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Risk Assessment of Sea Turtle Capture in the Queensland East Coast Otter Trawl Fishery

Final Report

This is a report prepared for TRAWLMAC and does not necessarily reflect Queensland State government policy

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EXECUTIVE SUMMARY

Sea turtles are caught incidentally in trawl fisheries along the east coast of Australia. This raised a number of concerns amongst management agencies and conservation groups. While trawl fisheries are a hazard, it is not clear just what level of risk the fisheries pose to the long term viability of sea turtle stocks along the east coast of Queensland. As a consequence of this concern, a risk assessment of trawling capture to sea turtles inhabiting waters of the Queensland east coast was undertaken by an inter-agency project team. This team comprised of officers from the following:

- Great Barrier Reef Marine Park Authority (GBRMPA)
- Queensland Department of Environment and Heritage (DEH)
- Queensland Department of Primary Industries (DPI)

The aim of the project was to undertake a spatial analysis of the exposure of sea turtles to trawl capture (risk assessment) within the Queensland East Coast Otter Trawl Fishery (ECOTF). This risk assessment was accomplished by pooling datasets held by each agency. These were: estimates of significant nesting areas (DEH, GBRMPA), frequency of turtle capture within trawl nets (DPI) and distribution of trawling effort (GBRMPA, Queensland Fish Management Authority). The risk assessment was undertaken for the following four sea turtles species:

- loggerheads
- flatbacks
- greens
- hawksbills

Specifically, the risk assessment used spatial overlays of the following datasets:

- distribution of significant sea turtle breeding and known feeding areas
- DPI turtle capture data and trawl effort (catch per unit effort-CPUE) from 1991-96 obtained through a DPI voluntary turtle monitoring program: 30 NM grid scale
- QFMA 'QFISH' trawl effort data 1993-1996 at 6 NM grid scale
- data on key population status parameters

These data were analysed to provide estimates of risk on a relative scale from 0 (lowest) to 10 (highest). The 0 - 10 point relative scale was also grouped into 4 broad categories of relative risk as follows —

- risk categories > 6 -10 assigned to "highest risk"
- risk categories > 3 -6 assigned to "medium risk"
- risk categories > 0 - 3 assigned to "lowest risk"
- risk categories 0 assigned to "no risk"

These four arbitrary relative risk categories are used to help summarise the 0 - 10 point risk scale and make it easier to visualise trends in the risk maps developed by the project team.

The output was a set of maps of the relative risk using both the 0 -10 point scale and the 4 category scale for each species from capture in trawl fisheries within 6 nautical mile (NM) grid cells. These four maps were then combined into a single fifth map showing the combined relative risk for all species at the same spatial scale.

Those five maps were then reviewed by the project team to identify areas where sea turtles were considered at most risk, and hence are areas that may require remedial action. The maps identify the following regions of highest risk:

- Milman Island area
- Round Pt (Shelbourne Bay) to Cape Melville (Bathurst Bay)
- Cape Flattery to Mulgrave River
- Townsville/Magnetic Island
- Ayr to Proserpine
- Mackay to Hay Pt
- Curtis Island
- Round Hill to northern Hervey Bay
- Moreton Bay
- Square Reef

The QFMA have proposed a number of areas for restricting trawling unless Turtle Exclusion Devices (TEDs) are fitted to trawl nets. Those areas were identified using less detailed datasets on sea turtle distribution and population status than was used in the current study. In general, the QFMA proposed areas coincide with many of the areas identified as high risk in the current study.

There are however a number of important differences including the following significant areas identified in the current study:

- Elliot River to Round Hill coast out to Sandy Cape including northern Hervey Bay
- Mackay area
- Ayr to Proserpine
- Magnetic Island
- Palm Islands
- Milman

Unlike the list of QFMA critical areas, the region from Repulse Bay to Newry Island area north to Mackay was not identified as an area of highest risk in this study.

The current risk assessment of sea turtles to trawl captures has —

- confirmed the appropriateness of most of the critical areas identified by the QFMA
- identified several additional areas that need consideration in the light of these findings

1. INTRODUCTION

1.1 Sea turtles

Six of the worlds seven species of sea turtles inhabit Australian waters. They are the loggerhead turtle, *Caretta caretta*; green turtle, *Chelonia mydas*; flatback turtle, *Natator depressus*; hawksbill turtle, *Eretmochelys imbricata*; olive ridley turtle, *Lepidochelys olivacea* and leatherback turtle, *Dermochelys coriacea*. Five of these species are listed under the Commonwealth *Endangered Species Protection Act 1992* and all six are listed under the *Queensland Nature Conservation Act 1994* (Table 1).

The listing reflects the perceived cumulative effects of human activities on sea turtles as well as the ability of particular species to sustain such effects (eg the consequence of a long age to maturity).

Table 1: Conservation listing of sea turtles (Commonwealth & Queensland Government Legislation)

Species		Conservation Status	
		Commonwealth[a]	Qld[b]
Chelonia mydas	green turtle	v	v
Caretta caretta	loggerhead turtle	e	e
Natator depressus	flatback turtle	nl	v
Eretmochelys imbricata	hawksbill turtle	v	v
Lepidochelys olivacea	olive Ridley turtle	v	e
Dermochelys coriacea	leatherback turtle	v	e

[a]Commonwealth: *Endangered Species Protection Act 1992*, schedule 1
[b]Queensland *Nature Conservation Act 1994*

The loggerhead turtle is classified as endangered under both sets of legislation and is considered by conservation agencies as a priority species for protection.

In Queensland, all sea turtle species except for leatherbacks, are regularly caught during trawl operations (Robins 1995; Poiner and Harris 1996). The risk of capture varies with the seasonal and spatial distribution of each species and how these factors overlap with the distribution of trawling. Trawl capture may result in the injury or death or increased predation of turtles.

In Queensland, trawling occurs on both the east and west coasts, and in Torres Strait. The west coast falls within the Commonwealth managed Northern Prawn Fishery where turtle captures were estimated to be about 6000 per year in 1990 (Poiner and Harris 1996).

The Torres Straight trawl fishery is managed by the Australian Fisheries Management Authority (AFMA) for which there are no published data on the numbers of turtles captured. The east coast falls mostly within Queensland State Government managed Queensland East Coast Otter Trawl Fishery (ECOTF) in which captures were estimated to be about 5000 per year (Robins 1995). Captures are not distributed uniformly in either fishery. The degree of risk of capture is potentially different for each species (Chaloupka 1997).

In July 1997, an inter-agency meeting was held in Townsville to discuss turtle-trawl interactions. It was sponsored by the Fisheries Research and Development Corporation (FRDC) Effect of Trawling Sub-programme and included representatives from the CSIRO (Division of Marine Research), Queensland Department of Primary Industries (DPI), Department of Environment and Heritage (DEH), Queensland Fish Management Authority (QFMA), Queensland Commercial Fisherman's Organisation (QCFO) and the Great Barrier Reef Marine Park Authority (GBRMPA). At this meeting it was agreed to combine information that had been collected by the DEH and the GBRMPA with that collected by the DPI.

DEH and the GBRMPA had established a project to identify biologically significant areas for sea turtles in Queensland (Appendix 2, Slater and Limpus 1998) and to map these against trawling effort data that had been analysed by the GBRMPA. The addition of the DPI dataset of turtle captures in trawl nets of the Queensland ECOTF would enhance the identification of areas where turtles were at risk as a consequence of trawling.

As such, an inter-agency working group was initiated to allow integration of the datasets as well as developing a logical and transparent method to analyse the risk of turtles to a trawl capture. The results are presented as spatial overlays of turtle catch per unit effort against trawl effort by species and for all species combined. The assessment is restricted to the Queensland east coast as datasets for the Northern Prawn Fishery and the Torres Straight were not available.

1.2 The Queensland East Coast Otter Trawl Fishery

The Queensland east coast supports a complex multi-species trawl fishery, extending from Cape York Peninsula in the north (10 30'S,142 30'E) to the Queensland/New South Wales border at about 28° S. This area includes several major estuaries and bays, a wide continental shelf and the Great Barrier Reef complex. The Great Barrier Reef is listed as a World Heritage Area. The fishery is dominated by vessels targeting prawns and scallops.

Commercial catch and effort is not uniformly distributed throughout the fishery. Four areas show a concentration of effort: (1) Moreton Bay, (2) Princess Charlotte Bay, (3) the Townsville region and (4) Bundaberg/Hervey Bay area. Hervey Bay and Moreton Bay are outside the Great Barrier Reef World Heritage Area. As such a major proportion of the catch from trawl fisheries catch of Queensland east coast is taken within the GBRWHA.

Operators within the Queensland ECOTF are required by law to complete a daily logbook of fish catch and effort. The daily catch (by weight) of each vessel is usually recorded within 30 square nautical-mile grids, with some of the more recent data being recorded within 6 nautical-mile (NM) grids or on a tow-by-tow basis. The database is managed by the QFMA.

1.3 Agency responsibilities

The incentive for this project was the recognition of the need to allow inter-agency collaboration to validate the location of 'critical areas' of turtle capture by trawl fisheries. This is one of the mitigation measures outlined by the QFMA in 1997, in a discussion paper on the Queensland Trawl Fishery.

The discussion paper contained an objective which was to 'develop management plans for all fisheries based on the principles of ecological sustainability'(Anonymous 1996). The QFMA is responsible for the fishery and the development of management plans under the Queensland *Fisheries Act 1994*. With respect to endangered, threatened or rare species, particularly sea turtles, the discussion paper proposed a package of mitigation measures based on:

- a pre-determined level of bycatch (particularly turtle) reduction within prescribed periods, aiming at reduction in the trawl capture of turtles by 50% by the year 2000
- the identification of critical areas/or times for restricting trawling, unless Turtle Exclusion Devices (TEDs) are fitted to trawl nets
- an educational program directed towards industry being well-informed on issues pertaining to endangered species
- spatial restrictions to the use of trawl nets without TEDs fitted
- seasonal closures to the use of trawl nets without TED fitted
- further development and utilisation of Codes of Practice that minimise the effects of trawling on endangered species

In the discussion paper, the Trawl Management Advisory Committee (TRAWLMAC) through the QFMA also recommended the immediate trialing of a range of turtle-excluding systems in areas where the probability of turtle capture is appreciable.

The three agencies which collaborated in the risk assessment are:

- The **Department of Primary Industries** is a rural economic development agency bringing together government and industry in partnership to increase the profitability of primary industries-based enterprises on a sustainable basis.

- The **Great Barrier Reef Marine Park Authority** is a Commonwealth agency that operates under the *Great Barrier Reef Marine Park Act 1975 (Cth)* and as such, is required to 'make provision for and in relation to the establishment, control, care and development of the Marine Park. It is also required to be informed by the precautionary principle[1] in protecting world heritage values under the *Act*, which include rare, threatened and endangered species. Under the 25 year strategic plan for the Great Barrier Reef World Heritage Area, the Authority has undertaken to pay special attention to conserving rare and endangered species and prevent ecologically unsustainable loss and degradation of marine biological communities. The *Act* also has effect subject to international law, including any agreement between Australia and any other country or countries.

- The **Department of Environment and Heritage,** which is the State Government's lead agency for promoting the protection and wise use of the environment to support the economic and social wellbeing of Queensland. The Departmental goals are —
  - a clean and safe environment
  - maintenance of biological diversity
  - sustainable use of wildlife resources
  - sustainable economic and community development
  - maintenance of cultural heritage

1.4 Risk assessment

Risk comprises the following four elements:

- Hazard
- Exposure to the hazard
- Consequences of exposure
- Social evaluation of the consequences

These four components comprise what is known as the conventional risk chain (Merkhofer 1987). Risk assessment comprises the first three components of the risk chain. This study is only a risk assessment and not a fully comprehensive risk analysis which would comprise all four components of the risk chain (Francis and Shotton 1997).

2. OBJECTIVE

To provide a risk assessment of sea turtles exposed to the Queensland East Coast Otter Trawl Fishery (ECOTF).

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[1] Great Barrier Reef Marine Park Act 1975 (Cth): Part VB, S39Z (1) The Authority to be informed by the precautionary principle in preparing plans and protecting world heritage values.

3. METHODS

The risk assessment involved two stages. Stage one was the pooling of datasets between DEH, the GBRMPA and DPI. The second stage was the spatial analysis of these overlaid datasets and the development and implementation of a method to calculate "risk" areas.

3.1 Stage 1: The datasets

3.1.1 Biological Data

The conservation component of this dataset was the determination of the appropriate weighting of each species in regard to priority. The parameters assessed were:

- **Conservation status** as listed under the Queensland *Nature Conservation Act 1992.*
- **Population stability** - This parameter relates to whether stocks are known to be stable, increasing or declining. It is based on census, tagging and aerial survey data (Limpus 1995).
- **Nesting population (x 1000)** - Refers to the size of annual nesting turtle counts within the Queensland east coast. Low nesting populations are regarded as those of less than 1000, except for leatherbacks, where the total number of nesting female turtles is usually less than 3 individuals per year.
- **Proportion of local stock within Queensland east coast waters** - This parameter is based on what proportion of the feeding and nesting animals within waters of the Queensland east coast belong to the same east coast stock. Genetic stock assessment data has been collected through mtDNA studies (Moritz et al 1998) and tagging (Limpus 1995).
- To explain the coding in Table 2, 'all' (e.g., flatbacks; loggerheads) means that the entire local stocks of those turtles are nesting and feeding animals belonging to that east coast population. This factor makes those populations more vulnerable to anthropogenic impacts in that discreet region compared to species such as hawksbill turtles, whose stocks are spread between the Queensland east coast and other regions. When combined, these parameters give an indication of vulnerability or "risk status" to which an inter-species weighting was assigned (Table 2). The inter-species weightings are used in the stage 2 of the risk assessment .
- **Endemism**- This parameter is based on whether a species is endemic to Australia, for example, the flatback.

Table 2: Overview of population parameters for six turtle species inhabiting the ECOTF.

Species	Conservation status in Qld	Population stability	Nesting Pop. [x 1000]	Endemic	Proportion of pop in east coast waters	Risk status	Inter species weight	Breeding season
Loggerhead	Endangered	decreasing	<0.5	no	all	H	3	Oct-Febr
Flatback	Vulnerable	no signif decline	~1	yes	all	H	2	Oct-Jan
Green	Vulnerable	no signif decline	~50	no	most	L	1	Oct-Apr
Hawksbill	Vulnerable	unknown	~2-3	no	50%[&]	M	2	Dec-April
Olive Ridley	Endangered	unknown	unknown	no	unknown	unknown	excluded	unknown
Leatherback	Endangered	unknown	see text	no	unknown	M	2	Dec-Febr

[&] South Pacific stocks.

With respect to the Table 2, loggerheads were weighted as high (3) because of the decreasing small population and a single stock impacted in Queensland east coast waters. Olive Ridleys were not included in this analysis because of the following:

- no known nesting in east coast Queensland
- breeding stock unknown
- foraging ground abundance unknown

Leatherbacks are rarely reported as captured by fishers from the Queensland ECOTF (Limpus 1995, Robins 1995) and there were no capture data for leatherbacks recorded in the DPI turtle monitoring program. Consequently, this species was not included in the risk assessment.

The spatial component of this dataset was the identification of times and locations of significant aggregations of each species of sea turtles. The criteria for determining significant rookeries and associated inter-nesting areas for each species were based on the known number of annually nesting females at each rookery and their genetic stock status (Limpus 1995; Appendix 1).

Numbers of nesting turtles for a significant rookery were loggerheads - 25, flatbacks -greater than 50, greens - greater than 100 and hawksbills - greater than 50 (Limpus 1997). This information was collected through mark-recapture studies, satellite tracking, census counts at rookeries and aerial surveys conducted primarily by the Turtle Research Project Group Department of Environment and Heritage (Limpus 1995). A detailed overview of the biological assessment undertaken is presented in Appendix 2.

Specific turtle feeding areas were not factored into the risk assessment because waters of the entire Queensland east coast are potential feeding grounds for sea turtles. It was assumed that turtle catch per unit effort would be an indicator of sea turtle density within areas that had been sampled by trawling effort within the DPI program.

3.1.2 Effort Data

The spatial distribution of trawl effort was derived by averaging annual trawl efforts from 1993 to and including 1996. Also the spatial distribution of 1996 trawl data for each of the breeding seasons (Table 2). Note that the breeding seasons were composed of months in the beginning of 1996 and at the end of 1996. The data was based QFMA commercial logbook data and reworked into a six minute grid by GBRMPA.

3.1.3 DPI Turtle Capture Information

A selective logbook program was set up in January 1991 to monitor the capture of sea turtles in trawls nets of the Queensland East Coast Otter Trawl Fishery. Fishers were approached individually to assist the program and only those that expressed keen interest in recording information were selected to participate.

Over the 6 years, 106 different boats took part in the program. Some fishers consistently returned information over the whole 6 years, others assisted the program for varying amounts of time. Overall, 12% of the Queensland trawling fleet were involved in the research program.

Fishers that were selected to participate in the program were supplied with a data kit that included species identification chart (based on taxonomic features, with assisting photographs), and standardised data sheets. Fishers recorded data including the date, time, location and species of the turtle captured.

Fishers were instructed how to identify different turtle species using the identification chart but if unsure of the species of the turtle, were instructed to record the species as unidentified. Fishers catching more than 5 turtles per year were given disposable cameras so that their species identification could be checked and verified. The physical condition of the turtle upon capture was recorded and classified as either healthy, externally injured, comatose or dead.

Recording of effort (days fished)

Catch and effort data for commercial fishers participating in the monitoring program (hereafter referred to as the sample fleet) were retrieved from the QFISH database as were the catch and effort data for the whole commercial trawl fleet (hereafter referred to as the total fleet).

Estimation procedures

The variable of interest is turtle captures, both by species and in total. This is estimated by the product of the two available variables, namely turtle CPUE by fleet effort. This product of two independent parameters gives an unbiased estimator of the total (Pollock et al. 1994). For each QFISH grid, the base data of individual turtle captures and sample fleet effort were summed into monthly values for CPUE and total fleet effort, over the six years 1991 to 1996. Simple arithmetic calculations were performed on the monthly CPUE and total fleet effort to calculate average CPUE (± standard deviation) and average annual effort as days fished (± s.d.). CPUE was calculated for all species combined and also individually for the 5 species (plus unidentified turtles) reported in the monitoring program. Estimated captures were the multiplication of average CPUE by average days fished.

Assumption in calculations of turtle CPUE

1. all turtles caught by the selected fishers in the turtle monitoring program were accurately reported
2. fishing effort is accurately reported to the QFMA compulsory catch and effort logbook system (QFISH)
3. average CPUE is representative of the frequency of turtle capture with 30 ^{2} nautical mile grids, and this average CPUE is constant throughout the year

Possible sources of error

CPUE was calculated from data supplied on a voluntary basis by commercial fishers participating in the monitoring program. It is possible that the sample fleet is not a random selection of the whole fleet. Because it was a voluntary program, commercial fishers who caught or killed many turtles may not have shown an interest to participate in the program.

It is also possible that commercial fishers who caught or killed few turtles showed not interest to participate in the program because they may feel that such non-capture data is not important. Any biases in the data due to the non-random representation of the whole fleet are unquantified, it would be extremely speculative to suggest the effect of bias in the dataset.

Small scale differences in the fishing behaviour of individual fishers may influence the catch rate of turtles in a particular area. These differences would be masked when the catch and effort data is pooled for each 30 x 30 nautical mile (NM) QFISH grid.

If fishers did not accurately record details of turtles caught (ie. assumption 1. of this study is violated), then CPUE may be underestimated. The degree of inaccurate reporting should be variable, because different fishers have different motivation an would report differently.

This variation in CPUE would be reflected in the 95% confidence intervals. The more variable the CPUE, the wider the 95% confidence interval. It would take a concerted effort from the majority of the commercial fishers in this study (some 100 individuals over the 6 years) to have a major effect on data accuracy.

3.2 Stage 2: Spatial overlay and risk assessment

Three data sets (biologically significant areas; CPUE at 30 NM scale; and trawling effort (at 6 NM scale) were spatially overlayed on a Geographical Information System (GIS). An algorithm was developed to analyse the overlay and determine a risk ranking for each cell at the 6 NM scale. The method follows the conventional risk chain concept and assumes that the risk is proportional to exposure to the hazard multiplied by the impact of that hazard.

3.2.1 Summary of method

A detailed discussion is given in Appendix 1, 'Methods and Implementation'. Due to the fact that there was insufficient information about population sizes of the various turtle species, the reported CPUE multiplied by the total trawl effort per grid cell was used as a substitute for the probability of a turtle being caught.

The impact was defined in terms of where the turtle was caught (inside or outside an inter-nesting area for that species) and what the risk status of that species was.

3.2.2 Risk by species

For each individual species (except olive ridley), the product of the estimates of the number of turtles caught, multiplied by the impact, was calculated for every 6 minute grid cell, and the resulting values were scaled to range between 0 (lowest risk) and 10 (highest risk). These data were then mapped.

3.2.3 Risk for all species combined

The risk assessment for the four species combined (flatback, loggerhead, green and hawksbill turtles) was achieved by finding the weighted (conservation status) maximum per grid-cell over the contributing species.

The resulting values were mapped and presented in an overall species risk map. Subsequently, all geometric parts making up an internesting area were given the same value, namely the maximum value of any of them. The overall maps were again scaled back to contain values between 0 and 10.

The olive Ridley was not included in the second step due to the absence of data regarding their biological risk status. However, maps were produced to show the relative risk distribution of the olive ridley based on CPUE for the species and trawl effort.

4. RESULTS

Four maps were produced (Figs.1-4) that display the spatial distribution of the risk of trawl capture for loggerhead turtles, flatback turtles, green turtles and hawksbill turtles

The fifth map (Fig. 5) displays the maximum risk of trawl capture of any of the above 4 species, weighted for conservation status (i.e. inter-species weighting, Table 2). For the Olive Ridley turtle, Figure 6 provides an overlay map of turtle-CPUE with trawling effort at the 6 NM grid scale

4.1 Interpretation of maps

- Areas in which trawl effort was recorded, but no turtle catch during the DPI turtle monitoring program, are represented as white spaces at the 6 NM grid scale and labelled 'true zero' cells.

Elsewhere, areas of pale yellow represent those parts of the ECOTF that were either:

- not sampled during the DPI turtle catch monitoring program
- for which no log book data were available. The majority of these areas occur on the edge of the Queensland continental shelf and represent a minor proportion of the Queensland east coast otter trawl fishery. The exceptions are the areas around Broadsound - Shoalwater Bay as well as waters south of Double Island Point to the Queensland border.

4.2 The combined species map

The project team identified 14 risk areas by reference to risk categories 6-10 in Fig. 5.

Location	Risk category	No. grid cells
Milman Island area	6-7	8
Round Pt (Shelbourne Bay) to Cape Melville (Bathurst Bay)	6-7	17
Cape Flattery to Mulgrave River	6-7	17
Cape Grafton (Cairns)	9-10	2
Magnetic Island	9-10 7-8 6-7	1 1 1
Townsville	8-9 7-8	1 1
Cape Upstart /Ayr to Proserpine	7-8 6-7	1 5
Mackay- Hay Point	7-8	1
Square Reef	9-10	1
Northwest side of Hayman Island	6-7	1
Curtis Island	6-7	1
Round Hill to northern Hervey Bay	9-10	16
Lady Elliot Island	6-7	1
Moreton Bay	9-10	26

Caution is required when interpreting the following areas scored as "highest risk" (categories 6-10) because of small sample sizes and difficulties with matching data collected at a 30 NM scale with data collected at a 6 NM scale —

Cape Grafton — This area has several grids with a risk category of 6-7 and 2 grids with a risk category of 9-10. The turtle captures that occurred within the 2 grids with a risk category of 9-10 occurred along the line of longitude of 146° 00 E and were arbitrarily allocated to the eastern QFISH grid I16 rather than the western QFISH grid H16. This means some caution should be used in interpreting this area. It is most likely that the Cape Grafton area has risk values within the mid-range rather than having 2 distinct grids with significantly higher risk values.

Square Reef — Turtle CPUE for this grid was calculated from limited sampling effort with few turtle captures. Regardless of the amount of total effort in this grid, the turtle CPUE would result in a high level of risk. Given the low sampling effort, it is possible that the risk category of 9-10 is not representative of the area. As such this 6 NM grid cell should be viewed with caution. However, because the captures recorded were of loggerheads, an endangered species, the area warrants monitoring and further investigation.

Lady Elliot Island (about 6 NM North East) — It is likely that the risk category 6-7 associated with 1 6 NM grid north east of lady Elliott Island is the result of an average turtle CPUE for QFISH grid V31 with a high concentration of trawl effort. All turtle captures within V32 were recorded in less than 11 metres water depth. The grid in question is in about 100 m water depth. As such this area should be viewed with caution as the risk category is likely to be a function of the overlying of 30 NM data with 6 NM data.

4.3 Loggerhead turtles

As this species is a priority for consideration, it is useful to examine where areas of elevated risk occur for loggerhead turtles. All areas of highest risk for this species (Fig. 1) are contained among the areas identified as highest risk for all species combined (Fig. 5).

The highest risk areas for loggerheads from this assessment include:

Location	Risk category	No.grid cells
Moreton Bay	9-10	26
Elliot River to Round Hill, out to Sandy Cape encompassing northern Hervey Bay	9-10	16
Cairns (Cape Grafton)	9-10	2
Mackay-Hay Point	7-8	1
Ayr to Proserpine	6-8	6
Townsville	8-9	1
Townsville	7-8	1
Square Reef	9-10	1

5. DISCUSSION

The QFMA have proposed a number of areas for restricting trawling unless TEDs are fitted to trawl nets. Those areas were identified using less detailed data on sea turtle distribution and population status than was available to the current study. In general, the QFMA proposed areas coincide with many of the areas identified as high risk in the current study. There are however a number of important differences including the following significant areas identified in the current study:

- Bundaberg to Round Hill coast out to Sandy Cape including northern Hervey Bay
- Mackay area
- Ayr to Proserpine
- Magnetic Island
- Palm Islands
- Milman Island area

Unlike the list of QFMA critical areas, the region from Repulse Bay to Newry Island area north to Mackay was not identified as an area of highest risk in this study.

The following limitations in the available data should be considered in interpreting the results of the risk assessment:

- The risk assessment in the current study was based on historical patterns of effort distribution and trawling closures. If the temporal and spatial nature of the fisheries should change, then the outcomes of the current risk assessment would no longer be valid.

- There is limited knowledge on the distribution of "important" feeding areas for each species. For this reason, the current risk assessment could not determine risk for the important feeding/developmental areas in which turtles spend most of their lives.
- The DPI turtle monitoring program covered a large portion of the east coast otter trawl fishery, but there are some gaps. The major gaps are between Double Island Point to the Qld/NSW border (excluding Moreton Bay); Lagoonal areas of the Swains/Pompey Reef complex and from Ayr and Townsville.

These deficiencies in the sampling program indicate the need for more comprehensive surveys to be undertaken in those areas before valid conclusions can be drawn about them.

This study was a risk assessment based solely on assessment of exposure of sea turtles to the ECOTF. The analysis has not explicitly taken into account the third component of the risk chain, and that is the consequences of that exposure (e.g. injury or drowning, Poiner and Harris 1996; Robins 1995).

Simulation modelling of loggerhead population viability (Chaloupka and Limpus 1997) has shown that the east Australian loggerhead stock is potentially at risk from exposure to trawl fisheries and that the apparent decline observed in the loggerhead nesting stock could be due in part to extensive drowning of subadult and adult loggerheads in the ECOTF. Therefore, the current study has based its analysis on the likelihood of capture in the ECOTF assuming that capture will lead to higher levels of mortality and hence decreased population viability.

REFERENCES

Chaloupka M (1997) Otter trawling, a threatening process for Australian marine turtles. Queensland Department of Environment submission to 'Environment Australia' regarding the public nomination of otter trawling as a key threatening process to ANCA 1995.

Chaloupka MY, Limpus CJ (1997) Heuristic modelling of trawl fishery impacts on sGBR loggerhead population dynamics. In: Epperly, S.P., and J. Braun (compilers) Proc 17th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech Memo NMFS, Miami.

Francis RICC, Shotton W (1997) Risk in fisheries management: a review. Can J Fish Aquat Sci 54: 1699-1715.

Limpus CJ (1997). Biologically significant areas for species of sea turtles in Queensland. Unpublished map series for the Queensland Department of Environment and the Great Barrier Reef Marine Park Authority.

Limpus CJ (1995) Conservation of Marine Turtles in the Indo-Pacific Region. Unpublished report to the Australian Nature Conservation Agency, October 1995.

Merkhofer MW (1987) Decision science and social risk management: a comparative evaluation of cost-benefit analysis, decision analysis and other formal decision-aiding approaches. D. Reidel Publishing Company, Dordrecht, Holland.

Moritz C (1998) Genetic status of sea turtle stocks for Queensland. Unoublished report to the National Turtle Recovery Team.

Pitcher CR, Burridge CY, Wassenberg TJ, Poiner IR (1996) The effects of prawn trawl fisheries on GBR seabed habitats. In Proceedings of The Great Barrier Reef, Science, Use and Management: A National Conference, November 25-29, Townsville 1996 (in press).

Poiner IR, Harris, ANM (1996) Capture and of sea turtles in Australia's Northern Prawn Fishery. Marine Biology 125: 813-825.

Pollock KH, Jones CM, Brown TL (1994) Angler survey methods and their applications in fisheries management. American Fisheries Society, Bethesda.

Queensland Fisheries Management Authority (1996) Discussion Paper No.5: Queensland Trawl Fishery. Prepared for the QFMA by the Trawl Fishery Management Advisory Committee.

Queensland Fisheries Management Authority (1998) Queensland Trawl Fishery proposed management arrangements, 1998-2005. QFMA.

Robins JB (1995) Estimated catch and mortality of sea turtles from the East Coast Otter Trawl Fishery of Queensland, Australia. Biological Conservation 74: 157-167.

Slater JE, Limpus CJ (1997) Assessment of biologically significant areas to species of sea turtles in Queensland. Unpublished report to the Great Barrier Reef Marine Park Authority

APPENDICES

Appendix 1: Methods and Implementation

In this case the risk that the trawling activity poses to the Queensland east coast turtle stocks equals the chance of capture multiplied by the impact of that capture. The definition of risk (in formula form) this would look like:

$$R_{sp} = P_c(\text{species}) * Imp_c(\text{species, life cycle stage}) \qquad (1)$$

where :

R_{sp} is the risk to a turtle species
P_c(species) is the probability of capture given the species
Imp_c(species, life cycle stage) is the impact of a capture given the species and the life history stage at catch.

The life history stage at which the turtle is caught was assumed to have an important impact on the population. As a proxy for this, the capture of an animal inside internesting areas is thought to have twice the impact on the population than it would if it had been caught outside the area. Consequently the risk is thought to be double.

These were called "biological significant areas" (Bsa). Note that the term Bsa has both spatial and temporal connotations. Temporal because internesting areas are only 'active' during the (species dependent) breeding season. The spatio-temporal character of the Bsa can be implemented through different weighting of trawl effort during the breeding season within and outside an internesting area.

P_c(species) is the probability of a turtle to be caught and formally this would be N_{caught}/N_{total} per unit effort given an area. Due to the fact that there are no reliable stock estimates, an estimate for the number of turtles caught in an area is used as a proxy for P_c in this analysis. An estimate for the number of turtles caught can be derived from turtle CPUE and trawl effort.

As such, the outcomes of this risk assessment will be in terms of the spatial distribution of relative risk. Substituting these considerations into equation (1) results in:

$$R_{sp} = K * Trawl\_effort_{commercial}(t) * CPUE_{turtle} * w_{Bsa}(t) \qquad (2)$$

where:

$w_{Bsa}(t)$ the (temporal) weight of an area according to its biological significance and K a constant of proportionality. Trawl effort is written as a function of time to indicate its time dependent (breeding season) weighting.

Sufficient data for analysis was only available for loggerhead, flatback, hawksbill and green turtles. A full risk analysis was not undertaken for olive ridleys. However, this report does provide a spatial overlay of CPUE and trawl effort for the species, which may be useful to managers as first order reference of potential risk areas and locations for future research.

Spatial distribution of risk

An output of the risk assessment was a map indicating the distribution of overall risk of trawl capture to all turtle species of the Queensland east coast. This combines the spatial risk distribution of each species into an overall spatial risk distribution. Converting eqn(2) to include spatial variability results in

$$R_{sp}(x,y) = w_{Bsa\ sp}(x,y,t) * Trawl\_effort_{commercial}(x,y,t) * CPUE_{turtle}(x,y,) \qquad (3)$$

where:

$w_{Bsa\ sp}(x,y,t)$, $\{w: w \in (1,2)\}$ is the spatio-temporal weighting to adjust for the Bsa.
$CPUE_{turtle}$ is a time independent measure, averaged over six years of data (QDPI, Julie Robins).

After the layers for each species were calculated separately, they were combined into a layer showing the overall spatial risk distribution. A choice was made to explicitly weight the species differently according to their conservation status (inter-species weight, Table 2). To make this explicit weighting effective, each risk distribution was 'normalised' between 0 and 10 (see the Implementation section for details).

Two most apparent methods of combining spatial risk distribution are (weighted) averaging the species contributions and performing a 'weighted' max-function over the contributing species distributions. The latter was chosen to represent the risk distribution for this assessment. The final overall risk value is given by eqn (5)

$$R_{overall}(x,y) = Max_{sp}\{\ w_{sp} * R_{sp}(x,y)\}$$
$$= Max_{sp}(w_{sp} * \{[\{Trawl\_effort(x,y,t) * CPUE_{sp}(x,y) * w_{Bsa\ sp}(x,y,t)\} - \alpha]/\beta\}) \quad (4)$$

where:

α and β are constants of normalisation.

Implementation and procedure description

This section aims to describe the actual data manipulation needed to implement the methods as described in the previous section. A main decision had to be made whether to produce (a) one spatial overlay per species and then combine them at the end or (b) to produce a combination overlay including all species so that all manipulations and calculations could be done on the attribute data. The latter option was chosen, making automation of the process easier.

The following procedures were followed:

1. Prepare the trawl effort data by spreading the 30 minute data over all **non-zero**[2] 6 minute grid cells for the each year between 1993 through to 1996.
2. Prepare the seasonal trawl effort distributions for 1996 by spreading the 30 minute data over all non-zero 6 minute grid cells. See table 1 for the season definitions
3. Add 1 and 2 as attributes to a generalised fisheries grid (6 minute)
4. Union all three data sets as described in the data description section
5. Delete all turtle CPUEs with sd=0
6. Update the total grid area per grid cell
7. Update the mean and standard deviation of boat days over 1993-1996
8. Calculate the risk values inside and outside inter-nesting areas
9. Combine in and outside values
10. Correct for calculations inside a species inter-nesting areas not intersecting with a species CPUE >0 to prevent areas (polygons resulting from the union of inter-nesting and trawl effort) to be broken into separate colours on the map. Note: This step could have been prevented if an identity operation had been used to overlay species specific CPUE distributions (not readily available) and the inter-nesting areas per species.
11. Transform risk distribution per species, based on 95% criteria (see section on transformations)
12. Perform a weighted maximum function over all polygons within each of the inter-nesting sites for each species resulting in a uniform risk value within the inter-nesting areas.
13. Calculate the weighted maximum over species and transform between 0 and 10
14. Identify all **null cells**[3] and exclude from the assessment

[2] A non-zero grid cell is any 6 minute grid cell for which turtle capture was recorded through the DPI log book programme established in 1991 to monitor the capture of sea turtles in trawl nets (Robins 1997).
[3] A null cell is any 30 NM QFISH grid which was excluded from the DPI turtle catch monitoring program, and for which no data were available.

Transformation

Table 4 summarises the statistics of the risk values attached to the grid-cells for the five species risk coverages. A couple of conclusions can be drawn from this table that are important for the process of transformation. Firstly, all distributions are highly skewed, excluding Z-transform and 'minus minimum divided by maximum' as feasible transformation methods (see also the histograms in figure 1).

Secondly, dynamic ranges if values vary strongly between species (between 252.64 for loggerhead and 2.07 for hawksbill), making it even more desirable to transform each layer before the (species weighted) recombination into a final coverage. Thirdly, attempts to find an acceptable Probability Distribution Functions (pdf) fit failed (eleven continuous distribution functions were tested, Milani Chaloupka, DEH).

Table 4 Descriptive statistics on the non-normalised risk values per species (coverage).

	Loggerhead	*Green*	*Hawksbill*	*Flatback*	*Olive Ridley*
Mean	3.99	1.62	0.19	1.23	0.51
Standard Error	0.709	0.133	0.014	0.064	0.026
Median	0.302	0.450	0.125	0.486	0.263
Mode	0.092	0.587	0.202	1.146	0.049
Standard Deviation	21.05	4.09	0.23	2.07	0.69
Sample Variance	443.22	16.74	0.053	4.29	0.48
Kurtosis	55.94	44.19	19.91	27.58	14.08
Skewness	7.10	5.96	3.49	4.31	3.11
Range	252.64	48.47	2.07	21.39	5.48
Minimum (>0)	2.53E-03	1.69E-03	2.07E-03	3.14E-03	3.62E-03
Maximum	252.64	48.47	2.07	21.39	5.49
Sum	3,515.68	1,541.35	51.57	1,305.55	365.24
Count	881	949	274	1059	719

The following heuristic transformation approach for each species is proposed:

1. Find the 95% cumulative frequency V_{sp} for each species risk value
2. Change all grid-cells /polygon values greater than V_{sp} to V_{sp}. This will get rid of the very long distribution tails and still retain the high values in the highest risk 'class'
3. Divide all risk values by V_{sp} and multiply by 10

This procedure transforms all species risk layer grid-cell values between 0 and 10. Subsequently, all layers are combined using a 'max' function, weighted by their appropriate species rating (Table 2).

Used values for transformation heuristic:

$V_{loggerhead}$ =3.60 (44 polygons out of 881 'shifted')
V_{green} =5.6 (47 polygons out of 949 'shifted')
$V_{flatback}$ =4.6 (53 polygons out of 1059 'shifted')
$V_{hawksbill}$ =0.56 (14 polygons out of 274 'shifted')
V_{Ridley} =1.75 (36 polygons out of 719 'shifted')

For loggerhead, example queries {Q11} and {Q12} were used to implement this procedure. {Q14} divides all risk values by the appropriate V_{sp}. {Q15} calculates the final overall risk, not normalised. Separate queries were used to calculate and manipulate the data during the development phase as described in the previous sections. After the development stage all queries were translated into one program, making all data manipulation less error prone and more reproducible.

APPENDICES

Appendix 2: Assessment of biologically significant areas for species of sea turtles in Queensland and the Great Barrier Reef

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INTRODUCTION

The objectives of this report are to:

1. Provide biological information for risk assessment studies of anthropogenic activities and sea turtle stocks of Queensland.

2. Identify areas that are biologically significant to the conservation of sea turtles in the East Coast Otter Trawl Fishery.

It is envisaged that results of both objectives will contribute useful information to TRAWLMAC.

Risk assessment is based on the conventional risk chain concept that comprises the following components:

1. The hazard (eg., sunlight).

2. The exposure process (eg., sunbathing in midsummer on a beach).

3. The effects process (eg., sunburn and then maybe cancer).

4. The risk valuation or judgement process (eg., so what I prefer a tan and to hell with the long-term risks or ..... NO the public liability is too great so kids must wear hats in the playground at school).

The risk chain approach has been adopted by the Queensland Department of Environment in the development of policy models for management of the commercial whale-watching industry in southeast Queensland waters (Chaloupka 1996) and in the formulation of a policy position on trawling as a key threatening process for loggerhead sea turtles based on the stochastic simulation modeling of Chaloupka and Limpus (see Chaloupka and Musick 1997; Chaloupka and Limpus 1997).

The first three components define risk and are the primary focus of this report, which can then be used to aid decision-making and to foster informed public debate about trawling as a key threatening process.

Six of the worlds seven species of sea turtles inhabit Australian waters. Five of these species are listed under the *Commonwealth Endangered Species Protection Act 1992*, and all six are listed under the *Queensland Nature Conservation Act 1994*. The species have been listed because the cumulative affect of various anthropogenic impacts have caused declines of their global and national populations or because it is expected that current impacts are likely to cause them to move into the endangered category. Trawling is regarded as one of those impacts, in that it is a recorded cause of entanglement for Green, Loggerheads, Hawksbill Olive ridely and Flatback turtles (Robins 1995, Poiner and Harris 1996). Entanglement may result in injury, death or subsequent reduced recruitment potential for species affected.

Trawling may also adversely impact some benthic habitats (Pitcher *et al.* 1996) which are important foraging grounds for some marine turtle species.

In Queensland, trawling is a hazard to sea turtles in certain locations along the east coast (Poiner and Harris 1996; Robins 1995, Chaloupka 1997). The degree of risk is potentially different for each species. What needs to be assessed on an individual species basis, is the location of significant areas for each marine turtle species (based on current biological and life-history data); where trawling coincides in both space and time with each species; locations of incidental capture and an evaluation of the likelihood of incidental capture and of what proportion are drowned; injured or reduced in reproductive capacity.

This report assesses the spatial distribution of sea turtle habitat usage for each of the 6 species and determines *significant areas* on a number of biological and life-history parameters, as well as habitat use. An initial assessment of risk to sea turtle viability from exposure to trawling is given below in accordance with 3 risk categories - high, medium, low. It is envisaged that the risk assessment will be completed in the next stage of the process which will comprise an overlay of the significant areas with the spatial data on trawling activities by fishery component (Robins 1995); and the overlay of incidental capture by species data since 1991 (Robins, QDPI 1997).

In summary, the process is:

1. To determine biologically significant areas (this report).

2. Make initial risk assessment from trawling, and assign rating (this report).

3. Overlay spatial data on trawling effort and incidental capture (by species) in order to determine the level of exposure to the trawl hazard, and establish where the trawl effort occurs in relation to significant areas (next stage).

4. Determine risk for each species and their habitats (final stage).

Criteria for determining biologically significant areas

The criteria for determining the biologically significant areas in Queensland and the Great Barrier Reef is given for each species in the following report, and is based on information about genetic stocks; breeding sites and known feeding areas. For example:

Nesting areas

It is recommended that nesting sites for all species are surrounded by a 12km buffer on the basis that loggerhead and green turtles are known to utilise an internesting habitat in the vicinity of rookeries of this order of magnitude. Internesting habitat is the area within range of the nesting beach that the female occupies between laying periods during the nesting season. Ovulation and egg maturation for successive clutches occurs while the turtle is within in the internesting habitat.

Risk rating of sea turtles to anthropogenic activities

As a result of this assessment, stocks of each of the six species of sea turtle occurring in the east coast Queensland waters have been rated in terms of their degree of vulnerability to human-induced mortality based on their current international, national and state conservation status; knowledge of population status and stability, nesting populations and feeding stocks:

1.	The endangered loggerhead	**very high risk**
2.	The endemic flatback	**high risk**
3.	The endangered leatherback	**medium to high risk**
4.	The Hawksbill	**medium risk**
5.	The Green	**lower risk**

6. Olive Ridleys: Although this species is listed as Endangered under Queensland legislation, there are no nesting populations on the east coast of Qld, and this study concludes that there is not enough data on the population stability or feeding stocks in the region to assess the level of risk in the area (Limpus 1995).

It is important to note that the results of this analysis reflect the current state of knowledge, and it will be essential to update and amend if necessary, boundaries of critical areas as new information is acquired.

Risk management strategies

Effective risk management strategies to reduce the likelihood of mortality ; disturbance and injury to sea turtles are required for the areas identified.

LOGGERHEAD TURTLES (*Carretta caretta*)

1. CONSERVATION STATUS

International	(*World Conservation Union*)	Vulnerable
Australia	(*Endangered Species Protection Act 1992, Cwth*)	Endangered
Queensland	(*Nature Conservation (Wildlife)Regulation 1994*)	Endangered

2. HIGH CONSERVATION VALUE

The eastern Australian loggerhead population has a high conservation status because:

- It is one of the two genetically distinct Australian nesting populations. The other occurs in Western Australia (Limpus 1995).
- The eastern Australian rookeries support the only significant stock for the species in the South Pacific Ocean (Limpus and Reimer 1994). This stock was estimated at less than 1000 nesting females per annum in 1990.
- The population is unstable, having declined by 50-80% over about 17 years (Limpus and Reimer 1994).
- Effectively all loggerhead turtles feeding within the region are from the east coast stock.
- The combined factors of long maturation and a low reproductive rate puts Australia's *Caretta* populations at risk from even small increases in mortality among adult and sub-adult populations (Chaloupka 1997).

3. CRITERIA FOR IDENTIFYING SIGNIFICANT AREAS

The identification of biologically significant areas is based on known breeding. The areas may require amendment as more data is collected. There appear to be no migratory routes followed by most individuals for the species. The criteria used for determining significant areas are as follows:

Breeding

- Any loggerhead rookery which supports 25 or more females per annum.
- Internesting areas within a 12km radius of those rookeries.

4. BIOLOGICAL AND LIFE HISTORY RISK FACTORS

4.1 Population

The size of the annual eastern Australian breeding population of females has been monitored since 1968 (Limpus 1995) and provides the only reliable population data for the species in Queensland waters at present. The annual nesting population has declined from about 3500 females in the 1976-77 breeding seasons to an estimated 1000 females during 1988-91 (Limpus and Reimer 1994). Major causes of this decline have been attributed to capture of turtles in trawl nets and fox predation of eggs at mainland rookeries where mostly female hatchlings are produced (Limpus and Reimer 1994; Chaloupka and Limpus 1997).

4.2 Survivorship

Loggerheads take about 30 years to reach breeding maturity (Limpus *et al.* 1994), and females have long breeding remigration intervals of a mean 3.8 years (Limpus and Reimer 1994; Limpus 1997). This long maturation and breeding period makes high levels of individual survivorship important to the viability of the population. Continuing additional low levels of mortality of the already depleted female population may threaten the survival of the species (Chaloupka 1997).

4.3 Maturation and migration

- Loggerheads enter the GBR as immature animals, following a post hatchling oceanic pelagic phase. They reside and mature in the lagoonal reef, coastal bays and inshore waters for 12 or more years (Limpus 1994). During this lengthy maturation phase individuals may be exposed to anthropogenic impacts such as capture in trawl nets. Annual survivorship is naturally high but may be reduced by up to 13% with exposure to human activities (Limpus 1997).

- Once maturity is reached, males and females migrate independently to courtship locations. Journeys of up to 2600km are recorded for some females. There are no recognised "routes" and individual turtles appear to follow independent migratory paths (Limpus 1995a).

- After mating, males return to residential areas and females travel to their traditional rookeries.

Turtles may be exposed to trawl nets during these migrations and on arrival at rookery areas.

4.4 Nesting and inter-nesting areas

- Loggerheads nest on mainland and island beaches of the southern Great Barrier Reef in summer, between October-February. Multiple clutches of eggs are laid at an average of 3.4 clutches per season at approximately 14 day intervals (Limpus 1997).

- Records indicate that breeding females may occupy internesting habitats up to 24km of their rookeries for up to three months during nesting (Limpus and Reimer 1994) where they may become vulnerable to human activities.

Mainland rookeries

- Mostly female hatchlings are produced from mainland beaches between Elliot River and Round Hill Head, near Miriamvale. These rookeries are a high priority for conservation because turtles here have at greater exposure to trawling capture and to egg predation by introduced predators (Limpus and Reimer 1994).

- Off northern Fraser Island are important courtship areas for the species.

Island rookeries

- Male hatchlings are mostly produced from the coral cay rookeries (Limpus *et al.* 1992). The key breeding rookeries are the islands of the Capricorn–Bunker Group and the Swain Reefs.

- Both the island and mainland rookeries are in close proximity to the path of the East Australian Current which is believed to transport hatchlings to the Pacific Ocean for the pelagic stage of their development (Limpus and Reimer 1994).

4.7 Diet and Feeding areas

- Adult and large immature Loggerheads are carnivorous, benthic foragers, which feed principally on molluscs, crabs and echinoderms in a variety of habitats from coral reefs to soft-bottomed embayments.

- Individual turtles may forage at distances of between 2 to 2620km distant from individual rookeries.

5. IMPACT OF TRAWLING

Loggerheads comprised 50.4% of all turtles caught over a 2 year monitoring program (Robins 1995) and the estimated capture rate is one to two hundred annually in the sampled areas of eastern Queensland (Robins 1995).

Whilst capture may occur throughout their range, particularly sensitive areas have been identified as:

- The inter-nesting areas adjacent to rookeries during the breeding season between October-February.
- Inshore feeding areas between Gladstone and the Gold Coast (Limpus and Reimer 1994).

6. SIGNIFICANT AREAS

Significant nesting areas have been identified as:

- Elliot river to Round Hill Head
- The Capricorn–Bunker Islands
- Sandy Cape
- Several cays of the Swains complex

FLATBACK TURTLE (*Natator depressus*)

1. CONSERVATION STATUS

International	(*World Conservation Union*)	Insufficiently known
Australia	(*Endangered Species Protection Act 1992, Cwth*)	Not listed
Queensland	(*Nature Conservation (Wildlife)Regulation 1994*)	Vulnerable

2. HIGH CONSERVATION VALUE

- The species is monotypic and endemic to tropical areas of Australia's continental shelf.
- Nesting is restricted to Australia.
- It has a limited feeding distribution on the east coast (northern Qld only).
- It is the second rarest marine turtle species.
- Aspects of its life history make it vulnerable to anthropogenic impacts.
- Based on genetic analyses, the eastern population appears to be distinct and therefore should be treated as a discreet management unit (Moritz *et al.* 1998).

3. CRITERIA FOR IDENTIFYING SIGNIFICANT AREAS

Breeding

- Major rookeries. A major rookery is defined as one which supports 50 females per annum.
- Internesting areas adjacent to major rookeries.

4. BIOLOGICAL AND LIFE-HISTORY RISK FACTORS

4.1 Population

- There are insufficient data to accurately determine population trends (Limpus 1997).
- The estimated eastern Australian population is about 1000 nesting females (Limpus 1997).

4.2 Maturation and migration

- East coast Flatback turtles spend their entire life within the turbid, shallow inshore waters off north-eastern Australia north from 25 degrees south. Unlike all other marine turtles, they do not have an oceanic phase. Tthere is a drifting phase, but this occurs over the continental shelf (Parmenter 1994).

4.3 Diet and feeding areas

- In the GBRMP, immature and mature flatbacks feed in the soft bottomed habitats of the mid-lagoonal reef on a diet of holothurians, soft corals, sea pens, molluscs, jellyfish and algae. Species of these taxa are recorded as by-catch species from trawling (ANCA 1995; Limpus 1997).
- There are no data on specific foraging areas.
- Flatbacks make long-distance migrations (216–1300km) between rookeries and feeding grounds.

- Flatbacks are presumed to have a long maturation period, low survivorship from juvenile to adult and low annual recruitment rates to breeding populations.

4.4 Breeding

- Breeding occurs in summer for the East Coast and West Coast populations; mid year for the Gulf of Carpentaria and all year for Crab Island (Limpus 1997)

- Females form breeding aggregations proximal to rookeries (Parmenter 1994)

Rookeries

On the east coast, breeding occurs mostly on beaches of inshore islands and the mainland coast between Mon Repos to Mackay.

The main rookeries are located at:

- Wild Duck Island, off Broad Sound

- Peak Island in Keppel Bay

- Avoid Island in Broad Sound

- Curtis and Facing Islands

- Islands between Mackay and Bowen

The nesting season is long, spanning 4 months between October and January. Breeding females migrate up to 1300km from feeding areas to aggregate at traditional beaches, where they nest 2-3 times in a season at intervals of 16 days over 4-6 weeks. During this time they occupy internesting areas adjacent to their rookeries .

After breeding, flatbacks move from rookeries to feeding areas throughout the entire lagoonal GBR.

5. IMPACTS OF TRAWLING

- It is estimated that flatbacks are caught in the thousands each year in the Northern Prawn Fishery (Limpus 1997; Poiner & Harris 1996). For the sampled Eastern Prawn Fishery, flatbacks comprised 10.9% (76) of 651 turtles caught in a 1991/92 survey (Robins 1995).

- Flatbacks are also frequently caught in the eastern tiger and endeavour trawl fisheries (Robins 1995).

- Flatbacks are most commonly caught in 20–30m depth during in winter (Robins 1995).

- Most catches occur north of latitude 24 degrees south, notably off Townsville–Cairns and Port Stewart to Cape York (Robins 1995).

- The cumulative rate of capture in trawl nets for this endemic species may have the potential to cause significant losses to the overall stock of the species.

- Flatbacks are vulnerable to the superficial injuries (cuts, lacerations etc) associated with landing of trawl nets, because they lack the protective cutaneous keratinisation found in other marine turtles (Parmenter 1994).

- Repeated trawling can significantly reduce the benthic biomass of the flatback's foraging habitat (Pitcher *et al.* 1996).

6. SIGNIFICANT AREAS

Nesting sites

The internesting areas within at least 12km of all rookeries at:

- Wild Duck Island, off Broad Sound
- Peak Island in Keppel Bay
- Avoid Island in Broad Sound
- Curtis and Facing Islands
- Islands between Mackay and Bowen

Feeding

Whilst there are few data on specific feeding locations, it is known that flatbacks forage widely throughout the soft bottomed communities of Queensland waters. Depth ranges of between 30-40m may be significant.

HAWKSBILL TURTLE (*Eretmochelys imbricata*)

1. CONSERVATION STATUS

International	(World Conservation Union)	Endangered
Australia	(*Endangered Species Protection Act 1992, Cwth*)	Vulnerable
Queensland	(*Nature Conservation (Wildlife) Regulation 1994)*	Vulnerable

2. HIGH CONSERVATION VALUE

- The Australian nesting population is genetically distinct from those in other countries (Limpus 1995).
- Australia has two genetically distinct breeding populations (Limpus 1995).
- The northern Great Barrier Reef nesting population is the only substantial breeding stock remaining in the Pacific.
- The Australian population is regarded as important in maintaining world stocks.
- The breeding population shows early signs of being in decline.
- Australia's GBRMP provides one of the most secure habitats for the species in its world-wide range.

3. CRITERIA FOR IDENTIFYING SIGNIFICANT AREAS

Nesting

Significant rookeries. A significant rookery is defined as one which supports more than 50 nesting females per year.

4. BIOLOGICAL AND LIFE HISTORY RISK FACTORS

4.1 Population

Australia appears to be supporting the largest remaining breeding populations of hawksbill turtles in the world (Limpus 1995) with the annual number of breeding females estimated at more than 2000 in the Torres Strait/northern GBR region; perhaps 1000 in northeast Arnhem Land and between 1-2000 in Western Australia.

4 2 Nesting and Internesting areas

- Hawksbills nest on islands and cays north of Princess Charlotte Bay in the GBR between December and April.
- In Eastern Australia, females migrate to the northern GBR rookeries from Queensland, Papua New Guinea and Indonesia and from northern GBR reefs to nesting in Vanuatu, Solomon Islands and Papua New Guinea.
- Migrations to nesting areas may be up to 2400km from feeding areas to aggregate at traditional beaches (Miller 1994).
- Females occupy internesting habitats for about two months, laying an average of 3.3 clutches at about 15 day intervals (Limpus 1997)

4.2 Diet and feeding areas

- Hawksbills feed on sponges, sea anemones, sea urchins, tunicates and algae (Miller 1994).
- Feeding is associated with the edges of the outer coral reefs and in lagoons and coralline reef flats (Miller 1994).

4.3 Survivorship

Like other species of marine turtles, hawksbills are long lived, slow to reach sexual maturity and must achieve high survivorship levels.

5. TRAWLING IMPACTS

Hawksbill turtles were recorded as occasionally captured in trawl nets during a monitoring study (Robins 1995) and comprised 1.5 % (10) of 651 turtles caught.

- Lighting from trawlers anchored off nesting beaches may cause disorientation and subsequent mortality of hatchlings during the breeding season.

6. SIGNIFICANT AREAS

Nesting sites: (NGBR and Torres Strait)

- Saddle Island
- Bet Island
- Long Island
- Aureed Island
- Layoak Island
- Kabbikane Island
- Aukane Island
- Bourke Island
- Mimi Island
- Zuikin Island
- Da Lai Islet
- Hawksbury Island
- Dayman Island Mt Adolphus Island
- Albany Island
- Sinclair Islet
- Crocodile Island
- Milman Island
- Boydong Island
- Hannibal Island
- Bird Island
- Farmer Island/Piper Group

OLIVE RIDLEY (*Lepidochelys olivacea*)

1. CONSERVATION STATUS

International	(World Conservation Union)	Endangered
Australia	(*Endangered Species Protection Act 1992 ,Cwth*)	Vulnerable
Queensland	*(Nature Conservation (Wildlife) Regulation 1994*	Endangered

2. HIGH CONSERVATION VALUE

- The Australian population is a distinct breeding unit (B. Bowen pers. comm.)
- Little is known about the species in Australia compared to the other species.

3. CRITERIA FOR IDENTIFYING SIGNIFICANT AREAS

There is no known nesting from the east Australian coast.

4. BIOLOGICAL AND LIFE HISTORY RISK FACTORS

4.1 Population

There is no information on the size or stability of Australia's population (Harris 1994). In the GBR, the species southernmost distribution for feeding is Tannum Sands, south of Gladstone.

4.2 Nesting

The species does not nest in eastern Australia.

4.2 Diet and Feeding areas:

Olive ridleys are benthic foragers, feeding on gastropods, molluscs (elephant snails), and crabs (little shield crabs) (Harris 1994; Limpus pers.comm,1997). The species forages widely through the mid-lagoonal reef communities of the GBRMP.

5. IMPACT OF TRAWLING

- Data from the Northern Prawn Fishery indicates that olive ridleys are caught at frequencies of 6.3 turtles/1000 shots with 80–84 drowned annually resulting in an estimated mortality rate of 10% (Harris 1994).
- As for flatbacks, most catches occur at depths of 30–40m (Harris 1994).
- Prawn trawling is regarded as the main anthropogenic impact on olive ridley populations in Australia (Harris 1994).

6. SIGNIFICANT AREAS

There is no known nesting from the east Australian coast.

LEATHERBACK TURTLE (*Dermochelys coriacea*)

1. CONSERVATION STATUS

International	(*World Conservation Union*)	Endangered
Australia	(*Endangered Species Protection Act 1992, Cwth*)	Vulnerable
Queensland	(*Nature Conservation (Wildlife) Regulation 1994*)	Vulnerable

2. HIGH CONSERVATION VALUE

- Leatherbacks are uncommon in coastal waters of north eastern Australia.
- Global nesting populations have been decimated by egg harvesting and adult turtle mortality.
- Australia has a small breeding population but has substantial feeding populations in northern, eastern and western Australia.
- Australia has a responsibility to maintain these feeding populations which may be part of the breeding stock of neighbouring countries of Indonesia (Java, Irian Jaya), Papua New Guinea, and Solomon Islands (Limpus 1995b).

The east Australian nesting stock is presumed to be a separate breeding stock to the larger PNG/Irian Jaya group (Limpus 1995).

3. BIOLOGICAL AND LIFE HISTORY RISK FACTORS

Diet and feeding areas

Leatherbacks are associated with deepwater habitats but will feed in shallow water to depths of 3m in the Gulf of Carpentaria (Limpus 1995). Its diet includes jellyfish, and large soft bodied invertebrates in (Limpus 1995b).

Nesting

- Low density nesting occurs on the southern Queensland coast at Mackay, and Wreck Rock beaches south to Hervey Bay.
- Breeding occurs between December and January (Limpus 1995c).

5. IMPACT OF TRAWLING

Leatherbacks are only occasionally caught in prawn trawls in southern Queensland and the Gulf of Carpentaria but there are no records of drowning as a result (Limpus 1995c).

6. SIGNIFICANT AREAS

Nesting

Internesting areas associated with the Wreck Rock to Mon Repos rookery area (as for loggerheads).

GREEN TURTLE (*Chelonia mydas)*

1. CONSERVATION STATUS

International	(World Conservation Union)	Endangered
Australia	(*Endangered Species Protection Act 1992, Cwth*)	Vulnerable
Queensland	(*Nature Conservation (Wildlife) Regulation 1994)*	Vulnerable

2. HIGH CONSERVATION VALUE

- Breeding population trends. Breeding populations have been estimated for the two genetic stocks which inhabit the Great Barrier Reef region. The Northern GBR population supports about 30,000 nesting females and the and the southern Great Barrier Reef supports about 8000 (Limpus 1997).
- Although the species has a global distribution, the Australian nesting populations are genetically distinct, and include five independent stocks.
- Australia supports the last remaining large green turtle breeding populations of the Australasian and Pacific Ocean regions (Limpus 1995).

3. Criteria for identifying significant areas

Breeding

- Rookery sites where more than 100 females nest annually.
- Internesting areas within a 12km radius of the rookeries.

4. Biological and life history risk factors

Population

Genetically distinct breeding populations are identified for the Northern and Southern GBR.

Maturation and migration

Chelonia mydas are slow to reach sexual maturity (up to 40 years); have long breeding intervals of up to 6 years, and breeding rates are highly variable and influenced by El Nino Southern Ocillation events (Limpus 1997).

Tag recoveries indicate that adults display a high degree of fidelity to their feeding and nesting areas. However, the routes taken are highly individual, and there are insufficient data to determine if migratory corridors can be identified for the species between their nesting and foraging areas.

Developmental phase

Hatchlings area carried out of the GBR by currents, and aggregate on convergences, where they settle into a pelagic developmental phase for up to 5 years. *Chelonia* from the GBR stocks then recruit to GBR feeding areas as immature turtles where they grow and develop for up to 40 years until reaching sexual maturity. It has been estimated that annual survivorship in these growth zones is very high in the absence of human impacts, to >81% for immatures and >95% for adults (Limpus 1997).

However, the population viability may be easily compromised if stocks are subjected to increased anthropogenic impacts.

Breeding

- In the southern GBR the breeding season commences mid September (mating) and nesting commences mid to late October through to early April (Limpus 1995).

- In the northern GBR, nesting can occur year round but is mainly from October to March.

- Breeding females undertake migrations of up to 3000km from feeding areas to nesting beaches and form breeding aggregations. They take up residence in internesting areas within up to 20km of their nesting beach, and during this period, will lay multiple clutches (mean 5.1) at 14 day intervals (Limpus 1997).

Nesting and internesting areas

Northern GBR
- Bramble Cay
- Murray Island
- Moulter Cay
- Raine Island
- Sandbank No.7
- Sandbank No.8

Southern GBR
- Bell Cay

Capricorn Bunker Island Group
- Tryon Island
- North West Island
- Wilson Island
- Wreck Island
- Heron Island
- Masthead Island
- Hoskyn Island
- Fairfax Island
- Lady Musgrave Island
- Sandy Cape

5. **Impact of trawling**

The green turtle is one of the three most commonly caught species in the east coast otter trawl fishery, comprising 30.1% of captures. It is recorded as less frequently caught in the northern prawn fishery (Robins 1995), comprising 8% of 168 turtles (Poiner and Harris 1996).

Diet

Chelonia mydas is an herbivorous species, feeding principally on seagrass, algae and mangrove fruits (Limpus 1995) and occasional jellyfish, crustaceans and dead fish. Foraging habitat includes inshore seagrass meadows; coral and rocky reefs and algal turfs on the sand and mud flats of their range.

Population dynamics

The most comprehensively studied Australian population has been the southern GBR population. The Qld turtle research program green turtle research commenced in 1974.

Tag recovery indicates that: Breeding southern GBR green turtles travel from PNG, New Caledonia, Fiji, Northern Territory and Queensland.

Breeding turtles in the northern GBR travel from eastern Indonesia, southern and eastern PNG, Vanuatu, New Caledonia, Northern Territory and Qld.

Vulnerability to decline

Green turtles populations are biologically vulnerable to decline from anthropogenic causes in the region because of their late sexual maturity; long life; low breeding capacity and extensive migrations between breeding and feeding grounds.

Stocks have become depleted through harvest for food outside Australia, and within Australia the cumulative impact of traditional harvest plus other anthropogenic mortality factors such as trawling and boat strike, may put populations at risk of decline, and require careful management.

REFERENCES

Australian Nature Conservation Agency (1995). Public nomination to the Endangered Species Protection Act: Incidental Bycatch of sea turtles, sea snakes, teleosts and other native species during otter trawling (Schedule 3- key threatening processes).

Chaloupka, M. (1996). A policy model for the Moreton Bay Marine Park commercial whale-watching industry. Queensland Department of Environment Report. 16 pp.

Chaloupka, M. (1997). Otter trawling, a threatening process for Australian marine turtles. Queensland Department of Environment submission to 'Environment Australia' regarding the public nomination of otter trawling as a key threatening process to ANCA 1995.

Chaloupka, M. and Limpus, C.J. (1997). Heuristic simulation modeling of trawl fishery impacts on sGBR loggerhead population dynamics. In: Epperly, S., et al (compilers) Proceedings of the 17th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS.

Chaloupka, M.Y. and Musick, J.A. (1997). Age, growth and population dynamics. In: Ch. 9. "The biology of sea turtles." (Eds. Lutz, P.J. and Musick, J.A.) (CRC Press Inc.: Boca Raton) pp. 235–278.

Harris, A. (1994). Species Review: The Olive Ridley. In Proceedings of the Marine Turtle Conservation Workshop (compiled by R. James) pp. 63-65 (Australian nature Conservation Agency).

Limpus, C.J. (1994). The loggerhead turtle, *Caretta caretta*, in Queensland: feeding ground selection following her first nesting season. *NOAA Technical Memorandum NMFS-SEFSC*-251, 78-81.

Limpus., C. J. (1995a). A biological review for conservation of the Loggerhead turtle, *Caretta caretta* (Linneaus), in Australia. Unpublished report.

Limpus., C.J. (1995b). A biological review for conservation of the Flatback turtle, *Natator depressus* (Garman), in Australia. Unpublished report.

Limpus, C.J. (1995c). Conservation of the Marine Turtles in the Indo Pacific Region. Final report to the Australian Nature Conservation Agency. Unpublished report.

Limpus, C.J. (1997). Summary of the Biology of Marine Turtles in Australia. Unpublished report to the National Turtle Recovery Team, November 1997.

Limpus, C.J., Parmenter, J., Baker, V., Fleay, A. (1983). The Flatback turtle, *Chelonia depressa*, in Queensland: Post nesting migration and feeding ground distribution. *Aust. Wildl. Res.* 10, 557-61.

Limpus, C. J., Miller, J. D., Parmenter, J.C., Reimer, D., McLachlan, N. and Webb, R. (1992). Migration of Green (*Chelonia mydas*) and Loggerhead (*Caretta caretta*) turtles to and from Eastern Australian Rookeries. *Wildl. Res*. 19, 347-58.

Limpus, C.J. and Reimer, D. (1994). The loggerhead turtle *Caretta caretta* in Queensland: a population in decline. In Proceedings of the Marine Turtle Conservation Workshop (compiled by R.James) pp 39-48 (Australian Nature Conservation Agency).

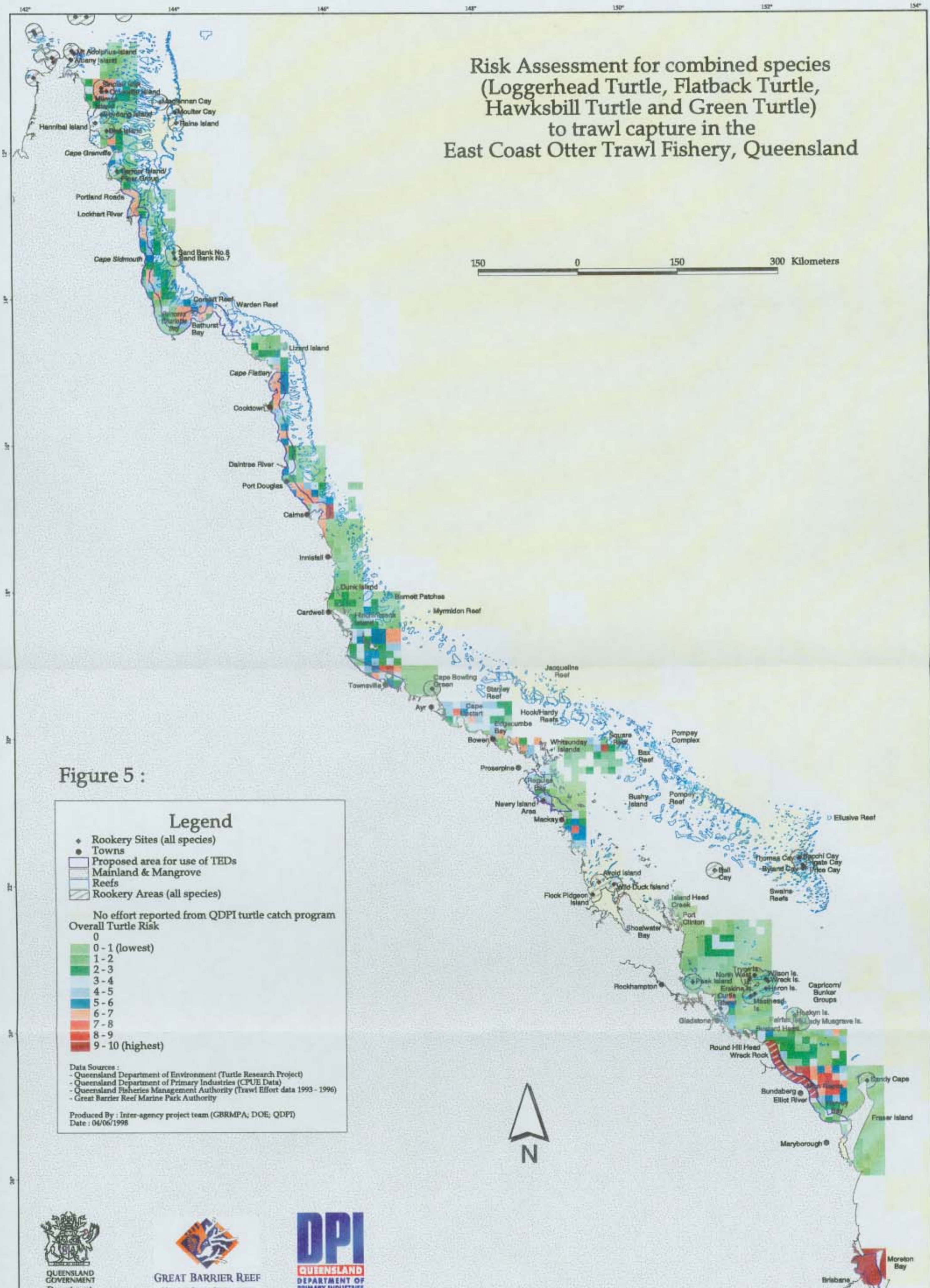
Miller, J. (1994) The hawksbill turtle, *Eretmochelys imbricata*: a perspective on the species. In Proceedings of the Marine Turtle Conservation Workshop pp 25-38. (Australian Nature Conservation Agency).

Parmenter, C.J. (1994). Species Review: The Flatback Turtle- *Natator depressus*. In Proceedings of the Marine Turtle Conservation Workshop (compiled by R.James) pp 60-62 (Australian Nature Conservation Agency)

Pitcher, C.R., Burridge, C.Y., Wassenberg, T.J., Poiner, I.R. (1996). The effects of prawn trawl fisheries on GBR seabed habitats. In: Proceedings of The Great Barrier Reef, Science, Use and Management: A National Conference, November 25-29, Townsville 1996 (in press).

Poiner, I.R. and Harris,A.N.M. (1996). Capture and mortality of sea turtles in Australia's Northern Prawn Fishery. *Marine Biology* **125**, 813-825.

Robins, J. B. (1995). Estimated catch and mortality of sea turtles from the East Coast Otter Trawl Fishery of Queensland, Australia. *Biological Conservation* **74,** 157-167.


Risk Assessment for combined species
(Loggerhead Turtle, Flatback Turtle,
Hawksbill Turtle and Green Turtle)
to trawl capture in the
East Coast Otter Trawl Fishery, Queensland
150 0 150 300 Kilometers
Legend
Rookery Sites (all species)
Towns
Proposed area for use of TEDs
Mainland & Mangrove
Reefs
Rookery Areas (all species)
No effort reported from QDPI turtle catch program
Overall Turtle Risk
0
0 - 1 (lowest)
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10 (highest)
Data Sources :
- Queensland Department of Environment (Turtle Research Project)
- Queensland Department of Primary Industries (CPUE Data)
- Queensland Fisheries Management Authority (Trawl Effort data 1993 - 1996)
- Great Barrier Reef Marine Park Authority
Produced By : Inter-agency project team (GBRMPA; DOE; QDPI)
Date : 04/06/1998
N
Hannibal Island
Cape Grenville
Portland Roads
Lockhart River
Cape Sidmouth
Raine Island
Moulter Cay
Sand Bank No.8
Sand Bank No.7
Warden Reef
Bathurst Bay
Lizard Island
Cape Flattery
Cooktown
Daintree River
Port Douglas
Cairns
Innisfail
Dunk Island
Barnett Patches
Myrmidon Reef
Cardwell
Townsville
Cape Bowling Green
Jacqueline Reef
Ayr
Bowen
Whitsunday Islands
Pompey Complex
Proserpine
Newry Island Area
Mackay
Bushy Island
Ellusive Reef
Swains Reefs
Flock Pidgeon Island
Wild Duck Island
Shoalwater Bay
Rockhampton
Capricorn/ Bunker Groups
Gladstone
Round Hill Head
Wreck Rock
Bundaberg
Elliot River
Sandy Cape
Fraser Island
Maryborough
Moreton Bay
Brisbane
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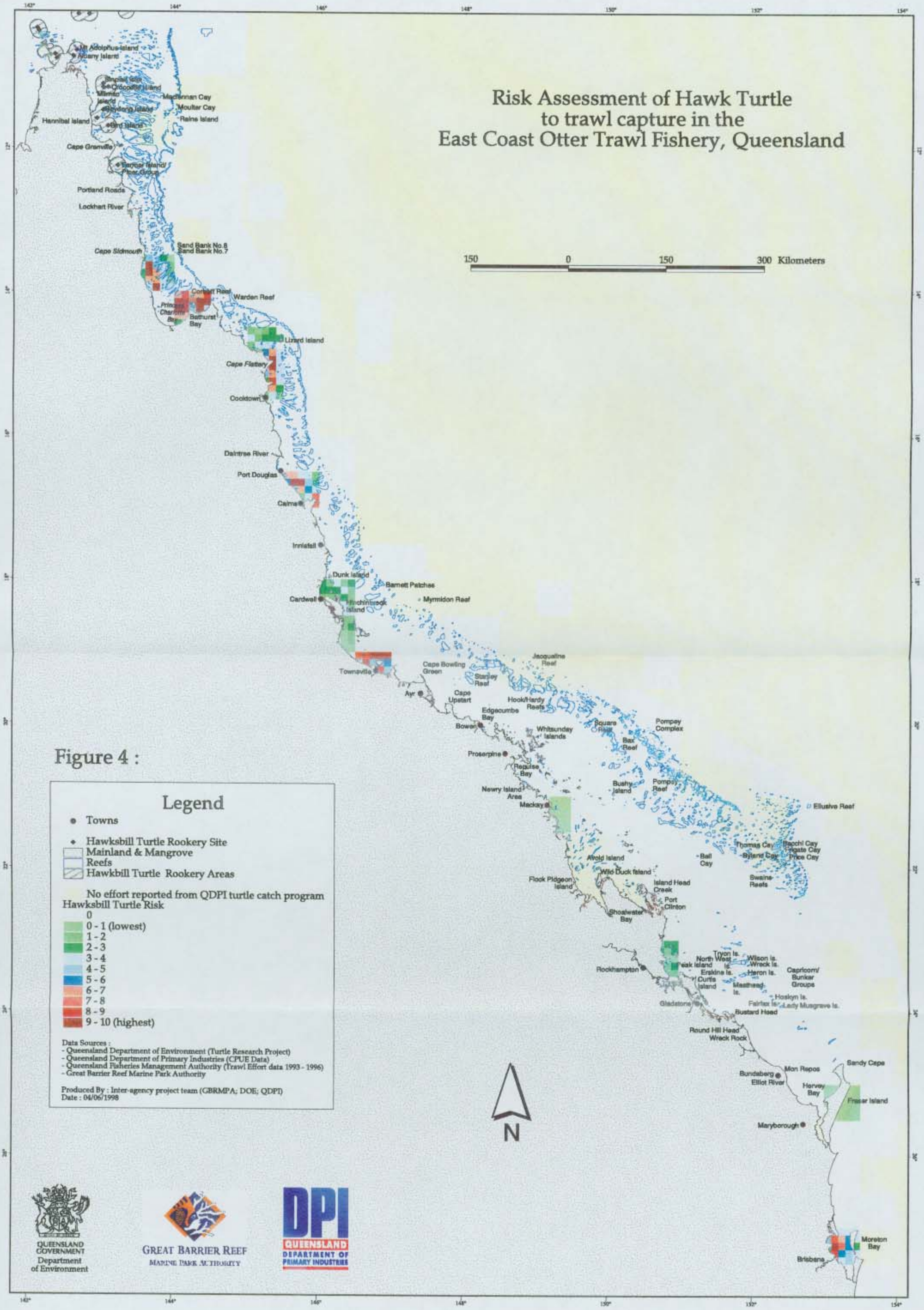
Department of Environment
GREAT BARRIER REEF
MARINE PARK AUTHORITY
DPI
QUEENSLAND
DEPARTMENT OF PRIMARY INDUSTRIES

Figure 5 :


Risk Assessment of Hawk Turtle
to trawl capture in the
East Coast Otter Trawl Fishery, Queensland
150 0 150 300 Kilometers
Figure 4 :
Legend
Towns
Hawksbill Turtle Rookery Site
Mainland & Mangrove
Reefs
Hawkbill Turtle Rookery Areas
No effort reported from QDPI turtle catch program
Hawksbill Turtle Risk
0
0 - 1 (lowest)
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10 (highest)
Data Sources :
- Queensland Department of Environment (Turtle Research Project)
- Queensland Department of Primary Industries (CPUE Data)
- Queensland Fisheries Management Authority (Trawl Effort data 1993 - 1996)
- Great Barrier Reef Marine Park Authority
Produced By : Inter-agency project team (GBRMPA; DOE; QDPI)
Date : 04/06/1998
N
Cape Sidmouth
Lizard Island
Cape Flattery
Cooktown
Daintree River
Port Douglas
Cairns
Innisfail
Dunk Island
Barnett Patches
Cardwell
Myrmidon Reef
Townsville
Ayr
Bowen
Proserpine
Mackay
Rockhampton
Gladstone
Bundaberg
Maryborough
Fraser Island
Sandy Cape
Moreton Bay
Brisbane
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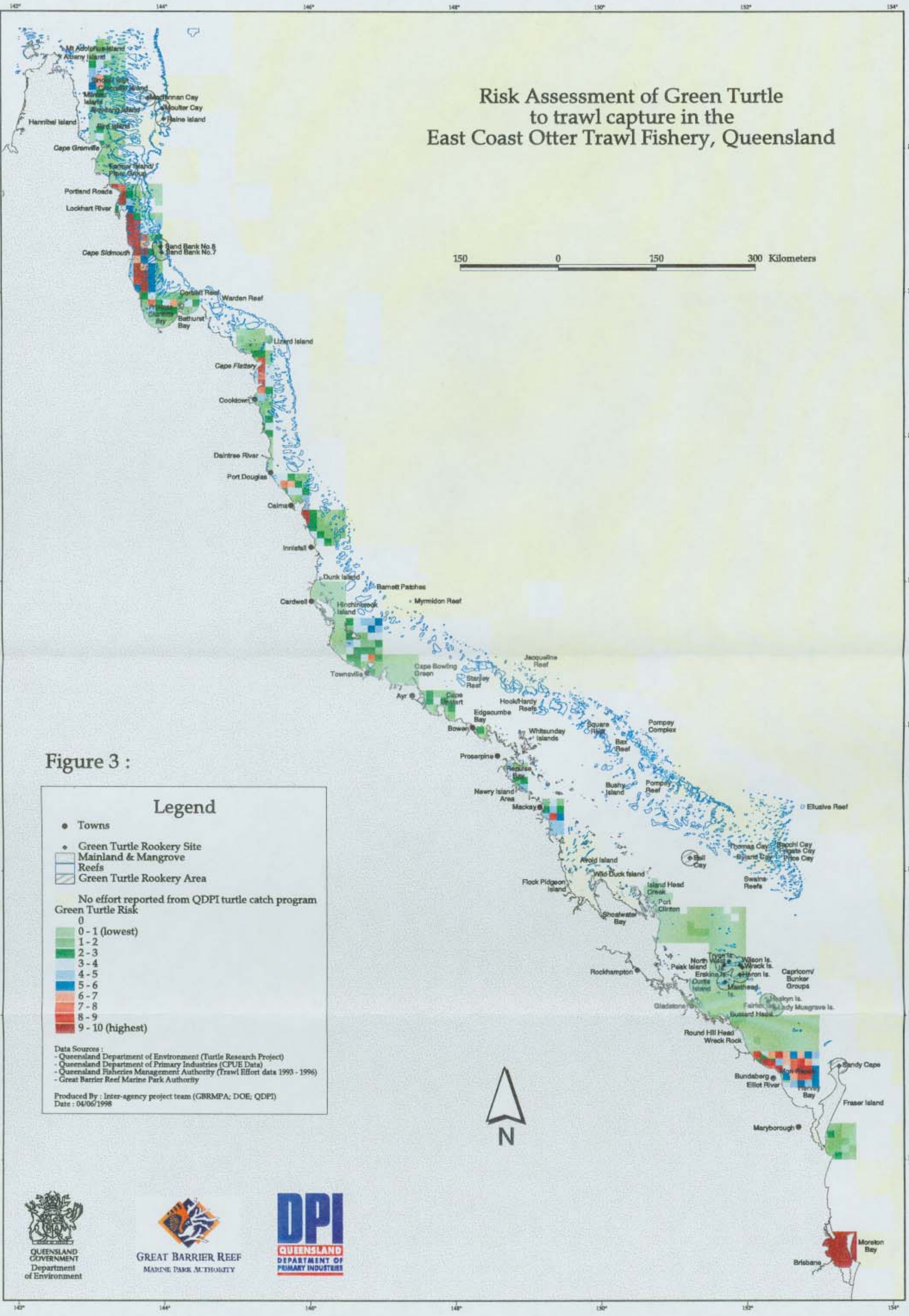
Risk Assessment of Green Turtle
to trawl capture in the
East Coast Otter Trawl Fishery, Queensland
150 0 150 300 Kilometers
Figure 3 :
Legend
Towns
Green Turtle Rookery Site
Mainland & Mangrove
Reefs
Green Turtle Rookery Area
No effort reported from QDPI turtle catch program
Green Turtle Risk
0
0 - 1 (lowest)
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10 (highest)
Data Sources :
- Queensland Department of Environment (Turtle Research Project)
- Queensland Department of Primary Industries (CPUE Data)
- Queensland Fisheries Management Authority (Trawl Effort data 1993 - 1996)
- Great Barrier Reef Marine Park Authority
Produced By : Inter-agency project team (GBRMPA; DOE; QDPI)
Date : 04/06/1998
N
Hannibal Island
Cape Grenville
Portland Roads
Lockhart River
Cape Sidmouth
Sand Bank No.8
Sand Bank No.7
Warden Reef
Bathurst Bay
Lizard Island
Cape Flattery
Cooktown
Daintree River
Port Douglas
Cairns
Innisfail
Dunk Island
Barnett Patches
Cardwell
Myrmidon Reef
Hinchinbrook Island
Townsville
Cape Bowling Green
Stanley Reef
Jacqueline Reef
Ayr
Cape Upstart
Hook/Hardy Reefs
Edgecumbe Bay
Bowen
Whitsunday Islands
Square Rock
Pompey Complex
Box Reef
Proserpine
Repulse Bay
Newry Island Area
Mackay
Bushy Island
Pompey Reef
Elusive Reef
Avoid Island
Wild Duck Island
Bell Cay
Thomas Cay
Bylund Cay
Price Cay
Swains Reefs
Flock Pidgeon Island
Island Head Creek
Port Clinton
Shoalwater Bay
Rockhampton
Peak Island
North West Is.
Tryon Is.
Wilson Is.
Wreck Is.
Heron Is.
Erskine Is.
Masthead Is.
Curtis Island
Capricorn/ Bunker Groups
Gladstone
Hoskyn Is.
Fairfax Is.
Lady Musgrave Is.
Bustard Head
Round Hill Head
Wreck Rock
Bundaberg
Elliot River
Hervey Bay
Sandy Cape
Fraser Island
Maryborough
Moreton Bay
Brisbane
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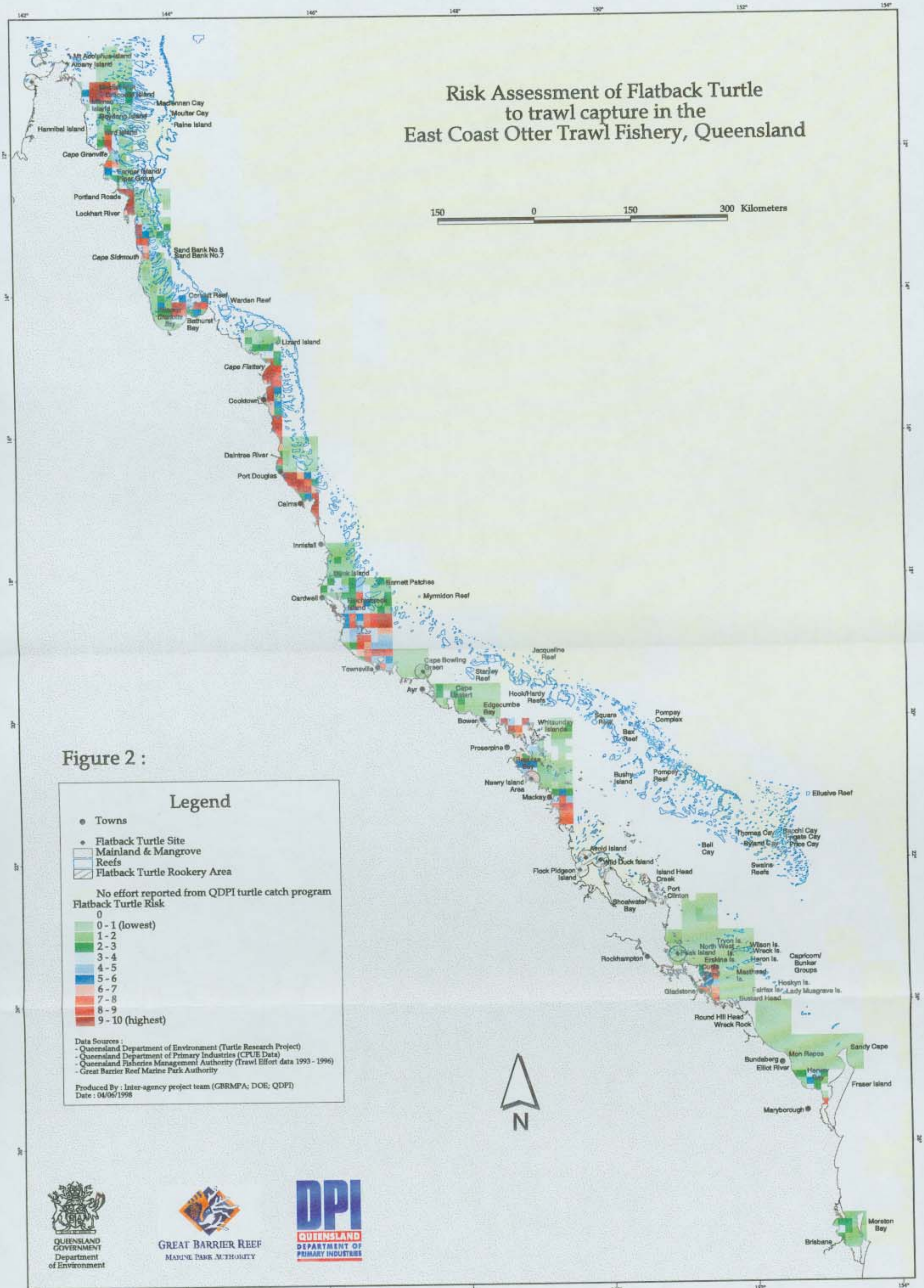

Risk Assessment of Flatback Turtle
to trawl capture in the
East Coast Otter Trawl Fishery, Queensland
150 0 150 300 Kilometers
Figure 2 :
Legend
Towns
Flatback Turtle Site
Mainland & Mangrove
Reefs
Flatback Turtle Rookery Area
No effort reported from QDPI turtle catch program
Flatback Turtle Risk
0
0 - 1 (lowest)
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10 (highest)
Data Sources :
- Queensland Department of Environment (Turtle Research Project)
- Queensland Department of Primary Industries (CPUE Data)
- Queensland Fisheries Management Authority (Trawl Effort data 1993 - 1996)
- Great Barrier Reef Marine Park Authority
Produced By : Inter-agency project team (GBRMPA; DOE; QDPI)
Date : 04/06/1998
N
QUEENSLAND GOVERNMENT
Department of Environment
GREAT BARRIER REEF
MARINE PARK AUTHORITY
DPI
QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
Albany Island
Hannibal Island
Cape Grenville
Raine Island
Moulter Cay
Portland Roads
Lockhart River
Cape Sidmouth
Sand Bank No.8
Sand Bank No.7
Warden Reef
Bathurst Bay
Lizard Island
Cape Flattery
Cooktown
Daintree River
Port Douglas
Cairns
Innisfail
Barnett Patches
Myrmidon Reef
Cardwell
Jacqueline Reef
Cape Bowling Green
Townsville
Stanley Reef
Ayr
Hook/Hardy Reefs
Edgecumbe Bay
Bowen
Whitsunday Islands
Pompey Complex
Proserpine
Box Reef
Bushy Island
Pompey Reef
Newry Island Area
Mackay
Ellusive Reef
Thomas Cay
Price Cay
Bell Cay
Swains Reefs
Wild Duck Island
Flock Pidgeon Island
Island Head Creek
Port Clinton
Shoalwater Bay
Tryon Is.
North West Is.
Wilson Is.
Wreck Is.
Heron Is.
Erskine Is.
Rockhampton
Capricorn/ Bunker Groups
Masthead Is.
Hoskyn Is.
Fairfax Is.
Lady Musgrave Is.
Gladstone
Bustard Head
Round Hill Head
Wreck Rock
Sandy Cape
Mon Repos
Bundaberg
Elliot River
Fraser Island
Maryborough
Moreton Bay
Brisbane

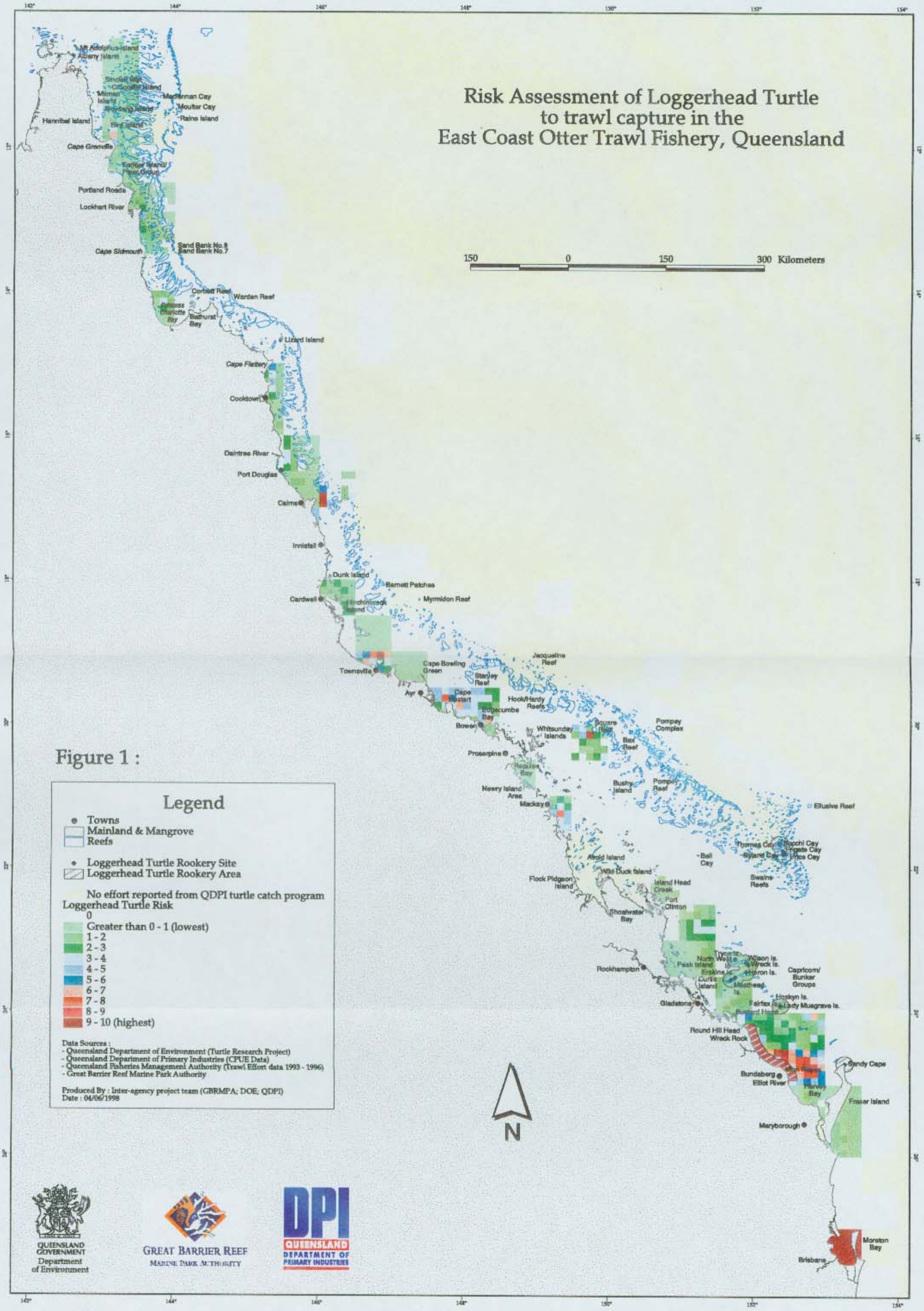
Risk Assessment of Loggerhead Turtle
to trawl capture in the
East Coast Otter Trawl Fishery, Queensland
150 0 150 300 Kilometers
Legend
Towns
Mainland & Mangrove
Reefs
Loggerhead Turtle Rookery Site
Loggerhead Turtle Rookery Area
No effort reported from QDPI turtle catch program
Loggerhead Turtle Risk
0
Greater than 0 - 1 (lowest)
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10 (highest)
Data Sources :
- Queensland Department of Environment (Turtle Research Project)
- Queensland Department of Primary Industries (CPUE Data)
- Queensland Fisheries Management Authority (Trawl Effort data 1993 - 1996)
- Great Barrier Reef Marine Park Authority
Produced By : Inter-agency project team (GBRMPA; DOE; QDPI)
Date : 04/06/1998
N
Cape Grenville
Portland Roads
Lockhart River
Cape Sidmouth
Sand Bank No.8
Sand Bank No.7
Warden Reef
Lizard Island
Cape Flattery
Cooktown
Daintree River
Port Douglas
Cairns
Innisfail
Dunk Island
Barnett Patches
Myrmidon Reef
Cardwell
Townsville
Cape Bowling Green
Jacqueline Reef
Ayr
Bowen
Whitsunday Islands
Pompey Complex
Proserpine
Mackay
Ellusive Reef
Swains Reefs
Rockhampton
Gladstone
Capricorn/ Bunker Groups
Round Hill Head
Wreck Rock
Bundaberg
Elliot River
Sandy Cape
Fraser Island
Maryborough
Moreton Bay
Brisbane
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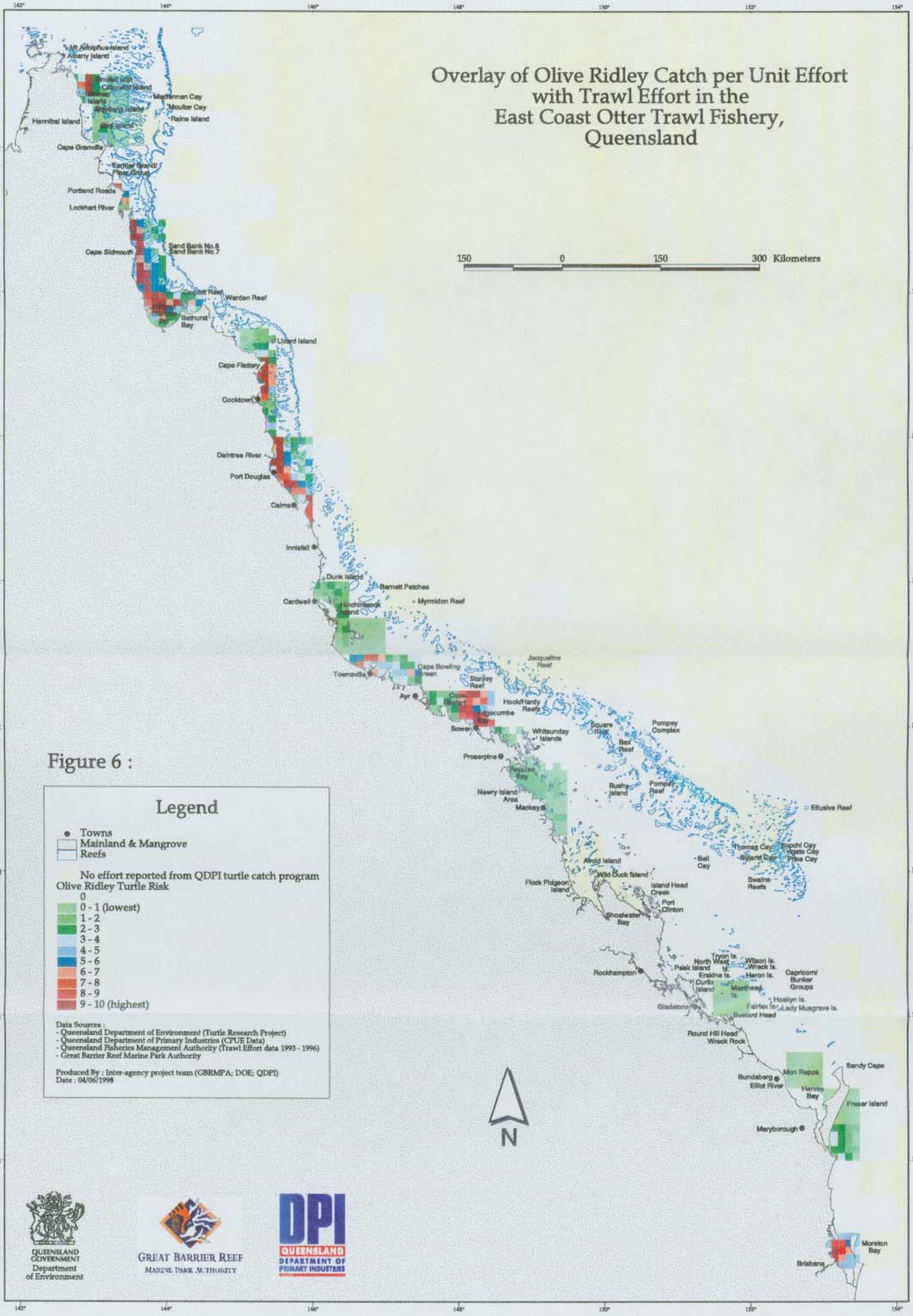
Figure 1 :



Overlay of Olive Ridley Catch per Unit Effort with Trawl Effort in the East Coast Otter Trawl Fishery, Queensland
150 0 150 300 Kilometers
Figure 6 :
Legend
Towns
Mainland & Mangrove
Reefs
No effort reported from QDPI turtle catch program
Olive Ridley Turtle Risk
0
0 - 1 (lowest)
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10 (highest)
Data Sources :
- Queensland Department of Environment (Turtle Research Project)
- Queensland Department of Primary Industries (CPUE Data)
- Queensland Fisheries Management Authority (Trawl Effort data 1993 - 1996)
- Great Barrier Reef Marine Park Authority
Produced By : Inter-agency project team (GBRMPA; DOE; QDPI)
Date : 04/06/1998
N
Hannibal Island
Cape Grenville
Portland Roads
Lockhart River
Raine Island
Cape Sidmouth
Sand Bank No.8
Sand Bank No.7
Warden Reef
Bathurst Bay
Lizard Island
Cape Flattery
Cooktown
Daintree River
Port Douglas
Cairns
Innisfail
Dunk Island
Barnett Patches
Cardwell
Myrmidon Reef
Townsville
Jacqueline Reef
Ayr
Bowen
Whitsunday Islands
Pompey Complex
Proserpine
Mackay
Ellusive Reef
Swains Reefs
Island Head Creek
Port Clinton
Shoalwater Bay
Rockhampton
Capricorn/ Bunker Groups
Gladstone
Lady Musgrave Is.
Round Hill Head
Wreck Rock
Sandy Cape
Bundaberg
Elliot River
Hervey Bay
Fraser Island
Maryborough
Moreton Bay
Brisbane
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