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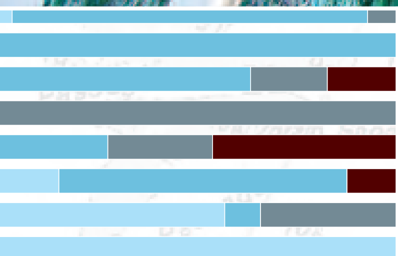
Great Barrier Reef Marine Park Authority

Ecological risk assessment of the

East Coast Otter Trawl Fishery

in the Great Barrier Reef Marine Park

Technical report **2**



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2012

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R J Pears[1], A K Morison[2], E J Jebreen[3], M C Dunning[3], C R Pitcher[4], A J Courtney[3], B Houlden[1] and I P Jacobsen[3]

[1] Great Barrier Reef Marine Park Authority
[2] Morison Aquatic Sciences
[3] Department of Agriculture, Fisheries and Forestry Queensland
[4] CSIRO Wealth from Oceans Flagship

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Other Authors/Contributors:
Pears, R. J.
Great Barrier Reef Marine Park Authority.

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Director, Communication
2-68 Flinders Street
PO Box 1379
TOWNSVILLE QLD 4810
Australia
Phone: (07) 4750 0700
Fax: (07) 4772 6093
info@gbrmpa.gov.au

Comments and enquiries on this document are welcome and should be addressed to:

Director, Ecosystem Conservation and Sustainable Use
info@gbrmpa.gov.au

www.gbrmpa.gov.au

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The QSIA has been a partner on the project, involved in the project advisory committee and members provided substantial input to the ecological risk assessment, including consideration of management responses to identified risks and issues. The project advisory committee members were Peter McGinnity (GBRMPA), Ian Yarroll (DAFF Queensland), Eddie Jebreen (DAFF Queensland), Richard Taylor (Trawl Industry), Gary Wicks (Trawl Industry), Winston Harris (QSIA) and Peter Doherty (AIMS). We are thankful for their guidance, input and encouragement throughout the assessment. We also received valuable guidance from members of the Ecosystem Reef Advisory Committee (for the Great Barrier Reef Marine Park) and the Trawl Plan Review Technical Advisory Committee (DAFF Queensland).

The development of this report has benefited from input and feedback from committee members, workshop participants, the project advisory committee and other staff from partner organisations (GBRMPA, DAFF Queensland and QSIA). The completed assessments and a full draft of this report were provided to expert workshop participants for review. Karen Astles provided valuable input to the report, particularly regarding the risk assessment methodology and development of Section 3.1. The report was also peer-reviewed by two independent scientists and their feedback was used to improve an earlier draft of the report. We are also grateful for review of the draft final report and scientific advice provided by Peter Doherty.

This assessment was funded by the GBRMPA (under the Great Barrier Reef Climate Change Action Plan 2007–2012), and received considerable in-kind support from DAFF Queensland, CSIRO and AIMS.

Executive Summary

An ecological risk assessment of the East Coast Otter Trawl Fishery in the Great Barrier Reef Region was undertaken in 2010 and 2011. It assessed the risks posed by this fishery to achieving fishery-related and broader ecological objectives of both the Queensland and Australian governments, including risks to the values and integrity of the Great Barrier Reef World Heritage Area.

This was a comprehensive, robust and transparent assessment of the current fishery that used accepted standards and the latest scientific findings. The risks assessed included direct and indirect effects on the species caught in the fishery as well as on the structure and functioning of the ecosystem. This ecosystem-based approach included an assessment of the impacts on harvested species, by-catch, species of conservation concern, marine habitats, species assemblages and ecosystem processes. In total, over 900 species, 10 habitat types, 16 assemblages and 14 ecosystem processes were considered in the assessment using a hierarchical process. The assessment also considered known external pressures (i.e. non-trawl fishery-related pressures such as modification of coastal ecosystems, degraded water quality and predicted climate change vulnerabilities), which may increase the susceptibility of an ecological component to the effects of trawling.

The assessment took into account current management arrangements and fishing practices at the time of the assessment. It also recognised that the ecosystem, which has been subject to multiple use for decades, is no longer pristine. The assessment was unusually well informed for an ecological risk assessment and captured a substantial range of published material as well as expert opinion from a diverse range of participants. This material included fishery-independent field studies, experimental manipulation of fishing activities to investigate impact and recovery of seabed species, modelling of the distributions of species, habitats and assemblages, and trophic interactions among the species groups affected by trawl fishing. Research and monitoring on harvested species, by-catch and protected species also informed the assessment. This broad body of knowledge provides a high degree of confidence that the findings about the remaining risk levels are robust.

The main findings of the assessment were:

- **Current risk levels from trawling activities are generally low.** Under current practices and 2009 effort levels the overall ecological risks from trawling in the Great Barrier Reef Region to harvested species and to the broader environmental values and integrity of the area are low, with most species, habitat types, species assemblages and ecosystem processes at low or intermediate-low risk from the fishery (Figure 1). As trawl fishing effort has remained at similar levels over the period 2007 to 2011, the risk findings are still considered relevant in 2012 and it is unlikely overall ecological risks have changed from those reported here.

- **Some risks from trawling remain.** In particular, high risks were identified for 11 species of skates and rays and two species of sea snakes. The by-product species Balmain bugs (three species of lobsters in the genus *Ibacus*) were at intermediate-high risk. A poorly known upper continental slope habitat (90 to 300 m depth) in the southern Great Barrier Reef Region (that includes deepwater eastern king prawn fishing grounds) and the plant and animal communities occurring there were also assessed as at high risk.

  This particular upper continental slope habitat is not afforded the same levels of protection provided to other habitat types within the Region. In part, this level of protection is an artefact of the way the habitat boundary was defined for this assessment. About half of this area receives consistently high levels of trawl fishing effort. Additional ecological and biological information is required to more confidently assess the risks posed by the fishery in this area.

Overall pattern of ecological risk in 2009

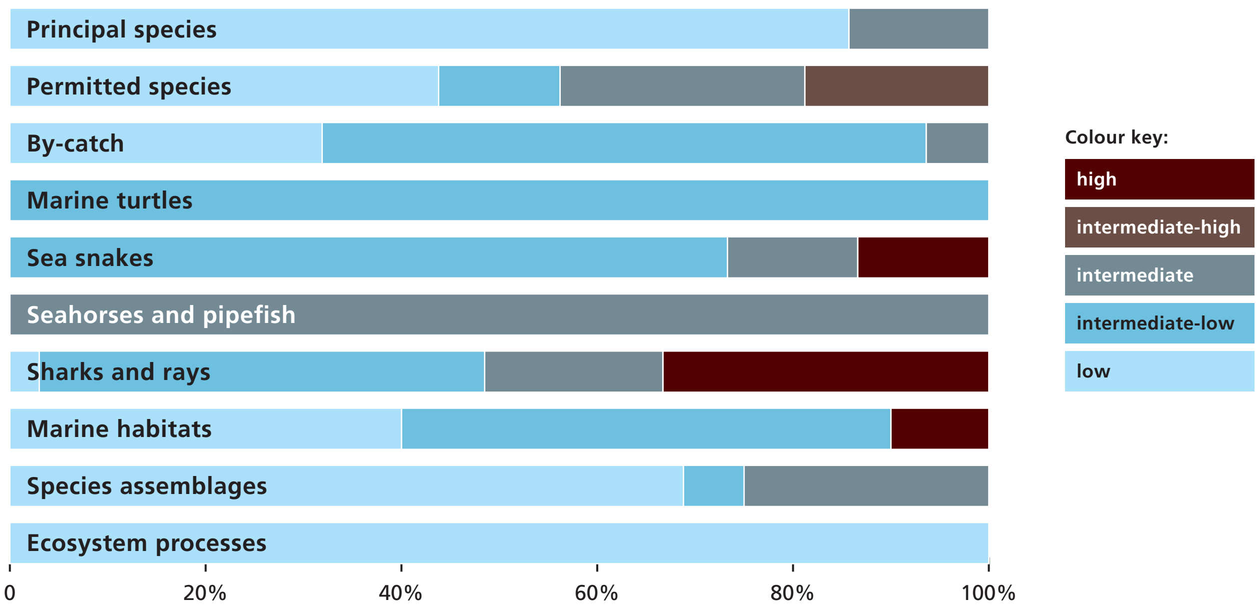

Figure 1. Overall ecological risk from activities of the East Coast Otter Trawl Fishery in the Great Barrier Reef Region.

The colour indicates the risk categories used (see colour key). Each bar is shaded to represent the proportion of species or types assigned to particular risk categories. The categories are explained in Section 3 and the contexts against which risk was assessed are defined in Section 4. The figure is based on trawl fishing effort data for 2009.

- **Risks from trawling have reduced in the Great Barrier Reef Region.** A comparison showed the overall ecological risk profile of the East Coast Otter Trawl Fishery was lower in 2009 compared to 2005 (Figure 2) as a result of a substantial reduction in trawl fishing effort over this period, principally in response to less favourable economic circumstances.

- **Trawl fishing effort is a key driver of ecological risk.** Risk may increase if fishing effort levels increase above those in 2009. Fishery management tools that actively manage effort within sustainable levels for each of the key trawl fishery sectors could provide a mechanism to control risks and impacts on harvested species and the environment.

- **Zoning has been important in reducing risks.** The protection afforded to the Great Barrier Reef Marine Park through zoning (particularly since rezoning in 2004) contributed to the relatively low ecological risks from the otter trawl fishery and is critical for protection of productive habitats, biodiversity conservation and maintaining ecosystem resilience.

  Trawling is allowed within 34 per cent, and currently occurs more than once per year in less than seven per cent, of the Great Barrier Reef Marine Park. Protection through zoning is an important measure which acts to limit spatial expansion of the fishery and potential risk to the ecosystem.

Risk pattern for 2009 compared to 2005

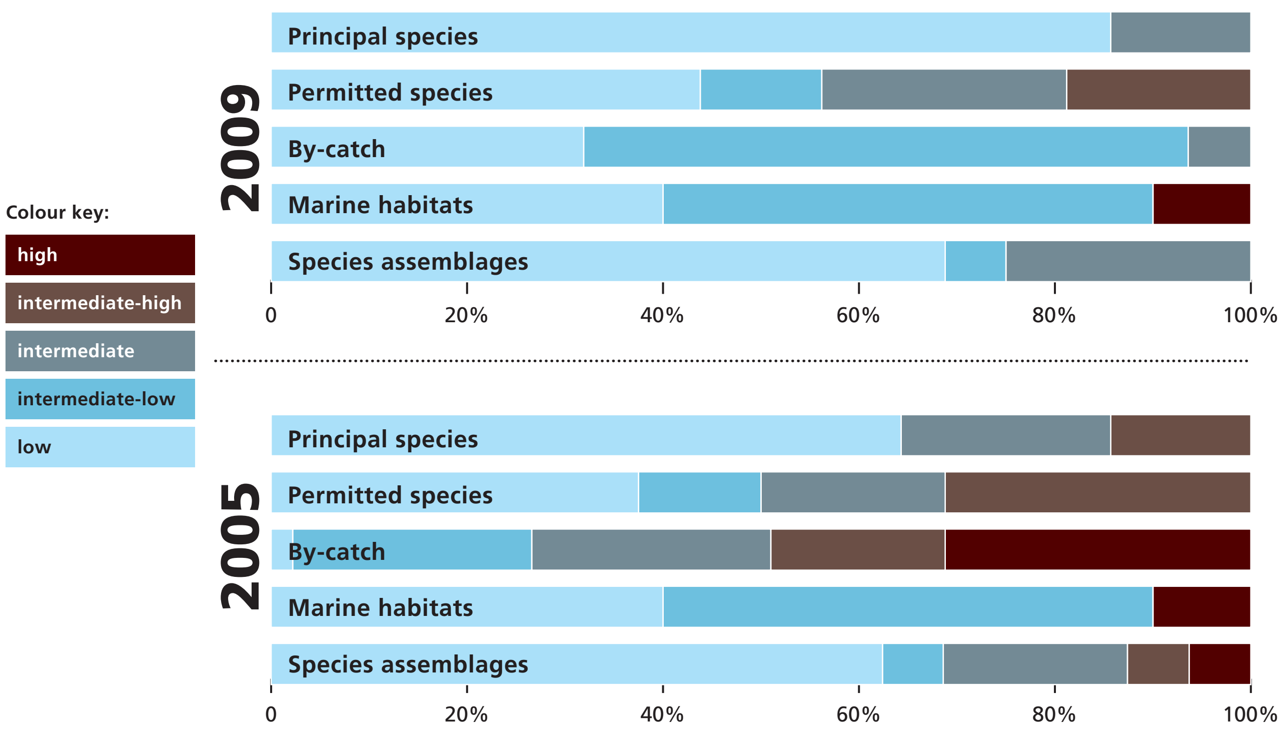

Figure 2. Comparison of overall ecological risk pattern at 2009 (top) and 2005 (bottom) trawl fishing effort levels, where data was available for both years.

The colour indicates the risk categories used (see colour key). Each bar is shaded to represent the proportion of species or habitat types assigned to particular risk categories.

The total annual trawl fishing effort in 2009 was over 40 per cent lower than in 2005, however 2005 levels were still allowable under management arrangements at the time of the assessment.

- **Reducing identified unacceptable risks requires a range of management responses.** Managers and industry will need to continue to work in partnership to prioritise and address the remaining risks. The assessment findings also validated other management actions implemented to address ecological sustainability concerns about trawling, and found that risks and impacts from trawling have been significantly reduced since the introduction of a management plan for the fishery in 1999.

- **The commercial fishing industry is supportive and being proactive.** Positive steps have been, and are being, taken by trawl fishers to reduce the risks from trawling to the species, seabed communities and habitats of the Great Barrier Reef Region. For example, mandatory use of turtle excluder devices (TEDs) throughout the otter trawl fishery for the last decade has greatly reduced incidental catch of loggerhead turtles and other large animals such as sharks. The trawl industry is encouraged to continue to work with managers and researchers on further improvements and innovation in by-catch reduction devices (BRDs) and related efforts to further reduce the remaining risks for skates, rays and sea snakes in particular. Measures that improve the efficiency with which the catch is taken (such as better by-catch reduction measures) or reduce the fishery's ecological impact also tend to have economic benefits for industry (e.g. improved product quality leading to higher market price or lower fuel usage).

- **Further reductions in trawl by-catch, high compliance with rules and accurate information from ongoing risk monitoring are important.** Risk monitoring would be assisted by improved reporting via logbooks, monitoring of discard levels and species composition through fishery observer programs and ongoing compliance programs. Measures to ensure adoption of best practice TEDs and BRDs throughout the fishery and other related efforts to reduce remaining risks for species of conservation concern should be promoted.

  These are important for effective management of the fishery, for any future re-evaluation of the ecological risks within the Great Barrier Reef Region and for public confidence in the sustainability of the fishery.

- **Trawl fishing is just one of the sources of risk to the Great Barrier Reef.** Continuing to take positive actions to further improve trawl fishery management and practices is important for maintaining the resilience of the Great Barrier Reef, for which the overall outlook has recently been assessed as poor, in the light of serious threats, especially from climate change.

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1. About the assessment

This report documents an ecological risk assessment of the East Coast Otter Trawl Fishery (ECOTF) in the Great Barrier Reef Region undertaken in 2010 and 2011. The assessment reviewed the available ecological information on the fishery and evaluated the current risks from trawling activities to species, habitats and the broader ecosystem of the Great Barrier Reef.

1.1. Need for a contemporary ecological risk assessment

It is well recognised that fisheries have an impact not only on the species they target or catch incidentally but also indirectly on other parts of the ecosystem. Globally, demersal trawl fishing (on or near the seabed) has come under increased scrutiny due to the indiscriminate nature of the fishing apparatus and the impact these fisheries have on regional ecosystems (Jones 1992, Thomas and Barnes 2005). In addition to target species such as prawns, demersal trawl fisheries frequently catch and discard a wide variety of non-commercial species known as by-catch (Walmsley et al. 2007). This problem is compounded by the fact that survival rates for by-catch tend to be low, particularly for smaller species and bony fish which are often discarded in a dead or moribund state (Chopin and Arimoto 1995).

Public concerns have also been raised about trawl by-catch of non-commercial species, incidental catch of species of conservation concern (i.e. species protected by law or requiring special management) and the potential for significant impacts on seabed habitats and the broader ecosystem of the Great Barrier Reef in Australia (Poiner et al. 1998). The *Great Barrier Reef Outlook Report 2009* (GBRMPA 2009) identified a range of potential risks to different components of the ecosystem relating to trawling including: extraction of filter feeders or detritivores (e.g. scallops, prawns); physical impacts of fishing on seabed habitats; illegal fishing (e.g. in areas where trawling is prohibited); death of discarded species; incidental catch of species of conservation concern; and extraction of top order predators (e.g. incidental catch of sharks, skates and rays). The World Heritage status of the area adds to the importance of ensuring that all such risks are appropriately assessed and reduced where necessary.

In response to this broad range of concerns, there has been a considerable investment to improve the information base and study the impacts of trawl fishing on the Great Barrier Reef ecosystem. Over the past decade, a number of significant scientific projects have been completed, including the Great Barrier Reef Seabed Biodiversity Project (Pitcher et al. 2007b), providing a much better information base for the fishery and its interactions with the Great Barrier Reef environment. This very substantial information base (detailed further in Section 4.1.2 and Appendix 2 of this report) has informed reviews of management of the fishery.

The Outlook Report 2009 also recognised that a number of risks from trawling have been reduced through management responses by the Queensland and Australian governments and the fishing industry or external factors. For example:

- The overall environmental impact of the fishery is lower as a result of a substantial reduction in annual fishing effort and fleet size.
- 66 per cent of the Great Barrier Reef Marine Park is now closed to trawling, and each year about seven per cent of the open area is trawled more than once (see also Appendix 2.2.3).
- Marine Park rezoning has effectively protected representative seabed habitats and associated biodiversity at levels consistent with the conservation targets underlying the 2004 rezoning of the Marine Park (Fernandes et al. 2005, Pitcher et al. 2007a).
- Implementation of a satellite-based vessel monitoring system (VMS) has enabled close monitoring of the trawl fleet’s activities, resulting in improved compliance and major benefits for fishery assessments such as the current assessment.
- Mandatory use of TEDs and BRDs has reduced the impacts on by-catch, including species of conservation concern such as loggerhead turtles and large sharks.

Notwithstanding these achievements, ensuring a healthy, resilient marine ecosystem that will support a viable and sustainable fishery into the future is an ongoing process. The ecological risk assessment reported here is the next step in that process. Understanding the remaining risks from fishing is part of the work by the Great Barrier Reef Marine Park Authority (GBRMPA) to protect the values and integrity of the Great Barrier Reef ecosystem. With a review of the trawl fishery management arrangements under way in Queensland at the time of this assessment (see Section 2.3.2), and new scientific information available, it was timely to gather this information together, review it collectively, and update our understanding of trawling and its interaction with the ecosystem of the Great Barrier Reef. Therefore, the review of trawl fishery management arrangements was a key driver for this updated ecological risk assessment to ensure future management directions take account of any remaining ecological risks posed by the fishery. The review also provides a pathway for adoption of any outcomes from the assessment requiring a fisheries management response.

The assessment is also addressing objectives under the Great Barrier Reef Climate Change Action Plan (2007–2012) relating to a resilient Great Barrier Reef ecosystem and adaptation of industries and regional communities (GBRMPA 2007). One of the actions identified in the Action Plan is to 'assess sustainability of fishing practices to ensure protection of habitat and key functional groups of plants and animals as a strategy for building resilience'. Current knowledge, including the latest scientific information, is critical for adaptation planning by the industry in the face of climate change and other pressures.

1.2. The approach taken

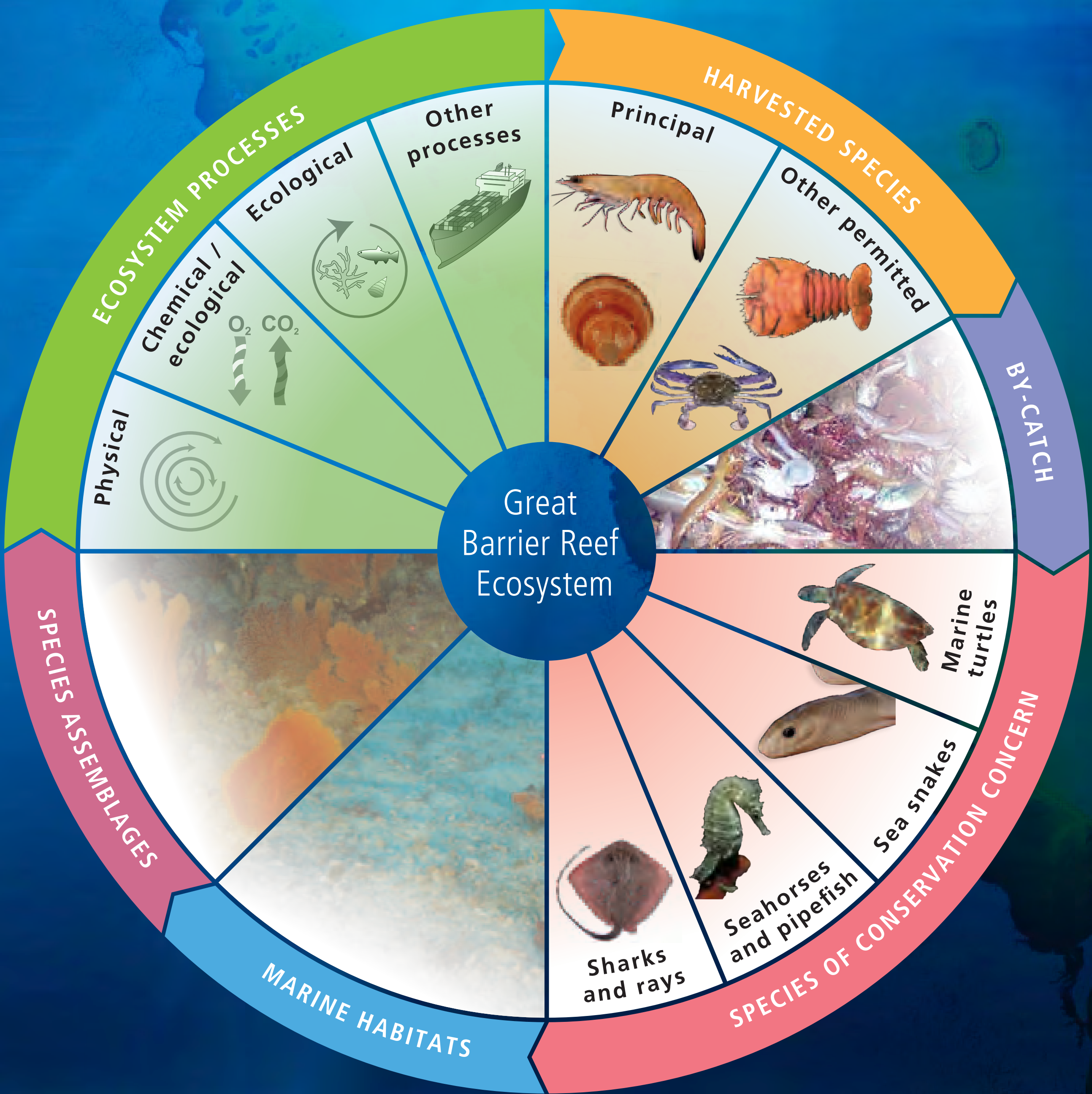
The ecological risk assessment method chosen for this fishery (outlined below and described in more detail in Section 3) was an established method that met key principles and was selected after consideration of a range of methods at a scoping workshop. The framework used is considered appropriate for a fishery operating in a World Heritage Area and Marine Park that have multiple-use objectives subject to the primary objective of long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region.

The choice of method was influenced by a range of factors, including that using this framework meant there was a consistent ecological risk assessment approach across state jurisdictions, aiding assessments of common species. It is not the only method that could have been used, but it is expected that the findings would have been similar if another risk assessment method had been applied.

Of the several methods developed for ecological risk assessments of fisheries all, including the one used here, consider likelihood and consequence in determining risk. This approach is consistent with the current Australian Standard for Risk Management that treats risk as the risk of not meeting objectives. For the ECOTF, this required that the questions addressed by the assessment were directed by the objectives outlined in the legislation and policy of the two key management agencies (Department of Agriculture, Fisheries and Forestry Queensland, DAFF Queensland and the GBRMPA). The assessment therefore included explicit consideration of the functional aspects of the ecosystem, and took into account any additional sensitivities of ecological components of conservation concern. Basing the assessment on these objectives also means that the findings are of relevance to management. In the approach adopted here, the negative consequences of failing to meet management objectives are incorporated into the risk context, so the assessment is focused on the likelihood of different risks. (For a detailed explanation of how likelihood was determined by scientific processes see Section 3.)

Figure 3. **Overview of the Great Barrier Reef ecological components assessed**

The risks assessed included direct and indirect effects on the species caught in the fishery as well as on the structure and functioning of the ecosystem. This ecosystem-based approach included an assessment of the impacts on harvested species, by-catch, species of conservation concern, marine habitats, species assemblages and ecosystem processes. In total, over 900 species, 10 habitat types, 16 assemblages and 14 ecosystem processes were considered in the assessment using a hierarchical process.



In keeping with the chosen method, the assessment therefore evaluated risks against management objectives, rather than against benchmarks of 'natural' or 'pristine' conditions. Returning the whole area to pristine conditions is not a management objective of either the state or national governments. However, information from comparisons to such benchmark conditions was included where relevant.

The assessment has taken into account the current management arrangements for the Great Barrier Reef Marine Park and World Heritage Area, including those specific to the fishery. Should these arrangements change in the future, some of the risks may also change. The assessment, however, identifies and treats separately those factors that are affected by the characteristics of the fishery (such as where fishing occurs and the types of fishing gear used) from intrinsic characteristics of the ecological component being assessed (such as the life history attributes of a species and the habitats in which it lives). Assessing the effects of changes to management arrangements would therefore be relatively straightforward.

The assessment encompasses all the components of the ecosystem at potential risk (Figure 3) and all sources of that risk (both direct and indirect) from trawling.

In considering the risks to this broad range of components of the ecosystem, the assessment has evaluated risk at a range of spatial scales and at different functional levels. It also considered effects at finer scales where the risks were thought to vary and, where relevant, incorporated information from beyond the boundaries of the system being considered.

Risks at recent relatively low trawl fishing effort levels (2009) were compared to risks at earlier higher (but still allowable) effort levels (2005) (Section 3.3.5).

Although the overall approach used was essentially qualitative, where available, quantitative information was incorporated in the assessment of risk. The assessment of risks to habitats and species assemblages, for example, incorporated quantitative data from modelling of the impacts of trawling over the whole Great Barrier Reef Region.

1.3. Undertaking the assessment

1.3.1. KEY STEPS IN THE ASSESSMENT

The GBRMPA, Fisheries Queensland within DAFF Queensland (formerly the Department of Employment, Economic Development and Innovation, DEEDI), and the Queensland Seafood Industry Association (QSIA) worked in partnership on the ecological risk assessment. This assessment incorporated expert advice from a number of other organisations, including Agri-Science Queensland in DAFF Queensland, Australian Institute of Marine Science, CSIRO, WWF and trawl industry members. An independent consultant, A.K. Morison, also provided input to the assessment.

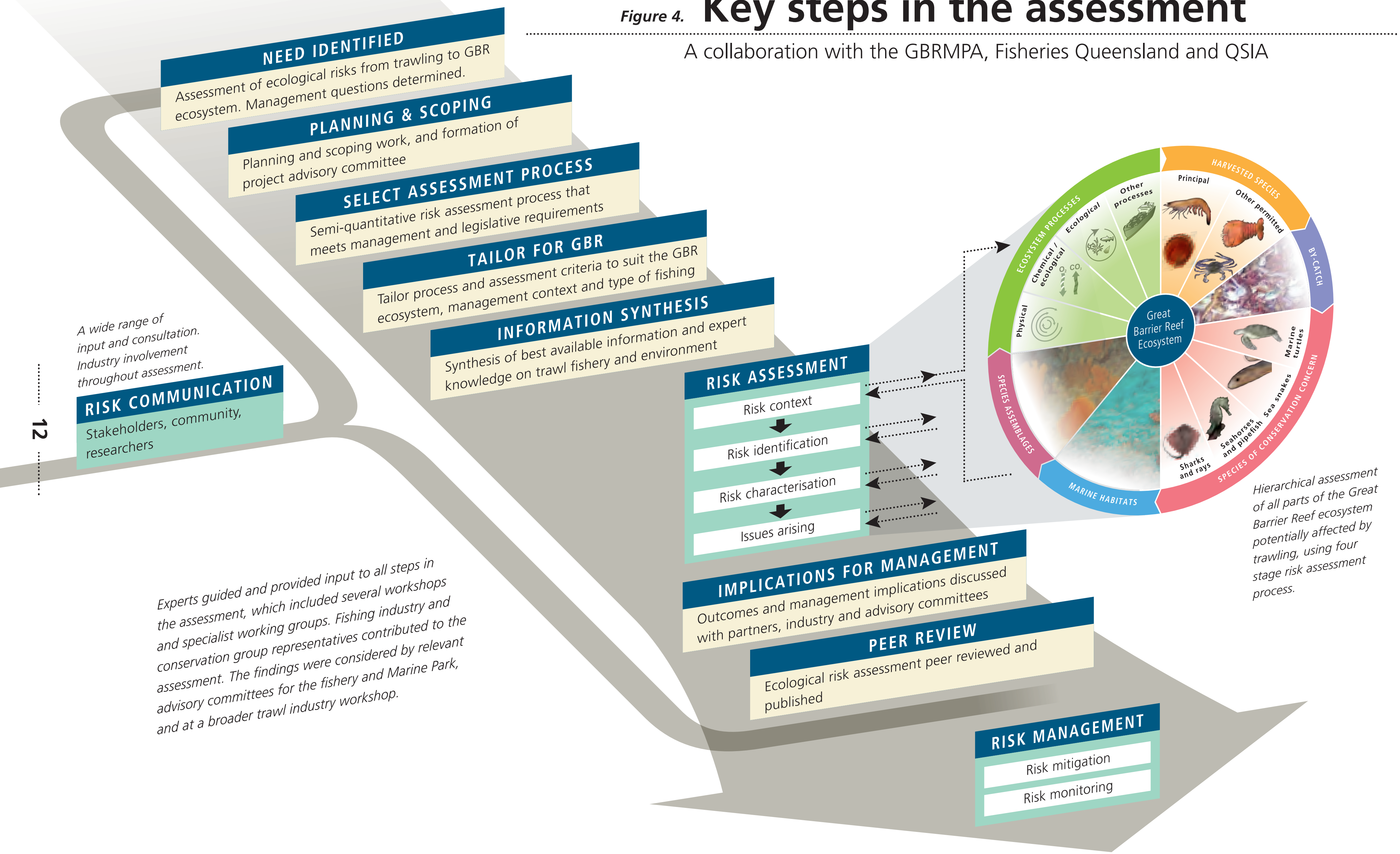
In a collaborative undertaking, these parties reviewed the latest information on prawn and scallop trawling and its interaction with the marine environment of the Great Barrier Reef. The best available information (see accompanying Data Report) was then incorporated into an established risk assessment framework (Astles et al. 2009) (Section 3). Phase I of the assessment assessed risk from trawling to harvested species, by-catch, species of conservation concern, marine habitats and species assemblages. Phase II of the assessment extended this to a consideration of risks trawling poses to ecosystem processes.

The assessment derived relative risk levels from trawling for the ecological components assessed, and identified the key issues reducing or contributing to risk status (Section 4). The report includes discussion of issues arising from the assessment and implications for management (in Sections 4 and 5).

The key steps in the assessment process are shown in Figure 4.

Figure 4. **Key steps in the assessment**

A collaboration with the GBRMPA, Fisheries Queensland and QSIA



1.3.2. ENGAGEMENT AND CONSULTATION

External engagement was an important part of the assessment (Figure 4) and commenced with a scoping workshop held in Townsville in January 2010. The workshop participants were from the GBRMPA, Fisheries Queensland, QSIA, trawl industry and the Australian Institute of Marine Science. The workshop resolved that the scope of the assessment would be the ECOTF within the Great Barrier Reef Region, with DAFF Queensland potentially interested in a parallel process for the remainder of the fishery. It was agreed that the assessment would apply the ecological risk assessment process developed by Astles and co-workers (2006, 2009, 2010) (see Section 3.2).

A project advisory committee was set up to guide implementation of the assessment and to facilitate inter-agency and broad stakeholder communication. Committee members were from GBRMPA, Fisheries Queensland, QSIA, trawl industry and research institutions.

The GBRMPA's Ecosystem Reef Advisory Committee and Fisheries Queensland's Trawl Plan Review Technical Advisory Group were kept updated on the assessment, and provided expert and strategic advice. These committees also provided guidance on the best way of consulting with their stakeholders.

The project team members were people with relevant expertise from the GBRMPA, DAFF Queensland, CSIRO and an independent consultant. Project team members consulted key scientific experts throughout the development and application of the assessment.

Two independently facilitated expert workshops were used to compile and review information about the fishery and environment and provide further expert input into the ecological risk assessment. Workshop participants (listed in Appendix 1) were invited based on their engagement in the trawl fishery, fisheries knowledge and/or related scientific/ecological expertise.

Participants at one of the expert workshops

The Phase I expert workshop focused on species and habitats and was held in August 2010. The workshop objectives were to:

1. Seek technical input to Phase I of the assessment
2. Draw out and capture expert opinion on risks to ecosystem components
3. Reach consensus (where possible) on risk gradings
4. Identify key issues and areas where additional work may be required.

The Phase II expert workshop focused on ecosystem processes and was held in November 2010. The workshop objectives were to:

1. Seek technical input to Phase II of the assessment
2. Draw out and capture expert opinion on risks specifically from the current trawl fishery to ecosystem processes
3. Identify approaches and information sources to complete the assessment.

The objectives were slightly different for each workshop, in recognition of the fact that the second phase of the assessment was tackling new issues in considering ecosystem processes, and the relevant information base was much more limited. Several expert working groups also provided input to the assessment.

The findings of the ecological risk assessment for species, assemblages and habitats were presented to, and discussed with, the relevant advisory committees and at a broader trawl industry workshop convened by DAFF Queensland (October 2010). The development of this report series has benefited from input and feedback from committee members, workshop and working group participants, the project advisory committee, project partner organisations and the formal scientific peer-review process.

1.4. Structure of the reports

The first of three volumes in this report series is a **Summary Report** of the ecological risk assessment. The Summary Report provides a brief account of the assessment process and key findings, and is intended for a general audience.

This **Technical Report** is the second volume in the report series, and is accompanied by a **Data Report** with all of the detailed data used in deriving scores for the assessment.

Section 1 of this report introduces the assessment, and explains the need for a contemporary ecological risk assessment of trawling in the Great Barrier Reef Region.

Section 2 provides background information on ecologically sustainable use of the Great Barrier Reef Marine Park and management of the Queensland trawl fishery.

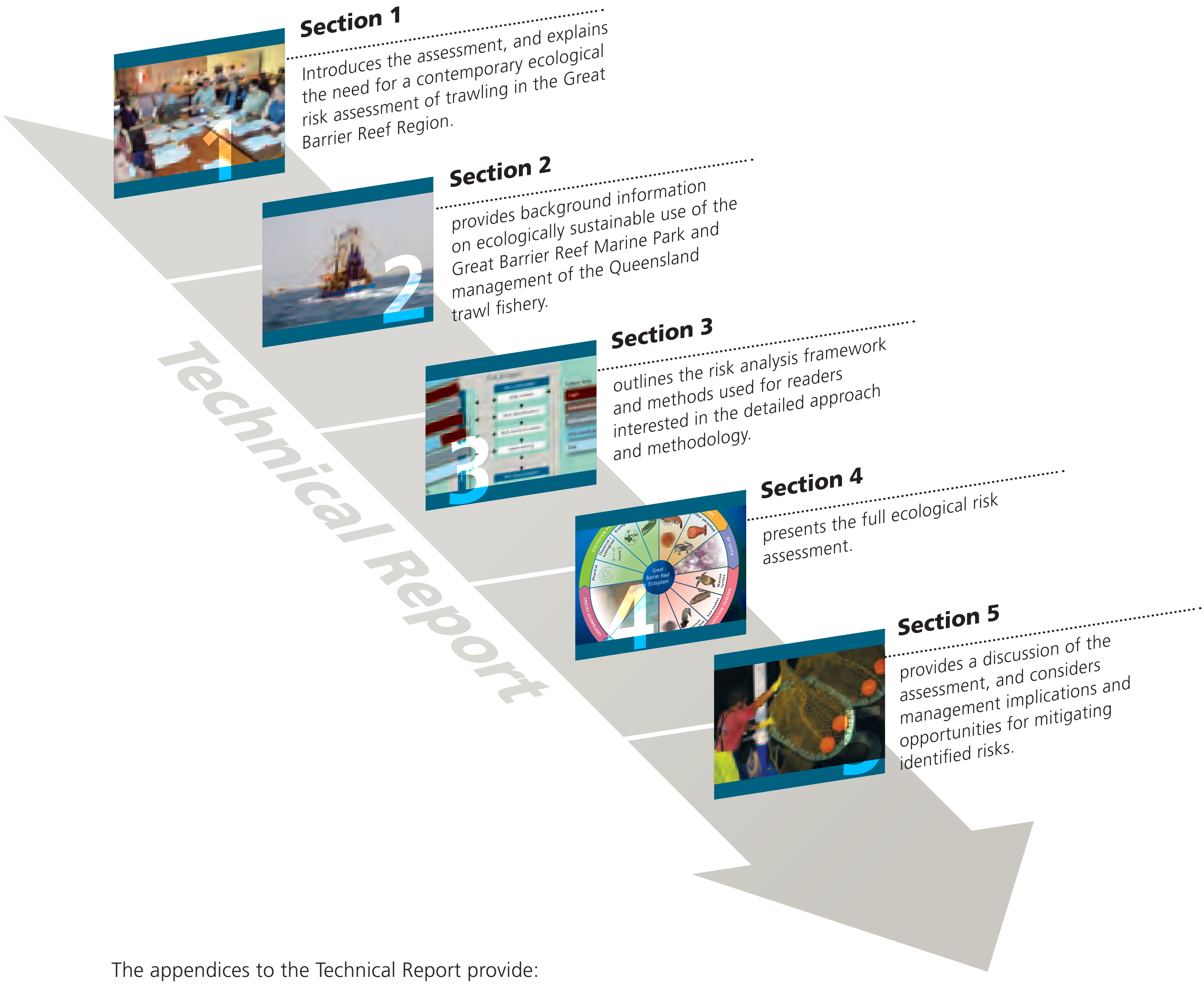
Section 3 outlines the risk analysis framework and methods used for readers interested in the detailed approach and methodology.

Section 4 presents the full ecological risk assessment. Section 4.1 is the first step in the risk assessment hierarchy, and determines initial risk levels for each of the activities of the ECOTF and the broad components of the ecosystem. Sections 4.2 to 4.7 cover the detailed ecological risk assessments for harvested species, by-catch species, species of conservation concern, habitats, species assemblages and ecosystem processes. Each of these subsections follows a four-stage risk assessment framework, and considers the risk context, risk identification, risk characterisation, and issues arising from the assessment.

Section 4.8 presents a summary of the ecological risk assessment findings and Section 4.9 summarises the issues arising from the assessment by fishery sector and for the fishery as a whole.

Section 5 provides a discussion of the assessment, and considers management implications and opportunities for mitigating identified risks.

Figure 5. **Structure of the technical report**



The appendices to the Technical Report provide:

1. Lists of expert participants.

2. An overview of trawl fishery management arrangements, the latest data for the fishery overall and major sectors within the fishery. This background material is provided to give the context for the ecological risk assessment, and includes some new information made available through this joint assessment.

3. Detailed tables of the resilience characters, fishery impact factors and decision rules used for each assessment and summaries of the risk assessment scoring.

The **Data Report** provides the detailed datasheets showing all the data used in the assessments.

2. Ecologically sustainable use of the Great Barrier Reef

This section outlines the management context for the ecological risk assessment of trawling in the Great Barrier Reef Marine Park.

2.1. The Great Barrier Reef Marine Park

The Great Barrier Reef Marine Park is vast, extending for more than 2300 km along the Queensland east coast and including 344,400 km^2 of seabed. The Great Barrier Reef is one of the most diverse ecosystems in the world and continues to support an outstanding array of plants and animals. Coral reefs are the best known part of the Great Barrier Reef Region, yet they make up only seven per cent of its area. The Great Barrier Reef Marine Park supports a wide variety of other habitats, including muddy and open sandy areas, seagrass meadows, continental slope and extremely deep oceanic habitats. Trawling, which is the fishing method assessed in this study, occurs in the areas of soft sediments and avoids coral reefs and other hard substrate habitats. The Marine Park is an integral part of the lifestyles and livelihoods of communities along the Great Barrier Reef coast. The Great Barrier Reef has been recognised as a World Heritage Area since 1981, highlighting the international significance of the area.

The area examined in the assessment is the Great Barrier Reef Region as defined in the *Great Barrier Reef Marine Park Act 1975*. The Great Barrier Reef Region is approximately 346,000 km^2 and covers the area of ocean from the tip of Cape York in the north to past Lady Elliot Island in the south, with mean low water as its western boundary and extending eastwards a distance of between 70 and 250 km. The Region's boundaries match those of the Great Barrier Reef Marine Park, except the Region also includes the areas around major ports.

The GBRMPA manages the Marine Park as a multiple-use marine park, in which reasonable uses (particularly tourism, fishing, recreation and shipping) are allowed so far as they are consistent with the main objective of the Act (i.e. long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region). A range of measures are employed to manage uses of the Marine Park and to protect its values (including those integral to its continued recognition as a World Heritage Area), using an ecosystem-based approach to management. A key measure to protect the marine environment and separate potentially conflicting uses is a Zoning Plan, which sets out the areas where different activities can occur consistent with the management objectives for each zone. Additionally, many other government agencies, stakeholders and community members contribute to the protection and management of the Great Barrier Reef Region.

The *Great Barrier Reef Outlook Report 2009* (GBRMPA 2009) provided a comprehensive assessment of what is known about the Great Barrier Reef ecosystem, its use, its management and the pressures it is facing. The Outlook Report states that while the Great Barrier Reef is one of the healthiest coral reef ecosystems in the world, its long-term outlook is now at a crossroad and the decisions made in the next few years are likely to determine its long-term future. The Outlook Report identifies climate change and remaining impacts from fishing among priority issues to be addressed to ensure the future of the Great Barrier Reef. (Other priority issues include continued declining water quality from catchment run-off, loss of coastal habitats from coastal development and illegal fishing and poaching.)

2.2. Management of fisheries in the Great Barrier Reef Region

Fishing is important to the Queensland and Australian economies and is a source of income and employment for Queensland coastal communities and the Queensland seafood industry. The commercial fisheries in Queensland are valued at approximately $185 million with 17,000 tonnes caught annually (DPIF 2008). Fisheries in Queensland, including those that occur in the Marine Park, are directly managed by Fisheries Queensland in DAFF Queensland. In addition to fisheries legislation, fishing activities in the Great Barrier Reef are also required to comply with Marine Park zoning and other relevant environmental legislation.

All fisheries operating in the Marine Park are assessed against the Australian Government's *Guidelines for the ecologically sustainable management of fisheries* and continued operation is approved under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. Regular assessments against the Guidelines have encouraged important improvements in fisheries management. The conditions and recommendations are designed around the principles of continuous improvement, and are developed in close cooperation with the fishery managers ensuring that fisheries continue to be managed in an ecologically sustainable way.

The GBRMPA is working collaboratively with Fisheries Queensland, QSIA and fishers to help ensure all fishing activities in the Great Barrier Reef Region are ecologically sustainable. This includes ensuring fishing activities are consistent with the *Great Barrier Reef Marine Park Act 1975* (discussed further in Section 2.4). An ongoing culture of continuous improvement has been recognised as important to ensure fishing use is consistent with the long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region. This will in turn help address any concerns from the wider community about the impacts that fishing activities have on the marine environment.

2.3. Overview of the trawl fishery

This section provides a brief overview of the East Coast Trawl Fishery (ECTF), its management and its operations within the Great Barrier Reef Region. More detail is provided in Appendix 2 to the Technical Report.

2.3.1. TRAWLING IN THE GREAT BARRIER REEF REGION

The whole ECTF (which includes the ECOTF and the beam trawl fishery) is the largest commercial fishery in Queensland by both product catch weight and economic value. The commercial gross value of production (GVP) of the fishery in 2009 was approximately $99 million (DEEDI 2010a). The ECOTF also provides about 7000 tonnes of seafood annually for local consumption and export. Since the late 1970s, when there were approximately 1400 licensed trawlers, the number of boats has been reduced to less than 350 active vessels in 2010 (Glaister et al. 1993, Kerrigan et al. 2004, Zeller 2012).

The fleet uses trawl nets designed to operate on or near the seabed targeting prawns, scallops, bugs and squid mainly over muddy, sandy or silty habitats that are found away from coral reefs (Figure 6). Prawns made up 85 per cent of the retained catch by weight in 2010. Various incidentally captured by-product (permitted) species such as some species of fish, crabs, octopus and cuttlefish are also retained and marketed by the fleet.

The ECTF is a complex fishery in terms of its fleet dynamics, areas fished, catch composition and the seasonal/temporal distribution of species (Huber 2003). Otter trawling, the subject of this report, accounts for about 95 per cent of the total retained trawl catch each year, with the remainder coming from coastal and estuarine beam trawling and fish trawling off southern Queensland.

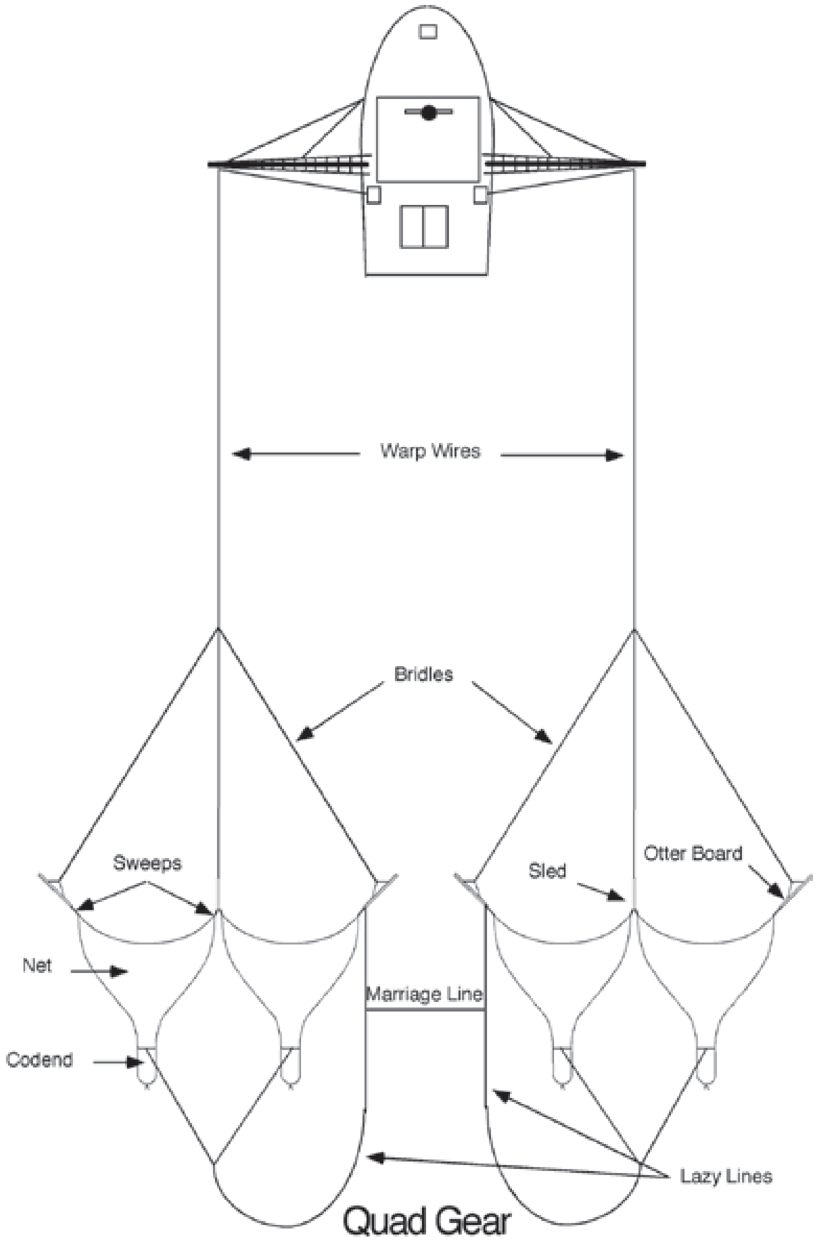


Figure 6. Diagram showing a typical configuration of trawl nets (with four towed nets in what is called a quad net arrangement).

The fishery extends along the entire Queensland east coast (Figure 7), but about 60 per cent of the total Queensland trawl fishing effort in any year is within the Great Barrier Reef Marine Park and World Heritage Area. Trawling is restricted to the General Use Zone in the Marine Park and occurs more than once per year in about seven per cent of the Marine Park area (Grech and Coles 2011) (see also Appendix 2.2.3).

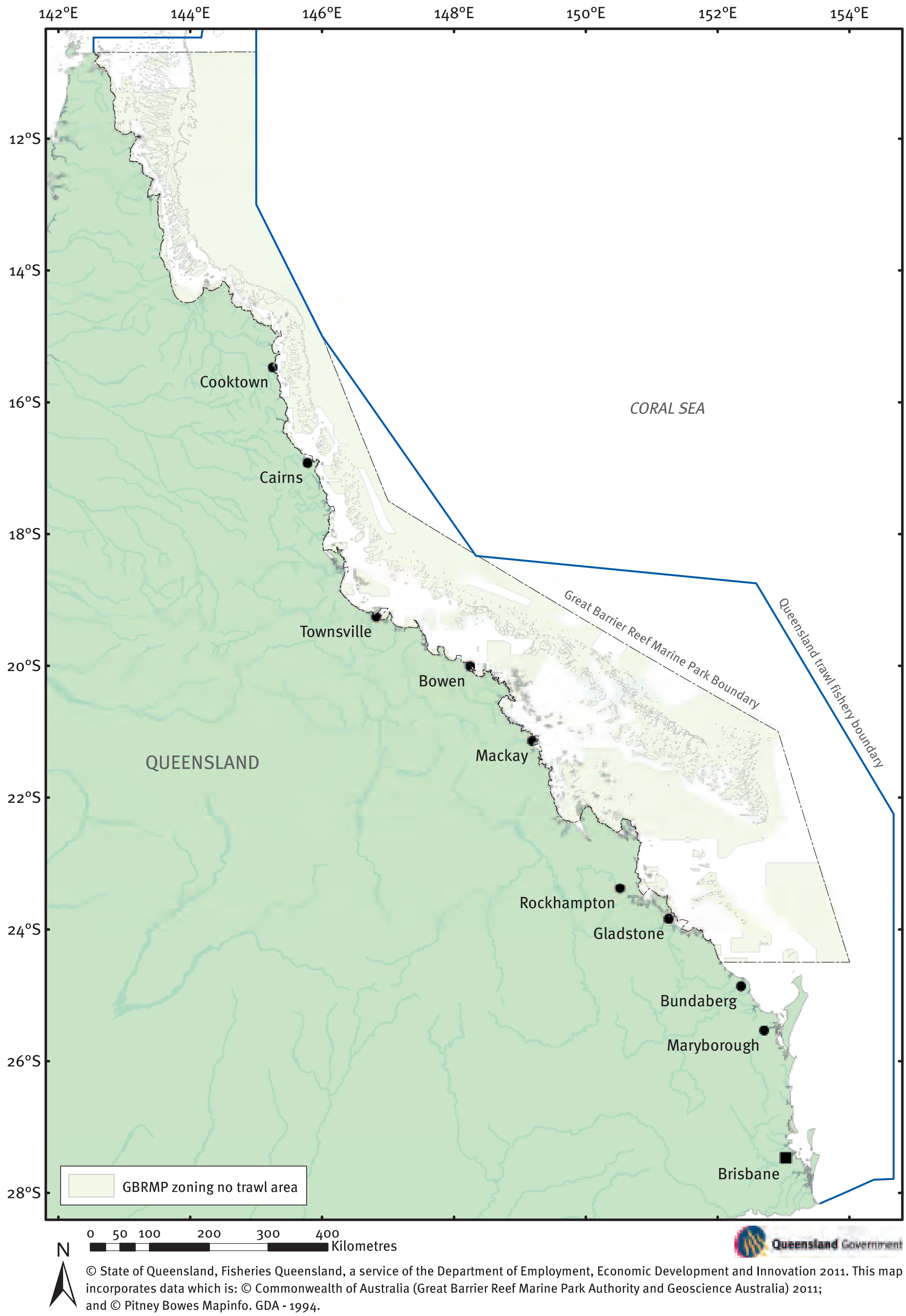
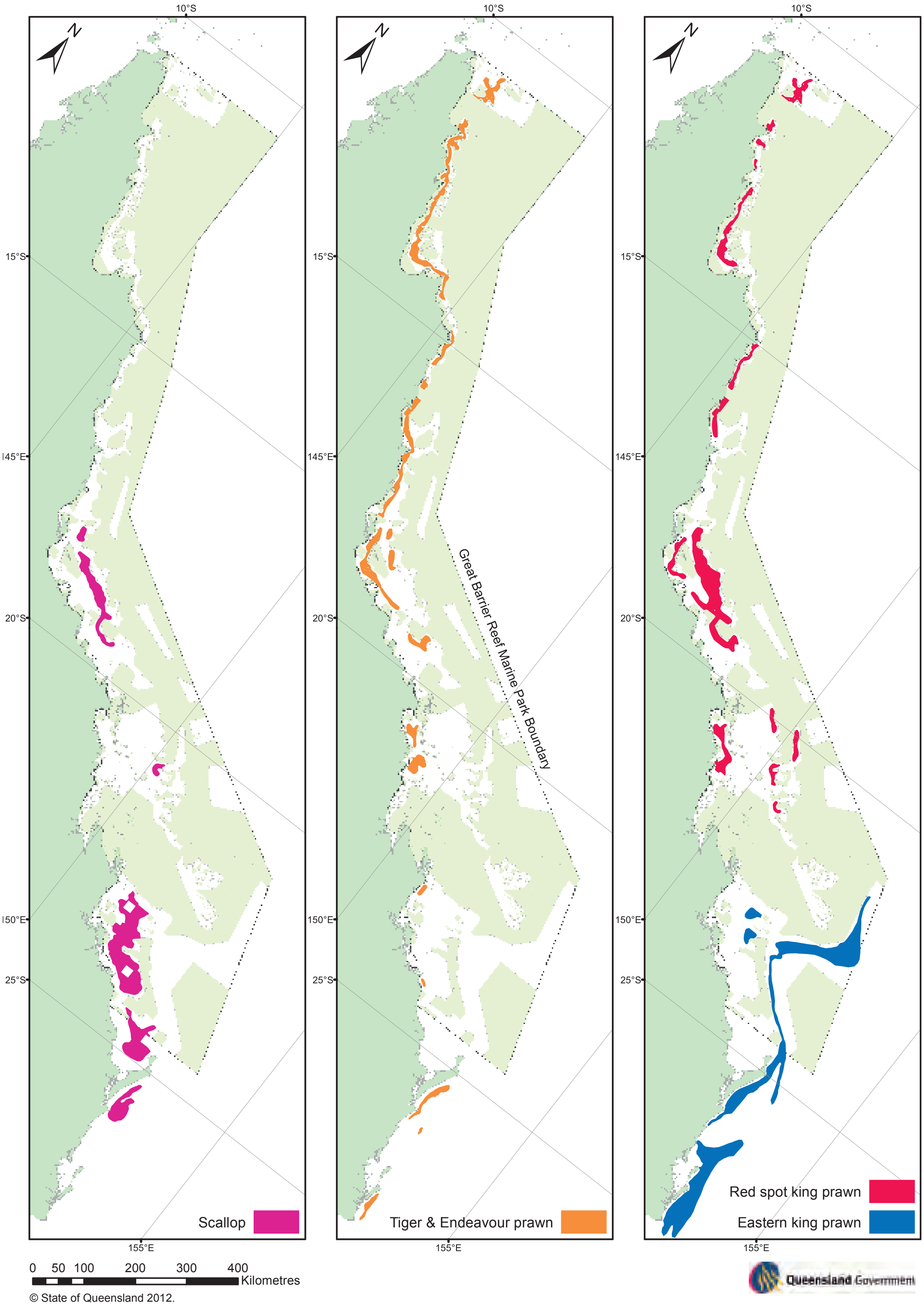


Figure 7. Map of east coast of Queensland showing trawl fishery area and Great Barrier Reef Marine Park.



This map incorporates data which is: © Commonwealth of Australia (Great Barrier Reef Marine Park Authority and Geoscience Australia) 2012; GDA - 1994.

Figure 8. Fishing sectors in the East Coast Otter Trawl Fishery.

Light green areas of water are closed to trawling under Great Barrier Reef Marine Park zoning.

There are several recognisable sectors within the otter trawl fishery that differ in their target species and geographical location:

1. Eastern king prawn (deep and shallow water)
2. Scallop (saucer and mud)
3. Tiger/endeavour and northern king prawns (including red-spot king prawn)
4. Banana prawn.

The main fishing grounds are shown on Figure 8. Note: fishing for banana prawns occurs mainly in coastal and inshore areas (this fishing activity is not depicted on Figure 8). The trawl fleet has a high degree of mobility and boats frequently operate in more than one fishery sector throughout the year.

Trawling occurs in the inter-reef areas of the Great Barrier Reef, which are made up of a wide range of habitat types, including bare muddy/sandy flats, seagrass and algal meadows, and diverse sponge and coral garden patches. In this report, the terms shelf habitat or shelf area are used to refer to continental shelf seabed habitats of the Great Barrier Reef Region in waters shallower than 100 metres and excluding emergent coral reefs and ramparts together with shoal areas which are not trawled.

The ECOTF has many similarities to other tropical prawn fisheries in Australia, especially the Northern Prawn Fishery that operates in the Gulf of Carpentaria, including the type of gear used, the habitat types fished and the environmental interactions. Information about similar fisheries has therefore been used in this assessment, where necessary, to supplement the knowledge available for the ECOTF.

Beam trawling, which occurs mainly in estuaries and inshore coastal waters outside the Great Barrier Reef Marine Park, is not considered in this ecological risk assessment. A separate ecological risk assessment undertaken in 2011 by DAFF Queensland used a similar risk assessment methodology to examine the remainder of the fishery. That assessment covered river and inshore beam trawling along the entire coastline and otter trawling in Queensland east coast waters outside the Great Barrier Reef (B. Zeller, DAFF Queensland, pers. comm., 2011).

2.3.2. MANAGEMENT OF THE QUEENSLAND TRAWL FISHERY

The ECTF is managed by Fisheries Queensland, part of DAFF Queensland, but is also subject to spatial closures resulting from Marine Parks zoning plans.

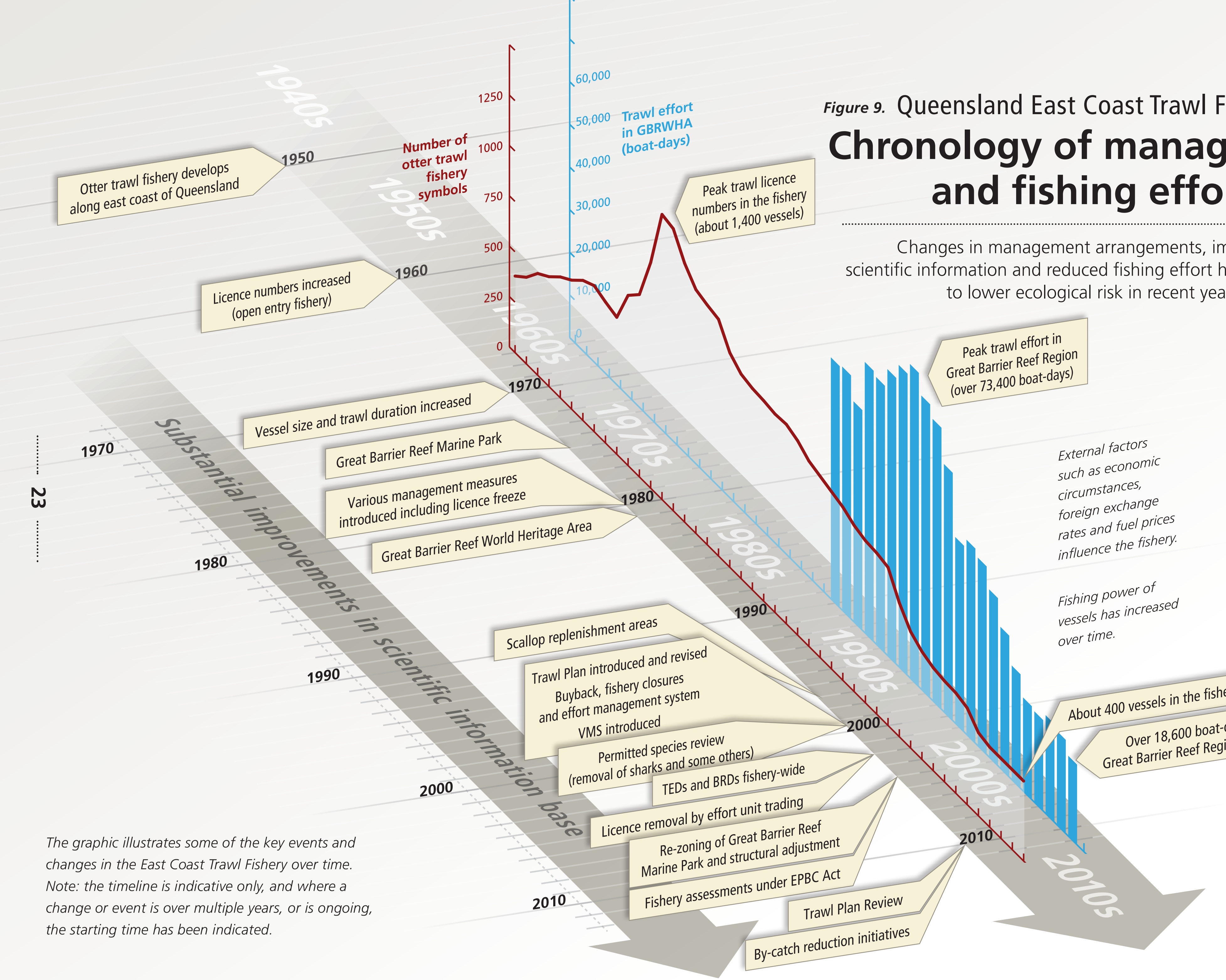
Fishing for prawns dates back to the mid-1880s in inshore waters of Queensland and since that time the management arrangements have been changed many times (Figure 9). A management plan for the fishery (the 'Trawl Plan') was first put in place in 1999 (see Appendix 2.1), and a further review of fishery management arrangements is currently under way (in 2012).

The Trawl Plan adopted an effort management system, and includes restrictions on where and when fishing is allowed (through seasonal and spatial closures). A range of other management measures are also employed and these are detailed in Appendix 2.1.7. There is, however, an increasing amount of surplus effort in the fishery and approximately 40 per cent of the total effort units available within the fishery were not used in 2010.

Figure 9. Queensland East Coast Trawl Fishery

Chronology of management and fishing effort

Changes in management arrangements, improved scientific information and reduced fishing effort have combined to lower ecological risk in recent years



The graphic illustrates some of the key events and changes in the East Coast Trawl Fishery over time. Note: the timeline is indicative only, and where a change or event is over multiple years, or is ongoing, the starting time has been indicated.

Trawl fishing effort (i.e. in days fished) peaked in 1997 at a level more than twice that in 2005 (Figure 10). In recent years, fishing effort has declined due to unfavourable economic conditions (e.g. high fuel prices combined with stagnant or declining prawn prices) and Commonwealth-funded licence buyouts associated with rezoning the Marine Park, and has been at historically low levels over the period from 2007 to 2011.

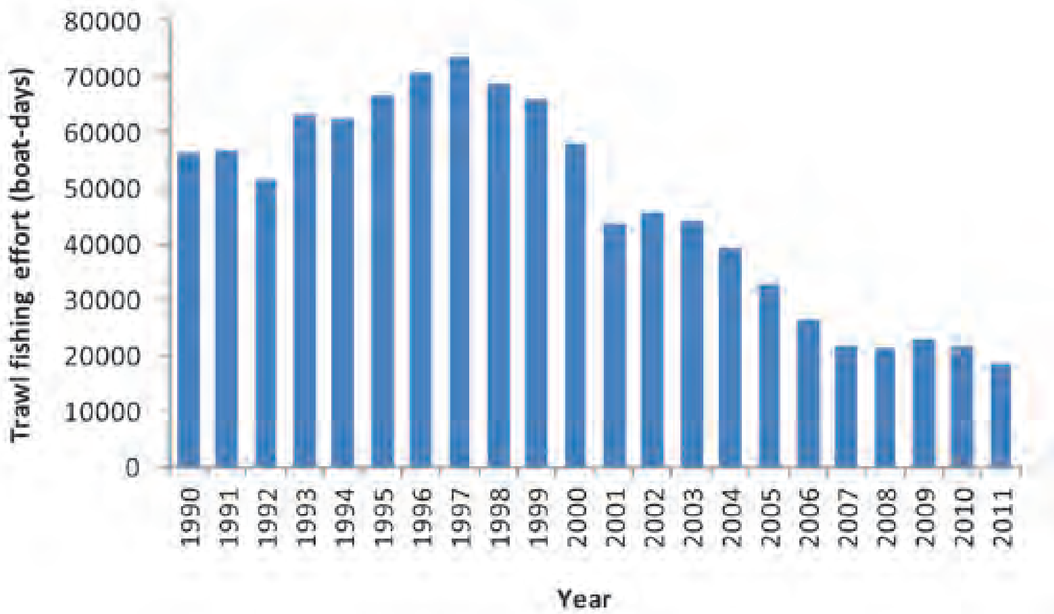


Figure 10. Annual trawl fishing effort levels for the Great Barrier Reef Region from 1990 to 2011 based on fisher logbook records.

The size of trawl nets is also limited to control effort in the fishery, and designs are prescribed to mitigate impacts of trawl gear on the seabed, and reduce by-catch and protected species interactions. Turtle excluder devices (TEDs) and other types of by-catch reduction devices (BRDs) introduced in the Trawl Plan are now mandatory for operators in the otter trawl fishery. TEDs are hard grids placed in trawl nets to exclude turtles and other large animals such as sharks and rays. BRDs are escape devices of various designs which enable smaller fish and other animals to swim out of the net (Figure 11). Each vessel is required to have both a TED and an additional BRD installed in each trawl net.

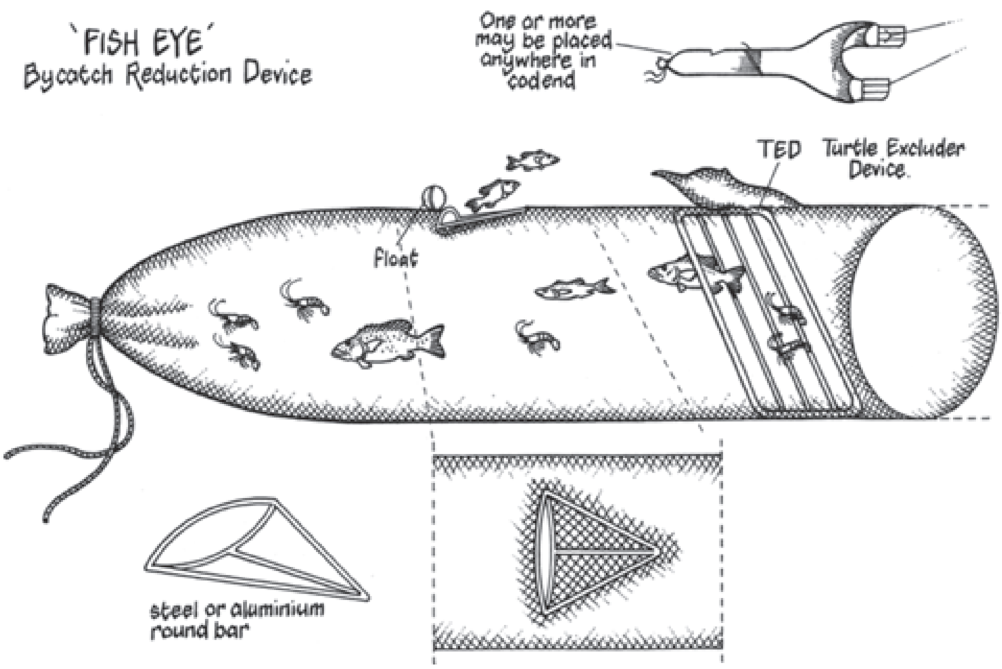


Figure 11. Turtle excluder device and example of a by-catch reduction device known as a 'fisheye'.

2.3.3. MONITORING AND CURRENT STATUS OF THE FISHERY

The fishery is monitored through a range of measures including compulsory logbooks (that record daily catches of retained species and species of conservation interest defined by Queensland), vessel monitoring systems (that report their position), an on-board observer program, and various compliance activities. Ongoing research programs also investigate a wide variety of issues concerning sustainability of target species, by-catch mitigation and environmental issues.

Annual reports on the status of the fishery are produced by DAFF Queensland, including assessment against agreed performance measures specified in the management arrangements. Exploitation (or stock) status assessments are undertaken for key target species. In 2010, six species (or species groups) were assessed as being sustainably fished (banana prawn, brown and grooved tiger prawns, eastern king prawn, Moreton Bay bugs, saucer scallop and three-spot crab), one was assessed as not fully utilised (endeavour prawns), and for a further 11 species, no assessment was attempted (Zeller 2012).

The operation of the fishery has also been assessed against national ecological sustainability guidelines under the EPBC Act since 2004.

Publications on the status and monitoring of the Queensland trawl fishery informed the ecological risk assessment.

2.4. Management context for the assessment

The assessment was directed by relevant legislation and policy of the two key management agencies, DAFF Queensland and the GBRMPA. (Additional information on the roles of these agencies in relation to trawling and the environment is provided in Sections 2.1 to 2.3.)

The *Great Barrier Reef Marine Park Act 1975* adopted a multiple-use philosophy, where reasonable uses are allowed so far as they are consistent with the long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region. Trawling is recognised as one of the allowed uses of the Great Barrier Reef Region. In allowing use of the Region, the natural values and integrity of the ecosystem must be protected. Therefore, the key legislative requirements for *long-term protection of the Great Barrier Reef...and maintenance of world heritage values and integrity ... and ecologically sustainable use of the Great Barrier Reef Region and its natural resources* were all taken into account in the assessment. [See text box: Management context: Great Barrier Reef Marine Park Authority]

The ECTF in state and Commonwealth waters is managed under an Offshore Constitutional Settlement arrangement with the Australian Government by DAFF Queensland under Queensland law (the *Fisheries Act 1994*, *Fisheries Regulation 2008* and *Fisheries (East Coast Trawl) Management Plan 2010*, see also Appendix 2.1.3) with the goals of ensuring that fisheries resources are taken in an ecologically sustainable way and that the fishery is managed to benefit the community in an optimal but sustainable way. Operational objectives to achieve these goals are defined in a policy document, the *Performance Measurement System: East Coast Trawl Fishery* (DEEDI 2009b). This document sets out performance measures for principal (target) species in the fishery as well as for permitted species (by-product), by-catch (including protected species) and the ecological systems (ecosystem) supporting the fishery. [See text box: Management context: Fisheries Queensland]

These marine park and fisheries requirements are largely complementary and management of fishery resources in the Great Barrier Reef Region aims to simultaneously achieve the objectives of both Acts mentioned above. Respective responsibilities in relation to management of fisheries in the Region are set out in the *Great Barrier Reef Intergovernmental Agreement 2009*. The Australian and Queensland governments have agreed to an integrated and collaborative approach to management so as to allow ecologically sustainable use of the Great Barrier Reef Region, subject to the overarching objective of long-term protection and conservation. The Agreement *inter alia* states that "Trends in the health, use of and risks to the Great Barrier Reef ecosystem will be regularly monitored and reported to ensure decisions are soundly based". The ecological risk assessment is contributing to the reporting of remaining risks to the Great Barrier Reef ecosystem and ensuring trawl fishery management decisions are soundly based and seek to minimise ecological risks.

The Great Barrier Reef Marine Park Authority's *Corporate Plan 2011–2014* sets out the agency's current direction and priorities (GBRMPA 2010). A key objective is to improve the outlook and resilience of the Great Barrier Reef by developing and implementing strategies to address the key pressures highlighted in the Outlook Report (GBRMPA 2009). The current assessment is contributing to this work by providing a contemporary assessment of ecological risks associated with trawling in the Great Barrier Reef. The assessment is informing efforts to mitigate those risks where possible and to improve management effectiveness.

The *Queensland Fisheries Strategy 2009–2014* sets the direction for the future of Queensland fisheries and aims to address some of the challenges impacting them (DEEDI 2009c). One of the themes of the Strategy is ecosystem-based fisheries management. This form of fisheries management takes into account the complex ecosystem impacts of fishing on the broader aquatic environment, rather than just the impacts of fishing on target species. The Strategy supports using risk-based assessments to determine the scope and level of data required to develop appropriate management responses corresponding with the expected level of impact. This approach will assist in reaching balanced decisions on the appropriate use of resources as part of broader ecosystems and generate the best overall ecological, social and economic outcomes for the community.

Therefore, the ecological risk assessment of trawling in the Great Barrier Reef Region has addressed some key management questions and priorities of both agencies. Of particular interest to the management agencies are the levels of remaining risks (i.e. specific low–high risks and overall pattern of risk) under current management arrangements and circumstances, and in the context of the significant changes to management arrangements that have occurred to ensure sustainability, especially since 1999.

Ecological risk assessment, in combination with the management arrangements for the Great Barrier Reef Region and Queensland fisheries (Sections 2.1 to 2.3 and Appendix 2.1), contributes to an ecosystem-based approach to management. Other processes are also in place to help achieve broader environmental objectives, including the *Reef Water Quality Protection Plan* (2003) and the *Reef Rescue Plan*, and a *Great Barrier Reef Biodiversity Conservation Strategy* is being developed to provide an overarching framework to guide biodiversity conservation efforts. In turn, this risk assessment has informed the development of the Biodiversity Conservation Strategy, including some associated vulnerability assessments.

The performance measures (including limit reference points), assessment criteria and questions used to set the context for the risk assessment were mainly derived from the management objectives, legislation and policies described above, and therefore give consideration to the values both Acts seek to protect. Guides as to 'best practice' for different ecological components were also used to support the selection of these aspects of the assessment.

The management agencies provided senior and expert advice throughout the assessment process, which ensured that the assessment satisfied the relevant legislative and management requirements for the two key management agencies discussed above. The Australian Department of Sustainability, Environment, Water, Population and Communities and relevant Queensland environmental departments were also kept informed about the assessment.

Management context: Great Barrier Reef Marine Park Authority

In managing the Marine Park....the Authority must have regard to, and seek to act in a way that is consistent with ... the protection of the world heritage values of the Great Barrier Reef World Heritage Area *(Great Barrier Reef Marine Park Act 1975, Section 7(c))*.

The Great Barrier Reef was inscribed on the World Heritage List in 1981. The World Heritage criteria against which the property was listed remain the formal criteria for this property. These criteria and the World Heritage values of the Great Barrier Reef World Heritage Area are available on-line at www.environment.gov.au.

Integrity is a measure of the wholeness and intactness of the natural and/or cultural heritage and its attributes.

The main object of the *Great Barrier Reef Marine Park Act 1975* is to provide for the long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region.

This Act [Section 2A (1 and 2)] allows ecologically sustainable use of the Great Barrier Reef Region, so far as it is consistent with the main object of long-term protection and conservation....

The key legislative requirements for ecologically sustainable use of the Great Barrier Reef Region were taken into account in the assessment.

Use of the Great Barrier Reef Marine Park must be consistent with ecosystem-based management and the principles of ecologically sustainable use *(Great Barrier Reef Marine Park Act 1975, Section 2A(3)(b))* ...where

Ecologically sustainable use of the Great Barrier Reef Region or its natural resources is use of the Region or resources:

a) that is consistent with:
    (i) protecting and conserving the environment, biodiversity and heritage values of the Great Barrier Reef Region; and
    (ii) ecosystem-based management; and
b) that is within the capacity of the Region and its natural resources to sustain natural processes while maintaining the life-support systems of nature and ensuring that the benefit of the use to the present generation does not diminish the potential to meet the needs and aspirations of future generations.

Principles of ecologically sustainable use are:

a) decision-making processes should effectively integrate both long-term and short-term environmental, economic, social and equitable considerations;
b) the precautionary principle;
c) the principle of inter-generational equity—that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;
d) the conservation of biodiversity and ecological integrity should be a fundamental consideration in decision-making;
e) improved valuation, pricing and incentive mechanisms should be promoted.

Section 3: **Precautionary principle** means the principle that lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there are threats of serious or irreversible environmental damage.

Section 3: **Ecosystem-based management** means an integrated approach to managing an ecosystem and matters affecting that ecosystem, with the main object being to maintain ecological processes, biodiversity and functioning biological communities.

Management context: Fisheries Queensland

The main purpose of the *Fisheries Act 1994* is to "provide for the use, conservation and enhancement of the community's fisheries resources and fish habitats in a way that seeks to—

apply and balance the principles of ecologically sustainable development; and

promote ecologically sustainable development." [Chapter 1, Division 2 (3)]

where

Ecologically sustainable development means using, conserving and enhancing the community's fisheries resources and fish habitats so that—

the ecological processes on which life depends are maintained; and

the total quality of life, both now and in the future, can be improved.

and

Principles of ecologically sustainable development include protecting biological diversity, ecological processes and life-support systems.

The objectives of the Fisheries Management (East Coast Trawl) Plan 2010 (Part 2) reflect the Act purposes and are to be achieved mainly by:

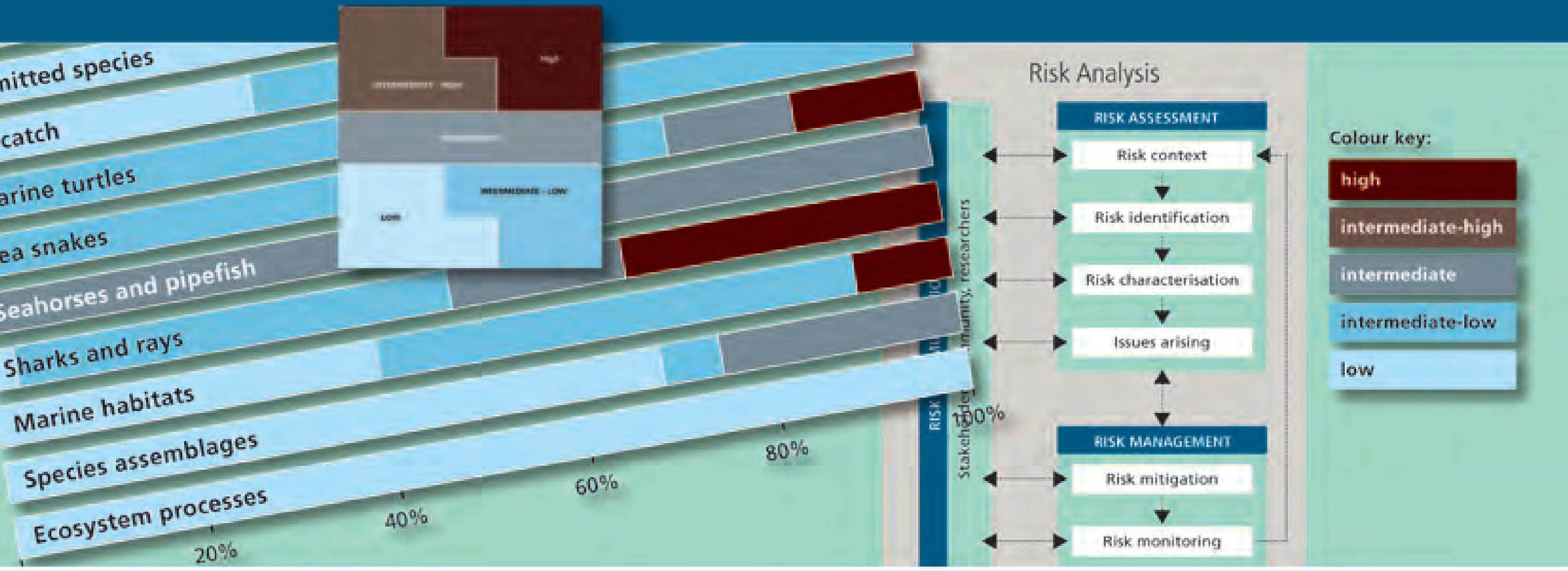
restricting the number of boats that can operate in the fishery [Chapter 1, Part 2, Section 5 (2a)]; and

requiring the use of a by-catch reduction device (BRD) or turtle exclusion device (TED) to minimize by-catch and specifically capture of protected species [Chapter 1, Part 2, Section 5 (2d); Chapter 3 Parts 3 & 4]; and

restricting the size of trawl nets used in the east coast otter trawl fishery to limit fishing effort [Chapter 1, Part 2, Section 5 (2b); Chapter 4, Part 2, Division 2, Subdivision 1]; and

capping effort units to restrict fishing effort in the GBR World Heritage Area [Chapter 1, Part 2, Section 5 (2e); Chapter 2, Part 6, Section 23 (1)].

3. Risk analysis framework



This section outlines the risk analysis framework and methods, including how these were applied to assess trawling activities in the Great Barrier Reef Region.

3.1. Understanding risk in a marine ecological context

Understanding risk in a marine ecological context is actually quite difficult. In general, there are two ways risk is understood and used in the ecological and fisheries literature (Francis and Shotton 1997, Astles et al. 2006, Astles 2008):

1. Risk is an expected loss and thus incorporates both the probability (likelihood) and severity (consequence) of the undesirable event (e.g. Rosenberg and Restrepo 1994).
2. Risk is the "probability (likelihood) of something undesirable happening" that will cause a change in the ecosystem as a result of some behaviour or action (in this case, fishing) (e.g. Francis 1992, Francis and Shotton 1997, Hayes 1998).

Examples of how these two definitions have been used in the scientific literature are given in Table 1.

Table 1. Examples of two different approaches for practically estimating risk in a marine ecological context.

Definition 1: Risk is an expected loss...	**Definition 2: Risk is the probability (likelihood) of something undesirable happening...**
Approach to estimating risk: Risk as the product of consequence and likelihood	**Approach to estimating risk: Risk as the estimation of likelihood**
Risks to Great Barrier Reef ecosystem posed by key threats (GBRMPA 2009)	Risks to estuarine habitats from human disturbance (Astles 2010)
Precautionary approach to single species management (Hilborn et al. 2001)	Assessment of extinction risk for target and non-target species (Milton 2001, Cheung et al. 2005).
Consequences of different Total Allowable Catch targets (Punt and Butterworth 1991)	Assessment of risk and economic costs for species-specific fisheries (Restrepo et al. 1992)

In the first definition, risk is defined as an impact or threat. In the context in which this definition is applied, impacts are generally consistent, well documented and occur with a known probability or are determined in a controlled environment, such as in ecotoxicology studies (Hayes 1998). Each impact is considered independent of any previous occurrences of that impact.

When dealing with risks of human disturbances in marine environments there are rarely similar well-documented relationships between these disturbances, their effects and their probability of occurrence. This is due to the natural spatial and temporal variability of marine ecosystems, inadequate knowledge of ecological processes, biology and ecology of species, assemblages and habitats and the limited understanding of how human disturbances affect these ecologies. Furthermore, even when a human activity is known to cause an effect, such effects vary from one ecosystem to another. For example, although benthic trawling can damage some habitats (Hiddink et al. 2007), the level and types of effects (i.e. consequences) will be different from one area to another in ways that are quantitatively unpredictable without adequate knowledge of the ecosystems being assessed. Thus the same magnitude of trawling will not necessarily result in the same level or type of consequence from one ecosystem to another (Jennings et al. 1999). Therefore, the first way of understanding risk may be problematic for use in an ecological risk assessment of human activities such as trawling.

The second definition of risk differs from the first in that the consequence is pre-defined and is not part of how the level of risk is determined. The consequence is the undesirable outcome or change that is to be avoided or mitigated against. Fishing of a targeted fish species past a pre-defined level is an example of a consequence (Francis 1992, Francis and Shotton 1997, Punt and Walker 1998). Another example is a fishing activity causing impacts on marine habitats that result in damage past a pre-defined level (Astles et al. 2009). In each case, the risk is assessed by determining the likelihood that a specific fishing activity will result in this consequence. The undesirable outcome that is to be avoided can be determined by the goals, requirements and policies of the relevant management agencies. The likelihood is determined by integrating what is known about the biological, ecological and/or geomorphological characteristics of an ecological component and the factors of the fishing activity that interact with these characteristics. Thus, consequence is chiefly determined by social–political processes and likelihood is determined by scientific processes (Scandol et al. 2009).

Another way of understanding risk has been applied to fishery ecological risk assessments, based on an exposure–effects risk assessment approach (Hobday et al. 2007, 2011). In this approach (discussed further in Section 3.2.5), 'risk' is defined as the probability of not achieving a management objective (similar to the second definition above), but is determined from the consequences of current fishing activity. Thus, the technical focus is on calculating the consequence rather than likelihood with the latter set equal to one given that a certain amount of fishing will occur because it is sanctioned within the current management arrangements (Hobday et al. 2007, Scandol et al. 2009).

In broader contexts, risk has been defined in many ways, and some of these additional ways of understanding risk may also have application in marine ecological contexts (Burgman 2005, Scandol et al. 2009), but they are not discussed here.

The second pathway to define risk was followed in the current assessment. A particular level of impact (an "undesirable event") was defined for each component of the marine ecosystem. The undesirable event was defined in line with relevant goals, requirements and policies for the ecologically sustainable use of the Great Barrier Reef Marine Park and Queensland fisheries (Section 2.4). In this way, due consideration was given specifically to the environmental values that marine park and fisheries managers were trying to protect by incorporating them into the risk analysis process. Risk becomes the likelihood of a part of the ecosystem experiencing one or more of these undesirable events as a result of an activity.

3.2. Generic description of risk analysis framework

The evaluation of risk used here follows the framework developed by the NSW Department of Primary Industries to assess commercial fisheries (DPI 2004, Astles et al. 2006, Astles et al. 2009) and further developed to assess other human activities on estuarine habitats (Astles 2010). This framework is consistent with risk management principals and guidelines by Standards Australia and Standards New Zealand (2009).

In this study, risk is defined as the likelihood of an undesirable event occurring that will have an impact on management objectives.

Risk assessment is a key part of an overall process called risk analysis (Figure 12). Risk assessment is intended to provide insights about sources and levels of risk and their potential impacts. Risk management takes action to mitigate against these risks and undesirable outcomes and monitors whether such action is effective. Risk communication occurs at all stages of a risk analysis between those doing the risk analysis and stakeholders. The latter both receive and provide information to all parts of the risk analysis.

Risk assessment consists of four stages: risk context, risk identification, risk characterisation, and issues arising (see Figure 12).

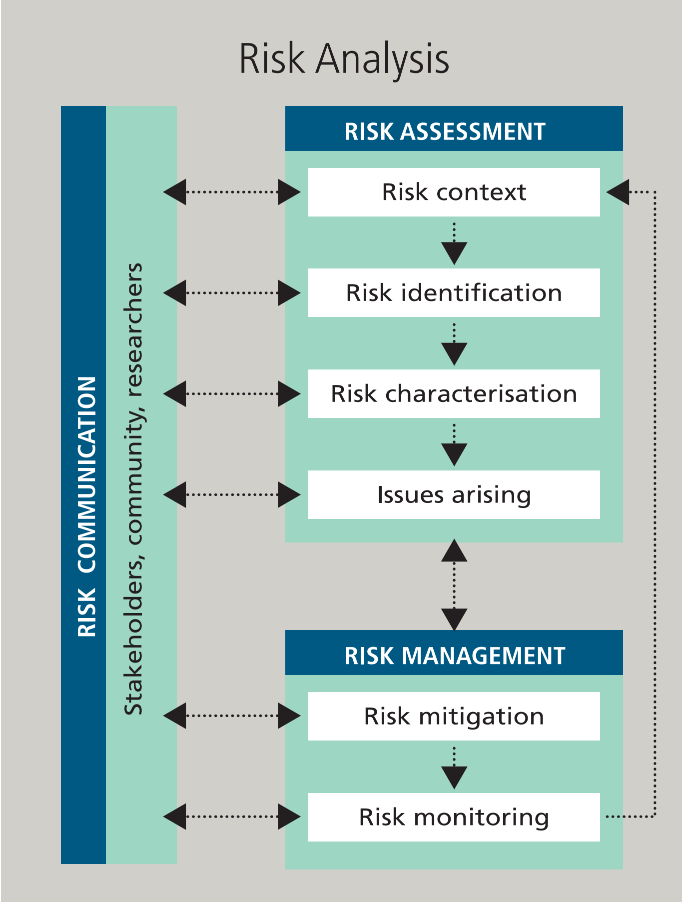


Figure 12. Risk analysis framework, which was developed by Astles and co-workers.

3.2.1. RISK CONTEXT

The first stage involves defining the risk context, which clarifies what is to be assessed and sets the direction for the rest of the assessment. The context of the risk analysis can be defined clearly by specifying the risk that is to be analysed (e.g. by (a) describing the undesirable event or outcome that is to be avoided; and (b) stating the consequence of the undesirable event or outcome), and by specifying the relevant temporal and spatial extents of the risk analysis (DPI 2004).

3.2.2. RISK IDENTIFICATION

Risk identification is the second stage in the risk assessment. The aim of risk identification is to generate a comprehensive list of sources of risk. To understand the risk to marine ecosystems from fishing activities, it is important that, as far as possible, all ecological components and fishing activities that could interact with each other either directly or indirectly are identified.

3.2.3. RISK CHARACTERISATION

This stage estimates the likelihood that the various sources of potential risk identified in the previous stage will cause the undesirable event articulated in the risk context. Risk characterisation is an iterative process that involves stepping down through a series of hierarchical levels. For example, risk characterisation can initially be done at the broad ecosystem level to determine initial risks, and then at a finer resolution for individual taxa (or other ecological component) impacted by the fishery. Negligible or low risks are accepted and eliminated from the subsequent risk analysis, with a justification supporting the conclusion reached. The remaining sources of risk above this threshold are reanalysed at a finer scale by investigating all lower level factors that may influence the probability or likelihood of that source of risk causing the undesired event.

3.2.4. ISSUES ARISING

The final stage in the risk assessment process is consideration of issues identified in the assessment. The reason(s) ecosystem components are assigned a particular risk is examined. Where risks have already been lowered by existing mitigation measures currently in place, there is an opportunity to recognise successful management and good marine stewardship actions by industry. Where risks are high and need to be mitigated, the issues that can be addressed are identified. These issues are then conveyed into a separate risk management component of risk analysis (beyond the scope of this report series), where solutions are sought for risks that are assessed as remaining at unacceptable levels.

The future implementation of any actions aimed at reducing risks can be evaluated through the same assessment process. That is, issues successfully addressed by management should result in a lower risk level in a future reassessment.

3.2.5. COMPARISON WITH OTHER ECOLOGICAL RISK ASSESSMENT METHODS

There have been three main ecological risk assessment frameworks applied to fisheries in Australia—the National Ecologically Sustainable Development (ESD) Reporting Framework (Fletcher 2008), the NSW ecological risk assessment (Astles et al. 2009) and the Ecological Risk Assessment for the Effects of Fishing (ERAEF) for Commonwealth fisheries (Hobday et al. 2007, 2011), which have been reviewed by Astles (2008), McPhee (2008) and Scandol et al. (2009). Any of these other methods could have been used for this risk assessment, and it is expected that the findings would have been similar if another risk assessment method had been applied.

Scandol et al. (2009) demonstrated that all three methods fit within the likelihood and consequence model of risk though they differ in the way these components are described and evaluated. In the NSW ecological risk assessment "the consequence is set by legislation so the risk becomes the likelihood." In the ERAEF "the likelihood is set by the management arrangements so the risk becomes the consequences of these arrangements." In the National ESD approach "the likelihood ratings are based on the conditional probability of the activities of the fishery generating a particular level of consequence. Thus the risk is the likelihood that, given a particular fishing management strategy (e.g. the current allowable catch levels for a tuna fishery), a particular level of impact (e.g. a reduction in spawning biomass to x% of unfished levels) may ultimately be the result (either from an accumulation of small events over time, or from a single large event)."

In developing their national guidelines for risk-based methods for stock assessments, Scandol et al. (2009) concluded that the NSW ecological risk assessment method was "the system that is most in line with the national guidelines recommended approach for determining consequence based on policy and legislation and calculating likelihood based on scientific analysis". The conclusion is also reinforced by one of these national guidelines (G18) that states that "risk management is usually carried out by reducing the likelihood of an undesirable outcome".

3.3. Application of framework to trawling activities in the Great Barrier Reef Region

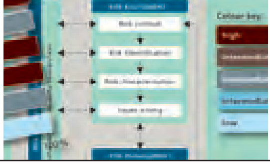
The risks assessed were to ecological components within the Great Barrier Reef Region from interaction with otter trawling activities within and adjacent to this area, under current (2010) management arrangements and circumstances (see Section 2.3 and Appendix 2).

The assessment took a broad ecosystem-based approach, which is consistent with the stated objectives of both the Queensland and Australian governments in relation to managing the Great Barrier Reef. This broad consideration of the environment included all marine ecological components (ranging from species, assemblages and habitats to ecosystem processes) that make up the ecosystem and may be affected by trawling, and all of the activities that make up the operation of the fishery in that area (from harvesting to presence of trawlers in an area). The risks assessed included direct and indirect effects on the species caught in the fishery, as well as on the structure and functioning of the ecosystem. Known external pressures (i.e. non-trawl fishery-related pressures such as degraded water quality) were also taken into account. This ecosystem-based approach included an assessment of the impacts on harvested species, by-catch, species of conservation concern, marine habitats, species assemblages and ecosystem processes (Figure 3). It therefore combines a reductionist approach that assessed risks to individual species with a more holistic approach that assessed risks to more difficult to define components such as species assemblages and ecosystem processes. By combining these approaches, there is a high likelihood that all significant risks were identified and assessed.

3.3.1. DEFINITION OF RISK CONTEXT AND CONSIDERATION OF SCALE

The definitions of risk are detailed later in this section and incorporate the negative consequences or outcomes that are to be avoided as defined by the management objectives for the fishery and Great Barrier Reef Marine Park. The Commonwealth *Great Barrier Reef Marine Park Act 1975* and the Queensland *Fisheries Act 1994* were considered in developing each risk context.

> *Great Barrier Reef Marine Park Act 1975*: The main object of this Act is to provide for the long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region. Other objects of the Act include, so far as is consistent with the main object, ecologically sustainable use of the Great Barrier Reef Region for purposes including recreational, economic and cultural activities.
>
> *Fisheries Act 1994:* The main purpose is to provide for the use, conservation and enhancement of the community's fisheries resources and fish habitats.



These stated objectives are largely complementary and integrated management of fishery resources and the potential environmental impacts of fishing activities in the Great Barrier Reef Region aims to simultaneously achieve the objectives of both Acts. A joint consideration of the risks to the values that both Acts seek to protect is considered beneficial in this assessment as part of this integrated approach to the management of the Great Barrier Reef.

Where available, best practice limit reference points or proxies were considered when identifying an undesirable outcome to be avoided. Sainsbury (2008) provided a review of what is regarded as 'best practice' and this view is expected to evolve over time.

A time frame of 20 years was used during the assessment to define each risk context. This was seen to be precautionary, relevant to current knowledge and life cycles of many of the species being considered, and would allow for measurement of responses to management actions if required. Over this time period, the collective effects of single or multiple large impacts and/or an accumulation of smaller impacts are considered.

Ecological risks were assessed at the scale of the whole Great Barrier Reef ecosystem. Nevertheless, the assessment considered whether ecological risk varied spatially or temporally (e.g. differing risks for the various subsectors of the fishery). Such information is important for identifying any issues that may affect regional (i.e. within Great Barrier Reef) sustainability of the marine environment or industry. At each step in the hierarchical risk identification and risk characterisation processes, the following question was asked: 'Does the characteristic vary spatially or temporally such that risk needs to be further assessed at a finer scale or for a particular subsector of the fishery?' If the answer was yes, details were documented and a more detailed assessment was conducted. The tables that detail the characteristics used in the finer level assessments also clearly indicate the scale of interest for characters and factors (e.g. in Table 30, population size is evaluated at the scale of the species range). A summary of the risk assessment findings by fishery sector is provided in Section 4.9.

The questions to define the risk contexts in Section 4 were reviewed by many internal and external experts, including detailed consideration through the expert workshop process.

3.3.2. SOURCES OF RISK: ECOLOGICAL COMPONENTS AND ACTIVITIES ASSESSED

To facilitate a comprehensive consideration of the risks to marine ecosystems in the Great Barrier Reef Region, six ecological components that could potentially interact with trawl fishing activities were identified (Table 2). These were similar to the ecological components assessed in the NSW Ocean Trawl Fishery (DPI 2004). The definitions adopted by this assessment were specifically designed to avoid duplication. For example, in this assessment, by-catch is considered to be species that are caught and landed on deck but are then always discarded because they are not permitted to be retained by the fishery. Other species that are also caught and discarded, including individuals of harvested species that are outside legal size or market requirements, and species of conservation concern, are dealt with under other sections.

Table 2. Definitions of ecological components.

Harvested species: this group comprised principal species targeted by the fishery and other permitted species incidentally caught but allowed to be retained as by-product (*Fisheries Regulation 2008; Fisheries (East Coast Trawl) Management Plan 1999*) i.e. commercially harvested species retained by the fishery.
By-catch: other species caught and landed on deck by the fishery but then discarded. *Note for this assessment by-catch species does not include any principal or other permitted species (defined above) which may be discarded for any reason or any species of conservation concern (defined below).*
Species of conservation concern: protected species as defined in the *Great Barrier Reef Marine Park Regulations 1983* and all sharks, rays and chimaeras (or ghost sharks). These include plants or animals that are protected by law or require special management. Specifically, all protected species in the Great Barrier Reef Marine Park, as well as all sharks, rays and chimaeras. Although species of sharks, rays and chimaeras may not necessarily be protected by legislation, many of these species are under pressure and require special management (Shark Advisory Group and Lack 2004, Camhi et al. 2009, GBRMPA 2009, White and Kyne 2010).
Marine habitats: habitat types in shelf seabed areas and the upper continental slope of the Great Barrier Reef Marine Park with which the fishery potentially interacts.
Assemblages: species assemblages in shelf seabed areas of the Great Barrier Reef Marine Park with which the fishery potentially interacts. For this assessment, the assemblages used were those defined in the Seabed Biodiversity Project (Pitcher et al. 2007b).
Ecosystem processes: includes other potential risks to the ecosystem from current or near future trawling activity not already considered under species or habitats. Ecosystem processes are the mechanisms which influence the distribution and abundance of organisms, the habitats in which they occur and by which components of an ecosystem are linked or interact.

Ecosystem components were further subdivided into individual species or types and reassessed at a more detailed level where warranted (i.e. if initial risks from trawling activities were identified as being at least intermediate in level, Section 4.1.3).

The separate assessments of all the ecological components combine together to provide a comprehensive assessment of risk to the Great Barrier Reef ecosystem and its component parts (Figure 3), arising from all activities of the fishery.

For the risk assessment, the activities of the trawl fishery were subdivided into seven discrete activities for detailed examination (Table 3). Again, these were similar to those assessed in the NSW Ocean Trawl Fishery.

Table 3. Definitions of activities of the trawl fishery.

Harvesting: capture and retaining of marine resources for sale.
Discarding: returning unwanted catch to the sea (these species are landed on the deck of the boat and then discarded).
Contact without capture: contact of any part of the trawl gear with ecological components (species, habitats, etc.) whilst being towed but which do not result in the ecological components being captured and landed on deck.
Loss of fishing gear: partial or complete loss from the boat of gear including nets, towing cables and otter boards.
Travel to/from grounds: steaming of boat from port to fishing grounds and return.
Disturbance due to presence in the area: other influences of boat on organisms whilst fishing activities take place (e.g. underwater sound disturbances).
Boat maintenance and emissions: tasks that involve fuel, oil or other engine and boat-associated products that could be accidentally spilled or leaked into the sea or air.

3.3.3. PROCESS USED FOR RISK CHARACTERISATION

In the current assessment, risk characterisation involved a two-stage hierarchical approach similar to that used by NSW (Astles et al. 2009), which initially examined major sources of risk at a broad ecosystem level and then included a finer level assessment for ecological subcomponents (e.g. individual species or habitat types) that are potentially impacted by the fishery as determined by the broader assessment.

For finer level assessment, risk characterisation involved the estimation of the likelihood that an ecological subcomponent will experience the specified undesirable event or outcome. The likelihood was determined by considering two independent aspects:

1. **Resilience**: the capacity of a subcomponent to resist or recover from disturbance, including fishing, based on intrinsic biological and/or ecological characteristics.
2. **Fishery impact profile**: the pressure exerted by the fishery on the subcomponent.

The levels of these two variables were determined by applying a set of decision criteria to a set of biological/ecological characters (for resilience) and fishery factors (for fishery impact profile).

The characters and factors used to assess risk were those considered most appropriate for the ECOTF in the Great Barrier Reef Region. The characteristics and decision rules developed in NSW for the Ocean Trawl Fishery were used as a basis for this assessment, but modified (see last column of the relevant tables in Appendix 3 to this report) where appropriate to suit the nature of the fishery in Queensland, and utilise the extensive data and knowledge base available for the fishery in the Great Barrier Reef Region. A set of characters and factors were developed for each ecological component and these are detailed under the relevant risk characterisation sections later in this section and in the supporting appendices. If only a few characters or factors are available, such as for species assemblages, confidence in the assessment will generally be low.

This risk characterisation process considered traits which directly contributed to ecological sustainability of each component, and assessed each species or type in detail. In developing each set of resilience characters and fishery impact factors, it was appropriate to include the key attributes that may influence the likelihood of that source of risk causing the undesirable event. Each set was selected to suit the circumstances and available information sources, and varies for different ecological components. For example, resilience characters used for principal species included fecundity, life history strategy, distribution, and natural mortality. The fishery impact profile comprised factors that collectively indicate the level of pressure exerted by the fishery on the subcomponent being assessed, such as catch levels, discard rates, gear selectivity, and overlap of fishing area with distributions of species or habitats.

The ecological risk assessed was from direct or indirect interaction with the activities of the trawl fishery. However, the current assessment also considered known external pressures (i.e. non-trawl related pressures such as modification of coastal ecosystems or predicted climate change vulnerabilities) under a resilience character called 'cumulative pressures'. This character took account of any known external pressures that may increase the susceptibility of a subcomponent to the effects of trawling, and hence lower its resilience.

By keeping inherent resilience characters separate from fishery impact factors, it was possible to examine how management arrangements have influenced the level of risk to ecological components. Generally, the assessment of resilience will only change if the information available for the ecological components improves, however, both improved information and management intervention can alter the fishery impact profile. The resilience of an ecological component functions as a prioritising factor in the method, because it is set by inherent characteristics of the ecological component and cannot be changed by management (except through external pressures). Thus, management action for an ecological component with intermediate fishery impact profile but low resilience would take higher priority than one with the same impact profile but with higher resilience.

A set of criteria or 'decision rules' were developed for each group of ecological components to determine the extent to which a particular resilience character or fishery impact factor made a subcomponent prone (P) or averse (A) to being at risk from the activity of the fishery (see for example Table 30). A risk averse character or factor is likely to make a species or type more resilient or result in a lower fishery impact profile. For example, a habitat type that is widely distributed and covers a large area is likely to be more resilient, overall, to stochastic events such as floods, cyclones or oil spills, and hence have higher resilience than a habitat type with a restricted distribution. Some characters or factors were given a double weighting in the assessment by including a 'risk double prone' (PP) option in the scoring, to reflect the larger potential contribution of these characters/factors to risk from the fishery. For example, under the fecundity character, bearing a small number of live young was 'risk double prone', whereas the strategy of spawning > 50,000 eggs was 'risk averse'. (A moderate fecundity between these two examples was scored as 'risk prone', as described in Table 30).

The setting of the decision rules was informed by scientific literature and expert opinion. These rules and their application to ecological components went through several expert evaluations both within and outside the project team (Section 1.3). This process aimed to reduce the potential for risk to be underestimated by giving too little weight to a factor, by excluding important factors, or by double counting factors through the inclusion of those that were highly correlated.

The assessment had a similar bias towards overestimating the level of risk as recognised in Astles et al. (2009, see page 2771), but was considered appropriate for a precautionary assessment of risk (Scandol et al. 2009). In effect, this means that the decision rules were set conservatively to reduce the risk of assigning a lower level of risk than the actual level (known as a 'type II error').

The assessment took into account the current management arrangements for the fishery in 2010 (as described in Appendix 2) through the fishery impact profile. Therefore, some of the risk scores can be attributed to past or present management arrangements. Should these arrangements change in the future, some of the risks may also change.

The overall resilience and overall fishery impact profile were determined by summing the number of risk prone characters/factors for each subcomponent. The detailed scoring rules are provided under the risk characterisation sections in Section 4. The resilience levels and fishery impact profile levels were qualitatively assigned to a risk category (from low to high) as shown on the risk matrix in Figure 13. The risk matrix was divided into five equal areas ranging from low to high, and it is implied that each category has an equal weighting of risk (i.e. the use of five categories implies each category accounts for one-fifth of the total risk). High levels of risk result from low resilience and high fishery impact profile scores.

The resilience and fishery impact profile axes contribute in different ways to risk gradings (through the risk matrix). For example, a species with intermediate resilience would move through all five risk categories as its fishery impact profile goes from low to high, whereas a particular risk category, or only one category higher, would apply to a species depending on its intrinsic resilience (for a particular level on the fishery impact profile axis). The risk matrix was designed in this way to reflect the fact that the resilience of an ecological component is based on its biological/ecological characteristics and therefore essentially fixed (unless knowledge gaps about its biology and ecology are filled by research), whereas the fishery impact profile can be influenced by management actions (or improved knowledge).

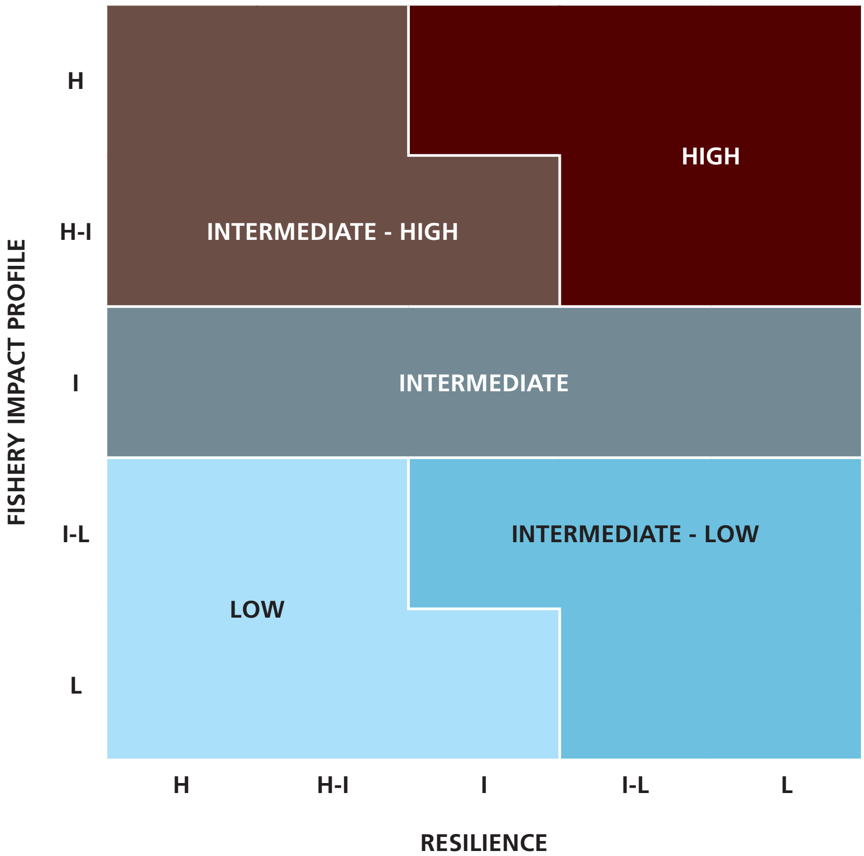


Figure 13. Risk matrix showing the relationship between risk and various levels of resilience and fishery impact profile.

The thresholds for the various decision criteria (and scoring rules) were determined by scientists based on their interpretation of information in scientific literature. The risk context and additional sensitivities for particular components (e.g. species of conservation concern) were taken into account in considering weightings and thresholds for the decision criteria, and in assigning risk prone scores to the resilience and fishery impact profile axes. Hence, when the resilience and fishery impact profiles were combined to give a risk grading, it took into account the current management arrangements and ecological sensitivity for the ecological component being assessed.

A hierarchical process using a series of tables was used to undertake the assessment. The detailed datasheets showing all the data behind the assessments have been provided in a supporting Data Report in this report series. Information was compiled for each component/species/type against every resilience character or fishery impact factor from scientific literature, reports, analysis of data or expert opinion.

This Technical Report fully documents how this information was incorporated into the assessment, and all of the decisions made in the assessment. Any unpublished data used in the assessment is provided in appendices to the Technical Report or in the Data Report. The level of certainty in the information was explicitly considered.

The best available knowledge was used to inform the assessment (including quantitative and qualitative information, expert knowledge and biological inferences). Where there was no available knowledge to inform the assessment, this was recorded and, consistent with a precautionary approach to assessing risk, was considered to elevate the assigned risk, and the information gap noted in the report. If a proposed character/factor was unknown for all or most subcomponents being assessed, this character/factor was removed from the assessment and not included in the scoring, and the scoring system revised accordingly. This was done by requiring fewer risk prone scores to be attributed to levels of resilience and fishery impact profile in the risk matrix, and hence each risk category. Critical data gaps identified in this way may indicate priority areas for future research.

Where relevant, this assessment has adopted the same terminology as the quantitative approach used in the Seabed Biodiversity Project report (Pitcher et al. 2007b). Appendix 2.2.4 explains particular indicators from that report used here, how these were derived and, where appropriate, how they were updated for use in the current assessment.

The assessment gives a ranking of species or types within each component of the ecosystem according to their level of risk relative to a specified undesirable event or outcome (i.e. to the risk context). The method does not provide absolute estimates of risk. To ground-truth the outcomes, a benchmarking approach was applied in which risk levels were calibrated, where possible, using 'benchmark species' known to fall within the upper and lower ends of the range of risk (DPI 2004). Likely combinations of scores were also considered from a theoretical perspective to determine appropriate assignment to a risk category.

3.3.4. CONSIDERATION OF ISSUES ARISING AND HOW THE INFORMATION WILL BE USED

There are two main outputs of the ecological risk assessment for each ecological component—a level of risk and a list of issues that contribute to the component being at that level of risk.

The reason(s) ecological components are at high or low risk was examined by reviewing their resilience characters and fishery impact factors. For ecological subcomponents at negligible or low risk, factors responsible for low risk gradings were reviewed to understand, for example, any dependencies on current management measures, and to recognise where prior actions by management and industry have addressed risks. For ecological subcomponents at intermediate or high risk, issues arising were reported on, such as knowledge gaps (e.g. lack of biological information) and management issues (e.g. adoption of best practice BRDs). This information can subsequently be used by industry and management to develop solutions collaboratively, based on a shared understanding of the nature and level of risk.

Input and feedback from expert workshop participants, the project advisory committee, other relevant GBRMPA and Fisheries Queensland committees and a broader industry workshop were taken into account in considering the findings of the assessment (see Section 1.3.2).

The effectiveness of management actions could be monitored and evaluated by reassessing the fishery using the same method and criteria. If new information becomes available in the future, it can be incorporated into a reassessment by systematically updating, or adding, resilience characters and fishery impact factors (Astles et al. 2009).

The assessment has provided an opportunity to recognise and evaluate the progress that has been made in reducing risks from trawling in the Great Barrier Reef Region. Through the incorporation of the best available information, such as from the Seabed Biodiversity Project (Pitcher et al. 2007b), the current assessment will help inform all stakeholders and the broader community about any risks currently posed by trawling to the Great Barrier Reef ecosystem.

The ecological risk assessment is a summary of the present ecological risks posed by trawling activities to the Great Barrier Reef ecosystem, and issues arising from the assessment. The report does not make recommendations about future management responses, as that responsibility rests with agencies in consultation, and risk management is beyond the scope of this report.

The assessment will inform discussions about management arrangements for trawling and the Great Barrier Reef to ensure that they meet high standards, and that the environmental impacts and risks from the fishery are minimised. The ecological risk assessment, and ongoing risk monitoring, will also inform other broader assessment processes. This includes the next Outlook Report (2014), particularly regarding the contribution of trawling activities to the remaining risks from fishing and the assessment of management effectiveness. The findings are also relevant to future reassessments of the fishery under national environmental law, the *EPBC Act 1999*, as the current EPBC assessment includes specific recommendations relating to this ecological risk assessment. The findings reported here will also inform a current strategic assessment of the Great Barrier Reef World Heritage Area under the *EPBC Act 1999*, including consideration of cumulative impacts on the ecosystem. The strategic assessment aims to ensure development activities are well planned and systems are in place to protect the area's World Heritage values.

3.3.5. TIME POINTS CONSIDERED IN THE ASSESSMENT

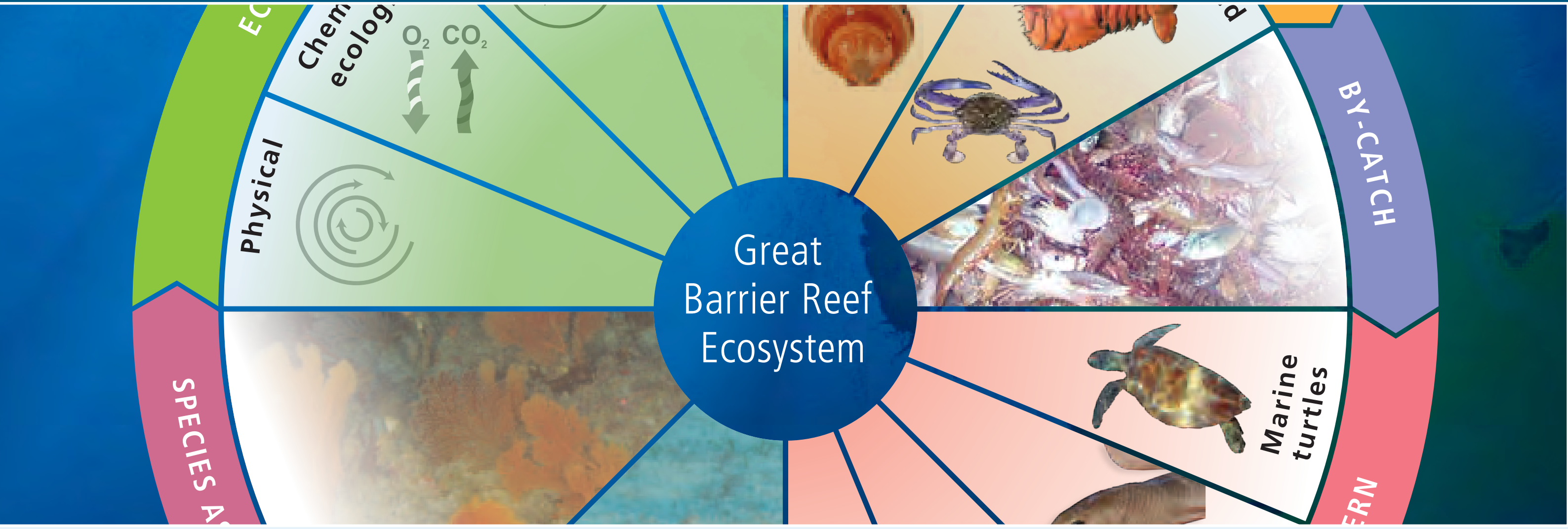
Within the current management arrangements, the otter trawl fishery has significant capacity for increases in fishing effort should economic pressures constraining the fishery be reduced. Therefore, it was desirable to consider a range of effort levels in assessing risk from the fishery. The years 2009 and 2005 were chosen, and are considered to provide an indication of risk from trawling at recent low (2009) and higher (2005) fishing effort levels.

While the 2005 effort levels were still about a third below the effort cap for the Great Barrier Reef World Heritage Area (see Appendix 2.1 and Appendix 2.2.2), higher levels of effort are considered unlikely based on trends in trawl fishing effort over the last decade (but would be allowable under the current effort cap).

The latest year for which effort data was available at the time of the assessment was 2009. As trawl fishing effort has remained at similar levels over the period 2007 to 2011 (Figure 10), the risk findings for 2009 trawl fishing effort levels are considered still relevant in 2012 and it is unlikely overall ecological risks have changed from those reported here.

Where data was available for 2005 and 2009 (see Appendix 2.2.4), the current assessment has completed and presented assessments for each year. Any differences in the risk gradings are discussed under issues arising for the relevant ecological components (e.g. Section 4.2.4) and the general implications are considered in Section 5.2.

4. Ecological Risk Assessment



This section presents the full ecological risk assessment. Each assessment follows a four-stage risk assessment framework that considers the risk context, risk identification, risk characterisation, and issues arising from the assessment.

4.1. Initial risk assessment

The initial assessment of the potential risks to the Great Barrier Reef ecosystem from current trawling activities looked separately at the impacts of trawling on the following ecological components: harvested species, by-catch species (those landed on deck but not retained), species of conservation concern (including protected species and sharks, rays and chimaeras), habitats, and species assemblages.

Finer level assessments are presented later in Section 4 for ecological subcomponents (e.g. individual species or habitat types) that are potentially impacted by the ECOTF as determined by the initial assessment at a broad ecosystem level.

Potential interactions between the fishery and ecosystem processes were considered separately (Section 4.7), because of the theoretical and conceptual complexity of these interactions.

4.1.1. RISK CONTEXT FOR THE ECOSYSTEM AS A WHOLE

For the broad assessment of ecosystem components, the risk assessed was:

What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will cause serious or irreversible change to the fishery resources and fish habitats, environment, biodiversity or heritage values of the Great Barrier Reef Region within the next 20 years?

As explained in Section 3.3.1, the risk context incorporates the negative consequences or outcomes that are to be avoided as defined by the management objectives for the fishery and Great Barrier Reef Marine Park (see also Section 2.4). In doing this, risks to the values that the Queensland *Fisheries Act 1994* and the Commonwealth *Great Barrier Reef Marine Park Act 1975* seek to protect were considered. A time frame of 20 years was seen to be relatively precautionary, relevant to current knowledge and life cycles of many of the species being considered, and responsive to management actions that may be implemented.

Examples of serious or irreversible change include:

- Environment, biodiversity and heritage values being unable to be maintained in a way that ensures the ecologically sustainable use of the Great Barrier Reef Region within the next 20 years (*Great Barrier Reef Marine Park Act 1975, Section 2A*)
- The Great Barrier Reef Region and its natural resources being unable to sustain natural processes in a way that maintains the systems of nature and that ensures the benefit of the use to the present generation does not diminish the potential to meet the needs and aspirations of future generations (*Great Barrier Reef Marine Park Act 1975, Section 3AA(b)*)
- Ecological systems being unable to support desired long-term environmental, economic and social outcomes for fishery resources and fish habitats within the next 20 years (*Fisheries Act 1994*, *Queensland Fisheries Strategy: 2009–2014* (DEEDI 2009c))
- Ecological components being unable to contribute to the persistence of a diverse, resilient and productive World Heritage Area and productive ecosystem within the next 20 years (25 Year Strategic Plan for the Great Barrier Reef World Heritage Area 1994–2019, 25 year objective, p. 15) (GBRMPA 1994).

4.1.2. RISK IDENTIFICATION FOR ECOSYSTEM COMPONENTS

In the first level of the hierarchical process, all ecological components (except ecosystem processes) (Table 2) and activities of the fishery (Table 3) were assessed.

This initial risk assessment considered information from reviews and publications covering identified impacts for overseas demersal trawl fisheries, but was mostly based on publications on Australian fisheries and particularly those operating in tropical waters.

Trawling impacts on harvested species

Trawl impacts on harvested species reflect the level of catch relative to the available population and vary among species caught. Some form of quantitative stock assessments are needed to determine the level of depletion caused by a fishery (and hence whether stocks are overfished or not) and the current level of fishing mortality (and hence whether stocks are subject to overfishing or not).

The species harvested in the fishery are detailed in Section 4.2.2 and include several prawn species, scallops, Moreton Bay bugs and squid, and some other species.

DAFF Queensland recently introduced reporting on stock status for major commercial and recreationally important species, and the information is summarised in fishery annual status reports published by Fisheries Queensland (see Section 2.3.3 for relevant stock status classifications).

The status of the fishery resources was assessed by the then Department of the Environment and Water Resources (DEWR 2007) as being variable between sectors from fully exploited to underexploited.

In the *Great Barrier Reef Outlook Report* (GBRMPA 2009) fishing on detritivores in general (a group which included prawns) was assessed as posing a medium risk to the Great Barrier Reef ecosystem.

In the current assessment, the risk to each harvested species was assessed in detail (Section 4.2) because the fishery interacts significantly with each of these species.

Trawling impacts on by-catch

It has been estimated that fisheries worldwide catch between 7.3 million and 27 million tonnes of by-catch annually, most of it from prawn trawl fisheries (Andrew and Pepperell 1992, Alverson et al. 1994, Kelleher 2005). In Australia (Kennelly 1995), by-catch has been estimated to be five to ten times the catch of prawns (Harris and Poiner 1990). In the shallow-water eastern king prawn sector of the ECOTF, by-catch rates can be over ten times the catch rates of prawns (Courtney et al. 2006). In the Great Barrier Reef Region, non-retained catch in the commercial sector is 43 per cent of the total commercial and recreational fisheries catch, and results mainly from trawling activities (Figures 4.11 and 4.13 in GBRMPA 2009).

The discarding of by-catch species is often criticised as being a threat to non-target species and ecosystem function, and as a waste of seafood resources. Some authors, however, have argued that discarding can have potential benefits, that there are acceptable amounts of discards that are consistent with ecosystem-based fishery management, and that selective fishing may also result in unexpected, undesirable impacts both to fisheries and marine ecosystems (Zhou 2008, Zhou et al. 2010).

The survival rate among discards from mobile fishing gears varies substantially and is influenced by a range of factors including the type of gear, trawl duration, the depth fished, the size and species composition of the catch, handling practices and water temperature (Chopin and Arimoto 1995). Survival from trawls is generally regarded as very low (Saila 1983), but survival from some mobile gears such as haul seines can be high when they are deployed in shallow depths, with low tow speeds, short tow durations and the catch is sorted in the water (Knuckey et al. 2002). Escapement can also be high with up to 95 per cent of fish encountering a net not being retained (Lambeth et al. 1995), however survival following contact without capture may be variable. Relatively minor changes to gears, such as changes in mesh sizes, can alter substantially the levels of by-catch (Kennelly and Gray 2000).

In the ECOTF, by-catch consists mostly of small fish, crabs, non-target penaeid prawns and numerous other seafloor-dwelling invertebrate species including sponges, sea stars and gastropod shellfish (DEEDI 2010a). The species composition of the by-catch varies among the different sectors of the fishery and also varies by latitude and depth (Courtney et al. 2006). Additionally, recent surveys on board ECOTF vessels during their normal fishing activities showed that by-catch rates vary by sector; the scallop fishery had the highest by-catch rate (9.39 S.E. 1.02 kg per hectare) while the deepwater eastern king prawn sector had the lowest (1.30 S.E. 0.19 kg per hectare) (Courtney et al. 2007).

One of the main responses to the issue of by-catch in prawn fisheries has been the introduction of various types of BRDs. These devices have been extensively investigated around the world, have been demonstrated to greatly reduce the catch of unwanted species, and the stages involved in developing effective gear modifications have been described (Broadhurst 2000). Trials in northern Australia reinforced their ability to reduce the catches of turtles, small fish, large sharks and stingrays, and potentially increase catch value (Brewer et al. 1998, Brewer et al. 2006).

There have been some positive results from trials of BRDs in Queensland. For example, by-catch rates (including calcareous rubble, algae and seagrass) in the saucer scallop sector of the ECOTF were reduced by 77 per cent during experiments using nets fitted with both a TED and a square mesh codend (a type of BRD), with no reduction in the catch rate of legal-size scallops and a 39 per cent reduction in the number of undersize scallops caught (Courtney et al. 2008). Similar experiments with square mesh codend BRDs and TEDs in the deepwater eastern king prawn sector of the fishery showed the mean by-catch rate was reduced by 29 per cent with no significant loss of targeted prawn catch (Courtney et al. 2007).

In the red-spot king prawn sector, fisheye and square mesh codend BRDs were found to reduce the catch rate of sea snakes by 63 per cent and 60 per cent, respectively, when compared with the standard net that had no BRD, with no significant reduction in the catch rate of marketable prawns (Courtney et al. 2007). These two devices also significantly lowered the catch rates of the remaining by-catch by 33 per cent and 31 per cent, respectively. The fisheye BRD was equivalent to the square mesh codend in terms of by-catch reduction, however the fisheye performed better at excluding larger sea snakes due to the limited size of the square meshes that almost certainly prevent large sea snakes from escaping.

Experiments in the north Queensland tiger/endeavour prawn fishery sector of the ECOTF showed a significant result of up to 20 per cent reduction in the mean by-catch rate when nets were fitted with a radial escape section BRD and TED (Courtney et al. 2007). The differences among sectors were attributed to differences in the characteristics of the by-catch (size and swimming capabilities), length of codends and the speed of trawling.

These reductions in by-catch rates found during experimental trials, however, were greater than those recorded on board commercial vessels in the main prawn fishery sectors during normal fishing operations (Courtney et al. 2007). If catches of the largest animals (large sharks, large rays and large sponges) were excluded from the analyses, there was a 25 per cent reduction in by-catch rates of the remaining animals during commercial operations. In the saucer scallop sector of the fishery, the TEDs and BRDs used by the fishers reduced the mean by-catch rate by 68 per cent, mainly because the TEDs excluded large sponges, but with an 11 per cent reduction in the catch rate of scallops. In the north Queensland tiger/endeavour prawn fishery sector, rates of prawn loss and by-catch reduction were similar (about nine per cent), indicating that the TED and/or BRD were inadvertently allowing the passive loss of both by-catch and target species, and not functioning as intended by providing escape routes for by-catch species only (Courtney et al. 2007).

This experimental work largely reflected commercial fishing conditions (i.e. trials deployed commercial vessels, commercial skippers and crews, used commercial trawl gear, were undertaken in the major trawl sectors in grounds that experienced medium to high levels of trawl fishing effort) (Courtney et al. 2007). However, the by-catch reductions achieved were considered to reflect the potential reductions in by-catch that could be achieved from certain devices in select sectors, rather than those of the commercial fleet.

Although the experimental work had shorter average tow durations than normal commercial trawl operations, previous studies have shown that such differences do not produce differences in size or species composition, although catch rates tend to be higher in shorter tows (Wassenberg et al. 1998).

The survival rates of discards is variable: for example, over 90 per cent of fish (which make up the majority of the discards) are dead when discarded from prawn trawl catches, but survival experiments on crabs showed that over 90 per cent were alive four days after being trawled, and bivalves also have a high survival rate (Poiner et al. 1998).

A recent comprehensive project that mapped seabed biodiversity in depths to about 90 metres in the Great Barrier Reef (Pitcher et al. 2007b) provided information on hundreds of species that are part of the by-catch in the ECOTF. Pitcher and co-authors (2007b) commented that exposure to trawl effort may present varying levels of risk for different species depending on how effectively the trawl net catches any given species (harvesting and discarding activities), or how much mortality is caused as a result of contact with the net (contact without capture). They gave the following examples: a species that lives well down in the sediment, or one that moves up into the water column during the night, is unlikely to be directly affected by the pass of a demersal prawn trawl net deployed at night (normal operation in all but the banana prawn sector). On the other hand, a slow-moving species that lives less than a metre from the seabed may be very effectively caught by a prawn trawl net.

In the Seabed Biodiversity Project, about 50 species were identified for further management attention. These included the 20 highest ranked species for four risk indicators (see Section 4.3.2 and Appendix 2.2.4). Only three of 840 species analysed, however, exceeded a limit reference point analogous to maximum sustainable yield (MSY) based on estimated annual catch relative to natural mortality: *Fistularia petimba* rough flutemouth, *Brachirus muelleri* tufted sole, and *Trixiphichthys weberi* blacktip tripodfish. One species (*Pomadasys maculatus* blotched javelin) exceeded a first conservative reference point (≡0.8×MSY) and two others (*Psettodes erumei* Australian halibut and *Sillago maculatus* (misidentified as *S. burrus)* trumpeter whiting) exceeded a second conservative reference point (≡0.6×MSY). A further 10 species were listed due to uncertainty in parameters, though they were below the sustainability reference points. The first reference point is the value adopted by Zhou and Griffiths (2008) as a suitable default reference point for a wide range of by-catch species.

In the *Great Barrier Reef Outlook Report* (GBRMPA 2009), the overall threat from death of discarded catch (from all fishing activities) was assessed as posing a high risk to the Great Barrier Reef ecosystem. The primary goal of by-catch management in Queensland is to reduce the volume and improve survival of by-catch. However, as for most other fisheries, by-catch from trawling at some level is inevitable.

The risk to by-catch was assessed in detail (Section 4.3) using information from previous studies to prioritise species assessments (detailed in Section 4.3.2), as by-catch species are potentially affected by several activities of the fishery.

Trawling impacts on species of conservation concern

The incidental catch of protected species in the Great Barrier Reef Region or other species of conservation concern is potentially more problematic than for other by-catch species because even low levels of mortality may put species of conservation concern at risk or compromise the ability of generally depleted populations to rebuild. Catches of marine mammals, birds and reptiles (often the main groups involved) in any fishery are also more likely to attract the attention of the public and the media and their capture is generally considered unacceptable by the public, regardless of the biological implications of any subsequent mortality.

Trends in the rates of by-catch of marine mammals and turtles for the east coast of Queensland were assessed using a combination of data from the Queensland Marine Wildlife Stranding and Mortality Database, the Queensland Shark Control Program, the Fishery Observer Program operated by DAFF Queensland, various research projects and Species of Conservation Interest (SOCI) logbook reports from commercial fishers. The SOCI logbook data are not considered to be complete, and validation against observer records has indicated that there are substantial discrepancies for sea snakes (Courtney et al. 2010).

In the *Great Barrier Reef Outlook Report* (GBRMPA 2009), the by-catch of species of conservation concern as a group, due to fishing activities of all types not just trawling, was assessed as posing a high risk to the Great Barrier Reef ecosystem. Similarly, the extraction of top predators such as sharks (due to all fishing activities) was considered a very high risk to the Great Barrier Reef ecosystem.

The following sections provide information on species of conservation concern that potentially have a direct or indirect interaction with the fishery. Some additional protected species occur in the Great Barrier Reef Marine Park, however the interaction with the ECOTF is considered to be negligible based on available research, at-sea observer reporting and marine stranding information.

Cetaceans

The 2000 to 2006 records of the Queensland Marine Wildlife Stranding and Mortality Database (Greenland et al. 2002, Greenland et al. 2005, Greenland and Limpus 2005, 2006) suggest that the by-catch levels of marine mammals on the urban coast of Queensland have been low in recent years, with none of the average of 15 individuals reported per year being caught in trawl nets. The SOCI logbook records for the ECOTF indicated that there were no interactions with cetaceans in 2008 or 2009 (DEEDI 2009a, 2010a).

The available data sources and expert knowledge indicate cetaceans have a negligible direct interaction with the ECOTF but some species of dolphins are known to scavenge food from the trawl fleet. Scavenging is considered in Section 4.7 on ecosystem processes.

Dugongs

Along the whole of the Queensland east coast, an average annual mortality of 45 individual dugongs per year has been reported (2000 to 2006) with none attributed to trawling.

Dugongs are considered to have a negligible direct interaction with the ECOTF, but there is the potential for an indirect interaction with trawling activities through direct physical disturbance of seagrasses, the major food source for dugongs (Grech et al. 2011). This potential interaction is considered in Section 4.7 on ecosystem processes.

Sharks, rays and chimaeras

At least 94 species of chondrichthyans (sharks, rays and chimaeras) occur in the area of the ECOTF, of which at least 48 have been recorded as by-catch in the eastern king prawn, tiger/endeavour prawn and scallop sectors (Kyne et al. 2007) or in the banana prawn sector (Stobutzki et al. 2001). The number of chondrichthyans in the whole fishery area may be as high as 109 species (Kyne 2008) but not all of these species occur in the Great Barrier Reef Region. Surveys on commercial trawlers indicated that the chondrichthyan by-catch varied among sectors, being low in the tiger/endeavour and eastern king prawn deepwater sectors (for the latter, the study area was south of the Great Barrier Reef Region) and moderate in the eastern king prawn shallow-water sector (Kyne et al. 2002) (see also Appendix 2.2.5). By-catch in the eastern king prawn shallow-water sector was predominantly three species of rays (one guitarfish and two stingarees) and in the eastern king prawn deepwater sectors south of the Great Barrier Reef Region, two species of catsharks (Scyliorhinidae) (Kyne et al. 2002). There is some research information and fishery observer information on interactions between the ECOTF and sharks and rays (Courtney et al. 2007, Kyne 2008) (and see Appendix 2.2.5), and there have been biological studies on a number of these species (e.g. Jacobsen and Bennett 2011). For species where biological information from the local region was lacking, however, knowledge of similar species in Australian waters or overseas was used.

Since 2001, no sharks or shark products (includes all species of chondrichthyans) have been permitted to be retained from trawl catches in the ECOTF in recognition of sustainability concerns for some species of sharks and rays.

The Fisheries Queensland compulsory SOCI logbook for the ECOTF records interactions for eight species of protected sharks and rays (and other animal groups): freshwater sawfish, green sawfish, dwarf sawfish, narrow sawfish, whale shark, grey nurse shark, white shark and speartooth shark. Records from these logbooks indicated that operators caught three narrow sawfish in 2008, and three narrow sawfish and one green sawfish in 2009, all of which were reported to be released alive (DEEDI 2009a, 2010a). Low numbers of interactions were also recorded with sawfish species in 2006 (DEWR 2007).

Information from other fisheries also indicates that sharks and rays are frequently caught in prawn fisheries. In the Northern Prawn Fishery (which is located off northern Australia between Cape York in Queensland and Cape Londonderry in Western Australia) 56 species of sharks and rays have been recorded as by-catch. For all species combined, 66 per cent of the individuals died in the trawl net (Stobutzki et al. 2002). The most susceptible species were batoid rays, which feed on benthic organisms, are highly susceptible to capture in prawn trawls, often have poor survival and have a low population recovery capacity. The Northern Prawn Fishery shares similarities with the ECOTF in terms of target species, diversity of by-catch composition, prohibition on the retention of any shark products and mandatory use of TEDs and BRDs.

The introduction of TEDs in the Northern Prawn Fishery was shown to reduce the catch of sharks by 17.7 per cent, and rays by 36.3 per cent, although the numbers of larger sharks and rays (> 1 m) were reduced by 86 per cent and 94 per cent respectively (Brewer et al. 2006). The number of the most commonly caught species of sawfish (*Anoxypristis cuspidata*, the narrow sawfish) was reduced by 73.3 per cent.

Given the observed frequency of interaction with a number of species, the risks to sharks and rays from the ECOTF were assessed in detail (Section 4.4.7).

Seabirds

Discards from trawling are an important part of the diet of some seabirds (Blaber et al. 1995) and may influence the breeding success and hence population sizes of these species (Blaber et al. 1998). For example, reductions in the amount of discards led to a reduction in the populations of crested terns in the northern section of the Great Barrier Reef Region (Poiner et al. 1998). Generally, seabirds in the Great Barrier Reef Region feed on discards that float, but over 80 per cent by weight of trawl discards sink and are consumed on the seabed by fish, small sharks and some crustaceans (e.g. cirolanid isopods) (Hill and Wassenberg 2000, C.P. Pitcher, pers. comm., 2012).

Direct capture and mortality of seabirds by the ECOTF is considered to be negligible. For example, in 2006 and 2007 low levels of interaction were recorded with seabirds, with one gannet and one gull reported as caught and released alive, and one tern reported as having died (DEEDI 2009a, 2010a). However, as some species of seabirds are known to scavenge food from the trawl fleet, scavenging by seabirds is considered in Section 4.7 on ecosystem processes.

Sea snakes

The by-catch of sea snakes in Australian prawn trawl fisheries was highlighted by Ward (1996) for the Northern Prawn Fishery off northern Australia. Heatwole and Burns (1987) had also previously raised this issue. Sea snakes can drown or be injured in trawl nets. Milton (2001) identified two species, *Hydrophis pacificus* large-headed sea snake and *Disteira kingii* spectacled sea snake, to be at high risk from the effects of trawling in northern Australia and mitigating the impacts of trawling was one of the conditions for the Australian Government granting the Northern Prawn Fishery an export approval. More recently, comparisons of nets with and without BRDs showed that the popeye fishbox BRD produced an 85 per cent reduction and a fisheye BRD produced a 43 per cent reduction in sea snake catch (Milton et al. 2008).

Interactions with sea snakes are the most common interactions reported between protected species and the ECOTF (DEWR 2007). In the ECTF (for otter and beam trawl), it was estimated that on average 105,210 sea snakes (including at least 12 different species) are caught each year of which 27,272 (25.9 per cent) died (Courtney et al. 2010). The estimate of total sea snake catch was based on a function which considered the average annual level of trawl fishing effort from 2003 to 2007, therefore the estimate is subject to the level of trawl effort. As effort has declined in recent years, it is highly likely that this estimate of sea snake catch has also declined (A.J. Courtney, pers. comm., 2012).

Most of this sea snake total catch (58.9 per cent) and most of the deaths (84.5 per cent) were in the red-spot king prawn fishery sector, because of the high spatial overlap between the areas fished and the habitat of the sea snakes. The by-catch in this sector includes bulky, calcareous and venomous by-catch that may injure sea snakes once caught in trawl nets. The fisheye BRD reduced the sea snake catch rate by 63 per cent (with no reduction in the catch rate of marketable prawns) but the position of the BRD in the net was very important for its effectiveness (Courtney et al. 2010).

The study also concluded that there was probably under-reporting of sea snake catch and mortality in the Queensland SOCI logbooks. The SOCI logbook records for the ECOTF indicated that operators caught 3493 sea snakes in 2008, and 3089 sea snakes in 2009, of which 3189 and 2890 were released alive respectively (DEEDI 2009a, 2010a). Although these data are subject to the same under-reporting issue, the spatial information is still interesting; therefore these records are mapped on Figure 14.

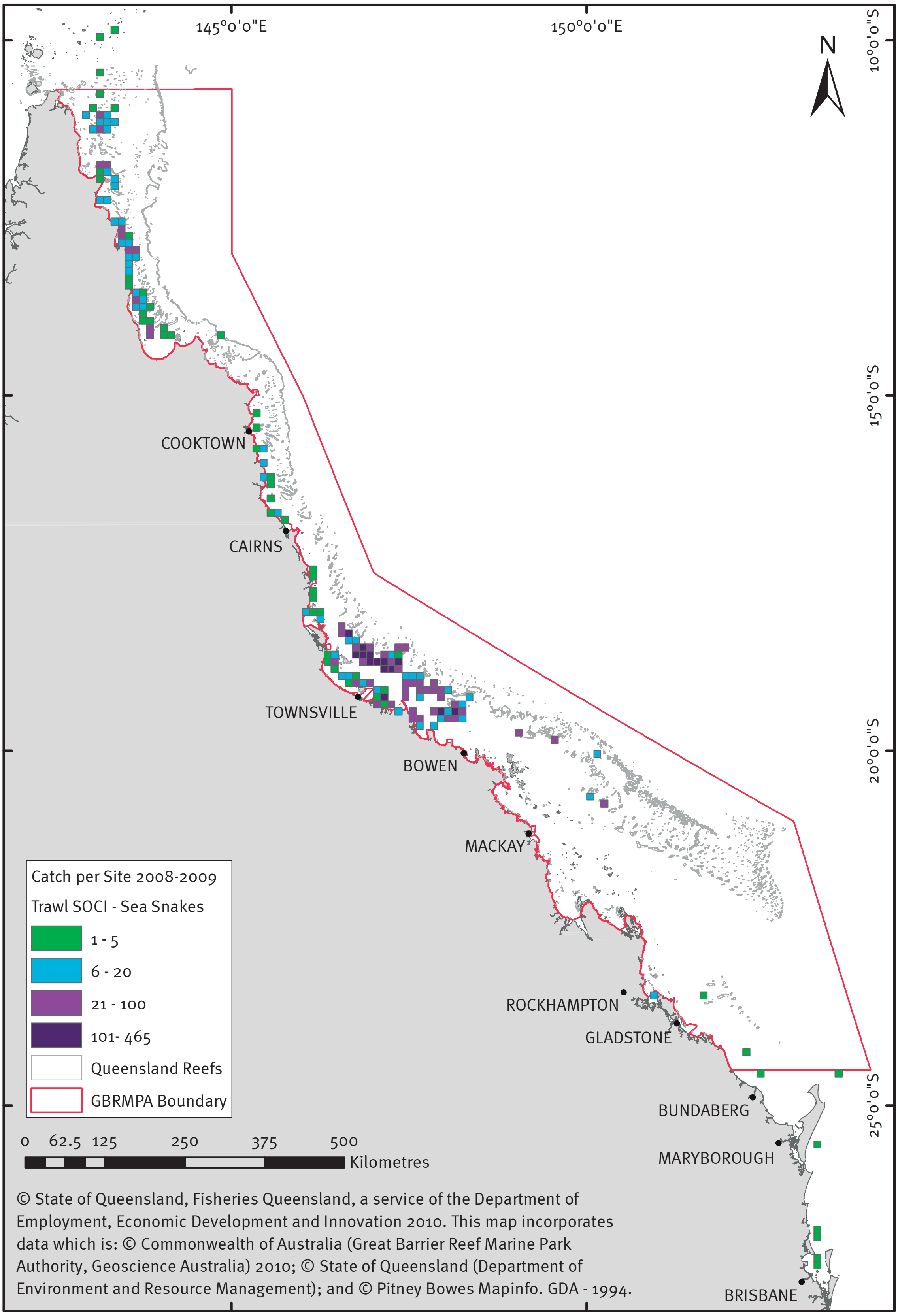


Figure 14. Reported interactions between the ECTF and sea snakes for 2008 and 2009, based on Species of Conservation Interest logbook records from commercial fishers.

Earlier experiments on survival of sea snakes caught by demersal trawlers in prawn fishing grounds of northern and eastern Australia (prior to the introduction of BRDs or TEDs) estimated that about half of those caught died (Wassenberg et al. 2001). For the Northern Prawn Fishery between 1989 and 1991, sea snake mortality was estimated to be between 33,591 and 45,664 animals in the tiger/endeavour prawn fishery and between 5734 and 6998 in the banana prawn fishery (Wassenberg et al. 2001). The survival rate was higher for smaller total catch weights for the two most commonly caught species (*Hydrophis elegans* elegant sea snake and *Lapemis hardwickii* spine-bellied sea snake (now called *L. curtus*)) and was also higher for shorter tow durations for *L. hardwickii* (Wassenberg et al. 2001).

Given the high level of interaction with a number of species, and the information discussed above on potentially low survival rates, the risk to sea snakes from the ECOTF was assessed in detail (Section 4.4.5).

Seahorses, pipefish and seadragons (syngnathids)

Under Australian Government legislation, the incidental harvest of Duncker's pipehorse (*Solegnathus dunckeri*) and pallid pipehorse (*Solegnathus cf. hardwickii*) by licensed operators in the ECOTF is permitted under a Wildlife Trade Operation approval granted under the *Environment Protection and Biodiversity Conservation Act 1999*. Both species are believed to be endemic to Australia and are listed as data deficient by the IUCN (Morgan et al. 2006). Catch data for pipefish is reported in Table 22 and Table 24.

In the Seabed Biodiversity Project (Pitcher et al. 2007b), two of seven species of syngnathids sampled were assessed, and no species of pipefish, seahorses or seadragons were among the top 50 or so species recommended for management attention because of possible sustainability concerns. However, there is known to be some interaction between seahorses and pipefish and the ECOTF, in addition to the retention of the permitted pipefish species. For example, in 2008 the SOCI logbook records for the ECOTF indicated that operators caught 13 seahorses, all of which were released alive (DEEDI 2009a). In 2006, similarly low levels of interaction were recorded with seahorses (DEWR 2007). As even a low level of mortality may put some species of conservation concern at risk, the risk to seahorse and pipefish from the ECOTF was assessed in detail (Section 4.4.6).

Marine turtles

Prior to the compulsory use of TEDs in the early 2000s, trawling was considered to be a major cause of turtle mortality through drowning. In the ECOTF in the 1990s, the average annual catch of turtles was estimated to be 5295 ± 1231 at a rate of 0.068 turtles per boat per day (Robins 1995). The main species caught were loggerhead turtles (*Caretta caretta*), 50.4 per cent, green turtles (*Chelonia mydas*), 30.1 per cent, and flatback turtles (*Natator depressus*), 10.9 per cent. That study was based on data from 1991 and 1992 before TEDs became mandatory, when there were about 900 operators in the fishery and when the total effort in the fishery was 80,558 boat-days (effort levels would have been substantially lower within the Great Barrier Reef Region). Fishing effort had fallen by about 66 per cent to a total for the fishery of 35,300 days in 2008, and this recent level of effort would be expected to result in a similar reduction in the number of turtle interactions per year for the ECOTF if other factors determining interaction rates had remained similar to the time of the Robins study. In considering the risk for marine turtles (and for other species of conservation concern and by-catch) from interaction with the trawl fishery, it is important to take account of survival after interaction as well as interaction rate. Today the majority of marine turtles that interact with the ECOTF are believed, based on overseas studies, to escape alive through TEDs.

The number of marine turtles landed on deck is now reported to be low in the ECOTF. For example, the SOCI logbook records for the ECOTF indicated that operators landed two flatback turtles in 2008 and three flatback turtles in 2009, all of which were released alive (DEEDI 2009a, 2010a).

Similarly, before the introduction of TEDs in the Northern Prawn Fishery, between 2000 and 5000 turtles were estimated to have been caught each year (Poiner et al. 1990). The use of TEDs and BRDs in the Northern Prawn Fishery has been shown to have reduced the number of turtles landed on deck by 99 per cent, while reducing the catch of commercially important prawns by six per cent but improving the proportion of soft and damaged prawns by 41 per cent (Brewer et al. 2006).

TEDs are usually positioned at the beginning of the trawl net's codend, and are a modification that allows larger animals to escape after being initially taken into the net. The use of TEDs is mandatory for otter trawls used in the ECOTF, but are not required in the small 'try gear' that is used in short duration tows by fishers to investigate likely catch and fishing conditions for their main gear (DEEDI 2009a).

The information discussed above shows that, although TEDs dramatically reduce the number of turtles landed on deck, six species of marine turtles still potentially interact with activities of the trawl fishery (e.g. by contact without capture, Table 3). Therefore marine turtles were assessed in detail (Section 4.4.4).

Trawling impacts on benthic habitats

The effects of trawling on seabed (benthic) habitats have been of substantial concern for many decades, particularly in areas of the world where there have been anecdotal reports of active clearing of seabed structure using heavy trawling gear. Early studies on the impact of trawling on tropical marine habitats off the north-west shelf of Australia, where the by-catch rates of sponges had decreased from over 500 kg/h to only a few kilograms per hour, suggested substantial changes in benthic structure with consequent negative changes to the catch composition of targeted fishes (Sainsbury 1987, Sainsbury et al. 1993).

An early review of trawling internationally by Jones (1992) concluded that, although it was often difficult to isolate causes for environmental changes, permanent faunal changes brought about by trawling have been recorded, and the level of impact is related to the type and weight of the gear on the seabed, the towing speed, the nature of the seabed sediments, and the strength of the tides and currents. Later meta-analyses of many international studies by Collie et al. (2000) and another by Kaiser et al. (2006) similarly showed that trawl impacts depended on the interaction of gear type and habitat dynamics, with the effects of otter trawling generally less than for other forms of trawling and less in naturally disturbed habitats. However, these meta-analyses did not separate studies on prawn trawls from those on other types of trawls designed to target scallops or fish, nor did they separate effects on infauna from epifauna. Scallop dredges and Dutch beam trawls used in other places are designed to penetrate the sediments and may be expected to affect the infauna more than otter trawls. Fish otter trawls examined in these studies were typically large, with heavy ground gear capable of being towed over structured habitat where larger fish are more abundant and long-lived sessile fauna may naturally occur. In comparison, typical Australian commercial prawn trawling gear is light and the target species are more abundant on silty habitats, which are often disturbed naturally by bioturbation and/or wind–wave action and have little long-lived emergent fauna (Pitcher et al. 2007b).

In the Great Barrier Reef Region, large-scale experimental research has been combined with simulation modelling to assess the effects and sustainability of trawling for prawns, the exposure of seabed species to risk from trawling, the protection provided by Marine Park zoning, and the effects of alternative fisheries management scenarios. These studies are outlined below.

In 1991–1996, the effects of prawn trawling were investigated in the 'Green Zone' of the far northern Great Barrier Reef (Poiner et al. 1998), which was closed to trawling in 1985, and areas to the north and south that remained open to trawling. Three experiments investigated the direct effects of trawling on seabed habitats and animals. The first assessed seabed species assemblages in and out of the closed zone, and found no significant differences that could be attributed unambiguously to trawling and that many of the differences between areas were probably due to environmental factors. The lack of differences was probably due to the combination of the level of natural variation in population densities, the effects of illegal trawling in closed areas, variability in the distribution of trawl effort in the open areas, and relatively low levels of trawl effort (Burridge et al. 2006). The second experiment simulated broad-area low-intensity trawling, and found no significant impact from a single trawl coverage and estimated removal (discard) rates of sessile benthos of about five per cent; much less than prior expectations and evidence (Pitcher et al. 2009). In the third experiment, which simulated intensive trawling repeatedly targeting small productive patches of prawns, each trawl removed about five to 25 per cent of seabed animals but the combined effect of 13 trawls over the same paths was substantial, removing about 70 to 90 per cent (Burridge et al. 2003).

These experiments showed that the cumulative effect of high intensity prawn trawling may be substantial. However, very few areas of the fishery were fished as intensively as the repeat-trawl experiment, and trawl impacts may be difficult to detect at low intensity (Poiner et al. 1998). To assess the effects of trawling and sustainability risks for seabed animals, it was necessary to measure recovery rates, examine commercial trawl effort patterns, map habitat and species distributions, and integrate these results in a spatial modelling framework (the 'Trawl Scenario Model') (Pitcher et al. 2000).

The recovery of populations of attached seabed animals was monitored (Pitcher et al. 2008) after the repeat-trawl experiment. While natural variability was substantial, the experiment indicated that 20 to 75 per cent of the species, their condition and much of the structure they provide recovered during the term of the study, but some other species were predicted to require decades. Another experiment, which measured the growth and deaths of tagged seabed animals (Pitcher et al. 2004), found that while some species could grow very quickly, recovery including recruitment of new individuals would typically take 5–20 years.

In 2003–2006, the seabed habitats and their biodiversity in the Great Barrier Reef Region were sampled by towing video cameras, a benthic sled at 1400 sites and a trawl at about 400 sites (Pitcher et al. 2007b). The results were used to map the distribution of habitats and abundance of about 850 of the more abundant seabed species to assess the status of seabed biodiversity. The assessment showed that trawling negatively affected about four per cent of species by one to 36 per cent and positively affected two per cent of species by one to 96 per cent. Further, most species had low or very low exposure to trawl effort. Importantly, seabed species shown in the impact and recovery experiments to be vulnerable to trawling, had distributions that overlapped little with commercial trawl fishery effort. Further, the mapping showed that the 2004 rezoning of the Great Barrier Reef increased the average level of protection by 30 per cent and achieved the target of protecting at least 20 per cent of all shelf seabed habitats (Pitcher et al. 2007a).

The research results on distributions, impact and recovery of seabed animals, as well as trawl fleet dynamics and management actions were integrated by a computer simulation model (Ellis and Pantus 2001) which predicted that the status of seabed animals typically declined as effort increased to its peak in 1996, and if effort had remained at year 2000 levels their status would have improved slightly above 1997 levels (Pitcher et al. 2007b). However, these generalised depletion trends up until the late 1990s have all been arrested and reversed by the sequence of management interventions implemented over a decade — the 2001 buyback of fishing licences and subsequent penalties on transfers made the biggest positive contributions, with the 2004 rezoning of the marine park and buyback of affected effort making a small positive contribution for some species that interact with trawling.

In the *Great Barrier Reef Outlook Report* (GBRMPA 2009), the physical impacts of fishing (which includes the impacts on marine habitats from trawling) were assessed as posing a medium risk to the Great Barrier Reef ecosystem. The report also recognised that trawling has the potential to cause habitat damage if not appropriately managed, and that damage to more sensitive lagoon communities may have occurred in the past. Ongoing habitat impacts in most regularly trawled areas are likely to be low as studies show these areas to be generally muddy, silty or sandy and likely to be regularly disturbed naturally (Pitcher et al. 2007b). The overall area in which trawling can occur has also been reduced through spatial closures (Pitcher et al. 2007a).

The risk to shelf habitats was assessed in detail (Section 4.5) as there is a potential interaction with several activities of the fishery.

Trawling impacts on species assemblages

Impacts of otter trawling on assemblages of species has seldom been investigated. This may in part reflect the difficulty in defining functional assemblages.

The assessment of seabed biodiversity in the Great Barrier Reef Region (Pitcher et al. 2007b) identified over 5300 species, of which only 850 (16 per cent) occurred at more than 25 sites (less than two per cent of the 1400 sites visited). Nevertheless, 16 relatively homogenous compositional groups were identified and mapped on the basis of their biophysical relationships. These site groups were consistent with gradients between high and low mud areas, shallow and deep areas, high and low current areas, with further separations on sediments, water chemistry and turbidity. The researchers found that trawl effort intensity was not a significant factor which defined species assemblages, i.e. there was not a single, typical trawl ground benthic species assemblage.

Based on data on the level, distribution and intensity of fishing effort in 2005, it was determined that most of these assemblages had very low to low exposures to trawl effort; three had exposures between 32 per cent and 41 per cent, one had an exposure of 58 per cent, and the highest was 108 per cent (Pitcher et al. 2007b). This indicator is an estimate of the percentage of area of each assemblage directly exposed to trawl effort taking into account the intensity of trawl effort, and may exceed 100 per cent where substantial areas of seabed are trawled more than once per year (as explained in Appendix 2.2.4). The Seabed Biodiversity Project (Pitcher et al. 2007b) also examined cumulative trawl exposure for species which occurred repeatedly across the more highly exposed assemblages, in which species with higher affinities for several more exposed assemblages would have a higher ranking.

The risk to species assemblages was assessed in detail (Section 4.6) as there are potential interactions with several activities of the fishery.

4.1.3. RISK CHARACTERISATION

The above literature review (Section 4.1.2) and expert knowledge of the fishery were used to examine potential interactions, and hence assign initial risk levels, between each of the activities of the ECOTF and the broad components of the ecosystem (Table 4). Initial risks were characterised as high (H), intermediate (I), low (L) or negligible or not applicable (blank) (Table 4), taking account of the scale and intensity of potential interactions. This assessment focused on the potential direct impacts and was used to see if any components might be excluded from more detailed analysis.

Potential indirect interactions with these ecological components were assessed separately as ecosystem processes, reported in Section 4.7.

Table 4. Summary of initial risk scores for ecological components from the main activities of the fishery.

Ecological component	Main activities of the fishery						
	Harvesting	Discarding	Contact without capture	Loss of fishing gear	Travel to/from grounds	Disturbance due to presence in area	Boat maintenance, emissions
Harvested: principal and other permitted species	H	H/I	I/L	L			
By-catch species		H	I/L	L			
Species of conservation concern		H	I/L	L	I/L	I/L	
Marine habitats		L	H	L			L
Species assemblages	I	I	H-L?				L

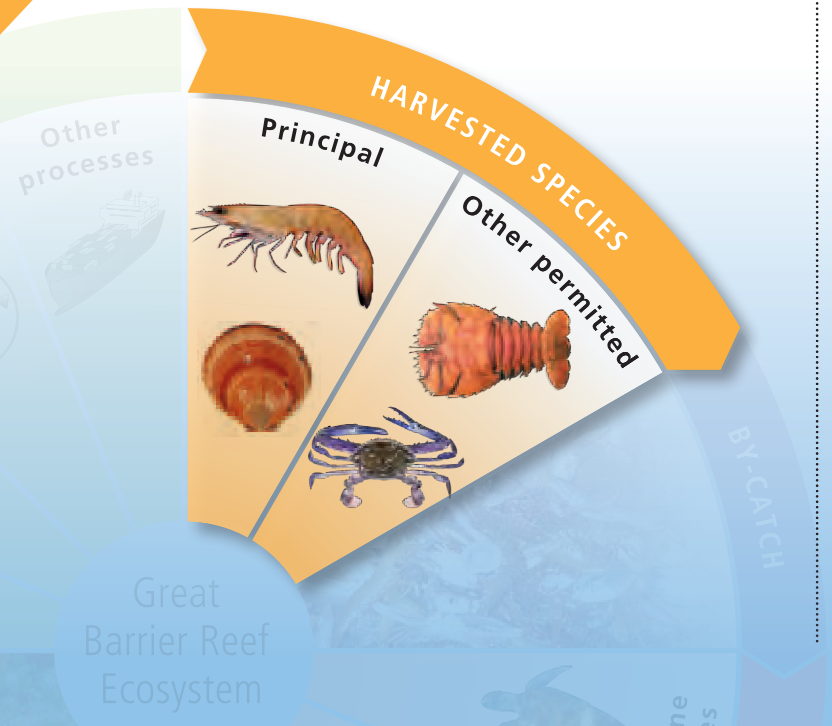
H=high, I=intermediate, L=low, blank=negligible or not applicable.

The main activities are described in Table 3.

4.1.4. ECOLOGICAL COMPONENTS REQUIRING FINER LEVEL ASSESSMENT

All ecological components showed at least an intermediate level of initial risk to at least one of the activities of the fishery. All were therefore carried through to the more detailed phase of the risk assessment process. However, the information discussed in Section 4.1.2 and a shortlisting process based on the best available information were used to determine which ecological subcomponents should be included in this process. Details of this shortlisting process are provided in the relevant risk identification sections in the remainder of Section 4.

Summary: Harvested species



Key facts

Ecological component assessed: Principal (target) species and other permitted species. All harvested species were assessed in detail because the fishery interacts significantly with each of these species.

Ecological role: These fishery species fulfil diverse ecological roles across a range of habitats. For example, scallops are particle feeders and prawns are detritivores. Harvested species are exposed to, or involved in, many ecosystem processes (e.g. predation).

Trawl fishery: Several prawn species, scallops, Moreton Bay bugs and squid are target species of the fishery. Various other species (e.g. some fish, three-spotted crabs, octopus and cuttlefish) are also retained for market.

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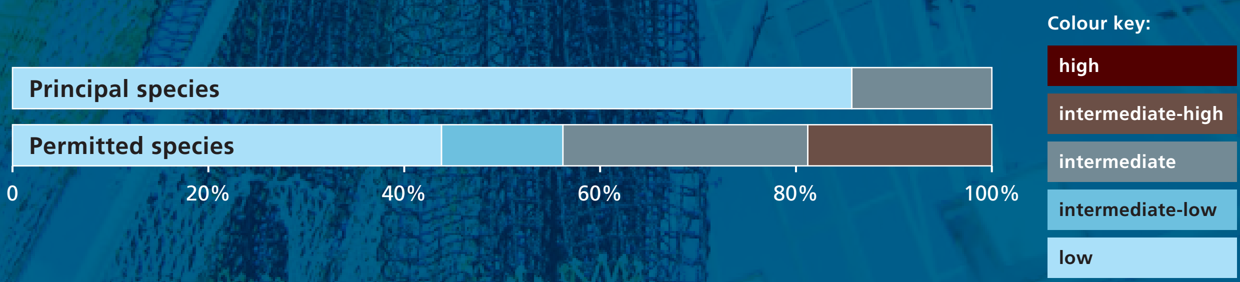
Consequences to avoid over the next 20 years: Excessive depletion of any harvested species (indicated by breaching the relevant limit reference point or any harvested species being classified as recruitment overfished). The aim is to ensure they continue to fulfil their ecological roles, support ecosystem processes and are able to provide seafood products into the future.

The direct ways trawling activities could cause excessive depletion of harvested species over a 20-year period, if risks are not managed:

Harvesting	By reducing the biomass and spawning stock of populations of harvested species to below sustainable levels
Discarding	By adding another source of fishery-induced mortality to a population
Contact without capture	By collective damage to individuals of harvested species without capturing them

FIGURE 15: OVERALL PATTERN OF RISK AT 2009 LEVELS OF TRAWL FISHING EFFORT



4.2. Harvested species

The risks to harvested species considered in Section 4.2 were primarily from the activities of harvesting and discarding by the ECOTF, but also the activity of contact without capture where relevant (definitions in Table 3). Later in Section 4, other risks *to* populations of harvested species, and *from* the harvesting of species to the ecosystem are considered. For example, risks to productive seabed habitats that support harvested species are assessed in Section 4.5. Risks to species assemblages (some of which include prawns and other harvested species) are assessed in Section 4.6. Risks to ecosystem processes (Section 4.7) considers, amongst other things, the flow-on effects of the trawling activities on harvested species to relevant ecosystem processes (e.g. effects on prawns are considered under detritivory and effects on scallops are considered under particle feeding, etc.). This all contributes to the consideration of current risks to the Great Barrier Reef ecosystem from trawling.

4.2.1. RISK CONTEXT

In setting the risk context for harvested species, ecologically sustainable use requirements under Section 3AA of the *Great Barrier Reef Marine Park Act 1975* were considered. Extractive use of natural resources, including fishing, is required to be within the capacity of the Region and its natural resources to sustain natural processes...and consistent with long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region (the main objective of that Act).

These requirements for fishing to be ecologically sustainable are also recognised and supported by DAFF Queensland in their work to conserve and enhance the community's fisheries resources and fish habitats. The DAFF Queensland goal of managing principal and other permitted species harvested commercially in the ECOTF is to ensure that the take of the species is ecologically sustainable, socially responsible and economically viable. The social and economic aspects of this goal, however, are outside the scope of this assessment.

The risk assessed was:

What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will breach the relevant limit reference point or lead to any harvested species or populations in the Great Barrier Reef Marine Park being classified as overfished (= recruitment overfished) within the next 20 years?

The reference points considered in this assessment were informed by reviews and policy guidelines, which in turn were grounded in the scientific literature and informed by empirical studies around the world (e.g. Myers et al. 1994, O'Neill et al. 2005). In general, limit reference points are set to avoid unacceptably high risks to the ecological component being assessed, for example the point at which recruitment overfishing is thought to occur for a harvested species.

Reference points developed by DAFF Queensland were used as a basis for assessing ecological risk, where available (DEEDI 2009b, 2010c). For target species, setting reference points for both biomass and fishing mortality is considered best practice (Sainsbury 2008).

Biomass and related population structures also influence other species as well as key ecosystem processes and functions; these influences were considered as part of the assessment of risks to other components. A relatively large biomass and full age/size structures for a population are considered more likely to be sustainable as genetic diversity and food webs are more likely to be maintained, and the population will be more resilient to recruitment overfishing and environmental perturbations. In essence, for both ecological sustainability and economic profitability, it is highly desirable to avoid very low levels of population biomass and to maintain relatively high levels. Identifying and maintaining an appropriate level of biomass is made difficult by factors such as measurement error, assessment error and natural variability (Sainsbury 2008).

Fishing mortality is under more direct fisheries management control, for example through regulation of catch, fishing effort, and other fishery rules, but in itself is less closely associated with ecosystem processes supporting a population.

The use of biomass and fishing mortality reference points requires that they, or some reasonable proxies for them, be estimated to assess the status of the stock and determine the appropriate management response.

Fisheries Queensland's process to assess the exploitation status (stock status) of Queensland's key fish stocks provides an assessment of whether or not a harvested species is overfished (DEEDI 2010c).

4.2.2. RISK IDENTIFICATION

All harvested species were assessed in detail because the fishery interacts significantly with each of these species.

Principal species targeted by the fishery in the Great Barrier Reef Region are:

- eastern king prawn (*Melicertus plebejus*)
- red-spot king prawn (*M. longistylus*)
- blue-legged king prawn (*M. latisulcatus*)
- brown tiger prawn (*Penaeus esculentus*)
- grooved tiger prawn (*P. semisulcatus*)
- black tiger prawn (*P. monodon*)
- blue endeavour prawn (*Metapenaeus endeavouri*)
- false endeavour prawn (*M. ensis*)
- banana prawn (*Fenneropenaeus merguiensis*)
- Moreton Bay bugs (*Thenus australiensis* and *T. parindicus*)
- saucer scallop (*Amusium balloti*)
- Asian moon/mud scallop (*A. pleuronectes*)
- squid (*Uroteuthis* spp. and *Sepioteuthis lessionana*).

Other permitted species are:

- Balmain bugs (*Ibacus alticrenatus, Ibacus chacei* and *Ibacus brucei*)
- slipper lobsters (*Scyllarides* spp.*,* includes *Scyllarides squammosus, Scyllarides haanii*)
- red champagne lobsters/barking crayfish (*Linuparus trigonus*)
- blue swimmer crab (*Portunus armatus*)
- three-spotted crab (*Portunus sanguinolentus*)
- mantis shrimp (Family Squillidae)
- octopus (*Octopus* spp.)
- cuttlefish (*Sepia* spp. and *Metasepia* spp.)
- threadfin bream/pinkies (Family Nemipteridae)
- pipefish (*Solegnathus cf. hardwickii* and *Solegnathus dunckeri*). (Note that pipefish were assessed as species of conservation concern, see Section 4.4.6.)

Information was assessed at the species level, where possible. Where detailed information was not available at the species level, the quality of data was generally considered to be low:

- For principal species, assessments at the species level were completed for all but one case: squid were evaluated at the 'species group' level because of the similar life histories for the major commercially important species.
- For other permitted species, slipper lobster, mantis shrimp and cuttlefish were evaluated at the species group level.

The key activities of the fishery likely to affect harvested species were harvesting and discarding (Table 4). Fishing reduces the biomass and spawning stock of marine resource species. In general, 'growth overfishing' occurs when too many small fish are harvested, e.g. fish are harvested prior to reaching the average size equivalent to the maximum yield per recruit. 'Recruitment overfishing' occurs when the proportion of older fish comprising the spawning stock are reduced, resulting in decreasing annual recruitment into the population and ultimately may lead to the collapse of the stock.

Discarding of harvested species in the ECOTF is generally low for principal species, but may be significant for some other permitted species on occasions. Discarding for these potentially valuable species would normally only occur if the catch is unmarketable, has a legal size limit or other output control (e.g. not allowed to retain egg-bearing females), or has a lower economic value. The risk posed by discarding relates to the added (but sometime poorly quantified) source of fishery-induced mortality to a population, which is a function of the quantity discarded and the survival of individuals after they have been returned to the water.

Trawling can also affect harvested species by damaging, but not capturing, individuals or indirectly through damage to seabed habitats that support harvested species. The initial risk to harvested species from 'contact without capture' was assessed as intermediate to low (Table 4) based on available knowledge from research and observations of the fishery.

4.2.3. RISK CHARACTERISATION

Information on the impact of trawling on harvested species was collated from a variety of sources with different levels of reliability, including:

- published research literature and reports, including fishery status reports, other quantitative stock assessments and fishery independent monitoring
- commercial fisher logbooks, fishery effort data and fishery observer program
- expert opinion of both scientists and commercial fishers.

Resilience levels of harvested species

Resilience of principal and other permitted species harvested by the fishery was assessed using the seven characters and decision rules detailed in Table 30.

The determination of the resilience levels of harvested species was based on general biological and ecological principles. Resilience characters included the type of trait used to assess 'productivity' in some risk assessment methods (Musick 1999), such as fecundity, growth rate and natural mortality. In addition, the distribution and abundance of the species was assessed, since how widely a species is distributed gives an indication of the potential for refuges from fishing and other impacts. Known external pressures (i.e. non-ECTF related pressures such as modification of coastal ecosystems or predicted climate change vulnerabilities) were explicitly considered under 'cumulative pressures' as external pressures may increase the susceptibility of a species to the effects of trawling, and hence lower its resilience. Population size or trend was considered as a character in the NSW study and in this assessment, but not used in either final assessment for harvested species as there were generally no data available. Growth rate was included, and is correlated with age at maturity, which was used in the NSW assessment, but that has been replaced here with natural mortality.

The detailed resilience data for harvested species is presented in Data Report: Appendix 1 and Data Report: Appendix 2.

The overall resilience level for each species or species group was determined by summing the number of risk prone scores attributed to each species/species group. Levels of resilience for harvested species were assigned qualitatively as either high (H; 0 prone), intermediate-high (H-I; 1 to 2 prone), intermediate (I; 3 prone), intermediate-low (I-L; 4 to 5 prone) or low (L; 6 or more prone out of a maximum risk prone score of 9).

All principal species were evaluated to have a high or intermediate-high resilience (Table 31). The resilience levels of other permitted species were mixed (Table 32), with intermediate resilience for red champagne lobster and red-spot night octopus, and intermediate-low resilience for slipper lobster and hammer octopus.

Fishery impact profiles of harvested species

The second part of the finer level assessment involved qualitative evaluation of the fishery impact profile using 13 factors to indicate the level of pressure exerted by the fishery on the species being assessed (Table 33). Some of the factors used for principal species differed slightly from those used for other permitted species, as noted in Table 33, to reflect the available information base and that the former are target species of the fishery, whereas the latter are incidentally caught by-products.

Appendix 2.2.4 explains some factors used in this assessment that were derived from quantitative indicators from the Seabed Biodiversity Project. Estimates of 'per cent caught' and 'per cent effort exposed' were based on 2005 levels of trawling effort in the fishery, taking intensity of trawling into account (Pitcher et al. 2007b). Where possible, 2005 data was compared to revised data based on 2009 levels of trawling effort as outlined in Appendix 2.2.4. The Seabed Biodiversity Project estimates of per cent caught were used after removing the BRD effect they included, as BRD effects were covered by another factor called 'BRD effectiveness'.

The NSW assessment of the Ocean Trawl Fishery used a factor concerned with whether the fishery targets sites where aggregations of the species occurs, however this factor was not considered informative for the ECOTF. Areas inaccessible to trawling within the General Use (light blue) Zone of the Great Barrier Reef Marine Park were taken account of under the estimates of effort exposure.

The detailed fishery impact profile data for harvested species is presented in Data Report: Appendix 3 to Data Report: Appendix 6.

The overall fishery impact profile for each species was determined by summing the number of risk prone scores attributed to each species. The fishery impact profile of each species was assigned qualitatively as either low (L; less than 5 prone), intermediate-low (I-L; 5 or 6 prone), intermediate (I; 7 or 8 prone), intermediate-high (H-I; 9 or 10 prone) or high (H; 11 or more prone out of a maximum risk prone score of 16).

The fishery impact profile of principal species for 2009 was low or intermediate-low for all species, except for grooved tiger prawn and Asian moon (mud) scallop which were intermediate, see Table 34. The fishery impact profile of other permitted species for 2009 varied from low to intermediate-high, with threadfin bream (pinkies), mantis shrimp, red champagne lobster (barking crayfish) and slipper lobster assigned as intermediate, and the three species of Balmain bugs assigned as intermediate-high, see Table 35.

In 2005, some species had higher fishery impact profiles (Table 36 and Table 37), reflecting the higher overall fishing effort levels (see Data Report: Appendix 3 and Data Report: Appendix 5).

Risk for harvested species

The risk gradings for harvested species are summarised in Table 5 and Table 6. The risk gradings were obtained by combining the resilience levels and fishery impact profile levels as shown on the risk matrix in Figure 13.

In summary for 2009:

- No harvested species in the ECOTF in the Great Barrier Reef Region were assessed as at high risk.
- One permitted species group taken incidentally as by-product (three species of Balmain bugs) had an intermediate-high risk level. An intermediate-high risk corresponds to species that have a higher level of fishery impact with at least an intermediate level of resilience (Figure 13).
- Two principal species (grooved tiger prawn and Asian moon scallop) and four other permitted species/species groups (slipper lobster, red champagne lobster, threadfin bream and mantis shrimp) had an intermediate risk level. An intermediate level of risk corresponds to species with intermediate levels of fishery impact, and high to low levels of resilience (Figure 13).
- Other harvested species had an intermediate-low or low level of risk from trawling.

Compared to the higher 2005 trawl fishing effort levels, overall risk to harvested species in 2009 was lower, with fewer species at intermediate-high risk. Four principal species, i.e. Asian moon (mud) scallop, Moreton Bay bug (mud bug), brown tiger prawn and tropical saucer scallop, had lower risk gradings in 2009 compared to 2005, and these are shown in Table 5. Similarly, mantis shrimp, threadfin bream (pinkies) and cuttlefish had lower risk gradings in 2009 compared to 2005, as shown in Table 6.

Table 5. Risk assessment of principal species (ordered according to 2009 risk levels).

Common name	Scientific name	Resilience	Fishery impact profile 2005	Risk 2005	Fishery impact profile 2009	Risk 2009
Asian moon (mud) scallop	*Amusium pleuronectes*	H	H-I	INT-HIGH	I	INT
Grooved tiger prawn	*Penaeus semisulcatus*	H	I	INT	I	INT
Moreton Bay bug (mud bug)	*Thenus parindicus*	H-I	H-I	INT-HIGH	I-L	LOW
Brown tiger prawn	*Penaeus esculentus*	H	I	INT	I-L	LOW
Tropical saucer scallop	*Amusium japonicum balloti*	H	I	INT	I-L	LOW
Moreton Bay bug/spotted legs (reef bugs)	*Thenus australiensis*	H-I	I-L	LOW	I-L	LOW
Black tiger prawn	*Penaeus monodon*	H	I-L	LOW	I-L	LOW
Blue-legged king prawn	*Melicertus latisulcatus*	H	I-L	LOW	I-L	LOW
False endeavour prawn	*Metapenaeus ensis*	H	I-L	LOW	I-L	LOW
Red-spot king prawn	*Melicertus longistylus*	H	I-L	LOW	I-L	LOW
Blue endeavour prawn	*Metapenaeus endeavouri*	H	I-L	LOW	L	LOW
Eastern king prawn	*Melicertus plebejus*	H-I	L	LOW	L	LOW
Squid spp. (pencil & tiger)	*Uroteuthis (Photololigo)* spp. & *Sepioteuthis*	H-I	L	LOW	L	LOW
White banana prawn	*Fenneropenaeus merguiensis*	H-I	L	LOW	L	LOW

Table 6. Risk assessment of other permitted species (ordered according to 2009 risk levels).

Common name	Scientific name	Resilience	Fishery impact profile 2005	Risk 2005	Fishery impact profile 2009	Risk 2009
Deepwater bug (velvet Balmain bug)	*Ibacus alticrenatus*	H-I	H-I	INT-HIGH	H-I	INT-HIGH
Shovel-nosed lobster (honey Balmain bug)	*Ibacus brucei*	H-I	H-I	INT-HIGH	H-I	INT-HIGH
Smooth bug (garlic Balmain bug)	*Ibacus chacei*	H-I	H-I	INT-HIGH	H-I	INT-HIGH
Mantis shrimp	Family Squillidae, order Stomatopoda	H-I	H-I	INT-HIGH	I	INT
Threadfin bream (pinkies)	Family Nemipteridae	H-I	H-I	INT-HIGH	I	INT
Slipper lobsters	*Scyllarus martensii, Scyllarus demani, Scyllarides squammosus, Scyllarides haanii*	I-L	I	INT	I	INT
Red champagne lobster (barking crayfish)	*Linuparus trigonus*	I	I	INT	I	INT
Hammer octopus	*Octopus australis*	I-L	I-L	INT-LOW	I-L	INT-LOW
Red-spot night octopus	*Callistoctopus dierythraeus*	I	I-L	INT-LOW	I-L	INT-LOW
Cuttlefish	*Sepia spp.*	H-I	I	INT	I-L	LOW
Scribbled night octopus	*Callistoctopus graptus*	H-I	I-L	LOW	I-L	LOW
Southern star-eyed octopus	*Amphioctopus cf. kagoshimensis*	H-I	I-L	LOW	I-L	LOW
Plain-spot octopus	*Amphioctopus exannulatus*	H	I-L	LOW	I-L	LOW
Veined octopus	*Amphioctopus marginatus*	H	I-L	LOW	I-L	LOW
Three-spotted crab (red-spotted crab)	*Portunus sanguinolentus*	H	I-L	LOW	L	LOW
Blue swimmer crab	*Portunus armatus*	H-I	L	LOW	L	LOW

Note: Pipefish were assessed as species of conservation concern (see Section 4.4.6).

4.2.4. ISSUES ARISING FROM THE RISK ASSESSMENT FOR HARVESTED SPECIES

For harvested species, the risk assessed was *'What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will breach the relevant limit reference point or lead to any harvested species or populations in the Great Barrier Reef Marine Park being classified as overfished within the next 20 years?'*. This section discusses the overall patterns of risk for harvested species, and any species identified as at intermediate or higher risk, against this risk context, and discusses the progress made in reducing risks and impacts, and other issues arising from the assessment.

Overall patterns of risk for harvested species

Based on 2009 trawl effort levels, all but two principal species (Asian moon scallop and grooved tiger prawn) were at low risk from trawling, and all principal species were assessed as resilient to fishery impacts. Their relatively high resilience is advantageous for the industry given that these are the target species upon which the fishery depends, and a couple of them had at least an intermediate fishery impact profile (depending upon the year considered).

Several other permitted species taken as by-product were at intermediate or intermediate-high risk in the Great Barrier Reef Region, based on 2009 levels of trawl fishing effort. The resilience of other permitted species was mixed, and generally supports the use of low possession limits or other controls to discourage targeting and limit the total harvest of these species.

The overall pattern of ecological risk for principal and permitted species at 2009 levels of trawl fishing effort is shown in Figure 15. There was a reduction in the number of harvested species at identified risk and a lower overall level of risk for principal and permitted species between 2005 and 2009 (Table 5 and Table 6). The key driver of this reduction in risk was the decrease in trawl fishing effort in the Great Barrier Reef by over 40 per cent in this time period. The proportion of the Great Barrier Reef Marine Park trawled more than once per year has also declined over the last decade (from about nine per cent in 2001 to about six per cent in 2009, Appendix 2.2.3), and this is likely to have reduced the risk to marine habitats and the species they support including commercial species.

Comments on identified risks to harvested species or species groups

The intermediate risk to grooved tiger prawns (*P. semisulcatus*) in 2009 partly resulted from the level of fishing pressure on the species. The high effort exposure value (of over 50 per cent) indicates the species is exposed to a high intensity of fishing effort from trawling. The fishery also tends to target areas where species with a high market demand (such as grooved tiger prawns) occur, which can result in the biomass being fished down to low levels in some areas. In the Exmouth Gulf and Northern Prawn trawl fisheries, there have been declines in tiger prawns due to high effort, with appropriate management responses to facilitate stock recovery (Wang and Die 1996, Dichmont et al. 2006, Kangas et al. 2006). However, the Exmouth Gulf example was for brown tiger prawns (*P. esculentus*), which may be more prone to recruitment overfishing than grooved tiger prawns (A.J. Courtney, pers. comm., 2012). Other risk prone fishery impact factors that resulted from uncertainties could potentially be mitigated by improving the information base for this commercially valuable species. Such steps could include collecting more data at the species level, qualitative assessment of the stock status, and quantitative stock assessment. Tiger prawns are not reported on separately in catch data, and although fishers can identify the different species, it would not be practical to report this information during normal commercial operations. However, some monitoring information is available at the species level. At 2005 effort levels, brown tiger prawn and grooved tiger prawn had high or very high effort exposure values and both species were assessed as at intermediate risk for similar reasons to those discussed above. As the tiger prawn fishery is seasonal, the species are not targeted for several months of the year. There are also a range of other measures (e.g. protection of inshore nursery areas, mesh size regulations) in place to protect these species from overfishing.

Asian moon (or mud) scallop is a commercially valuable species often taken in prawn trawl gear, it has an uncertain stock status, no stock assessment has been made, and there is a lack of species-level catch data. Small and large individuals are retained in trawl gear and sold (there is no minimum legal size). Current BRDs are not suitable for the exclusion of small Asian moon scallops, particularly if taken using prawn trawl nets. However, the unwanted component of the catch is also low for mud scallops as they are valuable at all sizes and there is no minimum legal size. The species may also be affected by interactions with trawl gear without being caught. These factors contributed to an intermediate risk in 2009. At the higher 2005 fishing effort levels, the estimated per cent caught and effort exposure values raised the risk profile of Asian moon scallop to intermediate-high.

Balmain bugs are a valuable by-product species in the shallow- and deepwater eastern king prawn fishery and are permitted to be retained. Partly because the species live in less studied deep waters, there is a lack of knowledge on stock distribution, stock size, refuge availability and exposure to fishing effort. However, fishery experts assessed catch and effort related factors as risk prone because the proportion of the population exposed to trawling and the proportion caught are expected to be moderately high for these species which are known to occur on trawl grounds in deeper water within the southern Great Barrier Reef Region. Discard rates of undersized individuals were estimated to be greater than 10 per cent, and there was no information at the time of the assessment to indicate BRDs are effective at excluding the unwanted component of the catch for these species (Data Report: Appendix 6). All these factors increased the estimates of risks posed by 2009 levels of fishing effort, and populations of all three species within the Great Barrier Reef were assessed as at intermediate-high risk from trawling in both 2009 and 2005. Minimum legal sizes and a prohibition on the take of egg-bearing females are already in place to help protect these species, and the southern trawl closure (for shallow waters) may have some benefit for egg-bearing females.

For the red champagne lobster and the three other permitted species groups (slipper lobster, threadfin bream and mantis shrimp) with an intermediate risk level in 2009, only limited biological information is available, exploitation status has not been assessed, BRDs are unlikely to be effective for these species, and for the three species groups there is a lack of species-level data. Some additional factors contributed to risk for particular species (Table 35). For example, overall discarding of threadfin bream and mantis shrimp in the Great Barrier Reef Region was considered to be high, which adds another form of fishery-induced mortality to a population, and is related to how much is discarded and how well individuals survive after trawling.

Legally, other permitted species are not allowed to be targeted, but before red champagne lobster (barking crayfish) was declared as a permitted species it used to be targeted in specific deepwater areas. Since becoming a permitted species, fishery logbook data suggest that red champagne lobster is no longer targeted and logbook data indicate that catches for this species have declined markedly (Haddy et al. 2003). Slipper lobsters were reported as permitted species by fishers from May 2009 (around the time slipper lobsters were added to the permitted species list for the fishery), but the reported quantity retained in that year was negligible (only about 4 kg, recorded as 0 tonnes in the ECOTF 2010 Annual Status Report). Starting in 2010, fishers have been asked to specifically record 'slipper lobster' landings in the logbook to facilitate future monitoring and assessment for these species. While significant catches of mantis shrimp are caught incidentally throughout the ECTF (see Appendices in Courtney et al. 2007 listing by-catch by sector), their retention and marketing are largely limited to the Moreton Bay fleet, probably because markets are strongest in the Brisbane region.

Seabed Biodiversity Project estimates of protection levels under Marine Park zoning (see Appendix 2.2.4) for these intermediate-risk permitted species were high, ranging from 34 to 65 per cent protected. No published protection level estimates were available for red champagne lobster, which occur outside the depth range studied by the Seabed Biodiversity Project. However, experts considered it is likely that substantial protected refugia exist for this species due to the protection provided by Marine Park zoning and that other measures in place for these species (e.g. size limits, possession limits, compliance effectiveness, and relevant fishery closures, Appendix 2.1.7) were generally considered adequate to protect reproductive function and prevent overfishing (Data Report: Appendix 3 to Data Report: Appendix 6).

Known external pressures not related to the ECTF (such as modification of coastal ecosystems or predicted climate change vulnerabilities) were explicitly considered under a character called 'cumulative pressures' because external pressures may increase the susceptibility of a species to the effects of trawling, and hence lower its resilience. For the key commercial species within the Great Barrier Reef Region, the only identified cumulative pressure was from trawl fishing pressure outside of this area on the stock of eastern king prawns (its distribution extends from Queensland to Tasmania). Over longer time periods, climate change may also affect these species (Morison and Pears 2012).

Progress made in reducing risks and impacts

The assessment recognised the range of current mitigation measures, and prior actions by management and industry have helped to address historical risks and contributed to the relatively low risk to harvested species. Important actions with benefits to the fishery resources and productive habitats have included introducing an effort management system into the fishery in 2001, capping effort levels at that time at five per cent less than 1996 levels representing a 15 per cent reduction in effort, closing areas under the Trawl Plan and reinforcing this protection under the rezoning of the Great Barrier Reef Marine Park in 2004. The fishery now has a decade of detailed spatial information following the introduction of a satellite-based vessel monitoring system under the Trawl Plan. Industry members involved in the expert workshops recognised the benefits this has provided to the industry, such as being better able to determine the current level of risk posed by the fishery to many of the species and habitats.

Additionally, recent reductions in risk from 2005 to 2009 were shown for Asian moon (mud) scallop, Moreton Bay bug (mud bug), brown tiger prawn and tropical saucer scallop, mantis shrimp, threadfin bream (pinkies) and cuttlefish. For some of these species, such as cuttlefish and mud bugs, current risk has now dropped below intermediate levels, and this progress in reducing risks and impacts is recognised. Notwithstanding the significant reduction in risk from intermediate-high in 2005 to low in 2009, the discard rate for undersized mud bugs is still contributing to risk for this species compounded by the recent management changes permitting the take of berried female bugs. The BRDs used by most of the fishery at the time of the assessment are not well designed for the exclusion of undersized Moreton Bay bugs (including mud bugs) and improvements to BRD designs are being considered under the current review of fishery management arrangements. Industry members are involved in ongoing initiatives with Fisheries Queensland to ensure best practice in by-catch reduction is adopted for the trawl fishery (Section 5), and this work is expected to further reduce risks to several commercial species (as well as by-catch and the broader ecosystem).

Further issues and information gaps

Fishing effort levels in both 2005 and 2009 were well within allowable levels. At higher fishing effort levels in 2005, several harvested species or species groups were at intermediate-high risk. Therefore, these species should be given due consideration in prioritisation processes for fishery assessment and monitoring to ensure sustainability of these species into the future and the long-term viability of the industry. Ways to improve the adequacy of management controls on fishing effort (or catch) to ensure the sustainability of harvested species are being considered under the current review of fishery management arrangements (see Section 5).

Several information gaps were identified for harvested species. For example, it was necessary to make assumptions about several resilience characters for Asian moon scallop, which were assumed to be similar to tropical saucer scallop, increasing the uncertainty in the risk assigned. As for all components, the risks and information gaps identified in this assessment will inform the priorities for future research, monitoring and assessment. Research priorities include those species at identified risk and information gaps mentioned in this section, plus brown tiger prawns and tropical saucer scallop (there was an intermediate risk to the latter two species based on 2005 effort levels).

Summary: By-catch species

Key facts

Ecological component assessed: Species caught and landed on deck but then discarded (not including any harvested species or species of conservation concern). The detailed assessment focused on the 45 most at-risk by-catch species, which were identified through a shortlisting process based on current understanding of the exposure of species to risk from activities of the fishery.

Ecological role: Part of biodiversity of Great Barrier Reef ecosystem. Fulfil various ecological roles and help sustain ecosystem processes such as herbivory, predation, connectivity and competition.

Trawl fishery: By-catch species in the trawl fishery comprises hundreds of species, many of which are caught very infrequently.

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Consequences to avoid over the next 20 years: By-catch species being no longer able to renew themselves (indicated by populations no longer being maintained, no longer able to fulfil their ecosystem role, or being excessively depleted). The impact of the fishery on these species should avoid excessively reducing their spawning and recruitment ability and avoid other serious detrimental effects.

The direct ways trawling activities could exceed the ability of by-catch species to renew themselves over a 20-year period, if risks are not managed:

Discarding	By reducing the population size of by-catch species to below sustainable levels
Contact without capture	By collective damage to individuals of by-catch species without capturing them

FIGURE 16: OVERALL PATTERN OF RISK AT 2009 LEVELS OF TRAWL FISHING EFFORT

Colour key:

- high
- intermediate-high
- intermediate
- intermediate-low
- low

4.3. By-catch species

4.3.1. RISK CONTEXT

Species that may be by-catch in the ECOTF are part of the biological diversity of the Great Barrier Reef ecosystem. They may play an ecological role in one or more species assemblages (or ecological communities) and they help sustain ecosystem processes such as herbivory, predation, connectivity and competition.

In setting the risk context for by-catch species, the *Great Barrier Reef Marine Park Act 1975* and *Fisheries Act 1994* were taken into account, including their requirements for long-term protection of the Great Barrier Reef...and maintenance of world heritage values and integrity ... and ecologically sustainable use of the Great Barrier Reef Region and its natural resources... and protection of biological diversity, ecological processes and life-support systems. In line with this, the requirements when considering species-level risks from an ecological perspective were that the impact of the fishery on these species will not excessively reduce the spawning and recruitment ability of the species and will avoid other serious detrimental effects, such that populations of by-catch species are maintained and continue to fulfil their ecosystem role and are not excessively depleted. Additionally, impacts on by-catch should not cause serious or irreversible change to habitats, species assemblages or ecosystem processes, and the risks to these other components are considered in later sections.

The risk assessed was:

> *What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will exceed the ability of the species to renew themselves, such that populations of by-catch species in the Great Barrier Reef Marine Park are no longer maintained or no longer fulfil their ecosystem role or are excessively depleted within the next 20 years?*

Stock status has not generally been formally determined for by-catch species and specific reference points are not set for such species by DAFF Queensland. In view of this, the findings for by-catch in a review of best practice reference points for Australian fisheries by Sainsbury (2008) are considered here.

The current best practice limit reference point for fishing mortality, as recommended in Sainsbury (2008), is 0.75 of the natural mortality rate, but this will be lower for species with very low productivity (e.g. for species likely to have very low natural mortality or very low steepness in the stock-recruitment relationship). A directly comparable indicator for individual species was used in the Seabed Biodiversity Project.

Sainsbury (2008) noted interim limits to catch or fishing mortality for by-catch species must be lower than that implied by the limit reference point (the latter should be the same as for targeted and retained species), and reflect what is currently regarded as being feasible or acceptable (Sainsbury 2008).

4.3.2. RISK IDENTIFICATION

The by-catch in the ECOTF comprises over a thousand species, many of which are very infrequently caught (Pitcher et al. 2007b, Courtney et al. 2007, 2010). A shortlisting process was used to identify the subset requiring finer level assessment, based on current understanding of the exposure of species to risk from the activities of the fishery. In summary, by-catch species were assessed in detail that met any of the following criteria:

1. Species recommended for ongoing management attention by the Seabed Biodiversity Project (Pitcher et al. 2007b). These species were the top 20 most highly ranked species for four risk indicators from the 840 species assessed in detail, and resulted in a list of 50 or so species (there are some taxonomic uncertainties). Of these, 42 were non-retained species and included in the detailed assessment of by-catch species (the remainder were harvested species and already included in the detailed assessment for that group).

2. Species identified for consideration of potential trawling interactions in previous fishery ecological risk assessments (Roelofs 2008). Three species of commercial importance in the marine aquarium fish trade were assessed.

3. Additional species of interest to expert stakeholders where there were ecological, economic, cultural and/or social reasons for detailed assessment of their interaction with the trawl fishery. For example, a species potentially at risk or that is ecologically important such as for an ecosystem process being assessed, a resource species important to another fishery or of interest to trawl fishers as potential by-product, a species with special cultural significance, or a species valued by recreational anglers. No additional species were included under this criterion.

We assessed a total of 45 by-catch species in detail. A caveat to this assessment is that the shortlisting process used for by-catch may have excluded species from consideration that may be at genuine risk, such as rare species for which there were insufficient data to make an assessment. (Some rare and/or 'at risk' species that interact with the fishery are considered under the assessment of species of conservation concern in Section 4.4.) Any future ecological risk assessment should review the shortlist and determine if additional species warrant detailed assessment.

Discarding was identified as an initial high risk for all by-catch species and contact with fishing gear without capture was initially rated as an intermediate to low risk (Table 4). In demersal otter trawl fisheries such as the ECOTF, the impact on by-catch species from discarding or contact without capture will be strongly influenced by the amount, distribution and intensity of fishing effort in relation to the species abundance and distribution. Risks to species were quantified for the more abundant species in the Seabed Biodiversity Project (Pitcher et al. 2007b). Estimates of species exposure to trawling showed that most species mapped had very low or low exposure, but about 33 of 840 species assessed had high to very high exposure in 2005. Of these species, taking catchability into account, five species had high estimates of proportion of standing biomass caught annually.

Discarded by-catch species also represent a source of food for other animals (e.g. fish, birds, dolphins) (Blaber et al. 1995, Hill and Wassenberg 2000, Svane 2005, Svane et al. 2008). The likely impacts of food provisioning on populations was considered under 'scavenging' and 'detritivory' in the assessment of ecosystem processes, see Section 4.7.

4.3.3. RISK CHARACTERISATION

Information on by-catch species distributions and relative abundance was derived from the Seabed Biodiversity Project (Pitcher et al. 2007b) and related studies (Poiner et al. 1998, Pitcher et al. 2008), work by Courtney and co-workers on by-catch in the various sectors of the trawl fishery (Stobutzki et al. 2000, Stobutzki et al. 2001, Courtney et al. 2007) other scientific literature, FishBase, unpublished data from the Fisheries Queensland Fisheries Observer Program and from expert opinion (where data was unavailable). For many species, there was little or no biological information available from the Great Barrier Reef Region to address many of the characters on which the assessment was based.

Resilience levels of by-catch species

Resilience of by-catch species was assessed using the six characters and decision rules detailed in Table 38. These characters were a simplified version of the resilience characters for harvested species to suit the more limited knowledge base for most non-commercial species in the Great Barrier Reef Region.

The depth range of a species was considered as a resilience character, after the NSW process, but was not used in the Great Barrier Reef assessment process because it was not considered very informative in addition to the characters 'mode of life' and 'habitat association'.

The detailed resilience data for by-catch species is presented in Data Report: Appendix 7.

The overall resilience level for each by-catch species was determined by summing the number of risk prone scores attributed to each species. Levels of resilience for by-catch species were assigned qualitatively as either high (H; 0 prone), intermediate-high (H-I; 1 prone), intermediate (I; 2 prone), intermediate-low (I-L; 3 or 4 prone) or low (L; 5 or more prone out of a maximum risk prone score of 7).

The resilience levels of by-catch species were mixed, ranging from low to high (Table 39 and Data Report: Appendix 7).

Fishery impact profiles of by-catch species

The fishery impact profile was derived from five factors used to indicate the level of pressure exerted by the fishery on by-catch species (Table 40). A factor used for harvested species called 'interaction throughout life cycle' was trialled but removed from the scoring due to lack of information for most by-catch species.

As for harvested species, estimates of 'per cent caught' and 'per cent effort exposed' were based on 2005 and 2009 levels of trawling effort in the fishery, taking intensity of trawling into account, and may exceed 100 per cent (Pitcher et al. 2007b) (see also Appendix 2.2.4). The Seabed Biodiversity Project estimates of per cent caught were used after removing the BRD effect they included, as BRD effects were covered by another factor called 'BRD effectiveness'.

The detailed fishery impact profile data for by-catch species is presented in Data Report: Appendix 8 and Data Report: Appendix 9.

The overall fishery impact profile for each species was determined by summing the number of risk prone scores attributed to each species. The fishery impact profile of each species was assigned qualitatively as either low (L; 0 or 1 prone), intermediate-low (I-L; 2 prone), intermediate (I; 3 prone), intermediate-high (H-I; 4 prone) or high (H; 5 or more prone out of a maximum risk prone score of 7).

The fishery impact profile of by-catch species ranged from low to intermediate at 2009 effort levels (Table 41). In 2005, some species had higher fishery impact profiles (Table 42), reflecting the higher fishing effort levels, giving profiles ranging from low to high (Data Report: Appendix 8).

Risk for by-catch species

The risk gradings for by-catch species are summarised in Table 7 based on 2005 and 2009 effort levels. The risk gradings were obtained by combining the resilience levels and fishery impact profile levels as shown on the risk matrix in Figure 13.

In summary for 2009:

- No otter trawl by-catch species in the Great Barrier Reef Region were assessed as at high or intermediate-high risk based on 2009 fishing effort levels.
- Three by-catch species (tufted sole, whipfin ponyfish and longfin silverbiddy) were assessed as at intermediate risk from trawling at 2009 effort levels.
- The other 42 by-catch species assessed in detail were at intermediate-low or low risk, and 37 by-catch species had lower risk ratings in 2009 compared to 2005.
- The risk from trawling for each of the many additional species that are caught as trawl by-catch on occasions (but were not shortlisted for detailed assessment) are likely to be low to negligible at 2009 effort levels. However, see a caveat relating to the shortlisting process above.

The by-catch species with lower risk gradings based on the 2009 fishing effort levels compared to 2005 levels are shown Table 7. No by-catch species were at higher risk in 2009 than 2005.

Table 7. Risk assessment for by-catch species (ordered according to 2009 risk levels).

Group	Common name	Scientific name	Resilience	Fishery impact profile 2005	Risk 2005	Fishery impact profile 2009	Risk 2009
Ray-finned fish	Tufted sole	*Brachirus muelleri / Dexillichthys muelleri*	I-L	H	HIGH	I	INT
Ray-finned fish	Whipfin ponyfish	*Leiognathus leuciscus / Equulites leuciscus*	I-L	H	HIGH	I	INT
Ray-finned fish	Longfin silverbiddy	*Pentaprion longimanus*	I	H-I	INT-HIGH	I	INT
Ray-finned fish	Pearly-finned cardinal fish	*Apogon poecilopterus*	I	H	HIGH	I-L	INT-LOW
Ray-finned fish	Shortfin saury (short-finned lizardfish)	*Saurida argentea/tumbil*	I	H	HIGH	I-L	INT-LOW
Ray-finned fish	Hairfin goby	*Yongeichthys nebulosus*	I	H	HIGH	I-L	INT-LOW
Ray-finned fish	Trumpeter whiting	*Sillago maculata*	L	H-I	HIGH	I-L	INT-LOW
Ray-finned fish	Rough flutemouth	*Fistularia petimba*	I-L	H-I	HIGH	I-L	INT-LOW
Gastropod	Small sea snail	*Lamellaria* sp1	I-L	H-I	HIGH	I-L	INT-LOW

Group	Common name	Scientific name	Resilience	Fishery impact profile 2005	Risk 2005	Fishery impact profile 2009	Risk 2009
Ray-finned fish	Blotched javelin	*Pomadasys maculatus*	I-L	H-I	HIGH	I-L	INT-LOW
Ray-finned fish	Largescale saury (brushtooth lizardfish)	*Saurida grandisquamis/ undosquamis*	I-L	H-I	HIGH	I-L	INT-LOW
Ray-finned fish	Longnose stinkfish	*Calliurichthys grossi / Callionymus grossi*	I	H-I	INT-HIGH	I-L	INT-LOW
Ray-finned fish	Flathead dragonet	*Repomucenus belcheri / Callionymus belcheri*	I	H-I	INT-HIGH	I-L	INT-LOW
Ray-finned fish	Ochreband goatfish	*Upeneus sundaicus*	I	H-I	INT-HIGH	I-L	INT-LOW
Crustaceans	Hairy crab (Family Pilumnidae)	*Cryptolutea arafurensis*	I-L	I	INT	I-L	INT-LOW
Sea pens	Sea pen	Sea pen *(Pteroides?)* sp1 of Pitcher et al. 2007b	I-L	I	INT	I-L	INT-LOW
Crustaceans	Hardback shrimp (penaeid shrimps)	*Trachypenaeus anchoralis*	I	I	INT	I-L	INT-LOW
Ray-finned fish	Personifer angelfish	*Chaetodontoplus meredithi*	I-L	I-L	INT-LOW	I-L	INT-LOW
Ray-finned fish	Pineapple fish	*Cleidopus gloriamaris*	I-L	I-L	INT-LOW	I-L	INT-LOW
Ray-finned fish	Damselfish sp.	*Pristotis obtusirostris*	I-L	I-L	INT-LOW	I-L	INT-LOW
Ray-finned fish	Razorfish	*Aeoliscus strigatus*	I	I-L	INT-LOW	I-L	INT-LOW
Ray-finned fish	Australian threadfin	*Polydactylus multiradiatus*	I	I-L	INT-LOW	I-L	INT-LOW
Ray-finned fish	Naked-headed catfish	*Euristhmus nudiceps*	I-L	H	HIGH	L	INT-LOW
Ray-finned fish	Australian halibut	*Psettodes erumei*	I-L	H	HIGH	L	INT-LOW
Ray-finned fish	Prickly leatherjacket	*Chaetodermis penicilligera*	I-L	H-I	HIGH	L	INT-LOW
Ray-finned fish	Spotted-fin tongue-sole	*Cynoglossus maculipinnis*	I-L	I	INT	L	INT-LOW
Ray-finned fish	Splendid ponyfish	*Leiognathus splendens / Eubleekeria splendens*	I-L	I	INT	L	INT-LOW
Crustaceans	Purse crab (Family Leucosiidae)	*Myra tumidospina*	I-L	I	INT	L	INT-LOW
Ray-finned fish	Yellowfin tripodfish	*Tripodichthys angustifrons*	I-L	I	INT	L	INT-LOW

Group	Common name	Scientific name	Resilience	Fishery impact profile 2005	Risk 2005	Fishery impact profile 2009	Risk 2009
Ray-finned fish	Blacktip tripodfish (long-nosed tripodfish)	*Trixiphichthys weberi*	I-L	I	INT	L	INT-LOW
Crustaceans	(Hermit crab)	*Diogenidae* sp356-1 of Pitcher et al. 2007b	I-L	I-L	INT-LOW	L	INT-LOW
Bivalves	Bivalve sp.	*Enisiculus cultellus*	I-L	I-L	INT-LOW	L	INT-LOW
Gastropod	Sea snail	*Aplysia* sp1_QMS of Pitcher et al. 2007b	H-I	H-I	INT-HIGH	I-L	LOW
Ray-finned fish	Orangefin ponyfish	*Leiognathus bindus / Photopectoralis bindus*	H-I	H-I	INT-HIGH	I-L	LOW
Crustaceans	Swimming crab (Family Portunidae)	*Portunus gracilimanus*	H-I	H-I	INT-HIGH	I-L	LOW
Ray-finned fish	Pygmy leatherjacket	*Brachaluteres taylori*	H-I	I	INT	I-L	LOW
Ray-finned fish	Largescale grunter (banded grunter)	*Terapon theraps*	H-I	I	INT	I-L	LOW
Ray-finned fish	Fourlined terapon	*Pelates quadrilineatus*	H	I	INT	I-L	LOW
Ray-finned fish	Spinycheek grunter	*Terapon puta*	I	H	HIGH	L	LOW
Ray-finned fish	Sunrise goatfish (sulphur goatfish)	*Upeneus sulphureus*	H-I	H-I	INT-HIGH	L	LOW
Crustaceans	Blunt-toothed crab	*Charybdis truncata*	I	I-L	INT-LOW	L	LOW
Bivalves	Family Glycymerididae	*Melaxinaea vitrea*	I	I-L	INT-LOW	L	LOW
Bivalves	Bivalve sp.	*Placamen tiara*	I	I-L	INT-LOW	L	LOW
Crustaceans	Swimming crab (Family Portunidae)	*Portunus tuberculosus*	I	I-L	INT-LOW	L	LOW
Gastropod	Sea snail	*Nassarius cremmatus cf.*	H	L	LOW	L	LOW

4.3.4. ISSUES ARISING FROM THE RISK ASSESSMENT FOR BY-CATCH

For by-catch species, the risk assessed was *'What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will exceed the ability of the species to renew themselves, such that populations of by-catch species in the Great Barrier Reef Marine Park are no longer maintained or no longer fulfil their ecosystem role or are excessively depleted within the next 20 years?'*. This section discusses the overall patterns of risk for by-catch species, and any species identified as at intermediate or higher risk, against this risk context, and discusses the progress made in reducing risks and impacts, and other issues arising from the assessment.

Overall patterns of risk for by-catch

The overall pattern of risk for the 45 by-catch species assessed in detail at 2009 levels of trawl fishing effort is shown in Figure 16. No by-catch species were assessed as at high risk from trawling in the Great Barrier Reef Region based on 2009 effort levels, and three species were at intermediate risk. The resilience of by-catch species varied widely, as did the fishery impact profiles for by-catch. At the higher 2005 trawl effort levels, 33 species were identified as being at intermediate or higher risk (Table 7). These species comprised 13 species of ray-finned fish and a species of gastropod at high risk of being unable to renew themselves, or being excessively depleted from trawling, a further eight by-catch species at intermediate-high risk (i.e. six ray-finned fish, one gastropod, one crustacean (Table 7)) and 11 species at intermediate risk. [These species counts do not include species of conservation concern, which were assessed separately (Section 4.4)].

The species-level results are recognised as a positive result demonstrating the improvements made towards by-catch reduction by the industry. However, there is still a substantial amount of non-retained catch from trawling in the Marine Park (Figure 4.13 in GBRMPA 2009). In practice, all trawl by-catch species cannot be monitored and managed individually, hence ensuring their individual sustainability is not practical (Sainsbury and Sumaila 2003). Instead, by-catch reduction efforts will continue to focus on reducing the overall amount of by-catch and addressing priority issues identified through this and other processes (e.g. assessments of the fishery under the EPBC Act).

Opportunities for further improvements to reduce the amount of by-catch generated through trawling have been considered including a number of factors that influence the amount and survival of trawl by-catch: spatial and temporal overlap between species distributions and fishing effort, type of gear, gear selectivity, by-catch reduction devices, duration of the trawl shot, the depth fished, the size and species composition of the catch, and handling practices. Ongoing efforts by managers and the trawl industry to reduce the amount of by-catch and improve the survival of these species are important to minimise the environmental impact of trawling, and are discussed below and in Section 5.

Comments on identified risks

Of the three by-catch species at intermediate risk from trawling at 2009 effort levels, the tufted sole and whipfin ponyfish had an intermediate-low resilience to fishing or other pressures, and longfin silverbiddy had an intermediate resilience, and each species had an intermediate fishery impact profile. These same species had improved from their previous high or intermediate-high risk based on the higher 2005 effort levels.

The tufted sole is a widespread flatfish found over sand but not abundant anywhere, and its high catchability in trawl gear combined with high exposure to the fishery and presumed ineffectiveness of BRDs for this species resulted in several risk prone factors. The longfin silverbiddy forms large schools, may be trawled in depths of up to 70 metres, and has poor survival after capture. As this fish is believed to occur closer to the seabed in daylight hours, it is most likely to be caught by the daytime banana prawn fishery, but may sometimes be caught at night around the time of the full moon. The whipfin ponyfish is found in coastal/inshore waters in the central and northern Great Barrier Reef Region (and elsewhere), is generally seen in early evening catches, and is thought to have a habitat association with trawl grounds. This ponyfish is extremely common in trawl by-catch in north Queensland, where it is captured at sizes less than maturity, has low survival, and may be affected by cumulative pressures such as from poor water quality. There were no known cumulative pressures for the other two species, and all three have at least 30 per cent protection of their estimated distribution under Marine Park zoning. Of all 45 by-catch species assessed in detail, cumulative pressures were considered likely to affect only three additional species (splendid ponyfish, trumpeter whiting and spinycheek grunter).

None of the top three species of concern identified in the Seabed Biodiversity Project (rough flutemouth, tufted sole, and blacktip tripodfish, Appendix 2.2.4) were found to be at high risk based on 2009 effort levels.

The assessment took account of the habitat association of the rough flutemouth, which for juveniles includes trawled areas, whereas adults (as ambush predators) are believed to be more reef-structure associated, and some refuge is available in deeper untrawled areas. Current low estimates of per cent caught and effort exposure were reflected in the assessment which, despite presumed poor survival and ineffectiveness of TEDs/BRDs, assigned an intermediate-low risk to rough flutemouth from otter trawling. The tufted sole was one of only three by-catch species assigned an intermediate risk based on 2009 effort levels. Both tufted sole and rough flutemouth were deemed at high risk in the assessment based on 2005 effort levels, driven by high or very high per cent caught and per cent effort exposures. The blacktip tripodfish, which inhabits sandy and muddy flats of coastal waters and feeds on benthic invertebrates, was at intermediate risk in 2005 and intermediate-low risk in 2009.

The catch and effort related fishery impact factors derived from the Seabed Biodiversity Project were given a strong (double prone) weighting in this assessment to reflect the large potential contribution of these factors to risk from the fishery (Section 3.3). Hence, it was not unexpected that our results using 2005 data would be similar to the Seabed Biodiversity Project findings, which also considered 2005 effort levels. However, the current assessment also considered three additional factors in the fishery impact profile for by-catch (i.e. survival after capture, effectiveness of TEDs/BRDs, refuge availability in the Great Barrier Reef, Table 40). In doing so, the current assessment was able to overcome challenges in interpreting high scores in the former project.

Progress made in reducing risks and impacts

There was a significantly reduced level of risk to trawl by-catch species in the Great Barrier Reef Region from lower 2009 levels of effort compared with 2005. This finding highlights the clear role a reduction in trawl fishing effort has had in reducing ecological risk, and reinforces the importance of adopting best practice regarding by-catch reduction throughout the fishery, especially as trawl effort is not constrained by management to current levels (the trawl effort cap for the Great Barrier Reef World Heritage Area is about double current trawl fishing effort levels, although effort levels that high are unlikely to be reached due to prevailing economic conditions, see Appendix 2.1.7). Additionally, many prior actions by managers and industry have contributed to the reduced risk to by-catch species from trawling, including the use of TEDs and BRDs, protection of areas from trawling, and industry stewardship initiatives. Reducing by-catch is increasingly recognised as having benefits for industry (e.g. improvements in the efficiency of operations and product quality), as well as the environment (Roy and Jebreen 2011).

It is encouraging to see a number of fishers have voluntarily adopted fishing practices with lower impacts on the environment, and several initiatives are under way or planned with industry to encourage further uptake of best practice across the fishery (see Section 5). For example, new prawn trawling otter boards designed and adopted by some fishers reduce physical impacts on the seabed and also reduce towing resistance and fuel usage (Sterling 2008, 2010). Additionally, many industry members have been actively working with DAFF Queensland to trial and improve BRDs, and this work is helping to inform the optimum selection of BRDs for different subsectors of the fishery.

Further issues and information gaps

The ongoing progress being made by the industry to reduce the risks to and impacts on by-catch is outlined above (and in Section 5). Despite low levels of risk to by-catch species based on 2009 effort levels and a significant reduction in risk since 2005, specific opportunities for improvements in the reduction of by-catch of certain species were identified. For example, the development of BRDs better suited to the exclusion of flatfish, however, this may be difficult to achieve in practice. It is important that future management arrangements for the fishery and the Great Barrier Reef Marine Park have appropriate flexibility to encourage and support innovation in by-catch reduction.

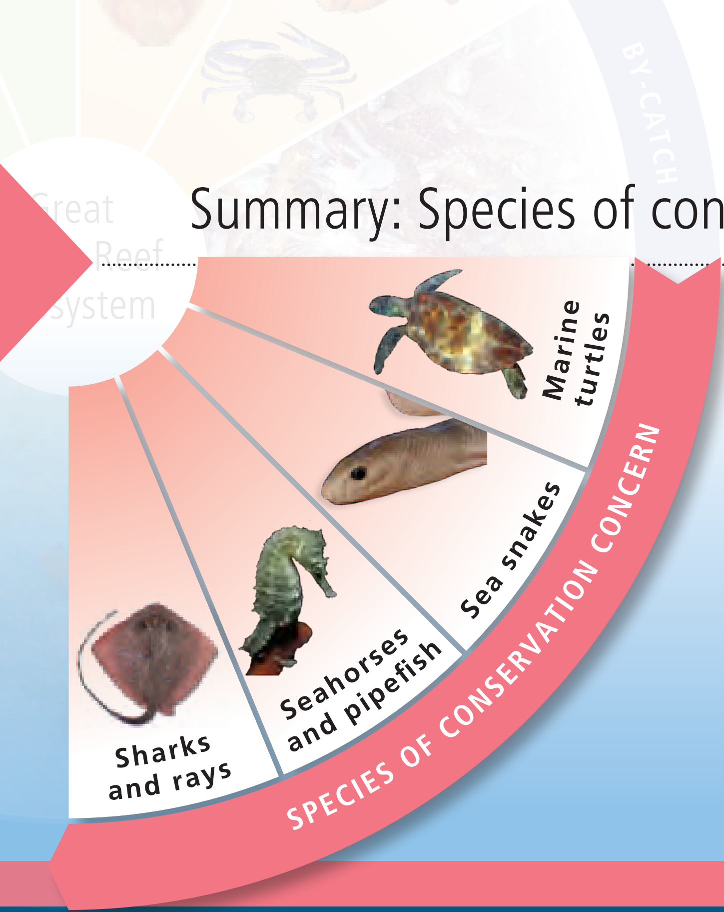
Given trawl effort is a key driver of ecological risk, implementing future fishery management arrangements that can control the amount of fishing effort in an area could help ensure overall risks for by-catch species remain low.

This section has considered species-level risks. Target species in the fishery may be associated with particular seabed habitat types or species assemblages, and so ecological risks to by-catch may vary by fishery sector. For example, some species such as trumpeter whiting and prickly leatherjacket are largely restricted in exposure to the inshore banana prawn sector of the ECOTF within the Great Barrier Reef Region.

The seabed community composition in the deepwater eastern king prawn fishery in the south-eastern Great Barrier Reef Region is typified by species such as champagne lobster, Balmain bugs, skates and rays as well as the target eastern king prawns, and differs from shallower shelf communities. While there is a basic understanding of the identity of the individual species that are prevalent in trawl catches from this deepwater area of the fishery, through DAFF Queensland observer activity primarily, little is known about the broader distribution, biology and abundance of many of these deepwater species.

The risks posed by trawling to species assemblage and habitats are discussed later in Section 4, and sector-level risks are summarised in Section 4.9. Additionally, Section 4.7 considers a range of potential direct and indirect effects of the fishery on ecosystem processes, including from activities that affect non-retained species, which may be additional to the impacts on individual species, species assemblages or habitats.

Summary: Species of conservation concern



Key facts

Ecological component assessed: Species of conservation concern include species protected by law and all sharks and rays. Four groups were identified for detailed assessment following an initial assessment of the levels of interactions with the fishery: marine turtles, sea snakes, seahorses and pipefish, and sharks and rays.

Ecological role: Part of biodiversity of Great Barrier Reef ecosystem. Fulfil various ecological roles and help sustain ecosystem processes such as herbivory, predation, connectivity and competition.

Trawl fishery: Some species that interact with the fishery are protected by law or require special management, and these additional sensitivities were considered in the risk assessment.

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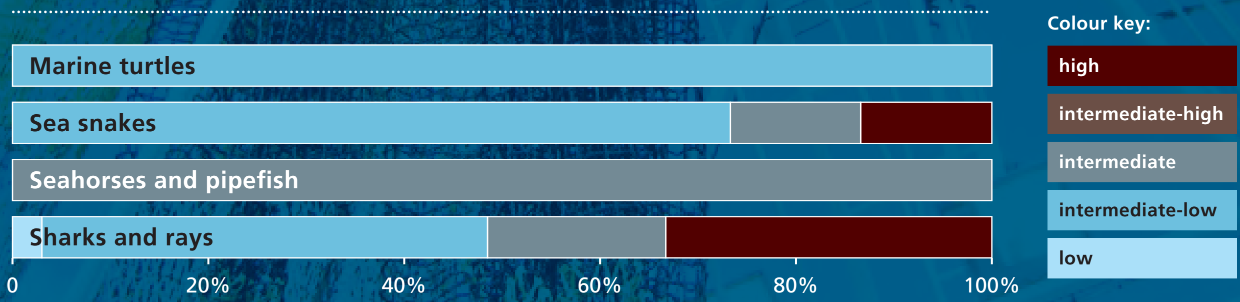
Consequences to avoid over the next 20 years: An unacceptable interaction level with species of conservation concern (indicated by exceeding acceptable levels of interaction determined by scientists and/or the community).

The direct ways trawling activities could lead to an unacceptable impact on species of conservation concern over a 20-year period, if risks are not managed:

Harvesting	Unlikely to contribute to such outcomes (except possibly for pipefish which are harvested)
Discarding	By adding a source of mortality which could compromise the ability of depleted populations to recover, cause declines in populations and/or exceed levels of human-induced mortality considered acceptable to the community. Also by providing additional food sources that may increase populations of some species.
Contact without capture	By collective damage to individuals without capturing them
Travel to/from grounds	By disturbing or interfering with some of these species, leading to loss of fitness and longer term population declines
Disturbance due to presence in area	By disturbing or interfering with some of these species, leading to loss of fitness and longer term population declines

FIGURE 17: OVERALL PATTERN OF RISK



4.4. Species of conservation concern

4.4.1. RISK CONTEXT

The risk context for species of conservation concern took into account requirements for long-term protection of the Great Barrier Reef...and maintenance of world heritage values and integrity ... and ecologically sustainable use of the Great Barrier Reef Region and its natural resources *[Great Barrier Reef Marine Park Act 1975]*... and protection of biological diversity, ecological processes and life-support systems *[Fisheries Act 1994, principles of ecologically sustainable development]*.

Consistent with the *Great Barrier Reef Marine Park Act 1975*, management of species of conservation concern seeks to ensure the long-term conservation of these species such that they fulfil their ecological roles within the Great Barrier Reef ecosystem by facilitating the recovery of populations that have declined, preventing future declines in populations, and only supporting uses that are ecologically sustainable. This is consistent with the Fisheries Queensland goal of taking an ecosystem-based approach to management and ensuring the sustainability of the trawl fishery's ecological systems by minimising catches of non-target species (including protected species) (DEEDI 2009b).

The risk being assessed was:

What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will exceed the level of interaction which is acceptable for the species of conservation concern in the Great Barrier Reef Marine Park within the next 20 years?

Best practice management for protected species or other species of conservation concern must take all reasonable steps to allow the species to recover, if it is depleted, and ensure human-induced mortality is within acceptable levels determined by the community. Scientific processes are used to determine sustainable levels of interaction that support species conservation objectives such as recovery of depleted populations. Best practice also establishes benchmark levels (which may be zero for some species) of catch or fishing mortality to reflect what is currently regarded as being feasible and acceptable to the community, and this is expected to change through time to reflect continuous improvement (Sainsbury 2008). The benchmarks can be used as triggers to initiate additional management intervention if the intended improvement is not achieved. Our use of the term 'acceptable' here includes considerations to ensure ecological sustainability, as well as broader considerations such as community acceptability of interactions for iconic species. The likely economic cost of specific remedial actions also needs to be considered.

4.4.2. RISK IDENTIFICATION

An initial assessment was carried out to evaluate the level of interaction with the trawl fishery, and taxa were not assessed further if this interaction was determined to be negligible (Section 4.1.3). Interaction with the fishery was based on the overlap between the species and the area in which the fishery operates (geographical and habitat), and the frequency and/or nature of the interaction taking place. The taxa identified for detailed assessment as species of conservation concern were marine turtles, sea snakes, seahorses and pipefish, and sharks, rays and chimaeras.

Harvesting for sale is not a source of risk to species of conservation concern, since they are not allowed to be retained by the fishery. The exceptions are two species of pipefish (*Solegnathus cf. hardwickii* and *Solegnathus dunckeri*) that are permitted species in the ECOTF. An assessment by the Australian Department of Sustainability, Environment, Water, Population and Communities (2010) determined that the current ECOTF management regime "does not, or is not likely to, adversely affect…the conservation status of" these Syngnathids. These pipefish are supplied to a domestic and export market, where they are valued for traditional Asian medicinal purposes (Martin-Smith and Vincent 2006).

Discarding was given a high initial risk for some species of conservation concern such as sea snakes (Courtney et al. 2010), and sharks and rays (Kyne et al. 2002) (Table 4). The incidental catch and subsequent discarding of species of conservation concern is potentially a high risk because even low levels of mortality may compromise the ability of depleted populations to recover, cause declines in populations and/or exceed levels of human-induced mortality considered acceptable to the community.

Contact without capture, travel to/from the fishing grounds and disturbance due to presence in the area had intermediate to low initial risk, depending on the taxa in question (Table 4). In general, these activities of the fishery are unlikely to cause mortalities of species of conservation concern, but may disturb or interfere with these species and may lead to loss of fitness and contribute to longer term population declines.

4.4.3. RISK CHARACTERISATION

For species of conservation concern, information on resilience characters was derived from scientific literature and from the expert opinion of workshop participants (where published data was unavailable). Information on their fishery impact profiles was obtained from research and monitoring studies, including work by Courtney and co-workers (2007, 2010), the fishery observer program, SOCI logbooks, and expert opinion. The likelihood that the interactions reported in the SOCI logbooks under-represents the true interaction rates was explicitly considered as part of this assessment.

Resilience levels of species of conservation concern

Resilience of species of conservation concern was assessed using the eight characters and decision rules detailed in Table 43.

The determination of resilience levels of species of conservation concern was based on the same characters as for harvested species. An additional character, 'population size/trend and/or current abundance', was included as this information is generally available for species of conservation concern.

The detailed resilience data is presented in Data Report: Appendix 10, Data Report: Appendix 12, Data Report: Appendix 14 and Data Report: Appendix 16.

The overall resilience level for each species was determined by summing the number of risk prone scores attributed to each species. Levels of resilience for species of conservation concern were assigned qualitatively as either high (H; 0 prone), intermediate-high (H-I; 1 to 2 prone), intermediate (I; 3 prone), intermediate-low (I-L; 4 to 5 prone) or low (L; 6 or more prone out of a maximum risk prone score of 11).

Fishery impact profiles of species of conservation concern

The second part of the finer level assessment involved qualitative evaluation of the fishery impact profile using four factors to indicate the current level of pressure exerted by the fishery on the species being assessed, and the decision rules outlined in Table 44. Fewer factors were used than for harvested species as there is generally limited information on interactions between the fishery and species of conservation concern.

For species of conservation concern, the assessment took into account the latest available information at the time of the assessment in 2010 and 2011. The Seabed Biodiversity Project generally lacked ecological indicator data for these relatively rare species, therefore a 2009 to 2005 comparison was not possible.

The detailed fishery impact profile data is presented in Data Report: Appendix 11, Data Report: Appendix 13, Data Report: Appendix 15 and Data Report: Appendix 17.

The overall fishery impact profile for each species was determined by summing the number of risk prone scores attributed to each species. The fishery impact profile was assigned qualitatively as either low (L; 0 or 1 prone), intermediate-low (I-L; 2 prone), intermediate (I; 3 prone), intermediate-high (H-I; 4 prone) or high (H; 5 or more prone out of a maximum risk prone score of 6).

Risk for species of conservation concern

Risk gradings were obtained by combining the resilience levels and fishery impact profile levels as shown on the risk matrix in Figure 13. The assessments for each group of species of conservation concern are discussed below.

4.4.4. RISK ASSESSMENT OF MARINE TURTLES

Six of the world's seven species of marine turtle occur within the Great Barrier Reef Marine Park, and potentially interact with the ECOTF. All six species are listed in Australia as either endangered (loggerhead, olive ridley) or vulnerable (green, hawksbill, flatback, leatherback). Marine turtles are long-lived, with slow growth and maturity rates, have high egg and hatchling mortality, inhabit a range of habitats during their life, and are migratory, ranging across international boundaries into areas where they may be targeted and are less protected (Limpus 2007, 2008a, 2008b, 2008c, 2009a, 2009b). Marine turtles are also vulnerable to climate change (Johnson et al. 2007), and to the cumulative pressures of coastal development, reduced water quality, incidental capture in fisheries or bather protection programs, boat strike, traditional collecting and hunting (in Australia and neighbouring countries), feral animal depredation of nests and eggs, ingestion of marine debris, and disease (Environment Australia 2003). The resilience level of all six species of marine turtles was low (Table 45, for detailed resilience data see Data Report: Appendix 10).

The assessment considered impacts from all relevant activities in the fishery, particularly contact without capture for marine turtles that interact with trawl nets but are released via TEDs (Table 4). Although only small numbers are now landed on deck (fewer than five recorded interactions in 2008 and 2009, (DEEDI 2009a, 2010a)), many more marine turtles probably still interact with trawl nets annually in the ECOTF. Over 5000 turtles were estimated to have been caught annually prior to the introduction of TEDs (Robins 1995, Robins et al. 2002), however trawling effort in the fishery is now much lower and areas around some important turtle nesting beaches are now closed to trawling at certain times of the year (Limpus 2008a).

The fishery impact profile (Table 46, for detailed fishery impact profile data see Data Report: Appendix 11) of marine turtles was low (olive ridley turtle) or intermediate-low (the five other species assessed), and the overall levels of risk to all six species of marine turtles from the ECOTF in the Great Barrier Reef Region was intermediate-low (Table 8).

Table 8. Risk assessment of marine turtles (ordered according to risk levels).

Common name	Scientific name	Resilience	Fishery impact profile	Risk
Flatback turtle	*Natator depressus*	L	I-L	INT-LOW
Green turtle	*Chelonia mydas*	L	I-L	INT-LOW
Hawksbill turtle	*Eretmochelys imbricata*	L	I-L	INT-LOW
Leatherback turtle	*Dermochelys coriacea*	L	I-L	INT-LOW
Loggerhead turtle	*Caretta caretta*	L	I-L	INT-LOW
Olive ridley turtle	*Lepidochelys olivacea*	L	L	INT-LOW

Issues arising from the risk assessment for marine turtles

For marine turtles, the risk assessed was *'What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will exceed the level of interaction which is acceptable for marine turtles in the Great Barrier Reef Marine Park within the next 20 years?'*. This section discusses the overall patterns of risk for marine turtles against this risk context, and discusses the progress made in reducing risks and impacts, and other issues arising from the assessment.

Overall patterns of risk for marine turtles

In the Great Barrier Reef Region, all marine turtle species were assessed to be at intermediate-low risk of exceeding an acceptable level of interaction for these species with trawling Figure 17). As each species had a low resilience and either low or intermediate-low fishery impact profile, this put marine turtles into the intermediate-low (rather than low) risk category of the risk matrix (Figure 13).

Progress made in reducing risks and impacts

Prior to the introduction of TEDs, trawling was a major cause of turtle mortality in the Great Barrier Reef Region through drowning and contributed to their subsequent population decline (especially the endangered loggerhead turtle) (Limpus 2008a). Oral history indicates that the loggerhead nesting population was stable prior to the 1960s. After the 1970s, increases in both the size of trawl vessels and the length of time the nets were deployed (shot time), and the use of multiple nets, contributed to decreases in the loggerhead turtle nesting population (GBRMPA 2009). The avoidable deaths of threatened species were of concern to managers and the community.

There has been a dramatic reduction in the level of trawl impacts on marine turtles as a result of the mandatory use of TEDs since 2001 by the ECOTF, the contraction in trawl effort, spatial and temporal closures, and gear restrictions. Trawl catch rates (number of animals landed on deck) have declined over 100-fold from more than 5000 (Robins 1995, Robins and Mayer 1998) to two to three reported marine turtle landings annually. With appropriate handling and resuscitation methods, survival has also improved substantially, with no recorded mortality from trawling in the Great Barrier Reef Region in 2008 and 2009 (DEEDI 2009a, 2010a). These changes have successfully addressed what was previously a major impact on turtle populations in the Great Barrier Reef Region (Robins 1995).

The use of TEDs (as well as being mandatory) is now generally well supported by the Queensland otter trawl industry, and the industry is commended for continuing to take positive actions for marine turtles.

New regulations specifying TEDs compliant with the USA National Oceanic and Atmospheric Administration (NOAA) guidelines were introduced into the ECOTF in February 2010, with a compliance grace period until December 2010 to enable fishers time to upgrade existing devices. A recent study reported a 98 per cent compliance rate with the new specifications (Roy and Jebreen 2011). Earlier TED specifications (including those in place at the time of this assessment) were not as effective for the exclusion of leatherback turtles and, despite a perceived low interaction rate for this species by experts, these recent improvements are an important step to minimise trawl impacts on these protected species.

Further issues and information gaps

The use of TEDs and trawl closures are considered to have arrested the decline in the loggerhead turtle population (Limpus 2008a). However, other non-trawl pressures (e.g. incidental capture in international longline fishing gear, ingestion of marine debris, coastal development, depredation of mainland nests by foxes, increased incidence of disease, potential climate change effects on nesting populations and severe weather events) are still of concern for their recovery (Johnson and Marshall 2007, Limpus 2008a, GBRMPA 2009, GBRMPA 2011). Therefore, ensuring the level of trawl impacts on marine turtles is minimised as far as practical, and that TEDs continue to be as effective as they can be in the fishery, are considered ongoing priorities for management and compliance programs. This ongoing attention (e.g. ensuring high compliance with TED rules) to minimise risks from interactions with trawl gear is important for marine turtle conservation, because trawling activities in the Great Barrier Reef Region are likely to still have a high interaction rate with marine turtles through contact without capture.

4.4.5. RISK ASSESSMENT OF SEA SNAKES

Sixteen species of sea snakes from the Families Hydrophiidae and Laticaudidae occur within the Great Barrier Reef Marine Park, with 14 of these species maintaining permanent breeding populations. All species of sea snakes are protected under the Queensland *Nature Conservation Act 1992* and the *Great Barrier Reef Marine Park Act 1975* and are 'listed marine species' (since 2000) under the *Environment Protection and Biodiversity Conservation Act 1999*. Fifteen species were assessed in detail as these species at least partly occur within habitats and at depths where prawn trawling also occurs. One species was not assessed as it was considered to have negligible interaction with the fishery.

The resilience for sea snakes is summarised in Table 47 (detailed data is presented in Data Report: Appendix 12). The resilience levels of three sea snake species (Stokes', spectacled, elegant) were assessed as low. The remaining sea snake species had intermediate-low resilience.

The fishery impact profile of sea snakes ranged from low to intermediate-high, with four species intermediate or above (elegant, ornate, spectacled, small-headed, Table 48 and details in Data Report: Appendix 13).

The overall levels of risk to sea snakes included two species assessed as at high risk (elegant, ornate) and two species at intermediate risk (spectacled, small-headed), and the other 11 species of sea snakes were at intermediate-low risk (Table 9).

Table 9. Risk assessment of sea snakes (ordered according to risk levels).

Common name	Scientific name	Resilience	Fishery impact profile	Risk
Elegant sea snake	*Hydrophis elegans*	L	H-I	HIGH
Ornate reef sea snake	*Hydrophis ornatus*	I-L	H-I	HIGH
Spectacled sea snake	*Hydrophis/Disteira kingii*	L	I	INT
Small-headed sea snake	*Hydrophis macdowelli*	I-L	I	INT
Stokes' sea snake	*Astrotia stokesii*	L	I-L	INT-LOW
Horned sea snake	*Acalyptophis peronii*	I-L	I-L	INT-LOW
Olive-headed sea snake	*Hydrophis/Disteira major*	I-L	I-L	INT-LOW
Large-headed sea snake	*Hydrophis pacificus*	I-L	I-L	INT-LOW
Beaked sea snake	*Enhydrina schistose*	I-L	L	INT-LOW
Dubois' sea snake	*Aipysurus duboisii*	I-L	L	INT-LOW
Spine-tailed sea snake	*Aipysurus eydouxii*	I-L	L	INT-LOW
Olive sea snake	*Aipysurus laevis*	I-L	L	INT-LOW
Spine-bellied sea snake	*Lapemis curtus*	I-L	L	INT-LOW
Turtle-headed sea snake	*Emydocephalus annulatus*	I-L	L	INT-LOW
Yellow-bellied sea snake	*Pelamis platura*	I-L	L	INT-LOW

Issues arising from the risk assessment for sea snakes

For sea snakes, the risk assessed was *'What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will exceed the level of interaction which is acceptable for sea snakes in the Great Barrier Reef Marine Park within the next 20 years?'*. This section discusses the overall patterns of risk for sea snakes, and any species identified as at intermediate or higher risk, against this risk context, and discusses the progress made in reducing risks and impacts, and other issues arising from the assessment.

Overall pattern of risk for sea snakes

The fishery still has a substantial interaction with sea snakes and the overall pattern of risk for sea snakes is shown in Figure 17. Courtney et al. (2010) estimated that from 2003 to 2007 about 27,000 sea snakes died annually as a result of incidental capture in the ECTF, with the majority within the Great Barrier Reef Region. This estimate was derived by considering the level of trawl fishing effort over the period. In 2011, trawl fishing effort declined to an historically low level (Figure 10) and so the number of incidental sea snake mortalities would have also declined that year. Recent management initiatives promoting the adoption of fisheye BRDs by the fleet (discussed below and in Section 5.2) would have further reduced incidental fishing mortality, although the estimate of annual sea snake mortalities has not been updated. Two sea snake species were assessed as at high risk (elegant sea snake, ornate reef sea snake), two species at intermediate risk (spectacled sea snake, small-headed sea snake), and the other 11 species of sea snakes were at intermediate-low risk of exceeding an acceptable level of interaction for these species with trawling. Reducing these risks to sea snakes from trawling had already been recognised as a high priority by scientists, managers and industry, and a program of further mitigation has occurred since this risk assessment (Roy and

Jebreen 2011). This assessment has reinforced the need for implementing measures to mitigate these risks to acceptable levels.

Comments on identified risks to sea snakes

The four higher risk sea snakes had intermediate-low or low resilience and their fishery impact profiles were intermediate or intermediate-high. The elegant sea snake's diet includes eels and it inhabits turbid deeper water areas between reefs (Heatwole 1999), with some specimens trawled in depths of more than 30 metres. The ornate reef sea snake has a more general diet of squid, crustaceans and fish, and lives in a range of habitats from coral reefs to turbid inshore waters and estuaries (Heatwole 1999). Risk prone fishery impact factors giving the high risk grading for these two species were a moderate interaction level with the fishery, combined with low survival after trawling and ineffectiveness for sea snakes of the BRDs being used by most of the fleet at the time of the assessment. Similar factors contributed to the intermediate risk for the spectacled sea snake (mainly caught in trawls between depths of 30 and 40 metres) and small-headed sea snake. Courtney et al. (2010) found that the small-headed sea snake had a relatively high within-trawl mortality rate compared to other snake species. The elegant sea snake was considered to be prone to cumulative risks affecting inshore habitats and also from incidental capture in crab pots (Data Report: Appendix 13), however no known cumulative risks were identified for the other species at risk from trawling.

There is considerable overlap between the spatial distribution of some sea snake species and trawl fishing effort in the Great Barrier Reef Region Figure 18). Most of the incidental trawl fishing mortality for sea snakes (Courtney et al. 2010), and therefore most of the risk, occurred in the central Queensland red-spot king prawn sector of the ECOTF. This is mainly due to habitat overlap between coral reef–associated snakes and red-spot king prawns, which are also a reef-associated species. However, there are also significant trawl-related mortality pressures on some sea snake species in other areas of the ECOTF, including the far northern area where red-spot king prawns are targeted (see Figure 8, Figure 14 and Figure 18).

A preliminary quantitative assessment of the risks posed by the ECOTF to sea snakes also found an elevated risk for the elegant sea snake (*Hydrophis elegans*) (Courtney et al. 2010). They estimated that the incidental fishing mortality was high enough to reduce recruitment for this species. One reason why the elegant sea snake was concluded to be at an elevated risk was because it was deemed to have a relatively low natural mortality rate, based on earlier CSIRO estimates for sea snakes in the Gulf of Carpentaria (Milton et al. 2008). This is because the mortality rate estimate was derived using Pauly's (1980) method, which is based on a function of body length and water temperature. As the elegant sea snake is a long snake, its natural mortality rate was estimated to be relatively low, which tended to increase its risk. Furthermore, experiments conducted at sea (Courtney et al. 2010) showed that the post-trawl survival rate of snakes was also affected by body length, such that the longer the snake, the lower the survival rate after trawling. Thus, the low estimate of natural mortality combined with the low post-trawl survival rate tends to predispose the elegant sea snake to higher risk from trawling.

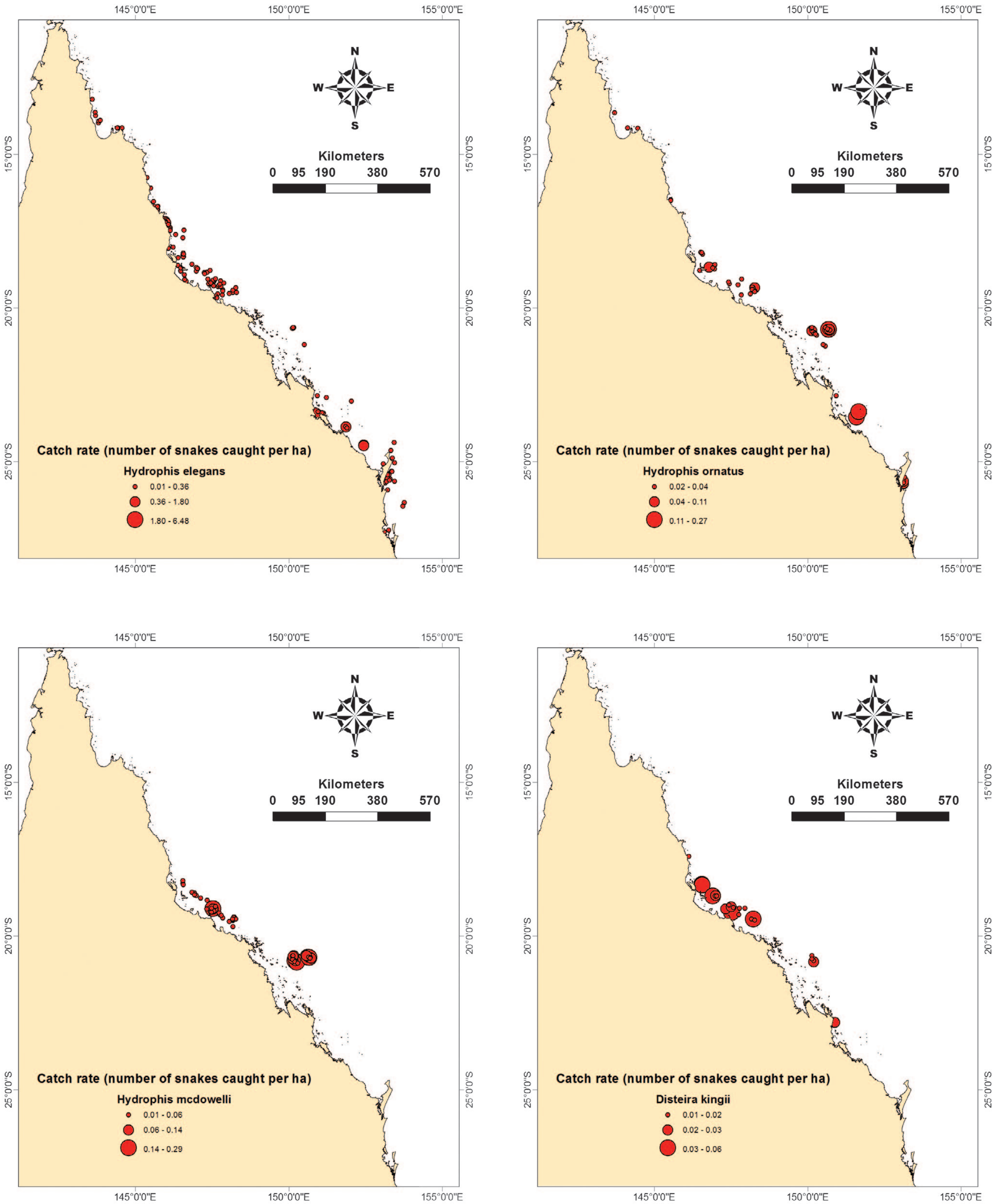


Figure 18. Maps showing trawl catch rates on the East Coast of Queensland for the sea snake species assessed as at high or intermediate risk from trawling. Source: Courtney et al. 2010

Progress made in reducing risks and impacts

Fisheries Queensland is working closely with the trawl industry on a range of improvements to BRD design specifications in the ECTF. There is a need to have a range of effective BRDs available to fishers for use in different parts of the fishery, particularly addressing the need to reduce by-catch of sea snakes.

Research has shown that the distance at which BRDs are installed from the codend drawstring can significantly affect their performance at excluding sea snakes. In Section 4.1.2 we gave the following example, which is also highly relevant here. Results from a dedicated research charter showed that the fisheye and square mesh codend BRDs were found to reduce the catch rate of sea snakes by 63 per cent and 60 per cent, respectively, compared with the standard net that had no BRD, with no significant reduction in the catch rate of marketable prawns (Courtney et al. 2010). These two devices also significantly lowered the catch rates of the remaining by-catch by 33 per cent and 31 per cent, respectively. The fisheye BRD was equivalent to the square mesh codend in terms of by-catch reduction, however the fisheye was more effective at excluding larger sea snakes due to the limited size of the square meshes that almost certainly prevent large snakes from escaping. The use of effective BRDs in specific areas of the fishery would help mitigate the high risk to some species of sea snakes. Fisheries Queensland has recently supplied each otter trawl licence holder with 12 fisheye BRDs free of charge to facilitate adoption of this effective BRD.

Further issues and information gaps

Sea snakes are prone to injury as well as drowning in trawl gear, and additional influences on survival after trawl interactions for sea snakes include the size of the individual (i.e. the girth of the snakes can affect their ability to escape through small openings), duration of the trawl, the depth fished, the composition of the remaining by-catch (the presence of bulky, calcareous and venomous by-catch can crush, injure and envenomate snakes), and handling practices. These aspects highlight opportunities where impacts on sea snakes may be further reduced. For example, shorter trawl durations may reduce the chance of drowning or injury to any sea snakes that are retained in the net. Another overriding influence on risk and impacts on sea snakes is clearly trawl fishing effort, particularly effort levels in the red-spot king prawn sector and other parts of the fishery with significant impacts on sea snakes.

At the time of the assessment, the effectiveness of BRDs used by operators in the trawl fishery on sea snakes was considered to be highly variable and often low. The use of BRDs across the fleet should continue to be monitored and reported on. Extension work on by-catch reduction (including for protected species) has been recognised as a priority (Roy and Jebreen 2011) and should continue to be supported.

The information used to inform the 'level of interaction' factor in these assessments was reliant upon logistic regression models of the spatial distribution for each sea snake species. However, some of the regressions resulted in poor model fits and there is therefore a strong need to improve existing empirical methods for estimating species' distribution. Further quantitative studies on the population dynamics of sea snakes would be valuable to improve these estimates and help determine sustainable interaction levels for these protected species. In turn, such information could be used to establish benchmark limits on interaction levels for sea snakes.

Continued industry participation is encouraged in research and monitoring of sea snakes and their interactions with the fishery, and development of ways to minimise these impacts. Further improvements in the knowledge base would help optimise mitigation actions and refine future risk assessments for sea snakes.

4.4.6. RISK ASSESSMENT OF SEAHORSES AND PIPEFISH

All species within the family Syngnathidae (seahorses, pipefish and seadragons) are 'listed marine species' under the *Environment Protection and Biodiversity Conservation Act 1999* and are 'protected species' under the *Great Barrier Reef Marine Park Act 1975*. As mentioned previously, two of these species (the pipefish *Solegnathus cf. hardwickii* and *Solegnathus dunckeri*) are taken incidentally in the ECOTF and are allowed to be retained as by-product.

The risk assessment considered the six species of seahorses and pipefish that are likely to interact with the otter trawl fishery in the Great Barrier Reef Region. The resilience levels of these species were all intermediate-low or low (Table 49, detailed data is in Data Report: Appendix 14). The fishery impact profiles were all intermediate (Table 50). The overall levels of risk to each species of seahorse and pipefish from trawling were intermediate (Table 10, detailed data is in Data Report: Appendix 15).

Table 10. Risk assessment of seahorses and pipefish.

Family	Common name	Scientific name	Resilience	Fishery impact profile	Risk
Pipefish	Straightstick pipefish	*Trachyrhamphus longirostris*	L	I	INT
Pipefish	Tiger pipefish	*Filicampus tigris*	L	I	INT
Seahorses	Queensland seahorse	*Hippocampus queenslandicus*	I-L	I	INT
Seahorses	Highcrown seahorse	*Hippocampus proceros*	I-L	I	INT
Pipefish	Bentstick pipefish	*Trachyrhamphus bicoarctatus*	I-L	I	INT
Pipehorse	Pallid/Hardwick(e)'s pipehorse	*Solegnathus cf. hardwickii*	I-L	I	INT

Issues arising from the risk assessment for seahorses and pipefish

For seahorses and pipefish, the risk assessed was *'What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will exceed the level of interaction which is acceptable for seahorses and pipefish in the Great Barrier Reef Marine Park within the next 20 years?'*. This section discusses the overall patterns of risk for seahorses and pipefish, and any species identified as at intermediate or higher risk, against this risk context, and discusses the progress made in reducing risks and impacts, and other issues arising from the assessment.

Overall pattern and comments on identified risks to seahorses and pipefish

All species of seahorses and pipefish were assessed as at intermediate risk from trawling (Figure 17), with low or intermediate-low resilience and intermediate fishery impact profiles. The level of interaction with the ECOTF in the Great Barrier Reef Region was assessed as being relatively low for these species based on available fishery and research data and expert opinion (e.g. Connolly et al. 2001, Pitcher et al. 2007b).

The fine-scale habitat preferences of seahorses and pipefish are generally considered to have limited overlap with trawled areas, as these species are predominantly associated with highly structured habitats such as coral reefs and 'garden bottom', which are areas generally avoided by trawlers (Kuiter 2000). However, when they occur in areas that are trawled, individuals of these species are vulnerable to trawling because they have very low survival after capture and BRDs are ineffective at excluding seahorses and pipefish. Their low resilience scores indicate they would have a low capacity to recover from any overfishing. All species of seahorse and pipefish assessed that had a coastal part to their distributions were considered to be prone to cumulative pressures such as from urban and coastal development, extreme weather events and climate change, which may increase the susceptibility of a species to the effects of trawling.

Progress made in reducing risks and impacts

A change that has helped reduce risks or impacts on seahorses and pipefish is the general trend of consolidating trawl fishing activities into more productive soft sediment seabed areas and away from more highly structured habitats. Protection of representative areas under Marine Park zoning, and areas closed to fishing under fisheries legislation, are also recognised as important measures that have reduced the risk to seahorses and pipefish on an ongoing basis. Additionally, current trawl impacts on incidentally caught species such as seahorses and pipefish are expected to be lower than they were historically given the substantial effort reductions in the fishery.

Further issues and information gaps

The pallid/Hardwick's pipehorse, which is permitted to be retained by operators in the ECTF, is recorded more in some fishery sectors than others, although the data have limitations because non-retained catch is not reported. There are indications that the scallop fishery and red-spot king prawn fishery sectors are more likely to interact with this pipehorse, and hence would represent more of the identified intermediate risk. Further estimates at a sector level on the true level of interaction with these species where they are not retained would be desirable to help refine future risk assessments. The two species allowed to be retained by the fishery (only *Solegnathus cf. hardwickii* is recorded from the Great Barrier Reef) are subject to a trip limit of 50 individual pipefish in total, and any catch above these levels or catch of the other species must be discarded. Pipefish are reported as number of individuals retained, and 5640 were reported in ECOTF catches in 2009 for the Queensland east coast (Table 22). Further research or fishery observer information on distribution and levels of discarding for seahorses and pipefish (preferably at the species level) would improve estimates of fishery interaction and mortality rates.

The information base for these species is quite limited, and increased the uncertainty in the assessment and the possibility that some risk may not have been considered. For example, several resilience characters for the highcrown seahorse were assumed to be similar to the Queensland seahorse. The population size or trend was unknown for any of these species, however it was noted that seahorses and pipefish are generally sparsely distributed and not very abundant. There are some taxonomic uncertainties for some seahorses and pipefish, including for the highcrown seahorse.

4.4.7. RISK ASSESSMENT OF SHARKS AND RAYS

There are eight protected species of sharks in the Great Barrier Reef Marine Park, and other sharks and rays are of conservation concern as potentially 'at risk' species. [Protected species are defined in Great Barrier Reef Marine Park legislation as any of the following (a) a cetacean; (b) a listed marine species, a listed migratory species, a listed threatened ecological community, or a listed threatened species as identified under the *Environment Protection and Biodiversity Conservation Act 1999* of Australia; (c) a species of marine mammal, bird or reptile that is prescribed as endangered wildlife, vulnerable wildlife or rare wildlife under the *Nature Conservation Act 1992* of Queensland; (d) other species declared to be a protected species (e.g. the narrow sawfish) including any species that is at risk or in need of special protection.]

Sharks and rays caught as by-catch in the ECTF include species from the families Urolophidae (stingarees), Dasyatidae (stingrays), Gymnuridae (butterfly rays), Rhynchobatidae (wedgefishes), Rhinobatidae (shovelnose rays), Carcharhinidae (whalers), Rajidae (skates) and Scyliorhinidae (catsharks) (Kyne et al. 2007).

The 33 species identified for detailed assessment included those sharks and rays that occur within the Great Barrier Reef Region in habitats that at least partially overlap with areas trawled by the ECOTF, and are considered to have some interaction with the fishery. Details of fishery interactions with sharks and rays from the Fisheries Queensland Fishery Observer Program between 2005 and 2010 provided inputs to this assessment (Appendix 2.2.5).

The scientific names for some sharks and rays have changed in recent years to reflect updated taxonomic information and scientific naming conventions. The species assessed here as *Himantura toshi* is the same species previously referred to as *Himantura* 'sp. A' in Last and Stevens 1994 and Stobutzki et al. 2000. As the two species *Rhynchobatus australiae* and *Rhynchobatus palpebratus* were not separated in the work by Kyne (2008), these species were considered together in this assessment. The species assessed here as *Atelomycterus marnkalha* was previously called *Atelomycterus* sp. A or grouped with *Atelomycterus fasciatus*. The species assessed here as *Neotrygon picta* was previously called *Dasyatis leylandi*, and the species assessed here as *Neotrygon kuhlii* was previously called *Dasyatis kuhlii*.

The resilience levels for the species of sharks and rays assessed were either low (20 species), intermediate-low (12 species) or intermediate-high (one species) (Table 51 and detailed in Data Report: Appendix 16).

The fishery impact profiles of sharks and rays varied from low to high, as summarised in Table 52 and detailed in Data Report: Appendix 17. Species with a high fishery impact profile were bluespotted maskray, speckled maskray, common stingaree, pale tropical skate, Argus skate and endeavour skate. A further five species had intermediate-high fishery impact profiles.

The risk was high for 11 species of skates and rays, intermediate for six species, intermediate-low for 15 species and low for one species (Table 11). The remaining species of sharks and rays that occur in Great Barrier Reef waters are likely to be at low to negligible risk from trawling (however see next section on issues arising for some further species recommended for detailed assessment in future projects).

Table 11. Risk assessment of sharks and rays (ordered according to risk levels).

Family	Common name	Scientific name	Resilience	Fishery impact profile	Risk
Stingarees (Urolophidae)	Common stingaree	*Trygonoptera testacea*	L	H	HIGH
Stingrays (Dasyatidae)	Bluespotted maskray	*Neotrygon kuhlii*	I-L	H	HIGH
Stingrays (Dasyatidae)	Speckled maskray	*Neotrygon picta*	I-L	H	HIGH
Skates (Rajidae)	Pale tropical skate	*Dipturus apricus*	I-L	H	HIGH
Skates (Rajidae)	Argus skate	*Dipturus polyommata*	I-L	H	HIGH
Skates (Rajidae)	Endeavour skate	*Dipturus endeavouri*	I-L	H	HIGH
Coffin rays (Hypnidae)	Coffin ray	*Hypnos monopterygius*	L	H-I	HIGH
Stingrays (Dasyatidae)	Blackspotted whipray	*Himantura astra*	L	H-I	HIGH
Stingarees (Urolophidae)	Patchwork stingaree	*Urolophus flavomosaicus*	L	H-I	HIGH
Butterfly rays (Gymnuridae)	Australian butterfly ray	*Gymnura australis*	L	H-I	HIGH
Shovelnose rays (Rhinobatidae)	Eastern shovelnose ray	*Aptychotrema rostrata*	I-L	H-I	HIGH
Blind sharks (Brachaeluridae)	Blue-grey carpet shark	*Brachaelurus colcloughi*	L	I	INT
Sawfish (Pristidae)	Narrow sawfish	*Anoxypristis cuspidata*	L	I	INT
Sawfish (Pristidae)	Green sawfish	*Pristis zijsron*	L	I	INT
Stingrays (Dasyatidae)	Brown whipray	*Himantura toshi*	L	I	INT
Catsharks (Scyliorhinidae)	Eastern banded catshark	*Atelomycterus marnkalha*	I-L	I	INT
Weasel sharks (Hemigalidae)	Australian weasel shark	*Hemigaleus australiensis*	I-L	I	INT
Whaler sharks (Carcharhinidae)	Whitecheek shark	*Carcharhinus coatesi*	L	I-L	INT-LOW
Wedgefishes (Rhynchobatidae)	Whitespotted guitarfish or eyebrow wedgefish	*Rhynchobatus australiae / Rhynchobatus palpebratus*	L	I-L	INT-LOW
Stingrays (Dasyatidae)	Estuary stingray	*Dasyatis fluviorum*	L	I-L	INT-LOW
Wobbegongs (Orectolobidae)	Tasselled wobbegong	*Eucrossorhinus dasypogon*	I-L	I-L	INT-LOW
Wobbegongs (Orectolobidae)	Spotted wobbegong	*Orectolobus maculatus*	I-L	I-L	INT-LOW

Family	Common name	Scientific name	Resilience	Fishery impact profile	Risk
Whaler sharks (Carcharhinidae)	Sliteye shark	*Loxodon macrorhinus*	I-L	I-L	INT-LOW
Whaler sharks (Carcharhinidae)	Milk shark	*Rhizoprionodon acutus*	I-L	I-L	INT-LOW
Whaler sharks (Carcharhinidae)	Spinner shark	*Carcharhinus brevipinna*	L	L	INT-LOW
Stingrays (Dasyatidae)	Pink whipray	*Himantura fai*	L	L	INT-LOW
Stingrays (Dasyatidae)	Reticulate whipray	*Himantura uarnak*	L	L	INT-LOW
Stingrays (Dasyatidae)	Bleeker's variegated whipray	*Himantura undulata*	L	L	INT-LOW
Stingrays (Dasyatidae)	Leopard whipray	*Himantura leoparda*	L	L	INT-LOW
Stingrays (Dasyatidae)	Mangrove whipray	*Himantura granulata*	L	L	INT-LOW
Stingrays (Dasyatidae)	Cowtail stingray	*Pastinachus astrus*	L	L	INT-LOW
Eagle rays (Myliobatidae)	Banded eagle ray	*Aetomylaeus nichofii*	L	L	INT-LOW
Longtailed carpetsharks (Hemiscylliidae)	Grey carpetshark	*Chiloscyllium punctatum*	H-I	I-L	LOW

The available information on shark and ray interactions with the various fishery sectors for the species at intermediate or higher risk is summarised in Table 12.

Table 12. Interactions with shark and ray species at identified risk by trawl fishery sector.

Shark and ray interactions by fishery sector, where known	Risk	Eastern king prawn (shallow)	Eastern king prawn (deepwater)	Scallop (saucer)	Tiger/ Endeavour prawn	Banana prawn	Red-spot king prawn
Eastern shovelnose ray	High	✔	✔	✔			
Coffin ray	High	✔	✔				
Blackspotted whipray	High			✔	✔		✔
Bluespotted maskray	High	✔		✔	✔		✔
Speckled maskray	High			✔	✔		
Common stingaree	High	✔					
Patchwork stingaree	High		✔				
Pale tropical skate	High		✔				
Argus skate	High		✔				
Endeavour skate	High		✔				
Australian butterfly ray	High		✔	✔	✔	✔	✔
Blue-grey carpet shark	Intermediate	✔	✔				
Eastern banded catshark	Intermediate			✔			
Australian weasel shark	Intermediate				✔	✔	
Narrow sawfish	Intermediate			✔	✔	✔	
Green sawfish	Intermediate				✔	✔	
Brown whipray	Intermediate				✔		

Sources: Kyne 2008 and Fishery Observer Program data (Appendix 2.2.5). Species-level data on shark interactions is quite limited, therefore some additional sector interactions may have been missed.

Issues arising from the risk assessment for sharks and rays

For sharks and rays, the risk assessed was *'What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will exceed the level of interaction which is acceptable for sharks and rays in the Great Barrier Reef Marine Park within the next 20 years?'*. This section discusses the overall patterns of risk for sharks and rays, and any species identified as at intermediate or higher risk, against this risk context, and discusses the progress made in reducing risks and impacts, and other issues arising from the assessment.

Overall pattern and comments on identified risks for sharks and rays

The overall pattern of ecological risk for sharks and rays is shown in Figure 17, and about half the species assessed in detail (17 out of 33 species) were at intermediate or high risk. The ecological risk assessment identified 11 species of sharks and rays at high risk of an unacceptable level of interaction with trawling within the Great Barrier Reef Marine Park within the next 20 years. These 11 species at high risk from the ECOTF included a shovelnose ray, a coffin ray, three species of stingrays, two species of stingarees, three species of skates and a butterfly ray (from the scientific families Rhinobatidae, Hypnidae, Dasyatidae, Urolophidae, Rajidae and Gymnuridae). None of the species assessed here as at high risk from trawling are protected species (see first paragraph in Section 4.4.7), which are generally considered to be the most vulnerable species to all human-induced pressures. A further six species were at intermediate risk from trawling, which included two protected species of sawfish. The remaining species of sharks and rays that potentially interact with the ECOTF were considered to be at lower risk.

Species at high risk from trawling were believed to have habitat associations with sandy and soft sediment habitats also used as trawl grounds and several of these species are known to feed on crustaceans including prawns (e.g. the blackspotted whipray (Jacobsen and Bennett 2011)). All of these species were susceptible to capture and mortality from discarding activities by the fishery throughout their life cycle. Additionally, for all but one of these species, TEDs and BRDs were not considered to be effective for reasons such as the relatively small size of the animals (which may allow them to pass through the TED parallel bars with ease) or their morphology. The exception was the eastern shovelnose ray (which reaches a maximum size of at least 120 cm (Last and Stevens 2009)), for which TEDs have been demonstrated to be effective in the scallop fishery sector (Courtney et al. 2007).

Sharks and rays only make up a small proportion of the ECOTF by-catch (Kyne 2008) but are not uncommon. Fishery observer program data for sharks and rays in the ECOTF (Appendix 2.2.5) indicated that twice as many individuals were released alive as dead in the banana prawn sector, while only 17 per cent of individuals taken in the deepwater eastern king prawn fishery were released alive (Table 29). In the scallop, red-spot king and tiger/endeavour prawn sectors, roughly equal numbers of sharks and rays were released alive as dead.

New information from the fishery observer program since this assessment was completed has indicated that some additional sharks and rays interact with the ECOTF in the Great Barrier Reef Region (e.g. *Asymbolus rubiginosus* (orange spotted catshark), *Mustelus walkeri* (eastern spotted gummy shark), *Figaro boardmani* (sawtail shark) and *Hydrolagus lemures* (blackfin ghostshark) (Last and Stevens 2009)), and should be included in future ecological risk assessments.

Progress made in reducing risks and impacts

The ecological risk assessment has updated our understanding of risks to sharks and rays from trawling, and has identified some remaining high risks, particularly for skates and rays.

Risks to large sharks and some rays from trawling have generally been reduced to low levels as a result of past management actions and improved practices. In particular, the mandatory use of TEDs has been recognised as substantially improving survival of large sharks and some rays that interact with the trawl fishery, in addition to providing benefits to other animals such as marine turtles (Kyne et al. 2007). The removal of all sharks and rays from the list of permitted species for the ECTF in the early 2000s, because of conservation concerns for these species, was also important as it removed any incentive for fishers to target or catch these species.

Further issues and information gaps

Skates and rays accounted for most of the high risk gradings in the whole assessment. The detailed assessment of sharks and rays under the species of conservation concern category represents a precautionary assessment given the risk context for that category is about unacceptable impacts to the broader community and not just strict sustainability concerns (see Section 4.6.1). This context was considered appropriate given national and international conservation concerns about sharks and rays (Food and Agricultural Organization 1999, Cavanagh et al. 2003). However, it should be remembered that only eight species of sharks and rays were protected at the time of the assessment, and none of these were found to be at high risk from trawling. This category was also considered more appropriate than the by-catch category because the available data for these animals were better matched to the characters and factors used for species of conservation concern.

Generally, research and observations of the fishery have indicated that TEDs and current BRDs are less effective for smaller species and the smaller life stages of larger sharks and rays (Kyne et al. 2007). Therefore, a priority area for further research and development is to seek to improve by-catch reduction measures for sharks and rays, particularly measures to minimise impacts on smaller species and those species that have a flattened body form (such as many skates and rays). In addition to further improvements in BRDs, there may be other ways to reduce interactions with sharks and rays, or improve survival of those animals that interact with trawling activities (e.g. avoiding any particular times or locations that are hotspots or improving handling protocols).

The greatest uncertainty in assessing the fishery impact profiles was for survival after interaction. Information on how well a species survives after any interaction with trawling (or any other fishing activity) is difficult to obtain for species that are landed on deck and almost impossible for other species that exit through a TED or BRD. Survival information is, however, a priority information gap.

Other priority information gaps include species distribution information, population status or trends, and degree of protection from trawling provided by zoning and areas closed to fishing under fisheries legislation. There is also a need to collate information for key species of sharks and rays, taking account of the latest knowledge on taxonomy (as some information is currently given using outdated species names). This is particularly evident for deepwater species including skates and stingarees where there are considerable information gaps.

For many of these species, the main sources of information have come from fishery dependent research, which demonstrates positive stewardship by industry through their support of such research. However, information on the species from outside of fishery areas is generally lacking, due to the difficulty and cost of studying such areas.

Summary: Marine habitats

Key facts

Ecological component assessed: Ten seabed habitat types of the Great Barrier Reef Marine Park with which the fishery potentially interacts. Habitats 1 to 9 are in shelf areas of less than 100 metres, and habitat 10 occurs on the upper continental slope (in depths of 90–300 m).

Ecological role: Populations of all species in the wild, including fishery species, depend on suitable habitats for their survival.

Trawl fishery: Trawling has physical impacts on habitats and can remove or damage seabed plants and animals.

RISK ASSESSMENT FOR THE GREAT BARRIER REEF REGION

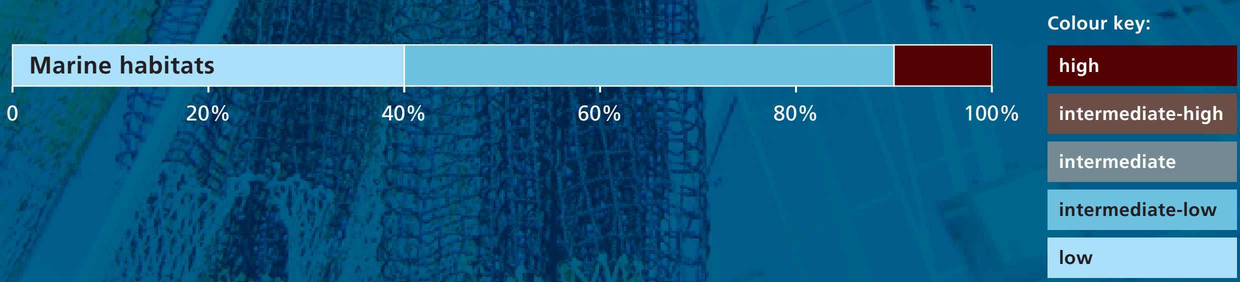
Consequences to avoid over the next 20 years: Serious or irreversible damage to the habitat type (such that the habitat type is not able to maintain viable populations, biodiversity, assemblages and/or ecosystem processes).

Habitat protection is an important part of providing for the long-term protection of the Great Barrier Reef and maintenance of World Heritage values and integrity.

The direct ways trawling activities could lead to serious or irreversible damage to habitats over a 20-year period, if risks are not managed:

Discarding	By removing structural habitat elements such as sponges, which are subsequently discarded, or by translocating plants and animals
Contact without capture	By direct physical damage to marine plants and animals on the seabed. Also by altering the vertical relief of seabed features and/or redistributing sediments.
Loss of fishing gear	By localised smothering effects on small areas of habitat
Boat maintenance, emissions	By potential impacts on marine plants and animals from any local contamination of the water column and the seabed with toxic chemicals

FIGURE 19: OVERALL PATTERN OF RISK AT 2009 LEVELS OF TRAWL FISHING EFFORT



4.5. Marine habitats

4.5.1. RISK CONTEXT

Populations of all species in the wild depend on there being suitable habitats for their survival. The protection of marine habitats is a clearly stated requirement of both the Queensland and Australian governments and is consistent with an ecosystem-based approach to fisheries management. Habitat protection is an important part of providing for the long-term protection of the Great Barrier Reef... and maintenance of world heritage values and integrity [*Great Barrier Reef Marine Park Act* 1975]... and protection of biological diversity, ecological processes and life-support systems [*Fisheries Act 1994, principles of ecologically sustainable development*].

The risk assessed was:

What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will result in serious or irreversible damage to the habitat type such that the habitat type is not able to maintain viable populations, biodiversity, assemblages and/or ecosystem processes in the Great Barrier Reef Marine Park within the next 20 years?

Trawling can affect seabed habitats through direct contact and removal of habitat-forming plants and animals (e.g. seagrasses, algae, sponges and corals) or some types of geomorphological structures. A review of best practice reference points for Australian fisheries noted that as yet there is no widely agreed approach to the selection or use of reference points for habitat management, and that the best practice target reference point for habitat impacts is for no impact on what they called vulnerable seabed habitats, modified as appropriate to include acceptance of minimal and temporary impacts (Sainsbury 2008).

The reference points for habitats considered in Sainsbury (2008) (e.g. a limit reference point for habitat impacts for relevant habitats to be reduced to no more than 0.3 of the unfished areal extent) lack precaution for a globally significant Marine Park and World Heritage Area. Instead, development of a suitable risk context took into account an ecosystem-based management approach and was informed by the principles of ecologically sustainable use, defined in the *Great Barrier Reef Marine Park Act 1975*, particularly the precautionary principle and the conservation of biodiversity and ecological integrity.

Definitions from Great Barrier Reef Marine Park Act 1975

Section 3AA: **Ecologically sustainable use** of the Great Barrier Reef Region or its natural resources is use of the Region or resources:

a) that is consistent with:

(i) protecting and conserving the environment, biodiversity and heritage values of the Great Barrier Reef Region; and

(ii) ecosystem-based management; and

b) that is within the capacity of the Region and its natural resources to sustain natural processes while maintaining the life-support systems of nature and ensuring that the benefit of the use to the present generation does not diminish the potential to meet the needs and aspirations of future generations

Section 3AB: The following principles are **principles of ecologically sustainable use**:

a) decision-making processes should effectively integrate both long-term and short-term environmental, economic, social and equitable considerations;

b) the precautionary principle;

c) the principle of inter-generational equity—that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;

d) the conservation of biodiversity and ecological integrity should be a fundamental consideration in decision-making;

e) improved valuation, pricing and incentive mechanisms should be promoted.

Section 3: **Precautionary principle** means the principle that lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there are threats of serious or irreversible environmental damage.

Section 3: **Ecosystem-based management** means an integrated approach to managing an ecosystem and matters affecting that ecosystem, with the main object being to maintain ecological processes, biodiversity and functioning biological communities.

4.5.2. RISK IDENTIFICATION

Detailed spatial data for the ECOTF was examined to determine the areas used by the fishery, and hence the habitats to be assessed (Appendix 2.2.3). Trawling principally occurs in the shelf areas, which support a great diversity of life. Additionally, the ECOTF includes a deepwater sector that trawls in water depths down to about 300 metres. Therefore, all shelf and upper continental slope habitat types of the Great Barrier Reef that at least partially overlap with the ECOTF were assessed in detail because each of these habitat types may potentially have significant interactions with the fishery.

The Seabed Biodiversity Project covered about 60 per cent by area of the Great Barrier Reef Marine Park (i.e. 210,000 km^2 out of a total 344,400 km^2). Deeper areas (below about 100 metres) were not included. About one-third of the Great Barrier Reef Marine Park is below 200 metres, and there has been little investigation of these continental slope and deep oceanic habitats. The continental slope is a complex area composed of relic reefs, landslides, canyons and plateaux.

Ten habitat types were assessed in detail, and are described below. Nine of these habitat types were identified by the Seabed Biodiversity Project (Pitcher et al. 2007b) and are depicted in Figure 20. These habitats were defined using a dataset of available biological and physical data plus video data characterising the seabed and biological structural types (e.g. seagrass, sponge garden). An additional habitat type was defined by this assessment (habitat 10, Figure 21) as detailed below. Habitat 10 covered an area of 14,056 sq km located in the southern Great Barrier Reef Region between about 90 and 300 m depths.

As an additional step in the risk identification process, to ensure all potentially impacted habitats were considered, the assessment looked at additional areas in deeper waters of the Marine Park that are open to trawling but outside of the area covered by all 10 habitat types already identified for detailed assessment (i.e. at other areas where the otter trawl fishery is allowed to operate within the Great Barrier Reef Marine Park not already covered by habitats 1 to 10). To do this, 2005 and 2009 otter trawl fishing effort for the region was overlaid on the habitats assessed. A small area deeper than 100 metres offshore from Tully experienced low intensity trawling effort in 2009. As the level of trawl effort was low, habitat type(s) in the area are likely to be at low or negligible risk from trawling, and were therefore not included in the detailed assessment. Other deepwater areas are likely to be occasionally fished, but at current very low effort levels in these habitats they are also likely to be at low or negligible risk from trawling.

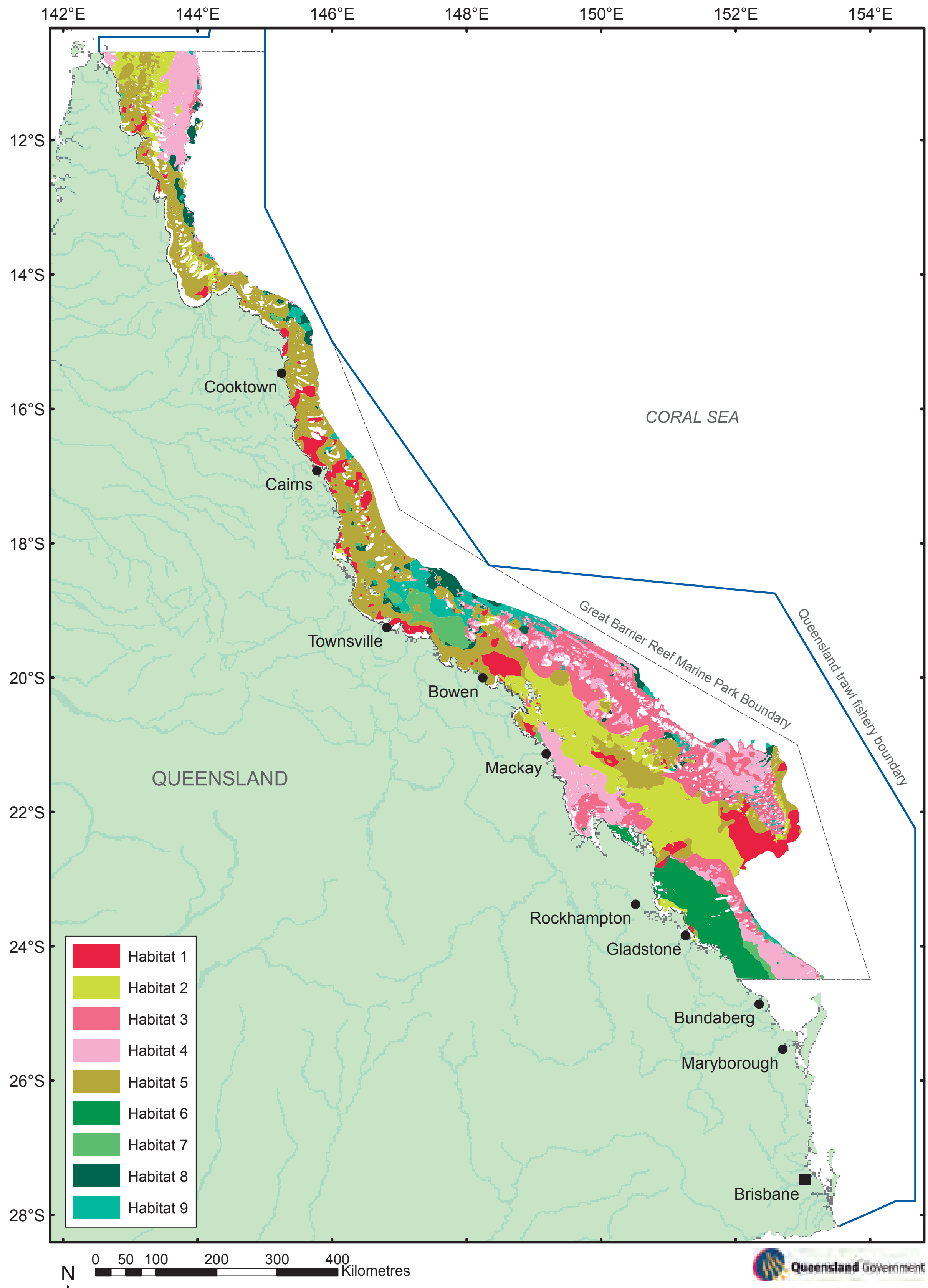


Figure 20. Map of predicted distribution of habitat types 1 to 9 in the Great Barrier Reef Marine Park (Pitcher et al. 2007b).

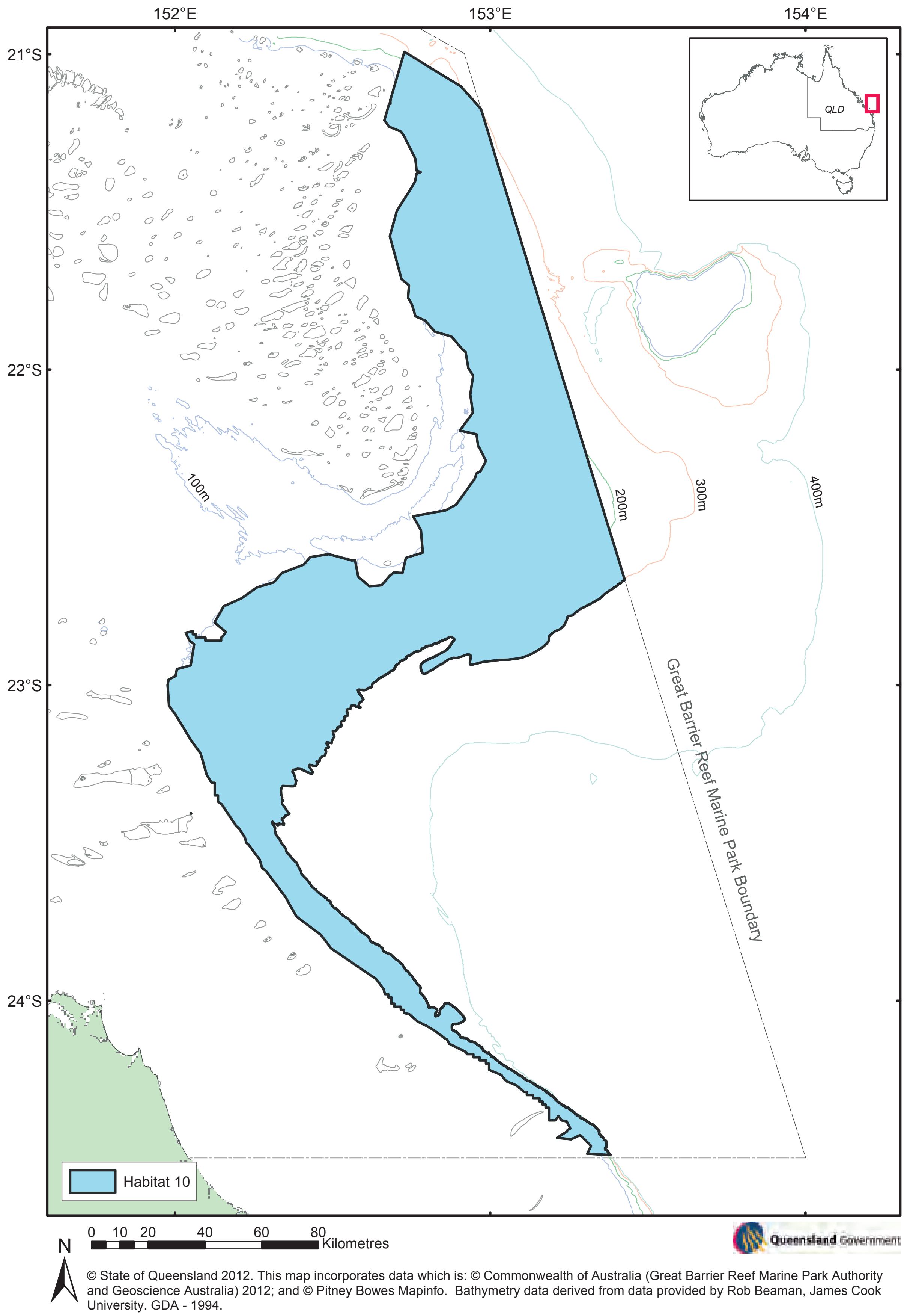


Figure 21. Map showing habitat 10 in the southern Great Barrier Reef Marine Park.

The habitat types were characterised as follows, with definitions for habitats 1 to 9 taken from the Seabed Biodiversity Project (Pitcher et al. 2007b):

- **Habitat 1** represents the most barren seabed type, almost entirely bare (making up about 20 per cent of the habitat area) and bioturbated (> 70 per cent) with very little observed biogenic habitat. It is distributed in muddy areas of the inshore and midshelf, as well as the deep end of the Capricorn Channel.
- **Habitat 2** is also very barren, with some bioturbation (about 20 per cent), 60–70 per cent bare seabed and very little epibenthos or algae (< one per cent). It is distributed in muddy–sandy areas of the southern midshelf and far north.
- **Habitat 3** has significant patches of whip gardens, sponge gardens, gorgonian gardens, alcyonarians, and algae separated by tracts of bare seabed (about 70 per cent). This habitat may also include very small amounts of hard coral gardens, *Halimeda* and *Caulerpa*. It is distributed in low mud, higher current areas, primarily in the southern Great Barrier Reef.
- **Habitat 4** is similar to habitat 3, but with more algae (about 16 per cent). It also had *Halimeda* and seagrass. This habitat may also include very small amounts of live reef corals, hard coral gardens, alcyonarians and *Caulerpa*. Habitat 4 is distributed in low mud, high current areas with higher benthic irradiance, in both the southern and far northern Great Barrier Reef.
- **Habitat 5** represents mostly bioturbated (about 40 per cent) and bare seabed (about 40 per cent) with a little algae and seagrass algal habitat and small amounts of whip, sponge and gorgonian gardens, live reef corals, hard coral gardens, *Halimeda*, alcyonarians and *Caulerpa*. It is distributed over much of the shelf in central and northern sections of the Great Barrier Reef.
- **Habitat 6** represents seagrass (about 30 per cent) and algal (about 10 per cent) habitats with about 10 per cent bioturbated and about 35 per cent bare seabed. May also include very small amounts of whip, sponge, and gorgonian gardens, alcyonarians, and *Halimeda*. It is distributed along much of the inner half of the shelf in the southern Capricorn section of the Great Barrier Reef.
- **Habitat 7** represents patchy seagrass (about 30 per cent) and algal (about 15 per cent) habitat with about 40 per cent bare seabed. It is distributed along the mid-shelf from Cape Upstart to Innisfail. This habitat also has very small amounts of whip, sponge, and gorgonian gardens, *Halimeda*, flora (i.e. unidentified marine plants other than *Halimeda* and *Caulerpa*), and *Caulerpa*.
- **Habitat 8** represents much of the *Halimeda* (> 40 per cent) habitat, as well as some other algae (about 20 per cent) and about 12 per cent bare seabed. Other characteristics include small amounts of whip gardens, sponge gardens, seagrass, live reef corals, hard coral gardens, gorgonian gardens, flora (as above), *Caulerpa*, and bioturbation.
- **Habitat 9** represents about 35 per cent patchy algae (including some *Halimeda*) with about 15 per cent bioturbation and about 35 per cent bare seabed. Other characteristics include small amounts of whip gardens, sponge gardens, seagrass, live reef corals, hard coral gardens, gorgonian gardens, *Caulerpa*, and alcyonarians. Habitat 9 is distributed primarily in the outer-shelf offshore from Townsville.

- **Habitat 10** is an additional habitat type to those defined above from the Seabed Biodiversity Project, and occurs in the southern Great Barrier Reef Marine Park between about 90 and 300 m depths. The area as defined includes part of two bioregions defined for the Great Barrier Reef Marine Park, namely the 'X8 Southern Embayment' bioregion (within that depth range) and the southern part of the 'NU Terraces' bioregion. Biological characteristics are largely unknown. The seabed sediments in this habitat are reported on Admiralty Charts as coral sand and shell, however this information would have been obtained from limited seabed sampling. There is no detailed knowledge about seabed habitats in the area.

The contact of trawl gear without capture was considered to pose an initial high risk of damage to habitats in the Great Barrier Reef Region (Table 4). Trawl gear can cause direct physical damage to marine plants and animals on the seabed (Poiner et al. 1998, Pitcher et al. 2000, Burridge et al. 2003, Pitcher et al. 2004, Burridge et al. 2006, Pitcher et al. 2007b, Pitcher et al. 2009) (see Section 4.1.2 'Trawling impacts on benthic habitats'). Some other activities of the fishery may also impact on habitats, however these were all assessed as posing a low initial risk. Trawl gear may impact on habitats by removing structural habitat elements such as sponges, which are subsequently discarded. Lost fishing gear (e.g. ground chains, trawl net) is likely to sink, with localised smothering effects on a small area of habitat where it lands, however trawl net will not generally continue 'ghost' fishing, and the level of lost or discarded fishing gear in the trawl industry is believed to be relatively low. Boat maintenance and emissions could potentially impact marine plants and animals by contaminating the water column and the seabed with toxic chemicals (e.g. fuel, oil or anti-fouling chemicals), however, the fleet size and amount of chemicals carried is relatively small compared with all shipping activity in the area, and most maintenance is carried out in port or on land.

In addition, as indicated in the overview of trawling impacts on benthic habitats (Section 4.1.2), trawling may alter the vertical relief of seabed features, redistribute sediments or translocate plants and animals through discarding, and such effects are considered further under the assessment for ecosystem processes (see Section 4.7).

4.5.3. RISK CHARACTERISATION

The available information base for seabed habitats in the Great Barrier Reef Region was robust for habitats shallower than 100 metres. The distribution and abundance of the habitat types was derived from the Seabed Biodiversity Project (habitats 1–9) (Pitcher et al. 2007a) and available spatial datasets for the Great Barrier Reef Region, including recent bathymetry data (habitat 10) (Beaman 2010). Information on other resilience characters was derived from fishery and Great Barrier Reef datasets, scientific literature (particularly work by Pitcher and co-workers (Poiner et al. 1998, Burridge et al. 2003, Pitcher et al. 2004, Burridge et al. 2006, Pitcher et al. 2007b, Pitcher et al. 2008)) and from the expert opinion of workshop participants (where published data was unavailable). Information on fishery impact profiles was obtained from fishery and Great Barrier Reef datasets, scientific literature (again including work by Pitcher and co-workers), the fishery observer program and expert opinion.

Resilience levels of marine habitats

Resilience of habitat types was assessed using the four characters and decision rules in Table 53 and detailed data is presented in Data Report: Appendix 18 and Data Report: Appendix 19.

The determination of the resilience levels of marine habitats was based on the distribution and abundance of habitats, recovery and resistance attributes for key structural elements and cumulative pressures (Data Report: Appendix 18). Significant external pressures (e.g. degraded water quality, other pressures including vulnerability to climate change) were explicitly considered as 'cumulative risks', where these influences were known.

The time taken for biota within a habitat to recover from trawling is influenced by the proportion of its population removed or damaged each year, and the proportion of its population rebuilt per year, through regrowth or recolonisation. Assessing the ability of the habitat to physically withstand/resist the impact of trawling and the capacity of the habitat to recover afterwards is complex, given habitats are varied and composed of many habitat elements with different characteristics. Consequently, we determined the resistance and the regrowth/recolonisation of habitats using a two-part process.

The assignment of risk prone or risk averse scores for the main living habitat elements was primarily informed by the findings of the major series of studies on seabed habitats and species of the Great Barrier Reef Region over the last two decades. These studies included assessment of the impact of trawling and assessment of recovery after trawling. References to these studies are provided below and the studies were discussed in Section 4.1.2.

The first part of the process consisted of determining (a) the 'impact of trawling' (proportion depleted/removed by trawling) and (b) 'ability to recover after being trawled' (proportion regrowing over time) for each of the main living habitat elements comprising at least three per cent of each habitat, and qualitatively assigning a grade of high, medium or low (Data Report: Appendix 18). For example, trawl gear used in this fishery generally damages the vegetative part of a plant rather than uprooting the rhizome, and may only remove a small fraction of the emergent biomass of seagrass or algae, so trawling was assessed as having a relativity low impact on seagrass. In addition, seagrass is known to have a high recovery ability after disturbance, with trawling potentially assisting with dispersal of propagules so seagrass was assessed as having a high ability to recover after trawling (Preen et al. 1995, Coles et al. 2007, De'ath et al. 2008) (Data Report: Appendix 18). Each main habitat element was assessed in a similar way at an expert workshop (Data Report: Appendix 18). The score was arrived at by consensus using expert opinion, based on a conservative interpretation of levels of trawling impact and recovery (Data Report: Appendix 18).

The second part of the process considered these estimated impacts of trawling, and ability to recover after being trawled for all the habitat elements that comprised at least three per cent of the habitat type, to derive an overall score of high, medium or low for the habitat. The score was arrived at using the decision rules detailed in Table 53. For example, habitat 3 contained sponge gardens (about six per cent) and alcyonarians (soft corals, about six per cent), which are highly impacted by trawling (Poiner et al. 1998, Pitcher et al. 2000, Pitcher et al. 2007b, Pitcher et al. 2009), and gorgonian gardens (about five per cent) which have a medium impact by trawling (Data Report: Appendix 18). Other habitat elements making up about four per cent each of the habitat type were whip gardens and algae, both of which have a low impact by trawling. Therefore, habitat 3 scored double prone for the 'impact' character, as it met the criterion 'high proportion of key structural elements removed by trawling: five per cent or more rated as high' (Table 53 and Table 55). Similarly, gorgonian gardens (about five per cent of habitat 3) and whip gardens (four per cent) have a long recovery time, and sponge gardens (about six per cent) have a medium recovery time (Pitcher et al. 2007a, Pitcher et al. 2000, Pitcher et al. 2008, Pitcher et al. 2004). Therefore, habitat 3 scored double prone for the 'ability to recover' character, as it met the criterion 'slow recovery of key structural habitat elements (recovery period): five per cent or more rated as low' (Table 55). In contrast, habitat 6 comprised the elements seagrass (about 30 per cent) and algae (about 10 per cent) with about 10 per cent bioturbated seabed, which are not highly impacted by trawling and which recover relatively quickly, and was risk averse for both characters (Table 55).

In general, cumulative pressures were deduced based on the inshore/offshore location of the habitat, and known associated risks from that location (e.g. reduced water quality, herbicides and other pollutants), and vulnerability to climate change, where known (Johnson and Marshall 2007). Offshore locations were generally not considered to be vulnerable to water quality issues or climate change impacts, unless upwelling patterns change. Coralline algae and *Halimeda* were considered vulnerable to climate change–induced ocean acidification and increasing run-off. Fleshy macroalgae and other biota were considered to be less vulnerable to climate change (Johnson and Marshall 2007). It was generally recognised that there is a low probability of seeing an effect due to climate change within the 20 year scope of the current ecological risk assessment. The assessment also noted if/when spatial and/or temporal variation in risk was relevant for a habitat (Data Report: Appendix 19).

The overall resilience level was determined by summing the number of risk prone scores attributed to each habitat type. Levels of resilience for each habitat were assigned qualitatively as either high (H; 0 prone), intermediate-high (H-I; 1 prone), intermediate (I; 2 prone), intermediate-low (I-L; 3 prone) or low (L; 4 or more prone out of a maximum risk prone score of 7).

The outcome of the assessment was that the resilience levels of habitats varied from high to low (Table 55).

Fishery impact profiles for marine habitats

The second part of the finer level assessment involved qualitative evaluation of the fishery impact profile using five factors to indicate the level of pressure exerted by the fishery on the habitat type being assessed, and the decision rules outlined in Table 54. Detailed data is presented in Data Report: Appendix 20 and Data Report: Appendix 21.

All of the factors used were taken (or modified) from the assessment of the NSW Ocean Trawl Fishery (DPI 2004). The first two factors relate to the adequacy of the information base, which contributes to risk. The detailed spatial distribution of fishing was known from the analysis of vessel monitoring system data (Appendix 2.2.3). Data for several factors were sourced from the Seabed Biodiversity Project for habitats 1 to 9 (Pitcher et al. 2007b, Pitcher et al. 2007a). Estimates of 'per cent effort exposed' were based on 2005 and 2009 levels of trawling effort in the fishery, taking intensity of trawling into account, as described in Appendix 2.2.4 (Pitcher et al. 2007b). The assessment also evaluated whether high impact fishing gear was used in the fishery, and noted if/when spatial and/or temporal variation in risk was relevant for a habitat (based on expert opinion) (Data Report: Appendix 20 and Data Report: Appendix 21).

The overall fishery impact profile for each habitat was determined by summing the number of risk prone scores attributed to each habitat type. The fishery impact profile was assigned qualitatively as either low (L; 0 prone), intermediate-low (I-L; 1 prone), intermediate (I; 2 prone), intermediate-high (H-I; 3 prone) or high (H; 4 or more prone out of a maximum risk prone score of 6).

Based on 2009 levels of trawl fishing effort, the fishery impact profiles for nine of the habitat types were low or intermediate-low. Habitat 10 had a high fishery impact profile because it scored precautionary risk prone or double prone for several factors (Table 56, see Section 3.3.3 for a discussion of weightings and how these took into account the sensitivity of the component being assessed). The scores were similar based on higher 2005 levels of fishing effort, with only two habitat types (1 and 5) scoring slightly higher fishery impact profiles (Table 57).

Risk for habitats

The risk gradings for habitats are summarised in Table 13. The risk gradings were obtained by combining the resilience levels and fishery impact profile levels as shown on the risk matrix in Figure 13.

The risk assessment outcomes for habitats in 2009 were:

- Habitats 1, 2, 4 and 5 were at low risk
- Habitats 3, 6, 7, 8 and 9 were at intermediate-low risk
- Habitat 10 was at high risk.

The risk gradings were the same for 2005 levels of fishing effort, even though the fishery impact profile varied slightly for a couple of habitat types (i.e. reduced from intermediate-low in 2005 to low in 2009 for habitats 1 and 5).

Table 13. Risk assessment of marine habitats (ordered according to 2009 risk levels).

Habitat type	Resilience	Fishery impact profile 2005	Risk 2005	Fishery impact profile 2009	Risk 2009
Habitat 10	L	H	HIGH	H	HIGH
Habitat 6	I	I-L	INT-LOW	I-L	INT-LOW
Habitat 7	I	I-L	INT-LOW	I-L	INT-LOW
Habitat 3	L	L	INT-LOW	L	INT-LOW
Habitat 8	L	L	INT-LOW	L	INT-LOW
Habitat 9	I-L	L	INT-LOW	L	INT-LOW
Habitat 1	H	I-L	LOW	L	LOW
Habitat 5	H	I-L	LOW	L	LOW
Habitat 4	H-I	L	LOW	L	LOW
Habitat 2	H	L	LOW	L	LOW

4.5.4. ISSUES ARISING FROM THE RISK ASSESSMENT FOR HABITATS

For habitats, the risk assessed was *'What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will result in serious or irreversible damage to the habitat type such that the habitat type is not able to maintain viable populations, biodiversity, assemblages and/or ecosystem processes in the Great Barrier Reef Marine Park within the next 20 years?'*. This section discusses the overall patterns of risk for habitats, and any habitat types identified as at intermediate or higher risk, against this risk context, and discusses the progress made in reducing risks and impacts, and other issues arising from the assessment.

Overall pattern of risk for habitats

The overall pattern of ecological risk for habitats at 2009 levels of trawl fishing effort is shown in Figure 19. Based on trawl effort levels in 2009 and 2005, nine of the ten marine habitats were evaluated as being at low or intermediate-low risk, and no major issues were identified for these habitats in relation to trawling (Table 13). The management arrangements in place are considered to provide adequate protection from trawling for these nine shallow (less than 100 m) habitat types, given the current levels of effort in the fishery compared to the scale of the Great Barrier Reef Region, and the current spatial distribution of the fishing effort. Based on fishing effort levels in both 2005 and 2009, the fishery was assessed as posing a high risk to the remaining habitat type 10, which is deeper than 100 metres and predominantly south and east of the Swains.

Comments on identified risks to habitats

The assessment of a high risk of serious or irreversible damage within 20 years to habitat 10 was precautionary and partly reflects the lack of biological information for deepwater habitat(s) in the areas fished for eastern king prawns. The certainty in the assigned risk level was low. Risk prone fishery impact factors for habitat 10 arose from lack of spatial knowledge of the habitat (it is unknown if the area is heterogeneous or to what extent the same habitats are represented elsewhere within deeper waters), very high effort exposure from trawling (the exposed 53 per cent of area was trawled an average of more than 2.1 times in 2009, contributing to a total indicator of 112 per cent of area exposed to trawl effort), and limited protection under Marine Park zoning (only 13.8 per cent), resulting in a high fishery impact profile. In part, this proportional level of protection is an artefact of the way the boundary of habitat 10 was defined here to encompass the extent of the trawl grounds in this region, however the choice of boundary was considered the most appropriate for the purposes of this assessment given the available information and to approximate a single habitat type.

The way the boundary of habitat 10 was defined differs from how the boundaries for the other habitats were defined (Section 4.5.2). It is not known if the habitat type(s) called here habitat 10 extends beyond the boundary used in this assessment. The depth strata that was used in part to define this habitat type extends further north than the Swains Reef area, with some deepwater areas open to trawling such as off Bowen. However, in recent years very little trawling has occurred in those deepwater areas outside of habitat 10 and little information is available on latitudinal change in the seabed community composition of these habitats.

In considering resilience characters for habitat 10, the impact of trawling on key structural elements (i.e. the proportion depleted/removed by trawling) was scored as risk prone (rather than double prone) for the following reasons. Available information from other places indicates some deepwater seafloor plants and animals are easily depleted by trawling (Sainsbury et al. 1997, Bax and Williams 2001, Asch and Collie 2008, Williams et al. 2010), however the fishery is not using heavy impact gear compared with other trawl fisheries (Astles et al. 2009) and the industry is tending to even lighter gear (Sterling 2008). The ability of key structural elements to recover after being trawled (i.e. the recovery period) was scored as risk double prone as some deepwater seafloor plants and animals are known to recover slowly after depletion. For example, recovery may take decades or longer for some slow-growing deepwater corals and sponges (Sainsbury et al. 1997, Bax and Williams 2001, Asch and Collie 2008, Williams et al. 2010). Overall, this resulted in habitat 10 being given a precautionary assessment as having low resilience; however, as the presence and characteristics of structural elements are poorly known, the certainty of the assessment was determined to be low.

No attempt has been made in this assessment to assign any level of relative importance to these 10 different habitat types, such as importance in terms of spawning or refuge habitats or as critical habitats for life cycle stages of species of conservation concern. Ranking habitats in terms of relative importance would allow the derivation of a weighted assessment of risk that might be helpful for priority setting of management responses or for developing a combined risk score across all habitats. This might be a useful extension of this work in the future, but for the purposes of this assessment, equal importance for all habitats was assumed.

Progress made in reducing risks and impacts

The findings recognise the progress made over the last decade or more by managers and industry towards protecting shelf habitats, conserving biodiversity and maintaining ecosystem resilience. In this regard, protection of habitats from trawling through Marine Park zoning and areas closed to fishing under fisheries legislation plays a particularly important role in reducing risks and impacts on habitats, and hence in the overall findings of this ecological risk assessment. The overall findings reached here in this risk assessment took into account the full suite of management arrangements for the ECOTF in the Great Barrier Reef Region including protected area management and used very fine spatial scale data on the distribution of fishing effort.

The various types of zones in the Marine Park take into account the ecological impacts of different fishing methods. Some 33 per cent of the Marine Park is set aside as strategically placed Marine National Park 'no-fishing' or 'green' zones in which all fishing activities are prohibited. In recognition of the habitat impacts of trawling, a further 33 per cent of the Marine Park is set aside in various other zones in which trawling is prohibited. These zones contribute to the maintenance of ecosystem processes, resilience and biodiversity of the Great Barrier Reef ecosystem. Areas zoned as no-trawl areas are also important for the communities of plants and animals that live there and the fish stocks that depend on them.

A further system of spatial and temporal fishery closures under Queensland fisheries legislation prohibits or restricts trawling activities in areas for ecological, economic and social reasons. These fishery closures include protection for productive habitats that support the fishery (e.g. inshore and intertidal seagrass beds important for some juvenile prawns) and help support ecosystem resilience, and spatial fishery closures are generally mirrored in Marine Park zoning throughout the Great Barrier Reef Marine Park.

The rezoning of the Great Barrier Reef Marine Park in 2004 for biodiversity conservation was designed to protect at least 20 per cent of each defined bioregion from extractive uses including fishing (Fernandes et al. 2005). The Seabed Biodiversity Project dataset was used to examine the protection levels for species, habitats and species assemblages before and after rezoning (Pitcher et al. 2007a) (the study encompassed shelf waters from about 7 m to about 100 m). That study found that before rezoning, four out of the nine habitat types had less than 20 per cent of their area in zones closed to trawling; but after rezoning, one habitat type had 20 per cent and all the others had greater than 20 per cent in zones closed to trawling. The average increase in protection was by 31 per cent. These protected areas act as a safeguard to ensure that marine habitats in the Great Barrier Reef will not be altered irreversibly by trawling. Additionally, the study confirmed that at least 20 per cent of the 850 species analysed and the 16 species assemblages assessed were protected.

Even though 34 per cent of Great Barrier Reef waters are open to trawling, only seven per cent and six per cent of the Marine Park and World Heritage Area were trawled more than once per year in 2005 and 2009, respectively (Appendix 2.2.3). Trawling operations tend to focus on areas of higher catch rates for target species, and this fishing behaviour helps to ensure substantial areas remain unaffected by trawling (Appendix 2.2.4). Untrawled areas may act as refugia for by-catch species and all other ecological components (from harvested species to ecosystem processes), and help to ensure the ecological footprint of the fishery avoids serious or irreversible damage to marine habitats.

Ongoing compliance and enforcement programs are in place for the Great Barrier Reef Marine Parks and Queensland managed fisheries, and are a very important part of risk management. Heavy penalties apply for trawling in no-trawl zones because of risks and impacts on biodiversity, habitats and ecosystem function. Such illegal activity also cheats those people who conduct commercial or recreational fishing in an honest manner.

Further issues and information gaps

For this assessment, the most important data gaps relate to habitat type 10 and its associated species. Information priorities include understanding which seabed species occur in the area, and what are their distributions, abundance and biology. Some species from the area have only recently been described (e.g. some skates and crustaceans). It is difficult to assess ecological risks from trawling confidently given these information gaps, and the risk assessment recognised this by taking a precautionary approach.

The vessel monitoring system (VMS)-derived spatial information on trawl fishing effort patterns (Appendix 2.2.3) underpinned this assessment. The extensive datasets provided by the Seabed Biodiversity Project (Pitcher et al. 2007b) and related suite of research undertaken over the past two decades have proved invaluable in assessing risk to most habitats within the Great Barrier Reef, and in providing confidence in the risk assessment outcomes.

Although not an identified risk, the results for habitats 1–9 merit some further discussion. The intermediate resilience levels of habitats 6 and 7 were a function of either size of the habitat or its distribution, and susceptibility to cumulative, largely land-based, pressures. These habitats both comprised patchy seagrass and algae. Habitat 6 is distributed along much of the inner half of the shelf in the southern Capricorn section of the Great Barrier Reef. Habitat 7 is distributed along the mid-shelf from Cape Upstart to Innisfail. Habitats 6 and 7 were subject to relatively high levels of fishing effort (34 per cent and 30 per cent, respectively, in 2009), and were afforded only moderate levels of protection from trawling (20 per cent and 26 per cent, respectively). Ensuring that the risk to these habitats does not increase will require ongoing monitoring of levels and spatial patterns of trawling effort. Risk management should also consider potential cumulative pressures on these habitats.

Habitats 1, 2 and 5 were mostly bioturbated/bare seabed and had high resilience to trawling or other disturbances, whereas habitat 4 had a higher proportion of algae (16 per cent) and an intermediate-high resilience. All four habitats had a low fishery impact profile.

The resilience levels of habitats 3 and 8 were low, which reflected the relatively high potential for impact from trawling and slow recovery ability of key structural habitat elements such as sponge gardens. Habitat 8 is also prone to cumulative pressures including potential climate change effects on upwelling patterns. Fortunately, the fishery impact was also low for these habitats. This is unlikely to change significantly in the future, since 68 per cent and 88 per cent of these habitats respectively are protected from trawling by zoning.

The resilience level of habitat 9 was intermediate-low. This habitat was dominated by algae (28 per cent) and *Halimeda* (seven per cent), giving risk prone scores for impact and recovery characters. In addition, the habitat was small in size, and so more prone to stochastic events. The fishery impact profile of habitat 9 was low and its level of protection was high (64 per cent).

Summary: Species assemblages

SPECIES ASSEMBLAGES

Key facts

Ecological component assessed: 16 species assemblages (often more commonly called 'communities'), which are groups of species that tend to occur together.

Ecological role: The association of species in an assemblage is likely to be ecologically important to the functioning and integrity of the ecosystem, even though the nature of any linkages may not be well understood.

Trawl fishery: Species assemblages represent an intermediate level of complexity between individual species (whether harvested, by-catch or species of conservation concern) and the more general level of ecosystem processes.

RISK ASSESSMENT FOR THE GREAT BARRIER REEF REGION

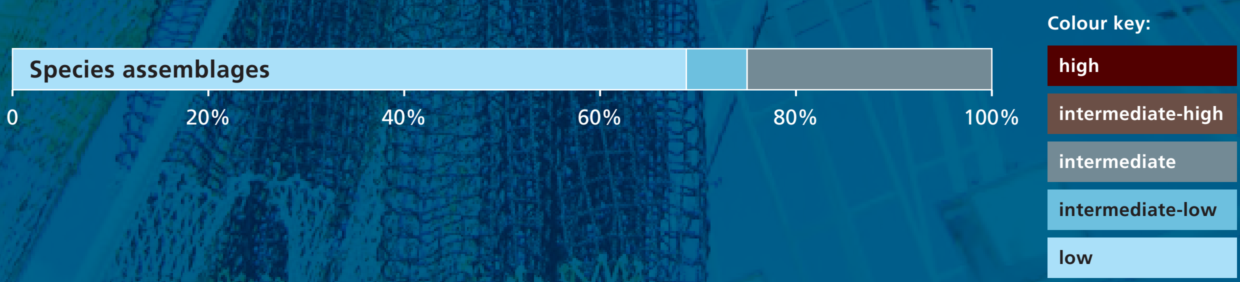
Consequences to avoid over the next 20 years: Serious or irreversible damage to species assemblages (such that the assemblage type is not able to maintain viable populations, biodiversity, and/or ecosystem processes).

An ecosystem-based approach to the management of trawling requires consideration of risks to all aspects of the ecosystem that the fishery might pose a risk to, such as species assemblages.

The direct ways trawling activities could lead to serious or irreversible damage to species assemblages over a 20-year period, if risks are not managed:

Harvesting	By impacts on the relative abundance of species in assemblages via removal of harvested species
Discarding	By impacts on the relative abundance of species in assemblages via death of species landed on the deck of the boat and then discarded
Contact without capture	By physical damage to marine plants and animals on the seabed, or the key structural habitat elements on which they depend
Loss of fishing gear	By localised smothering effects on assemblages in small areas
Boat maintenance, emissions	By potential impacts on marine plants and animals from any local contamination of the water column and the seabed with toxic chemicals

FIGURE 22: OVERALL PATTERN OF RISK AT 2009 LEVELS OF TRAWL FISHING EFFORT



4.6. Species assemblages

4.6.1. RISK CONTEXT

An ecosystem-based approach to the management of trawling in the Great Barrier Reef Region requires consideration of risks to all aspects of the ecosystem that the fishery might pose a risk to, such as species assemblages.

The risk assessed was:

> *What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will result in serious or irreversible damage to species assemblages such that the assemblage type is not able to maintain viable populations, biodiversity and/or ecosystem processes in the Great Barrier Reef Marine Park within the next 20 years?*

Assemblages (often more commonly called 'communities') can be thought of as groups of species that are associated with each other because they tend to occur together in the same places. Their attributes (e.g. species composition and relative abundances, and location) may change over time. For example, where an assemblage occurs may change in response to influences such as changing current regimes, unless there is an overriding association with a particular seafloor feature or habitat type.

Species assemblages are assessed as a separate entity to their individual component species on the assumption that the association of the species in an assemblage is ecologically important even though the nature of any linkages may not be well understood. Such assemblages are included in the assessment to represent an intermediate, but still site-based, level of complexity between individual species (whether harvested, by-catch or species of conservation concern) and the more general level of ecosystem processes.

Sainsbury (2008) noted best practice reference points are poorly developed for the non-targeted elements of the ecosystem and, in particular, best practice with respect to habitats, food webs and overall ecosystem composition (biodiversity at the genetic, species and community levels) is at an early stage of development. This remains true in the fisheries performance measurement system for the ECOTF.

Similar to the approach used for marine habitats, development of a suitable risk context for species assemblages took into account an ecosystem-based management approach and was informed by the principles of ecologically sustainable use, defined in the *Great Barrier Reef Marine Park Act 1975*, particularly the precautionary principle and the conservation of biodiversity and ecological integrity (see Section 4.5.1).

4.6.2. RISK IDENTIFICATION

The assemblage components that were assessed comprised the 16 site-based species assemblages (Figure 23) defined in the Seabed Biodiversity Project (Pitcher et al. 2007b). Species assemblages in waters deeper than 100 metres were not part of this assessment. Each of these species assemblages were defined statistically to represent a mix of plants and animals that was as homogeneous as possible and in some way distinct from the mix in other assemblages. The data used differed from that used to define habitats, so it is valid to consider risks both to the habitats and to the species assemblages identified by the Seabed Biodiversity Project (Pitcher et al. 2007b). For descriptions of the species assemblage types, see the Seabed Biodiversity Project (especially Sections 3.4 and 3.7.3 in Pitcher et al. 2007b).

The contact of trawl gear without capture was considered to pose an initial variable risk of damage to assemblages (depending on the assemblage type) in the Great Barrier Reef Region (Table 4). Trawl gear can damage assemblages through direct effects on species or the key structural habitat elements on which they depend (Poiner et al. 1998, Pitcher et al. 2004, Pitcher et al. 2007b). Trawling can also potentially have indirect effects on assemblages, for example through effects on food sources of associated species.

Harvesting and discarding were assessed as posing an intermediate initial risk because these activities have direct effects on the species taken as catch or by-catch and therefore may also impact on associated assemblages (Table 4). As for habitats, boat maintenance and emissions was assigned an initial low risk as a result of potential impacts on marine plants and animals.

In addition, trawling may have indirect effects on assemblages, for example through altering food webs or community composition, and such effects were considered further under the assessment of ecosystem processes (see Section 4.7).

4.6.3. RISK CHARACTERISATION

Information used in the assessment of species assemblages came primarily from the Seabed Biodiversity Project and related work, and incorporated a number of spatial datasets for the Great Barrier Reef and information on trawl fishing effort patterns. As only a few characters and factors were able to be assessed, overall confidence in the assessment of species assemblages was low.

The assessment of species assemblages was informed by the assessments reported earlier in this report on some of their individual component species (including harvested species such as prawns, by-catch species and species of conservation concern).

Resilience levels of species assemblages

Resilience of assemblages was assessed using the three characters and decision rules in Table 58 and detailed data is presented in Data Report: Appendix 22.

The characters and factors used for the finer level assessment of species assemblages were newly developed or modified significantly from those developed for the NSW Ocean Trawl Fishery, to suit the nature of the fishery in Queensland, and available data for the Great Barrier Reef Region. Only macroalgal and benthic motile invertebrate assemblages were characterised in the NSW Ocean Trawl Fishery, and for these components only one or a few characters were used in their risk assessment (DPI 2004).

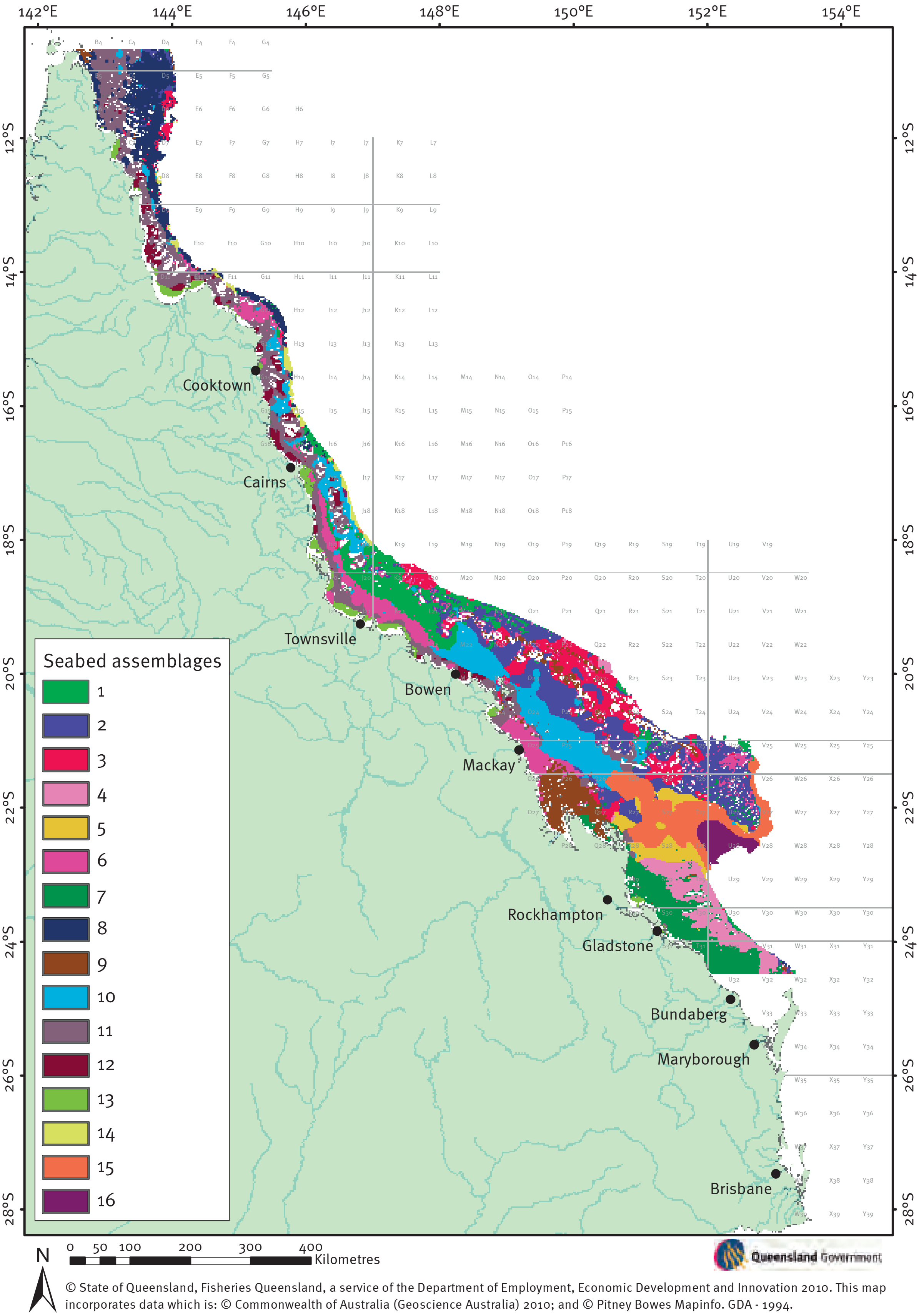


Figure 23. Map of predicted distribution of species assemblages in the Great Barrier Reef Marine Park.

Assemblage types 1–16 as described by the Seabed Biodiversity Project. Commercial fishery logbook reporting grids are also shown. (Pitcher et al. 2007b)

The distribution and abundance of the assemblage types was derived from the Seabed Biodiversity Project (Pitcher et al. 2007a). The same project also identified those individual species that had a high affinity with particular assemblages (Pitcher et al. 2007a). The character 'risk to species with high affinity and fidelity' assumes a high affinity species plays an important (but possibly unknown) ecological role in its associated assemblage, and was used to evaluate whether any of these species were exposed to trawling to a significant extent and hence such exposure was also impacting on the assemblage. Cumulative pressures were also evaluated, including vulnerability to climate change (Johnson and Marshall 2007). In general, cumulative pressures were deduced based on the inshore/offshore location of the assemblage, and the known risks associated with that location (e.g. water quality issues), plus any known cumulative risks to associated species. Offshore locations were generally not considered to be vulnerable to water quality impacts.

The overall resilience level for each assemblage was determined by summing the number of risk prone scores attributed to each type. Levels of resilience for each assemblage were assigned qualitatively as either high (H; 0 prone), intermediate-high (H-I; 1 prone), intermediate (I; 2 prone), intermediate-low (I-L; 3 prone) or low (L; 4 prone out of a maximum risk prone score of 4).

The outcome of the assessment was that the resilience levels of assemblages varied from intermediate-low to high (Table 60).

Fishery impact profile scores of species assemblages

The second part of the finer level assessment involved qualitative evaluation of the fishery impact profile using two factors to indicate the level of pressure exerted by the fishery on the assemblage type being assessed, and the decision rules outlined in Table 59 (detailed data is presented in Data Report: Appendix 23 and Data Report: Appendix 24).

As noted above, the factors used for species assemblages were newly developed or modified significantly from those developed for the NSW Ocean Trawl Fishery. The factor relating to 'accessibility' of trawl gear used in the assessment of the NSW Ocean Trawl Fishery (DPI 2004) was not used. 'Accessibility' was concerned with whether trawl gear was able to fish very close to or over the top of the assemblage's seafloor surface, based on the habitat and/or the use of specific trawling gear. The current assessment used 'per cent effort exposed' instead, which estimated the proportion of the assemblage type exposed to trawling taking intensity of trawling into account, available from the Seabed Biodiversity Project (Pitcher et al. 2007b). As explained in Appendix 2.2.4, we considered estimates of 'per cent effort exposed' for 2005 and 2009, based on 2005 and 2009 trawling effort data, respectively.

The overall fishery impact profile for each assemblage was determined by summing the number of risk prone scores attributed to each assemblage type. The fishery impact profile was assigned qualitatively as either low (L; 0 prone), intermediate-low (I-L; 0 prone), intermediate (I; 1 prone), intermediate-high (H-I; 2 prone) or high (H; 3 prone out of a maximum risk prone score of 3).

The fishery impact profile of species assemblages can be summarised as follows for 2009 (Table 61). Twelve of the 16 assemblages (2, 3, 5–11 and 14–16) had a low fishery impact profile. The other four assemblages (1, 4, 12 and 13) had an intermediate fishery impact profile. No assemblage had a high fishery impact profile.

The fishery impact profiles were similar based on higher 2005 levels of fishing effort (Table 62), however two species assemblages had higher fishery impact profiles.

Risk for assemblages

The risk gradings for assemblages are summarised in Table 14. The risk gradings were obtained by combining the resilience levels and fishery impact profile levels as shown on the risk matrix in Figure 13.

The risk assessment outcomes for assemblages in 2009 were:

- Eleven assemblages (2, 3, 5, 6, 8, 9, 10, 11, 14, 15 and 16) were at low risk
- One assemblage (7) was at low-intermediate risk
- Four assemblages (1, 4, 12 and 13) were at intermediate risk.

Compared to the higher trawl fishing effort levels in 2005, the 2009 risks to two assemblage types were lower, and no assemblages increased in risk (Table 14).

Table 14. Risk assessment for assemblages (ordered according to 2009 risk levels).

Assemblage type	Resilience	Fishery impact profile 2005	Risk 2005	Fishery impact profile 2009	Risk 2009
Assemblage 12	I-L	H-I	HIGH	I	INT
Assemblage 13	I-L	I	INT	I	INT
Assemblage 4	H-I	I	INT	I	INT
Assemblage 1	H	I	INT	I	INT
Assemblage 7	I-L	L	INT-LOW	L	INT-LOW
Assemblage 11	I	H-I	INT-HIGH	L	LOW
Assemblage 16	I	L	LOW	L	LOW
Assemblage 5	I	L	LOW	L	LOW
Assemblage 9	I	L	LOW	L	LOW
Assemblage 6	H-I	L	LOW	L	LOW
Assemblage 10	H-I	L	LOW	L	LOW
Assemblage 14	H-I	L	LOW	L	LOW
Assemblage 15	H	L	LOW	L	LOW
Assemblage 2	H	L	LOW	L	LOW
Assemblage 3	H	L	LOW	L	LOW
Assemblage 8	H	L	LOW	L	LOW

4.6.4. ISSUES ARISING FROM THE RISK ASSESSMENT FOR SPECIES ASSEMBLAGES

For species assemblages, the risk assessed was *'What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will result in serious or irreversible damage to species assemblages such that the assemblage type is not able to maintain viable populations, biodiversity and/or ecosystem processes in the Great Barrier Reef Marine Park within the next 20 years?'*. This section discusses the overall patterns of risk for species assemblages, and any assemblage types identified as at intermediate or higher risk, against this risk context, and discusses the progress made in reducing risks and impacts, and other issues arising from the assessment.

Overall pattern and comments on identified risks for species assemblages

The overall pattern of ecological risk for species assemblages in waters less than 100 metres at 2009 levels of trawl fishing effort is shown in Figure 22. In 2009, twelve of the assemblages were at low or intermediate-low risk, and no particular management issues were identified for these assemblages at current levels of effort in the fishery, and its current spatial distribution. The other four assemblages (1, 4, 12 and 13) were at intermediate risk, with each having an intermediate fishery impact profile but varying resilience. The key risk prone factors influencing the (simple) fishery impact profiles for each assemblage type were the per cent effort exposure values, which were given a double weighting (i.e. could be scored as risk double prone, as explained in Section 3.3.3). These values were derived from the Seabed Biodiversity Project (Appendix 2.2.4) and are estimates of the proportion of the assemblage type actually exposed to trawling, taking intensity of fishing effort into account.

There was a reduced risk based on the lower 2009 levels of trawl fishing effort compared to 2005 levels; that is, one assemblage had dropped from a high risk (type 12, distributed in patches along the coastal/inner shelf from the Whitsundays to Cape Upstart and from Cairns north) and another had dropped below an intermediate-high risk (type 11) (Table 14). There was some redistribution of fishing effort over this period, and not just an overall reduction in effort, as shown in Figure 31. The assessment took this into account by considering the detailed pattern and intensity of spatial use in relation to the distribution of each assemblage type, as well as the overall level of trawl fishing effort, under the per cent effort exposure factor.

Progress made in reducing risks and impacts

The findings for species assemblages are generally positive for the industry. Again, environmental benefits and reduced risks have resulted from prior actions by managers and industry, and the overall lower effort levels. As found for the species-level assessments, there was a significant reduction in risk to assemblages in the Great Barrier Reef Region based on 2009 levels of trawl fishing effort compared with 2005 levels. Risk could increase again if trawl fishing effort increases. Again, this finding highlights the value of initiatives under way to reduce by-catch in the fishery, and the need for better fishery management controls on fishing pressure with the ability to adjust trawl effort if required for sustainability reasons.

Further issues and information gaps

The current performance measurement system for the trawl fishery (DEEDI 2009b) includes a measure covering species assemblages, providing a mechanism for managers to monitor risks to assemblages. However, the concept of species assemblages may be difficult to operationalise for assessment and monitoring purposes. The Seabed Biodiversity Project provided comprehensive ground-truthing of modelled distributions for assemblages with patterns on the ground. However, while determining the trawl effort exposure of a habitat or assemblage is relatively straightforward, the implications of that exposure are more difficult to assess, because the component elements have different impact and recovery rates. So, instead for assemblages, it was considered whether there were any indicator species that were at risk (Section 4.6.3). In addition, because composition of assemblages and habitats is not fixed over time, this presents some challenges in monitoring their levels of risk from trawling.

Of the four assemblages currently at intermediate risk, types 12 and 13 are at the greatest risk of moving into the high risk category if their fishery impact profiles increase, as a consequence of their intermediate-low resilience levels. In fact, the per cent effort exposure factor would only have to increase by five per cent to place assemblage 12 back into the high risk category. However, 43 per cent of this assemblage type is protected in refuges in the Great Barrier Reef Marine Park.

The assessment could be refined by analysing which sectors of the fishery are contributing to trawl effort for each of the assemblages at identified risk to better understand fishing impacts and risks. If such an analysis identified particular fishery sectors posing a risk to an assemblage, then managers could monitor effort levels within the relevant sectors as a proxy for risk to the assemblage.

Summary: Ecosystem processes

Key facts

Ecological component assessed: 14 ecosystem processes, which are physical, chemical, ecological and other processes that underpin the functioning of the Great Barrier Reef ecosystem.

Ecological role: Ecosystem processes are the mechanisms which influence the distribution and abundance of organisms, the habitats in which they occur and by which components of an ecosystem are linked or interact.

Trawl fishery: Processes on which trawling could have a potential impact were included as part of the assessment of risks from trawling to the ecosystem.

RISK ASSESSMENT FOR THE GREAT BARRIER REEF REGION

Consequences to avoid over the next 20 years: serious or irreversible change to ecosystem processes (such that fishery resources and fish habitats, environment, biodiversity or heritage values of the Great Barrier Reef Marine Park are degraded or exposed to an unacceptable risk).

An ecosystem-based approach to the management of trawling requires consideration of risks to all aspects of the ecosystem that the fishery might pose a risk to, such as ecosystem processes.

The ways trawling activities could lead to serious or irreversible change to ecosystem processes over a 20-year period, if risks are not managed:

Harvesting	By impacts on the relative abundance of species via removal of harvested species. Also by other flow-on effects from removal of individuals such as nett loss of nutrients from ecosystem or changes to connectivity or predation processes.
Discarding	By impacts on the relative abundance of species via death of discarded species. Also by other flow-on effects from removal or translocation of individuals such as changes to feeding opportunities or availability of decomposing organic matter locally or changes to connectivity or predation processes.
Contact without capture	By direct physical damage or disturbance to seabed habitats and species. Also via effects such as behavioural disturbance, provisioning or translocation. Also by altering the vertical relief of seabed features, increasing turbidity and/or redistributing sediments.
Travel to/from grounds	Fishing boats may be vectors for the introduction or translocation of species

FIGURE 24: OVERALL PATTERN OF RISK

Colour key:

- high
- intermediate-high
- intermediate
- intermediate-low
- low

4.7. Ecosystem processes

4.7.1. BACKGROUND TO THE ASSESSMENT OF ECOSYSTEM PROCESSES

The need to consider the impacts of fishing on the full range of ecological components is now widely recognised and is embodied in state and national legislation in Australia and in a wide range of international agreements and conventions (Scandol et al. 2005). A key part of predicting ecosystem effects of fishing is to understand the way in which components of the ecosystem interact (Shannon et al. 2000). The main frameworks that have been developed for examining the ecological impacts of fishing in Australia (Fletcher 2005, Hobday 2006, Astles et al. 2009) all allow for the assessment of ecosystem processes to be a part of the process, but to our knowledge ecological processes potentially affected by a fishery have either not been assessed or have been assessed only in a relatively rudimentary manner. The paucity of examples where ecosystem processes have been assessed is partly the result of the difficulty in identifying, let alone measuring, robust indicators of marine ecosystem processes, although there is now evidence as to which indicators would be worth measuring (Fulton et al. 2005, Christensen et al. 2008).

The importance of using indicators that are of relevance to managers has been stressed by some (Lackey 1994, Fletcher 2005) and it may not be obvious that the focus on ecosystem processes here fits that criterion. The assessment of risks to ecosystem processes, however, attempts to identify any issues that may not be apparent by looking solely at the lower order components and may prove to be of greater relevance to management than initially appears to be the case. A suite of ecosystem processes was included in an assessment of ecosystem health published in the *Great Barrier Reef Outlook Report 2009* (GBRMPA 2009), so this management agency has decided that assessing these processes is a worthwhile exercise for determining ecosystem health. The list of processes in the Outlook Report was the starting point for the selection of ecosystem processes considered in this assessment.

The same framework used for assessing risks to other components was also used for assessing risks to ecological processes but, as outlined below, the ecosystem processes considered differed from those assessed for the NSW Ocean Trawl Fishery (Astles et al. 2009) and were more closely aligned with those considered in the *Great Barrier Reef Outlook Report 2009* (GBRMPA 2009).

4.7.2. RISK CONTEXT

As for the other ecological components that were assessed, the risk context for ecosystem processes was developed considering the *Great Barrier Reef Marine Park Act 1975* and the *Fisheries Act 1994*. It specifically addressed risks posed by the ECOTF to functional aspects of the ecosystem, including changes to processes that may affect the distribution and abundance of organisms, the habitats in which they occur or the way they may interact with each other.

The risk assessed was:

What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will cause serious or irreversible change to ecosystem processes such that the fishery resources and fish habitats, environment, biodiversity or heritage values of the Great Barrier Reef Marine Park are degraded or exposed to an unacceptable risk within the next 20 years?

Examples of serious or irreversible change would include:

- Environment, biodiversity and heritage values being unable to be maintained in a way that ensures the ecologically sustainable use of the Great Barrier Reef Region within the next 20 years (*Great Barrier Reef Marine Park Act 1975, Section 2A*)
- The Great Barrier Reef Region and its natural resources being unable to sustain natural processes in a way that maintains the life-support systems of nature and that ensures the benefit of the use to the present generation does not diminish the potential to meet the needs and aspirations of future generations (*Great Barrier Reef Marine Park Act 1975, Section 3AA(b)*)
- Ecological systems being unable to support desired long-term environmental, economic and social outcomes for fishery resources and fish habitats within the next 20 years (*Fisheries Act 1994*, *Queensland Fisheries Strategy: 2009–2014* (DEEDI 2009c))
- Ecological components being unable to contribute to the persistence of a diverse, resilient and productive World Heritage Area and productive ecosystem within the next 20 years (25 Year Strategic Plan for the Great Barrier Reef World Heritage Area 1994–2019, 25 year objective, p.15).

4.7.3. RISK IDENTIFICATION

Ecosystem processes relevant to trawling in the Great Barrier Reef

Ecosystem processes are the physical, chemical, ecological and other processes that underpin the functioning and health of the entire Great Barrier Reef ecosystem. These processes are all interconnected and the overall health of the ecosystem requires that no natural functions are impaired.

The ecosystem processes are also the mechanisms which influence the distribution and abundance of organisms, the habitats in which they occur and by which components of an ecosystem are linked or interact. Many species are exposed to, or involved in, every process and every species is exposed to or involved in many processes. Some processes are purely physical and some chemical, but many are fundamentally biological. Many processes affect the distribution and abundance of individual species, but studies of whole systems can reveal multiple layers of feedbacks, hidden drivers and emergent properties (Lohrer et al. 2004).

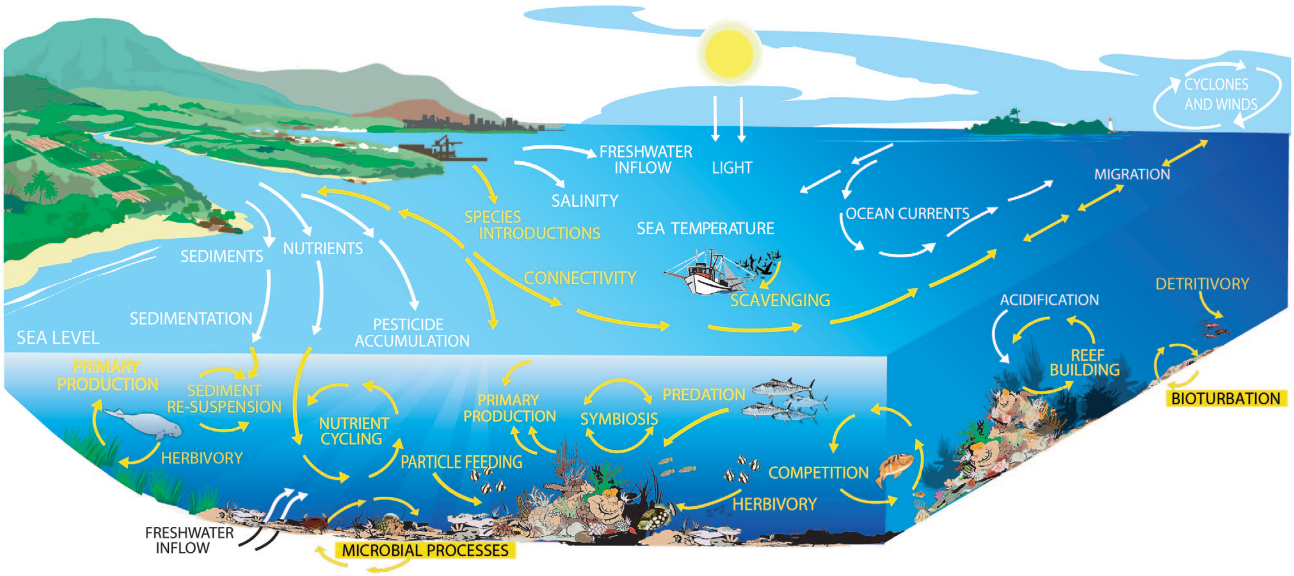


Figure 25. Ecosystem processes considered in the ecological risk assessment (indicated in yellow).

The initial list of ecosystem processes identified for consideration in the assessment included those described in the *Great Barrier Reef Outlook Report 2009* (GBRMPA 2009) with a few additional processes added by participants at the Phase II expert workshop (Figure 25 and Table 15).

A number of physical and chemical processes that occur in the Great Barrier Reef, and were considered in the ecosystem health assessment in the Outlook Report, were excluded from the current assessment because trawling was considered to have no impact upon them (Figure 25). The exclusion of processes on which trawling would have no impact does not mean that they may not be important influences on the fishery resources. Indeed several of these processes (such as freshwater inflow) are known to be important factors in the cyclic abundance of some prawn populations (e.g. banana prawns (Halliday and Robbins 2007)). Other impacts on the resources, while potentially important, are considered under other work programs by the GBRMPA and DAFF Queensland. The processes considered but excluded were cyclones and wind, freshwater inflow, light, ocean currents, sea level, sea temperature, pesticide accumulation, ocean acidity, ocean salinity, disease outbreaks, crown-of-thorns starfish outbreaks and other outbreaks (e.g. algal blooms).

Table 15. Description of ecosystem processes assessed.

Type	Process	Description
Physical	Sediment resuspension[1]	Sediments being resuspended in the water column and then resettling on substrates
Chemical/ Ecological	Microbial processes/ nutrient cycling[2]	Microbially controlled input, export and recycling of nutrients within the ecosystem
Ecological	Particle feeding	Feeding process targeted at particles suspended in the water column, or deposited on submerged surfaces
	Primary production	The conversion of the sun's energy into carbon compounds that are then available to other organisms
	Herbivory	The consumption of plants
	Predation	Animals consuming other animals
	Bioturbation[3]	The biological reworking of sediments during burrow construction and feeding and bioirrigation (mixing of solutes) leading to the mixing of oxygen-bearing waters into sediments
	Detritivory[3]	Feeding on detritus (decomposing organic matter)
	Scavenging[3]	Predators eating already dead animals
	Symbiosis	The interdependence of different organisms for the benefit of one or both participants
	Reef building	Mainly the process of creating habitats composed of coral and algae but for this assessment includes the creation of all biogenic (i.e. of living origin) habitats
	Competition	Includes both positive and negative interactions between species that favour or inhibit mutual growth and functioning of populations
	Connectivity	Includes migration, movement and dispersal of propagules between habitats at a range of scales; and functional connectivity which represents ontogenetic cycles of habitat use
Other processes	Species introductions[4]	The introduction of exotic species to the Great Barrier Reef and their spread once established

[1] *Sedimentation was recharacterised as 'Sediment resuspension' in acknowledgement that this is the only component of the process that trawling will impact upon.*

[2] *Nutrient cycling and microbial processes were considered to be so closely linked (when examining the potential impacts of trawling) that they would best be assessed together.*

[3] *Additional processes not considered in the Great Barrier Reef Outlook Report.*

[4] *In the Great Barrier Reef Outlook Report this was listed as 'Introduced species' but was renamed in this assessment to correctly identify it as a process.*

4.7.4. RISK CHARACTERISATION

In the following section a description of each process is provided, including any separate subcomponents that were identified. An outline of the inherent resilience of the process is then provided, the potential fishery impact on the process by trawling is summarised, and the level of risk is characterised using the risk matrix (Figure 13). The detailed assessments of species, habitats and assemblages earlier in this report informed the risk characterisation stage for relevant ecosystem processes. Where relevant, some new analyses of the Seabed Biodiversity Project dataset were undertaken to support this assessment, and the results are included in the relevant sections.

Sediment resuspension

This is the process of sediments being resuspended in the water column and then resettling on substrates. (The input of suspended sediments from rivers, while ecologically important, is not a process that trawling would affect.) This process can influence the distribution and abundance of organisms in a range of ways including by physically smothering them, by making the water column more turbid, by interfering with particle feeding, by affecting recruitment of seabed plants and animals (e.g. algae, corals), and by changing the proportion of soft sediments in an area.

The *Great Barrier Reef Outlook Report* (GBRMPA 2009) assigned a grade of 'poor' for the more broadly defined process of sedimentation due to the increased exposure to terrestrial sediments, particularly in inshore areas. Trawling, however, was not implicated in that assessment.

Resilience: *High*

The process of sediment resuspension is likely to vary spatially and to be potentially influenced by seabed type, including seabed hardness, sediment particle size, mud content and vegetative cover, as well as depth and current stress. The process was considered to have high resilience at the scale of the whole Great Barrier Reef.

Fishery impact profile: *Low*

While trawling can produce local turbidity plumes especially in shallow waters with soft muddy bottoms, the contribution of this extra stirring was considered inconsequential relative to the regular wind-driven resuspension of bottom sediments. Therefore, the fishery impact profile was assessed as very low to negligible.

Risk: *Low*

At the scale of the whole of the Great Barrier Reef, the risk from trawling was considered to be low to negligible. Within trawled areas, the impacts are likely to be well within natural variation, and would be short term (lasting a matter of hours). Therefore, this process should not be included in any future reassessments.

Nutrient cycling and microbial processes

These two processes were assessed together as they were considered to be intimately linked, with nutrient cycling being mainly driven by microbial processes. Separate components were identified for oxic (aerobic respiration including chemical oxidation) and suboxic (denitrification and metal reduction) processes.

Nutrient cycling is concerned with the input, export and recycling of nutrients within the ecosystem. It includes the release of nutrients, such as nitrate and phosphate, from organic matter by decomposers, to be harnessed by phytoplankton or other plants to produce organic matter. This process influences the distribution and abundance of organisms through its influence on the nutrient sources for primary producers and on the food sources for secondary producers and detritivores. Within the Great Barrier Reef, both normal and above normal nutrient levels are closely associated with terrestrial run-off (GBRMPA 2009). The high productivity of coral reefs is partly a manifestation of the efficient nutrient recycling that occurs in these areas (Hoegh-Guldberg and Dove 2008). There are many microbial processes operating in the Great Barrier Reef, but the role of microbes in trophic interactions is not known in detail, having received only very limited scientific study.

There has been increased exposure to nutrients for much of the Great Barrier Reef, especially in inshore waters, leading to a grading of 'poor' in the *Great Barrier Reef Outlook Report* (GBRMPA 2009). Trawling, however, was not implicated in that assessment.

Microbial processes were assigned a grade of 'good based on uncertain information' on the basis that changes in the physical and chemical environment are likely to be causing changes in microbial processes, but there is little information available (GBRMPA 2009).

Resilience: *Intermediate-High*

Microbial processes and nutrient cycling occur in all habitats and involve a vast array of species and multiple pathways. This assessment considered that the process as a whole would be quite resilient to perturbations, including disturbance from trawling. Nevertheless, microbial processes were considered likely to have changed in the Great Barrier Reef as a result of major human-induced changes to the physical and chemical environment, but there is little information available (GBRMPA 2009).

Fishery impact profile: *Intermediate-Low*

Trawling may have an impact on this process through harvesting, discarding and contact without capture. Removal of animals through harvesting is a direct loss of nutrients to the ecosystem.

A rough approximation of the minimum annual catch and discard rates by trawling was estimated to be 1.18 kg per hectare based on the trawl effort estimates for 2005 and using the Seabed Biodiversity Project's modelled distributions of 850 sufficiently abundant species and estimates of per cent caught for each of these species. This calculation involved dividing by the whole shelf study area and is therefore an average estimate over the entire region. In comparison, a first approximation of minimum levels of shelf total average biomass was about 26 kg per hectare. Nevertheless, because much of the trawling effort occurs in about 10 per cent of the shelf area and discarding would be confined to these areas, a rough estimate of discard rates on the main trawl grounds would be about 10 times higher than the shelf-wide average (i.e. about 11–12 kg per hectare), but essentially zero kg per hectare in the remaining 90 per cent of the area. Therefore, the annual catch and discard rates by trawling were not considered likely to affect nutrient cycling and microbial processes at the scale of the Great Barrier Reef, but may have local effects in very intensely trawled areas (which may cover less than one per cent of the region).

Nutrient cycling could be accelerated or lead to alterations to the relative importance of different nutrient pathways through discarding of by-catch that then dies. Indirect effects include the potential for increased availability of biological material for colonising by microbes. Trawling will physically disturb the benthic habitats and physical environments which, at high intensities, could lead to local effects on microbial processes but little is known about the potential impacts.

Risk: ***Low***

The potential impact of trawling on microbial processes and nutrient cycling may be significant within intensely fished trawl grounds, but as the area trawled more than once a year represents only about seven per cent of the Great Barrier Reef Marine Park (Appendix 2.2.3), the risk from trawling to the process was assessed as likely to be low at the scale of the Great Barrier Reef.

Particle feeding

This feeding process targets particles suspended in the water column, or deposited on submerged surfaces. Particle feeders include a large proportion of marine invertebrates including some filter feeding sea cucumbers, scallops, other bivalves, sponges, heterotrophic corals, basket star, many other crustaceans, and some fish. This process influences the distribution and abundance of organisms through its importance as a feeding mechanism for a wide range of species, including many species near the base of food webs.

Populations of most particle feeders in the Great Barrier Reef are considered to be healthy, excepting sea cucumbers which are at risk of localised depletion (GBRMPA 2009).

Detritivory, which comprises feeding on larger pieces of decomposing organic matter, was considered separately (see below).

Resilience: ***Intermediate-High***

Expert opinion, supported by other studies (Gribble 2003, Pitcher et al. 2007b), concluded that the diversity of species and groups of animals that are particle feeders and contribute to the process would be expected to confer resilience through a substantial level of functional redundancy. Additionally, particle feeders are widely distributed within all or most habitat types within the Great Barrier Reef, which tends to increase their resilience to stochastic events and cumulative impacts, and hence was expected to increase the resilience of the process of particle feeding.

Fishery impact profile: ***Intermediate-Low***

Trawling may impact on the process of particle feeding through harvesting, discarding or contact without capture. Trawling, particularly in the scallop sector, directly targets a number of particle feeders (e.g. scallops) and reduces their standing biomass. It may also remove or damage other particle feeders (e.g. sponges).

To determine the fishery impact profile for the process of particle feeding, the assessment considered the impacts on particular groups of particle feeders affected by trawling and their contribution to the process, and the proportion of all filter feeders in seabed communities of the Great Barrier Reef impacted annually by trawling.

In scallop beds, the negative effect on particle feeding may be locally high where scallops have been depleted, but is unlikely to be high on the process as a whole as any localised effects are not expected to disrupt this process outside the immediate area of depletion or damage to the particle feeders. As the relative biomass of scallops (*Amusium* species) is estimated to be only approximately 0.9 per cent of the overall biomass of particle feeders in the Seabed Biodiversity Project dataset, scallops are likely to make a relatively small contribution to the overall process of particle feeding in the Great Barrier Reef. Furthermore, additional analyses of the Seabed Biodiversity Project dataset (Table 63) identified the relative biomass of the various filter feeding groups in the Great Barrier Reef, and scallops (*Amusium* species) made up 555 average grams per hectare of the total of 8651 average grams per hectare for all bivalves (6.4 per cent).

This reanalysis also indicated that trawling does not impact on a significant proportion of the biomass of filter feeders at the Great Barrier Reef scale. For example, few if any particle feeders were in the top 100 species in the Seabed Biodiversity Project results for exposure to the impacts of fishing at 2005 effort levels; e.g. the first sponge was at rank 109 with 33 per cent effort exposure and only one per cent caught. Discarding and contact without capture may also reduce the abundance of some other filter feeders, but results from the Seabed Biodiversity Project suggest that there is not a substantial impact for most species.

Risk: *Low*

The level of trawl effects on non-target particle feeders (e.g. sponges, gorgonians) was generally expected to be low based on the Seabed Biodiversity Project findings. The overall level of exposure and impact from trawling on all particle feeders was considered to be low at current effort levels at the scale of the whole Great Barrier Reef. The effect of harvesting on the process of particle feeding at the ecosystem level is likely to be low. Any localised effects were not expected to disrupt this process outside the immediate area of depletion or damage to the particle feeders.

Primary production

Primary production is a process that converts the sun's energy into carbon compounds that are then available to other organisms. As such it is the single most important factor for potential catches and productivity. In tropical marine ecosystems, contributions to primary production come not only from plants such as macroalgae, turf algae, seagrasses and mangroves, but also, in large part, from microscopic free floating algae (phytoplankton), and from corals, which have microscopic algae (zooxanthellae) within their tissues (GBRMPA 2009). Blue-green algal mats also contribute to primary production. In the Great Barrier Reef Region, the highest levels of primary production are found in the well-flushed conditions of the fore-reef but high values are also found in more nearshore areas (Hoegh-Guldberg and Dove 2008). All primary production is closely linked to levels of light and substratum type and, to a lesser degree, inorganic nutrients.

The *Great Barrier Reef Outlook Report* (GBRMPA 2009) considered there to be insufficient information to assess whether patterns of primary production are changing but assigned a grade of 'very good'.

Resilience: *Intermediate*

The diversity of species involved and the ubiquity of the process make the process as a whole resilient at the scale of the Great Barrier Reef. Nevertheless, there is concern about the potential for changes in the relative abundance of groups of primary producers such as from primary production in reefs to macroalgae or from algae to phytoplankton blooms. Such changes have been recorded in reef areas elsewhere partly as a result of increased nutrient levels and reductions in the abundance of herbivores. The resilience of a species to physical disturbance depends on its growth habit, with phytoplankton being most resilient and more rigid rooted species, like the green alga *Halimeda,* much less so.

Fishery impact profile: *Low*

Trawling may impact on primary production through discarding and contact without capture. Trawling may directly remove plant material or damage plants in situ. Trawl gear may remove some of the above ground biomass although for some species, such as algae in the genus *Caulerpa*, it frequently passes over the plants without causing much damage. Beds of *Halimeda* are prone to damage from trawling. Trawling may indirectly impact on primary production, at least locally, through reductions in the light environment from resuspension of sediments.

To determine the fishery impact profile for primary production, the assessment considered the impacts from trawling on each subcomponent (blue-green algal mat, macroalgae, turf algae, seagrasses, mangroves, phytoplankton and zooxanthellae). The impact and risk from trawling to mangroves and zooxanthellae were considered to be negligible because of the limited interaction between these components and trawling. The findings earlier in this report did not identify a significant risk from trawling for the other subcomponents. However, the assessment further examined trawl effects on filamentous algae because the expert workshop, when assessing this process, recommended further consideration of the extent of algal mats, their overlap with trawled areas, and the impact of trawling on them.

In the Seabed Biodiversity Project, filamentous algae (not just blue-green algal mats) had the greatest per cent cover of video transects of any algae identified on video. Over all 1198 Great Barrier Reef sites, filamentous algae averaged 8.4 per cent cover of the seabed. Among the algae, filamentous had the greatest cover comprising 42 per cent of all cover due to algae (followed by 'bushy' algae 27 per cent and *Halimeda* 12 per cent). Based on point data at sites (i.e. not modelled full-coverage distributions), 68 per cent of filamentous algae was protected by Marine Park zoning, 19 per cent was exposed to trawling and 25 per cent was effort intensity exposed. These values would be highly variable in space and time, however, as experience from repeated visits to sites for other projects indicates that the filamentous mats come and go over time. They also vary in thickness; sometimes they are thin with sediment visible through them, and sometimes much thicker. Eventually they detach from the seabed, float around and settle on and cover other areas of the seabed.

It was concluded the overall trawling impact on primary production is likely to be low at the scale of the whole Great Barrier Reef. The certainty in the assessment was low as there is little information on the relative importance of each subcomponent to primary production.

Risk: *Low*

Trawling may have local impacts on some species of plants but at the scale of the whole Great Barrier Reef the risk to the process of primary production was considered to be low.

Herbivory

Herbivory is the consumption of plants. The process is known to be important for coral reefs as reductions in herbivory may allow an increased abundance of macroalgae leading to overgrowth of corals and reef degradation. However, the importance of herbivory in other parts of the Great Barrier Reef ecosystem (e.g. shelf habitats) is less well understood but likely to be lower. Fish are the main herbivores on the coral reefs of the Great Barrier Reef Region, but large herbivores such as dugongs would have been more important to the total process of herbivory before their abundances declined.

The *Great Barrier Reef Outlook Report* (GBRMPA 2009) assigned herbivory a grade of 'good'. It regarded populations of herbivorous fish as healthy and not under pressure, although larger herbivores, such as dugongs, have declined along the urban coast of the Great Barrier Reef.

Resilience: *Intermediate-High*

The variety of herbivorous species creates redundancy and was considered to add to the resilience of the process of herbivory at the scale of the whole Great Barrier Reef. Nevertheless, different herbivores live in different habitats and consume different types of plants so they cannot all act as substitutes in the process.

Fishery impact profile: *Low*

Trawling may impact on the process of herbivory through discarding and contact without capture. This includes potential impacts on herbivores and on the plants they feed on. The majority of the by-catch of trawling is small fish that are benthic-feeding omnivores and herbivores but also include invertebrate herbivores and omnivores (Poiner et al. 1998). A relatively small proportion of herbivory is expected to be associated with trawled grounds in the Great Barrier Reef.

To assess the fishery impact profile for herbivory, the assessment considered current risks to any species that may contribute to the process of herbivory presented earlier in Section 4 and no high risks were identified. It also considered the species assemblages from the Seabed Biodiversity Project that were dominated by benthic macroproductivity (i.e. assemblage 6 found on the mid-shelf off Townsville and comprising mixed algae/seagrass, assemblage 7 consisting of mixed algae/seagrass in the Capricornia area, and assemblage 8 which is northern *Halimeda* banks) and examined risks to the species assemblages and to any high affinity species (regardless of whether they were herbivores as this may not be known). As none of the assemblages or high affinity species were at risk, then the risk to herbivores was also expected to be low.

The assessment also considered potential indirect impacts, such as through disruption to the feeding behaviour of turtles and other herbivores that pass through a TED/BRD and on others in the area that are not captured but may be disturbed. The significance of this effect was difficult to quantify, however, as there is little information on the post-release behaviour of turtles.

Indirect impacts may occur through changes to the abundance or distribution of the food species (algae and seagrass), however this was covered under assessment of primary production. Trawling may also indirectly affect herbivory through other changes to the habitats of herbivores or through changes to food webs

Risk: *Low*

The impact overall from the current level of trawling activities on species within these herbivorous groups was suggested to be low (based on 2009 levels of trawl fishing effort). If individual species of herbivores are not at risk from trawling, the group as a whole (and hence the process of herbivory) is unlikely to be at risk from trawling.

The species and habitat risk assessments generally considered seagrasses and algae relatively resilient to current trawling activities in the Great Barrier Reef Region, therefore the indirect risk to herbivores and the process of herbivory is likely to be low.

Predation

Predation is the process of animals consuming other animals. Predators and top predators in coral reef ecosystems include most big bony fish and sharks, as well as a wide array of smaller fish and invertebrates, seabirds, marine reptiles and marine mammals (GBRMPA 2009). The prey is similarly diverse. The process of predation includes a range of complex interactions that even in simple predator-prey models make prediction of responses to changes highly uncertain (Bax 1998). This process influences the distribution and abundance of organisms directly through the removal of consumed animals, and indirectly through a range of cascading effects through food webs including its influence on the behaviour of prey species.

The *Great Barrier Reef Outlook Report* (GBRMPA 2009) identified that most predator populations are relatively healthy but a few species are under serious pressure and assessed the process as being in 'poor' condition. Fishing methods other than trawling (particularly the net and line fisheries), however, are responsible for most of this fishing pressure.

Resilience: *Intermediate-High*

The diversity of species and predator–prey interactions and the number of generalist predators was considered to create considerable redundancy in the process of predation and confer a level of resilience.

Fishery impact profile: *Low*

Trawling may impact on the process of predation through harvesting, discarding or contact without capture. Direct impacts may occur through the removal of predators as harvested species, by-catch or species of conservation concern. Predators directly impacted by trawling may include animals that are top predators (such as sharks) or others that feed at lower levels in the food chain.

In assessing the fishery impact profile for the process of predation, the assessment considered the impact and risk to each of the groups of predators. However, there is very little information on the relative importance of the groups of predators to the process of predation.

The most likely mechanism for the current trawling activities to have a detectable effect on predation was considered to be via an effect on top predators. Although total discard rates of top predators from otter trawling in the Great Barrier Reef Region have not been estimated, where data are available sharks and rays made up roughly three per cent by weight of all trawl by-catch on average (Courtney et al. 2006, Courtney et al. 2008). This suggests there is a low total trawl discard rate across the whole World Heritage Area of approximately 0.013 kg sharks and rays per hectare per year. These tonnages on the scale of the whole Great Barrier Reef were not considered to be very significant and, while the discard rate and hence the local depletion would be about an order of magnitude higher if only trawl grounds are considered, the impact of discarding sharks and rays on the process of predation was deemed likely to be low to negligible. However, as a number of sharks and rays were assessed as at intermediate or high risk from trawling (Table 11), considering only total discards of sharks and rays may tend to underestimate the fishery impact on the process of predation by top predators. Nevertheless, in an ecosystem model for part of the Great Barrier Reef, large sharks and rays were estimated to represent less than seven per cent of the biomass of top predators (trophic level > 3) and less than three per cent of the consumption by this group (Gribble 2003). Therefore, although trawling poses risks to individual species of shark and rays, it was considered that this does not equate to more than a low impact on the overall process of predation for which fish are much more important.

The effects of current trawling activities on predators were also considered. For sea snakes, the risk assessment has identified potential for localised impacts where there is high interaction/overlap between snakes and trawling, e.g. red-spot king prawn fishery off Townsville. However, as population sizes for many sea snakes are large, the overall effects on the process of predation via impacts on sea snakes is likely to be low.

Some principal and other permitted species are predators (e.g. squid, pinkies, octopus, cuttlefish) and their removal could be expected to reduce the mortality on their prey species. The total of these main predatory permitted species landed in 2009 was 110 tonnes (DEEDI 2010a), of which approximately 60 tonnes were taken in the Great Barrier Reef Region, and perhaps two to three times this amount of permitted species is discarded annually (e.g. unmarketable).

Based on the Seabed Biodiversity Project findings, the lack of evidence for changes in species composition as a result of trawling suggests that trawling has not had a significant impact on ecological processes (including predation) that may affect species composition on a Great Barrier Reef-wide scale.

Trawling may cause disruption to the feeding behaviour of predators including effects on individuals that pass through a TED/BRD and on others in the area that are not captured but may be disturbed. Trawling may also indirectly affect predation through other changes to the habitats of predators or prey or through changes to food webs. Effects on species such as dolphins from feeding on trawl by-catch were considered under the process of scavenging.

The majority of harvested species are prey species and their removal changes the abundance or distribution of the prey species. The total Great Barrier Reef principal species landings in 2009 was approximately 4500 tonnes. This would be expected to have flow-on effects for their predators which may be high locally in intensively trawled areas. Predators, however, are generally relatively mobile species, and so a relatively wide area should be taken into account when considering the scale of potential effects on predation from trawling. Past declines in loggerhead turtles, in part due to trawling, may have reduced food availability for large shark species that prey on these marine turtles.

Risk: *Low*

Overall direct and indirect impacts are likely to be low at current effort levels. At the scale of the whole of the Great Barrier Reef, the risk from trawling to the process of predation was expected to be low.

Bioturbation

Bioturbation involves biologically reworking sediments during burrow construction and feeding and bioirrigation (mixing of solutes) leading to the mixing of oxygen-bearing waters into sediments. This process can influence the distribution and abundance of organisms through its ability to change nutrient fluxes and improve conditions for production by microphytobenthos (sedimentary microbes and unicellular algae) (Lohrer et al. 2004).

Three groups of animals were recognised as contributing to the process:

I. Infauna: These are pioneering, opportunistic species that rapidly recolonise areas and have a high resilience. They will produce bioturbation on a widespread scale spatially but at local levels will influence only the top few centimetres of sediment.

II. Mobile epifauna: Surface deposit feeders with a mix of resilience. There is likely to be functional redundancy among species within this group. The bioturbation effect can be very widespread and be more intense than for the infauna but is also likely to be only superficial.

III. Demersal megafauna: Sharks and rays likely to have lower resilience. Fish likely to be more resilient than the sharks but less than the invertebrates. Functional redundancy not very high within this group. The bioturbation effects of sharks and rays can be intense and penetrate deeper than the other faunal groups but will be significant only at smaller spatial scales.

The relative contribution of the three groups to the overall process of bioturbation could not be determined and may vary locally.

Bioturbation was not assessed as a process in the *Great Barrier Reef Outlook Report* (GBRMPA 2009).

Resilience: *Intermediate-High*

The variety of species contributing to the process adds to its resilience as there is likely to be redundancy within and among groups. The process must also be resilient to the frequent natural disturbances to the sediment, particularly in shallower areas (see section on sediment resuspension). Invertebrate bioturbators are generally likely to be short-lived with high natural mortality rates and would therefore tend to be resilient to the impact of trawl-induced mortality. The demersal megafauna are less resilient and include species identified as susceptible to impacts from trawling.

Fishery impact profile: *Low*

Trawling may have an impact on bioturbation through the activities of contact without capture and discarding. Trawling will physically disturb some habitats and physical environments important to bioturbation processes. There is the potential for the direct removal or disturbance of bioturbators by trawling. This will mostly be through contact without capture except for bioturbators in the demersal megafauna group (e.g. rays) that are part of the by-catch.

In assessing the fishery impact profile for the process of bioturbation, the assessment considered the impact and risk to each of the groups identified above. However, the relative importance of the groups of bioturbators to the process of bioturbation is unknown.

The impact of trawling on demersal megafauna is the most likely pathway for trawling to have an impact on the process of bioturbation. Trawling has a significant impact on some sharks and rays (see Section 4.4.7) but these are likely to represent a small proportion of the species contributing to bioturbation. Also, any impact of this on the process would be mitigated to some degree by the expected small effect on the other bioturbating components. Therefore, the impact on the overall process of bioturbation via impacts on sharks and rays was considered likely to be low.

Risk: *Low*

Overall direct and indirect impacts from trawling to bioturbation processes are likely to be low at current effort levels. At the scale of the whole of the Great Barrier Reef, the risk from trawling to bioturbation was expected to be low.

Detritivory

The process of feeding on detritus (decomposing organic matter) contributes to decomposition and nutrient cycling. Sea cucumbers, prawns, crabs, lobsters, and some fish ingest detritus on the seafloor.

Detritivory was not assessed as a process in the *Great Barrier Reef Outlook Report* (GBRMPA 2009).

Resilience: *High*

The variety of species contributing to the process adds to its resilience as there is likely to be redundancy within and among groups.

Fishery impact profile: *Intermediate-Low*

Trawling may impact on the process of detritivory through harvesting, discarding and contact without capture. Trawling directly targets a number of detritivores such as prawns and reductions in their abundance could have an impact on the amount of detritivory because they are removed on a regular basis in large numbers. Discarding and contact without capture has direct and indirect effects. There are direct effects on some detritivores that are killed or damaged such as crabs, sea cucumbers and polychaete worms. On occasions, trawling can have a high interaction with sea cucumbers; however, these species were not assessed as being at risk in the species-level assessments. Discarding probably increases the quantity of organic matter available to detritivores and modelling work suggests that discarding can help sustain populations of prawns (Gribble 2003). The results of the Seabed Biodiversity Project and findings of the current assessment suggest that few or no species of detritivores are at risk from trawling at current effort levels.

Risk: ***Low***

Detritivory as a process has probably been enhanced by trawling through the quantity of organic matter discarded.

Scavenging

Scavenging is the process of predators eating already dead animals. In the context of this assessment, scavengers feed on trawl by-catch that is discarded, or on animals killed on the seabed through contact without capture. This process can influence the distribution and abundance of organisms by directly providing food for potential scavengers and by changing the pathways that nutrients follow through food webs.

Scavenging was not assessed as a process in the *Great Barrier Reef Outlook Report* (GBRMPA 2009).

Resilience: ***Intermediate-High***

Many scavengers are predators opportunistically exploiting additional food sources. As for predation, the diversity of species was expected to create considerable redundancy in the process of scavenging and confer a level of resilience.

Fishery impact profile: ***Low***

Trawling may impact on the process of scavenging through discarding and contact without capture. Some animals may alter their behaviour through scavenging in response to trawling activities. Airborne or pelagic scavengers are animals (e.g. seabirds, dolphins, sharks) that may follow the trawl fleet and seek out feeding opportunities on dead animals. These animals may be affected over tens or hundreds of kilometres. Benthic scavengers (e.g. crabs) are likely to move over much shorter distances, e.g. less than 100 metres, to feed on dead animals.

To determine the fishery impact profile for the process of scavenging, the assessment considered the impacts on particular species or groups of scavengers affected by trawling and their contribution to the process.

In the Great Barrier Reef Region, seabirds feed on discards that float but over 80 per cent by weight of discards sink and are consumed on the seabed by fish, small sharks and possibly cirolanid isopods (Hill and Wassenberg 2000). The total quantities of discards are relatively small per area of seabed (e.g. in the range of a few kg per hectare per year as estimated above). For some species, however, such as the crested tern, discards can become a significant part of their diet and their populations have increased. Some provisioning of benthic scavengers is also likely to occur through increased availability of benthic organisms following the passage of a trawl net. The effects may be local and unpredictable for species with limited mobility such as crabs, but mobile species can seek out and source provisioning over a wide area. Some scavengers are also among those killed as by-catch in the ECOTF (e.g. in 2006 and 2007, one gannet and one gull were reported as caught and released alive, and one tern was reported as having died (DEEDI 2009a, 2010a)), but the overall effect of trawling is likely to increase scavenging.

If there were single species effects from trawling on scavengers, a positive trawl coefficient would be expected in the single species modelling under the Seabed Biodiversity Project (implying an increase in biomass of that species with trawling). There were several species with positive trawl coefficients (see Table 64) and some may be scavengers, but the effects were quite subtle.

Risk: *Low*

Trawling is likely to have increased the importance of scavenging as a process by provisioning scavengers with additional food sources. Probably the most measurable effect is on seabirds, where populations are thought to have increased with trawling. Overall effects on scavenging were not regarded as serious or irreversible.

Symbiosis

Symbiosis is the interdependence of different organisms for the benefit of one or both participants. This process is particularly important in coral reef habitats (e.g. the relationship between corals and zooxanthellae) where the low nutrient conditions are thought to favour a close association between primary producers and consumers (Hoegh-Guldberg and Dove 2008). Symbiosis also occurs in habitats that are trawled (e.g. between sponges and zoanthids, and between soft corals and molluscs).

The *Great Barrier Reef Outlook Report* (GBRMPA 2009) considered that little was known about most symbiotic relationships but assigned a grade of 'good?'.

Resilience: *High*

The resilience of symbiosis as a process is determined by the combined resilience of both host and symbiont, and in general was assessed as high. Although there is a large variety of species that are in symbiotic relationships this would not lead to redundancy in the process as many of the relationships are quite species specific. This also means, however, that most relationships, while crucial to the particular species involved, may not have a wider importance to the ecosystem. Exceptions may occur such as when one species is symbiotically dependent on a range of other species, for example, for species involved in cleaning parasites from fish.

Fishery impact profile: *Low*

Where both host and symbiont are sessile or sedentary, trawling was considered likely to affect both the host and symbiont equally and therefore would not affect the symbiotic relationship. While symbiotic relationships for some species may be affected by trawling activities, e.g. if a host or symbiont (but not both) are associated with a particular habitat that is affected by trawling, the overall fishery impact profile for the process of symbiosis was expected to be very low to negligible.

Risk: *Low*

Given the previous results on the lack of high risks at current effort levels to habitats less than 100 metres deep, at the scale of the Great Barrier Reef the impact and risk of trawling on the process of symbiosis was considered likely to be negligible. Therefore, this process should not be included in any future reassessments.

Reef building

Reef building is mainly the process of creating habitats composed of coral and algae but for this assessment included the creation of all biogenic (i.e. of living origin) habitats. This process may influence the distribution and abundance of organisms such as by changing the distribution and abundance of hard substrates on which a range of them depend. Small areas of biogenic habitats within lagoonal areas may have an importance to some species or processes that is greater than would be anticipated by the area they occupy. Even areas of low relief or small size are sites where fish preferentially aggregate. They may also be important locations for fish cleaning.

Coral reef building is dependent on light to power algal symbiosis, temperature to lift the rate of reef growth over that of erosion, and the availability of carbonate ions to allow deposition of calcium carbonate (limestone) by corals, calcifying algae and other organisms (GBRMPA 2009). Optimal conditions for coral reef building only occur where the water is shallow and clear, the currents are strong and the ocean pH is alkaline.

The *Great Barrier Reef Outlook Report* (GBRMPA 2009) considered that reef building was generally in 'good' condition across the whole Great Barrier Reef although it may be beginning to slow.

Resilience: *Intermediate*

Resilience of reef building as a process concerns both the ability of established corals to continue to grow and of new corals to settle and establish. The resilience of corals in nearshore environments has been reduced by the impacts of terrestrial run-off and the sediments, nutrients and pollutants it contains. Across the whole Great Barrier Reef there is evidence that the rate of coral growth has slowed in recent years. Recruitment of corals was considered likely to vary depending on likelihood of larval resupply.

Fishery impact profile: *Low*

Trawlers avoid solid reef areas and shoals, so the potential impact of trawling is on small calcareous isolates lying on trawl grounds. While these structures are important biogenic structures that provide microhabitats for other species, they are not the precursors to significant reefs on the timescales relevant to this risk assessment and so do not qualify under the category of reef-building.

In the Seabed Biodiversity Project, 44 of approximately 450 trawl samples had some coral recorded. For these 44 trawls, the average catch rate of coral with an 8 fathom net was 3 kg per km of tow. Many of the species were solitary corals not hermatypic (reef-building) forms. Therefore, the fishery impact profile was assessed as low.

Risk: *Low*

The risk from trawling to the process of reef building was assessed as being very low at the scale of the whole Great Barrier Reef, but may be somewhat higher for isolated corals in lagoonal areas where trawling occurs.

Competition

Competition includes both positive and negative interactions between species that favour or inhibit mutual growth and functioning of populations. This process influences the distribution and abundance of organisms because competition for all resources, including space, nutrients and food, is always intense in tropical marine ecosystems (GBRMPA 2009). Only interspecific competition (i.e. competition between individuals of different species) was considered here.

The *Great Barrier Reef Outlook Report* (GBRMPA 2009) considered that little was known about most types of competition except that competition between corals and algae appeared normal. It assessed competition as being in 'good?' condition.

Resilience: *High*

As for other processes, the diversity of species involved was expected to create considerable redundancy in the process of competition and confer a level of resilience at the scale of the whole Great Barrier Reef.

Fishery impact profile: *Low*

Trawling could have an impact on competition by changing the relative abundance of species, but this is not very likely with such a generalised capture method.

Trawl effort was not selected in statistical analyses of assemblages by the Seabed Biodiversity Project and thus was interpreted as not being a factor influencing species composition. This is evidence, by inference, that trawling was also non-influential on ecosystem processes (such as competition) that may affect species composition.

Risk: *Low*

As there was no significant effect on species composition as a result of trawling (Pitcher et al. 2007b), trawling was considered unlikely to have had a significant impact on the process of competition on a Great Barrier Reef-wide scale.

Connectivity

Considered in the context of populations, not biophysical processes, the major pathways of connectivity in marine ecosystems are migration, movement and the dispersal of propagules. Trawling has some potential to impact these pathways for a small number of species. Connectivity influences the distribution and abundance of organisms because a large number of species rely on these linkages to complete their life cycles.

The *Great Barrier Reef Outlook Report* (GBRMPA 2009) considered that most species and habitats remained adequately connected and assessed connectivity to be in 'good' condition, although only limited information was available.

Resilience: *High-Intermediate*

At the scale of the Great Barrier Reef, connectivity is a highly resilient property of the ecosystem because of the localisation of disturbances, the sheer size of most populations, the patchiness of both biota and habitats, and the continuity of the aquatic habitat.

Fishery impact profile: *Intermediate-Low*

Trawling can directly impact on the movement of animals through the activities of harvesting or discarding. Indirect impacts on movement can also occur via the activity of contact without capture leading to the elimination of small patches of biogenic habitat that provide resources for the migrating animals (food and/or shelter) as they pass through the trawl ground. On the Great Barrier Reef, a number of lutjanids (tropical snappers) settle in nearshore environments (seagrasses and mangroves) and make ontogenetic migrations across the shelf to deeper water adult habitats. Examples include the red emperor (*Lutjanus sebae*) and the two nannygai's (*Lutjanus erythropterus, L. malabaricus*). While small juveniles of these species are found in trawl by-catch, they are not a major component of the catch.

The second impact of trawling on connectivity can be produced by the overfishing and loss of a local patch of broodstock. If any such events have occurred, they are likely to be isolated events.

In contrast to these few specific examples, the Seabed Biodiversity Project and this current ecological risk assessment raised few concerns about risks to the abundance of individual species or assemblages from the impacts of trawling, which suggests that connectivity is unlikely to be substantially impacted by trawling at current effort levels.

Risk: *Low*

Connectivity was considered unlikely to be substantially impacted by trawling at current effort levels, but the degree of connectivity may have been somewhat reduced in more heavily trawled areas, such as through loss of stepping stones provided by biogenic patches of habitat on the seafloor.

Species introductions

This process includes the introduction of exotic species to the Great Barrier Reef and their spread once established. In Australia, the primary modes of introduction have been vessel hull fouling and accidental releases associated with mariculture, followed by ballast water, dry ballast and intentional releases (Bax et al. 2003). For the most part, tropical marine environments seem less susceptible to invasion than temperate ones (GBRMPA 2009). Introduced marine species (Asian green mussel, Asian bag mussel) have been found in ports along the Great Barrier Reef coastline, although none have been recorded in marine waters beyond these ports. This process may influence the distribution and abundance of organisms in a variety of ways including changing the nature of habitats, direct predation on other species, competition for food or space, and changing nutrient pathways through food webs.

The *Great Barrier Reef Outlook Report* (GBRMPA 2009) considered that the occurrence of introduced marine species was increasing in areas adjacent to the Great Barrier Reef but still rated its condition as 'good' on this criterion.

Resilience: *Intermediate*

Species introductions are an anthropogenic risk and resilience in this process is mainly a function of human activity rather than an inherent characteristic. Resilience, therefore, needed to be interpreted differently in this assessment for species introductions, compared to the other ecosystem processes. Here, the resilience of the ecosystem to recover from species introductions or resist introduced species becoming established was considered, based on intrinsic ecological characteristics of the ecosystem.

In general, the Great Barrier Reef ecosystem is comparatively healthier than most coral reef ecosystems around the world, and this would confer a level of resilience. However, the overall condition and resilience of the Great Barrier Reef have declined (GBRMPA 2009). Any disruption to other processes, such as competition, and changes to habitats or species assemblages may also increase the likelihood that introduced species become established within areas of the Great Barrier Reef. Therefore, the resilience in relation to species introductions was assessed as intermediate.

Fishery impact profile: *Low*

Trawling may affect species introductions through discarding, contact without capture, travel to/from fishing grounds and boat maintenance and emissions. Discarding may lead to the translocation of introduced species from one area to another. Any such impacts are likely to be at a local scale, but over time could facilitate dispersal over broader areas. The deployment of fishing gear may act to transfer organisms from a vessel to the water column or seabed. Any of the direct or indirect impacts of contact without capture on other ecological components or processes may act to increase the likelihood that introduced species become established within the Great Barrier Reef.

The movements of fishing vessels may be a vector for the introduction of species to the Great Barrier Reef or their translocation to new areas within the Great Barrier Reef. The trawl fleet was considered to contribute a relatively small part of the overall shipping-related risk of species introductions, given the trawl fleet is a relatively small proportion of overall shipping traffic in the Great Barrier Reef Region. Ports are the most common sites for introduced marine species to become established. Ports were therefore also considered the most likely location for a vessel to come into contact with introduced species and for such species to become attached to, or otherwise present on, a vessel. An activity that would pose a risk of species introductions is polishing hulls or propellers at sea to remove biofouling.

Risk: *Low*

The risk of species introductions posed by trawling was considered to be low with current rates of species introductions. Nevertheless, if serious new pests are identified in ports or other areas used or traversed by trawlers, it is likely that responses would require trawlers to implement new measures to reduce the likelihood that trawlers became vectors for its spread.

Risk for ecosystem processes

The results for ecosystem processes are summarised in Table 16. It was found the overall risks from trawling were low, with all 14 processes assessed as at low risk from trawling.

Table 16. Risk assessment for ecosystem processes (ordered according to risk levels). Final risk scores reflect the combination of resilience and fishery impact profile scores following the categories in the risk matrix (Figure 13).

Ecosystem process	Resilience	Fishery impact profile	Risk
Nutrient cycling and microbial processes	H-I	I-L	LOW
Particle feeding	H-I	I-L	LOW
Connectivity	H-I	I-L	LOW
Detritivory	H	I-L	LOW
Primary production	I	L	LOW
Reef building	I	L	LOW
Species introductions	I	L	LOW
Predation	H-I	L	LOW
Bioturbation	H-I	L	LOW
Herbivory	H-I	L	LOW
Scavenging	H-I	L	LOW
Competition	H	L	LOW
Sediment resuspension	H	L*	LOW
Symbiosis	H	L*	LOW

** The fishery impact profiles for sediment resuspension and symbiosis were assessed as low to negligible; therefore these two processes should not be included in any future reassessments.*

4.7.5. ISSUES ARISING FROM THE RISK ASSESSMENT FOR ECOSYSTEM PROCESSES

For ecosystem processes, the risk assessed was *'What is the likelihood that the current activities of the ECOTF within or adjacent to Great Barrier Reef waters will cause serious or irreversible change to ecosystem processes such that the fishery resources and fish habitats, environment, biodiversity or heritage values of the Great Barrier Reef Marine Park are degraded or exposed to an unacceptable risk within the next 20 years?'*. This section discusses the overall patterns of risk for ecosystem processes against this risk context, and discusses the progress made in reducing risks and impacts, and other issues arising from the assessment.

Overall patterns of risk for ecosystem processes

The assessment found that all 14 ecosystem processes assessed were at low risk of serious or irreversible change from current trawling activities in the Great Barrier Reef (Figure 24). Ecosystem processes were generally considered to have relatively high resilience to impacts at the scale of the whole Great Barrier Reef. The fishery impact profiles were generally assessed as being relatively low at the scale of the whole Great Barrier Reef, but may be higher in fished areas for some processes.

Progress made in reducing risks and impacts

As far as we are aware, this is the first example of the inclusion of the full suite of ecosystem processes as a component in an ecological risk assessment for a fishery. The findings that there are no high risks posed by otter trawling to any of the processes considered is encouraging and is consistent with there being relatively few species, habitats or assemblages that were found to be at high risk. This is probably not surprising in that the assessment of ecosystem processes has been informed by the knowledge of the risks to these other components to the ecosystem. Theoretically at least, the emergent properties that these ecosystem processes describe could be at greater risk than the subcomponents. It seems inherently more likely, however, that the diversity of species and groups of animals involved in each process would confer a high level of resilience through a substantial level of functional redundancy.

Further issues and information gaps

The findings for ecosystem processes, however, are inherently more uncertain than those for other ecological components because the processes are higher level attributes that arise from the interactions among these components and from the effects of other physical and chemical processes on them. These attributes also often concern the hard-to-measure rates rather than more tractable metrics such as numbers, biomass or species composition.

Deriving measures of any of these processes that can be even occasionally monitored at a scale that is relevant for management is also a difficult task. Such measures need to be developed if effects on ecosystem processes are to be incorporated into a management decision framework.

As for habitats, there has been no attempt to rank the relative importance of these processes for ecosystem functioning. Each process has been assessed independently on the default assumption that all of these processes are important and that a risk to any one of them is worthy of attention. Future studies, such as more sophisticated ecosystem modelling, may permit a more sensitive assessment of risk and identify some processes as being more critical than others to the overall functioning of the system.

The approach taken for this assessment does not imply that all processes influence the ecosystem in the same manner. It is recognised, for example, that the impacts of changes to some processes will be 'dose-dependent', whereas for other processes there are likely to be threshold effects. Nevertheless, even for processes that are likely to be dose-dependent, such as sediment resuspension, it is also likely that change may reach a threshold level that would cause a sudden and potentially irreversible change to the ecosystem. Similarly, when changes are largely threshold effects, such as the introduction of exotic species, there is likely to be a dose-dependent component that reflects the spatial scale and intensity of the change.

4.8. Summary of ecological risk assessment findings

This report provides a contemporary assessment of ecological risks associated with trawling in the Great Barrier Reef Marine Park. The approach adopted in this assessment used a conventional examination of the risks to components of the ecosystem, from individual species through to species assemblages, combined with a novel examination of the risks to the ecosystem processes that link these components for the final broader view of ecosystem impacts from trawling. Risk was assessed based on the combination of the inherent resilience of the component being assessed, together with the nature of the impacts of the fishery (termed the fishery impact profile) as detailed in Section 3. The approach has previously been used in NSW fisheries but, as far as we are aware, the impacts on the full suite of potentially impacted ecosystem processes have not previously been considered as part of a formal ecological risk assessment for any fishery.

In summary, based on the most current data available for analysis (generally up to 2009 or 2010), most species, habitat types, species assemblages and ecosystem processes in the Great Barrier Reef Region were considered to be at low or intermediate-low risk from the ECOTF (Table 17).

Table 17. Summary of risk assessment scores for each ecological component.

Ecological component	Risk seeking to avoid in next 20 years (detailed risk contexts provided in Section 4)	Risk scores* (tally of numbers of species or types by risk category**)				
		Low	Int-Low	Int	Int-High	High
Principal species	Breaching relevant limit reference point, or any harvested species being classified as overfished	12	0	2	0	0
Permitted species		7	2	4	3	0
By-catch	Exceeding ability of by-catch species to renew themselves, or any by-catch species being excessively depleted	15	29	3	0	0
Marine turtles	Exceeding an acceptable level of interaction for the species of conservation concern	0	6	0	0	0
Sea snakes		0	11	2	0	2
Seahorses and pipefish		0	0	6	0	0
Sharks and rays		1	15	6	0	11
Habitats	Serious or irreversible damage to habitats	4	5	0	0	1
Species assemblages	Serious or irreversible damage to species assemblages	11	1	4	0	0
Ecosystem processes	Serious or irreversible change to ecosystem processes	14	0	0	0	0

** Note: These risk scores were based on 2009 levels of trawl fishing effort, where relevant.*

*** The numbers given are the number of species/types in each risk category, for example, 12 principal species were at low risk and two principal species were at intermediate risk.*

The assessment also found that some significant ecological risks remain; in particular 11 species of sharks and rays, two species of sea snakes and one habitat type were at high risk from trawling. Also, three permitted species were at an intermediate-high risk.

Elegant sea snake *Hydrophis elegans*

Ornate reef sea snake *Hydrophis ornatus*

Small-headed sea snake *Hydrophis macdowelli*

Spectacled sea snake *Hydrophis/Disteira kingii*

These four species of sea snakes were assessed as at high or intermediate risk from trawling in the Great Barrier Reef Region.
Picture credit: Courtney et al. 2010

4.9. Summary of issues by fishery sector or for the fishery as a whole

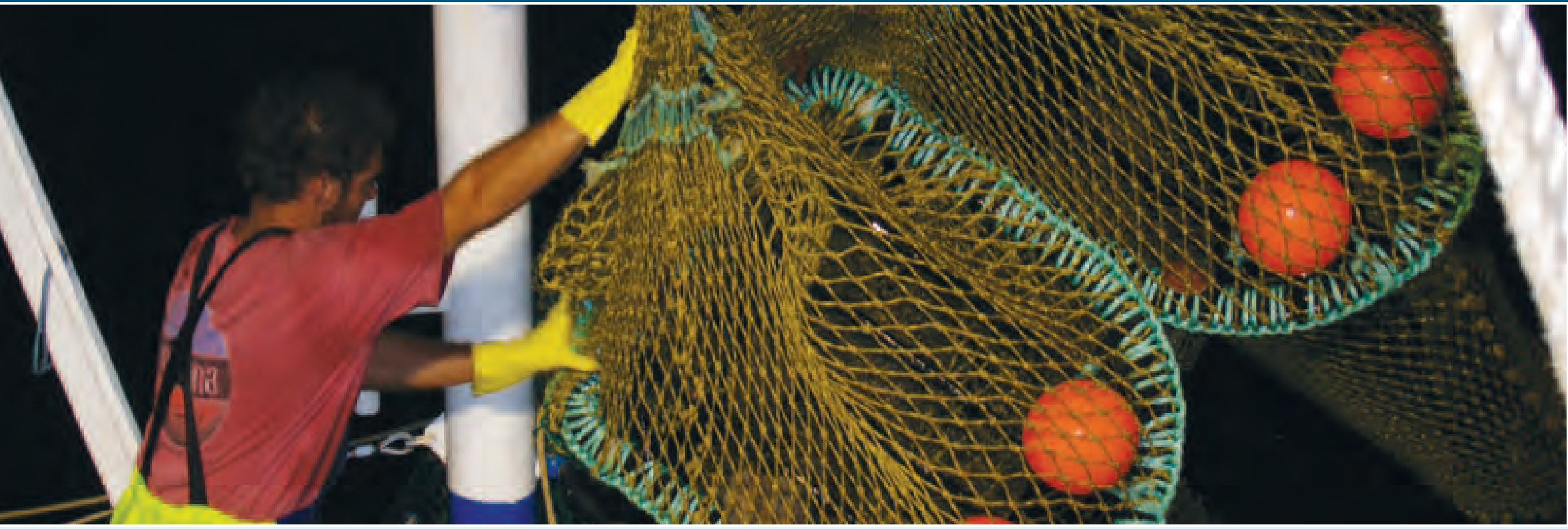
Many of the identified risks could potentially be further reduced through targeted improvements in areas such as effort management and by-catch reduction. From an industry and management perspective, it is therefore useful to understand if these remaining ecological risks are posed by the activities in specific fishery sectors, or apply generally across the whole otter trawl fishery. To build this understanding, the detailed risk assessment framework allowed for consideration of fishery sector-level risks in addition to the main assessment of ecological risks at the scale of the Great Barrier Reef ecosystem.

Issues arising from the assessment as they relate to specific fishery sectors, or the fishery in the Great Barrier Reef Region as a whole, are summarised in Table 18. Some of the identified risks arise from only one or a few fishery sectors, whereas other risks apply fishery-wide.

Table 18. Summary of remaining ecological risks and mitigation strategies by fishery sector or for the otter trawl fishery as a whole.

Fishery sector	Remaining significant risks
Overall: Otter trawling within the Great Barrier Reef Region	17 species of sharks and rays at high or intermediate risk from the fishery.
	Two sea snake species at high risk (elegant sea snake, ornate reef sea snake) and two sea snake species at intermediate risk (spectacled sea snake, small-headed sea snake).
	Three species of pipefish, one species of pipehorse, and at least one species of seahorse at intermediate risk from most ECTF sectors.
	Two principal species (grooved tiger prawn and Asian moon scallop) and four other permitted species/species groups (slipper lobster, red champagne lobster, threadfin bream and mantis shrimp) at intermediate risk.
	Risks to by-catch species, particularly at higher trawl fishing effort levels.
	Four assemblages (1, 4, 12 and 13) at intermediate risk.
Eastern king prawn (deep and shallow water)	An intermediate-high risk to the three species of Balmain bugs, which are retained as by-product in the eastern king prawn fishery sector.
	The deepwater fishery poses a high risk to habitat type 10, which is deeper than 90 m and predominantly south and east of the Swains. The certainty in this assessment is low, however, as it is a precautionary assessment resulting from very limited knowledge of this newly defined habitat type. An improved knowledge base for the habitat(s) in this area is needed for future reassessments of ecological risks.
Scallop (saucer)	By-catch (as identified in the overall fishery risks) as relevant to the scallop sector.
Tiger/endeavour	Two principal species (grooved tiger prawn and Asian moon scallop) at intermediate risk.
	Intermediate risk to a by-catch species (tufted sole).
	Intermediate risk to whipfin ponyfish, known to occur in coastal/inshore waters in the central and northern Great Barrier Reef, and extremely common in trawl by-catch in north Queensland.
King prawn (including red-spot king prawn)	The highest proportion of sea snake capture occurred in the red-spot king prawn sector of the fishery, and hence the highest risks related to this sector.
	Intermediate risk to whipfin ponyfish, known to occur in coastal/inshore waters in the central and northern Great Barrier Reef, and extremely common in trawl by-catch in north Queensland.
Banana prawn	A by-catch species (longfin silverbiddy) incidentally caught in daytime trawls for banana prawns at intermediate risk.

5. Discussion and Implications



This section discusses the assessment approach and management implications, and provides a summary of research needs.

5.1. The assessment approach

The ecological risk assessment method chosen for use for this fishery was that developed for fisheries in NSW (Astles et al. 2009). It was selected at a scoping workshop, after consideration of a range of methods being used nationally and some key principles or attributes of a preferred method, which should:

- ensure broad consideration of ecological issues and risks, consistent with ecosystem-based management
- provide a rigorous and transparent risk assessment
- provide logical and easily understood results for stakeholders
- be underpinned by detailed assessment and appropriate supporting documentation
- be developed collaboratively to ensure key issues are covered and assessment outputs supported
- fit with other assessment requirements
- make best use of current information and prior assessments
- adopt (or adapt only minimally if necessary) a well-established method/process (i.e. focus on the ecological risk assessment itself)
- allow flexibility to refine the method/process if required
- account for uncertainty and recognise limitations/assumptions
- be achievable with available resources
- facilitate future re-examination to take into account alternative management and potential climate scenarios.

The above principles are entirely consistent with the desirable attributes of an ecological risk assessment process identified by Hobday et al. (2011). The method chosen also meant there was a consistent ecological risk assessment approach across state jurisdictions, aiding assessments of common species.

The assessment framework was able to incorporate all types of information (e.g. quantitative, qualitative, expert knowledge, biological inferences) into a common framework to assess diverse ecological components (e.g. prawns, marine habitats). This information was combined from a variety of sources and assessed by many people with expertise from diverse backgrounds. As a result, participants in the assessment have significant ownership of the assessment results. Although a large workload was required to achieve this high level of inclusivity, the benefits of including a broad range of stakeholders, fishers in particular, from the initial planning stages through the workshops and during the reporting, certainly outweighed the costs.

The level of risk was estimated using scientific information that was integrated in a qualitative manner, using decision criteria to interpret this information. In doing this, it was important to identify what attributes contributed to making an ecological component susceptible to being affected by a human activity, in this case fishing. These attributes can be broadly grouped into two aspects—factors that describe the external pressure being placed on an ecological component by aspects of a fishery (e.g. catch levels of harvested species, types of fishing gear, adequacy of any species-specific measures to protect reproductive function and prevent overfishing, by-catch reduction) and characteristics that describe how an ecological component might respond to that pressure (e.g. reproductive biology, growth rates, dietary requirements, habitat interactions, foraging patterns). These two aspects were based on the same principles used by other Australian ecological risk assessments (e.g. Fletcher 2005, 2008, Hobday et al. 2011) (Section 3.2.5).

The characters, factors and decision criteria used in this assessment are grounded in scientific literature and were systematically compiled. Where available, relevant quantitative information for these characters, factors and decision criteria were incorporated, but data are frequently sparse or lacking. What makes this type of risk assessment rigorous and defensible is not how quantitative it is, but to what extent it captures and integrates the aspects that could contribute to determining the likelihood of an ecological component being susceptible to the undesirable outcome. Having a fully quantitative risk assessment does not guarantee a more reliable result. For example, quantitative risk assessments of the northern cod fishery in Canada, in the form of fish stock assessments, did not prevent it from collapsing partly because some critical aspects relating to pressure from the fishery, such as the proportion of available refuge areas from fishing, were not taken into account (Walters and Maguire 1996).

This assessment evaluated risks against management objectives rather than against any benchmarks of 'natural' or 'pristine' conditions for two reasons. Firstly, it is a requirement of the chosen method to consider a failure to meet management objectives as the consequence to be avoided (Section 3). Returning the whole area to pristine conditions is not a current management objective of either state or national governments (Section 2.4). Therefore it is of no relevance to management or the assessment to estimate the risks posed by fishing to achieving such an outcome. Secondly, defining pristine conditions for the Great Barrier Reef, against which current conditions or trajectories could be compared, is difficult as human impacts began long before any biological studies of the system began. However, scientific knowledge of the longer term and historical impacts of trawl fishing on Great Barrier Reef seabed communities was incorporated into the assessment, using estimates from comparisons of fished and unfished areas and on knowledge from experiments to measure trawl fishing impacts and recovery rates (Poiner et al. 1998, Pitcher et al. 2000, Ellis and Pantus 2001, Pitcher et al. 2007b, Pitcher et al. 2008, Pitcher et al. 2009). Additionally, information from relevant stock assessments of some of the target species was incorporated (e.g. Tanimoto et al. 2006), which make reference to levels of virgin (pre-fishing) biomass and therefore compare with assumed 'pristine' levels. Using this information has reduced the potential for assessment outcomes to have been biased and risks underestimated by 'shifting baselines'—a failure to consider historical changes when assessing current conditions.

The particular strengths and weaknesses of the NSW ecological risk assessment method (and other ecological risk assessment methods) have been described by Scandol et al. (2009). In addition to the strengths they identified, application of this method is precautionary in that uncertainty is explicitly considered in the assessment. A further strength of the assessment method is that it evaluated risk at a range of spatial scales and at different functional levels and, where relevant, incorporated information from beyond the boundaries of the system being considered.

This risk assessment is unusual in that it covered all components of the ecosystem at potential risk from fishing including harvested species, by-catch species, species of conservation concern, marine habitats, species assemblages and ecosystem processes. Where known external pressures (e.g. degraded water quality) may make a component more susceptible to trawling, this was also taken into account. Thus, not only the direct and intended effects of fishing but also the indirect and unintended impacts were all explicitly considered.

The risk assessment was also unusually well informed for an ecological risk assessment and was able to draw on not only a wide array of expert opinion but also a substantial range of published material. This broad body of knowledge provides a high degree of confidence that the findings about the remaining risk levels are robust in most cases. It also provided a basis for the preliminary screening of risks and the identification of those components requiring more detailed analyses (Section 4.1). This helped address one of the potential weaknesses of the method identified by Scandol et al. (2009) that it can "result in considerable effort being expended on components that are obviously not at risk".

However, approaches that use decision rules and ranking criteria may contain biases which may either under- or overestimate the level of risk. All qualitative ecological risk assessment methods for fisheries used in Australia have this weakness (Astles 2008, Astles 2012). In the current assessment, the setting of the decision rules and their application to ecological components went through several expert evaluations both within and outside the project team (Section 1.3). Any potential under- or overestimations of risk are likely to have been captured and corrected in this process. Additionally, the reasoning followed has been specified so that risks can be more readily reassessed in the future when new information is available or if circumstances change. The use of quantitative information, when available, also reduced the potential for the results to be subject to participant bias.

Emphasis was given to external stakeholder engagement activities in the modified ecological risk assessment framework adopted here for the Great Barrier Reef Region. This was expected to help improve understanding of the fishery and its interactions with the marine environment, and to improve risk communications.

Despite the range of spatial scales considered, and the generally robust nature of the findings, it is quite possible that local-scale effects may be greater than anticipated by this assessment. The system is large, dynamic and heterogeneous and the fishery is also dynamic and concentrates effort in preferred areas where and when target species are abundant. So local impacts may be more pronounced than those identified.

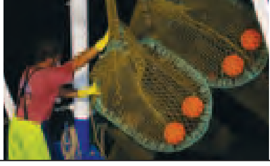
This assessment has not considered the issue of fishing as an evolutionary pressure, which may lead to permanent changes in fished populations in such factors as size and age at maturity, growth and fecundity (Dunlop et al. 2009). This is a relatively new area of concern for fisheries, but is one of the 'ten commandments' identified as important for ecosystem-based fisheries management by Francis et al. (2007). There are now well-documented examples of fishing-induced evolutionary changes (e.g. Conover et al. 2007, Sharpe and Hendry 2009), but these are generally based on studies of bony fish and it is not clear whether the same concerns would apply to short-lived and abundant species, such as prawns that are also fished less selectively than most bony fish. Including evolutionary considerations is also problematic because the setting of evolutionary objectives is at a very early stage of development.

5.2. Management implications

The issues arising from the assessment for each of the different ecological components have already been described and discussed in the relevant sections of the report (see Section 4). Here the findings of the assessment as a whole are considered and the overall pattern and sources of risks that emerged are discussed.

5.2.1 OVERALL PATTERN AND SOURCES OF RISKS

The overall ecological risk profile for the ECOTF within the Great Barrier Reef Region was found to be relatively low in this assessment (Section 4.8). This low risk profile largely resulted from a combination of: 1) those species, habitats and the broader ecosystem exposed to prawn trawling in the Great Barrier Reef having characteristics that give them a degree of resilience to impacts, including from fishing; 2) the relatively low effort exerted by the trawl fishery in recent years leading to relatively low pressure at the scale of the Great Barrier Reef ecosystem under current circumstances; and 3) the extensive knowledge base for the fishery and Great Barrier Reef. These aspects are discussed further below.



Many of the species caught by trawlers (particularly among the harvested species) have relatively high resilience to trawling impacts, due to biological/ecological characteristics such as high rates of population growth and widespread geographic distributions. For those species with lower resilience, interactions with the fishery are often rare due to different distributional patterns, or there may already be effective measures in place to mitigate risks — these characteristics lead to lower risk.

Several of the shelf habitat types that are trawled in the Great Barrier Reef Region had a relatively high resilience to trawling, and these tend to be predominantly muddy, sandy or silty habitats where prawns are abundant. Although the resilience of other shelf habitat types was lower, their exposure to trawling was low to very low, and they had high levels of protection under the zoning. Hence, all of the shelf habitat types (habitats 1 to 9) had relatively low fishery impact profiles leading to low or intermediate-low risks.

The areas trawled by the fishery overlap by varying, but often only limited, proportions with the distribution of habitats and most species, which lowers risk (Section 4). For example, the overall exposure to current trawling effort, taking intensity into account, was low for seven habitat types and moderate for the other two shelf habitat types. Additionally, seven of the habitat types assessed had over 50 per cent of their areas permanently protected from trawling under Marine Park zoning (Pitcher et al. 2007a). Relatively few individual species or habitat types were considered to be affected by external (cumulative) impacts from non-trawl fishery pressures, the exceptions tended to be mainly associated with some inshore areas of the Great Barrier Reef Region, which have pressures arising from poor water quality from catchment run-off, loss of coastal habitats from coastal development and ports and shipping activities.

The broader ecosystem – as assessed by considering more complex aspects such as species assemblages and ecosystem processes – was also considered to be relatively resilient to trawling impacts at the scale of the whole Great Barrier Reef. The fishery impact profiles were generally assessed as being relatively low at the scale of the whole Great Barrier Reef, but may be higher in heavily trawled areas for some processes.

The large amount of past research provided a robust basis for assessing ecological risks (e.g. Courtney et al. 2007, Pitcher et al. 2007b). Without this body of work it is likely the assessment would have found a lot of precautionary high risks. In many cases, the research has also informed discussions about management options to ensure the long-term sustainability of the fishery or identified specific solutions to address particular risks (e.g. Courtney et al. 2007).

This previous research, and particularly quantitative sustainability indicators from the Seabed Biodiversity Project, also allowed the assessment to compare risks based on 2009 levels of fishing effort against risks arising from the higher levels of fishing effort reported in 2005 (discussed below, and see Section 3.3.5). The results from this assessment reinforced earlier findings by the Seabed Biodiversity Project, which found very few species, assemblages or habitats exceeded sustainability reference points — most were at low or very low risk from the fishery (based on 2005 trawl fishing effort data). The outcomes for habitats in this Great Barrier Reef ECOTF ecological risk assessment were very different to those for the NSW Ocean Trawl Fishery ecological risk assessment (Astles et al. 2009). The NSW Ocean Trawl Fishery considered the resilience and resistance of geological and biogenic habitats qualitatively, but did not have detailed information about their spatial distribution or fishing patterns. The fishing gear used also differs from gear used in the ECOTF. In addition, the relatively high risk assigned for habitat types in the NSW Ocean Trawl Fishery assessment was in part a function of a number of data gaps (e.g. biological knowledge of habitats); such data gaps generally did not exist for the majority of habitat types within the Great Barrier Reef Region.

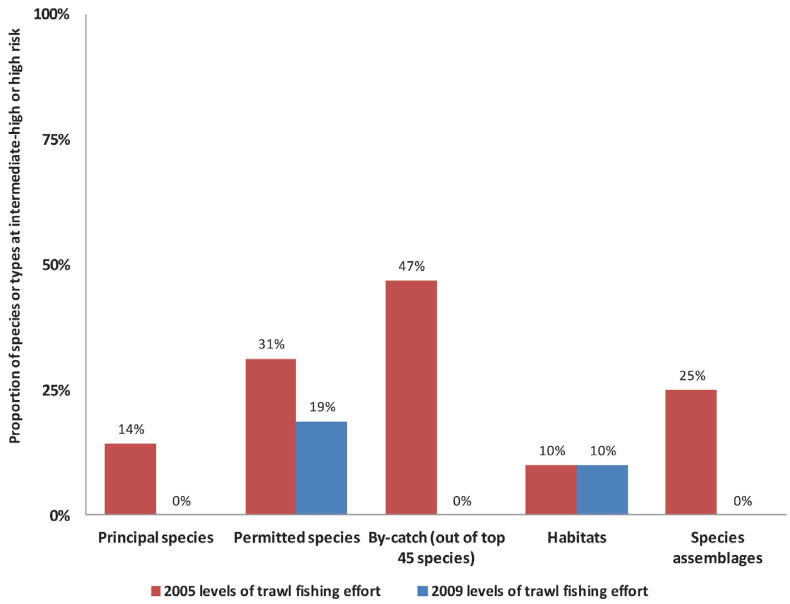


Figure 26. Comparison of risk levels by year showing an overall lower risk at 2009 trawl fishing effort levels compared to 2005 levels in the Great Barrier Reef Region.

The bars represent the proportion of species or assemblage/habitat types of those assessed in detail at intermediate-high or high risk for each ecological component and year assessed.

Comparison of risk patterns for the two years of trawl fishing effort considered in this assessment (2009 trawl effort levels and 2005 levels) revealed an overall decrease in risk from 2005 to 2009 (Figure 2 and Figure 26). Four of the five comparisons showed lower risk in 2009, and habitats showed low overall risk in both years (Figure 26). The same pattern of reduced risk was found for most individual species and habitat types assessed, and no species or habitat types had an increased risk over this period. The key driver for this reduction in risk was lower fishing effort levels; in 2009, total trawl fishing effort in the Great Barrier Reef World Heritage Area was more than 40 per cent lower than in 2005 predominantly in response to less favourable economic circumstances. This finding is important and confirms that lower fishing effort levels result in lower ecological risks and impacts from this fishery, including the total amount, intensity, location and timing of effort.

In understanding this reduction in risk it is important to know the differences between the fishery as it was in 2005 and as it was at the time of this assessment, as well as the drivers for these differences. Changes during 2011 that would be relevant to a future reassessment are also discussed. Although not specifically assessed, it can be assumed that the ecological risk profiles in both 2009 and 2005 were substantially lower than at earlier times over the last two decades, since 2005 effort levels were less than half the peak days fished in 1997. So it is also worth considering the significant changes to management arrangements that have occurred to ensure sustainability, especially since 1999.

For the Great Barrier Reef Region, in 2005 the fishery had 346 active vessels and a total effort of approximately 33,000 boat-days, down from a maximum of almost 73,500 boat-days in 1997 (Figure 10), when there were 614 active trawl vessels. Effort has continued to decline to the lowest levels on record in 2011 (Figure 10).

The introduction of an effort management system under the Trawl Plan in 2000 was accompanied by a structural adjustment program aimed at capping effort to 1996 levels. The structural adjustment resulted in a significant reduction in trawl fishing entitlements, although not sufficient on its own to explain continued reductions in trawl effort through to 2005. An increase in average fishing efficiency across the fleet, penalties on transfer of effort units and increasing costs of production were some of the other reasons total effort in the fishery continued to decline between 2000 and 2005.

Significant increases in protection were afforded to key habitats by the introduction of the Trawl Plan in 2000 and further reinforced by the rezoning of the Great Barrier Reef Marine Park for biodiversity conservation purposes, which came into effect in 2004. In relation to trawling, the Marine Park rezoning drove further reduction in ecological risk from the fishery through two key areas of reform. The first was the protection of representative habitats from risks associated with trawling activities through the zoning of areas where future trawl fishing was not allowed. The second was a reduction in total trawl fishing effort through an accompanying structural adjustment program.

Reductions in total trawl fishing effort — principally as a result of the two structural adjustment programs, key management reforms and declining profitability — drove absolute reductions in ecological risk from trawl fishing to the low levels identified in this assessment. However, this does not infer that trawling *per se* represents a low risk to marine habitat. Scientific evidence from the Great Barrier Reef Region shows that historical patterns and amounts of trawl fishing resulted in unacceptable impacts and changes to marine habitats and species (Poiner et al. 1998, Burridge et al. 2003, Pitcher et al. 2007b). The findings of this ecological risk assessment take into account current fishing effort levels and the full suite of management arrangements in place, including protected area management and very fine spatial scale data on the distribution of fishing effort.

However, current effort levels in the fishery are only utilising approximately 60 per cent of the permitted total allocation of effort units. Effort is currently being constrained by poor terms of trade through high operating costs and low catch revenue. Effort unitisation and effort controls under the current management plan do not attempt to manage effort at or below the relatively low levels that form the basis of the reduced ecological risk identified in this assessment for 2009. Since total effort levels are the key driver of ecological risk for this fishery, the potential for higher levels of effort means there is potential for ecological risk to increase.

Fisheries Queensland is currently reviewing the management arrangements for the ECOTF and the review has identified that controlling effort is considered an appropriate management approach at this time for several reasons, including the importance of managing ecological risk (Dichmont et al. 2012). Ensuring the results of this risk assessment are incorporated into the current review of management arrangements is a clear pathway to the development of appropriate solutions for the future management of effort in the ECOTF as a key driver of ecological risk.

It is uncertain whether trawling will return to 2005 or higher fishing effort levels; the industry view is that it would not reach these levels given the current economics of the fishery. Nevertheless, given there are currently no regulatory impediments to this happening, ongoing monitoring of the economic performance of the fishery and the key economic factors that have recently constrained fishing effort (including fuel prices, prawn prices and foreign exchange rates) would be important to ensure that management can respond promptly should circumstances change.

The Trawl Plan further reduced risks to some protected species through the mandatory use of TEDs and BRDs. TEDs have been mandatory in all otter trawl nets since 2001, reducing the unintended impacts of trawling on marine turtles and other large marine species (such as large sharks and rays). At the time of the assessment (2010), TEDs were considered to be effective at allowing most marine turtles to escape from trawl nets, but were not effective for the exclusion of very large leatherback turtles, despite a low interaction rate for this species (e.g. Robins 1995). The TED design specifications have since been specifically improved to increase protection for leatherback turtles and meet strict accreditation standards (Section 4.4.4) and this improved specification is now (2012) mandatory fleet-wide.

In 2009, following several years of research and industry-based gear innovation, Fisheries Queensland began a trawl by-catch reduction program. The program included a BRD and TED rebate scheme, the testing of new and improved BRD designs, and an education program to facilitate and evaluate the uptake and use of these devices. This by-catch reduction work received $1.5m in funding from the Queensland Government as part of its commitment to 'taking by-catch off our beaches'. This funding was used to provide the commercial fishing industry with assistance to move to more efficient BRDs, therefore helping to reduce the level of by-catch and the impact on the marine environment from trawling activities. As well as providing environmental benefits by reducing ecological risk, the effective use of these devices in the trawl fishery can result in a significant improvement in industry-wide profitability (Roy and Jebreen 2011). Industry benefits include access to new markets, reduced operating costs, improved product quality and community perception.

An extension program supported by the Fisheries Research and Development Corporation (FRDC) and completed in 2011, promoted the benefits of utilising the most effective BRDs to industry, leading to the success of the associated rebate scheme and significant uptake of these devices by industry (Roy and Jebreen 2011). This work is an extension of FRDC-funded research results on improved BRDs to the ECOTF (Courtney et al. 2007, 2010). Fisheries Queensland has complemented this extension work with new programs delivering fisheye and square mesh codend (SMC) BRDs to industry for trial and development in the shallow water prawn fisheries. As a consequence, a range of the best performing BRDs are now being trialled by commercial fishers throughout the ECOTF.

5.2.2. REMAINING RISKS

The significant remaining ecological risks included risk to an upper continental slope habitat and risk to some incidentally caught species.

Despite the 2004 rezoning of the Great Barrier Reef Marine Park protecting representative habitats at the scale of the Great Barrier Reef, and overall reductions in fishing effort, an area of habitat in the south-eastern corner of the Marine Park was identified as being at high ecological risk from trawling. This area of habitat is 14,056 sq km (about 4 per cent of the Marine Park) and lies between about 90 and 300 m deep. Factors driving this high risk include consistently high levels of trawl fishing effort for eastern king prawns in half of this area and a general lack of knowledge about seabed habitats in this area of the Marine Park deeper than 100 metres. Additional ecological and biological information is required to more confidently assess the risks posed by the fishery in this area.

Remaining high and intermediate–high ecological risks to species were mainly attributed to the catch of non-target species, including some protected species.

Despite a low number of species found to be at high risk, of particular note is the relatively high number of skates and rays represented among this group. These included a shovelnose ray, a coffin ray, three species of stingrays, two species of stingarees, three species of skates and a butterfly ray. While the ecological risk to large sharks and rays has been significantly reduced through their exclusion from trawl nets by mandatory TEDs, many smaller species of sharks and rays remain in the by-catch of prawn and scallop trawlers. Unfortunately, the biological life history traits of many of these species mean that some may be at high ecological risk from the fishery.

Survival of sharks and rays after being caught in trawl nets then discarded is often poor, with fishery observer information indicating immediate survival was 35 per cent on average, and only 17 per cent were released alive in the deepwater eastern king prawn sector. All fishery sectors in the ECOTF interact with one or more of these sharks and rays at high risk from trawling, and several of these species are caught in two or more fishery sectors on occasions (Table 12). These high risks were therefore attributable to a combination of relatively high fishery impact profiles and inherently low resilience (due to the lower biological productivity of this group of animals).

Reducing the remaining risks for sharks and rays may therefore be problematic as risk prone factors that contribute to the fishery impact profile may not be readily altered. Changes to levels of fishing effort are likely to be the most important aspect of the fishery for mitigating risks to sharks and rays (as this influences level of interaction). Improved gear selectivity through better BRD performance may provide opportunities to further exclude smaller sharks and those with a flattened body form (such as many rays and skates) from the catch. It is important that future research into BRD design strives to improve exclusion and reduce the catch of these at-risk species. Other opportunities to reduce risks may include ways to minimise interactions with sharks and rays (e.g. avoiding any interaction hotspots).

The risks posed by the ECOTF to sharks and rays reflect patterns found in other fisheries. Their demographic characteristics and vulnerability to fishing gear means they may either make up a substantial proportion of the species found to be at high risk in other fisheries (e.g. Murua et al. 2009, AFMA 2010) or become the subject of special attention (Stobutzki et al. 2002, Griffiths et al. 2006, Gallagher et al. 2012).

For sea snakes, the remaining risks should be more amenable to reduction by changes to the characteristics of the fishery (particularly effectiveness of BRDs). Recent research data on the capture of sea snakes shows that catch rates are high in particular areas of the fishery, such as when fishers are targeting the reef associated red-spot king prawns, and that many existing BRDs are not optimal for sea snake escape (Courtney et al. 2010). Fortunately, the same research identified BRD designs that are suitable for sea snake escape. It is important that the current Fisheries Queensland review of management arrangements for the fishery considers opportunities to address this high ecological risk.

When fishing for prawns and scallops, many non-target species are captured and under current management arrangements are allowed to be retained as permitted species. Despite not being targeted, many of these species are of high economic value and are captured in reasonably high quantities, including three species of Balmain bugs. A poor understanding of the distribution of these species, their exposure to trawl fishing effort and a lack of knowledge about their life history traits resulted in these three permitted species being considered at intermediate-high ecological risk from the fishery.

Where risk levels from trawling have been assessed as low or intermediate-low, these risks are currently considered acceptable by Marine Park and fishery managers, but need to be monitored and communicated. At the other end of the risk spectrum, remaining intermediate-high or high risks should be considered in current risk management processes to reduce risks, and are a high priority for monitoring and communication.

Potential risk mitigation strategies may include preventing effort from rising to unacceptable levels, ensuring compliance with rules, supporting research to address knowledge gaps, optimising the use of current BRDs, improving BRD design, developing ways to improve post-trawl survival rates or other initiatives to reduce by-catch and interactions with protected species, and supporting measures that discourage targeting and limit the total harvest of other permitted (by-product) species.

Risk monitoring will also be important for intermediate risks, including monitoring of changes to fishery characteristics that may alter fishery impact profiles or changes to external pressures on ecological components that may alter their resilience. While risk management and communication is a lower priority for intermediate compared to high risks and no specific action may be required, these intermediate risks may point to areas where a further reduction in ecological risks is readily achievable, leading to flow-on benefits for the marine environment and/or industry. For example, measures to ensure the long term ecological sustainability and optimise yields of harvested species, and opportunities for the commercial fishing industry to help improve the outlook for the Great Barrier Reef and dependent industries by reducing intermediate risks from trawling to the ecosystem. Maintaining or building ecosystem resilience has been identified as a key strategy to improve the outlook for the Great Barrier Reef, especially in light of serious threats including climate change.

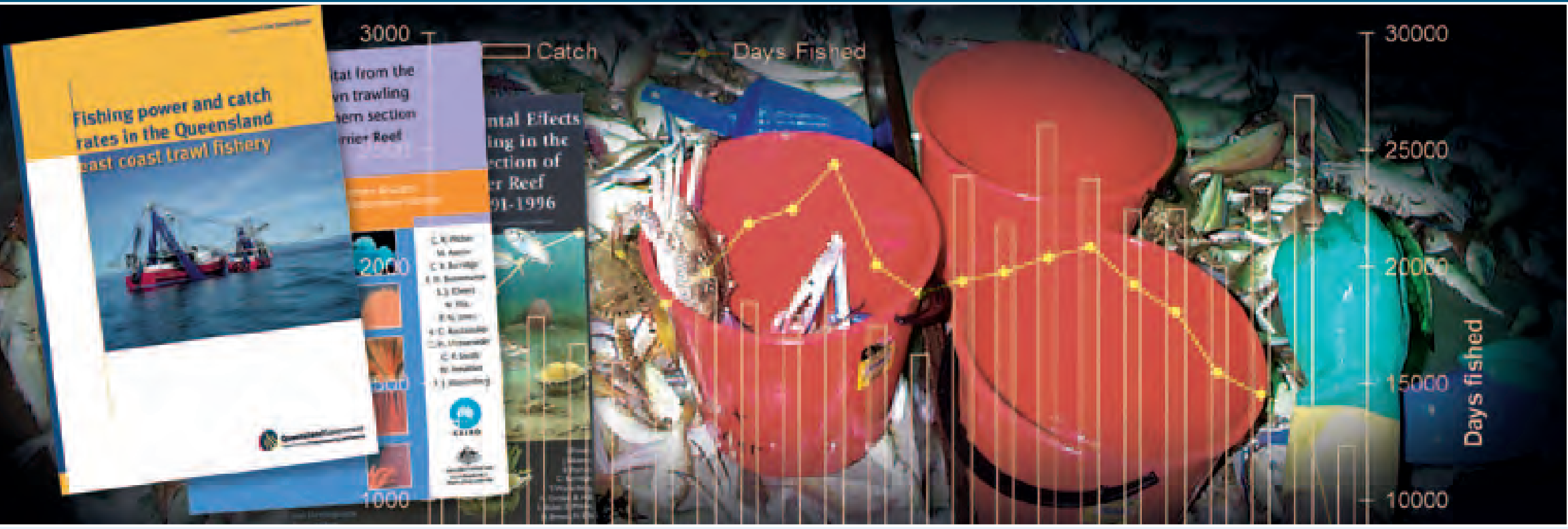
5.3. Summary of research needs

This risk assessment assigned risk prone scores as a precautionary approach whenever there were key information gaps. The relatively low number of components that were assessed as being at more than a low risk reflects the substantial and cumulative contribution of knowledge from many researchers over many years. Nevertheless, there remain a number of information gaps to be addressed in order to improve future assessments of ecological risks from the ECOTF to the ecosystem in which it operates. Table 19 summarises the gaps that were identified during this assessment, but does not attempt to prioritise them.

Table 19. Summary of research needs identified during the assessment.

Species/species groups/types	Information gap
Principal and permitted species	There is a lack of species-level data for the three species groups that are included in this category.
	There is only limited species-level fishery data for some prawn species (particularly tiger, endeavour, red-spot king).
Asian moon scallop	Resilience characters for Asian moon scallop (assumed to be the same as for the tropical saucer scallop).
Deepwater species	Knowledge of the distribution, abundance and exposure to fishing effort for deepwater species.
Deepwater habitats (particularly 'habitat 10')	Knowledge of their distribution, abundance, species composition, species biology, exposure to fishing effort, the impacts of trawling and the rate of recovery after trawling for deepwater habitats.
Sea snakes	Development of BRDs and specific details on how they should be installed so that they can be both effectively used, inspected, policed and enforced.
	Improved knowledge of sea snake distribution, abundance and population dynamics.
Seahorses and pipefish	Improved knowledge of true interaction rates and levels of discarding for all seahorse and pipefish species for all fishing sectors.
	Improved knowledge of seahorse and pipefish distribution, abundance and population dynamics.
Sharks and rays	Improved by-catch reduction measures especially for skates and rays, particularly to minimise impacts on smaller species.
	Information on the post-release survival of sharks and rays.
	Improved knowledge of distribution, abundance, population dynamics and degree of protection from trawling provided by areas closed to fishing for species of sharks and rays.
	Collate information for key shark and ray species taking account of the latest knowledge on taxonomy.
Ecosystem processes	Ecosystem process modelling, including trawling (and other fishing), such as Atlantis, to improve understanding of ecosystem-level risks.

6. References



This section provides a full bibliography of over 180 scientific references cited in the Technical Report.

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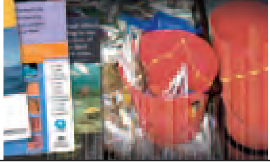

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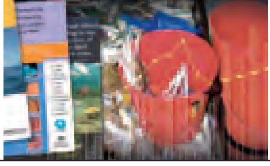

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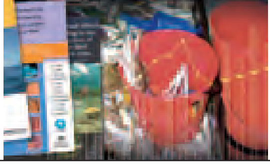

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APPENDICES TO TECHNICAL REPORT

Appendix 1. List of participants in the expert workshops

Participants in the expert workshop and follow-up working groups for species and habitats.

Name	Organisation	Expertise
Peter Doherty	AIMS	Seabed biodiversity, Great Barrier Reef science, trawl fishery (attended Day 2)
Roland Pitcher	CSIRO	Seabed biodiversity, Great Barrier Reef science, trawl fishery
Sandy Morison	Facilitator	Facilitation of risk assessment processes
Eddie Jebreen	Fisheries Queensland, DAFF Queensland	Trawl fishery management
Malcolm Dunning	Fisheries Queensland, DAFF Queensland	Fisheries assessment and monitoring
Brad Zeller	Fisheries Queensland, DAFF Queensland	Trawl fishery sustainability reporting, risk assessment
Randall Owens	Great Barrier Reef Marine Park Authority	Great Barrier Reef sustainable use
Mark Read	Great Barrier Reef Marine Park Authority	Great Barrier Reef biodiversity and species
Laurence McCook	Great Barrier Reef Marine Park Authority	Great Barrier Reef science (attended part of workshop)
Neil Gribble	Northern Fisheries Centre, DAFF Queensland	Fisheries research, seabed biodiversity, ecosystem modelling
Clive Turnbull	Northern Fisheries Centre, DAFF Queensland	Stock assessment of prawn species especially tiger/endeavour and red-spot king trawl by-catch, long term monitoring program
Karen Astles	NSW DPI	Ecological risk assessment process
Tony Courtney	Agri-Science Queensland, DAFF Queensland	Trawl by-catch composition and reduction, bugs, sea snakes and prawns
Gary Wicks	Trawl Industry	Fishing practices of the various subfisheries
Richard Taylor	Trawl Industry	Fishing practices of the various subfisheries
Steve Murphy	Trawl Industry	Fishing practices of the various subfisheries
Sian Breen	WWF	Conservation, ecosystem assessment
Bronwyn Houlden	Great Barrier Reef Marine Park Authority	Great Barrier Reef ecosystem-based management
Rachel Pears	Great Barrier Reef Marine Park Authority	Trawl Ecological Risk Assessment Project Manager, Great Barrier Reef sustainable use and ecosystem-based management
Mick Bishop	Great Barrier Reef Marine Park Authority	Marine Park compliance and Great Barrier Reef fisheries
Peter McGinnity	Great Barrier Reef Marine Park Authority	Environment and sustainability (initial morning only)
Jon Day	Great Barrier Reef Marine Park Authority	Great Barrier Reef ecosystem conservation, heritage and sustainable use (initial morning only)
Peter Kyne	Charles Darwin University	Sharks and rays, including interactions with ECTF
Ian Jacobsen	Fisheries Queensland, DAFF Queensland	Trawl fishery management, sharks and rays
Bonnie Holmes	Fisheries Queensland, DAFF Queensland	Fisheries assessment and monitoring, sharks and rays

Participants in the expert workshop for ecosystem processes.

Name	Organisation	Expertise
Bronwyn Houlden	GBRMPA	Great Barrier Reef ecosystem-based management
Cathy Dichmont	CSIRO	Northern fisheries and ecosystems
Dan Alongi	AIMS	Biogeochemical functioning of tropical marine ecosystems
Eddie Jebreen	Fisheries Queensland, DAFF Queensland	Trawl fishery management
Eva Plaganyi-Lloyd	CSIRO	Fisheries assessments
Jim Higgs	Department of Environment and Heritage Protection	Queensland environment and marine resources
Malcolm Dunning	Fisheries Queensland, DAFF Queensland	Fisheries assessment and monitoring
Miles Furnas	AIMS	Ecological processes in GBR
Neil Gribble	Northern Fisheries Centre, DAFF Queensland	Fisheries research, seabed biodiversity, ecosystem modelling
Peter Doherty	AIMS	Seabed biodiversity, GBR science, trawl fishery
Rachel Pears	GBRMPA	Trawl Ecological Risk Assessment Project Manager, GBRMP sustainable use and ecosystem-based management
Richard Taylor	Trawl Industry	Fishing practices of the various subfisheries
Rodrigo Bustamante	CSIRO	Ecosystem function and the impacts of fisheries
Roland Pitcher	CSIRO	Seabed biodiversity, GBR science, trawl fishery
Sandy Morison	Facilitator	Fisheries and risk assessment processes
Sian Breen	WWF	Conservation, ecosystem assessment
Terry Harper	Department of Environment and Heritage Protection	Queensland environment and marine resources
Tony Courtney	Agri-Science Queensland, DAFF Queensland	Trawl by-catch composition and reduction, bugs, sea snakes and prawns

Appendix 2. Overview of fishery management, data and sectors

This section provides a detailed overview of trawl fishery management arrangements, current fisheries and ecological data at the time of the assessment, and the key fishery sectors in the East Coast Otter Trawl Fishery. This information on the current circumstances and history of the fishery informed the ecological risk assessment and is provided here for two purposes: 1) to help readers understand the assessment if they are not familiar with the fishery, and 2) to make the assessment process as transparent as possible.

Appendix 2.1. The East Coast Trawl Fishery

The East Coast Trawl Fishery (ECTF) is a complex fishery in terms of its fleet dynamics, areas fished (Figure 7), catch composition and the seasonal/temporal distribution of species (Huber 2003). The fishery comprises both otter and beam trawl fisheries, with otter trawl accounting for about 95 per cent of the total catch retained each year.

The ecological risk assessment considers otter trawling within and adjacent to Great Barrier Reef waters. It does not, however, take into consideration the beam trawl fishery which mainly occurs in estuaries and inshore coastal waters outside the Great Barrier Reef Marine Park. A separate ecological risk assessment in 2011 examined the remainder of the fishery, covering river and inshore beam trawling along the entire Queensland coastline and otter trawling outside the Great Barrier Reef. Further information on the second ecological risk assessment is available from the Queensland Department of Agriculture, Fisheries and Forestry (DAFF Queensland, formerly the Department of Employment, Economic Development and Innovation, DEEDI).

Appendix 2.1.1. Brief history of the fishery prior to 1999

This history of the ECTF is abbreviated from Ruello (1975) and Huber (2003). Fishing for prawns dates back to the mid-1880s in inshore waters of Queensland. By the 1950s, a prawn fishery using otter trawl had developed in Moreton Bay and expanded northwards along the coast to Townsville. The fishery started to diversify in the mid-1950s, with the discovery of scallop grounds off Bundaberg, followed by the discovery of eastern king prawn grounds in deeper offshore waters. By 1979, the ECTF fleet reached about 1400 vessels, driven by the emergence of lucrative export markets for prawns and scallops into Asia and greater offshore capabilities through technological advances. Despite the introduction of a cap on vessel numbers and other input measures, fishing effort in the ECTF continued to increase as smaller vessels were replaced with larger, more efficient vessels and engine design advanced. In June 1987, Queensland took over responsibility for the management of the ECTF under the Offshore Constitutional Settlement from the Australian Government. By 1997, effort in the ECTF had peaked at around 108,000 fishing days. Around this time, the fishery showed signs of being 'fully exploited' (if not overexploited) with declining catch rates for some species (such as scallops) and the serial depletion of fishing grounds.

Appendix 2.1.2. Management of the fishery

The ECTF is managed by Fisheries Queensland within DAFF Queensland. The fishery has undergone significant changes in its management arrangements over time.

A management plan for the fishery was first introduced in November 1999. A revised *Fisheries (East Coast Trawl) Management Plan 1999* was introduced in December 2000, with most of the new provisions coming into effect on or after 1 January 2001. Recently, the plan was remade without changes in management intent as the *Fisheries*

(East Coast Trawl) Management Plan 2010 , hereafter referred to as the 'Trawl Plan', while a review of fishery management arrangements was under way (see end of this Section).

The 1999 Trawl Plan, amongst other objectives, aimed to restrict effort to sustainable levels. This was implemented by the introduction of effort units, reducing the number of available effort units by 15 per cent and introducing a cap on the total effort allowed within the Great Barrier Reef Marine Park. The allocation of effort quota was in the form of tradeable effort units based on an operator's fishing history. The 15 per cent reduction was realised by both a Commonwealth and State government-funded buyback of effort units and an industry-funded forgone allocation of units. The Great Barrier Reef Marine Park effort cap equated to approximately 70 per cent of effort in the fishery. These measures reduced the fleet to about 530 boats, with an annual production and GVP for the fishery in 2001 of 7500 tonnes and $95.5 million respectively.

From 2001, fishery closures under the revised Trawl Plan covered an additional 96,000 square kilometres of the Great Barrier Reef Marine Park, where trawling had not been reported through logbooks previously. A satellite-based vessel monitoring system was introduced enabling closer monitoring of the fleet’s activity for compliance and fishery management purposes. The detailed spatial and temporal effort data from the vessel monitoring system can be combined with catch data from the commercial logbook program to inform assessments of harvested species.

The fishery has also evolved in response to changed economic circumstances over the last decade. Local and global economic drivers that have contributed to reshaping the trawl fleet include the higher cost of fuel, the effect of a stronger Australian dollar on exports, increased competition from cheap imported or farmed products, and issues with finding crew with the loss of labour to the mining boom.

Since 2004, the operation of the fishery has been assessed against national ecological sustainability guidelines under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The 2010 EPBC Act assessment includes specific recommendations relating to this ecological risk assessment, and also covers other issues discussed in this report such as mitigating impacts on protected sea snakes, by-catch reduction, and managing effort levels in the Great Barrier Reef World Heritage Area.

Management arrangements for the ECTF are currently being reviewed, consistent with requirements to review subordinate legislation in Queensland every 10 years. DAFF Queensland has been working with industry and other stakeholders to identify and develop potential future management options as part of this comprehensive review of management arrangements for the fishery.

Appendix 2.1.3. Legislation

The ECTF is principally managed through the following Queensland legislation:

- *Fisheries Act 1994*
- *Fisheries Regulation 2008*
- *Fisheries (East Coast Trawl) Management Plan 2010.*

Provisions relating to trawl activities in the Great Barrier Reef are also provided for in the:

- *Great Barrier Reef Marine Park Act 1975* (Commonwealth)
- *Great Barrier Reef Marine Park Regulations 1983* (Commonwealth)

- *Great Barrier Reef Marine Park Zoning Plan 2003* (Commonwealth)
- *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
- *Marine Parks (Great Barrier Reef Coast) Zoning Plan 2006* (Queensland)
- *Nature Conservation Act 1992* (Queensland).

As the fishery governance is under Queensland law and occurs in waters under Commonwealth jurisdiction, several State and Commonwealth Acts apply in the management of the ECTF. The above list of legislation with provisions relating to trawl fishing is not exhaustive.

Appendix 2.1.4. Principal and other permitted species taken by the fishery

Principal target species for the ECOTF are:

- Prawns (eastern king, red-spot, tiger, endeavour, banana) (Family Penaeidae)
- Scallops (saucer and mud) (Family Pectinidae)
- Bugs (Moreton Bay bugs, *Thenus* spp.)
- Squid (*Loliolus* sp., *Nototodarus*, *Photololigo* and *Sepioteuthis* spp.).

In addition to the above, the fishery has a number of other permitted species which can be retained as by-product (but not targeted) under varying management requirements. These include numerous additional species of crustaceans, molluscs and finfish:

- Balmain bugs
- Blue swimmer crabs
- Cuttlefish
- Mantis shrimp
- Octopus
- Pipefish
- Red champagne lobster
- Slipper lobster
- Threadfin bream
- Three-spotted crab.

Some of these species are subject to minimum legal size, take and in-possession limits. Ancillary restrictions have also been implemented to ensure they do not become a target species over time (see Appendix 2.1.7). All other species must be returned to the water.

Appendix 2.1.5. Fishery areas

The ECOTF covers all tidal waters (excluding estuaries) east of longitude 142°31.89'E out to the East Coast Offshore Constitutional Settlement Boundary between Cape York and the Queensland/New South Wales border (Figure 7).

The ECTF comprises nine separate fishery symbols which dictate the area that can be fished. Within the Great Barrier Reef Marine Park, otter trawling is conducted under two fishery symbols:

- T1, Trawl Fishery (Cape York to QLD/NSW border excluding Moreton Bay)
- T2, Trawl fishery (Concessional).

Within the Great Barrier Reef Marine Park, trawling is restricted to the General Use (light blue) Zone. Since July 2004, 34 per cent of the Great Barrier Reef Marine Park is zoned as General Use and therefore open to trawling.

In addition to permanent closures under Marine Park Zoning, there are many fishery closures throughout the fishery where trawling is prohibited or restricted. These areas are declared for a number of reasons, including habitat and nursery ground protection, maintenance of brood stock, minimising conflicts with other marine users, and by-catch reduction.

Appendix 2.1.6. Fishing gear and methods used in the ECOTF

The vessels used by the fleet are mostly purpose built and range in size from about 10 to 20 metres. Demersal otter trawling is the fishing method used in the ECOTF, and various configurations of trawl nets are used (DEEDI 2010a). Triple and quad net arrangements (i.e. three or four towed nets) are frequently used in the fishery depending on the species targeted, fishing conditions and length of net permitted. Headrope height varies according to target species, as does the detailed configuration of nets. Heavier net and ground gear with a larger mesh size is permitted when targeting scallops to reduce net wear from shell cuts and to account for the larger size of scallops compared with prawns.

Many of the gear provisions and limitations to fishing capacity are intended to help control effort in the fishery, mitigate impacts of trawl gear on the seabed, or reduce by-catch and protected species interactions. Selected examples are mentioned below.

The dimension and configuration of the ground and tickler chains is restricted to help minimise impacts on the seabed. Since the revised Trawl Plan was introduced, ground chains are limited to a diameter of 12 mm in the deepwater fishery and 10 mm in other waters. The use of weights or attachments on the ground and tickler chains is prohibited.

Queensland east cost otter trawlers have traditionally used flat, rectangular otter boards to spread their nets, but there is an increasing tendency to use more streamlined and smaller boards. These are designed to make nets more manoeuvrable and generally have less contact with the substrate. They also reduce drag and hence fuel costs (Sterling 2008).

By-catch reduction devices (BRDs) and turtle excluder devices (TEDs) are now mandatory for operators in the otter trawl fishery. TEDs are hard grids placed in trawl nets to exclude turtles and other large animals. By-catch reduction devices are escape devices designed to enable smaller animals to swim out of the net. These devices either reduce mesh selectivity for by-catch (through altered mesh size/design) or create physical escape holes in the codend of the net.

As of 2010, the Trawl Plan provides fishers with the following choice of BRDs that they can install in their nets: 1) square mesh codend, 2) half-round square mesh codend, 3) square mesh panel, 4) fisheye, 5) bigeye, 6) radial escape section, 7) V-cut and bell codend, or 8) popeye fish excluder. Otter trawl fishers are required, by law, to install at least one of these devices with a TED in each net, with the exception of the smaller nets (called try gear) used for short exploratory shots. The headrope length of a try net must not exceed 10 m and a try shot must not exceed 25 minutes.

A recent survey of current BRD usage by the ECTF fleet was conducted by the DAFF Queensland Fisheries Observer Program and information was obtained for 174 trawlers. Of the 207 BRDs stated, some vessels used more than one type of BRD, 116 were fisheyes (56 per cent), 29 bigeyes (14 per cent), 21 square mesh panels (10 per cent), 20 square mesh codends (9.7 per cent) and 10 V-cut/flapper (five per cent). No radial escape sections were reported. Where two BRDs were reported, one was generally used in one trawl fishery sector and the other in another trawl fishery sector.

Appendix 2.1.7. Current management arrangements

The fishery is managed under a suite of input (effort) and output (harvest) controls. Total fishing effort in the fishery is limited by a cap on total fishing effort (days fished), which is distributed among licensed operators in the form of tradeable effort units.

There is an increasing amount of surplus effort (i.e. unused effort units) in the fishery. The proportion of unused effort units has increased from 22 per cent in 2002 to approximately 40 per cent of the total effort units within the fishery at the end of 2010. Consequently, in recent years the fishery has been predominantly restricted by economic pressures.

Key management arrangements (DPIF 1999, DEEDI 2009a) directed at ensuring ecologically sustainable harvest of target and by-product species while minimising the impacts on by-catch and the environment include:

- Limited entry: restrictions on the number and size of boats which can operate in the fishery
    - Boat size restriction is 20 m for T1, T2 fishery symbols
    - 70 hull unit (hull volume) limit for T1, T2
    - Engine restriction of 300 continuous brake kW (maximum).
- Gear restrictions: vessel length, net headrope length and mesh restrictions apply depending on the areas of operation.
- Licence holders only have a certain number of nights they can fish each year in the form of tradeable effort units. The number of units required to operate a vessel for a single day depends on the hull units (hull volume) of the vessel.
- When effort units were introduced to the fishery in 2001, effort was capped at the 1996 level less five per cent.
- Numerous and extensive permanent area closures apply to the fishery, particularly in waters of the Great Barrier Reef World Heritage Area, and Great Sandy and Moreton Bay Marine Parks.
- Seasonal closures (mainly for economic reasons) in place during summer and autumn north of 22°S latitude and during spring and summer south of this latitude.
- Daytime and weekend closures apply to trawling in estuaries and some inshore areas (e.g. Moreton Bay) to reduce any interactions with recreational users.
- Daylight closures (e.g. 6 am to 6 pm), such as those applying to the far northern area and to the scallop grounds, designed to limit effort and reduce by-catch.
- Mandatory use of TEDs and BRDs.
- A range of by-product harvesting protection arrangements (detailed in Table 20).
- Logbooks for both the retained catch and Species of Conservation Interest, surveillance by fisheries enforcement officers (the Queensland Boating and Fisheries Patrol), remote tracking of otter effort and compliance of fishing operations through mandatory satellite-based vessel monitoring system, and an observer program.

Details of management arrangements for the various fishery sectors are outlined in Appendix 2.3.

Table 20. Summary* of harvest regulations on principal and permitted species harvested in the ECOTF at the time of the assessment (DEEDI 2010a)**.**

Species	**Harvest regulations**	**Desired outcomes**
Blue swimmer (BS) and three-spotted (TS) crabs	1. Total ban on damage or separation of carapace from the body 2. Minimum legal carapace width (BS–11.5 cm; TS–10 cm) 3. Total ban on taking female BS crabs and egg-bearing TS crabs 4. In-possession limit (BS–Moreton Bay–100; 500 for each seven continuous fishing day period in waters outside Moreton Bay)	1. Protect undersized crabs 2. Protect spawners 3. Enhance egg production 4. Limits total harvest and targeting 5. Industry viability
Red champagne lobster (barking crayfish)	Total ban on harvesting egg-bearing females and a minimum legal size of 7.5 cm.	Enhance egg production
Octopus	In-possession limits (max. 0.0612 m^3 if frozen, 66 litres if not frozen) for each seven continuous fishing day period in waters outside Moreton Bay	1. Limits harvest and targeting 2. Industry viability
Slipper lobster	1. Total ban on harvesting egg-bearing females 2. In-possession limit (max. 20) for each seven continuous fishing day period in waters outside Moreton Bay	Industry viability
Mantis shrimp	In-possession limit (max. 0.0153 m^3 if frozen, 15 litres if not frozen) in Moreton Bay	Limits total harvest
Smooth bug, deepwater bug and shovel-nosed lobster (Balmain bugs)	1. Total ban on damage or separation of carapace from the body 2. Total ban on possession of bug meat 3. Minimum legal carapace width (smooth bugs 10.5 cm, shovel nosed lobsters and deepwater bugs 7.5 cm) 4. Total ban on harvesting egg-bearing females 5. Total ban on removal of eggs from berried females	1. Protect undersized bugs 2. Protect spawners 3. Enhance egg production
Pipefish	Trip limit of 50 individuals in total	Limits harvest and targeting

** This information is provided as a summary only, and users should refer to Queensland fisheries legislation including Schedule 2 of the Fisheries Regulation 2008 for precise details.*

Appendix 2.1.8. Interactions with other fisheries

The ECTF has limited overlap with other fisheries, the exceptions being:

- Eastern king prawns are also taken in NSW trawl fisheries.
- A commercial pot fishery takes approximately 500 tonnes per annum of blue swimmer crabs with an estimated 160 tonnes taken annually by the recreational sector.
- Some prawns (e.g. banana prawns) are also taken recreationally in inshore areas.
- The take by Indigenous fishers is unknown but is believed to be restricted to inshore prawn species only.
- A relatively small number of by-catch species in this fishery are targeted by alternate recreational and commercial fisheries such as pink snapper, flathead and yellowfin bream. These by-catch species are not allowed to be retained in the trawl fishery.
- Sharks and rays (caught as by-catch by the trawl fishery) are also caught in other commercial fisheries and by recreational fishers.

Information on the proportion the ECTF takes by species compared with other fisheries was provided by DAFF Queensland as an input to the finer level ecological risk assessments.

Appendix 2.2. Latest data on the fishery

Fishers are required to complete and return logbooks each month that contain daily records of the species caught, the quantity retained (in kilograms), dates fished and the fishing location (on 6 nautical mile grids). Fishery data for the ECOTF is reported annually. Some species are reported in species groups that are morphologically similar, for example the logbook categories of ‘tiger’ can be mixtures of three species of tiger prawns, and ‘endeavour’ includes two species of endeavour prawns. (Fisheries Queensland obtains data to assist with extrapolation of logbook data to the species level from an at-sea observer program.)

Catches reported in commercial logbooks were validated about 10 years ago and found to be within 10 to 15 per cent of actual values (L. Williams, DAFF Queensland, pers. comm., 2010). Since 2003, a separate logbook for Species of Conservation Interest has also been required, but this logbook is not as accurately completed as that containing catch and effort data (L. Williams, DAFF Queensland, pers. comm., 2010). By-catch species and discards of principal and permitted species are not recorded within the logbooks.

Up-to-date information to inform the ecological risk assessment included:

- The latest fishery data (Fisheries Queensland).
- An analysis of the level and distribution of fishing effort (Fisheries Queensland, see Appendix 2.2.3).
- A review of the outputs from the Seabed Biodiversity Project in light of current effort patterns by fishery (CSIRO, see Appendix 2.2.4).
- Current industry practices (industry members and QSIA).
- By-catch lists (compiled by T Courtney from published sources including Courtney et al. 2007).
- Various data from the Queensland Fishery Observer Program (BRD usage, discarding practices, interactions etc.).
- Observations of shark and ray interactions from the Queensland Fishery Observer Program (detailed in Appendix 2.2.5).

- A review of literature on potential risks to the Great Barrier Reef ecosystem from trawling (A.K. Morison, Section 4.1.2).

Additional background information on the fishery and the Great Barrier Reef ecosystem:

- The Trawl Fishery: http://www.dpi.qld.gov.au/28_15511.htm
- By-catch reduction: http://www.dpi.qld.gov.au/28_14251.htm
- Fishery sustainability reporting: http://www.dpi.qld.gov.au/28_10732.htm
- Fishery Assessment: http://www.environment.gov.au/coasts/fisheries/qld/eco-trawl/index.html
- *Great Barrier Reef Outlook Report* (GBRMPA 2009)
- The Great Barrier Reef Seabed Biodiversity Project (Pitcher et al. 2007b) (Appendix 2.2.4).

The fishery went through a transition period for management arrangements in 1999 and 2000 (Appendix 2.1.2) resulting in significant changes to fishing operations. As a consequence, data used for the ecological risk assessment was mostly sourced from 2001 onwards because 2001 is considered to be the first typical effort year in the post–Trawl Plan period (DEEDI 2009a).

Appendix 2.2.1. Catch data for the fishery

The total catch in the ECOTF (including the catch from the area outside the Great Barrier Reef Region) was approximately 7880 tonnes in 2009 (prawns 6350 t, scallops 790 t, Moreton Bay bugs 403 t, Balmain bugs 137 t, blue swimmer crabs 61 t, squid 60 t, cuttlefish 28 t, three-spotted crab 14 t, red champagne lobster 12 t, octopus 12 t, threadfin bream 10 t, mantis shrimp 1 t, and pipefish < 1 t) (DEEDI 2010a). In 2009, prawn landings were composed of 45 per cent eastern king, 20 per cent tiger, 10 per cent banana, 10 per cent endeavour, and 10 per cent red-spot and blue-legged king prawns. Five per cent of prawn landings are reported under other catch categories (e.g. school, greasyback and coral prawns) (DEEDI 2010a). Catch volumes and species composition in the ECOTF are highly variable among years.

Catch of principal species in the entire ECOTF

- From 2004 to 2007, prawn catches declined by 43 per cent, before increasing back to 2005 levels in 2009 (Table 21).
- From 2001 to 2006 the annual harvest of scallops varied, but in 2007 increased to levels comparable to 2000–2001.
- Squid harvest increased steadily (Table 21) from 2001 to 2005. Since 2005 squid landings have declined by more than half.

Table 21. Annual catch (tonnes) of principal species in the ECOTF (2000–2009).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Prawns	5891	6153	7017	7402	7392	6129	5666	4192	4949	6350
Scallops	922	992	560	436	673	735	530	920	567	790
Moreton Bay bugs	374	317	476	476	486	467	474	417	359	403
Squid	174	117	126	139	157	186	90	58	26	60

(DEEDI 2010a)(Source: Fisheries Queensland CFISH database, 28 July 2010).

Catch of other permitted species in the entire ECOTF

Any trends in catches of permitted species are difficult to interpret since the introduction of in-possession limits for some species from 2000 and because they are caught incidentally.

Table 22. Annual reported catch (tonnes) of other permitted species for the entire ECOTF (2001–2009).

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Balmain bugs	63	56	94	116	119	140	111	84	137
Blue swimmer crabs	145	95	87	107	76	59	61	39	61
Three-spotted crabs (red-spotted crabs)	17	29	22	38	27	22	18	8	14
Cuttlefish	62	33	37	32	26	21	25	18	28
Octopus	29	22	13	13	14	15	10	6	12
Red champagne lobster (barking crayfish)	50	15	30	37	10	9	18	17	12
Threadfin bream (pinkies)	12	8	10	6	10	8	5	7	10
Mantis shrimp	3	3	2	2	2	2	2	1	1
Slipper lobster	-	-	-	-	-	-	-	-	< 1
Pipefish (*Solegnathus* spp.)*	7891	5218	10551	8196	5904	4990	4673	3479	5640

(DEEDI 2010a)(Source: Fisheries Queensland CFISH database, 16 October 2009).
**Pipefish are reported as number of individuals retained.*

Catch of principal species within the Great Barrier Reef Marine Park

- Annual prawn catches from the Great Barrier Reef increased in 2008 and 2009 from a low catch in 2007, 65 per cent of the total Queensland east coast prawn catch was from the Great Barrier Reef.
- Annual scallop catches have been variable with no consistent trend emerging. In 2009, 64 per cent of the total Queensland east coast scallop catch was from the Great Barrier Reef.
- Moreton Bay bug (*Thenus* spp.) catches peaked in 2002, 88 per cent of the total Queensland east coast Moreton Bay bug catch was from the Great Barrier Reef.
- Squid catches have been variable, and only about 16 per cent of the total Queensland east coast catch is from the Great Barrier Reef.

Table 23. Annual catch (tonnes) by the ECOTF of principal species within the Great Barrier Reef Marine Park (2001–2009).

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Prawns	4016	5172	5534	4899	4180	3612	2379	2974	3704
Scallops	795	434	244	402	455	304	504	390	438
Moreton Bay bugs	268	438	433	415	390	415	369	331	347
Squid	26	16	22	22	19	13	9	6	10

(DEEDI 2010a)(Source: Fisheries Queensland CFISH database, 2 August 2010).

Catch of other permitted species within the Great Barrier Reef Marine Park

- Annual catches of other permitted species from the Great Barrier Reef were variable between 2001 and 2009, and totalled between 70 and 215 tonnes per year.
- The dominant four species or species groups were Balmain bugs, red champagne lobster, blue swimmer crabs and cuttlefish.
- Together these four groups accounted for an average of 90 per cent of the permitted species catch for the Great Barrier Reef between 2001 and 2009.
- Minor species or species groups in the reported catch were cuttlefish, threadfin bream, octopus, three-spotted crabs, mantis shrimp and slipper lobster.

Table 24. Annual catch (tonnes) by the ECOTF of other permitted species within the Great Barrier Reef Marine Park (2001–2009).

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Balmain bugs	55	45	34	52	41	34	43	38	32
Red champagne lobster (barking crayfish)	102	50	15	29	36	10	8	17	17
Blue swimmer crabs	16	38	31	36	35	21	15	7	4
Cuttlefish	23	33	16	17	14	10	9	11	10
Threadfin bream (pinkies)	13	11	6	8	6	4	5	3	5
Octopus	5	6	6	4	3	3	2	2	2
Three-spotted crabs (red-spotted crabs)	0.8	1.1	1.2	0.5	1.0	0.2	0.4	0.5	0.6
Mantis shrimp	0.3	0.3	1.3	0.3	0.1	0.2	0.3	0.1	0.1
Slipper lobster	-	-	-	-	-	-	-	-	-
Pipefish (*Solegnathus* spp.)*	7890	5257	10551	8196	5904	4990	4673	3512	5640

(Source: Fisheries Queensland, 20 May 2011).
**Pipefish are reported as number of individuals retained (Source: Fisheries Queensland 1 June 2011).*

Appendix 2.2.2. Fishing effort data for the fishery

Effort usage in the entire ECOTF

Effort unit usage for the entire ECOTF for 2001 to 2009 (inclusive) is shown in Figure 27 as a percentage of the total ECOTF unit allocation. Overall, the proportion of unused effort units in the ECOTF increased progressively from a low of 10.0–11.6 per cent (2001/02) to 43.3 per cent in 2008 (Figure 27). While the proportion declined slightly in 2009, over a third of the total effort unit allocation remained unused for the year. This equates to a real term surplus of 1,240,826 effort units in 2007, 1,290,876 in 2008 and 1,131,924 effort units in 2009.

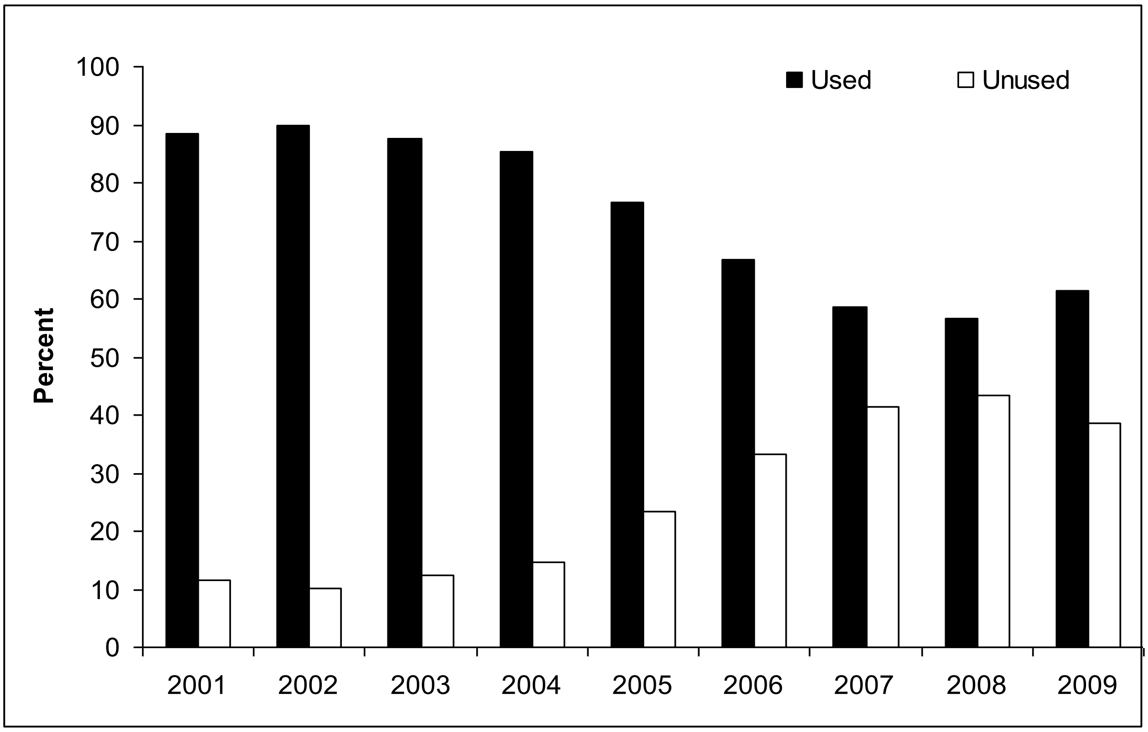


Figure 27. Effort unit usage for the East Coast Otter Trawl Fishery between 2001 and 2009.

Effort usage within the Great Barrier Reef World Heritage Area

An effort cap is in place for the Great Barrier Reef World Heritage Area (Appendix 2.1.2). Figure 28 shows effort usage by the ECOTF within the Great Barrier Reef World Heritage Area each year from 2001 to 2009 and the level of the effort cap in 2009. Only half (48 per cent) of the allowable effort units in the World Heritage Area were used in 2009 meaning there is significant capacity for effort to increase in this area (effort could almost double) despite the cap.

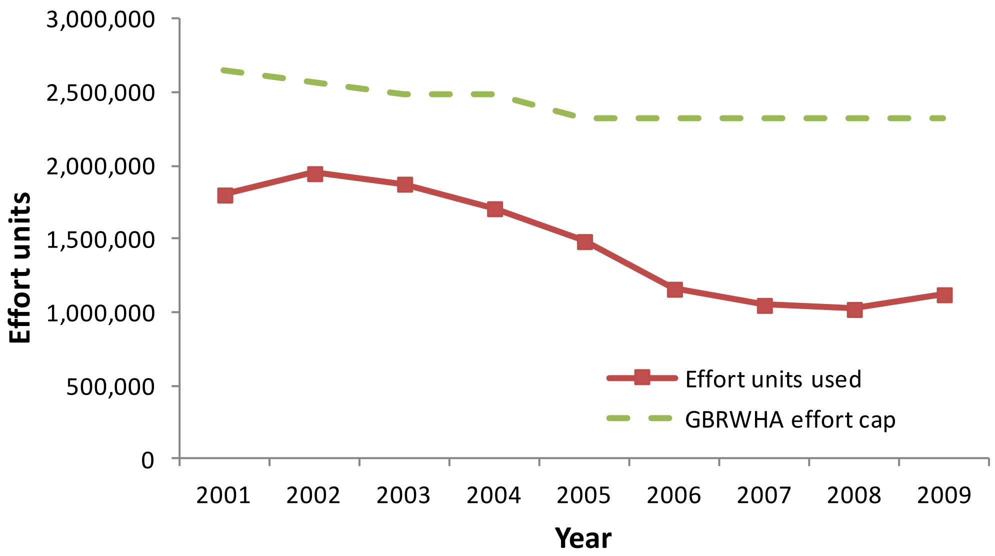


Figure 28. Annual trawl fishing effort usage in Great Barrier Reef World Heritage Area from 2001 to 2009. The level of the trawl effort cap for the World Heritage Area is also shown, and has reduced over time.

Participation rates in the entire ECOTF

Participation rates for northern (north of 22ºS) and southern (south of 22ºS) regional regulated waters have declined (Figure 29).

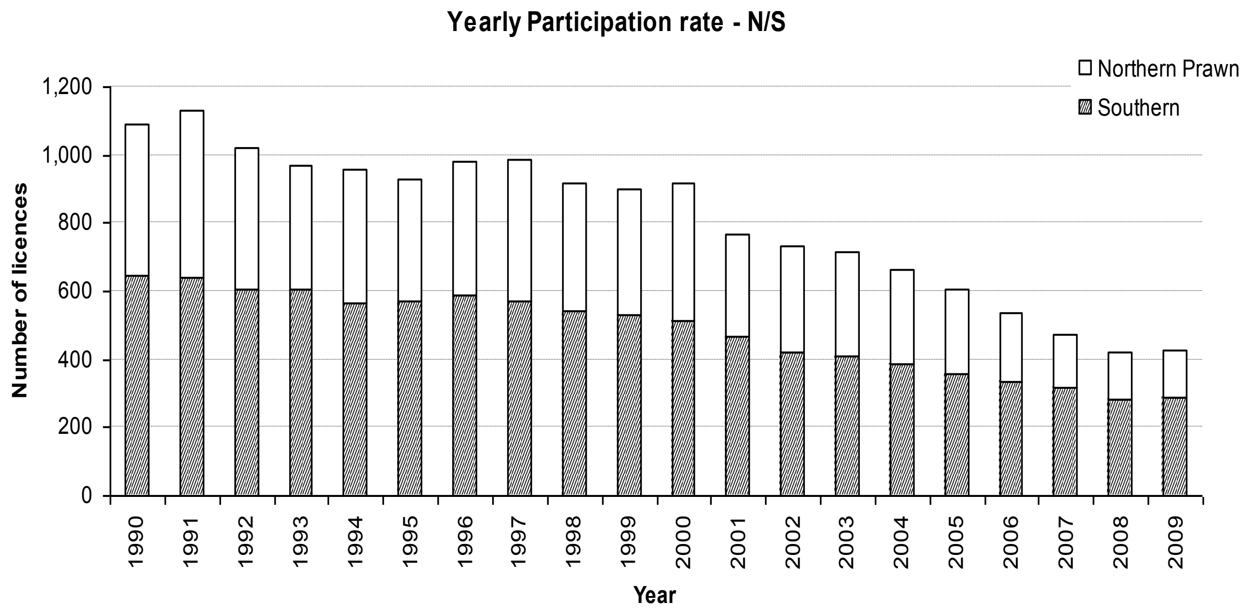


Figure 29. Otter trawl participation rates for northern and southern regional regulated waters, represented as number of licences operating in each of the respective regions.

Appendix 2.2.3. Updated spatial analysis of trawl fishing effort within the Great Barrier Reef

The pattern and level of fishing effort by the trawl fishery is a key determinant of ecological risks and impacts. The current assessment supported an updated analysis of the vessel monitoring system (VMS) effort data prepared by Fisheries Queensland, DAFF Queensland, to assist with this ecological risk assessment and future analysis of climate change impacts on the ECOTF.

The information presented was derived from confidential location information collected from trawlers at regular time intervals by Fisheries Queensland through the VMS, with actual trawl tracks (area of seabed swept by the trawl net) modelled using methods described in a report by Good and co-workers (2007). Information included on the maps enables assessment of spatial change in both the overall areas trawled within each major trawl sector between 2001 and 2009, as well as any concentration of fishing effort that has occurred over time. It should be noted that this time period captures the reduction to the area available to trawling as a result of the Great Barrier Reef Marine Park rezoning in July 2004 and the various changes that have been made to the Scallop Replenishment Areas through the Trawl Plan.

Trawl effort (total annual hours fished within one minute of latitude x longitude areas) from Torres Strait in the north to 25ºS latitude was mapped for each of the years 2001–2009 for each of the major fishery sectors that make up the ECOTF. Fishing effort was derived from VMS data with speed 'signatures' for each sector based on empirical data gathered between 2000 and 2003 and with buffers around areas of known anchorages that are not trawled. Commercial fishery daily catch data from fisher logbooks (known also as CFish data) was matched to the VMS data and filtered on species codes for the target species/species groups to assign to a trawl fishery sector.

The differences in the spatial distribution and intensity of trawl effort between 2001 and 2009 and between 2005 and 2009 (Figure 30 and Figure 31) shows that patterns of use have changed over time, with some areas experiencing less trawling (such as north of Cairns, off Bowen, north of Rockhampton and some areas between Gladstone and Maryborough) but other areas experiencing more trawling (especially south of the Swains Reefs and off Bundaberg).

The percentages of the Great Barrier Reef World Heritage Area and Marine Park trawled more than once each year from 2001 to 2009 inclusive (Grech and Coles 2011) are provided in Table 25. On average each year, trawling was conducted more than once (i.e. greater than five hours per year in each grid of 1 minute by 1 minute, or approximately 3.61 km^2) in about seven per cent of the Great Barrier Reef World Heritage Area. As the World Heritage Area (at 348,000 km^2) is similar in size to the Marine Park (at 344,400 km^2), the proportion of the Marine Park trawled more than once per year is also about seven per cent. About half of the total area trawled in any of the fishing years between 2001 and 2009 was trawled more than once in a year (Grech and Coles 2011); however the areas trawled more than once per year vary from year to year. Therefore, in considering the areal footprint of the fishery, the trawling patterns across the whole area need to be considered.

Table 25. Proportion of the Great Barrier Reef World Heritage Area and Marine Park where trawl fishing was conducted more than once (i.e. greater than five hours per year) from 2001–2009. Source: calculated from Grech and Coles 2011

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
World Heritage Area	9.3%	9.1%	8.6%	8.2%	7.0%	6.3%	6.3%	6.2%	6.3%	7.5%
Marine Park	9.3%	9.2%	8.7%	8.2%	7.1%	6.4%	6.3%	6.2%	6.4%	7.5%

Maps of trawl effort by otter trawl fishery sector were examined and the effort patterns for the major fishery sectors are described below (DEEDI 2010b). Appendix 2.3 provides information on the fishery sectors.

Banana prawn sector

Over the period 2001 to 2009, no clear trends in annual patterns of fishing effort in the banana prawn sector were evident, with the possible exception of a reduction in fishing effort off Princess Charlotte Bay in north Queensland.

Eastern king prawn sector

Data reported in logbooks as eastern king prawn from north Queensland is believed to refer to blue-legged king prawns (C. Turnbull, DAFF Queensland, pers. comm., 2010). Effort where eastern king prawn was reported has been filtered to the geographical region south of the Swain Reefs as defined for this sector under the methodology (Good et al. 2007). There was a possible trend to relocation of effort from inshore to the offshore grounds for this sector of the fishery between 2001 and 2009.

Scallop sector

Catches of scallops are dominated by the larger saucer scallops (*Amusium japonicum balloti*). However, the smaller mud scallops (*Amusium pleuronectes*) are more predominant in northern waters, such as the nearshore waters off Bowen in north Queensland where a reduction in effort was noted from 2005 onwards.

Tiger/endeavour prawn sector

Some evidence of concentration of effort into smaller areas was shown from 2001 to 2009, with a reduction especially apparent off Bowen and in Repulse Bay (in the Whitsundays area).

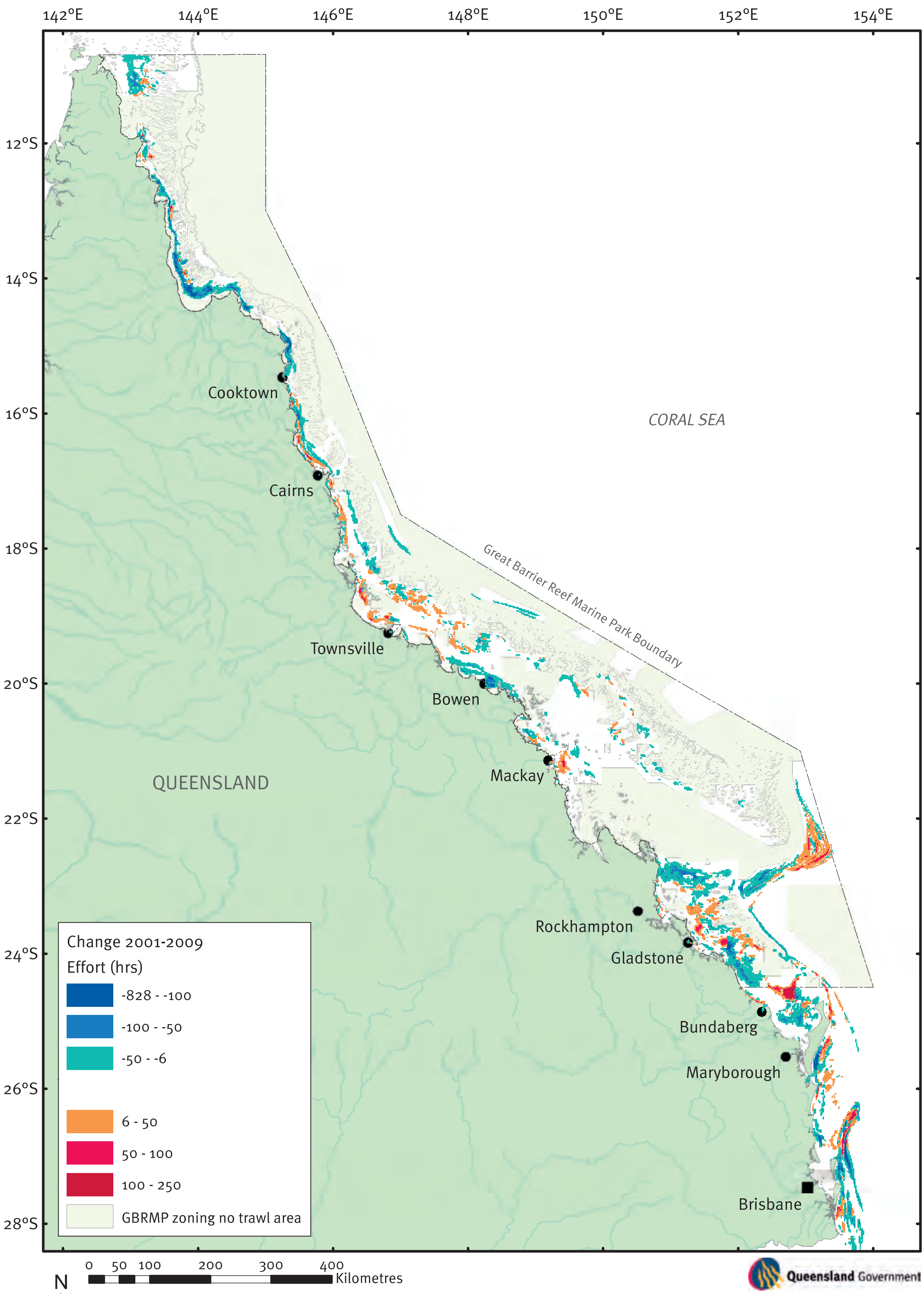


Figure 30. Comparison of otter trawl fishing effort for 2001 and 2009.

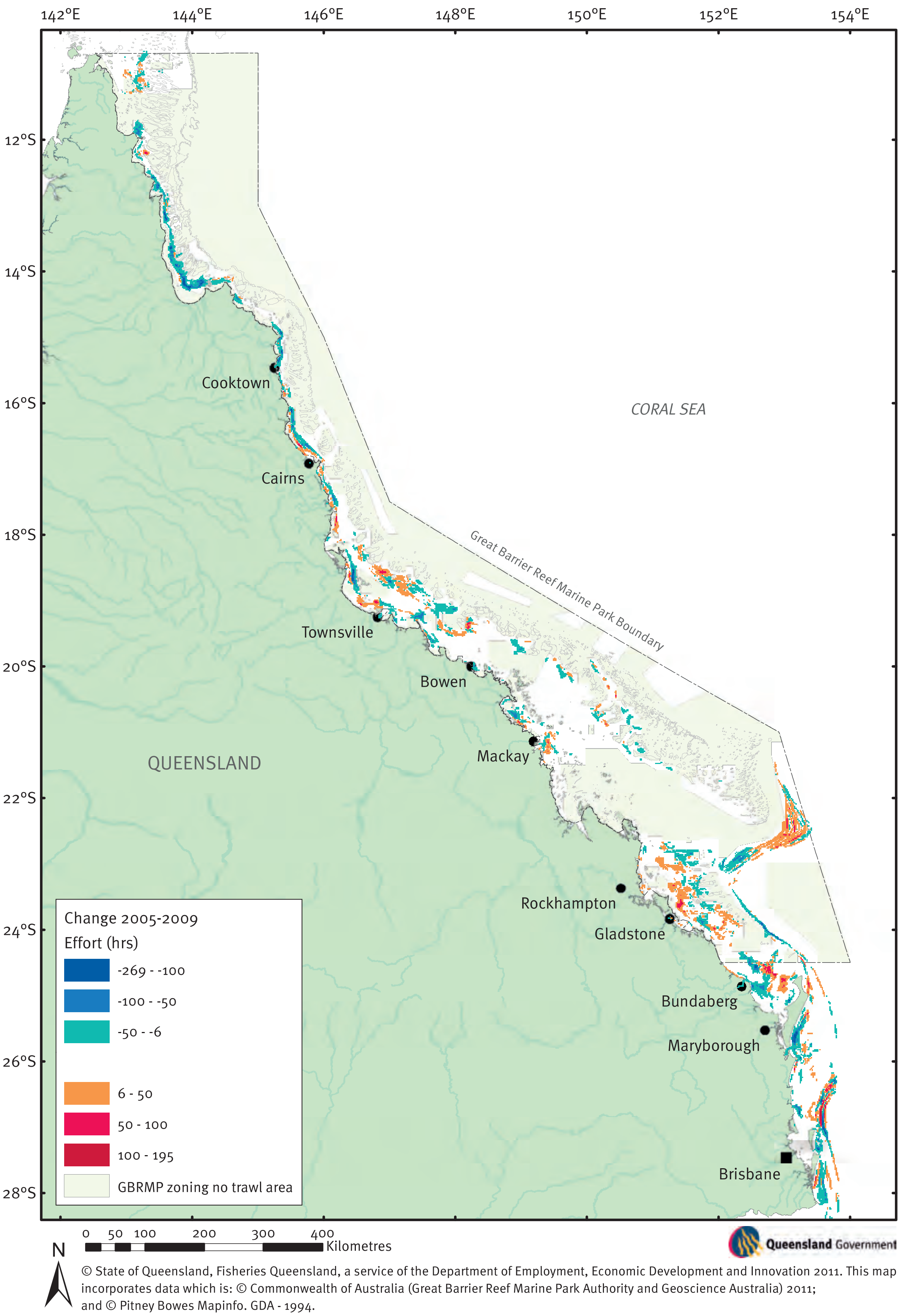


Figure 31. Comparison of otter trawl fishing effort for 2005 and 2009.

Appendix 2.2.4. Ecological risk indicators from the Great Barrier Reef Seabed Biodiversity Project and 2009 update

Ecological risk indicators derived from the Seabed Biodiversity Project (Pitcher et al. 2007b) were used to inform this assessment. This section outlines how these indicators were estimated and updated by the first author (C.R. Pitcher, CSIRO) of that report.

The Seabed Biodiversity Project mapped the distribution and abundance of seabed habitats and species on the continental shelf, within and beyond trawl grounds, and estimated the proportion of their populations exposed to trawling by conducting spatial analyses of species abundance in relation to trawl effort distribution and intensity for the year 2005. The species exposure estimates used by the current assessment were these estimates of '**per cent effort exposed**' from the Seabed Biodiversity Project (Pitcher et al. 2007b). Similarly, estimates of per cent effort exposed were available for habitat types and species assemblages. The 2009 trawl effort data was used by Pitcher to recalculate the per cent effort exposed to give an updated estimate for 2009 that was used in this assessment.

Additionally, by multiplying the effort exposure by the relative catch rate and a BRD effect (if appropriate), a percentage of the population caught annually was estimated for seabed species by the Seabed Biodiversity Project (Pitcher et al. 2007b). These estimates of the potential proportion of populations caught annually (termed '**per cent caught**') were used by the current assessment after removing the BRD effect, as another factor used in this ecological risk assessment covered BRD effectiveness. The published estimates were based on 2005 trawl effort data and, again, a 2009 estimate was provided by Pitcher, where relevant.

In estimating per cent of the total population caught, it is important to take account of how effectively the trawl net catches any given species (catchability), and how much mortality there is by contact without capture of the trawl gear. For species estimated to have higher levels of exposure, the Seabed Biodiversity Project used information on relative catchability wherever possible, including from that study and the Great Barrier Reef Effects of Trawling Study (Poiner et al. 1998), in estimating the per cent caught. Similarly, they used available information on the possible impact on species remaining on the seabed from the Great Barrier Reef Effects of Trawling Recovery Dynamics Project (Pitcher et al. 2004) and the Northern Prawn Fishery Effects of Trawling Project (Haywood et al. 2005), where appropriate, in estimating per cent caught.

The current assessment also used estimates of '**per cent protected**' for species, assemblage types and habitat types, which indicate the proportion of the species or type that is located outside of areas available to the trawl fishery (i.e. outside of the General Use Zone in the Great Barrier Reef Marine Park) and therefore permanently protected from trawling.

These estimates were derived from per cent available estimates by the Seabed Biodiversity Project of the amount of biomass of each species, or area of each assemblage/habitat type, located in the Great Barrier Reef Marine Park General Use Zone available to trawling and potentially at risk. The Seabed Biodiversity Project used current zoning information (i.e. after the 2004 rezoning) and therefore this indicator is the same for 2005 and 2009.

Note that the Seabed Biodiversity Project indicators of 'per cent caught' and 'per cent effort exposed' may exceed 100 per cent. Some species had high proportions of their exposed biomass in areas of high effort, so that their total effort exposed biomass was greater than their trawled biomass, and in a few cases levels of exposure were greater than 100 per cent of their standing biomass. This is possible because these indicators are designed to account for the aggregated nature of trawl fishing where some areas are trawled intensively with more than one or many passes per year. Values of over 100 per cent for 'per cent caught' or 'per cent exposed' for a species therefore indicate a concentration of fishing effort in areas where this species is found in abundance. For example, a key prawn target species, the grooved tiger prawn, had a very high level of exposure based on 2005 effort levels. Even though 26 per cent of its biomass was protected by marine park zoning and 36 per cent of its biomass was not exposed to any effort, the exposed 64 per cent of biomass was trawled an average of more than 2.7 times in 2005, contributing to a total indicator of 174 per cent of standing biomass exposed to trawl effort (Figure 3-108a in Pitcher et al. 2007b). Such high levels are to be expected for target species but may also occur for other components such as by-catch species, habitats or species assemblages.

For some species included in the current ecological risk assessment, one or more of the above estimates were not available. For example, species found in deep water or only sampled in low numbers by the Seabed Biodiversity Project. In these cases, simple proxies were estimated by experts using the best available information on the fishery. Proxies were used for black tiger prawn, white banana prawn, squid, red champagne lobster, the three Balmain bug species and octopus.

Within the current management arrangements, the otter trawl fishery has significant capacity for increases in fishing effort should economic pressures constraining the fishery be reduced. Therefore, it was desirable to consider a range of effort levels in assessing risk from the fishery. The years 2009 and 2005 were chosen, and are considered to provide an indication of risk from trawling at recent relatively low (2009) and higher (2005) fishing effort levels. While the 2005 effort levels were still about a third below the effort cap for the Great Barrier Reef World Heritage Area (see Figure 28), higher levels of effort are considered unlikely based on trends in trawl fishing effort over the last decade (but would be allowable under the current effort cap). Where data was available for both years, the current assessment has completed and presented assessments for each year. Any differences in the risk gradings are discussed under issues arising for the relevant ecological components (e.g. Section 4.2.4) and the general implications are considered in Section 4.8.

Appendix 2.2.5. Fishery observer program data on interactions with sharks and rays

The previously unpublished information presented here was provided by DAFF Queensland from the Fishery Observer Program and covers observation of sharks, rays and chimaeras from the ECOTF in the Great Barrier Reef Marine Park for the period 2005 to 2010. Most of the observer coverage was in the years 2009 or 2010 and has resulted from the voluntary participation of fishers. Hence, these results should be seen as indicative of the shark and ray catches from the various sectors of the fishery rather than a comprehensive assessment. Nevertheless, even this indicative information is useful for assessing risks from the fishery to sharks and rays.

Sharks and rays (i.e. sharks, shovelnose rays, guitarfish, skates and rays) were present in 31 per cent of the 882 trawl shots observed in the Great Barrier Reef Region between 2005 and 2010. A total of 700 individuals of 55 taxa (Table 26, the species or species groups are detailed in Table 27) were observed. Of those whose fate could be determined, 35 per cent were released alive (Table 29).

Table 26. Results from the observer program for sharks and rays caught in the ECOTF, by fishing sector, in the Great Barrier Reef Region.

Sector	Total number of shots observed	Number of shots with sharks or rays	Number of sharks and rays observed *(number of taxa = species or species groups)*
Banana prawn	107	39	74 (16)
Eastern king prawn	116	97	341 (21)
Red-spot king prawn	289	30	38 (16)
Scallop	145	85	213 (12)
Tiger and endeavour prawn	225	23	34 (19)
Total all sectors	**882**	**274 (31 per cent)**	**700 (55)**

Table 27. Sharks and rays (species or species groups) and number of individuals observed by trawl fishery sector.

Common name	Banana sector	Red-spot king prawn sector	Deepwater eastern king prawn sector	Scallop sector	Tiger/endeavour sector
Argus skate			102		
Eastern spotted gummy shark			86		
Australian butterfly ray	4	1	2	62	8
Bluespotted maskray		4		58	
Blackspotted whipray		1		41	1
Pale spotted catshark			41		2
Whitecheek shark	1		32		2
Giant shovelnose ray		2	6	20	
Blackfin ghostshark			24		
Milk shark	20				2
Whaler and weasel sharks	15				
stingrays		6	7		
Catsharks		11			
Scalloped hammerhead	10				1
Grey carpetshark			7	3	
[greeneye dogfish]			9		
Whitespotted guitarfish	1			7	1
Painted maskray		2		6	
Weasel shark		1		3	4
Guitarfishes	7				
Spinner shark	7				
Eastern shovelnose ray			1	4	1
Pale tropical skate			6		
Shovelnose & fiddler rays	1	3			1
Smooth stingray				5	
[an angel shark]			4		
Guitarfishes & wedgefishes	1	3			
Blacktip shark					3
Colclough's shark			3		
Spotted wobbegong			3		
Banded catshark		1			1
Banded eagle ray					2
[a catshark]	1		1		
Galapagos shark			2		
Sandbar shark			2		
Shark ray				2	
Whitespotted eagle ray	2				
Australian blacktip shark					1
Australian sharpnose shark		1			
Banded wobbegong		1			
Blacktip whaler complex		1			
Blind, nurse, carpet and zebra sharks				1	
Bull shark	1				

Common name	Banana sector	Red-spot king prawn sector	Deepwater eastern king prawn sector	Scallop sector	Tiger/endeavour sector
Epaulette shark		1			
Fossil shark		1			
Green sawfish	1				
Grey sharpnose shark	1				
Hammerhead sharks	1				
Hardnose shark		1			
Patchwork stingaree			1		
Port Jackson shark		1			
[a sawshark]			1		
Silvertip shark			1		
Spot-tail shark					1
Whitetip reef shark		1			

Table 28. Sharks and rays (chondrichthyan taxa) observed by Fisheries Queensland observers 2005–2010 in the trawl fishery by CAAB code (i.e. codes used for Australian marine species), common name and scientific name*.

CAAB code	Common name	Scientific name
37007001	Port Jackson shark	*Heterodontus portusjacksoni*
37013000	Blind, nurse, carpet and zebra sharks	Brachaeluridae and related families
37013001	Banded wobbegong	*Orectolobus ornatus*
37013003	Spotted wobbegong	*Orectolobus maculatus*
37013008	Grey carpetshark	*Chiloscyllium punctatum*
37013013	Colclough's shark	*Brachaelurus colcloughi*
37013014	Epaulette shark	*Hemiscyllium ocellatum*
37015000	Unidentified catsharks	Family Scyliorhinidae
37015005	Banded catshark	*Atelomycterus fasciatus*
37015013	[a catshark]	*Cephaloscyllium albipinnum*
37015025	Pale spotted catshark	*Asymbolus pallidus*
37015031	[a catshark]	*Cephaloscyllium variegatum*
37017011	Eastern spotted gummy shark	*Mustelus walkeri*
37018000	Unidentified whaler and weasel sharks	Families Carcharhinidae and Hemigaleidae
37018006	Milk shark	*Rhizoprionodon acutus*
37018007	Sandbar shark	*Carcharhinus plumbeus*
37018009	Whitecheek shark	*Carcharhinus coatesi*
37018011	Fossil shark	*Hemipristis elongata*
37018013	Spot-tail shark	*Carcharhinus sorrah*
37018014	Australian blacktip shark	*Carcharhinus tilstoni*
37018020	Weasel shark	*Hemigaleus microstoma*
37018021	Bull shark	*Carcharhinus leucas*
37018023	Spinner shark	*Carcharhinus brevipinna*
37018024	Australian sharpnose shark	*Rhizoprionodon taylori*
37018025	Hardnose shark	*Carcharhinus macloti*
37018027	Silvertip shark	*Carcharhinus albimarginatus*

CAAB code	Common name	Scientific name
37018037	Grey sharpnose shark	*Rhizoprionodon oligolinx*
37018038	Whitetip reef shark	*Triaenodon obesus*
37018040	Galapagos shark	*Carcharhinus galapagensis*
37018901	Unidentified blacktip sharks	various *Carcharhinus* spp.
37018903	Blacktip whaler complex	*Carcharhinus tilstoni/limbatus*
37019000	Unidentified hammerhead sharks	Family Sphyrnidae
37019001	Scalloped hammerhead	*Sphyrna lewini*
37020901	Unidentified greeneye dogfish	*Squalus* spp.
37023004	Tropical sawshark	*Pristiophorus delicatus*
37024004	Eastern angel shark	*Squatina albipunctata*
37025001	Green sawfish	*Pristis zijsron*
37026001	Whitespotted guitarfish	*Rhynchobatus djiddensis*
37026002	Shark ray	*Rhina ancylostoma*
37026900	Unidentified guitarfishes & wedgefishes	*Rhynchobatus* spp.
37027000	Shovelnose & fiddler rays	Family Rhinobatidae - undifferentiated
37027009	Eastern shovelnose ray	*Aptychotrema rostrata*
37027010	Giant shovelnose ray	*Rhinobatos typus*
37031032	Pale tropical skate	*Dipturus apricus*
37031042	Argus skate	*Dipturus polyommata*
37035000	Stingrays	Family Dasyatidae - undifferentiated
37035001	Smooth stingray	*Dasyatis brevicaudata*
37035004	Bluespotted maskray	*Neotrygon kuhlii*
37035013	Painted maskray	*Neotrygon picta*
37035020	Blackspotted whipray	*Himantura astra*
37037001	Australian butterfly ray	*Gymnura australis*
37038010	Patchwork stingaree	*Urolophus flavomosaicus*
37039002	Banded eagle ray	*Aetomylaeus nichofii*
37039003	Whitespotted eagle ray	*Aetobatus narinari*
37042003	Blackfin ghostshark	*Hydrolagus lemurs*

** Some questions about the identity of specimens identified as Australian blacktip sharks have been raised by the recent identification of hybridisation between this species and common blacktip sharks* (Morgan et al. 2012).

In terms of survival (Table 29), the banana prawn sector had the highest proportion of animals released alive, with twice as many individuals released alive as dead. Approximately equal numbers were released alive and dead in the scallop, red-spot king and tiger/endeavour prawn sectors. The sector with highest immediate post-capture mortality was the deepwater eastern king prawn fishery sector, where relatively large numbers of skates of the genus *Dipturus* were observed and none were released alive. Estimates of post-release survival are generally not available for these species from this fishery.

Table 29. Sharks and rays for which more than 10 individuals were observed and their fate by sector.

Common name	Banana sector			Red-spot king prawn sector			Deepwater eastern king prawn sector			Scallop sector			Tiger/endeavour sector		
	Released alive	Released dead	Sector total*	Released alive	Released dead	Sector total*	Released alive	Released dead	Sector total*	Released alive	Released dead	Sector total*	Released alive	Released dead	Sector total*
Argus skate								102	102						
Eastern spotted gummy shark								83	86						
Australian butterfly ray	3	1	4	1		1	2		2	21	41	62	6	2	8
Bluespotted maskray				3	1	4				32	26	58			
Blackspotted whipray				1		1				17	24	41	1		1
Pale spotted catshark							6	30	41					2	2
Whitecheek shark	1		1					32	32						2
Giant shovelnose ray				1	1	2	2	4	6	16	4	20			
Blackfin ghostshark							20	4	24						
Milk shark	14	4	20											2	2
Whaler and weasel sharks	8	7	15												
Stingrays				3	3	6	5		7						
Catsharks				2	3	11									0
Scalloped hammerhead	7	3	10											1	1
Grey carpetshark							7		7	3		3			
Overall number of sharks and rays**	**48**	**24**	**74**	**17**	**15**	**38**	**55**	**274**	**340**	**99**	**110**	**212**	**13**	**16**	**34**

** Sector totals may include some animals for which the fate was unknown, and data on fate is only provided on species for which more than 10 individuals were observed.*

*** Overall numbers of sharks and rays in the last row of this table may differ slightly from totals in Table 26, however this information has been included as it gives an indication of overall fate of sharks and rays by sector. The total number of shots observed varied by sector and is provided in Table 26.*

Appendix 2.3. ECOTF sectors operating within the Great Barrier Reef Marine Park

There are several recognisable sectors within the ECOTF based on target species composition and geographical location. This section provides information on the fishery sectors considered in this ecological risk assessment of trawling within the Great Barrier Reef Marine Park. The sectors are:

1. Eastern king prawn (deep and shallow water)
2. Scallop (saucer)
3. Northern prawn (tiger/endeavour) and king prawn (including red-spot king)
4. Banana prawn.

The main fishing grounds are shown on Figure 8. Note: fishing for banana prawns occurs mainly in inshore areas (this fishing activity is not depicted on Figure 8). Bugs (excluding Balmain bugs) are also a principal species for the fishery, however fishing activities for Moreton Bay bugs are discussed separately below as they are predominantly retained (incidentally) while targeting other species. The trawl fleet has a high degree of mobility and boats frequently operate in more than one fishery sector.

Sectors of the fishery that are outside the scope of the current assessment because they occur entirely or largely outside the Great Barrier Reef Marine Park are Moreton Bay (bay prawns), river and inshore beam trawl fishery, and the stout whiting fishery. In addition, some of the scallop and eastern king prawn fishing areas are in southern Queensland outside of the Great Barrier Reef Marine Park. A separate (but comparable) ecological risk assessment project is under way to assess the remainder of the fishery.

Lobsters in the genus *Thenus* are commonly referred to as Moreton Bay bugs, and comprise two species: the reef bug *Thenus australiensis* and the mud bug *Thenus parindicus*. The reef bug is primarily retained within the scallop and red-spot king prawn sectors (central and northern Queensland), whereas the mud bug is more commonly associated with the tiger/endeavour sector. While Moreton Bay bugs are predominantly retained as incidental catch while targeting prawns and scallops, they can, however, be targeted at certain times and locations.

No stock assessments have been undertaken for bugs in Queensland, although some information on this species can be found in broader studies including work by Courtney et al. (2007) and Pitcher et al. (2007b).

The harvesting of these species is managed through a minimum legal size, although gear, effort, spatial and temporal closures also apply. In October 2009, at the request of industry, a long standing prohibition on retaining legal-sized berried (egg-bearing females) bugs was removed. Key management requirements include:

- size restrictions of 7.5 cm carapace width (CW) for males and females of each species
- logbook monitoring requirements.

Appendix 2.3.1. Eastern king prawn

Background information

The eastern king prawn sector is essentially divided into three sectors based on location, water depth and prawn life history: Moreton Bay, shallow and deep water. While the Moreton Bay trawl fishery plays a significant role in the eastern king prawn sector for the ECOTF, it is outside of the Great Barrier Reef Marine Park and therefore not included here. The following information covers the shallow-water and deepwater eastern king prawn sectors.

The shallow-water (less than 50 fathoms, which is about 91 metres) eastern king prawn sector principally targets prawns as they migrate offshore and northwards from the estuaries into coastal embayments, i.e. Moreton Bay and across coastal bars (around November–January). Tiger prawns, school prawns, scallops, Moreton Bay bugs, Balmain bugs, blue swimmer crabs, squid and cuttlefish are all important components of the catch from the shallow-water eastern king prawn sector. The deepwater eastern king prawn sector is restricted to waters deeper than 50 fathoms, and is mainly focused on larger eastern king prawns that have migrated out of the shallow-water environment.

In 2000, a stock assessment was undertaken for eastern king prawn on the east coast of Queensland (Courtney et al. 2002). A second stock assessment was being finalised when this report was prepared.

Key management arrangements

Whole eastern king prawn sector

The eastern king prawn shallow- and deepwater sectors are principally managed through broader controls and reporting requirements of the entire ECTF. There are, however, some notable differences between the two, namely gear requirements. A recently introduced effort trigger and related 24 day per month per operator resultant restriction also applies to both the deep- and shallow-water sectors.

Shallow-water specific

In addition to the general management restrictions on the ECTF, there are several key management aspects that influence the shallow-water eastern king prawn sector including:

- maximum net length of 88 m (varies in some areas)
- a 38–60 mm mesh size restriction
- south of 22°S closes for six weeks from 20 September to 1 November (annually) under the Southern regulated waters closure.

Deepwater specific

In addition to the general management restrictions on the ECTF, there are several key management aspects that influence the deepwater eastern king prawn sector including:

- maximum net length of 184 m
- 38–60 mm mesh size restriction
- no closed season
- limited spatial closures in Commonwealth marine park legislation only.

Data summary for eastern king prawn

The following information was compiled using logbook data from 1989 to 2010 and includes total number of days fished in the eastern king prawn sector, participation rates (boat numbers) and catch and effort trends.

Catch and effort trends—whole eastern king prawn sector

Catch and effort trends for the whole eastern king prawn sector were compiled using data from 1989 through to 2010, however the full data for 2010 was not available at the time of the assessment. Baseline catch and effort data (Figure 32) was based on total yearly catch (tonnes) and total days fished.

Information on catch per unit effort (CPUE) has been provided as both annual and average monthly trends. Annual CPUE trends are plotted in Figure 33 along with the total number of boats accessing the sector that year (participation rates). Information on the number of boats accessing the sector (on average) per month and average monthly CPUE are provided in Figure 34. The primary purpose of the monthly comparisons was to examine seasonal trends in the sector.

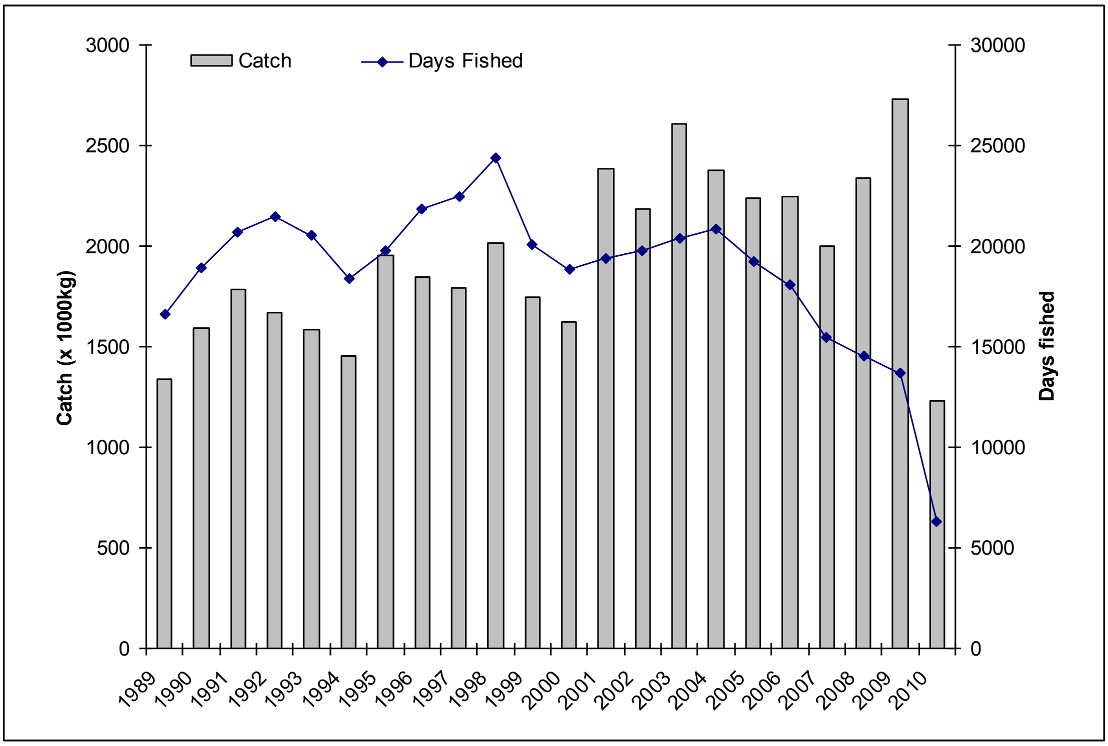


Figure 32. Catch and effort trends for the eastern king prawn sector represented in tonnes and days fished respectively. The data for 2010 does not cover the full year.

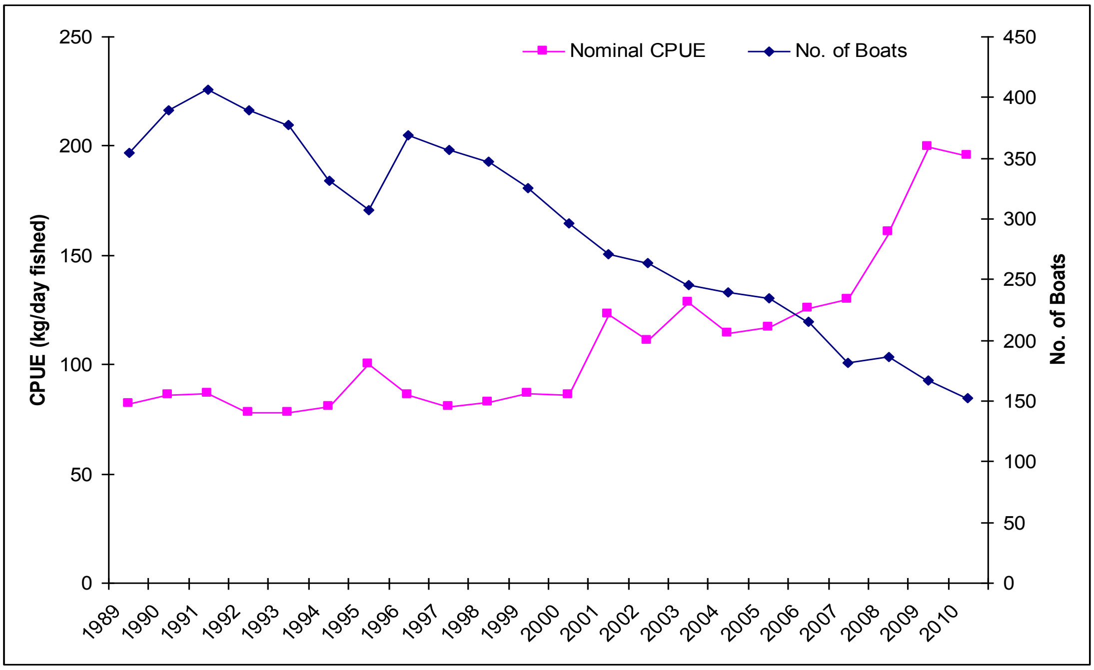


Figure 33. Average catch per unit effort (CPUE, kg/day fished) and participation rates (total number of boats accessing the sector) for the eastern king prawn sector between 1989 and 2010. Note: 2010 data is based on an incomplete dataset.

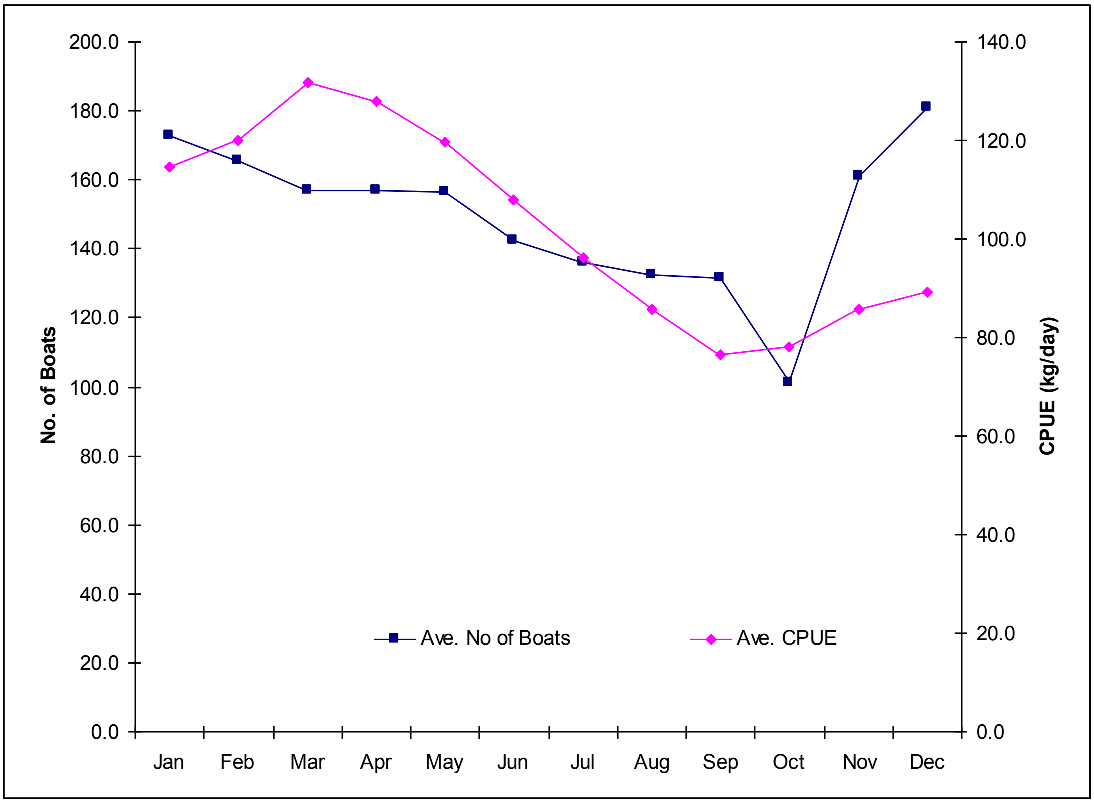


Figure 34. Average monthly CPUE (kg/day fished) and average participation (average number of boats) rates for the eastern king prawn sector between 1989 and 2009.

Catch per unit effort—shallow-water eastern king prawn and deepwater eastern king prawn

Catch and effort trends for shallow- and deepwater eastern king prawn sectors have been outlined below. Data used in this analysis was compiled from sectors where it was certain an operator was fishing for eastern king prawn in shallow waters or deep water, i.e. does not include fishery reporting grids where operators may have been fishing in one or the other. As such, the data presented here only represents about 70 per cent of the total effort used in the eastern king prawn sector.

Shallow-water eastern king prawn (only)

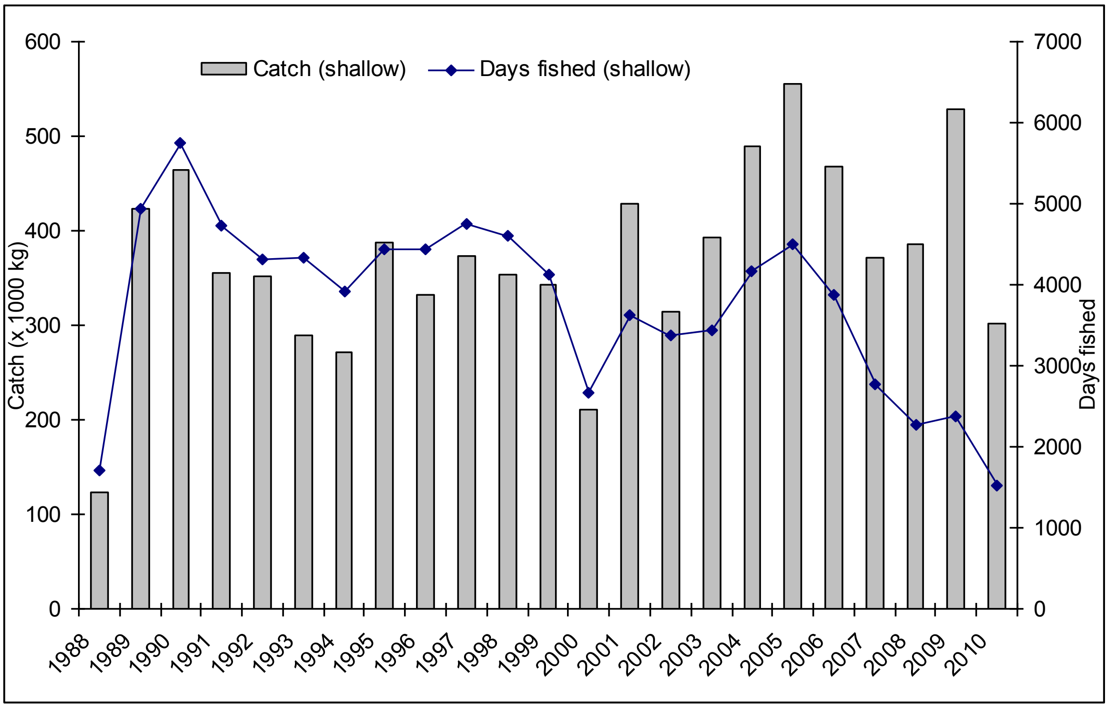


Figure 35. Catch and effort trends for the eastern king prawn (shallow) sector. *Only contains catch and effort data from grids where operators definitely fishing for eastern king prawn in shallow water. The data for 2010 does not cover the full year.

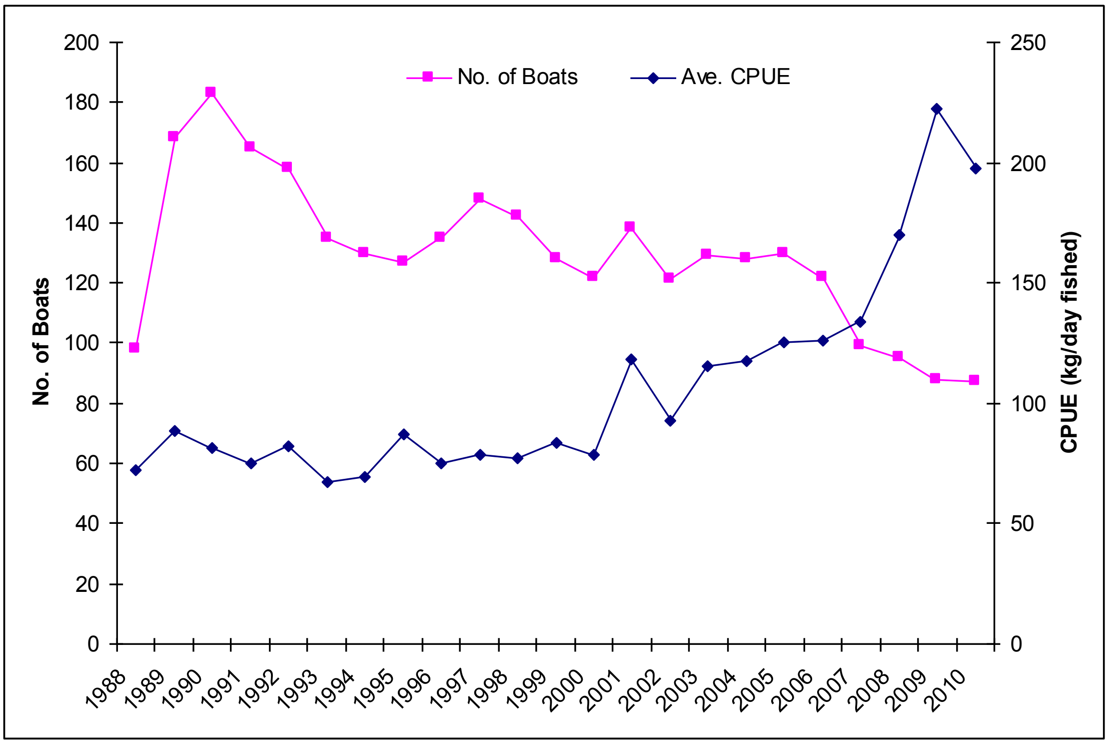


Figure 36. CPUE and participation rates for the eastern king prawn (shallow) sector. *Only contains catch and effort from grids where operators definitely fishing for eastern king prawn in shallow water.

Deepwater eastern king prawn (only)

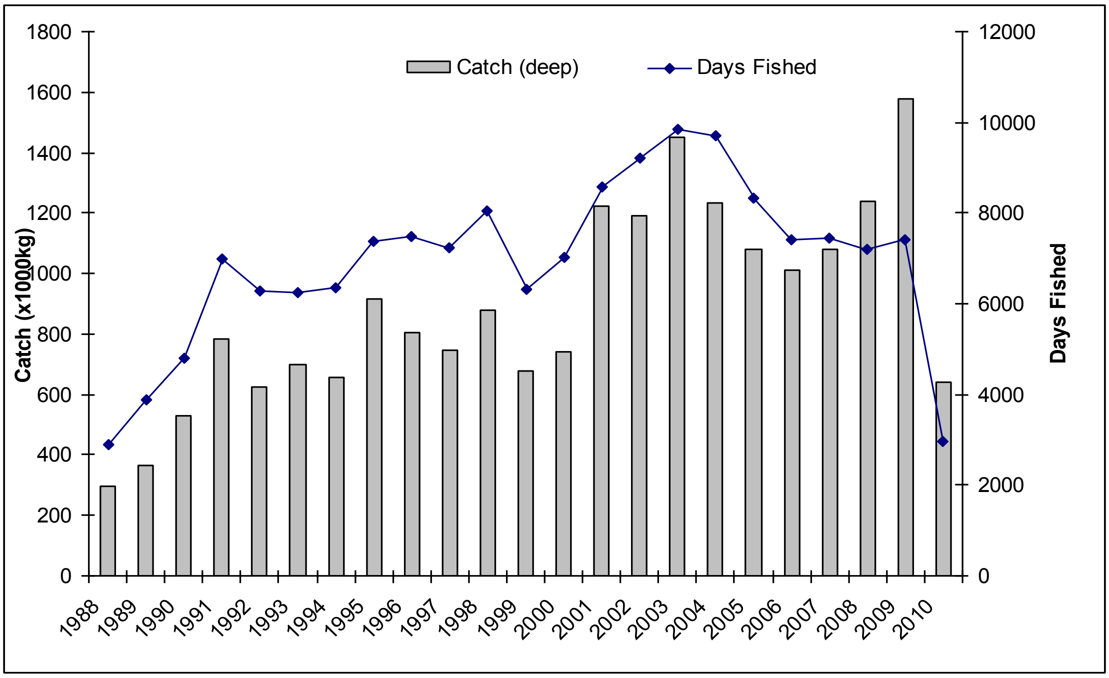


Figure 37. Catch and effort trends for the eastern king prawn deep sector. *Only contains catch and effort data from grids where operators definitely fishing for eastern king prawn in deep water. The data for 2010 does not cover the full year.

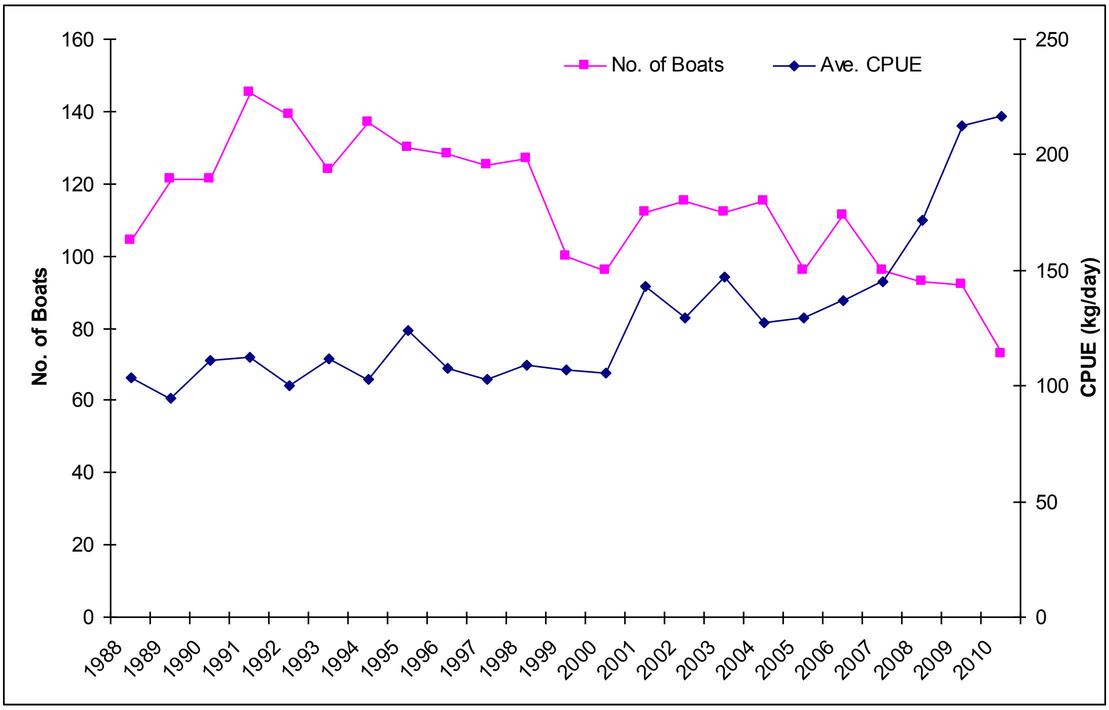


Figure 38. CPUE vs participation rates in the eastern king prawn deep sector. *Only contains catch and effort from grids where operators definitely fishing for eastern king prawn in deep water.

Appendix 2.3.2. Scallop (saucer)

Background information

The saucer scallop fishery, which occurs partly outside the Great Barrier Reef Region, has been included in the current ecological risk assessment, as the northern scallop beds are within the southern part of the Great Barrier Reef Marine Park, and 64 per cent of the total fishery catch was from the Great Barrier Reef Region in 2009 (Appendix 2.2.1).

While saucer scallops can be captured over a broad range of the Queensland coastline, the majority are caught between Hydrographers Passage and Noosa (about 20.5°S–27°S). No stock assessments have been completed for the saucer scallop sector, although a management strategy evaluation (Campbell et al. 2010) has recently been completed and will soon be complemented by a stock assessment.

The management strategy evaluation, among other things, provided further insight into current management arrangements including the effectiveness of Scallop Replenishment Areas, improved estimates of trawl discard levels and tumbling-related mortality and calculated standardised catch rates for the sector. A stock assessment building on this management strategy evaluation work will deliver estimates of sustainability reference points for the scallop sector.

Key management arrangements

In addition to the general management restrictions on the ECTF, there are a number of management arrangements relating specifically to the scallop sector. These include:

- taking of scallops limited to the use of otter trawl nets
- regulated waters for scallop ranching
- regulated waters (15 month spatial closures) for scallop replenishment (Hervey Bay, Bustard Head, Yeppoon) on 24 month open/close cycles. Under these rotational closures, some scallop beds are closed to fishing at any one time, whereas access is allowed to others
- net length maximum of 109 m and a minimum net mesh of at least 75 mm
- additional seasonal and spatial closures in the Hydrographers Passage area
- restrictions on processing scallops and being in possession of scallop meat
- a 90 mm minimum shell size
- southern regulated waters effectively closing the scallop fishery south of 22°S latitude for six weeks from 20 September to 1 November annually.

Data summary for scallop sector

The following information was compiled using logbook data from 1999 to 2009 and includes total number of days fished in the scallop sector, participation rates (boat numbers) and catch and effort trends. Baseline catch and effort data (Figure 39) was based on total yearly catch (kilograms) and total days fished. Monthly effort trends for the sector have also been reported in Figure 40.

Annual catch per unit effort trends are plotted in Figure 41. Information on the number of boats accessing the sector (on average) per month and average monthly catch per unit effort are provided in Figure 42. The primary purpose of the monthly comparisons was to examine seasonal trends in the sector. While the minimum and maximum number of boats accessing the sector in one month is available, the total number of individual boats accessing the scallop sector throughout the year is not yet known.

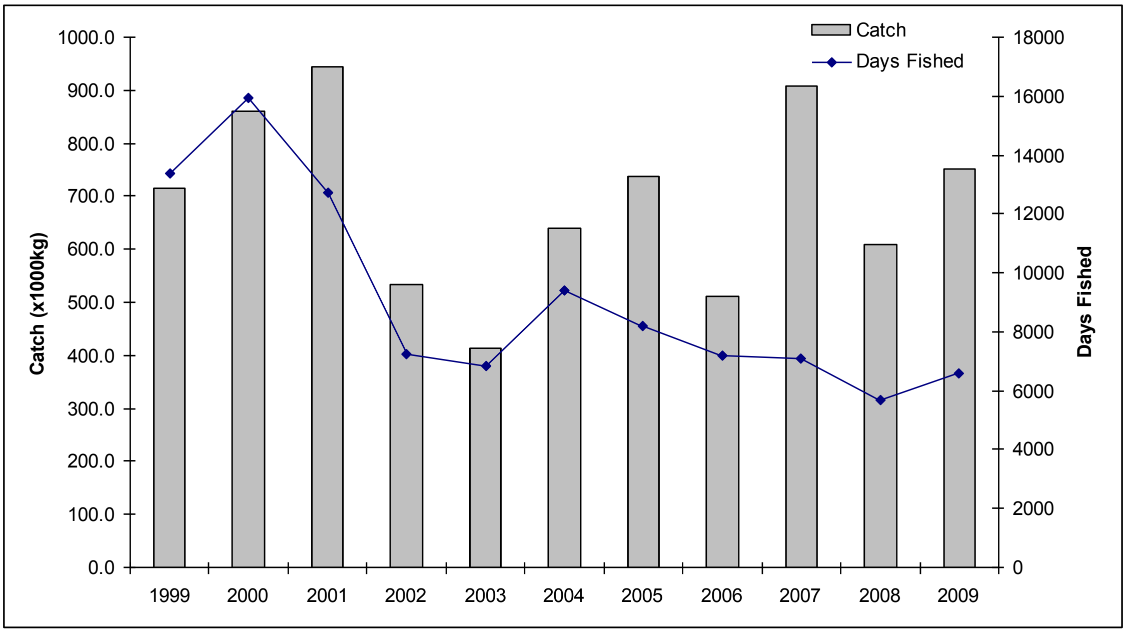


Figure 39. Catch and effort trends for the scallop sector represented in tonnes and days fished respectively.

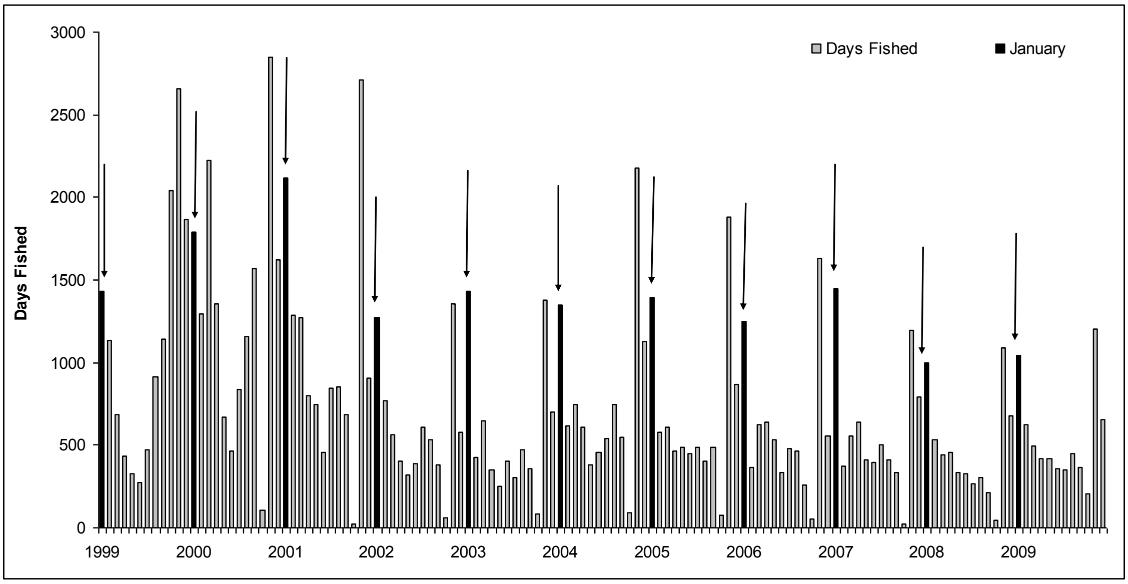


Figure 40. Monthly effort usage trends for the scallop sector between 1999 and 2009 (arrow denotes the start of calendar year).

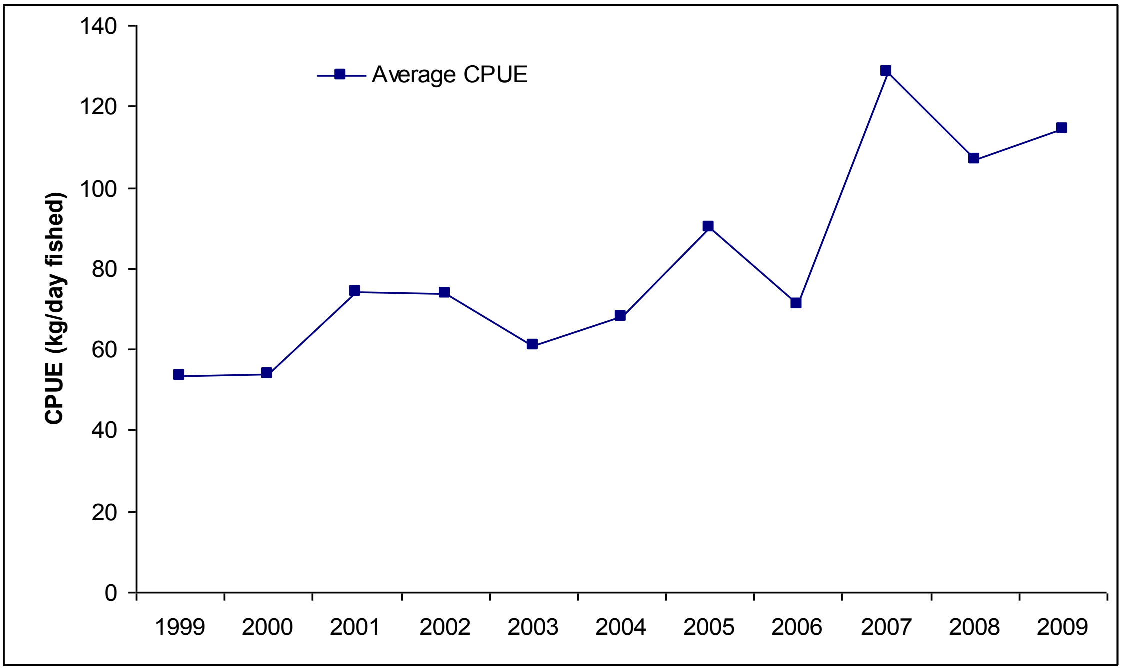


Figure 41. Average catch per unit effort (CPUE, kg/day fished) trends for the scallop sector between 1999 and 2009.

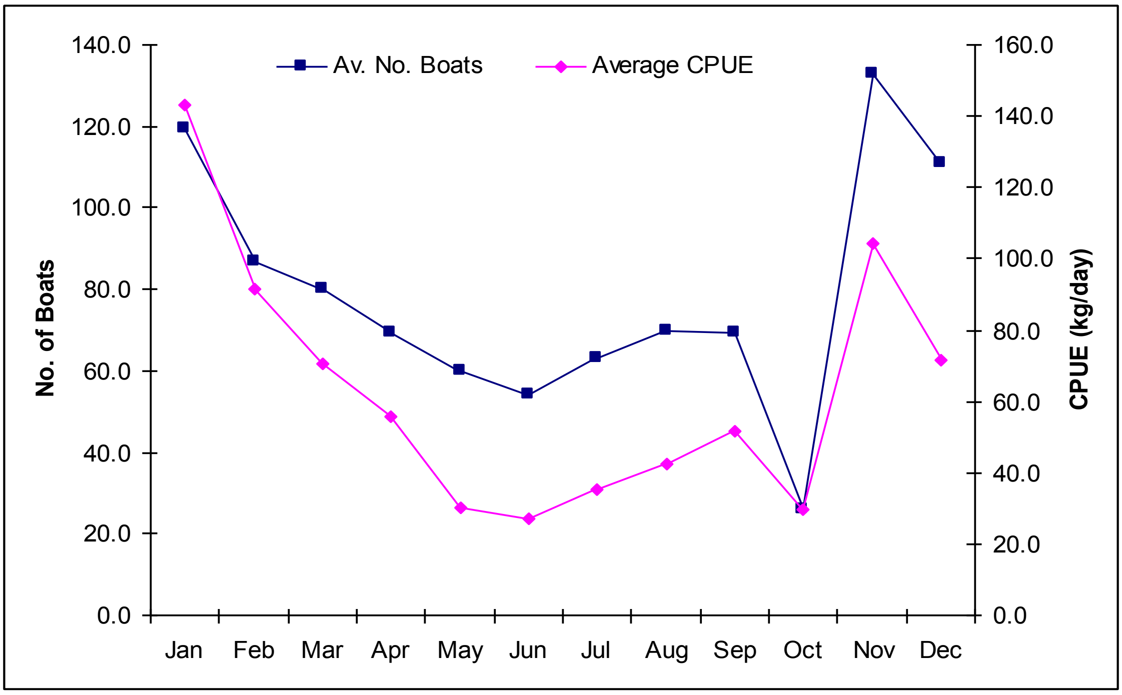


Figure 42. Average monthly CPUE (kg/day fished) and participation rates (average number of boats) in the scallop sector between 1999 and 2009.

Appendix 2.3.3. Northern prawn (tiger/endeavour) and king prawn (including red-spot king)

Background information

The tiger/endeavour prawn sector is a multi-species sector that generally operates within the Great Barrier Reef Region between Mackay and the Torres Strait (Figure 8). The majority of catch however is centralised within the northern region of Great Barrier Reef Marine Park between Cape Flattery and Cape York. The tiger and endeavour prawn sector is a night-time fishery and operates predominantly in water depths of less than 20 m over sandy and muddy habitats preferred by adult tiger and endeavour prawns. While northern prawn (tiger and endeavour) comprise multiple species (two species of endeavour prawns and three species of tiger prawns), they are marketed under a two species grouping (endeavour prawns or tiger prawns). Two other fisheries, the red-spot king prawn fishery and the banana prawn fishery also occur within the range of the tiger/endeavour fishery sector. In the southern part of the fishery sector, more species are retained as by-product than in the northern part, where the catch is made up predominantly of target prawn species.

The red-spot king prawns are predominantly harvested in the central–north region of Queensland offshore between Townsville and Mackay, i.e. 15ºS–22ºS, although a smaller fishing ground exists in far north Queensland close to the Torres Strait (Figure 8). The red-spot king prawn is more abundant than the blue-legged king prawn and is generally associated with white coralline sand sediments in near-reef areas or inter-reef gutters.

In 2003, a stock assessment was undertaken for both the Queensland tiger and endeavour prawn stocks, and this was subsequently updated in 2004 (Turnbull and Gribble 2004). Both of these studies indicated that Queensland tiger and endeavour prawn stocks are fully exploited. No stock assessments have been undertaken for red-spot king prawns.

Key management arrangements

The tiger/endeavour and king prawn sectors are currently managed through the broader ECTF reporting and management controls. The location of both sectors, however, means that restrictions placed on the fishery via Great Barrier Reef Marine Park zoning and the northern regional seasonal closure play a prominent role in their overall functioning. The large-scale northern regional seasonal waters closure between 15 December and 1 March is designed to allow tiger and endeavour prawns to grow to an optimum size before harvest, and has an impact on both the tiger/endeavour and king prawn sectors.

Data summary for tiger, endeavour and king prawns

Logbook data from 1990 to 2009 was used to compile catch and effort trends including CPUE for the northern region. The data has been subdivided into species complexes and includes tigers, endeavours and king prawns. Data encompassed in the summary includes yearly and monthly effort usage trends, and participation rates for each of the three species complexes (tiger, endeavour, king prawns). However, effort is not reported on at the species or species group level and is therefore reported as total effort for the region, e.g. CPUE data for tiger prawns uses tiger prawn catch/total regional effort.

It is difficult to isolate red-spot king prawn catch from reported king prawn catch. Therefore, king prawn data is presented herein as a species complex which includes the red-spot king prawn.

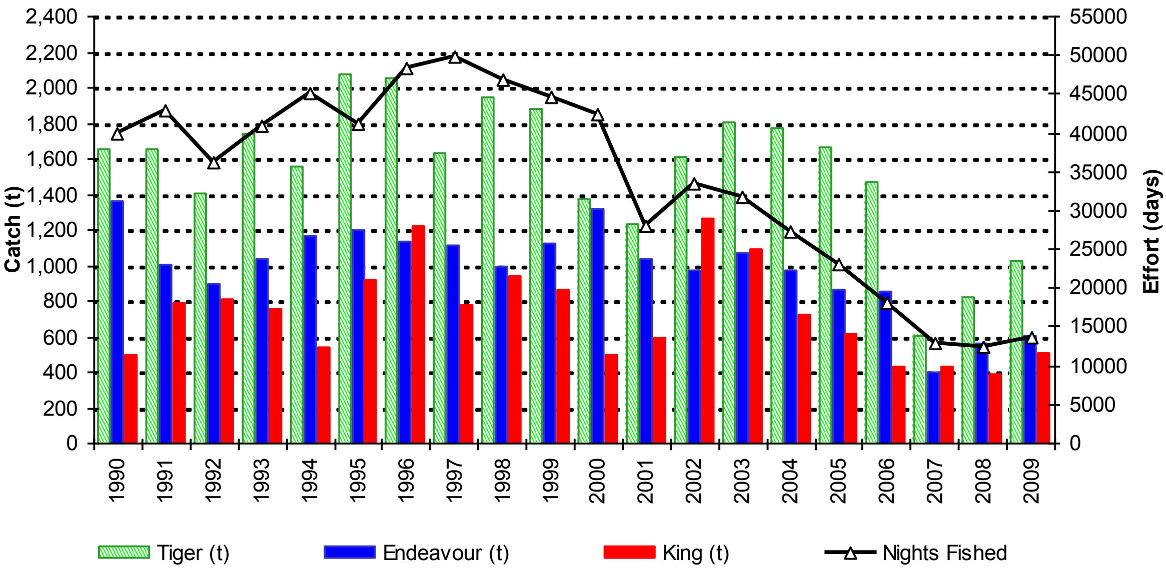


Figure 43. Catch and effort trends for the northern region of the ECTF represented by species complex (tiger, endeavour, king), tonnes caught and days fished.

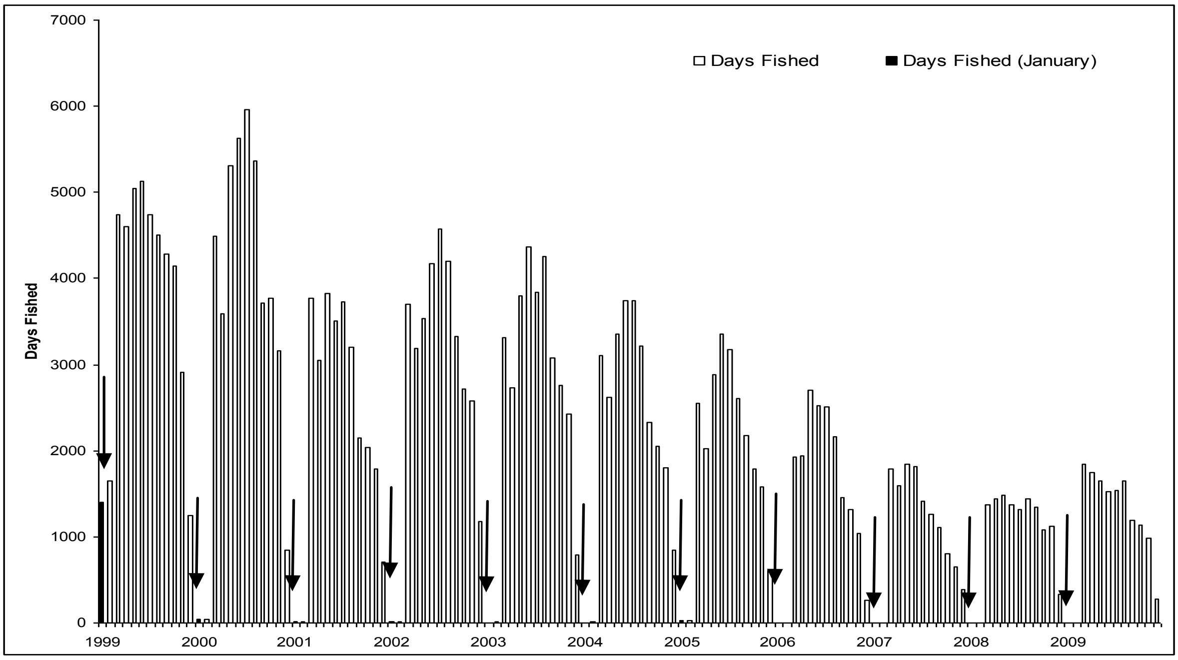


Figure 44. Monthly effort usage trends for the northern region of the ECTF between 1999 and 2009 (arrow denotes the start of calendar year).

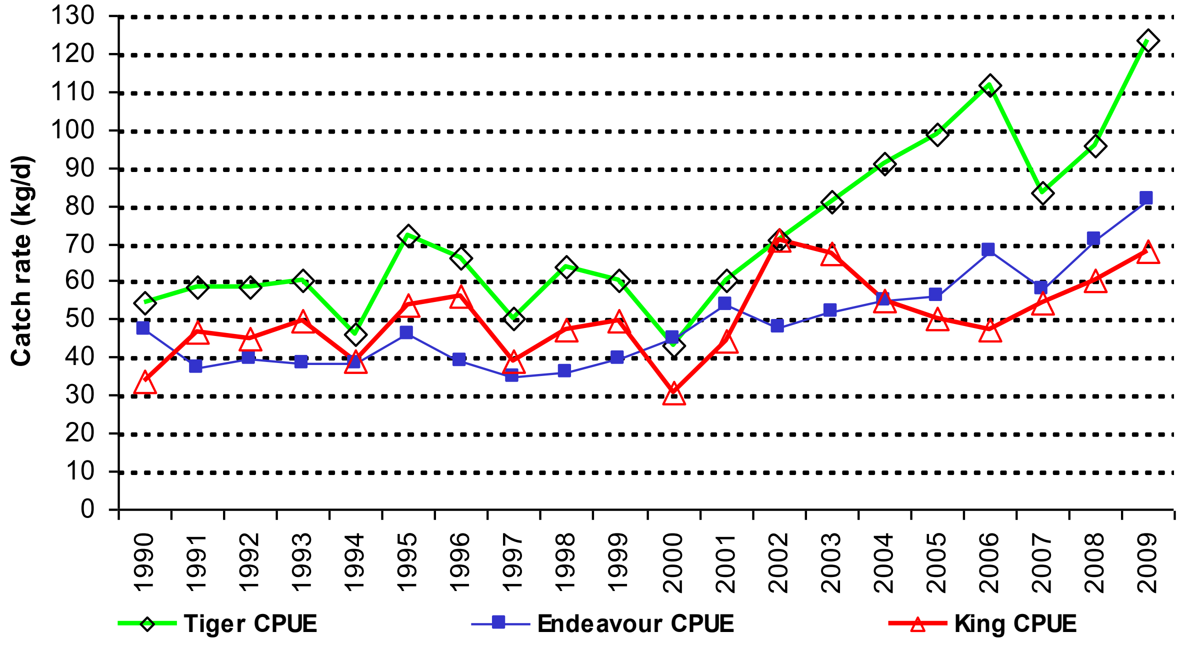
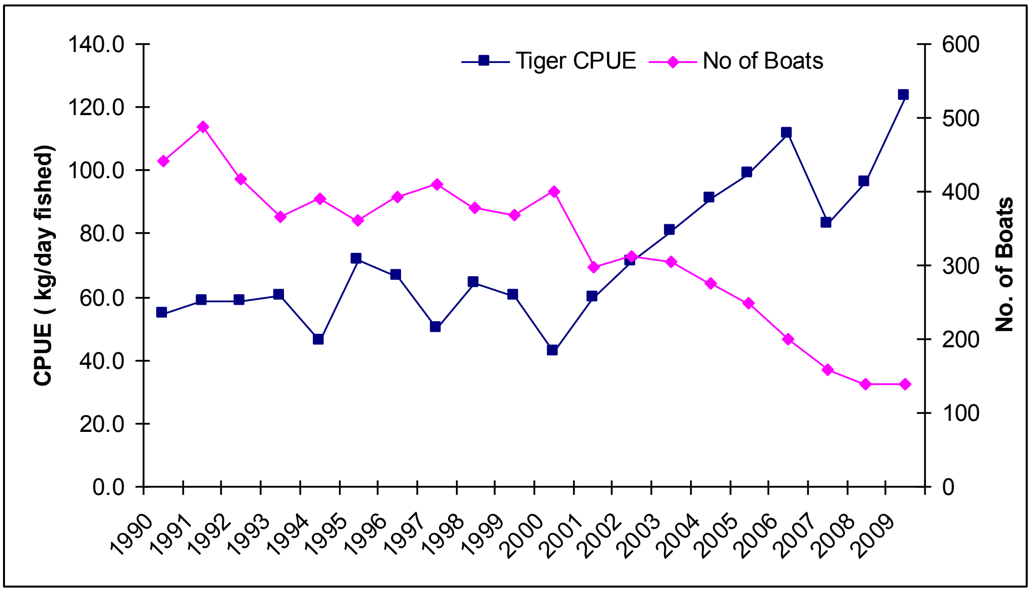
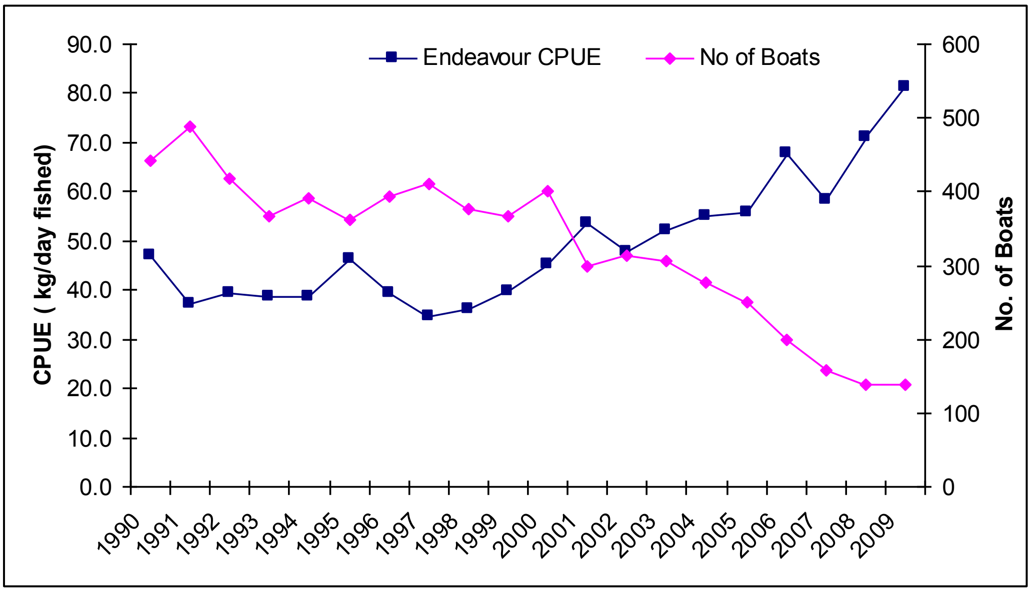


Figure 45. Catch per unit effort (CPUE, kg/day fished) for tiger, endeavour and king prawns in the northern region of the ECTF between 1990 and 2009.





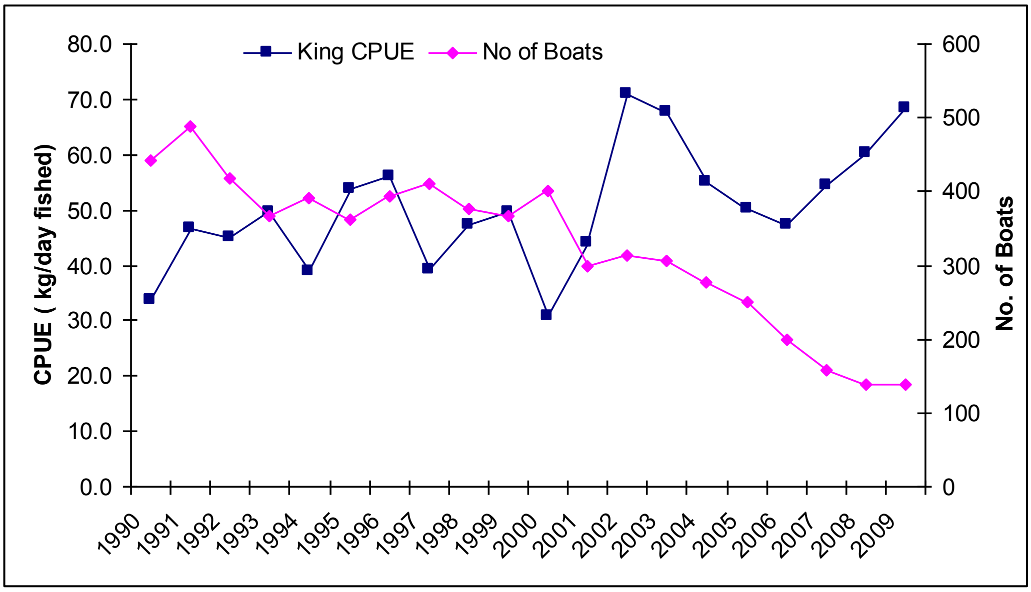


Figure 46. Average catch per unit effort (CPUE, kg/day fished) and participation rates (total number of boats accessing the fishery) for each species complex.

Tiger prawns

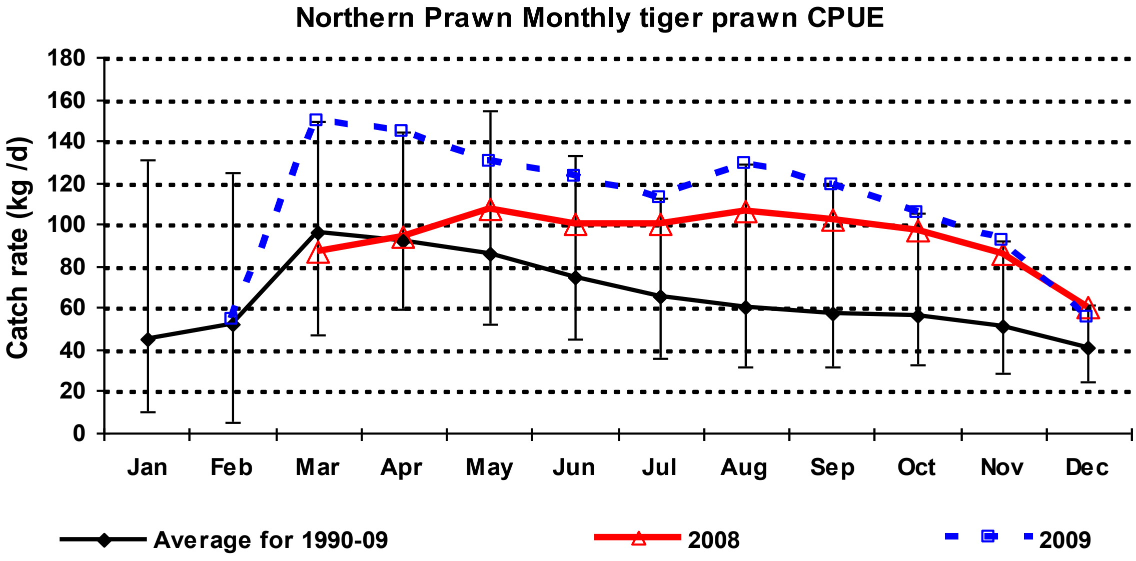


Figure 47. Average monthly tiger CPUE (kg/day fished) for the northern region of the ECTF based on 1990–2009 data, including monthly maximums, monthly minimums and comparative data from the 2008 and 2009 season.

Endeavour prawns

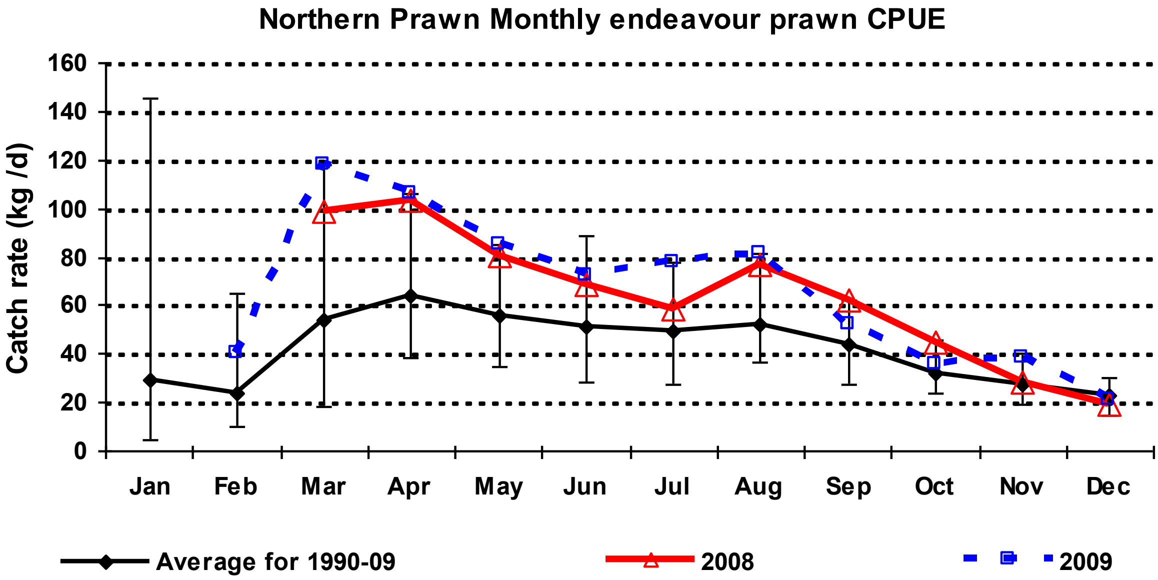


Figure 48. Average monthly endeavour CPUE (kg/day fished) for the northern region of the ECTF based on 1990–2009 data, including monthly maximums, monthly minimums and comparative data from the 2008 and 2009 season.

King prawns

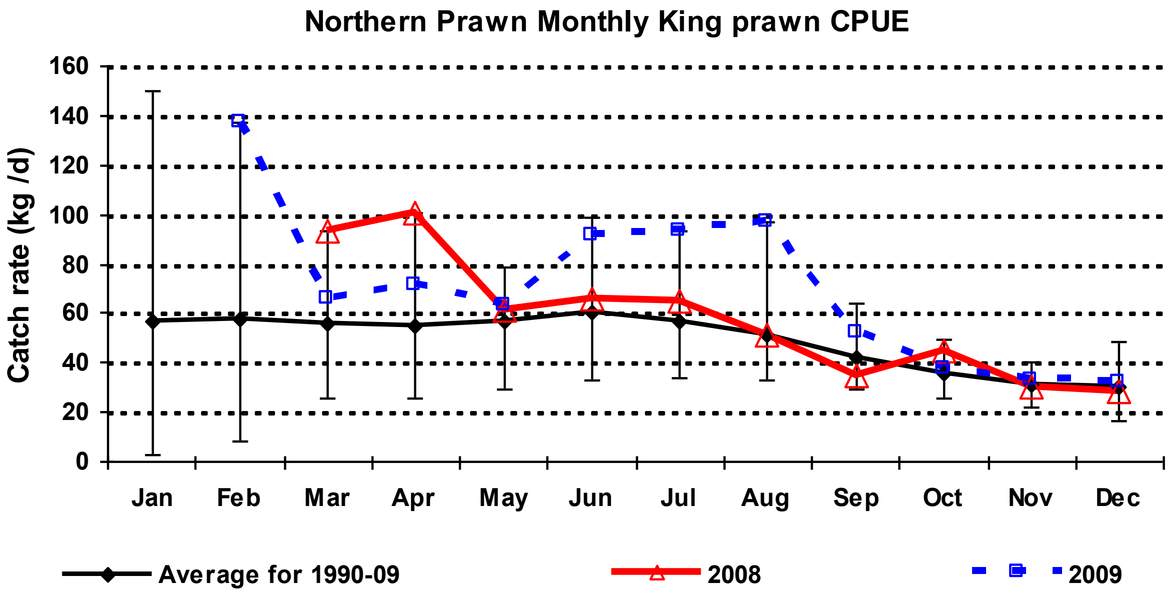


Figure 49. Average monthly king CPUE (kg/day fished) for the northern region of the ECTF based on 1990–2009 data, including monthly maximums, monthly minimums and comparative data from the 2008 and 2009 season.

Appendix 2.3.4. Banana prawn

Background information

Banana prawns are generally associated with more turbid inshore environments, i.e. estuaries, mud flats and mangrove areas, and have an estuarine juvenile phase and an inshore coastal adult phase. The species is harvested using both beam and otter trawl, with the majority of product caught between Cape Flattery (about 15°S) and Moreton Bay (about 27°S). The species is also harvested recreationally by cast nets. The species tends to occur in inshore environments, but overlaps spatially with other species, i.e. tiger/endeavour in the northern region. Catch rates for banana prawns are highly variable and seasonal. On the east coast of Queensland, the majority of product is caught during daylight hours and between February and May.

When compared with other prawn species, banana prawns display a more prominent schooling behaviour. This behaviour combined with the variable catch rates has, on occasion, resulted in an oversupply of product to the market. This in itself creates issues not only for the marketing and value of banana prawns, but for other prawn species targeted by the ECTF.

A banana prawn stock assessment was undertaken in 2006 examining regional catch rates or substocks (Tanimoto et al. 2006). The results obtained indicated that exploitable biomass levels for banana prawns were about 50–70 per cent of virgin biomass. The study also found that regional catch rates are influenced by environmental factors, namely rainfall.

Key management arrangements

Banana prawns are principally managed through the broader controls and reporting requirements of the entire ECTF.

Data summary for banana prawns

The following information was compiled using logbook data from 1999 to 2009 and includes total number of days fished in the banana sector, participation rates (boat numbers) and catch and effort trends. The information provided within this summary is for the entire east coast of Queensland, however, as noted in the 2006 stock assessment, the entire east coast Queensland banana prawn stock is likely to be made up of subpopulations.

Catch and effort trends for banana prawns were compiled using data from 1999 through to 2009. Baseline catch and effort data (Figure 50) was based on total yearly catch (kilograms) and total days fished. Monthly effort trends for the sector are reported in Figure 51.

Annual catch per unit effort trends are plotted in Figure 52. Information on the number of boats accessing the sector (on average) per month and average monthly catch per unit effort are provided in Figure 53. The primary purpose of the monthly comparisons was to examine seasonal trends in the sector. While the minimum and maximum number of boats accessing the sector in one month is available, the total number of individual boats accessing the banana prawn sector throughout the year is not yet known.

Additional information for the banana prawn stocks is available in the banana prawn stock assessment (Tanimoto et al. 2006).

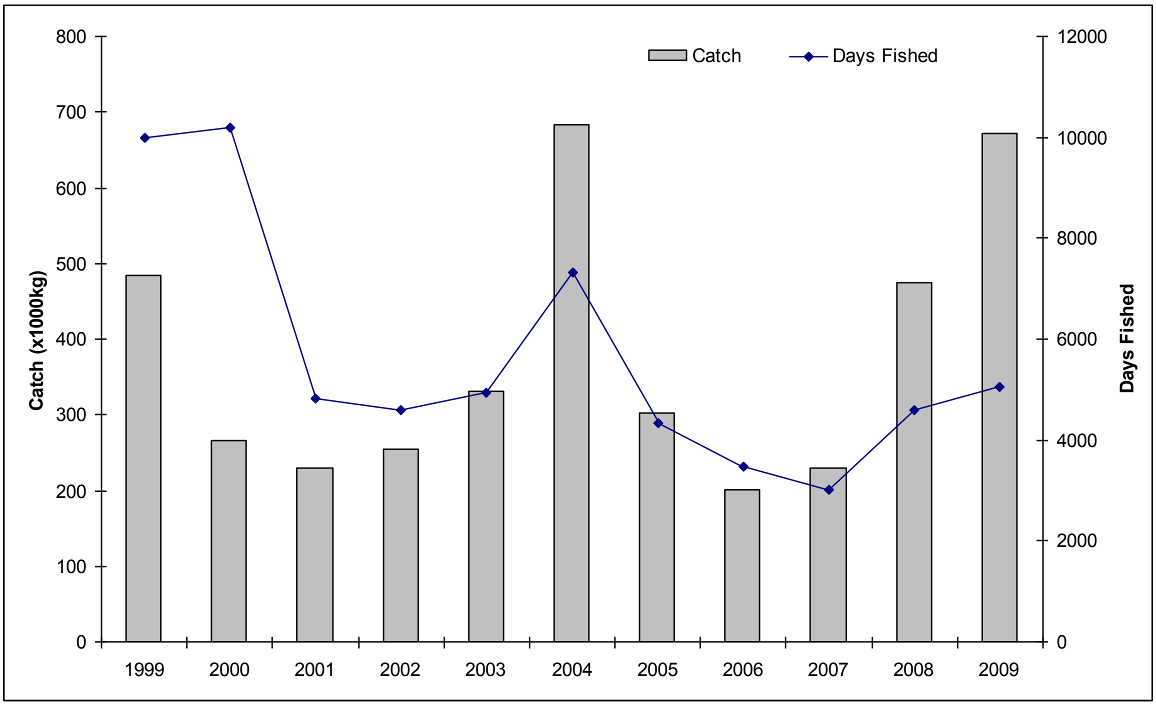


Figure 50. Catch and effort trends for banana prawns represented in tonnes and days fished respectively.

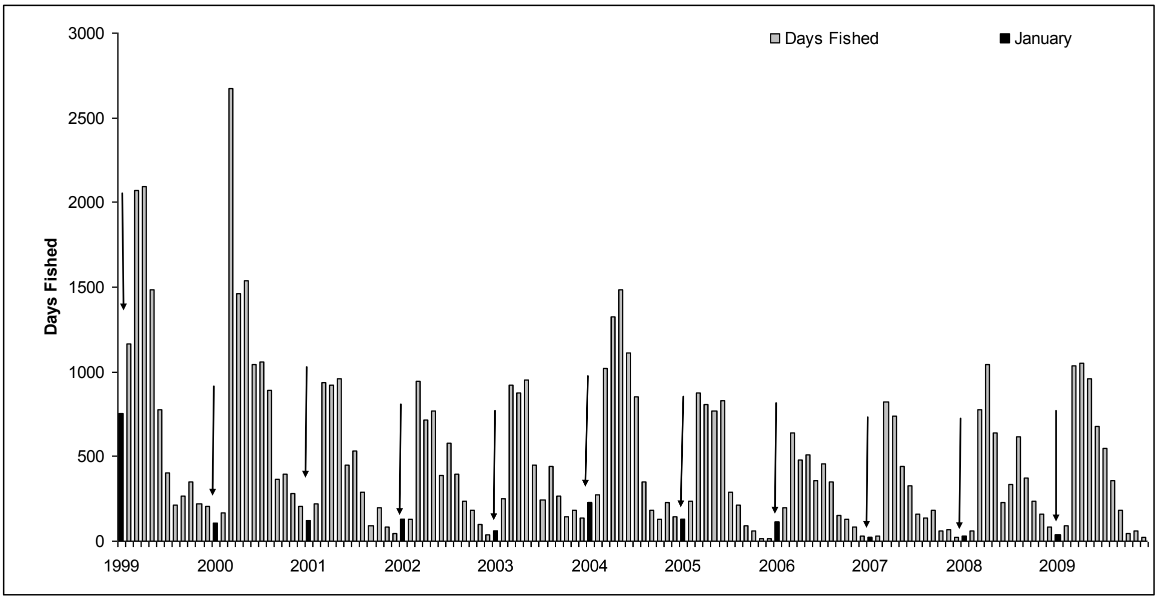


Figure 51. Monthly effort usage trends for banana prawns between 1999 and 2009 (arrow denotes the start of calendar year).

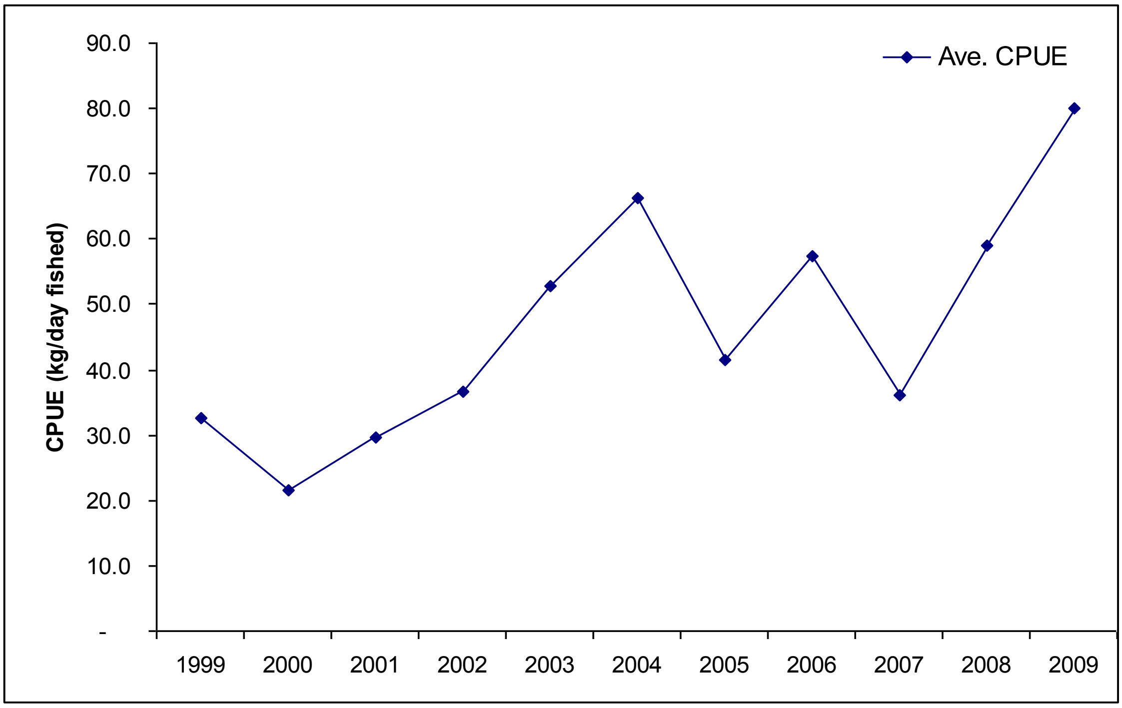


Figure 52. Average catch per unit effort (CPUE, kg/day fished) for banana prawns between 1999 and 2009.

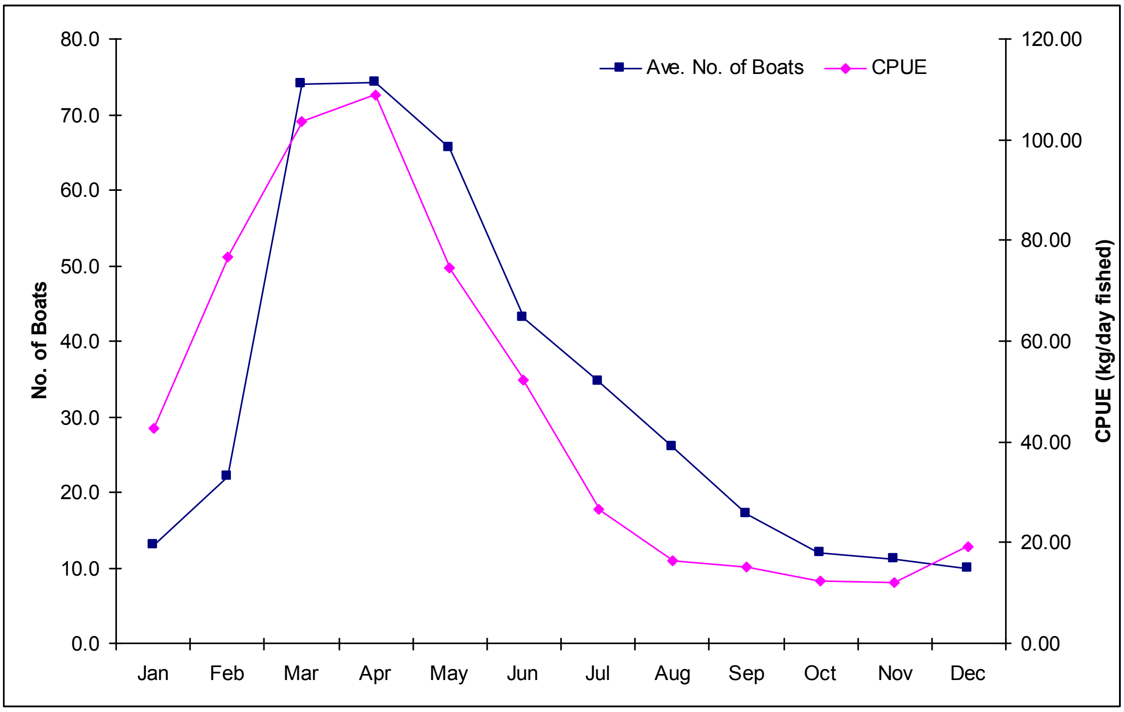


Figure 53. Average monthly CPUE (kg/day fished) and participation rates (average number of boats) for banana prawns between 1999 and 2009.

Appendix 3. Tables supporting the ecological risk assessment

List of tables in Appendix 3

Table 30. Resilience characters and decision rules: harvested species.

Category	Character	Reasons for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
Life history	Fecundity	Indication of a species' productivity in producing recruits	High fecundity: For example, > 50,000 eggs per annum	Moderate fecundity: For example < 50,000 eggs per annum and/or large eggs (≥ 2 mm) or > 10 young per annum	Low fecundity: For example, ≤ 10 young per annum	Character used in NSW
	Life history strategy	Indication of a species' ability to maintain viable population sizes or to rebuild populations after depletion	Good ability to maintain/rebuild population. For example: pelagic eggs; and/or rapid turnover; and/or long spawning duration	Moderate ability to maintain/rebuild population. For example: demersal eggs; and/or egg cases or parental care; and/or slow turnover; and/or short spawning period	Poor ability to maintain/rebuild population. For example: Live bearing or breed < once/yr	Character used in NSW
Distribution and abundance	Geographic distribution	How widely a species is distributed gives an indication of the potential for refuges from fishing and other impacts	Widespread in Great Barrier Reef Marine Park and/or adjacent jurisdictions	Restricted range (< 50 per cent latitudinal range) within Great Barrier Reef or range has contracted significantly		Character used in NSW
	Habitat specificity or ecological niche	Indicates how vulnerable a species is to impacts, with broad habitat requirements/generalist taxa less vulnerable due to their wide range of habitats/niches they associate with, which may provide refugia from fishery and climatic impacts	Generalist: For example, broad habitat requirements or narrow habitat requirements but larger area of available habitat and/or generalist taxa associated with range of niches	Specialist: For example, narrow habitat requirements with small area of available habitat and/or specialist taxa with limited or defined niche		Combines two characters (after Roelofs and Silcock 2008)
	Population size/trend and/or current abundance (throughout the species range)	Indicates the species prevalence and trend (recovery/decline) where available of the species	Large- or medium-sized population, and/or relatively common	Large and declining population or small population size, with trend increasing, stable or unknown and/or uncommon	Severely depleted population, or small declining population	Proposed in NSW but also not used because of lack of information

Category	Character	Reasons for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
Demography	Growth rate	Indicates how quickly the species reaches adult size and therefore its ability to escape the more vulnerable stages of development. Growth rate is a simple proxy for age at maturity. If age at maturity is known, include this information under factual data.	Reaches adult size within two years	Reaches adult size at greater than two years		Character used in NSW. Correlated with age at maturity, which was used in NSW, but was replaced here with natural mortality
	Longevity	Indicates turnover of populations and productivity of a species. Only used natural mortality or longevity to derive score, as these characters are highly correlated.	Short–medium (< 20 years)	Long (20 to 50+ years)		Character used in NSW
	Natural mortality	Indicates natural rate of mortality of individuals from the stock due to natural causes, which is associated with capacity to withstand exploitation	High natural mortality (≥ 1 per annum)	Low natural mortality (< 1 per annum)	Low natural mortality is the default condition where data is unavailable	New character
Other pressures in Great Barrier Reef Marine Park	Cumulative pressures	Degree of susceptibility to other non-ECTF pressures within the Great Barrier Reef (e.g. degraded water quality, habitat loss, climate change, non-ECTF fishing pressures) influences resilience and gives an indication of the ability to withstand exploitation	Other pressures have little effect on species or effect is unknown	Other pressures considered to have significant effect on species		New character

'Note: the resilience character 'Population size/trend and/or current abundance' was note used in the assessment, and longevity and natural mortality were combined into one character.

Table 31. Summary of resilience scores for principal species.

Common name	Scientific name	Fecundity	Life history strategy	Geographic distribution	Habitat specificity or ecological niche	Growth rate	Longevity / natural mortality	Cumulative pressures	Resilience level
Brown tiger prawn	*Penaeus esculentus*	A	A	A	A	A	A	A	H
Grooved tiger prawn	*Penaeus semisulcatus*	A	A	A	A	A	A	A	H
Black tiger prawn	*Penaeus monodon*	A	A	A	A	A	A	A	H
Blue endeavour prawn	*Metapenaeus endeavouri*	A	A	A	A	A	A	A	H
False endeavour prawn	*Metapenaeus ensis*	A	A	A	A	A	A	A	H
Eastern king prawn*	*Melicertus plebejus*	A	A	A	A	A	A	P	H-I
Red-spot king prawn	*Melicertus longistylus*	A	A	A	A	A	A	A	H
Blue-legged king prawn	*Melicertus latisulcatus*	A	A	A	A	A	A	A	H
White banana prawn	*Fenneropenaeus merguiensis*	A	A	A	P	A	A	A	H-I
Moreton Bay bug (spotted legs/reef bug)	*Thenus australiensis*	P	P	A	A	A	A	A	H-I
Moreton Bay bug (mud bug)	*Thenus parindicus*	P	P	A	A	A	A	A	H-I
Squid spp. (pencil & tiger)	*Uroteuthis (Photololigo)* spp. & *Sepioteuthis*	P	A	A	A	A	A	A	H-I
Tropical saucer scallop	*Amusium japonicum balloti*	A	A	A	A	A	A	A	H
Asian moon (mud) scallop	*Amusium pleuronectes*	A	A	A	A	A	A	A	H

** Cumulative pressures for eastern king prawn assessed at level of stock (which includes southern Queensland and New South Wales)*

Table 32. Summary of resilience scores for other permitted species.

Common name	Scientific name	Fecundity	Life history strategy	Geographic distribution	Habitat specificity or ecological niche	Growth rate	Longevity / natural mortality	Cumulative pressures	Resilience level
Threadfin bream (pinkies)	Family Nemipteridae	P	A	A	A	A	A	A	H-I
Mantis shrimp	Family Squillidae, order Stomatopoda	P	P	A	A	A	A	A	H-I
Blue swimmer crab	*Portunus armatus*	A	A	A	A	A	A	P	H-I
Three-spotted crab (red-spotted crab)	*Portunus sanguinolentus*	A	A	A	A	A	A	A	H
Red champagne lobster (barking crayfish)	*Linuparus trigonus*	A	P	A	A	P	P	A	I
Slipper lobsters	*Scyllarus martensii, Scyllarus demani, Scyllarides squammosus, Scyllarides haanii*	P	P	A	A	P	P	A	I-L
Deepwater bug (velvet Balmain bug)	*Ibacus alticrenatus*	P	P	A	A	A	A	A	H-I
Shovel-nosed lobster (honey Balmain bug)	*Ibacus brucei*	P	P	A	A	A	A	A	H-I
Smooth bug (garlic Balmain bug)	*Ibacus chacei*	P	P	A	A	A	A	A	H-I
Cuttlefish	*Sepia* spp.	P	A	A	A	A	A	A	H-I
Hammer octopus	*Octopus australis*	P	P	P	P	A	A	A	I-L
Red-spot night octopus	*Callistoctopus dierythraeus*	P	P	A	P	A	A	A	I
Scribbled night octopus	*Callistoctopus graptus*	P	P	A	A	A	A	A	H-I
Plain-spot octopus	*Amphioctopus exannulatus*	A	A	A	A	A	A	A	H
Veined octopus	*Amphioctopus marginatus*	A	A	A	A	A	A	A	H
Southern star-eyed octopus	*Amphioctopus cf. kagoshimensis*	A	A	P	A	A	A	A	H-I

Table 33. Fishery impact factors and decision rules: harvested species.

Category	Factor	Reason for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
How much is caught	Per cent caught	Indicates proportion caught by the fishery, which is a measure of pressure on the stocks	≤ 25 per cent	> 25 per cent but ≤ 50 per cent	> 50 per cent	Modified from NSW to suit available information and fishery
	Per cent effort exposed	Indicates intensity of fishing effort the species is exposed to from trawling	≤ 25 per cent	> 25 per cent but ≤ 50 per cent	> 50 per cent	New factor to suit available information and fishery
	Nominal catch rate trends (principal)	Used as a rough index of abundance; changes in catch rate may indicate changes in abundance	Principal: Performance Measurement System not triggered	Principal: Performance Measurement System triggered		Modified from NSW to suit available information and fishery
	Can it be targeted/is it truly incidental catch? (permitted)	Used to indicate degree of fishing effort directed at species, noting permitted species are generally not targeted	Permitted: Species is not targeted by fishery (truly incidental)	Permitted: Species occasionally or often targeted by fishery		
	Discard rate (i.e. estimated per cent discarded of total number of individuals caught for species)	Indicates level of commercial species landed on deck but not retained for any reason; essentially adds another form of mortality on the population or stock. Includes discard of 'regulated fish' such as undersize/egg-bearing, and/or unmarketable catch for any reason.	< 10 per cent	10 per cent or more		Factor used in NSW
	Stock assessment adequacy (principal)	For principal species, indicates whether a stock assessment has been completed in the last five years and whether the information on which the stock assessment was based was sufficient.	Principal: adequate assessment in last five years	Principal: Inadequate assessment in last five years		Modified from NSW to suit available information and fishery

Category	Factor	Reason for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
	Biological information adequacy (permitted)	For permitted species, indicates whether the biological information on which the management measures were based was sufficient.	Permitted: Adequate information	Permitted: Inadequate information		
	Exploitation status	Indicates whether there is evidence of growth or recruitment overfishing	Not fully utilised or sustainably fished	Uncertain or no assessment made	Overfished	Factor used in NSW
How is it fished	Interaction throughout life cycle	Indicates whether the species interacts with the fishery at all life stages	Only limited life stages of the species interact with the fishery	Juvenile and adult life stages of the species interact with the fishery		New character
	Species specific measures	Indicates adequacy of any species specific measures to protect reproductive function and prevent overfishing (e.g. size limits, catch limits, compliance effectiveness, relevant fishery closures etc.)	Range of measures in place well matched to species. Note which measures considered important for the species.	Measure(s) in place not well matched to species. If not well matched, make a note of why this is considered to be the case.		Modified from NSW to suit available information and fishery. This is broader than the NSW assessment to reflect the greater range of management options in place.
	By-catch reduction device(s) in use/effectiveness for species	Indicates whether the BRD is effective in reducing unwanted/unmarketable catch of a species. Includes discard of 'regulated fish' such as undersize/egg-bearing, and/or unmarketable catch for any reason.	Effectively precludes unwanted/ unmarketable catch of the species or not applicable as there is negligible unwanted/unmarketable catch of the species	Ineffective in precluding unwanted/ unmarketable catch of the species		Factor used in NSW
Pressure from this fishery	Proportion this fishery takes of total catch in GBRWHA	Indicates the level of fishing pressure being exerted by the ECOTF in comparison to all other relevant fishing	Less than or equal to 50 per cent of estimated catch of the species in the GBRWHA	Over 50 per cent of estimated catch of the species in the GBRWHA		Factor used in NSW

Category	Factor	Reason for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
		sectors including other commercial and recreational and Indigenous. If the stock or population boundary(ies) is known, use data for that area, if not use whole of GBRWHA as default boundary				
What is caught	Species identification problem	Indicates whether species of the same taxa are differentiated in available data; if not, then the resilience and fishery impact profile of different species cannot be determined at the species level and the species management optimised	No problem, data available at the species level	Difficult, data generally not available at the species level, or no separation into species after capture		Modified from NSW to suit available information and fishery
	Marketability	Surrogate for the economic value of a species and therefore it is a proxy for likely pressure on a species (e.g. tendency to target areas where a species occurs)	Low or moderate demand	High demand		Factor used in NSW
Where is it fished	Refuge availability in Great Barrier Reef Marine Park	Indicates whether a species has available places to escape fishing mortality	Substantial refuge areas within Great Barrier Reef Marine Park (outside of general use zones available to trawling) i.e. equal to or greater than 20 per cent protection provided by Marine Park zoning.	Few refuge areas within Great Barrier Reef Marine Park (outside of general use zones available to trawling) i.e. less than 20 per cent protection by Marine Park zoning, or protection level uncertain.		Factor used in NSW

Table 34. Summary of fishery impact factor scores for principal species based on 2009 fishing effort levels.

Common name	Scientific name	Per cent caught 2009 (without BRD effect)	Per cent effort exposed 2009	Nominal catch rate trends	Discard rate	Stock assessment adequacy	Exploitation status	Interaction throughout life cycle	Species specific measures	BRD effectiveness	Proportion this fishery takes of total catch in GBRWHA	Species identification problem	Marketability	Refuge availability	Fishery impact profile 2009
Brown tiger prawn	*Penaeus esculentus*	A	A	P	A	P	P	A	A	A	P	P	P	A	I-L
Grooved tiger prawn	*Penaeus semisulcatus*	A	PP	A	A	P	P	A	A	A	P	P	P	A	I
Black tiger prawn	*Penaeus monodon*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Blue endeavour prawn	*Metapenaeus endeavouri*	A	A	P	A	P	A	A	A	A	P	P	A	A	L
False endeavour prawn	*Metapenaeus ensis*	A	P	P	A	P	A	A	A	A	P	P	A	A	I-L
Eastern king prawn	*Melicertus plebejus*	A	A	A	A	A	A	A	A	A	P	A	P	A	L
Red-spot king prawn	*Melicertus longistylus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Blue-legged king prawn	*Melicertus latisulcatus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
White banana prawn	*Fenneropenaeus merguiensis*	A	A	A	A	A	A	A	A	A	P	A	A	A	L
Moreton Bay bug (spotted legs/reef bug)	*Thenus australiensis*	A	A	A	A	P	P	A	A	P	P	P	P	A	I-L
Moreton Bay bug (mud bug)	*Thenus parindicus*	A	A	A	A	P	P	A	A	P	P	P	P	A	I-L
Squid spp. (pencil & tiger)	*Uroteuthis (Photololigo)* spp. & *Sepioteuthis*	A	A	A	A	P	P	A	A	A	P	A	P	A	L
Tropical saucer scallop	*Amusium japonicum balloti*	A	A	A	P	A	P	P	A	A	P	P	P	A	I-L
Asian moon (mud) scallop	*Amusium pleuronectes*	A	A	A	A	P	P	P	A	P	P	P	P	A	I

Table 35. Summary of fishery impact factor scores for other permitted species based on 2009 fishing effort levels.

Common name	Scientific name	Per cent caught 2009 (without BRD effect)	Per cent effort exposed 2009	Can it be targeted/is it truly incidental catch?	Discard rate	Biological information adequacy	Exploitation status	Interaction throughout life cycle	Species specific measures	BRD effectiveness	Proportion this fishery takes of total catch in GBRWHA	Species identification problem	Marketability	Refuge availability in GBRMP	Fishery impact profile 2009
Threadfin bream (pinkies)	Family Nemipteridae	A	A	A	P	P	P	P	A	P	P	P	A	A	I
Mantis shrimp	Family Squillidae, order Stomatopoda	A	A	A	P	P	P	P	P	**P**	P	P	A	A	I
Blue swimmer crab	*Portunus armatus*	A	A	A	P	A	A	A	A	P	A	A	A	A	L
Three-spotted crab (red-spotted crab)	*Portunus sanguinolentus*	A	A	A	P	A	P	A	A	P	P	A	A	A	L
Red champagne lobster (barking crayfish)	*Linuparus trigonus*	A	A	P	A	P	P	P	A	P	P	A	P	A	I
Slipper lobsters	*Scyllarus martensii, Scyllarus demani, Scyllarides squammosus, Scyllarides haanii*	A	A	A	A	P	P	P	A	P	P	P	P	A	I
Deepwater bug (velvet Balmain bug)	*Ibacus alticrenatus*	P	P	A	P	A	P	P	A	P	P	P	P	P	H-I
Shovel-nosed lobster (honey Balmain bug)	*Ibacus brucei*	P	P	A	P	A	P	P	A	P	P	P	P	P	H-I
Smooth bug (garlic Balmain bug)	*Ibacus chacei*	P	P	A	P	A	P	P	A	P	P	P	P	P	H-I
Cuttlefish	*Sepia* spp.	A	A	A	A	A	A	P	P	P	A	P	P	A	I-L
Hammer octopus	*Octopus australis*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Red-spot night octopus	*Callistoctopus dierythraeus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L

Common name	Scientific name	Per cent caught 2009 (without BRD effect)	Per cent effort exposed 2009	Can it be targeted/is it truly incidental catch?	Discard rate	Biological information adequacy	Exploitation status	Interaction throughout life cycle	Species specific measures	BRD effectiveness	Proportion this fishery takes of total catch in GBRWHA	Species identification problem	Marketability	Refuge availability in GBRMP	Fishery impact profile 2009
Scribbled night octopus	*Callistoctopus graptus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Plain-spot octopus	*Amphioctopus exannulatus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Veined octopus	*Amphioctopus marginatus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Southern star-eyed octopus	*Amphioctopus cf. kagoshimensis*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L

Table 36. Summary of fishery impact factor scores for principal species based on 2005 fishing effort levels.

Common name	Scientific name	Per cent caught 2005 (without BRD effect)	Per cent effort exposed 2005	Nominal catch rate trends	Discard rate	Stock assessment adequacy	Exploitation status	Interaction throughout life cycle	Species specific measures	BRD effectiveness	Proportion this fishery takes of total catch in GBRWHA	Species identification problem	Marketability	Refuge availability	Fishery impact profile 2005
Brown tiger prawn	*Penaeus esculentus*	A	P	P	A	P	P	A	A	A	P	P	P	A	I
Grooved tiger prawn	*Penaeus semisulcatus*	P	PP	A	A	P	P	A	A	A	P	P	P	A	I
Black tiger prawn	*Penaeus monodon*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Blue endeavour prawn	*Metapenaeus endeavouri*	A	P	P	A	P	A	A	A	A	P	P	A	A	I-L
False endeavour prawn	*Metapenaeus ensis*	A	PP	P	A	P	A	A	A	A	P	P	A	A	I-L
Eastern king prawn	*Melicertus plebejus*	A	P	A	A	A	A	A	A	A	P	A	P	A	L
Red-spot king prawn	*Melicertus longistylus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Blue-legged king prawn	*Melicertus latisulcatus*	A	P	A	A	P	P	A	A	A	P	P	P	A	I-L
White banana prawn	*Penaeus merguiensis/ Fenneropenaeus merguiensis*	A	A	A	A	A	A	A	A	A	P	A	A	A	L
Moreton Bay bug (spotted legs)/reef bugs	*Thenus australiensis*	A	A	A	A	P	P	A	A	P	P	P	P	A	I-L

Moreton Bay bug/mud bugs	*Thenus parindicus*	P	PP	A	A	P	P	A	A	P	P	P	P	A	H-I
Squid spp (pencil, tiger & arrow)	Family Loliginidae *Uroteuthis* (*Photololigo*) spp.	A	A	A	A	P	P	A	A	A	P	A	P	A	L
Tropical saucer scallop	*Amusium japonicum balloti*	A	P	A	P	A	P	P	A	A	P	P	P	A	I
Asian moon/mud scallop	*Amusium pleuronectes*	P	PP	A	A	P	P	P	A	P	P	P	P	A	H-I

Table 37. Summary of fishery impact factor scores for other permitted species based on 2005 fishing effort levels.

Common name	Scientific name	Per cent caught 2005 (excluding BRD effect)	Per cent effort exposed 2005	Can it be targeted/is it truly incidental catch?	Discard rate	Biological information adequacy	Exploitation status	Interaction throughout life cycle	Species specific measures	BRD effectiveness	Proportion this fishery takes of total catch in GBRWHA	Species identification problem	Marketability	Refuge availability in GBRMP	Fishery impact profile 2005
Threadfin bream (pinkies)	Family Nemipteridae	P	P	A	P	P	P	P	A	P	P	P	A	A	H-I
Mantis shrimp	Family Squillidae, order Stomatopoda	A	P	A	P	P	P	P	P	P	P	P	A	A	H-I
Blue swimmer crab	*Portunus armatus*	A	P	A	P	A	A	A	A	P	A	A	A	A	L
Three-spotted crab (red-spotted crab)	*Portunus sanguinolentus*	A	P	A	P	A	P	A	A	P	P	A	A	A	I-L
Red champagne lobster (barking crayfish)	*Linuparus trigonus*	A	A	P	A	P	P	P	A	P	P	A	P	A	I
Slipper lobsters	*Scyllarus martensii, Scyllarus demani, Scyllarides squammosus, Scyllarides haanii*	A	P	A	A	P	P	P	A	P	P	P	P	A	I
Deepwater bug (velvet Balmain bug)	*Ibacus alticrenatus*	P	P	A	P	A	P	P	A	P	P	P	P	P	H-I
Shovel-nosed lobster (honey Balmain bug)	*Ibacus brucei*	P	P	A	P	A	P	P	A	P	P	P	P	P	H-I
Smooth bug (garlic Balmain bug)	*Ibacus chacei*	P	P	A	P	A	P	P	A	P	P	P	P	P	H-I
Cuttlefish	*Sepia* spp.	P	P	A	A	A	A	P	P	P	A	P	P	A	I
Hammer octopus	*Octopus australis*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Red-spot night octopus	*Callistoctopus dierythraeus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Scribbled night octopus	*Callistoctopus graptus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Plain-spot octopus	*Amphioctopus exannulatus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L

Veined octopus	*Amphioctopus marginatus*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L
Southern star-eyed octopus	*Amphioctopus cf. kagoshimensis*	A	A	A	A	P	P	A	A	A	P	P	P	A	I-L

Table 38. Resilience characters and decision rules: by-catch species.

Category	Character	Reasons for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
Biological character	Life history strategy	Indication of a species' ability to maintain viable population sizes or to rebuild populations after depletion	Good ability to maintain/rebuild population. For example: pelagic eggs; and/or rapid turnover; and/or long spawning duration	Moderate ability to maintain/rebuild population. For example: demersal eggs; and/or egg cases or parental care; and/or slow turnover; and/or short spawning period	Poor ability to maintain/rebuild population. For example: Live bearing or breed < once/yr	Character used in NSW
	Mode of life—pelagic or demersal	Indicates its vulnerability to being caught by a demersal trawler	Pelagic	Demersal or benthic or unknown		Character used in NSW
	Habitat association	Indicates its vulnerability to being caught by occupying habitats usually trawled by the fishery	Habitat not usually trawled by the ECTF or habitat trawled but larger area of available habitat	Habitat trawled with small area of available habitat		Character used in NSW
	Natural mortality	Indicates natural rate of mortality of individuals from the stock due to natural causes, which is associated with capacity to withstand exploitation	High natural mortality (≥ 1 per annum)	Low natural mortality (< 1 per annum)		New character
Distribution and abundance	Geographic distribution	How widely a species is distributed gives an indication of the potential for refuges from fishing and other impacts	Widespread in GBRMP and/or adjacent jurisdictions	Restricted range (< 50 per cent latitudinal range) within GBR or range has contracted significantly		NSW put this forward but did not use for lack of data
Other pressures in GBRMP	Cumulative pressures	Degree of susceptibility to other non-ECTF pressures within the Great Barrier Reef (e.g. degraded water quality, habitat loss, climate change, non-ECTF fishing pressures) influences resilience and gives an indication of the ability to withstand exploitation	Other pressures have little effect on species or Effect is unknown	Other pressures considered to have significant effect on species		New character

Table 39. Summary of resilience scores for by-catch.

Common name	Scientific name	Life history strategy	Mode of life—pelagic or demersal	Habitat association	Natural mortality	Geographic distribution	Cumulative pressures	Resilience level
Ray-finned fish								
Pearly-finned cardinal fish	*Apogon poecilopterus*	P	P	A	A	A	A	I
Pygmy leatherjacket	*Brachaluteres taylori*	A	P	A	A	A	A	H-I
Tufted sole	*Brachirus muelleri / Dexillichthys muelleri*	A	P	P	P	A	A	I-L
Longnose stinkfish	*Calliurichthys grossi / Callionymus grossi*	A	P	P	A	A	A	I
Prickly leatherjacket	*Chaetodermis penicilligera*	P	P	P	A	A	A	I-L
Spotted-fin tongue-sole	*Cynoglossus maculipinnis*	A	P	P	P	A	A	I-L
Naked-headed catfish	*Euristhmus nudiceps*	P	P	P	P	A	A	I-L
Rough flutemouth	*Fistularia petimba*	PP	A	A	P	A	A	I-L
Orangefin ponyfish	*Leiognathus bindus / Photopectoralis bindus*	A	P	A	A	A	A	H-I
Whipfin ponyfish	*Leiognathus leuciscus / Equulites leuciscus*	A	P	P	A	A	P	I-L
Splendid ponyfish	*Leiognathus splendens / Eubleekeria splendens*	A	P	P	A	A	P	I-L
Fourlined terapon	*Pelates quadrilineatus*	A	A	A	A	A	A	H
Longfin silverbiddy	*Pentaprion longimanus*	A	P	P	A	A	A	I
Australian threadfin	*Polydactylus multiradiatus*	A	P	P	A	A	A	I
Blotched javelin	*Pomadasys maculatus*	P	P	P	P	A	A	I-L
Damselfish sp.	*Pristotis obtusirostris*	P	P	A	P	A	A	I-L
Australian halibut	*Psettodes erumei*	P	P	P	P	A	A	I-L
Flathead dragonet	*Repomucenus belcheri / Callionymus belcheri*	A	P	P	A	A	A	I
Shortfin saury (short-finned lizardfish)	*Saurida argentea/tumbil*	A	P	P	A	A	A	I
Largescale saury (brushtooth lizardfish)	*Saurida grandisquamis/ undosquamis*	P	P	P	A	A	A	I-L

Common name	Scientific name	Life history strategy	Mode of life—pelagic or demersal	Habitat association	Natural mortality	Geographic distribution	Cumulative pressures	Resilience level
Trumpeter whiting	*Sillago maculata*	A	P	P	P	P	P	L
Spinycheek grunter	*Terapon puta*	A	P	A	A	A	P	I
Largescale grunter (banded grunter)	*Terapon theraps*	A	A	P	A	A	A	H-I
Yellowfin tripodfish	*Tripodichthys angustifrons*	P	P	P	P	A	A	I-L
Blacktip tripodfish (long-nosed tripodfish)	*Trixiphichthys weberi*	P	P	P	P	A	A	I-L
Sunrise goatfish (sulphur goatfish)	*Upeneus sulphureus*	A	P	A	A	A	A	H-I
Ochreband goatfish	*Upeneus sundaicus*	A	P	P	A	A	A	I
Hairfin goby	*Yongeichthys nebulosus*	P	P	A	A	A	A	I
Razorfish	*Aeoliscus strigatus*	A	P	A	P	A	A	I
Pineapple fish	*Cleidopus gloriamaris*	PP	P	A	P	A	A	I-L
Personifer angelfish	*Chaetodontoplus meredithi*	P	P	A	P	A	A	I-L
Sea pens								
Sea pen	*Sea pen (Pteroides)* sp1	A	P	P	P	P	A	I-L
Bivalves								
Bivalve sp.	*Enisiculus cultellus*	A	P	P	P	A	A	I-L
Glycymerididae	*Melaxinaea vitrea*	A	P	A	P	A	A	I
Bivalve sp.	*Placamen tiara*	A	P	A	P	A	A	I
Crustaceans								
Blunt-toothed crab	*Charybdis truncata*	A	P	P	A	A	A	I
Hairy crab (Family Pilumnidae)	*Cryptolutea arafurensis*	P	P	P	P	A	A	I-L
(Hermit crab)	*Diogenidae* sp356-1	P	P	P	P	A	A	I-L
Purse crab (Family Leucosiidae)	*Myra tumidospina*	P	P	P	P	A	A	I-L
Swimming crab (Family Portunidae)	*Portunus gracilimanus*	A	P	A	A	A	A	H-I
Swimming crab (Family Portunidae)	*Portunus tuberculosus*	A	A	P	P	A	A	I
Hardback shrimp (penaeid shrimps)	*Trachypenaeus anchoralis*	A	P	P	A	A	A	I
Gastropods								
Sea snail	*Aplysia* sp1_QMS	A	P	A	A	A	A	H-I

Common name	Scientific name	Life history strategy	Mode of life—pelagic or demersal	Habitat association	Natural mortality	Geographic distribution	Cumulative pressures	Resilience level
Small sea snail	*Lamellaria* sp1	P	P	P	P	A	A	I-L
Sea snail	*Nassarius cremmatus cf.*	A	A	A	A	A	A	H

Table 40. Fishery impact factors and decision rules: by-catch species.

Category	Factor	Reason for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
How much is caught	Per cent caught	Indicates proportion caught by the fishery, which is a measure of pressure on the stocks	≤ 25 per cent	> 25 per cent but ≤ 50 per cent	> 50 per cent	Modified from NSW to suit available information and fishery—as used for Harvested Species
	Per cent effort exposed	Indicates intensity of fishing effort the species is exposed to from trawling	≤ 25 per cent	> 25 per cent but ≤ 50 per cent	> 50 per cent	New factor to suit available information and fishery—as used for Harvested Species
	Survival after capture	Indicates how well they survive after being trawled and handled on deck and returned to the water	Moderate: survive moderate trauma	Low: trawl trauma from handling on deck, barotrauma or predation from marine predators when returned to the water		Factor used in NSW
	Effectiveness of TEDs/BRDs	Indicates whether TEDs/BRDs currently in use are effective at preventing capture during trawling	Best practice TEDS and BRDS used by most of the fleet from Observer Surveys and likely to be effective at precluding the species, or trawl catchability negligible so not applicable	Best practice TEDS and BRDS not used by most of the fleet from Observer Surveys and/or TEDs and BRDs in use considered to be ineffective at precluding the species		NSW put this forward but did not use because lacked data
Where is it fished	Refuge availability in GBRMP	Indicates whether a species has available places to escape fishing mortality	Substantial refuge areas within GBRMPA jurisdiction (outside of general use zones available to trawling) i.e. equal to or greater than 20 per cent protection provided by Marine Park zoning.	Few refuge areas within GBRMPA jurisdiction (outside of general use zones available to trawling) i.e. less than 20 per cent protection by Marine Park zoning, or protection level uncertain.		New factor to suit available information and fishery—as used for Harvested Species

Table 41. Summary of fishery impact factor scores for by-catch based on 2009 fishing effort levels.

Common name	Scientific name	Per cent caught 2009 (without BRD effect)	Per cent effort exposed 2009	Survival after capture	Effectiveness of TEDs/BRDs	Refuge availability	Fishery impact profile 2009
Ray-finned fish							
Pearly-finned cardinal fish	*Apogon poecilopterus*	A	A	P	P	A	I-L
Pygmy leatherjacket	*Brachaluteres taylori*	A	P	A	P	A	I-L
Tufted sole	*Brachirus muelleri / Dexillichthys muelleri*	P	P	A	P	A	I
Longnose stinkfish	*Calliurichthys grossi / Callionymus grossi*	A	A	P	P	A	I-L
Prickly leatherjacket	*Chaetodermis penicilligera*	A	A	A	P	A	L
Spotted-fin tongue-sole	*Cynoglossus maculipinnis*	A	A	A	P	A	L
Naked-headed catfish	*Euristhmus nudiceps*	A	A	A	P	A	L
Rough flutemouth	*Fistularia petimba*	A	A	P	P	A	I-L
Orangefin ponyfish	*Leiognathus bindus / Photopectoralis bindus*	A	A	P	P	A	I-L
Whipfin ponyfish	*Leiognathus leuciscus / Equulites leuciscus*	A	P	P	P	A	I
Splendid ponyfish	*Leiognathus splendens / Eubleekeria splendens*	A	A	A	P	A	L
Fourlined terapon	*Pelates quadrilineatus*	A	P	A	P	A	I-L
Longfin silverbiddy	*Pentaprion longimanus*	A	P	P	P	A	I
Australian threadfin	*Polydactylus multiradiatus*	A	A	P	P	A	I-L
Blotched javelin	*Pomadasys maculatus*	A	A	P	P	A	I-L
Damselfish sp.	*Pristotis obtusirostris*	A	A	P	P	A	I-L
Australian halibut	*Psettodes erumei*	A	A	A	P	A	L
Flathead dragonet	*Repomucenus belcheri / Callionymus belcheri*	A	A	P	P	A	I-L
Shortfin saury (short-finned lizardfish)	*Saurida argentea/tumbil*	A	A	P	P	A	I-L
Largescale saury (brushtooth lizardfish)	*Saurida grandisquamis/undosquamis*	A	A	P	P	A	I-L
Trumpeter whiting	*Sillago maculata*	A	A	P	P	A	I-L
Spinycheek grunter	*Terapon puta*	A	A	A	P	A	L
Largescale grunter (banded grunter)	*Terapon theraps*	A	P	A	P	A	I-L
Yellowfin tripodfish	*Tripodichthys angustifrons*	A	A	A	P	A	L
Blacktip tripodfish (long-nosed tripodfish)	*Trixiphichthys weberi*	A	A	A	P	A	L

Common name	Scientific name	Per cent caught 2009 (without BRD effect)	Per cent effort exposed 2009	Survival after capture	Effectiveness of TEDs/BRDs	Refuge availability	Fishery impact profile 2009
Sunrise goatfish (sulphur goatfish)	*Upeneus sulphureus*	A	A	A	P	A	L
Ochreband goatfish	*Upeneus sundaicus*	A	P	A	P	A	I-L
Hairfin goby	*Yongeichthys nebulosus*	A	A	P	P	A	I-L
Razorfish	*Aeoliscus strigatus*	A	A	P	P	A	I-L
Pineapple fish	*Cleidopus gloriamaris*	A	A	P	P	A	I-L
Personifer angelfish	*Chaetodontoplus meredithi*	A	A	P	P	A	I-L
Seapens							
Sea pen	*Sea pen (Pteroides?)* sp1	A	A	P	P	A	I-L
Bivalves							
Bivalve sp.	*Enisiculus cultellus*	A	P	A	A	A	L
Glycymerididae	*Melaxinaea vitrea*	A	A	A	A	A	L
Bivalve sp.	*Placamen tiara*	A	A	A	A	A	L
Crustaceans							
Blunt-toothed crab	*Charybdis truncata*	A	A	A	P	A	L
Hairy crab (Family Pilumnidae)	*Cryptolutea arafurensis*	A	P	A	P	A	I-L
(Hermit crab)	*Diogenidae* sp356-1	A	A	A	P	A	L
Purse crab (Family Leucosiidae)	*Myra tumidospina*	A	A	A	P	A	L
Swimming crab (Family Portunidae)	*Portunus gracilimanus*	A	P	A	P	A	I-L
Swimming crab (Family Portunidae)	*Portunus tuberculosus*	A	A	A	P	A	L
Hardback shrimp (penaeid shrimps)	*Trachypenaeus anchoralis*	A	P	A	P	A	I-L
Gastropods							
Sea snail	*Aplysia* sp1_QMS	A	A	P	P	A	I-L
Small sea snail	*Lamellaria* sp1	A	A	P	P	A	I-L
Sea snail	*Nassarius cremmatus cf.*	A	A	A	A	A	L

Table 42. Summary of fishery impact factor scores for by-catch based on 2005 fishing effort levels.

Group	Common name	Scientific name	Per cent caught 2005 (without BRD effect)	Per cent effort exposed 2005	Survival after capture	Effectiveness of TEDs/BRDs	Refuge availability	Fishery impact profile 2005
Ray-finned fish	Pearly-finned cardinal fish	*Apogon poecilopterus*	P	PP	P	P	A	H
Ray-finned fish	Pigmy leatherjacket	*Brachaluteres taylori*	A	PP	A	P	A	I
Ray-finned fish	Tufted sole	*Brachirus muelleri / Dexillichthys muelleri*	PP	PP	A	P	A	H
Ray-finned fish	Longnose stinkfish	*Calliurichthys grossi / Callionymus grossi*	A	PP	P	P	A	H-I
Ray-finned fish	Prickly leatherjacket	*Chaetodermis penicilligera*	P	PP	A	P	A	H-I
Ray-finned fish	Spotted-fin tongue-sole	*Cynoglossus maculipinnis*	A	PP	A	P	A	I
Ray-finned fish	Naked-headed catfish	*Euristhmus nudiceps*	PP	PP	A	P	A	H
Ray-finned fish	Rough flutemouth	*Fistularia petimba*	P	P	P	P	A	H-I
Ray-finned fish	Orangefin ponyfish	*Leiognathus bindus / Photopectoralis bindus*	A	PP	P	P	A	H-I
Ray-finned fish	Whipfin ponyfish	*Leiognathus leuciscus / Equulites leuciscus*	P	PP	P	P	A	H
Ray-finned fish	Splendid ponyfish	*Leiognathus splendens / Eubleekeria splendens*	A	PP	A	P	A	I
Ray-finned fish	Fourlined terapon	*Pelates quadrilineatus*	A	PP	A	P	A	I
Ray-finned fish	Longfin silverbiddy	*Pentaprion longimanus*	A	PP	P	P	A	H-I
Ray-finned fish	Australian threadfin	*Polydactylus multiradiatus*	A	A	P	P	A	I-L
Ray-finned fish	Blotched javelin	*Pomadasys maculatus*	P	P	P	P	A	H-I
Ray-finned fish	Damselfish sp.	*Pristotis obtusirostris*	A	A	P	P	A	I-L
Ray-finned fish	Australian halibut	*Psettodes erumei*	PP	PP	A	P	A	H
Ray-finned fish	Flathead dragonet	*Repomucenus belcheri / Callionymus belcheri*	A	PP	P	P	A	H-I

Group	Common name	Scientific name	Per cent caught 2005 (without BRD effect)	Per cent effort exposed 2005	Survival after capture	Effectiveness of TEDs/BRDs	Refuge availability	Fishery impact profile 2005
Ray-finned fish	Shortfin saury (Short-finned lizardfish)	*Saurida argentea/tumbil*	PP	PP	P	P	A	H
Ray-finned fish	Largescale saury (Brushtooth lizardfish)	*Saurida grandisquamis/ undosquamis*	P	P	P	P	A	H-I
Ray-finned fish	Trumpeter whiting	*Sillago maculata*	P	P	P	P	A	H-I
Ray-finned fish	Spinycheek grunter	*Terapon puta*	PP	PP	A	P	A	H
Ray-finned fish	Largescale grunter (Banded grunter)	*Terapon theraps*	A	PP	A	P	A	I
Ray-finned fish	Yellowfin tripodfish	*Tripodichthys angustifrons*	P	P	A	P	A	I
Ray-finned fish	Blacktip tripodfish (Long-nosed tripodfish)	*Trixiphichthys weberi*	P	P	A	P	A	I
Ray-finned fish	Sunrise goatfish (Sulphur goatfish)	*Upeneus sulphureus*	P	PP	A	P	A	H-I
Ray-finned fish	Ochreband goatfish	*Upeneus sundaicus*	P	PP	A	P	A	H-I
Ray-finned fish	Hairfin goby	*Yongeichthys nebulosus*	PP	PP	P	P	A	H
Ray-finned fish	Razorfish	*Aeoliscus strigatus*	A	A	P	P	A	I-L
Ray-finned fish	Pineapple fish	*Cleidopus gloriamaris*	A	A	P	P	A	I-L
Ray-finned fish	Personifer angelfish	*Chaetodontoplus meredithi*	A	A	P	P	A	I-L
Seapens	Sea pen	*Sea pen (Pteroides?)* sp1	A	P	P	P	A	I
Bivalves	Bivalve sp.	*Enisiculus cultellus*	A	PP	A	A	A	I-L
Bivalves	Family Glycymerididae	*Melaxinaea vitrea*	A	PP	A	A	A	I-L
Bivalves	Bivalve sp.	*Placamen tiara*	A	PP	A	A	A	I-L
Crustaceans	Blunt-toothed crab	*Charybdis truncate*	A	P	A	P	A	I-L
Crustaceans	Hairy crab (Family	*Cryptolutea arafurensis*	A	PP	A	P	A	I

Group	Common name	Scientific name	Per cent caught 2005 (without BRD effect)	Per cent effort exposed 2005	Survival after capture	Effectiveness of TEDs/BRDs	Refuge availability	Fishery impact profile 2005
	Pilumnidae)							
Crustaceans	(Hermit crab)	*Diogenidae* sp356-1	A	P	A	P	A	I-L
Crustaceans	Purse crab (Family Leucosiidae)	*Myra tumidospina*	A	PP	A	P	A	I
Crustaceans	Swimming crab (Family Portunidae)	*Portunus gracilimanus*	P	PP	A	P	A	H-I
Crustaceans	Swimming crab (Family Portunidae)	*Portunus tuberculosus*	A	P	A	P	A	I-L
Crustaceans	Hardback shrimp (penaeid shrimps)	*Trachypenaeus anchoralis*	A	PP	A	P	A	I
Gastropods	Sea snail	*Aplysia* sp1_QMS	P	P	P	P	A	H-I
Gastropods	Small sea snail	*Lamellaria* sp1	P	P	P	P	A	H-I
Gastropods	Sea snail	*Nassarius cremmatus cf.*	A	P	A	A	A	L

Table 43. Resilience characters and decision rules: species of conservation concern.

Category	Character	Reasons for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
Life history	Fecundity	Indication of a species' productivity in producing recruits	High fecundity: For example, > 50,000 eggs per annum	Moderate fecundity: For example < 50,000 eggs and/or large eggs (≥ 2 mm) or > 10 young per annum	Low fecundity: For example, ≤ 10 young per annum	Character used in NSW
	Life history strategy	Indication of a species' ability to maintain viable population sizes or to rebuild populations after depletion	Good ability to maintain/rebuild population. For example: pelagic eggs; and/or rapid turnover; and/or long spawning/breeding season.	Moderate ability to maintain/rebuild population. For example: demersal eggs; and/or egg cases; or parental care; and/or slow turnover; and/or short breeding/spawning season.	Poor ability to maintain/rebuild population. For example: live bearing or breed < once/year.	Character used in NSW
Distribution and abundance	Geographic distribution	How widely a species is distributed gives an indication of the potential for refuges from fishing and other impacts	Widespread in Great Barrier Reef Marine Park and/or adjacent jurisdictions	Restricted range within Great Barrier Reef (< 50 per cent of latitudinal range) or range has contracted significantly or discrete stocks within the Great Barrier Reef		Character used in NSW
	Habitat specificity or ecological niche	Indicates how vulnerable a species is to impacts, with broad habitat requirements/generalist taxa less vulnerable due to their wide range of habitats/niches they associate with, which may provide refugia from fishery and climatic impacts	Generalist: For example, broad habitat requirements or narrow habitat requirements but larger area of available habitat and/or generalist taxa associated with range of niches	Specialist: For example, narrow habitat requirements with small area of available habitat and/or specialist taxa with limited or defined niche		Character used in NSW
	Population size/trend and/or current abundance	Indicates the species prevalence and trend (recovery/decline) where available for the species (throughout the species range)	Large- or medium-sized population, and/or relatively common	Large and declining population or small population size, with trend increasing, stable or unknown and/or uncommon	Severely depleted population or small declining population	Modified from NSW to suit available information and fishery

Category	Character	Reasons for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
Demography	Growth rate	Indicates how quickly it reaches adult size and therefore its ability to escape the more vulnerable stages of development	Reaches adult size within two years (proxy for age at maturity)	Reaches adult size at greater than two years (proxy for age at maturity)		Character used in NSW
	Longevity	Indicates turnover of populations and productivity of a species	Short–medium (< 20 years)	Long (20 to 50+ yrs)		Character used in NSW
	or Natural mortality	Indicates natural rate of mortality of individuals from the population due to natural causes, which is associated with capacity to withstand exploitation	High natural mortality (≥ 1 per annum)	Low natural mortality (< 1 per annum). Low natural mortality is the default condition where data is unavailable.		New character
Other pressures in Great Barrier Reef Marine Park	Cumulative pressures	Degree of susceptibility to other non-ECTF pressures within the Great Barrier Reef (e.g. degraded water quality, habitat loss, climate change, non-ECTF fishing pressures) influences resilience and gives an indication of the ability to withstand exploitation. Scoring based only on information for the Great Barrier Reef, however other known cumulative pressures elsewhere in the species range are noted.	Other pressures have little effect on species or effect is unknown	Other pressures considered to have significant effect on species		New character

Table 44. Fishery impact factors and decision rules: species of conservation concern.

Category	Factor	Reason for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
Interaction with the fishery	Level of Interaction	Interaction with the fishery is based on the overlap between the species and the area in which the fishery operates (geographical and habitat), and where data are available, the frequency of the interaction	Some contact with the East Coast Trawl Fishery within the Great Barrier Reef World Heritage Area, but number of individuals encountered or affected is small enough to have a negligible impact on the species	Contact with a moderate number of individuals or relatively infrequent contact within the Great Barrier Reef World Heritage Area	Contact with a significant number of individuals, or relatively frequent contact within the Great Barrier Reef World Heritage Area	Factor used in NSW
	Survival after interaction	Indicates how well they survive after any interaction with trawling. e.g. Survival after being trawled and handled on deck and returned to the water, or survival after interaction with another trawling activity	Good survival. e.g. 100 to 80 per cent survival	Moderate survival. e.g. < 80 to 50 per cent survival	Low survival. e.g. < 50 per cent survival	New factor
What is caught?	Interaction throughout life cycle	Indicates whether the species interacts with the fishery at all life stages	Only limited life stages of the species interact with the fishery	All or most life stages of the species interact with the fishery		New factor
	TED/BRD effectiveness	Interaction with the fishery may be frequent, but the impact of the interaction is reduced through effective BRDs or TEDs	Effectively precludes the species and best practice TEDs and BRDs used by most of the fleet from Observer Surveys or not applicable because interaction is negligible	Ineffective in precluding the species or effective but best practice TEDs and BRDs not used by most of the fleet from Observer Surveys		New factor

Table 45. Summary of resilience scores for marine turtles.

Common name	Scientific name	Fecundity	Life history strategy	Geographic distribution	Habitat specificity or ecological niche	Population size or trend	Growth rate / age at maturity	Longevity / natural mortality	Cumulative pressures	Resilience level
Flatback turtle	*Natator depressus*	P	PP	A	A	P	P	P	P	L
Green turtle	*Chelonia mydas*	P	PP	A	A	P	P	P	P	L
Hawksbill turtle	*Eretmochelys imbricata*	P	PP	A	A	P	P	P	P	L
Leatherback turtle	*Dermochelys coriacea*	P	PP	A	A	PP	P	P	P	L
Loggerhead turtle	*Caretta caretta*	P	PP	A	A	P	P	P	P	L
Olive ridley turtle	*Lepidochelys olivacea*	P	PP	A	A	A	P	P	P	L

Table 46. Summary of fishery impact factor scores for marine turtles.

Common name	Scientific name	Level of interaction	Survival after interaction	Interaction throughout life cycle	TED/BRD effectiveness	Fishery impact profile
Flatback turtle	*Natator depressus*	P	A	P	A	I-L
Green turtle	*Chelonia mydas*	P	A	P	A	I-L
Hawksbill turtle	*Eretmochelys imbricata*	P	A	P	A	I-L
Leatherback turtle	*Dermochelys coriacea*	A	A	P	P	I-L
Loggerhead turtle	*Caretta caretta*	P	A	P	A	I-L
Olive ridley turtle	*Lepidochelys olivacea*	A	A	P	A	L

Table 47. Summary of resilience scores for sea snakes.

Common name	Scientific name	Fecundity	Life history strategy	Geographic distribution	Habitat specificity or ecological niche	Population size or trend	Growth rate / age at maturity	Longevity / natural mortality	Cumulative pressures	Resilience level
Horned sea snake	*Acalyptophis peronii*	PP	P	A	A	A	A	P	A	I-L
Dubois' sea snake	*Aipysurus duboisii*	PP	P	A	P	A	A	P	A	I-L
Spine-tailed sea snake	*Aipysurus eydouxii*	PP	P	A	P	A	A	P	A	I-L
Olive sea snake	*Aipysurus laevis*	PP	PP	A	A	A	A	P	A	I-L
Stokes' sea snake	*Astrotia stokesii*	PP	P	P	P	P	A	P	A	L
Spectacled sea snake	*Hydrophis/Disteira kingii*	PP	P	P	P	P	A	P	A	L
Olive-headed sea snake	*Hydrophis/Disteira major*	PP	P	A	A	P	A	P	A	I-L
Beaked sea snake	*Enhydrina schistosa*	P	P	A	A	A	A	P	P	I-L
Elegant sea snake	*Hydrophis elegans*	P	PP	A	P	A	A	P	P	L
Small-headed sea snake	*Hydrophis macdowelli*	PP	P	A	P	A	A	P	A	I-L
Ornate reef sea snake	*Hydrophis ornatus*	PP	P	A	A	A	A	P	A	I-L
Large-headed sea snake	*Hydrophis pacificus*	PP	P	A	P	A	A	P	A	I-L
Spine-bellied sea snake	*Lapemis curtus*	PP	P	A	A	A	A	P	P	I-L
Turtle-headed sea snake	*Emydocephalus annulatus*	PP	P	A	A	A	A	P	A	I-L
Yellow-bellied sea snake	*Pelamis platura*	PP	P	A	A	A	A	P	A	I-L

Table 48. Summary of fishery impact factor scores for sea snakes.

Common name	Scientific name	Level of interaction	Survival after interaction	Interaction throughout life cycle	TED/BRD effectiveness	Fishery impact profile
Horned sea snake	*Acalyptophis peronii*	A	P	A	P	I-L
Dubois' sea snake	*Aipysurus duboisii*	A	A	A	P	L
Spine-tailed sea snake	*Aipysurus eydouxii*	A	A	A	P	L
Olive sea snake	*Aipysurus laevis*	A	A	A	P	L
Stokes' sea snake	*Astrotia stokesii*	A	P	A	P	I-L
Spectacled sea snake	*Hydrophis/Disteira kingii*	P	P	A	P	I
Olive-headed sea snake	*Hydrophis/Disteira major*	A	P	A	P	I-L
Beaked sea snake	*Enhydrina schistosa*	A	A	A	P	L
Elegant sea snake	*Hydrophis elegans*	P	PP	A	P	H-I
Small-headed sea snake	*Hydrophis macdowelli*	A	PP	A	P	I
Ornate reef sea snake	*Hydrophis ornatus*	P	PP	A	P	H-I
Large-headed sea snake	*Hydrophis pacificus*	A	P	A	P	I-L
Spine-bellied sea snake	*Lapemis curtus*	A	A	A	P	L
Turtle-headed sea snake	*Emydocephalus annulatus*	A	A	A	A	L
Yellow-bellied sea snake	*Pelamis platura*	A	A	A	A	L

Table 49. Summary of resilience scores for seahorses and pipefish.

Family	Common name	Scientific name	Fecundity	Life history strategy	Geographic distribution	Habitat specificity or ecological niche	Population size or trend	Growth rate / age at maturity	Longevity / natural mortality	Cumulative pressures	Resilience level
Seahorses	Queensland seahorse	*Hippocampus queenslandicus*	P	P	A	A	P	A	P	P	I-L
Seahorses	Highcrown seahorse	*Hippocampus proceros*	P	P	A	A	P	A	P	P	I-L
Pipefish	Bentstick pipefish	*Trachyrhamphus bicoarctatus*	P	P	A	P	P	A	P	A	I-L
Pipefish	Straightstick pipefish	*Trachyrhamphus longirostris*	P	P	A	P	P	A	P	P	L
Pipefish	Tiger pipefish	*Filicampus tigris*	P	P	A	P	P	A	P	P	L
Pipehorse	Pallid/Hardwick(e)'s pipehorse	*Solegnathus cf. hardwickii*	P	P	A	P	A	A	P	P	I-L

Table 50. Summary of fishery impact factor scores for seahorses and pipefish.

Family	Common name	Scientific name	Level of interaction	Survival after interaction	Interaction throughout life cycle	TED/BRD effectiveness	Fishery impact profile
Seahorses	Queensland seahorse	*Hippocampus queenslandicus*	A	PP	A	P	I
Seahorses	Highcrown seahorse	*Hippocampus proceros*	A	PP	A	P	I
Pipefish	Bentstick pipefish	*Trachyrhamphus bicoarctatus*	A	PP	A	P	I
Pipefish	Straightstick pipefish	*Trachyrhamphus longirostris*	A	PP	A	P	I
Pipefish	Tiger pipefish	*Filicampus tigris*	A	PP	A	P	I
Pipehorse	Pallid/Hardwick(e)'s pipehorse	*Solegnathus cf. hardwickii*	A	PP	A	P	I

Table 51. Summary of resilience scores for sharks and rays.

Common name	Scientific name	Fecundity	Life history strategy	Geographic distribution	Habitat specificity or ecological niche	Population size or trend	Growth rate / age at maturity	Longevity / natural mortality	Cumulative pressures	Resilience level
Blue-grey carpet shark	*Brachaelurus colcloughi*	PP	PP	P	A	P	P	A	P	L
Tasselled wobbegong	*Eucrossorhinus dasypogon*	P	PP	A	A	A	P	P	A	I-L
Spotted wobbegong	*Orectolobus maculatus*	P	PP	A	A	A	P	P	A	I-L
Grey carpetshark	*Chiloscyllium punctatum*	P	P	A	A	A	A	A	A	H-I
Eastern banded catshark	*Atelomycterus marnkalha*	P	P	A	A	P	P	P	A	I-L
Australian weasel shark	*Hemigaleus australiensis*	P	PP	A	A	A	P	P	A	I-L
Sliteye shark	*Loxodon macrorhinus*	PP	PP	A	A	A	P	A	A	I-L
Milk shark	*Rhizoprionodon acutus*	PP	PP	A	A	A	A	A	P	I-L
Spinner shark	*Carcharhinus brevipinna*	P	PP	A	A	A	P	P	P	L
Whitecheek shark	*Carcharhinus coatesi*	PP	PP	A	A	P	P	P	P	L
Narrow sawfish	*Anoxypristis cuspidata*	P	PP	A	P	P	P	P	P	L
Green sawfish	*Pristis zijsron*	P	PP	P	P	PP	P	P	P	L
Whitespotted guitarfish or eyebrow wedgefish	*Rhynchobatus australiae / Rhynchobatus palpebratus*	P	PP	A	A	A	P	P	P	L
Eastern shovelnose ray	*Aptychotrema rostrata*	P	P	A	A	A	P	P	P	I-L
Coffin ray	*Hypnos monopterygius*	PP	PP	A	A	P	P	P	A	L
Estuary stingray	*Dasyatis fluviorum*	PP	PP	A	P	P	P	P	P	L
Blackspotted whipray	*Himantura astra*	PP	PP	A	A	A	P	P	A	L
Pink whipray	*Himantura fai*	PP	PP	A	A	A	P	P	A	L
Reticulate whipray	*Himantura uarnak*	PP	PP	A	A	A	P	P	A	L
Bleeker's variegated whipray	*Himantura undulata*	PP	PP	A	A	A	P	P	A	L

Common name	Scientific name	Fecundity	Life history strategy	Geographic distribution	Habitat specificity or ecological niche	Population size or trend	Growth rate / age at maturity	Longevity / natural mortality	Cumulative pressures	Resilience level
Leopard whipray	*Himantura leoparda*	PP	PP	A	A	P	P	P	A	L
Brown whipray	*Himantura toshi*	PP	PP	A	A	A	P	P	A	L
Mangrove whipray	*Himantura granulata*	PP	PP	A	P	P	P	P	A	L
Bluespotted maskray	*Neotrygon kuhlii*	PP	PP	A	A	A	P	A	A	I-L
Speckled maskray	*Neotrygon picta*	PP	PP	A	A	A	P	A	A	I-L
Cowtail stingray	*Pastinachus astrus*	PP	PP	A	A	A	P	P	A	L
Common stingaree	*Trygonoptera testacea*	PP	PP	A	A	P	P	A	A	L
Patchwork stingaree	*Urolophus flavomosaicus*	PP	PP	A	A	P	P	A	A	L
Pale tropical skate	*Dipturus apricus*	P	P	A	A	P	P	P	A	I-L
Argus skate	*Dipturus polyommata*	P	P	A	A	P	P	P	A	I-L
Endeavour skate	*Dipturus endeavouri*	P	P	A	A	P	P	P	A	I-L
Australian butterfly ray	*Gymnura australis*	PP	PP	A	A	A	P	P	A	L
Banded eagle ray	*Aetomylaeus nichofii*	PP	PP	A	A	P	P	P	A	L

Table 52. Summary of fishery impact factor scores for sharks and rays.

Common name	Scientific name	Level of interaction	Survival after interaction	Interaction throughout life cycle	TED/BRD effectiveness	Fishery impact profile
Blue-grey carpet shark	*Brachaelurus colcloughi*	P	A	P	P	I
Tasselled wobbegong	*Eucrossorhinus dasypogon*	A	A	P	P	I-L
Spotted wobbegong	*Orectolobus maculatus*	A	A	P	P	I-L
Grey carpetshark	*Chiloscyllium punctatum*	A	A	P	P	I-L
Eastern banded catshark	*Atelomycterus marnkalha*	A	P	P	P	I
Australian weasel shark	*Hemigaleus australiensis*	A	P	P	P	I
Sliteye shark	*Loxodon macrorhinus*	A	P	P	A	I-L
Milk shark	*Rhizoprionodon acutus*	A	A	P	P	I-L
Spinner shark	*Carcharhinus brevipinna*	A	A	A	A	L
Whitecheek shark	*Carcharhinus coatesi*	A	A	P	P	I-L
Narrow sawfish	*Anoxypristis cuspidata*	P	P	A	P	I
Green sawfish	*Pristis zijsron*	P	A	P	P	I
Whitespotted guitarfish or eyebrow wedgefish	*Rhynchobatus australiae / Rhynchobatus palpebratus*	P	A	P	A	I-L
Eastern shovelnose ray	*Aptychotrema rostrata*	PP	P	P	A	H-I
Coffin ray	*Hypnos monopterygius*	P	P	P	P	H-I
Estuary stingray	*Dasyatis fluviorum*	A	A	P	P	I-L
Blackspotted whipray	*Himantura astra*	P	P	P	P	H-I
Pink whipray	*Himantura fai*	A	A	A	A	L
Reticulate whipray	*Himantura uarnak*	A	A	A	A	L
Bleeker's variegated whipray	*Himantura undulata*	A	A	A	A	L

Common name	Scientific name	Level of interaction	Survival after interaction	Interaction throughout life cycle	TED/BRD effectiveness	Fishery impact profile
Leopard whipray	*Himantura leoparda*	A	A	A	P	L
Brown whipray	*Himantura toshi*	A	P	P	P	I
Mangrove whipray	*Himantura granulata*	A	A	A	A	L
Bluespotted maskray	*Neotrygon kuhlii*	P	PP	P	P	H
Speckled maskray	*Neotrygon picta*	P	PP	P	P	H
Cowtail stingray	*Pastinachus astrus*	A	A	A	A	L
Common stingaree	*Trygonoptera testacea*	P	PP	P	P	H
Patchwork stingaree	*Urolophus flavomosaicus*	P	P	P	P	H-I
Pale tropical skate	*Dipturus apricus*	P	PP	P	P	H
Argus skate	*Dipturus polyommata*	P	PP	P	P	H
Endeavour skate	*Dipturus endeavouri*	P	PP	P	P	H
Australian butterfly ray	*Gymnura australis*	P	P	P	P	H-I
Banded eagle ray	*Aetomylaeus nichofii*	A	P	A	A	L

Table 53. Resilience characters and decision rules: marine habitats.

Category	Character	Reasons for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
Distribution and abundance	Geographic distribution in Great Barrier Reef Marine Park	Extent and distribution of a habitat gives an indication of the potential risk from stochastic events (physical, chemical, ecological)	Large area within the Great Barrier Reef (≥ 10,000 km sq) widely distributed (≥ 50 per cent latitudinal spread)	Large area restricted (< 50 per cent latitudinal spread) within Great Barrier Reef; or small area (< 10,000 km sq) widely distributed (≥ 50 per cent latitudinal spread) throughout Great Barrier Reef	Small restricted area (< 10,000 sq km, < 50 per cent latitudinal spread) within Great Barrier Reef	New character
Resistance	Impact of trawling on key structural elements (proportion depleted/ removed by trawling)	The effects of trawling on key structural habitat elements (which make up 3 per cent or more of habitat type) provides an indication of ability of the habitat type to withstand the activities of the fishery	Low proportion of key structural elements removed by trawling: < 5 per cent of key structural elements rated as H or M	Medium proportion of key structural elements removed by trawling: < 5 per cent of key structural elements rated as H but > 5 per cent rated as M	High proportion of key structural elements removed by trawling: ≥ 5 per cent rated as H or unknown	Modified from NSW to suit available information and fishery
Regrowth or recolonisation	Ability of key structural elements to recover after being trawled (recovery period)	Capacity of key structural habitat elements (which make up 3 per cent or more of habitat type) to recover and/or recolonise the depleted area after trawling provides an indication of the ability of the habitat type to recover after trawling	Fast recovery of key structural habitat elements (recovery period): < 5 per cent of key structural elements rated as L or M	Medium recovery of key structural habitat elements (recovery period): < 5 per cent of key structural elements rated as L but > 5 per cent rated as M	Slow recovery of key structural habitat elements (recovery period): ≥ 5 per cent rated as L or unknown	Modified from NSW to suit available information and fishery
Other pressures in Great Barrier Reef Marine Park	Cumulative pressures	Degree of susceptibility of habitat type to other non-ECTF pressures (e.g. degraded water quality, habitat loss, climate change, non-ECTF fishing pressures) influences resilience and gives an indication of the ability to withstand activities of the fishery	Other pressures have little effect on habitat or effect is unknown. For example: Located offshore away from catchment influences and no cumulative risks known for major structural elements.	Other pressures considered to have significant effect on habitat. For example: Located inshore and exposed to cumulative pressures and/or cumulative risks known for major structural elements.		New character

Table 54. Fishery impact factors and decision rules: marine habitats.

Category	Factor	Reason for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
Do we know where the habitats are?	Knowledge of spatial distribution of habitat types	Basic knowledge of spatial habitat distributions is needed for risk analysis of fishery-wide impacts on habitats	Risk averse when distribution of habitats is known	Risk prone when distribution of habitats is not known		Factor used in NSW
Where does the fishing occur?	Knowledge of spatial distribution of fishing effort	Knowledge of where the fishery-related impact is occurring is needed for risk analysis of fishery-wide impacts on habitats	Risk averse when detailed distribution of fishing effort is known	Risk prone when detailed distribution of fishing effort is not known		Factor used in NSW
What overlap is there between the area in which the fishery operates and the distribution of habitat types?	Proportion of available habitat impacted by fishing gear (i.e. per cent effort exposed)	Gives indication of overlap of habitat type with current trawling effort, taking intensity into account. An indicator of impact effect size on different habitat types. Fishing effort may be concentrated on preferred subareas within broad habitat types.	≤ 25 per cent	> 25 per cent but ≤ 50 per cent	> 50 per cent	Modified from NSW to suit available information and fishery
Do habitats have adequate protection (refuge) from fishing impacts?	Proportion of total habitat which is permanently protected from trawling (i.e. per cent protected)	An indicator of protection from fishing impacts for habitats	Substantial refuge areas within Great Barrier Reef Marine Park (outside of general use zones available to trawling) i.e. equal to or greater than 20 per cent protection provided by Marine Park zoning	Few refuge areas within Great Barrier Reef Marine Park (outside of general use zones available to trawling) i.e. less than 20 per cent protection by Marine Park zoning, or protection level uncertain		Modified from NSW to suit available information and fishery
Is the use of 'high-impact' fishing gear currently permitted in the fishery?	Impacts caused by different gear types used in the fishery	An assessment of the need to exclude or modify certain gear types from the fishery	Risk averse in Great Barrier Reef Marine Park when high-impact gear is excluded or not used in the fishery	Risk prone in Great Barrier Reef Marine Park when high-impact gear is used in the fishery		Factor used in NSW

Table 55. Summary of resilience scores for habitats.

Habitat type	Geographic distribution in Great Barrier Reef Marine Park	Impact of trawling on key structural elements (proportion depleted/removed by trawling)	Ability of key structural elements to recover after being trawled (recovery period)	Cumulative pressures	Resilience level
Habitat 1	A	A	A	A	H
Habitat 2	A	A	A	A	H
Habitat 3	A	PP	PP	A	L
Habitat 4	A	P	A	A	H-I
Habitat 5	A	A	A	A	H
Habitat 6	P	A	A	P	I
Habitat 7	P	A	A	P	I
Habitat 8	P	P	P	P	L
Habitat 9	P	P	P	A	I-L
Habitat 10	P	P	PP	P	L

Table 56. Summary of fishery impact factor scores for habitats based on 2009 fishing effort levels.

Habitat type	Knowledge of spatial distribution of habitat types	Knowledge of spatial distribution of fishing effort	Per cent effort exposed 2009	Per cent protected	Impacts caused by different gear types used in the fishery	Fishery impact profile 2009
Habitat 1	A	A	A	A	A	L
Habitat 2	A	A	A	A	A	L
Habitat 3	A	A	A	A	A	L
Habitat 4	A	A	A	A	A	L
Habitat 5	A	A	A	A	A	L
Habitat 6	A	A	P	A	A	I-L
Habitat 7	A	A	P	A	A	I-L
Habitat 8	A	A	A	A	A	L
Habitat 9	A	A	A	A	A	L
Habitat 10	P	A	PP	P	A	H

Table 57. Summary of fishery impact factor scores for habitats based on 2005 fishing effort levels.

Habitat type	Knowledge of spatial distribution of habitat types	Knowledge of spatial distribution of fishing effort	Per cent effort exposed 2005	Per cent protected	Impacts caused by different gear types used in the fishery	Fishery impact profile 2005
Habitat 1	A	A	P	A	A	I-L
Habitat 2	A	A	A	A	A	L
Habitat 3	A	A	A	A	A	L
Habitat 4	A	A	A	A	A	L
Habitat 5	A	A	P	A	A	I-L
Habitat 6	A	A	P	A	A	I-L
Habitat 7	A	A	P	A	A	I-L
Habitat 8	A	A	A	A	A	L
Habitat 9	A	A	A	A	A	L
Habitat 10	P	A	PP	P	A	H

Table 58. Resilience characters and decision rules: species assemblages.

Category	Character	Reasons for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
Distribution and abundance	Geographic distribution in Great Barrier Reef Marine Park	Extent and distribution of an assemblage gives an indication of the potential risk from stochastic events (physical, chemical, ecological)	Large area within the Great Barrier Reef (≥ 5000 km sq) widely distributed (≥ 25 per cent latitudinal spread)	Large area restricted (< 25 per cent latitudinal spread) within Great Barrier Reef; or small area (< 5000 km sq) widely distributed (≥ 50 per cent latitudinal spread) throughout Great Barrier Reef	Small restricted area (< 5,000 sq km, < 25 per cent latitudinal spread) within Great Barrier Reef	New character
Associated species	Risk to species with high affinity and fidelity	Risk level for high affinity (> 5 per cent) species influences resilience of species assemblages. The assemblage resilience is expected to be lower if one or more high affinity species have a high effort exposure and/or catch from trawling.	No high affinity species at risk from trawling (i.e. each high affinity species has ≤ 25 per cent effort exposure and ≤ 25 per cent caught)	At least one high affinity species at moderate to high risk from trawling (i.e. one or more high affinity species has > 25 per cent effort exposure and/or > 25 per cent caught)		New character for Great Barrier Reef (NSW only used one character—physical resistance—to assess macroalgae)
Other pressures in Great Barrier Reef Marine Park	Cumulative pressures	Degree of susceptibility of assemblage type to other non-ECTF pressures (e.g. degraded water quality, habitat loss, climate change, non-ECTF fishing pressures) influences resilience and gives an indication of the ability to withstand activities of the fishery	Other pressures have little effect on assemblage or effect is unknown. For example: Located offshore away from catchment influences and no cumulative risks known for high affinity species and no cumulative risks known for associated habitat types.	Other pressures considered to have significant effect on assemblage. For example: Located inshore and exposed to cumulative pressures and/or cumulative risks known for high affinity species and/or cumulative risks known for associated habitat types.		New character

Table 59. Fishery impact factors and decision rules: species assemblages.

Category	Factor	Reason for use	Risk averse (A)	Risk prone (P)	Risk double prone (PP)	Compared to NSW?
What overlap is there between the area in which the fishery operates and the distribution of assemblage types?	Proportion of available assemblage impacted by fishing gear (i.e. per cent effort exposed)	Gives indication of overlap of assemblage type with current trawling effort, taking intensity into account. An indicator of impact effect size on different assemblage types. Fishing effort may be concentrated on preferred subareas within broad assemblage types.	≤ 25 per cent	> 25 per cent but ≤ 50 per cent	> 50 per cent	New factor to suit available information and fishery. Considered, but not used in NSW due to lack of information.
Do assemblages have adequate protection (refuge) from fishing impacts in Great Barrier Reef Marine Park?	Proportion of total assemblage which is permanently protected from fishery activity (i.e. per cent protected)	An indicator of protection from fishing impacts for assemblages	Substantial refuge areas within Great Barrier Reef Marine Park (outside of general use zones available to trawling) i.e. equal to or greater than 20 per cent protection provided by Marine Park zoning	Few refuge areas within Great Barrier Reef Marine Park (outside of general use zones available to trawling) i.e. less than 20 per cent protection by Marine Park zoning, or protection level uncertain		New factor to suit available information and fishery

Table 60. Summary of resilience scores for assemblages (as defined in Pitcher et al. 2007 and shown in Figure 23).

Assemblage type	Geographic distribution in Great Barrier Reef Marine Park	Risk to species with high affinity and fidelity	Cumulative pressures	Resilience level
Assemblage 1	A	A	A	H
Assemblage 2	A	A	A	H
Assemblage 3	A	A	A	H
Assemblage 4	A	P	A	H-I
Assemblage 5	P	A	P	I
Assemblage 6	A	A	P	H-I
Assemblage 7	P	P	P	I-L
Assemblage 8	A	A	A	H
Assemblage 9	A	P	P	I
Assemblage 10	A	A	P	H-I
Assemblage 11	A	P	P	I
Assemblage 12	P	P	P	I-L
Assemblage 13	P	P	P	I-L
Assemblage 14	P	A	A	H-I
Assemblage 15	A	A	A	H
Assemblage 16	PP	A	A	I

Table 61. Summary of fishery impact factor scores for assemblages based on 2009 fishing effort levels.

Assemblage	Per cent effort exposed 2009	Per cent protected	Fishery impact profile 2009
Assemblage 1	P	A	I
Assemblage 2	A	A	L
Assemblage 3	A	A	L
Assemblage 4	P	A	I
Assemblage 5	A	A	L
Assemblage 6	A	A	L
Assemblage 7	A	A	L
Assemblage 8	A	A	L
Assemblage 9	A	A	L
Assemblage 10	A	A	L
Assemblage 11	A	A	L
Assemblage 12	P	A	I
Assemblage 13	P	A	I
Assemblage 14	A	A	L
Assemblage 15	A	A	L
Assemblage 16	A	A	L

Table 62. Summary of fishery impact factor scores for assemblages based on 2005 fishing effort levels.

Assemblage	Per cent effort exposed 2005	Per cent protected	Fishery impact profile 2005
Assemblage 1	P	A	I
Assemblage 2	A	A	L
Assemblage 3	A	A	L
Assemblage 4	P	A	I
Assemblage 5	A	A	L
Assemblage 6	A	A	L
Assemblage 7	A	A	L
Assemblage 8	A	A	L
Assemblage 9	A	A	L
Assemblage 10	A	A	L
Assemblage 11	PP	A	H-I
Assemblage 12	PP	A	H-I
Assemblage 13	P	A	I
Assemblage 14	A	A	L
Assemblage 15	A	A	L
Assemblage 16	A	A	L

Table 63. Class level summary of Seabed Biodiversity Project SLED sampled biomass (i.e. site point data) scaled to average grams per hectare. The major filter feeding groups are highlighted, although some other classes do include a few filter feeding taxa. Sponges appear to dominate, but the sampling biases of any device should be noted.

Phylum	Class	Average grams per hectare	Per cent*	Per cent exposed*	Per cent effort exposed*
Annelida	Polychaeta	6	0.00	25.29	18.12
Arthropoda	Crustacea	2036	1.25	28.86	12.81
Bryozoa	Gymnolaemata	10354	6.34	24.36	9.39
Bryozoa	Stenolaemata	7	0.00	8.09	4.83
Chlorophyta	Chlorophyceae	30408	18.62	11.28	1.34
Chordata	Actinopterygii	1507	0.92	42.75	17.26
Chordata	Ascidiacea	15976	9.79	16.67	6.77
Chordata	Cephalochordata	0	0.00	0.00	0.00
Chordata	Chondrichthyes	3	0.00	0.00	0.00
Cnidaria	Actinaria	3	0.00	11.84	5.71
Cnidaria	Anthozoa	12657	7.75	24.47	6.72
Cnidaria	Cnidaria	694	0.43	97.44	1.35
Cnidaria	Hydrozoa	1494	0.91	10.69	2.25
Cnidaria	Octocorallia	5	0.00	25.37	5.42
Cyanophyta	Cyanophyceae	116	0.07	14.27	7.15
Echinodermata	Asteroidea	5637	3.45	35.05	17.18
Echinodermata	Crinoidea	5873	3.60	11.48	3.68
Echinodermata	Echinoidea	4137	2.53	22.62	10.68
Echinodermata	Holothuroidea	4414	2.70	21.38	14.46
Echinodermata	Ophiuroidea	1465	0.90	23.07	4.07
Magnoliophyta	Liliopsida	4552	2.79	49.04	17.93
Mollusca	Aplacophora	32	0.02	65.60	45.47
Mollusca	Bivalvia	8651	5.30	25.15	15.57
Mollusca	Cephalopoda	232	0.14	28.72	11.31
Mollusca	Gastropoda	2061	1.26	26.82	10.94
Phaeophyta	Phaeophyceae	2927	1.79	72.98	26.36
Porifera	Calcarea	180	0.11	17.64	2.40
Porifera	Demospongiae	33385	20.45	16.27	6.86
Rhodophyta	Rhodophyceae	14452	8.85	62.59	7.84

** Percent is the proportion of total biomass contributed by each class. See Appendix 2.2.4 for explanation of Per cent exposed and Per cent effort exposed.*

Table 64. Species with positive trawl coefficients in the Seabed Biodiversity Project. Source: Data provided by Pitcher, C.R. 2011

Class	Genus	Species	Per cent protected	Per cent exposed	Per cent effort exposed	Per cent change
Actinopterygii	*Brachaluteres*	*taylori*	29	60	72	96
Crustacea	*Penaeus*	*semisulcatus*	26	64	174	50
Crustacea	*Cryptolutea*	*arafurensis*	43	41	128	19
Actinopterygii	*Pelates*	*quadrilineatus*	31	47	103	18
Actinopterygii	*Pentaprion*	*longimanus*	38	48	117	13
Bivalvia	*Amusium*	*balloti*	45	37	45	12
Crustacea	*Portunus*	*gracilimanus*	41	38	86	11
Actinopterygii	*Leiognathus*	*leuciscus*	41	43	95	10
Actinopterygii	*Leiognathus*	*bindus*	58	28	63	9
Actinopterygii	*Saurida*	*grandi/undo*	41	37	46	7
Gastropoda	*Xenophora*	*indica*	56	27	30	7
Crustacea	*Penaeus*	*latisulcatus*	41	39	49	6
Crustacea	*Myra*	*tumidospina*	43	38	60	6
Crustacea	*Liagore*	*rubromaculata*	52	25	43	5
Crustacea	*Trachypenaeus*	*anchoralis*	36	44	67	4
Actinopterygii	*Elates*	*ransonnetii*	70	12	17	1
Rhodophyceae	*Haloplegma*	*duperreyi*	56	24	20	0

** See Appendix 2.2.4 for explanation of Per cent protected, Per cent exposed and Per cent effort exposed. Per cent change is the relative change in biomass of those species as a result of the history of trawling in the Great Barrier Reef Region: for example, the Per cent change for Brachaluteres taylori was 96%, indicating this species was nearly twice as abundant due to trawling.For further background, see Pitcher et al. 2007b (particularly section 3.7.2.1 starting on page 3-217 of that report). The coloured shading in this table follows that used in Pitcher et al. 2007b.*

The content of the accompanying DATA REPORT (available from www.gbrmpa.gov.au) is as follows:

Data Report: Appendix 1.	Resilience of principal species
Data Report: Appendix 2.	Resilience of other permitted species
Data Report: Appendix 3.	Fishery impact profile of principal species 2005
Data Report: Appendix 4.	Fishery impact profile of principal species 2009
Data Report: Appendix 5.	Fishery impact profile for other permitted species 2005
Data Report: Appendix 6.	Fishery impact profile for other permitted species 2009
Data Report: Appendix 7.	Resilience of by-catch species
Data Report: Appendix 8.	Fishery impact profile of by-catch species 2005
Data Report: Appendix 9.	Fishery impact profile of by-catch species 2009
Data Report: Appendix 10.	Resilience of marine turtles
Data Report: Appendix 11.	Fishery impact profile of marine turtles
Data Report: Appendix 12.	Resilience of sea snakes
Data Report: Appendix 13.	Fishery impact profile of sea snakes
Data Report: Appendix 14.	Resilience of seahorses and pipefish
Data Report: Appendix 15.	Fishery impact profile of seahorses and pipefish
Data Report: Appendix 16.	Resilience of sharks and rays
Data Report: Appendix 17.	Fishery impact profile of sharks and rays
Data Report: Appendix 18.	Impact and recovery of the main living habitat elements
Data Report: Appendix 19.	Resilience of marine habitats
Data Report: Appendix 20.	Fishery impact profile of marine habitats 2005
Data Report: Appendix 21.	Fishery impact profile of marine habitats 2009
Data Report: Appendix 22.	Resilience of species assemblages
Data Report: Appendix 23.	Fishery impact profile for species assemblages 2005
Data Report: Appendix 24.	Fishery impact profile for species assemblages 2009

This ecological risk assessment is available at www.gbrmpa.gov.au