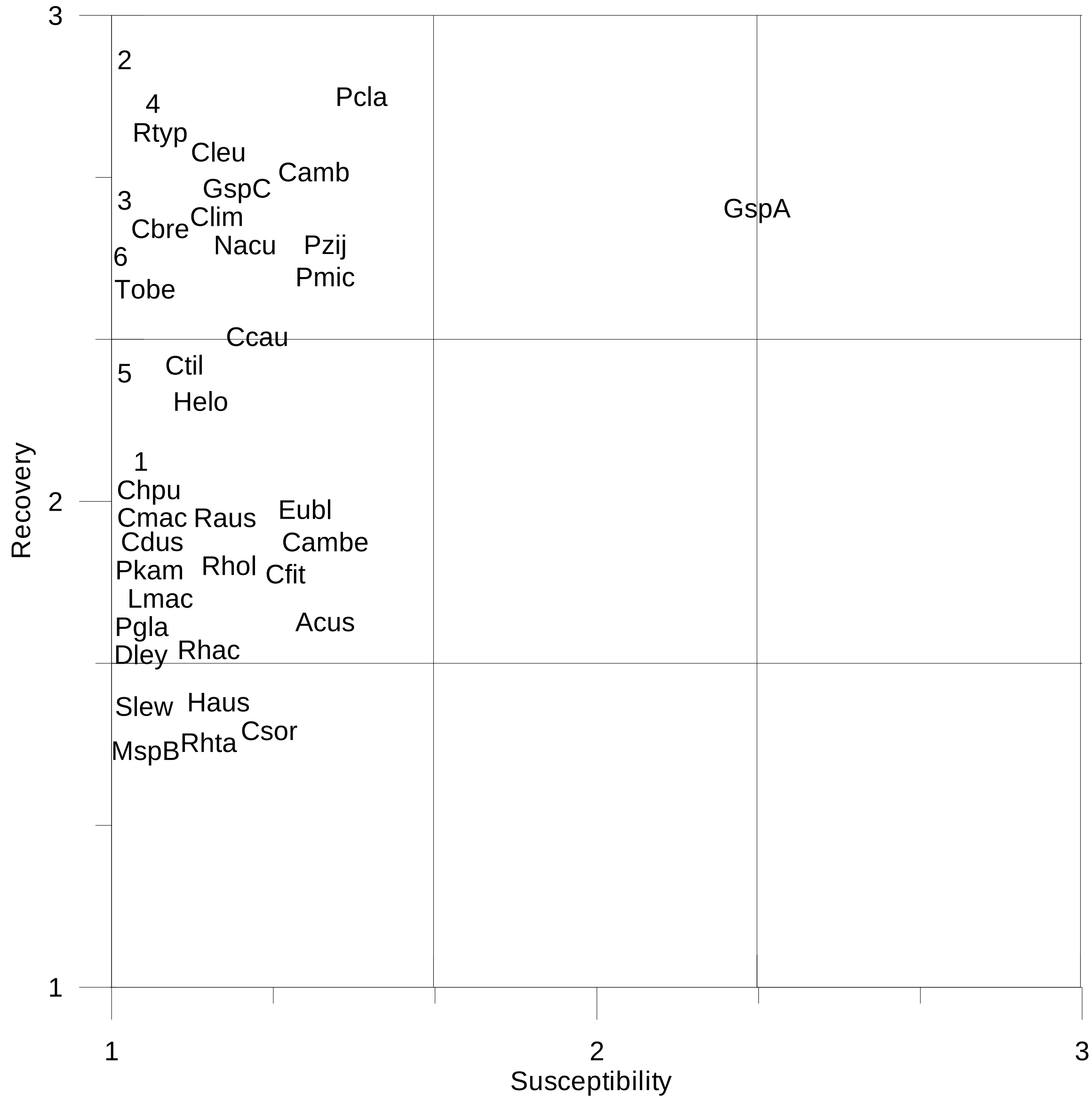
Figure 6.5-8: Sustainability plot for the NPF fishery calculated using the multiplicative method.



NPF - Weighted average

1 = Cambo, Ctau, Apel
2 = Calt, Cplu
3 = Hund, Mbir, Mere, Psep, Ranc, Uasp, Htos, Rtyp
4 = GspC, Camb

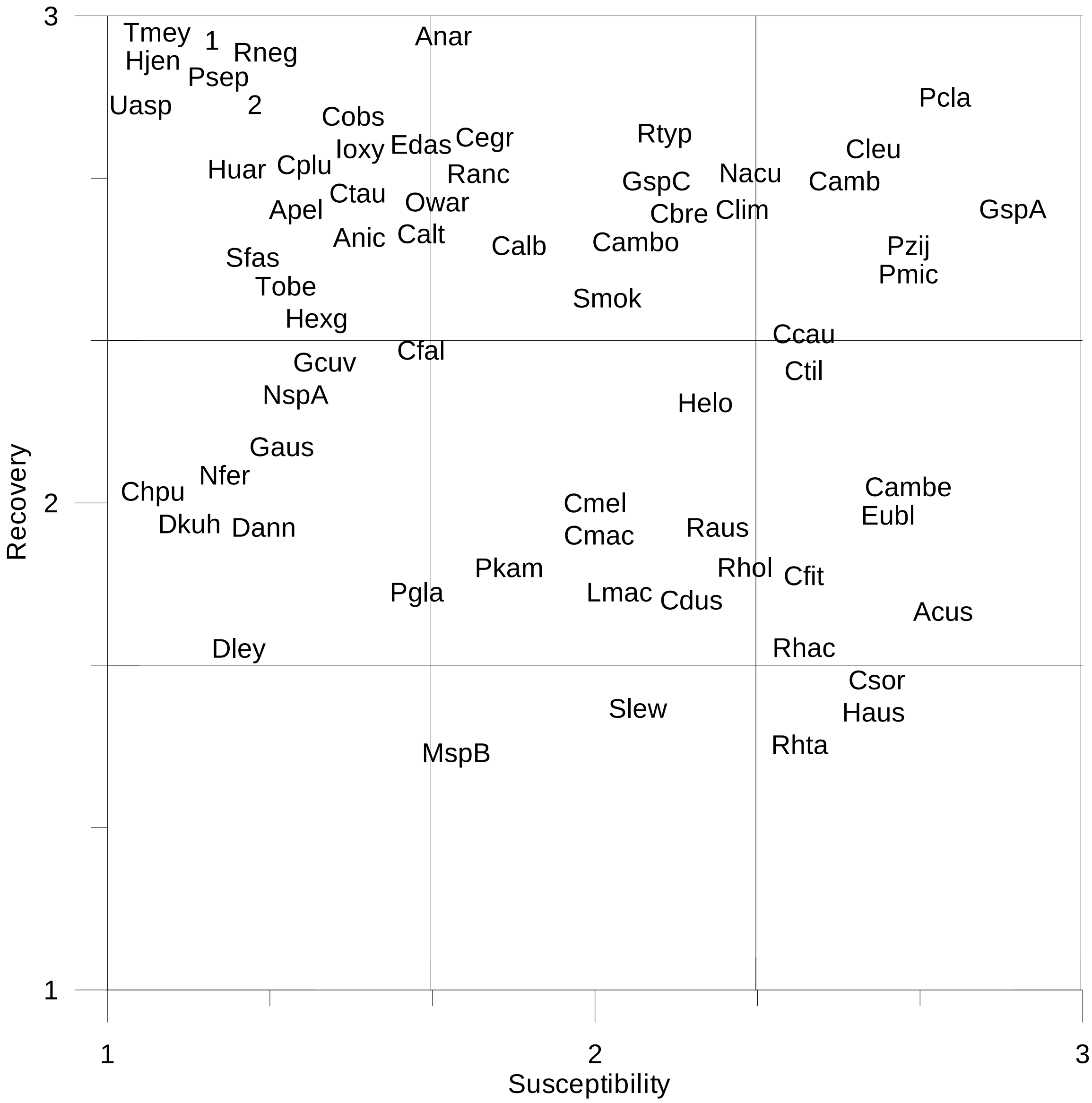
Figure 6.5-9: Sustainability plot for the NPF fishery calculated using the weighted average method.



NTBarr - Multiplicative

1 = Dkuh, Nfer, Dann, Gaus, Cmel
2 = Hjen, Htos, Hund, Mbir, Mere, Psep, Rneg, Tmey, Uasp, Cegr, Anar, Owar, Ranc
3 = Cplu, Calt, Ctau, Edas, Cambo
4 = Cobs, Huar, Ioxy
5 = Gcuv, NspA, Cfal
6 = Hexg, Sfas, Anic, Calb, Smok

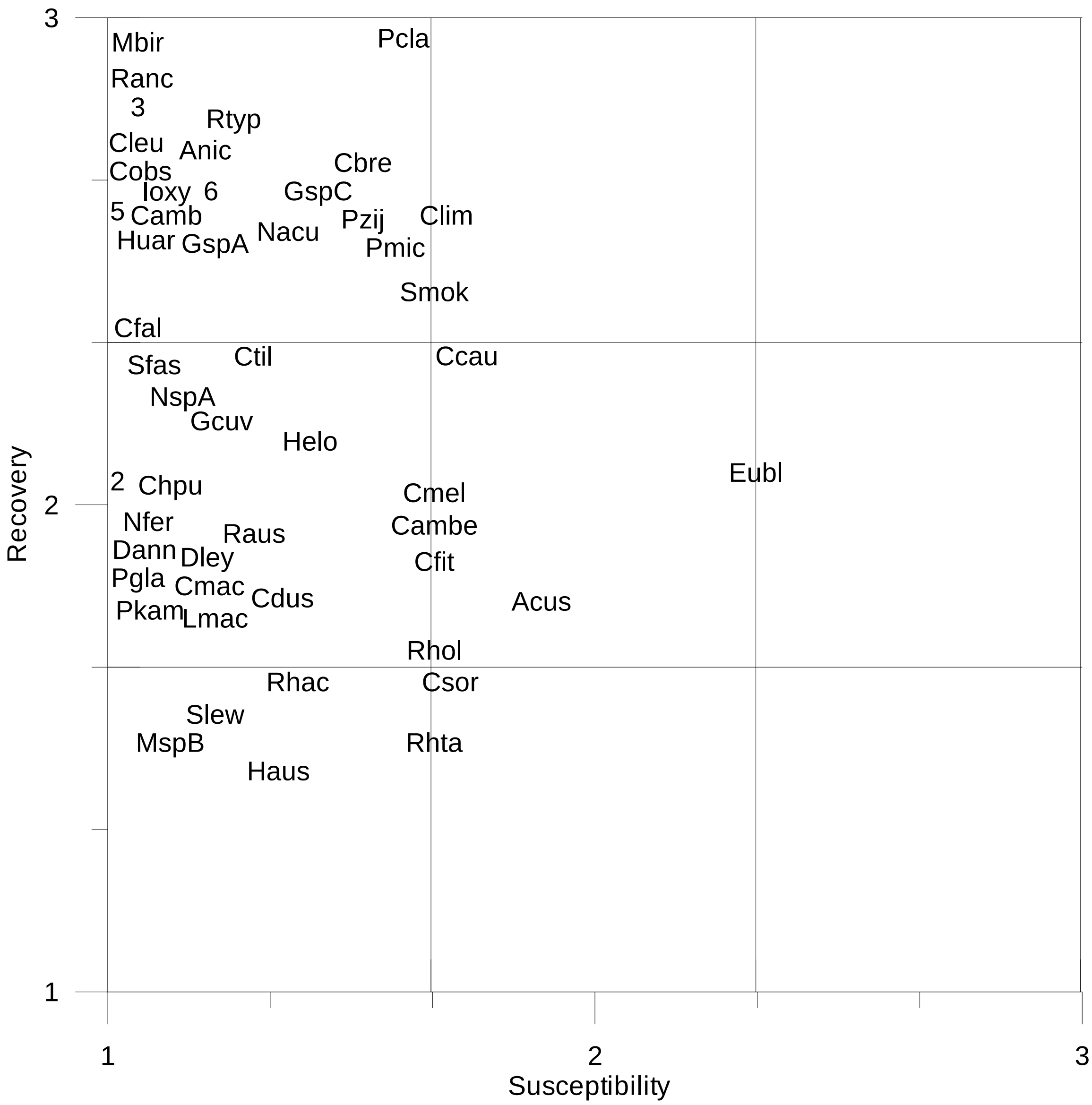
Figure 6.5-10: Sustainability plot for the NTBarr fishery calculated using the multiplicative method.



NTBarr - Weighted average

1 = Mbir, Mere
2 = Htos, Hund

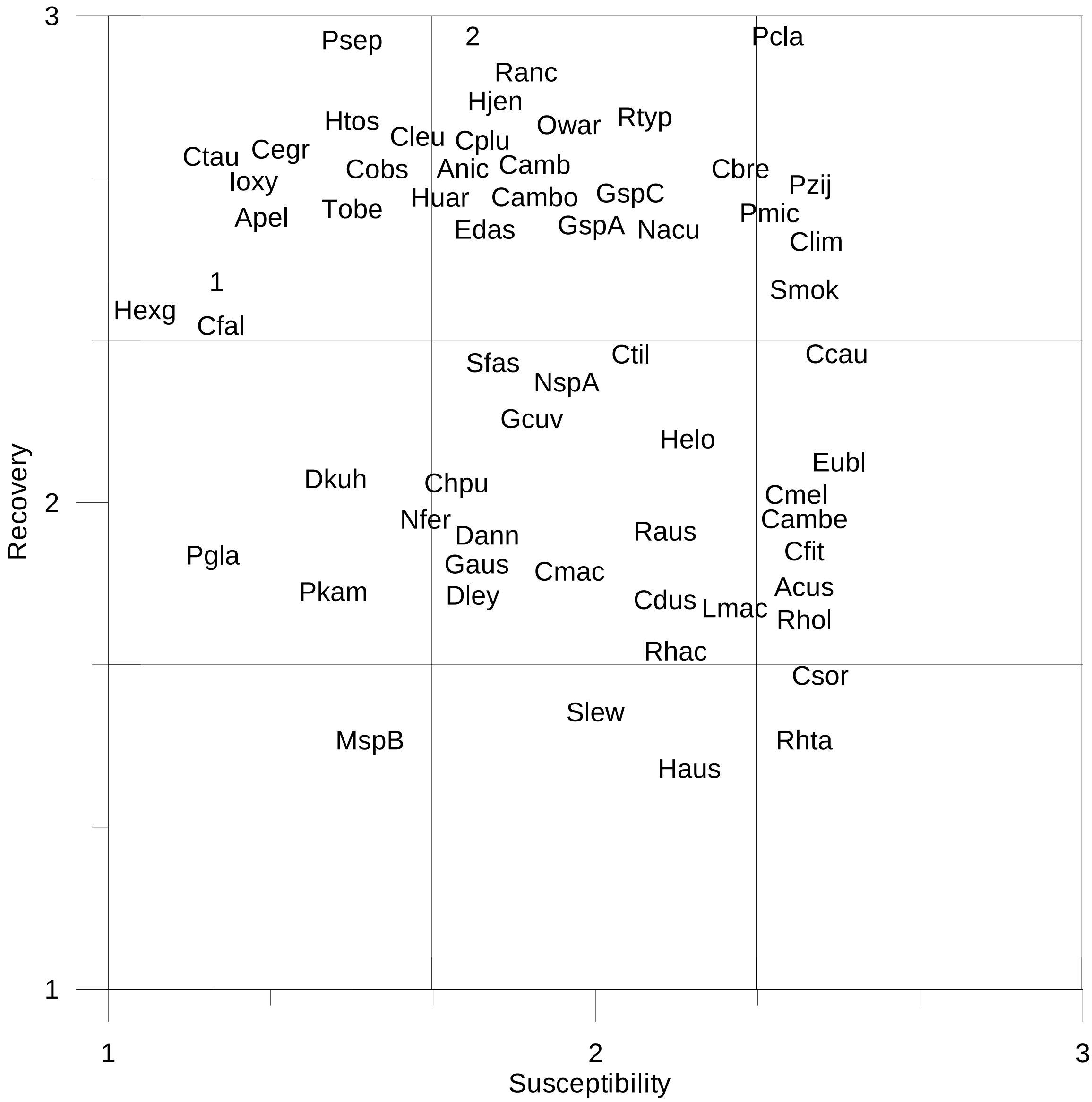
Figure 6.5-11: Sustainability plot for the NTBarr fishery calculated using the weighted average method.



NTONL - Multiplicative

1 = Calt, Cplu, Ctau, Cambo
2 = Dkuh, Gaus
3 = Mere, Anar, Hund, Rneg, Tmey, Uasp, Cegr, Hjen, Htos, Owar, Psep
5 = Calb, Hexg, Tobe
6 = Apel, Edas
7 = Hund, Rtyp, Uasp, Hjen, Htos

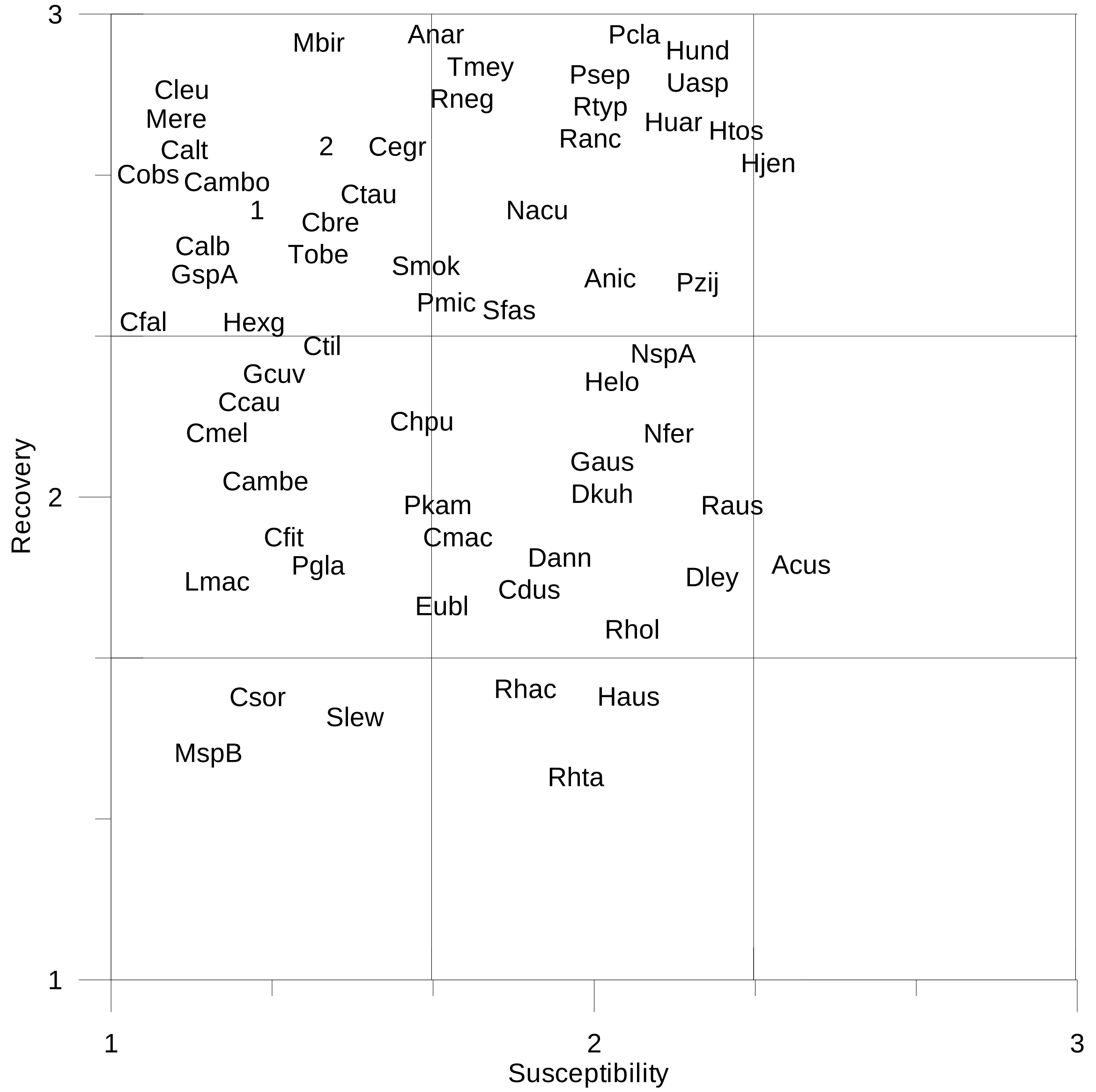
Figure 6.5-12: Sustainability plot for the NTONL fishery calculated using the multiplicative method.



NTONL - Weighted average

1 = Calt, Calb
2 = Mere, Anar, Hund, Rneg, Tmey, Uasp, Mbir

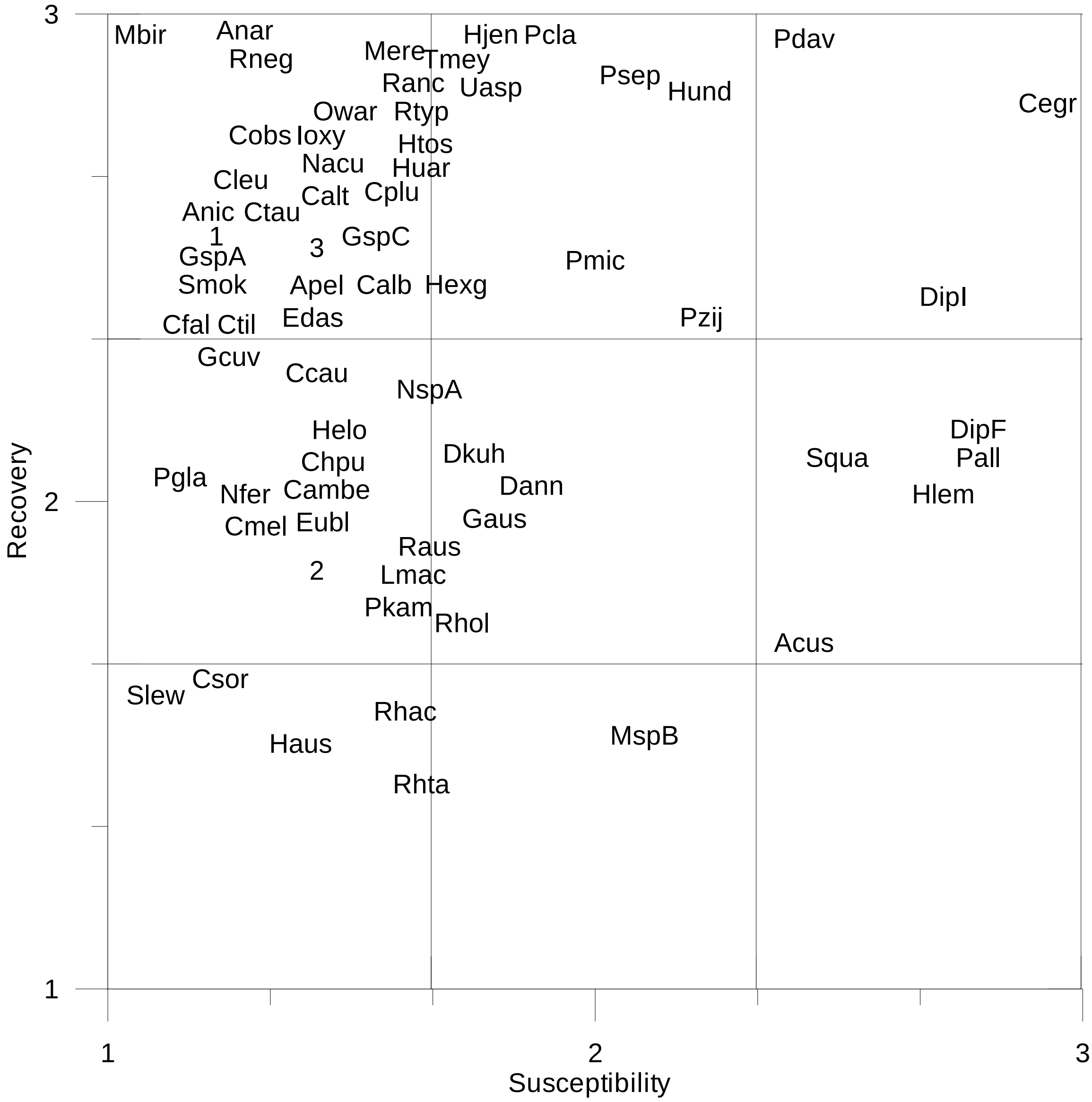
Figure 6.5-13: Sustainability plot for the NTONL fishery calculated using the weighted average method.



NTFT - Weighted average

1 = Apel, Camb, Clim, Cplu, GspC, Edas
2 = Ioxy, Owar

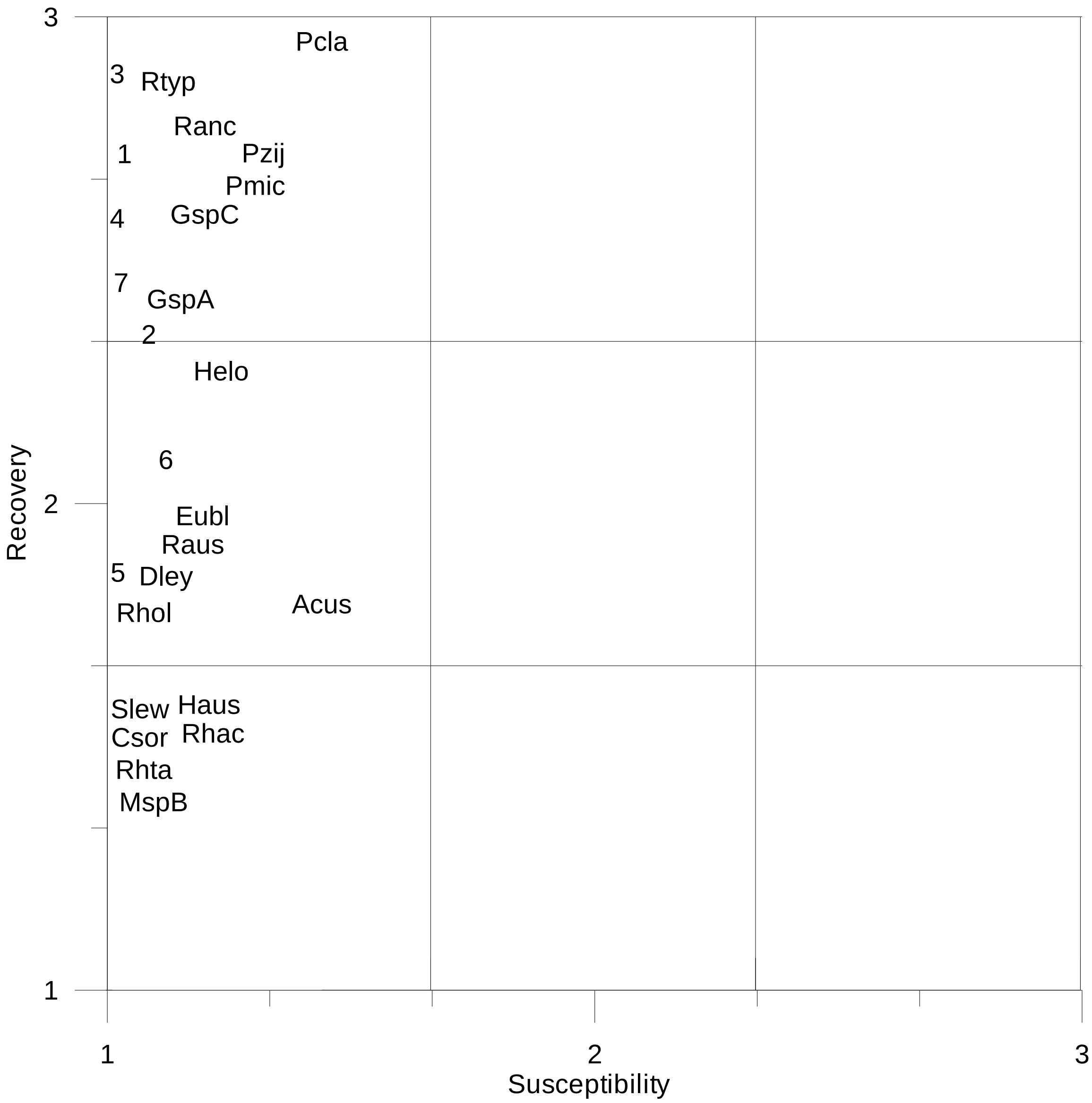
Figure 6.5-14: Sustainability plot for the NTFT fishery calculated using the weighted average method.



NWSTF - Weighted average

1 = Cambo, Camb, Cbre, Clim
2 = Cdus, Cfit, Cmac, Dley
3 = Sfas, Tobe

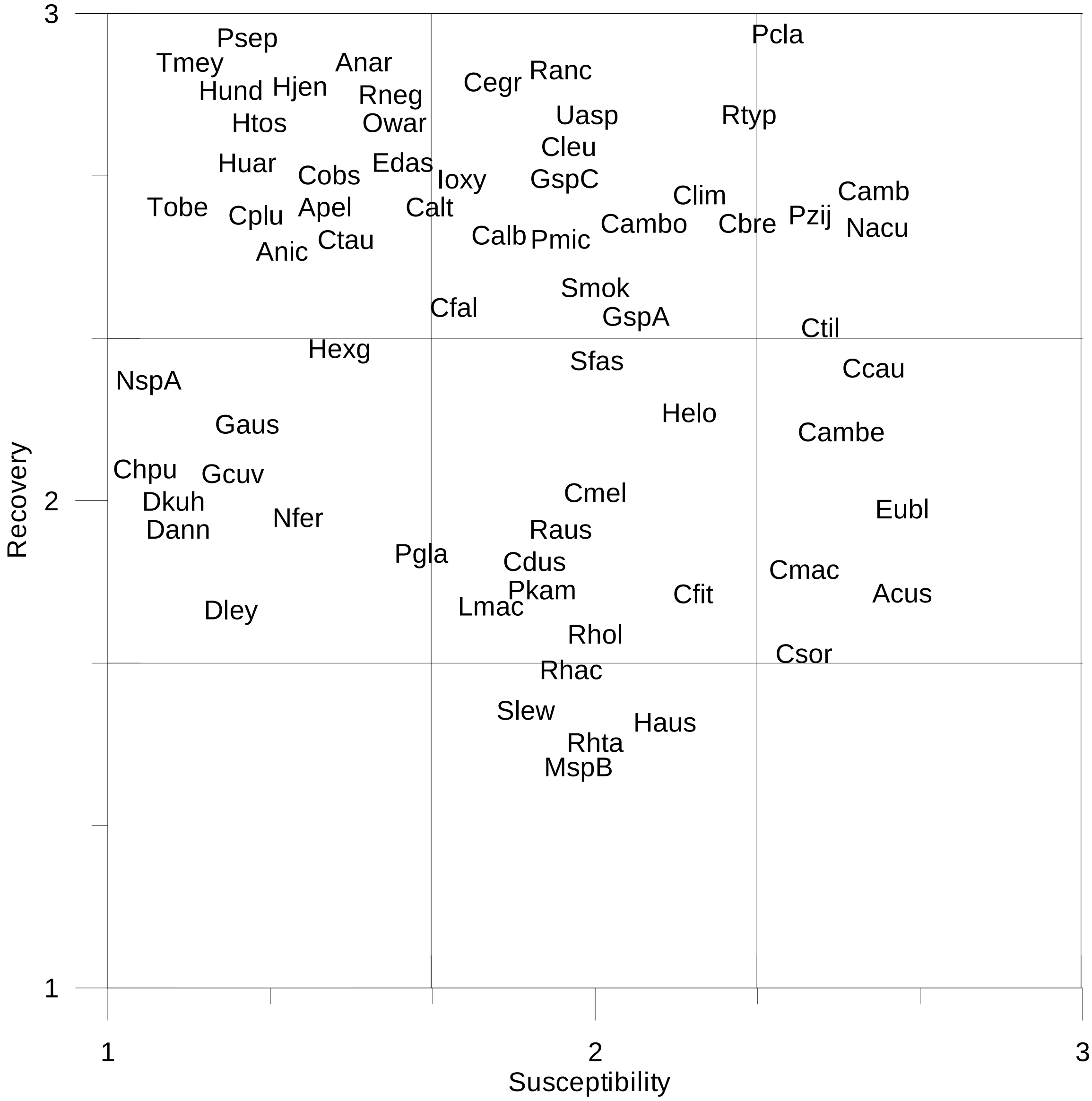
Figure 6.5-15: Sustainability plot for the NWSTF fishery calculated using the weighted average method.



WAEMBGF - Multiplicative

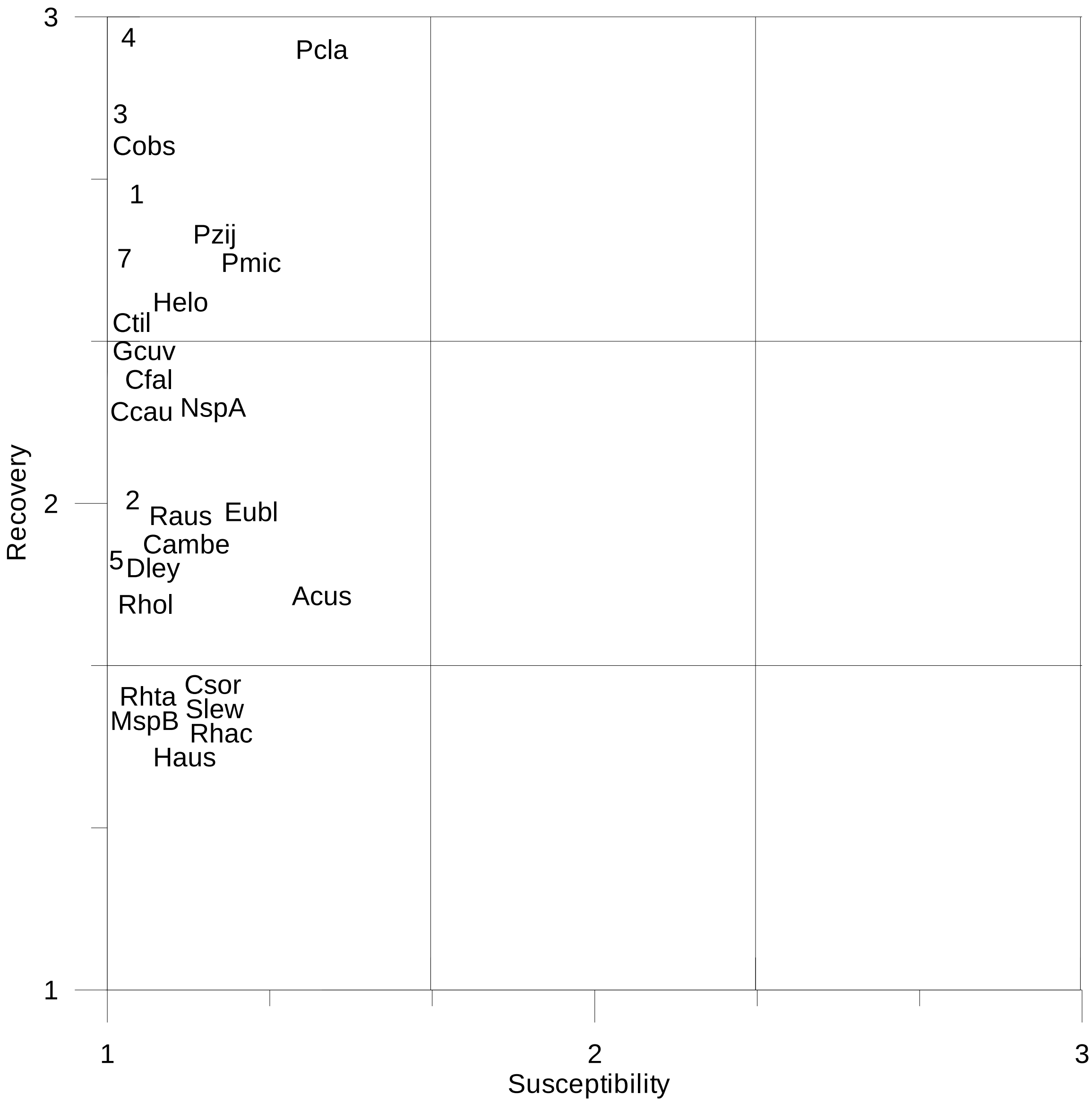
1 = Cobs, Huar, Ioxy, Cleu
2 = Gcuv, NspA, Cfal, Ctil, Ccau
3 = Tmey, Uasp, Htos, Hund, Psep, Hjen, Anar, Owar, Rneg, Mbir, Mere, Cegr
4 = Cplu, Calt, Clim, Apel, Cbre, Ctau, Edas, Cambo, Cambe, Nacu
5 = Pgla, Cdus, Cmac, Pkam, Cfit, Lmac
6 = Chpu, Nfer, Dkuh, Gaus, Cmel, Cambe, Dann
7 = Smok, Calb, Sfas, Tobe, Hexg, Anic

Figure 6.5-16: Sustainability plot for the WAEMBGF fishery calculated using the multiplicative method.



WAEMBGF - Weighted average

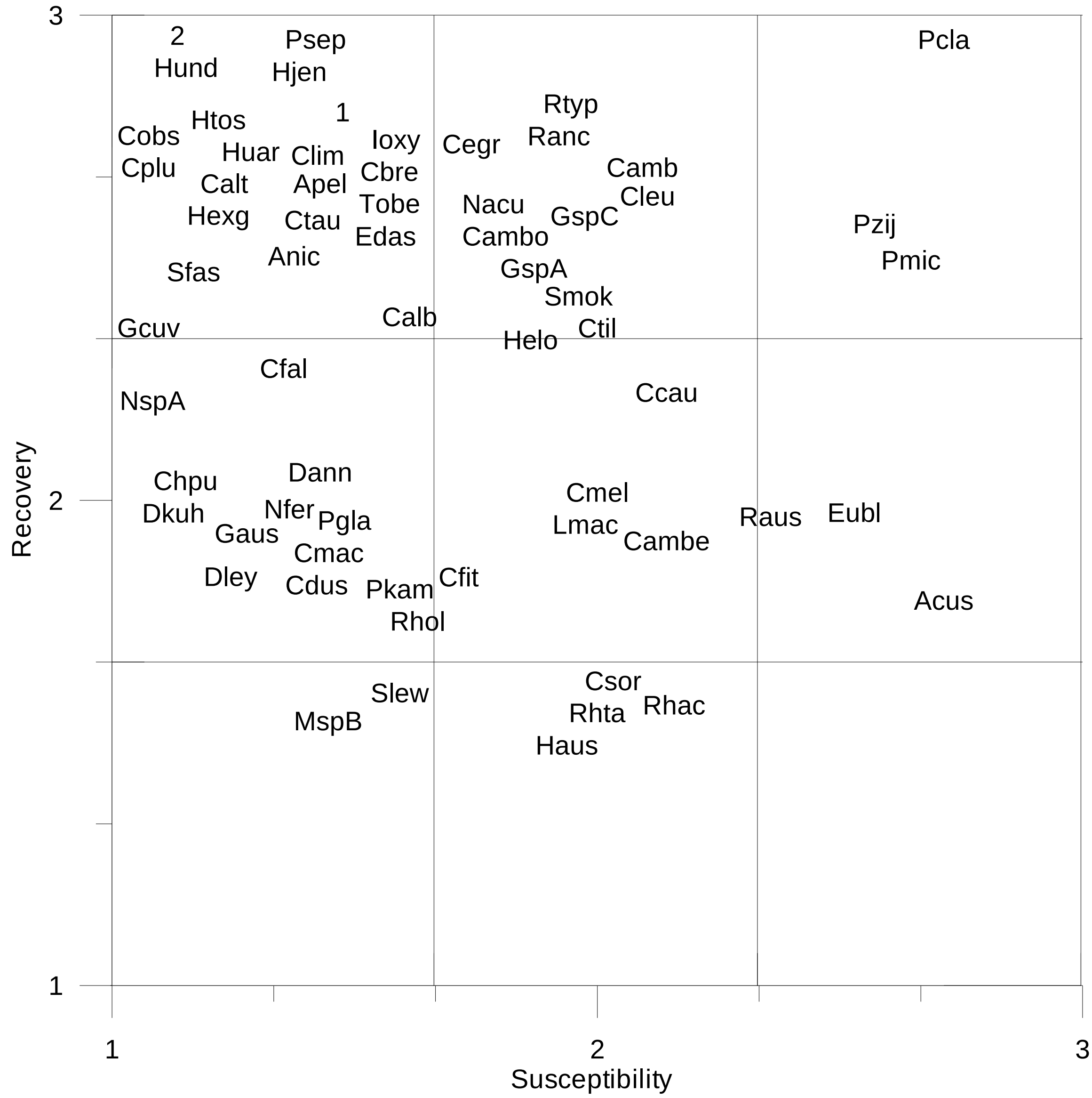
Figure 6.5-17: Sustainability plot for the WAEMBGF fishery calculated using the weighted average method.



WAKGBF - Multiplicative

1 = Calt, Apel, Anic, Cbre, Calb, Ctau, Edas, Tobe, Cambo, Nacu, GspA, GspC, Camb
2 = Dkuh, Sfas, Cfal, Clim, Gaus, Hexg, Nferm Skok, Szyg
3 = Htos, Huar, Ioxy, Owar, Cegr, Cleu, Ranc, Rtyp
4 = Tmey, Uasp, Hjen, Psep, Anar, Mbir, Mere, Rneg
5 = Pgla, Cdus, Lmac, Pkam, Cfit, Lmac

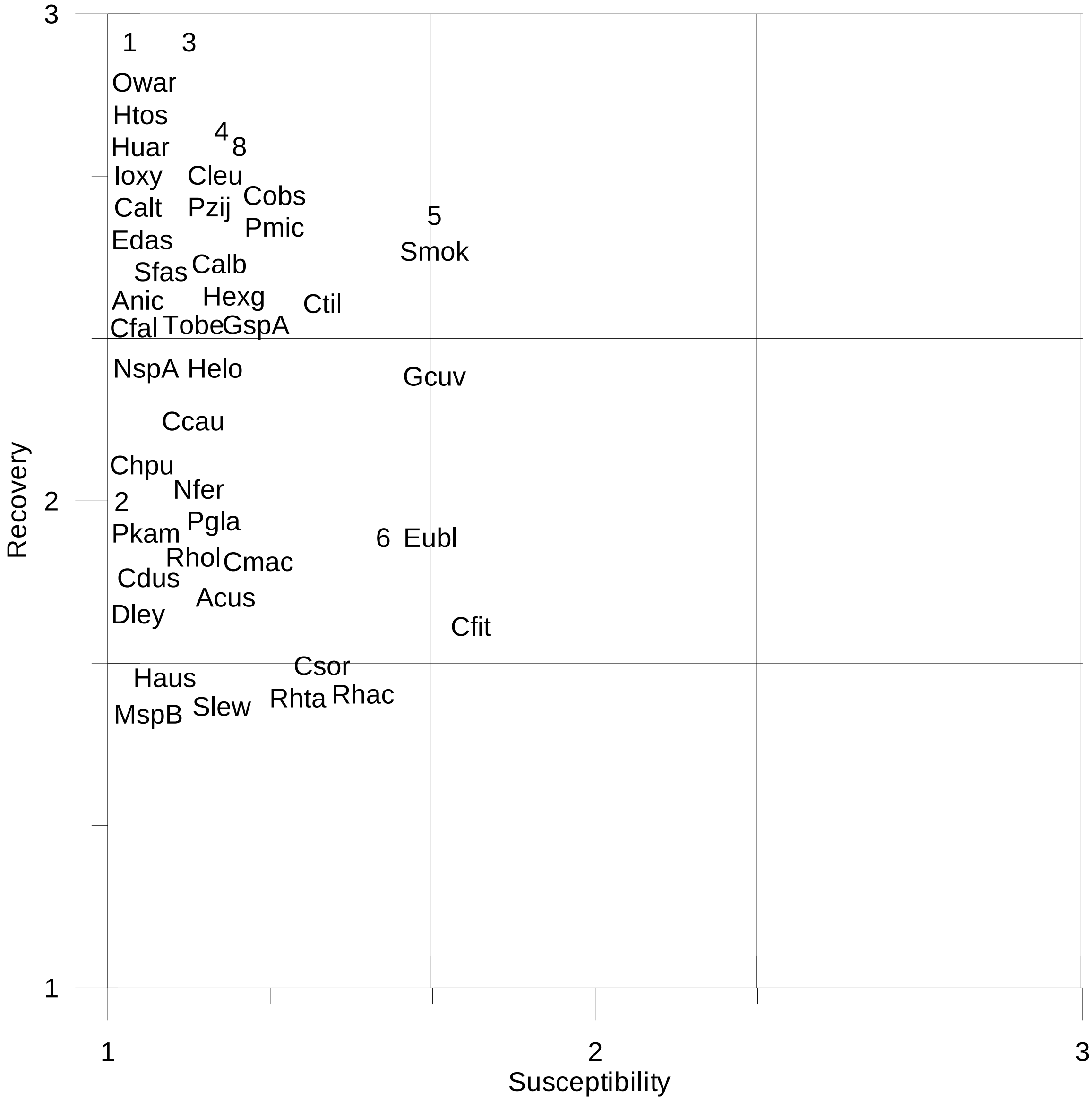
Figure 6.5-18: Sustainability plot for the WAKGBF fishery calculated using the multiplicative method.



WAKGBF - Weighted average

1 = Anar, Mbir, Mere, Rneg
2 = Tmey, Uasp

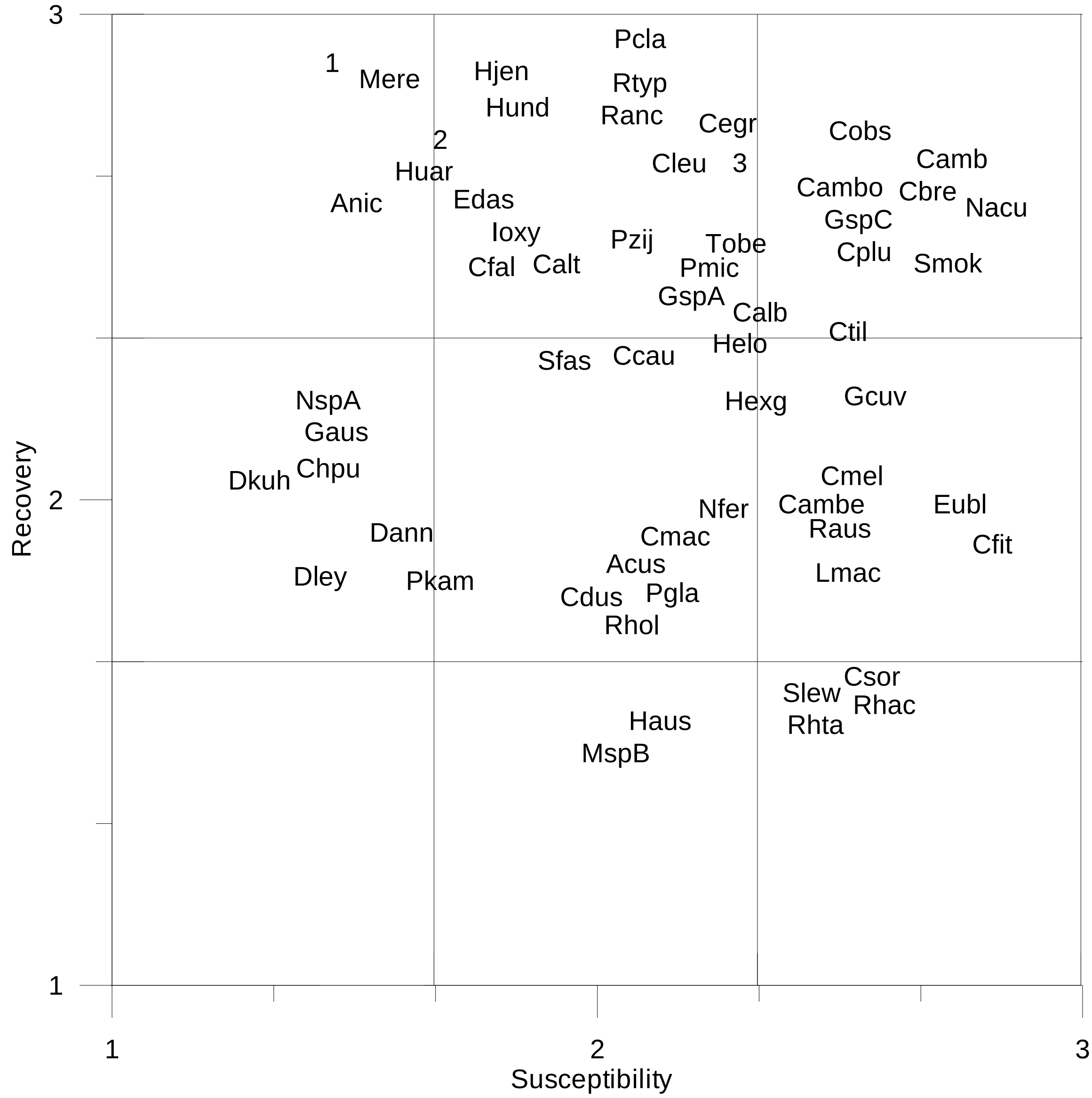
Figure 6.5-19: Sustainability plot for the WAKGBF fishery calculated using the weighted average method.



WANCSF - Multiplicative

1 = Anar, Mbir, Rneg, Mere, Psep, Tmey, Uasp
2 = Dkuh, Gaus, Dann
3 = Hjen, Hund, Pcla
4 = Cegr, Ranc, Rtyp
5 = Camb, GspC, Cbre, Nacu
6 = Cambe, Cmel, Lmac, Raus
7 = Tobe, GspA, Pmic
8 = Apel, Clim, Ctau, Cambo, Cplu

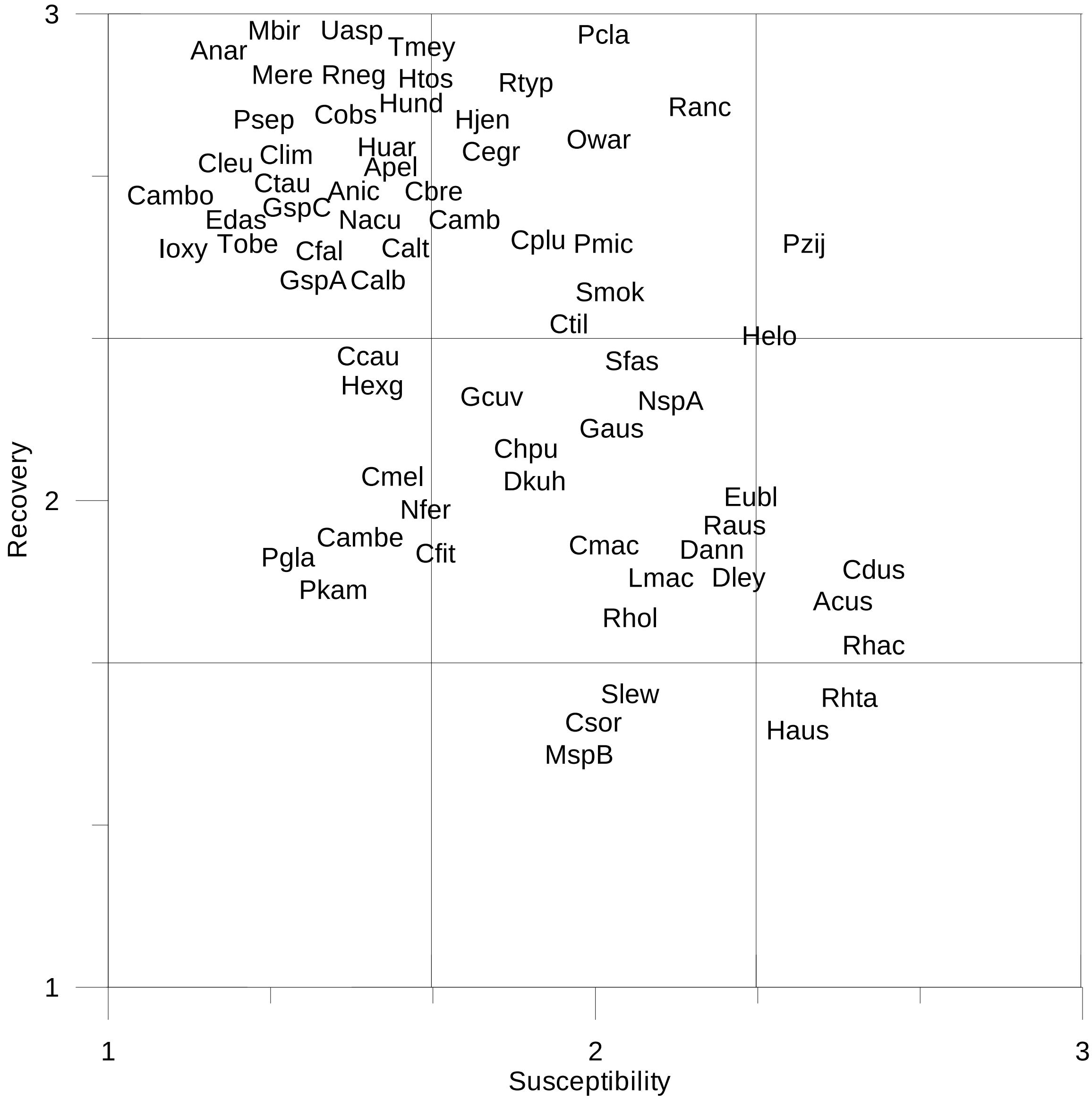
Figure 6.5-20: Sustainability plot for the WANCSF fishery calculated using the multiplicative method.



WANCSF - Weighted average

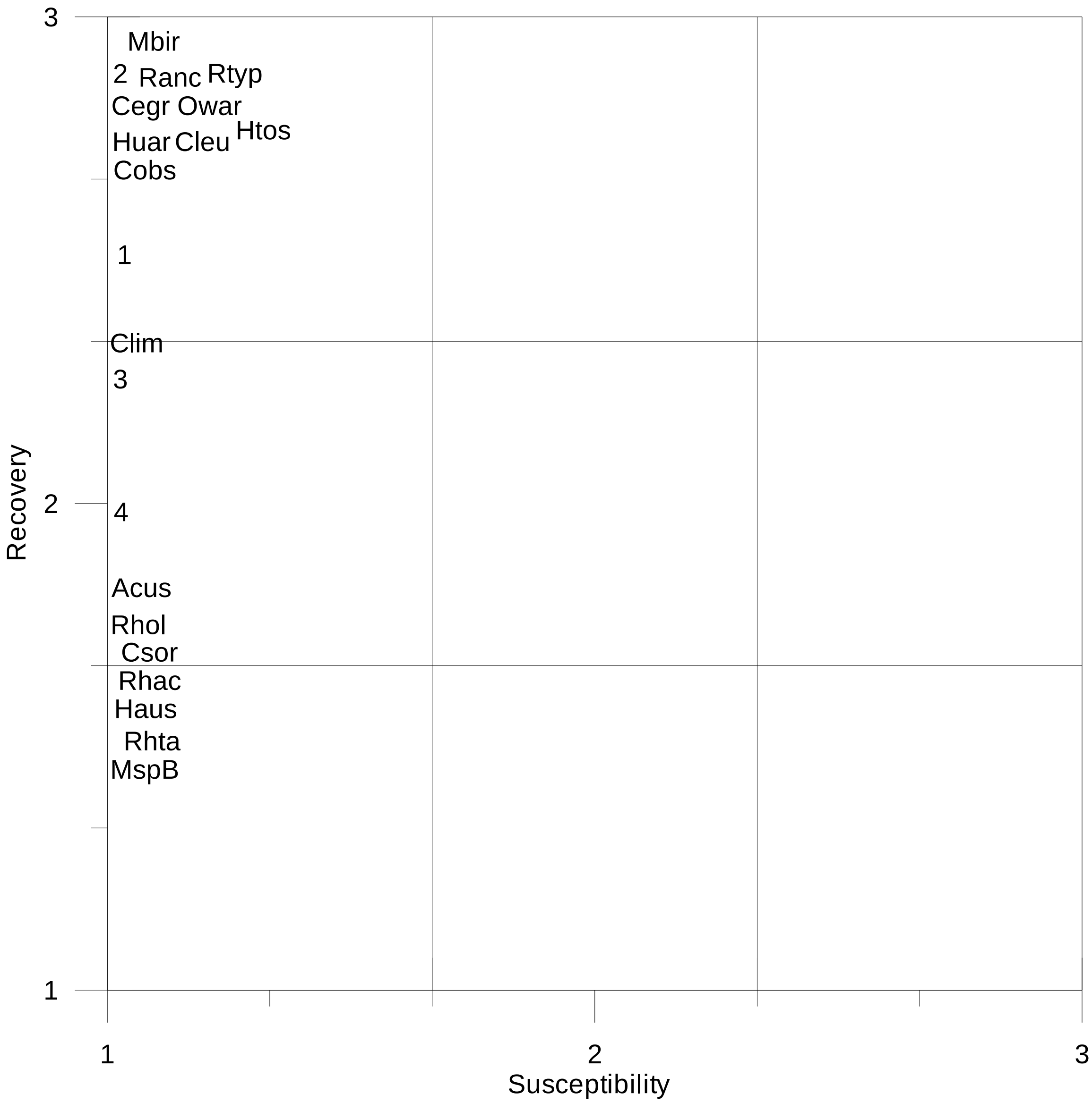
1 = Anar, Mbir, Rneg
2 = Psep, Tmey, Uasp, Htos, Owar
3 = Apel, Clim, Ctau

Figure 6.5-21: Sustainability plot for the WANCSF fishery calculated using the multiplicative method.



PFFT - Weighted average

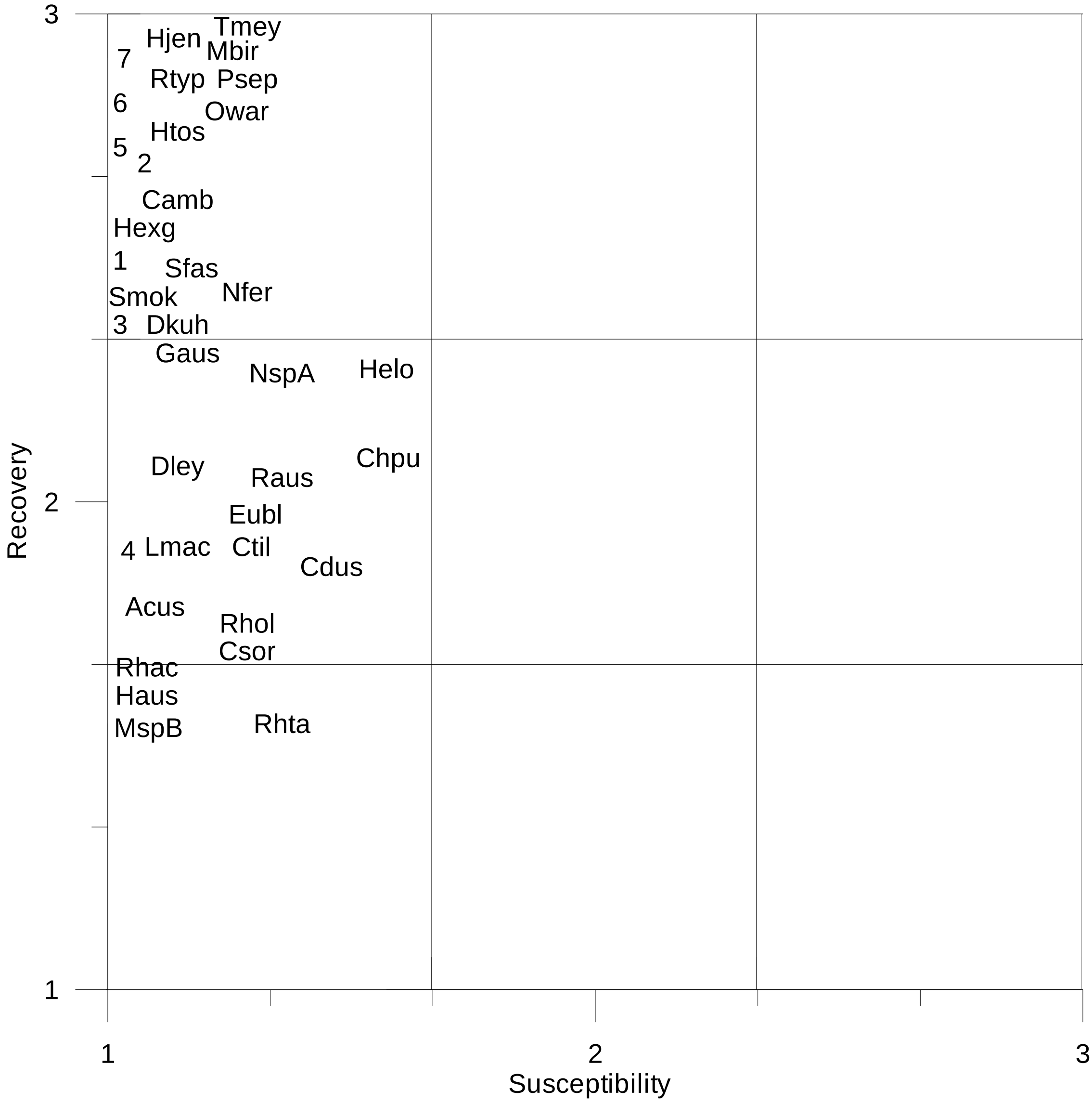
Figure 6.5-22: Sustainability plot for the PFTF fishery calculated using the weighted average method.



NTTRF - Multiplicative

1 = Calb, Calt, Cambo, Cplu, Edas, GspA, GspC, Pmic, Pzij
Tobe, Anic, Apel, Cbre, Ctau, Nacu, Camb
2 = Mere, Pcla, Anar, Hund, Rneg, Uasp, Hjen, Psep, Tmey
3 = Cfal, Hexg, Slew, Szyg, Ccau, Dann, Gcuv, Gaus, Smok
Smok, Sfas, Dkuh, Nfer, NspA, Helo
4 = Cfit, Pgla, Pkam, Cambe, Cmel, Ctil, Dley, Lmac, Cdus, Chpu, Raus

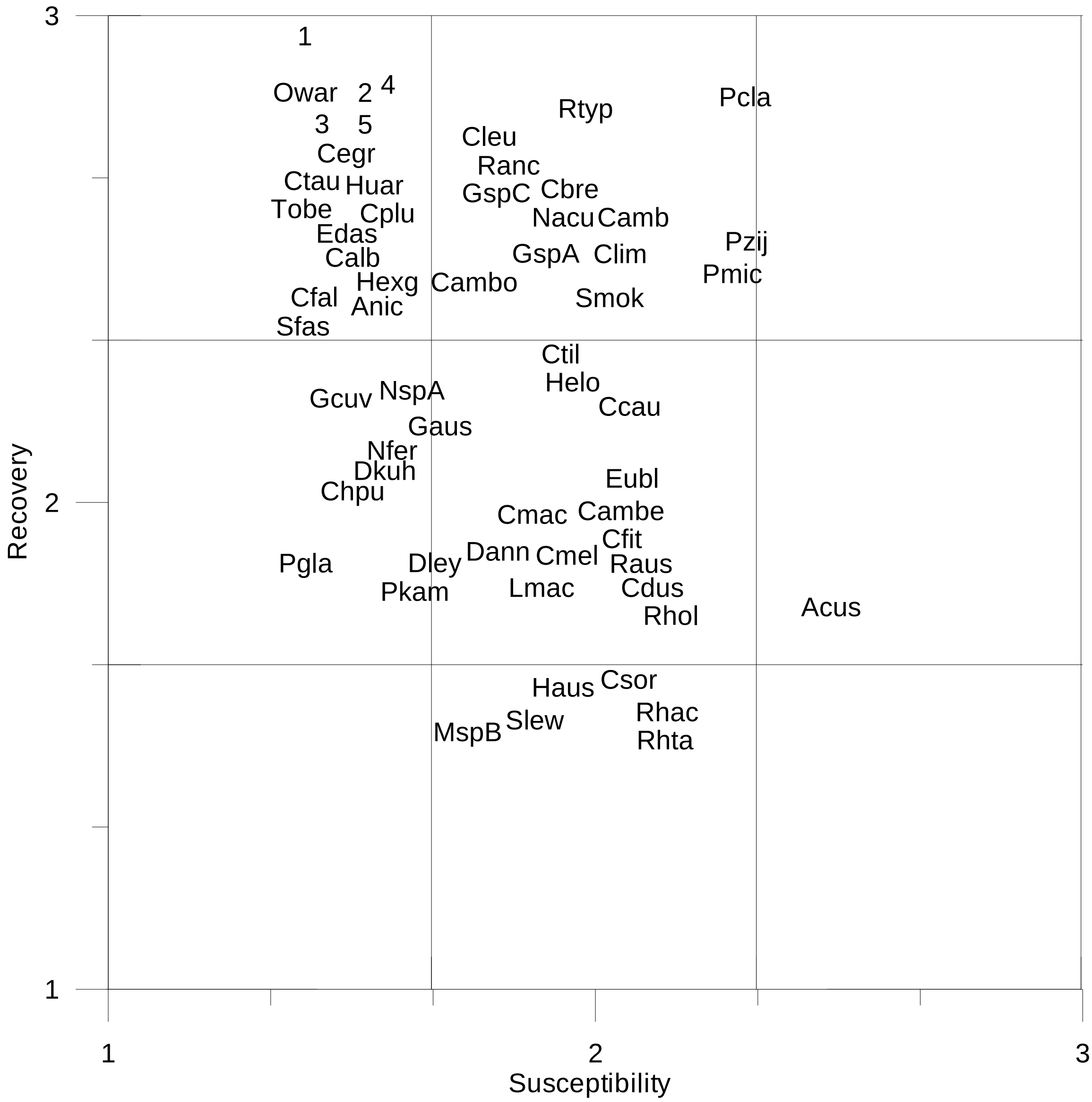
Figure 6.5-23: Sustainability plot for the NTTRF fishery calculated using the multiplicative method.



NTTRF - Weighted average

1 = Calb, GspA, Pmic, Pzij, Tobe, Anic
2 = Calt, Cambo, Cplu, Edas, GspC, Apel, Cbre, Ctau, Nacu
3 = Cfal, Clim, Szyg
4 = Cfit, Pgla, Pkam, Cambe
5 = Cobs, Ioxy, Ccau, Cleu, Huar
6 = Cegr, Ranc
7 = Pcla, Anar, Hund, Rneg, Uasp
8 = Cambe, Cmel
9 = Slew, Dann, Gaus

Figure 6.5-24: Sustainability plot for the NTTRF fishery calculated using the weighted average method.



Cumulative risk assessment for all species

1 = Tmey, Anar
2 = Rneg, Uasp, Mbir, Mere, Psep
3 = Calt, Apel
4 = Hjen, Htos, Hund
5 = Ioxy, Cobs

Figure 6.5-25: Cumulative risk assessment for all fisheries.

6.6 Discussion

6.6.1 Cumulative Risk Assessment

Using a combination of catch data of elasmobranchs in northern Australian fisheries, fishing methods and biological data collected during by fisheries observers in this project, we have produced a semi quantitative risk assessment of 75 species in 29 individual fisheries as well as a cumulative risk assessment for all fisheries. Using data collected by fisheries observers in target and bycatch fisheries, this risk assessment provides a more realistic assessment than previous attempts (Stobutzki et al., 2003). The cumulative risk assessment identified at least 14 species that are least likely to be sustainable in northern Australia due to the cumulative effect of fisheries in northern Australia. These species include *C. amboinensis*, *C. brevipinna, C. leucas, C. limbatus*, *Glyphis* sp. A, *Glyphis* sp. C, *N. acutidens, P. clavata, P. microdon, P. zijsron* and S. *mokarran*. *Anoxypristis cuspidata* had the highest susceptibility rank but a relatively low recovery rank suggesting it is more capable of recovering from fishing. The high susceptibility and the fact that this species is captured in nearly all fisheries suggest that it should also be classified as one of the least sustainable species.

While the results of the cumulative assessment provide estimate of relative risk, the fact that values were clumped together due to the averaging over 29 fisheries requires additional modification of the methods. We weighted susceptibility in each fishery based on total elasmobranch catch in each fishery. Although this approach reduced the influence of small fisheries that capture few elasmobranchs, the weighting might be more useful if applied to a criteria used to determine fishery specific susceptibility. Additional research into the use of weighting with respect to sensitivity analysis using a 3-way ordination approach should be considered to determine the best time to apply a catch weighting and also which criteria should be weighted in order to reduce the influence of redundant criteria.

Management options for species that were classified as being at high risk or least likely to sustainable need to be considered. The Ecological Risk Assessment for Effects of Fishing (ERAEF) developed by Hobday *et al.* (2004) recommends that species that are classified as high risk by a “level 2” risk assessment, which is equivalent to the analyses undertaken in this project, should be assessed using a “level 3” assessment (quantitative stock assessment). Data required for a level 3 assessment would only be available for the target species of *C. sorrah* and *C. tilstoni*, which were not identified as being at high risk. A recent stock assessment of these species was conducted by the Northern Shark Assessment group (NSAG) and showed that both species were sustainable at the current of fishing mortality (NSAG, 2005). For high risk species were there is insufficient data for a quantitative assessment, research efforts should be directed towards obtaining data for stock assessment. In the absence of long term time series of catch and effort data traditional dynamic fishery models are not suitable. Instead, demographic models that rely on life history parameters can provide guidelines for management and have been used extensively to aid management of elasmobranchs due to the lack of data on this group (Hoenig and Gruber, 1990; Cortés, 1999; Simpfendorfer, 1999a, b; Beerkircher *et al.*, 2002; McAuley *et al.*, 2005).

Once age and growth parameters for species are determined from Von Bertalanffy growth curves, demographic models can be applied to high risk species. Demographic models can then be used to estimate how changes in fishing mortality as well as changes in gear selectivity (age specific mortality) influences intrinsic rate of population increase (r). Demographic analysis can be done for all species were sufficient life history data exists. Data on the species specific catch and effort from the Australian and illegal FFV fleet can be incorporated into demographic models to model the impact of the combined legal and illegal fishing components and would provide a better estimate of sustainability than risk assessment methods.

The outcomes of this risk assessment need to be incorporated in management and used to prioritise research needs. To ensure a consistent process for responding to risk assessment outcomes AFMA has developed an Ecological Risk Management (ERM) framework which provides outlines of the process for individual fisheries to respond to the results of the risk assessment. State management agencies should be encouraged to use this approach in addition to the responses outlined by the OPSUNASR. In addressing the issues and priorities for northern fisheries that interact with elasmobranchs, OPSUNASR (2005) identified several management responses relating to the outcome of the risk assessment. These include:

- Developing rehabilitation strategies for any species identified as high risk by the risk assessment based on requirements set out in guidelines 1.2.1 and 1.2.2 of the Commonwealth Guidelines for the Ecologically Sustainable Management of Fisheries.
- Develop criteria with industry that can be used to establish the need for rehabilitation
- Ensure management arrangements allow for the implementation of rehabilitation strategies
- Encourage complementary research to improve the quality of risk assessments and assessments of resource status
- Evaluate management strategies and information requirements to minimise risk

The fact that all threatened and protected species (Glyphis sp. and sawfishes) were classified as high risk warrants the implementation of a recovery plan for these species. The issue of threatened and protected species was raised by the NPAO – Sharks as well as OPUNASR. One of the objectives of the NPOA – Sharks was: to identify and provide special attention, in particular, to vulnerable or threatened sharks. The shark plan also recommended the following action: Assess current management arrangements for listed threatened shark species against the requirements of the recovery plans for those species and address any deficiencies within 12 months of that assessment. Despite *Glyphis* sp. A, *Glyphis* sp. C and *Pristis microdon* being listed under the EPBC act for more than five years, there are still no recovery plans for these species. These recovery plans need to be developed so that management responses can be assessed against DEH recovery plan recommendations.

6.6.2 Recovery

While recovery parameters give an indication of the potential for species to recover from depletion by fishing, the recovery ranks can be misleading as species ability to recover from fishing depends on the level of fishing mortality. An estimate of fishing mortality is not available for all but two species (*C. sorrah* and *C. tilsoni*) and is one of the reasons why risk assessment methods were chosen. It is possible that a species with low recovery ranks (most likely to recover from fishing) will be at risk if fishing mortality is higher than the species ability to recover. For this reason, data on the species specific catches should be used to interpret the final sustainability estimate.

Species-specific age and growth data are likely to be a better reflection of a species ability to recover from fishing than parameters such as size at birth, size at maturity and maximum size (Smith *et al.*, 1998). However, in the absence of age and growth data, these parameters are useful but more data on the empirical relationships between age and size parameters (for the species assessed in this study) are required if size data are used as a proxy for “productivity’. The lack of age and growth data is therefore limiting to risk assessment and stock assessment/demographic methods and needs to be collected for all species in order to better assess the sustainability of these species, either though improved risk assessment methods, or preferably demographic and stock assessment models.

The scarcity of biological data reflects a lack of understanding of the life histories of many northern Australian elasmobranchs, especially species in the genus Dasyatidae, Myliobatidae, Rajidae, Rhinobatidae and Rhinopteridae where even basic information on size at maturity is lacking. While the paucity of data is likely to overestimate the recovery rank for certain species where two or more criteria are unknown, the effect this has on overall sustainability is minimal as the majority of these species have low susceptibility. This is a reflection of the fact that basic biological data such as size at birth, size at maturity, maximum size and number of pups is only known for target species. Of the species where at least 4 out of 5 criteria were known, large whaler sharks such as *Carcharhinus leucas*, *C. obscurus*, *C. amblyrhynchos*, *C. plumbeus*, *C. limbatus*, *C. brevipinna*, *C. amboinensis*, *Negaprion acutidens*, *Glyphis* sp. A and *Glyphis* sp. C had the highest recovery rank and lowest capacity to recover from overfishing. Sawfishes of the genus Pristidae also had high recovery ranks, however *Anoxypristis cuspidata* had a remarkably low recovery rank suggesting it is more capable of recovering from fishing than other sawfishes. Species with the lowest recovery ranks included smaller Carcharhinids including *C. sorrah, Rhizoprionodon acutus, R. taylori,* and *Hemigaleus microstoma*.

Using parameters such as size at birth, size at maturity and maximum size to estimate recovery does have advantages over using age and growth data when data on age and growth are lacking as it does not lead to the overestimation of recovery ability. During a workshop held to assess the risk assessment methods used in this project, a group of experts agreed that while the methods used to determine recovery ranked species is the correct order, the degree of separation between certain species was not an accurate reflection of their ability to recover from exploitation. For example, *C. sorrah*, *S. lewini* and *R. acutus* all had a recovery rank of 1.64. Taking age and growth data into account, *R. acutus* would have a higher intrinsic rate of population increase than *C. sorrah* and *S. lewini*, however the method for determining the recovery rank does not allow for separation based on these criteria used.

Although not possible with the limited data for most species assessed in this project, using measures of *r*, or λ (intrinsic rate of population increase), $F_{r=0}$ (fishing mortality rate at which population growth is zero) and r_{2M} (intrinsic rate of population increase at MSY) (see Dudley and Simpfendorfer, 2006; Smith et al., 1998) would provide a more realistic estimate of a species ability to recover from exploitation. The importance of the collection of biological data required for risk assessment and stock assessment purposes was identified by OPSUNASR with the response to these issues being: encourage complementary research to improve the quality of risk assessments and assessments of resource status and develop research priorities for northern Australian fisheries through the NAFM workshop.

6.6.3 Susceptibility

The weighted average approach was determined to be the best method for assessing susceptibility to capture. The main reason for this decision was the tendency of the multiplicative approach to underestimate susceptibility by placing too much emphasis on one or two criteria. Weighting each criterion based on its importance to overall susceptibility and averaging all values provides a better reflection of risk and is a more conservative approach which follows the precautionary principle.

The multiplicative method was originally tailored to act only as a means of assessing susceptibility to fishing and not recovery (Walker, 2004). Using the multiplicative method in combination with recovery criteria results in the two determinants of sustainability being calculated with different methods. It is not appropriate to use the multiplicative approach to determine recovery as this method would not differentiate between species with low and high recovery.

Differentiating between low and medium/high risk species is more difficult using the multiplicative method. Using two species in the ECN fishery as an example, the difference between multiplicative ranks for Apel (1.01) and Cambo (1.22) is small (0.21), however using the weighted average method, the difference between the two species (Apel = 1.43 and Cambo = 2.57) is 1.04. The multiplicative method compresses the final ranks of species that are at low to medium risk. Interpretation of the susceptibility ranks when using the multiplicative method requires a greater knowledge of the fishery and the species biology and ecology as the risk of some species is underestimated using this method. As a result, we have used the weighted average method to show the risk in each fishery and also to determine the cumulative risk to all species in all fisheries.

6.6.4 Comparison with previous risk assessments

By using catch data from the fisheries, the number of species in this risk assessment (75) was halved compared to the initial risk assessment on northern Australian elasmobranchs where 148 species were assessed (Stobutzki *et al.*, 2003). This was because Stobutzki *et al.* (1998) assumed that all species found in the northern part of Australia were captured by the fisheries assessed. Similarly, by obtaining additional biological data and tailoring the risk assessment to utilise data on size at maturity and maximum size rather than age at maturity and longevity, there was a significant reduction in the number of unknown criteria. In the current project, 25 % of all recovery criteria were unknown compared to 43 % in Stobutzki *et al.* (2003). Using criteria where biological data were available reduced the number of species that would otherwise have been assigned a rank of 3. Thus, the number of species with high recovery ranks was reduced.

There was general agreement in the results of the current risk assessment with those of Stobutzki *et al* (2003). The major difference between the two risk assessments was between stringrays and skates. In the Stobutzki report, several stingrays such *D. kuhlii, H. uarnak, H. jenkinsi, G. australis* and *Pastinachus sephen* were classified as high risk. In the current assessment, all stingrays were classified as low risk due to their capture in only a few fisheries. Furthermore, it is now compulsory for most prawn trawl fisheries to use TEDs, which has significantly reduced the number of stingrays landed in these fisheries (Brewer *et al.*, 2004).

Species that were classified as high risk by both methods included all species of sawfishes, *C. amboinensis, C. cautus, C. fitzroyensis, C. leucas, E. blochii, N. acutidens, S. mokarran* and *R. australiae*. Species ranked as high risk by this project and low risk by Stobutzki *et al* (2004) include *C. amblyrhynchoides, C. limbatus, C. sorrah, C. tilstoni* and *Glyphis* sp. A. *Carcharhinus sorrah* and *C. tilstoni* were classified as high risk because they are target species in gill net fisheries and are frequently captured in other fisheries, such as the NPF. A recent stock assessment of *C. sorrah* and *C. tilstoni* (NSAG, 2005) showed that populations of these species appear to be maintaining and that current rates of harvest are sustainable, but stocks have apparently not yet recovered from heavy fishing pressure by the Taiwanese between 1975 – 1985 (Stevens, 1990). The fact that *C. tilsoni* and *C. sorrah* were classed as high risk in the risk assessment but are considered to be sustainable when using stock assessment methods illustrates the importance of detailed biological and catch data for all species but also suggests that catches of these species need to be closely moniroted in order to prevent over fishing. *Carcharhinus amblyrhynchoides* and *Glyphis* sp. A were classified as high risk in this project due largely to observer data from inshore gill net fisheries that capture these species.

6.6.5 Selected individual fisheries

The following individual fisheries are briefly discussed due to their importance in terms of the size of the fishery, or interactions with threatened and protected species.

ECN

Anoxypristis cuspidata has a high susceptibility rank in this fishery and should also be closely monitored due to the fact that population of all species of sawfish have declined along the east coast of Australia in the past 20 years.

Species such as *C. amblyrhynchoides*, *C. cautus, E. blochii* and *R. australiae* that have a high susceptibility rank and mid-range recovery ranking are likely to be at high risk from the ECN fishery due to high amount of fishing effort in this fishery (13000 days when elasmobranchs was recorded in the catch in 2003) combined with the diversity of habitat and depth fished.

N9

Despite *C. tilstoni* being considered as high risk in this fishery, catches are likely to be sustainable based on increasing CPUE in this fishery and a low amount of fishing effort (Gribble et al., 2005). *Carcharhinus tilstoni* is a target species and comprises about 25 % by number of the total catch in this fishery. It is therefore likely that any reduction in population size will be reflected in overall catches. Catches should be closely monitored if effort in this fishery increases.

Catches of *H. elongata*, which were also identified as least likely to be sustainable are likely to be sustainable in the N9 at current fishing effort as this species only forms less than 1% of the recorded catch (Chapter 4). Similarly, catches of *Carcharhinus dussumieri*, *C. macloti*, *C. sorrah, Rhizoprionodon acutus, R. oligolinx*, *R. taylori* and *Sphyrna lewini* are likely to be sustainable due to the relatively high fecundity of these species and low fishing effort in the N9 (less than 500 days fished in 2004, Section 3).

NPF

All sawfishes were classified as being at high risk from the NPF. This is largely due to their entanglement with the trawl gear and the difficulty in removing animals from the nets due to their large size. *Anoxypristis cuspidata* is the most commonly captured sawfish in the NPF. Although TEDs have reduced the capture of this species in the NPF (Brewer *et al.*, 2004), it is still classified as high risk due to the fact that mortality of landed animals is high and there is currently no data on the survival of animals that are released alive. Although capture of other sawfish species occurs infrequently, the majority of animals landed are large sexually mature animals, which are becoming less common in all northern Australian waters.

Although *D. annotata, D. kuhlii, D. leylandi* and *Gymnura australis* were least likely to be sustainable, their risk status would be significantly reduced if post-capture mortality was lower. There are currently no estimates of post capture mortality for elasmobranchs in the NPF and it was therefore assumed that post-capture mortality was high.

NTBarr

Glyphis sp. A was one of the least sustainable species in the NTBarr fishery, however recent amendments to the fishery prevent fishing in the rivers where *Glyphis* sp. A are known to frequent. This may reduce the impact of the NTBarr fishery on *Glyphis* sp. A, however additional information on habitat utilisation and distribution of *Glyphis* sp. A is required before these data can be incorporated into the risk assessment. Closing rivers to the NTBarr fishery is likely to cause an increase in effort at river mouths and the coastal fringes. The impact of a shift in effort on *Glyphis* sp. A is currently unknown. It is likely that increased effort in the marine environment will increase the impact of this fishery on species such as *C. amboinensis, C. fitzroyensis, P. zijsron, P. clavata, A. cuspidata, C. amblyrhynchoides* and *E. blochii*.

The species-specific catch composition of elasmobranchs is not recorded by the NTBarr fishery and logbook records of elasmobranch catches in this fishery are small (3.7 tonnes). Given the number of species that were classified as high risk in this fishery and the high catches in similar inshore gill net fisheries in Queensland, it is likely that catches of elasmobranchs in the NTBarr fishery are significantly higher than those recorded. Management action is required to: 1) Introduce logbooks that record elasmobranch species (similar to those introduced by NTONL) in order to record catches of elasmobranchs. 2) Fishers need to be trained in the identification of elasmobranchs to ensure logbook records reflect species specific catches. 3) Introduce voluntary code of conduct for the release of sawfish and *Glyphis* sp. A.

NTONL

Species such as sawfishes, C. *brevipinna C. fitzroyensis*, *C. tilstoni* and *E. blochi* which are susceptible to capture in gill net fisheries as well as larger species such as *C. amboinensis*, *Glyphis* sp. C, *N. acutidens* and *S. mokarran* that are captured more frequently on longlines were the least sustainable species in the NTONL. The use of both methods results in a greater number of high risk species due to different selectivity of the gears.

Although sawfishes were among the least sustainable species, the NTONL fishery has introduced a voluntary code of conduct for the release of all sawfish. Early reports suggest this is being adhered to by the fishery which will lead to reduced mortality and therefore increased sustainability of these species. However, post-release survival of sawfish captured from boats is currently unknown and research is needed to determine if releasing all animals is resulting in reduced mortality.

NTFT and QDFT

Despite the release of all elasmobranchs, *A. cuspidata* was still deemed to be unsustainable due to the difficulty of removing animals from nets and low survival of this species. The short shots in this fishery combined with an effective hopper system results in almost all large animals being released shortly after being landed. As with other trawl fisheries, the mortality of released animals is unknown and needs to be determined in order to accurately assess the sustainability of animals captured as bycatch. If the mortality is greater than current estimates, species that have a susceptibility ranking between 1.66 and 2.33 would be ranked as unsustainable.

NWSTF

Data on the catches of elasmobranchs in the NWSTF were not available; however a species composition list was compiled by observers in this fishery was provided by AFMA. Besides *A. cuspidata*, species at high risk are found in deep water and have limited geographic distribution. In addition, very little is known about the biology of these species. Catches of *P. daviesi, C. granulosus* and *Dipturus* sp. I. *Dipturus* sp. F, *H. lemures, P. alleni* and *Squatina* sp. B need to be monitored to ensure that these species are not overexploited. Although the NWSTF is the only fishery that has any impact on these species, they are considered as high risk in the cumulative risk assessment due to the fact that this fishery operates throughout range of these species. Although *A. cuspidata* had a high susceptibility ranking; it is least likely to be captured frequently by the NWSTF due to the depth this fishery operates in (200 – 600 m, Wade Whitelaw, AFMA, Pers. Comm.).

WAEMBGF

Both *N. acutidens* and *C. amboinensis* were least likely to be sustainable in this fishery because it operates in the same habitat these species utilise as nursery areas. The gill net mesh size is effective at capturing most animals utilising the inshore nursery areas leading to high selectivity and overlap with primary habitat. Although this fishery does not capture adults due to the mesh size, the high catch rates of these species is least likely to be sustainable. Adults of both species are also taken by the WANCSF which operates offshore. The combination of both adults and juveniles being targeted in this area warrants concern. Additional research into the biology of both species is required in order to produce demographic/stock assessment models for these species which have a low ability to recover and are also taken in NTONL fishery.

WANCSF

A large number of species were not considered to be sustainable in the WANCSF due to the use of both longlines and gillnets in this fishery. Of particular concern were *C. plumbeus, N. acutidens* and *C. amboinensis*. Recent management initiatives in response to unsustainable harvest of *C. plumbeus* have resulted in a large reduction in long line fishing effort as well spatial closures in the southern region of this fishery (McAuley *et al.*, 2005). Fishing effort in 20004/05 was 1412 boat days, primarily by long line (only 9 days gill net effort). This has now been reduced to 300 days longline and 600 days gill net. Longline operators can swap 300 longline days to 600 gillnet days but to date no operators have done this. Long line effort has therefore been reduced by nearly 80% and total effort by

36%. There is some concern that the effort cap has resulted in more boats moving across to the NT resulting in an increase in effort in the joint authority section of this fishery, however logbooks have not yet recorded this. This issue needs to be monitored through the complementary management via the OCS between NT and WA. The reduction in long line effort should reduce catches of *C. amboinensis* and *N. acutidens*, catches need to be monitored closely and data on the biology of both species needs to be collected for stock assessment purposes.

Increasing gillnet effort in this fishery is likely to result in an increased risk to sawfishes due to their high susceptibility to this fishing method. Following the shift in effort, catch composition will need to be monitored closely.

6.6.6 The impact of IUU fishing

The current project did not include the issue of IUU fishing in northern Australia in the risk assessment due to the lack of species composition and fishing effort data from the illegal component. It is likely that given the reported level of IUU fishing effort in northern waters, these fisheries are having a significant impact on the sustainability of several species, in particular large Carcharhinids which have valued fins. However, until data on the fishing methods, distribution of fishing effort and species composition become available it is not possible to estimate the risk to individual species. Similarly, the extent of overlap between Australian and IUU fishing has not yet been determined and therefore a comparison between the risks each “fishery” poses to individual species is not possible. We feel that this should be the highest future research priority for northern Australian elasmobranchs.

Table 6.6-1: Primary habitat used by species in this study. Habitat ranks were determined from these data using rules in Table 6.2-1.

Scientific name	Primary habitat
Aetobatus narinari	benthopelagic, coastal, reef, soft substrate, estuarine
Aetomylaeus nichofii	benthopelagic, coastal, shelf
Alopias pelagicus	oceanic, pelagic
Anoxypristis cuspidata	demersal, benthopelagic, coastal, shelf, soft substrate
Carcharhinus albimarginatus	pelagic, reef, shelf
Carcharhinus altimus	benthopelagic, shelf, slope
Carcharhinus amblyrhynchoides	benthopelagic, coastal, estuarine
Carcharhinus amblyrhynchos	benthopelagic, coastal, shelf, reef
Carcharhinus amboinensis	benthopelagic, coastal, estuarine, shelf
Carcharhinus brevipinna	benthopelagic, coastal, shelf
Carcharhinus cautus	benthopelagic, coastal, estuarine
Carcharhinus dussumieri	benthopelagic, coastal, shelf
Carcharhinus falciformis	oceanic, pelagic, shelf
Carcharhinus fitzroyensis	benthopelagic, coastal, estuarine, shelf
Carcharhinus leucas	benthopelagic, coastal, estuarine
Carcharhinus limbatus	benthopelagic, coastal, shelf
Carcharhinus macloti	benthopelagic, coastal, shelf
Carcharhinus melanopterus	benthopelagic, coastal, shelf, reef
Carcharhinus obscurus	benthopelagic, shelf, slope
Carcharhinus plumbeus	benthopelagic, shelf, slope
Carcharhinus sorrah	benthopelagic, coastal, shelf
Carcharhinus tilstoni	benthopelagic, coastal, shelf
Carcharias taurus	benthopelagic, shelf, reef
Centrophorus granulosus	demersal, slope
Chiloscyllium punctatum	demersal, coastal, shelf
Dasyatis annotata	demersal, coastal, shelf, soft substrate
Dasyatis kuhlii	demersal, reef, coastal, shelf
Dasyatis leylandi	demersal, soft substrate, coastal, shelf
Dipturus sp. A	demersal, soft substrate, slope
Dipturus sp. F	demersal, soft substrate, slope
Eucrossorhinus dasypogon	demersal, reef, coastal, shelf
Eusphyra blochii	benthopelagic, coastal, shelf, estuarine
Galeocerdo cuvier	benthopelagic, coastal, shelf, slope
Glyphis sp. A	benthopelagic, coastal, estuarine
Glyphis sp. C	benthopelagic, coastal, estuarine
Gymnura australis	demersal, coastal, shelf, soft substrate
Hemigaleus microstoma	demersal, soft substrate, benthopelagic, coastal, shelf
Hemipristis elongata	benthopelagic, soft substrate, coastal, shelf
Hexanchus griseus	demersal, slope
Himantura jenkinsii	demersal, shelf, soft substrate
Himantura toshi	demersal, coastal, shelf, soft substrate
Himantura uarnak	demersal, coastal, shelf, soft substrate
Himantura undulata	demersal, soft substrate, coastal, shelf

Scientific name	Primary habitat
Hydrolagus lemures	demersal, soft substrate, slope
Isurus oxyrinchus	pelagic, oceanic, shelf, slope
Loxodon macrorhinus	demersal, benthopelagic, coastal, shelf
Manta birostris	pelagic, coastal, shelf
Mobula eregoodootenkee	pelagic, coastal, shelf
Mustelus sp. B	demersal, shelf, slope
Narcine sp. A	demersal, soft substrate, shelf, slope
Nebrius ferrugineus	demersal, coastal, shelf
Negaprion acutidens	benthopelagic, inshore, shelf, estuarine
Orectolobus wardi	demersal, reef, coastal, shelf
Pastinachus sephen	demeral, soft substrate, coastal
Pavoraja alleni	demersal, soft substrate, slope
Plesiobatis daviesi	demersal, soft substrate, slope
Prionace glauca	pelagic, oceanic
Pristis clavata	demersal, coastal, estuarine, shelf, soft substrate
Pristis microdon	demersal, coastal, shelf, estuarine, soft substrate
Pristis zijsron	demersal, coastal, shelf, estuarine, soft substrate
Pseudocarcharias kamoharai	pelagic, oceanic
Rhina ancylostoma	demersal, coastal, shelf, soft substrate
Rhinobatos typus	demersal, coastal, shelf, soft substrate
Rhinoptera neglecta	benthopelagic, coastal, shelf
Rhizoprionodon acutus	benthopelagic, coastal, shelf
Rhizoprionodon oligolinx	benthopelagic, coastal, shelf
Rhizoprionodon taylori	benthopelagic, coastal, shelf
Rhynchobatus australiae	demersal, coastal, shelf, soft substrate
Sphyrna lewini	benthopelagic, coastal, shelf, slope
Sphyrna mokarran	benthopelagic, coastal, shelf
Stegostoma fasciatum	demersal, coastal, shelf
Taeniura meyeni	demersal, coastal, shelf, reef, soft substrate
Triaenodon obesus	demersal, reef, coastal, shelf
Urogymnus asperrimus	demersal, shelf, soft substrate

Table 6.6-2: Summary of biological data used to obtain ranks for recovery criteria. Values were obtained from the literature, unpublished data and from biological data collected from this project.

SCIENTIFIC_NAME	REFERENCE	Length type	Size at birth	Size female maturity	Maximum size	Age at maturity	Litter size	Reproductive periodicity
Aetobatus narinari	JD_Stevens	DW	17		330	4		
Aetomylaeus nichofii	White 2003	DW	17	39	64			
Alopias pelagicus	White 2003; Liu et al. (1999)	TL	140	264	330	7	2	
Anoxypristis cuspidata	Peverell Unpublished MsC thesis; (FRDC 2002/064)	TL	85	225	350	5	15	1
Carcharhinus albimarginatus	Last & Stevens (1994)	TL	55	195	275		6	2
Carcharhinus altimus	Last & Stevens (1994)	TL	60	225	285		9	
Carcharhinus amblyrhynchoides	Stevens & McLoughlin (1991); Last & Stevens (1994)	TL	50	110	170		5	1
Carcharhinus amblyrhynchos	Stevens & McLoughlin (1991); Last & Stevens (1994); JD_Stevens	TL	50	130	190	7	3.4	2
Carcharhinus amboinensis	Stevens & McLoughlin (1991); Last & Stevens (1994), FRDC 2002/064	TL	60	215	280		9.5	2
Carcharhinus brevipinna	JD_Stevens	TL	75	210	278	9	10	2
Carcharhinus cautus	JD_Stevens	TL	40	91	140		3	1
Carcharhinus dussumieri	Last & Stevens (1994); Stevens & McLoughlin (1991)	TL	35	67	90		2	1
Carcharhinus falciformis	Last and Stevens, 1994	TL	70	200	350	7	8	2
Carcharhinus fitzroyensis	JD_Stevens	TL	50	100	135		4	1
Carcharhinus leucas	JD_Stevens, Pillans unpublished	TL	60	230	340	20	7	2
Carcharhinus limbatus	JD_Stevens	TL	68	190	250	6	6	2
Carcharhinus macloti	Stevens & McLoughlin, 1991; Last and Stevens, 1994	TL	40	74	110		1.5	1
Carcharhinus melanopterus	JD_Stevens; Last and Stevens, 1994	TL	48	97	140		4	1
Carcharhinus obscurus	Last and Stevens, 1994; Simpfendorfer et al., 2002	TL	70	220	365	17	8.5	3
Carcharhinus plumbeus	McAuley, 2005	TL	42.5	158	280	13	6.5	2
Carcharhinus sorrah	Last and Stevens, 1994;	TL	52	97	155	2.5	3.5	1

SCIENTIFIC_NAME	REFERENCE	Length type	Size at birth	Size female maturity	Maximum size	Age at maturity	Litter size	Reproductive periodicity
	Davenport & Stevens, 1988; FRDC 2002/064							
Carcharhinus tilstoni	JD_Stevens; Davenport & Stevens, 1988, FRDC 2002/064	TL	53	115	180	3.5	3.3	1
Carcharias taurus	Last and Stevens, 1994	TL	100	220	318	7	2	2
Centrophorus granulosus	JD_Stevens	TL	35		160		1	
Chiloscyllium punctatum	Last and Stevens, 1994	TL	17	70	118			
Dasyatis annotata	JD_Stevens	DW		23	24		2	
Dasyatis kuhlii	Last and Stevens, 1994, White 2005 (ACIAR)	DW	16	38	38		2	1
Dasyatis leylandi	JD_Stevens; Barrat, 2004;	DW	11	18	31.7		1	1
Eucrossorhinus dasypogon	JD_Stevens	TL	20		125			
Eusphyra blochii	Last and Stevens, 1994	TL	45	120	186		8	1
Galeocerdo cuvier	Last and Stevens, 1994; Natanson *et al.*, 1999; Winter and Dudley, 2000	TL	63	350	500	8	40	2
Glyphis sp. A	FRDC 2002/064	TL	55	200	250		5	2
Glyphis sp. C	FRDC 2002/064	TL	60	177	252		9	
Gymnura australis	JD_Stevens	DW		61	73		4	
Hemigaleus microstoma	Stevens & McLoughlin (1991)	TL	30	65	110		9	1
Hemipristis elongata	Last and Stevens, 1994	TL	52	120	230		6.5	2
Hexanchus griseus	Last and Stevens, 1994	TL	65	420	480		65	
Himantura jenkinsii	White, 2003	DW		71	104			
Himantura toshi	Last and Stevens, 1994	DW	20	66	69		2	
Himantura uarnak	JD_Stevens	DW	28		200		4	
Himantura undulata	White 2003	DW	20	90	140			
Hydrolagus lemurs	Last and Stevens, 1994	TL	<50	58	1			
Isurus oxyrinchus	JD_Stevens, Bishop *et al.*, 2006	TL	70	275	395	19	4	3
Loxodon macrorhinus	Stevens & McLoughlin (1991)	TL	40	57	88		1.5	1
Manta birostris	JD_Stevens	DW	110	430	910		2	
Mobula eregoodootenkee	Fishbase 2005	DW			100			
Mustelus sp. B	JD_Stevens	TL	27	62	117		9	1

SCIENTIFIC_NAME	REFERENCE	Length type	Size at birth	Size female maturity	Maximum size	Age at maturity	Litter size	Reproductive periodicity
Narcine sp. A	JD_Stevens	DW		17	17			
Nebrius ferrugineus	Last & Stevens (1994); FRDC 2002/064	TL	40	230	320		22	1
Negaprion acutidens	JD_Stevens	TL	60	213	300		7	
Orectolobus wardi	JD_Stevens	TL			63			
Pastinachus sephen	Last and Stevens, 1994	DW	18		180			
Pavoraja alleni	Last and Stevens, 1994	DW	14	32	1			
Plesiobatis daviesi	Last and Stevens, 1994	DW		130	3			
Prionace glauca	Last and Stevens, 1994	TL	35	220	383	4	35	
Pristis clavata	Peverell Unpublished MsC thesis (FRDC 2002/064)	TL	64	284	320			
Pristis microdon	Peverell Unpublished MsC thesis (FRDC 2002/064)	TL	72	303	656	8		1
Pristis zijsron	Peverell Unpublished MsC thesis (FRDC 2002/064)	TL	80	380	535	9		1
Pseudocarcharias kamoharai	Last and Stevens, 1994	TL	40	79	110		4	
Raja sp. F	Last and Stevens, 1994	DW	<50	50	1			
Raja sp. *I*	Last and Stevens, 1994	DW	18	43	2			
Rhina ancylostoma	JD_Stevens	TL	45		270			
Rhinobatos typus	JD_Stevens, FRDC 2005	TL	38		270			
Rhinoptera neglecta	JD_Stevens	DW			86			
Rhizoprionodon acutus	Stevens & McLoughlin, 1991; Last and Stevens, 1994	TL	35	75	100		3.5	1
Rhizoprionodon oligolinx	Last and Stevens, 1994	TL	20	35	70		4	
Rhizoprionodon taylori	Simpfendorfer, 1993	TL	23	57	69	1	4.5	1
Rhynchobatus australiae	FRDC 2002/064	TL	49	155	282		15	
Squatine sp. B	Last and Stevens, 1994	TL	<64	<64	64			
Sphyrna lewini	Branstetter, 1987; Dudley and Simpfendorfer, 2006, FRDC 2002/064	TL	48	200	345	11	17	
Sphyrna mokarran	JD_Stevens, FRDC 2002/064	TL	65	229	600		15	2
Stegostoma fasciatum	Last and Stevens, 1994	TL	20	170	235		3	
Taeniura meyeni	JD_Stevens; White 2003	DW	35	120	180			

SCIENTIFIC_NAME	REFERENCE	Length type	Size at birth	Size female maturity	Maximum size	Age at maturity	Litter size	Reproductive periodicity
Triaenodon obesus	Last and Stevens, 1994, Fishbase 2005	TL	52	105	170	5	3	
Urogymnus asperrimus	Fish base	DW			100			

The following decision rules were used to obtain values from multiple sources of information:

In all cases, regional data was used in preference to data from other areas.

Birth size (cm TL) – where more than one credible value is available, chose the smallest.

Size at female maturity (cm TL) – where more than one credible value is available, chose the smallest. If no data for females then use data from males (no cases with these species).

Maximum size (cm) – where more than one credible value is available, chose the largest.

Age at female maturity (y) – where more than one credible value is available, chose the smallest. If no data for females then use data from males (no cases with these species).

Litter Size – where average is available, use it, otherwise mean of max and min. If only one value available, use it.

Reproductive Period (y) – where more than one credible value is available, chose the largest. Adjust for gestation period where inconsistent.

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Table 6.7-1: Summary of biological data used to obtain ranks for recovery criteria. Values were obtained from the literature, unpublished data and from biological data collected from this project. The following decision rules were used to obtain values from multiple sources of information:

In all cases, regional data was used in preference to data from other areas.

Birth size (cm TL) – where more than one credible value is available, chose the smallest.

Size at female maturity (cm TL) – where more than one credible value is available, chose the smallest. If no data for females then use data from males (no cases with these species).

Maximum size (cm) – where more than one credible value is available, chose the largest.

Age at female maturity (y) – where more than one credible value is available, chose the smallest. If no data for females then use data from males (no cases with these species).

Litter Size – where average is available, use it, otherwise mean of max and min. If only one value available, use it.

Reproductive Period (y) – where more than one credible value is available, chose the largest. Adjust for gestation period where inconsistent.