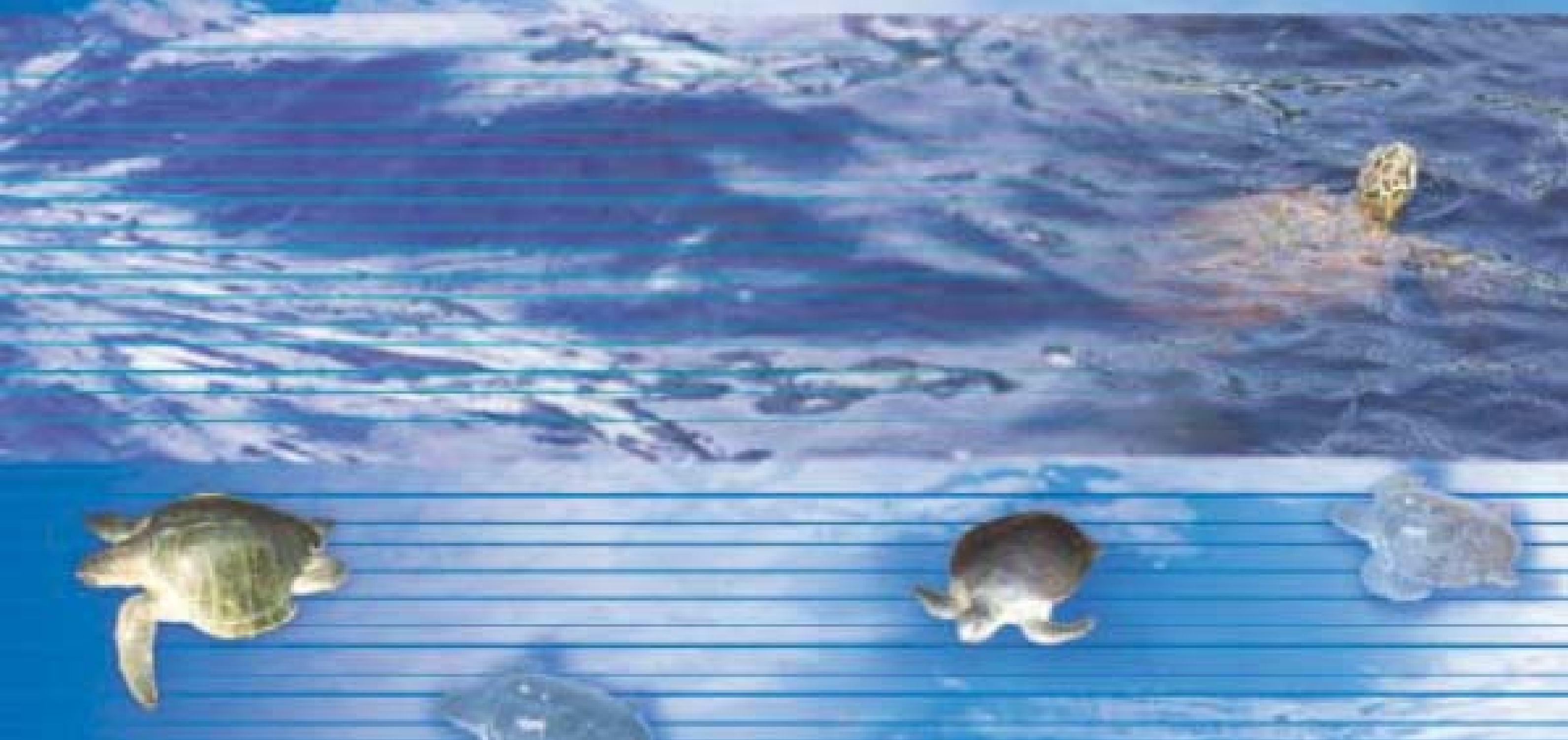
Department of AGRICULTURE FISHERIES & FORESTRY - AUSTRALIA

MONITORING THE CATCH OF TURTLES IN THE NORTHERN PRAWN FISHERY



C. M. Robins, A. M. Goodspeed, I. Poiner and B. D. Harch

FINAL REPORT

FRDC Project No. 1998/202

BUREAU OF RURAL SCIENCES AUSTRALIA BRS

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

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AGRICULTURE, FISHERIES AND FORESTRY – AUSTRALIA

Monitoring the Catch of Turtles in the Northern Prawn Fishery

Fisheries Research Development Corporation
Final Report 1998/202

July 2002

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1998/202 Monitoring the Catch of Turtles in the Northern Prawn Fishery

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OBJECTIVES:

1. Collect detailed information on the species composition, catch and mortality rates of sea turtles captured incidentally by the Northern Prawn Fishery (NPF), before and after the introduction of Turtle Excluder Devices (TEDs) between 1998 and 2001.

2. Compare these results to previously accepted sea turtle catch and mortality rates in the fishery.

3. Evaluate the effectiveness of TEDs in reducing sea turtle bycatch.

4. Recommend changes or additions to the Australian Fisheries Management Authority (AFMA) logbook monitoring of sea turtle bycatch in the NPF.

OUTCOMES ACHIEVED

The evaluation of the effectiveness of Turtle Excluder Devices (TEDs) is important given the endangered status of sea turtles and the significant numbers of sea turtles killed in trawl fisheries worldwide. This study has demonstrated that the catch of sea turtles in the Northern Prawn Fishery (NPF) has been substantially reduced following the mandatory adoption of TEDs. These results provide evidence that TEDs are a feasible option to reduce sea turtle mortality as a result of trawling operations.

This project also clearly demonstrates the usefulness of working in collaboration with fishers. Sea turtle catch rates estimated from fisher reports were shown to be valid when compared with sea turtle catch rates from scientific observers. In terms of economics, this approach costs a fraction of what it would have if scientific observers were used or research vessels were contracted. Lessons learnt through the running of this project will assist similar projects not only in Australia, but also further afield, in trawl and other commercial fisheries.

Bycatch, the catch of non-target species, is a significant issue in many of the world's fisheries. Sea turtles are of particular concern given their endangered status and the considerable numbers caught, and occasionally killed, worldwide in commercial fishery operations. Trawl fisheries, in particular, are recognised as discarding the greatest amount of bycatch compared to other commercial fishing methods. An estimated 37.2% of the total global discards have been attributed to trawlers (Alverson *et al.,* 1994). In addition, trawling operations have been held responsible for more sea turtle deaths than any other human-related factor (Bisong, 2000). A project conducted in 1989 and 1990 estimated that 5 000 to 6 000 turtles were caught by NPF trawlers annually, with a mortality rate of up to 39% (Poiner and Harris, 1996).

For many years Turtle Excluder Devices (TEDs) have been hailed as the solution to sea turtle mortality from trawl fisheries. TEDs – devices sewn into trawl nets that selectively remove large organisms, such as turtles, while allowing the smaller target species to be caught – have been introduced in many trawl fisheries worldwide. In 2000, the use of TEDs was made mandatory in the NPF.

The issue of sea turtle bycatch in trawl fisheries is important given the 1996 United States import embargo on wild caught prawns that were taken in a fishery without adequate turtle bycatch management practices, the objectives of the Draft Australian Recovery Plan for Marine Turtles and the requirement of the Australian Environment Protection and Biodiversity Conservation Act (EPBC Act) for Commonwealth fisheries to become ecologically sustainable.

This study evaluates the effectiveness of TEDs in reducing sea turtle bycatch in the NPF. It is based on data collected by volunteer fishers from the fleet and verified using independent scientific observers. The study demonstrates that TEDs substantially reduce capture of sea turtles during trawling activities in the NPF. Prior to the use of TEDs in NPF trawl nets, an estimated 5 000 sea turtles were caught annually by the trawl fleet. Since TEDs were installed the catch of sea turtles is estimated to have fallen to possibly fewer than 200 turtles per year. In addition, prior to the use of TEDs turtle mortality is estimated to have decreased from close to 40% in earlier years to around 22% in recent years. This may be attributed to the improvement in turtle handling techniques adopted by the fishers in the fleet. The turtles that continue to be captured while TEDs are used in the fishing gear are primarily taken during the winching-up of the nets, a late stage in the fishing operation. These sea turtles are presumed to survive due to the short time they are in the trawl and, consequently, since the introduction of TEDs few turtles are expected to die as a result of capture in trawl nets in the NPF.

The use of fishers to monitor the catch of rare species was demonstrated to be effective in terms of cost and validity of results. Appropriate timing was considered to be a fundamental aspect to the success of the project. In this case the timing was right in that TEDs were becoming mandatory in the NPF in 2000, so the research were unlikely to impact negatively on fishing operations.

While TEDs have been shown to be effective in reducing deaths of sea turtles as a result of trawling operations, there is the need to address sea turtle mortality from capture in other commercial fishing gears. Substantial numbers of turtles die during longline, pound net, gill-net, purse seine and pot trapping operations (Crouse, 1984; Oravetz, 1999). Mortality from these operations is reported to be much lower than from trawl operations, however, it may still be contributing to the decline of sea turtle populations.

KEYWORDS: Sea turtles, Northern Prawn Fishery, Turtle Excluder Devices, TEDs.

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Mr Aubrey Harris was the instigator and initial investigator of the project. Reviewing of the draft report by Dr Robert I. T. Prince (Western Australian Marine Turtle Project), Ms Patty Hobsbawn (Bureau of Rural Sciences), Mr Brent Wise (Bureau of Rural Sciences); production of maps by Mr David Barratt (Bureau of Rural Sciences); data management by Ms Justine Johnston (Australian Fisheries Management Authority), editing by Dr Penny Olsen (Australian National University) and cover design by Racheal Bruhn was greatly appreciated.

Background

Bycatch in commercial fisheries

In recent years, bycatch has become one of the most significant issues affecting fisheries management, both nationally and globally, and in many cases bycatch strategies have become the focal point of this management (Alverson *et al.,* 1994). Not only does bycatch have negative biological and ecological impacts but it is also waste of a biological resource – making it an ethical issue (Andrew and Pepperell, 1992; Hall *et al.,* 2000). In 1994, the Food and Agriculture Organisation of the United Nations (FAO) estimated conservatively that 27 million tonne of fish products were discarded globally every year (Alverson *et al*., 1994). It is recognised that trawl fisheries tend to have higher discard levels than any other fishing gear type. An estimated 37.2% of total global discards result from trawling activities (Alverson *et al*., 1994) due primarily to the non-selective nature of trawl gear (Kennelly, 1995).

The bycatch of sea turtles by commercial fisheries is of particular concern. Even though turtles are rarely caught in most fisheries some species are considered vulnerable to local and even global extinction because of declining numbers. In addition, turtles are charismatic creatures whose fate arouses public concern (Harris and Ward, 1999).

As with bycatch generally, over the last few decades trawl fisheries have been singled out as causing the death of significant numbers of sea turtles (Hillestad *et al.,* 1981; Crouse, 1984; Murphy and Hopkins-Murphy, 1989; Caillouet *et al*., 1996). Indeed, Bisong (2000) noted that, globally, shrimp or prawn trawling results in more sea turtle deaths than any other human-related factor. Prawn trawlers have also been identified as the most significant cause of death of sea turtles in the United States (National Research Council, 1992, cited in Alverson *et al*., 1994).

Sea turtles

Worldwide, there are only seven species of sea turtle, six living in Australian waters: the loggerhead sea turtle *Caretta caretta*, green sea turtle *Chelonia mydas*, hawksbill sea turtle *Eretmochelys imbricata*, olive ridley sea turtle *Lepidochelys olivacea*, flatback sea turtle *Natator depressus* and leatherback sea turtle *Dermochelys coriacea*. The remaining species, the Kemp's ridley *Lepidochelys kempii* occurs only in the Gulf of Mexico and northwest Atlantic (Limpus, 1998). Descriptions, distributions and photographs of each species are given in Appendix 3.

In addition to natural events, there are many diverse anthropogenic events that result in the death of sea turtles (see Appendix 4). The relative importance of mortality rates during the different life phases from hatchling to adult to the recovery of turtle populations is not always agreed upon. Nevertheless, the consensus is that there is the need to minimise, to the greatest extent possible, the negative effects of human activities on sea turtles throughout all phases of their life history.

Widespread concern at the alarming declines in sea turtle numbers in recent years is reflected in their high conservation status (Appendix 5). They are classified by various listing agencies as threatened or endangered, both nationally and globally (Crowder *et al*., 1994; Bisong, 2000). Various countries, including Australia and the United States, have drafted recovery plans that attempt to address the issue of declining sea turtle populations.

Turtle Excluder Devices to minimise sea turtle bycatch

TED is the acronym commonly used for Turtle Excluder (or Exclusion) Device, but can also stand for Trawl Exclusion Device, Trawl Efficiency Device, Trash Eradication Device or Trash Elimination Device (Andrew and Pepperell, 1992). For many years TEDs have been considered to be the solution to sea turtle bycatch. Designed to allow prawn trawling to continue while protecting sea turtles, TEDs are sewn into trawl nets to separate large unwanted animals, generally sea turtles but also other large organisms like sharks and rays, from the smaller target species, generally prawns or fish. They enable large animals to exit the net before reaching the cod-end. There are many designs, although most commonly they consist of a grid (or grating) that directs the turtle towards a hole in the net (Figure 1).

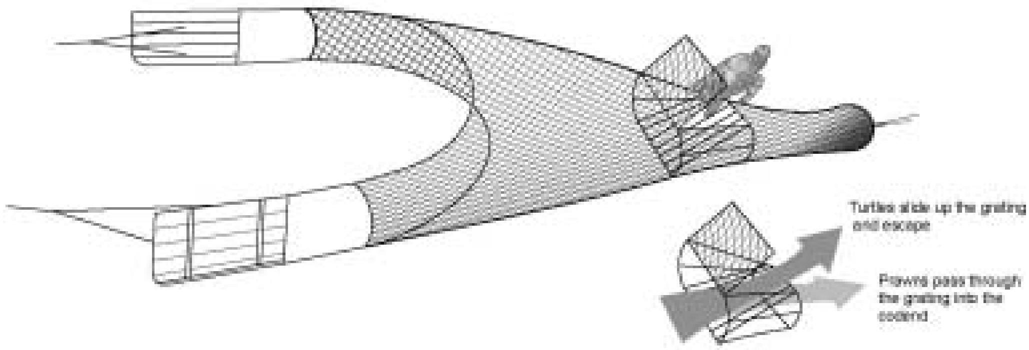


Figure 1 Diagram of one style of TED.

Initially developed by fishers in the 1960s, TEDs were further refined by the United States National Marine Fisheries Service (NMFS) in the late 1970s. Over the last 20 years they have undergone significant changes in design (Steiner and Arauz, 1998). There are many TED types and their efficiency depends on various factors such as design, suitability to the grounds being worked and the skill of the skipper in using the device. Extensive research has gone into designing effective TEDs, and the importance of evaluating them in different fisheries has been recognised repeatedly. Examples of adoptions of TED design and testing projects in various countries can be found in Ogren *et al.* (1977), Arauz (1990), Arauz (1998), Arauz *et al.* (1998), Crouse (1998), Chokesanguan (1999), and Behera (2000).

Following many years of domestic discord in the United States – regulations, challenges, lawsuits and court cases, amendments, public hearings, injunctions, and delays (examples in Oravetz, 1988 and 1992) – in 1996 the issue of mortality of sea turtles as a result of capture in trawl nets moved into the international arena. The U.S. placed an import embargo on wild-caught prawns from fisheries that did not have a sea turtle conservation program in place, including the use of TEDs. This embargo followed significant conflicts between conservation groups, government organisations and commercial fishers (Anon., 1997). The domestic regulations and international embargo continue to be debated.

Currently, TED use is routine in many countries, including Australia, Belize, Colombia, Costa Rica, Equador, El Salvador, Guatemala, Guyana, Honduras, Indonesia, Mexico, Nicaragua, Nigera, Pakistan, Panama, Suriname, Thailand, Trinidad, Tobago and Venezuela (Brewer *et al.*, 1998; Anon., 2001a). Several countries are in the process of implementing mandatory use of TEDs. Various other nations' trawl fisheries do not pose a threat to sea turtles and, according to the U.S. embargo, do not require the use of TEDs (Anon, 2001a).

TEDs in Australia's Northern Prawn Fishery

The Australian Northern Prawn Fishery (NPF) is an otter-trawl fishery that had a bycatch problem with wastage a major concern (Appendix 6). Bycatch in this fishery includes bony fishes, sharks and rays, crustaceans, molluscs, echinoderms, sponges, other invertebrates and reptiles (Harris and Ward, 1999). An example of bycatch and target catch from a trawl shot in the NPF is in Figure 2. It has been estimated that before Bycatch Reduction Devices (BRDs) and TEDs were adopted into the fishery around 95% of the catch was being discarded (Harris and Ward, 1999).

Figure 2 Bycatch on an NPF trawler.

Since the early 1990s, Australian government agencies, in cooperation with commercial fishers, have developed and trialed TEDs and other bycatch reduction devices for the NPF and the East Coast Prawn Trawl Fishery (Mounsey *et al*., 1995; Robins-Troeger *et al*., 1995; Rawlinson *et al*., 1997; Tucker *et al*., 1997; Brewer *et al*., 1998; McGilvray *et al*., 1999; Robins and McGilvray, 1999). In 2000, their use was made mandatory in the NPF and in July 2000 the U.S. embargo was lifted. Research projects further developing and evaluating the efficiency of, TEDs and other bycatch reduction devices are currently in progress.

Previous research on sea turtles in the Northern Prawn Fishery

In 1989 and 1990, the Commonwealth Scientific Industrial Research Organisation (CSIRO) used trained fishers to collect a variety of scientific data, including prawn catch and species composition, sea turtle catch, and environmental factors such as temperature and water depth (Poiner and Harris, 1996). This study was preceded by another, (Poiner *et al*., 1990), that used data from various research surveys to estimate sea turtle catches in the NPF.

Poiner and Harris (1996) estimate that between 5 000 and 6 000 sea turtles were caught incidentally by NPF trawlers from August to November each year. Of these, 39% may have died as a result of capture, made up of 14% drownings and 25% with injuries or being returned to the water comatose. They concluded that, even though trawl-induced-drownings were not having a significant impact on sea turtle populations in northern Australia, it would be desirable to reduce these mortalities.

Catch and mortality in other trawl fisheries

Worldwide, trawl fisheries have been recognised as posing a serious threat to sea turtles. Following the introduction of TEDs, many of these fisheries no longer kill significant numbers of turtles, but not all trawl fisheries have successfully adopted this technology and there have been compliance issues in some fisheries. Also, there have been reports of sea turtle mortality still occurring to a significant extent irrespective of the adoption of TEDs (National Marine Fisheries Service, 1999; McDaniel *et al*., 2000).

A variety of methods are used to estimate turtle capture rates from trawl fisheries – fisher interviews, observer programs, logbook records and stranding records (dead or injured turtles washed up on beaches). Factors such as the turtles' relative rarity resulting in lack of accurate data, however, makes catch estimates difficult.

Documented estimates of turtle catch and mortality for some trawl fisheries before the introduction of TEDs for some of these fisheries include:

- A possible 20 000 turtles, mainly olive ridleys, caught annually by Costa Rican trawlers, around half which are assumed to die as a result of capture (Arauz, 1998).
- Fisher questionnaires were used to estimate that an annual average of 742 sea turtles were caught in Terengganu waters, Malaysia, by trawlers in 1984 and 1985 (Chan *et al.,* 1988).
- In the mid-1970s fisher interviews, on-board observations, aerial and ground surveys, tagging program, and licensing records were used to derive an estimated capture rate of 30.7 sea turtles per vessel per year by shrimp trawlers in Georgia waters in the U. S. (Hillestad *et al*., 1978). In total this equates to a minimum of 9 855 turtles in 1976 with an estimated minimal mortality rate of 7.9%. These were identified as mostly loggerhead turtles.
- The incidental capture of sea turtles by the industrial shrimping fleet off north-eastern Venezuela is 1 370 turtles per year with a mortality of 260 (Marcano and Alio, 1998).
- A maximum of 44 000 sea turtles killed annually in the Gulf of Mexico and the south-eastern USA Atlantic shrimp fishery (National Marine Fisheries Service, 1999).
- There were over 35 000 olive ridleys recorded dead on Orissa beaches in India from the 1993/94 to the 1997/98 season. This is thought to result primarily from trawling activities (Pandav and Choudhury, 1999). These deaths are particularly alarming as the Orissa coastline has some of the world's largest mass-nesting rookeries for olive ridleys.
- Fisher reports were used to estimate that 5 295 ± 1 231 turtles were caught annually by the Queensland East Coast Otter Trawl Fishery. The most common species caught were the loggerhead turtle (50.4%), the green sea turtle (30.1%) and the flatback turtle (10.9 %). Mortality rate was estimated to be very low compared to other trawl fisheries (between 1.1 % and 6.8%) due to the relatively short tow duration of less than 80 minutes (Robins, 1995).
- The estimated sea turtle capture rates in Guyana and Suriname were 1 300 turtles annually, with a 60% mortality rate, and 3 200 turtles annually, with a 50% mortality rate, respectively. The high mortality rates were attributed to long tow duration and lack of recovery techniques. These estimates were obtained from interviews with fishers and government official and from unpublished data. (Tambiah, 1994).
- Total estimated turtle takes for trawl fisheries in Pacific Central America and Caribbean Central America is 60 042 and 514 turtles, respectively. These estimates are derived from a range of methods and mortality rates were not addressed (Arauz, 1996).
- A report published in 1978 estimated that between 860 and 1 396 sea turtles could have died as a result of capture by Southern Carolina trawlers during 1976 and 1977 (Ulrich, 1978 from Murphy and Hopkins-Murphy, 1989).
- The total turtle catch per year for the Italian bottom trawl fishery in the North Adriatic in 1999 and 2000 was estimated at 3 588 ± 2 975. This was determined from observer records and considered to be conservative (Laurent *et al*., 2001).

Monitoring the catch of sea turtles in the Northern Prawn Fishery from 1998 to 2001

This report presents the results of a sea turtle monitoring program conducted in the Northern Prawn Fishery before and after the introduction of TEDs, in order to evaluate their effectiveness. Trained fishers reported sea turtle captures from July 1998, 1.5 years before TEDs became mandatory, to June 2001, 1.5 years after. Estimates of the number of turtles caught and killed annually, along with length and species composition, are reported.

Need

There is a need for accurate estimation of sea turtle capture and mortality rates in the NPF to enable the Australian Fisheries Management Authority (AFMA), Northern Prawn Fishery Management Advisory Committee and the fishing industry to address concerns regarding sea turtle interactions with the fishery. This is especially crucial given the compulsory adoption of TEDs in all NPF trawl nets in the year 2000. These management measures, and other measures indirectly affecting on sea turtle captures, need to be evaluated and possibly modified if sea turtle bycatch has not been reduced.

The use of fishers to collect catch data on rare species is still in its infancy and needs to be developed. Lessons learnt through the running of this project will assist similar work not only in Australia but also further afield in trawl and other commercial fisheries.

Objectives

The objectives of the study were to:

1. Collect detailed information on the species composition, catch and mortality rates of turtles captured incidentally by the NPF before and after the introduction of TEDs;
2. Compare these results to previously accepted sea turtle catch and mortality rates in the fishery;
3. Evaluate the effectiveness of TEDs in reducing sea turtle bycatch; and
4. Recommend changes or additions to the AFMA logbook monitoring of sea turtle bycatch in the NPF.

Additional objectives were also met, including to:

1. Tag and collect data for as many sea turtles as possible, with information being provided to Dr Colin Limpus, Queensland Environmental Protection Agency;
2. Evaluate the effectiveness of using fishers as data collectors for the capture of rare bycatch species; and
3. Collect snake and sawfish catch and mortality data to be provided to scientists.

Methods

Data was collected by volunteer fishers. Similar collaborative projects between fishers and scientists have been successful in many parts of the world, including in Nova Scotia, Newfoundland and Prince Edward Island (James, 2000), Costa Rica (Arauz *et al*., 1998), U.S. (Kelley, 1995) and Spain (Pont Gassau and Alegre Ninou, 2000). In Australia, the use of trained fishers to collect data on rare bycatch species as an alternative to expensive observer programs was successful in a 1989–1991 project by Poiner and Harris (1996) and in a 1991–1992 study of the East Coast Otter Trawl Fishery by Robins (1995).

Volunteers

Initially faxes and messages were sent to all fishing vessels via the Vessel Monitoring System to call for project volunteers. Their position on the boat – fishing masters, crew, cooks or engineers – was not considered to be important. All volunteers were assessed for their suitability for the project through interviews with their fishing masters and AFMA logbook officers. The size range of volunteers' boats was compared to the whole fleet's size range to ensure a mixture of lengths, and consequently gear lengths, was included. Enthusiasm and genuine interest in sea turtle conservation was the main criteria for acceptance in the project. Throughout the project, participants were asked to recruit other fishers who found the project interesting and wished to take part. Volunteers are referred to as 'taggers'. A small number of fishers agreed to record turtle catches during the 2000 season. These fishers, however, were not considered 'taggers' as they had not been trained in the same way. Due to a small sample size these data were not used.

Observers

During the project there were various other BRD and TED projects in the NPF, some using independent scientific observers to record bycatch rates. Where possible, sea turtle data was obtained from these projects. However, problems arose in that the observers were trialing BRDs against non-BRD gear, which resulted in one net being fitted with a TED and one without. It was not considered appropriate to raise turtle catch rate from one net up to two nets by doubling the rate. This would incorrectly assume that if one turtle is captured in a net then one would also be captured in the other net – an unlikely event given the rarity of multiple captures of these animals. Therefore, this data was excluded from the catch rate analysis. Catch rates estimated from observer data when there were no TEDs in the fishing gear, however, were compared with the corresponding catch rates from tagger data in order to determine if the tagger data were reasonable. The observer data were used in species composition and mortality rates as these statistics are independent of the number of TEDs.

Workshops

Taggers attended annual workshops during which they were taught all the necessary skills in handling, measuring, tagging and resuscitating sea turtles, as well as scientific data collection procedures. In addition, sea turtle biology and conservation was presented, to increase the volunteers' appreciation and awareness of the global nature of bycatch problems, principally with respect to sea turtles. Specialists were invited from various organisations, and activities included hands-on training using live sea turtles and preserved sea turtles. Programs and photographs of the workshops are in Appendix 7.

Pre- and post-season contact

Before the start of the season each year AFMA personnel contacted each tagger to check for any problems, re-fill their tagging kit and ensure any changes to the procedures were understood. This was undertaken either by port visits or over the phone. Ongoing support was available from AFMA (Wendy O'Brien and Mandy Goodspeed), Bureau of Rural Sciences (Carolyn Robins), Commonwealth Scientific Industrial Research Organisation (Ted Wassenburg and Burke Hill) and Queensland Environmental Protection Agency (Colin Limpus), although AFMA was generally the first point of contact. At the end of each season each participating fisher was contacted so they could receive a summary of the project's progress and have the opportunity to provide feedback to the researchers on the season or procedures. In addition, annual reports on the project were provided to taggers, other fishers and other interested persons. The annual reports provided during the projects' duration are in Appendix 8.

Recording procedure

During the fishing season, taggers decided at the start of each day if they would be recording turtles, snakes or sawfish, or any combination. This was then noted on the data sheet. Daily vessel information was also completed if possible. This information included latitude and longitude, hours fished, number of shots, time of shot away and winch up. If this section was unable to be completed then data was taken from the skipper logs. The procedures changed slightly each year to accommodate suggestions made by the taggers and to improve the data collection process. The aim was to enable taggers to complete the project requirements without imposing on their routine fishing duties. Instructions and data recording sheets that were used are in Appendix 9.

On turtle-recording days all turtles interacting with the fishing gear were reported. If no turtles were reported the words NO TURTLES were written in the comments column for that day. This was to ensure that days when the tagger was recording turtles but on which none were caught (nil catch days) were not confused with days when the tagger was not recording turtles. When possible captured turtles were tagged (inside front flipper with titanium turtle tags), measured (curved carapace length and estimated height), assessed for health and injuries (healthy, injured, comatose or dead) and released if either healthy or dead. If the turtle was comatose it was kept on deck for up to 24 hours in the recovery position. Identification (species and health) and recovery instructions are presented in Appendix 10.

If the tagger decided to record snakes and/or sawfish on the day, then each animal of this type seen on deck was noted, including its life status (alive or dead). The length of sawfish was estimated to the nearest metre. All sawfish and where possible, snakes, were identified to species, although the snakes proved difficult for most taggers. It was suggested that taggers record sawfish every day but snakes only 1 or 2 days per week.

Data sheets were either posted or faxed to AFMA throughout the season or at the end of each season. The taggers were given incentives and entered into prize draws for being part of the program. Prizes included cash, t-shirts, caps, stubby holders, mugs and books. The whole fishing fleet was provided with 'tagger turtle' reports to complete if they caught a tagged turtle (Appendix 9). Fishers reporting tag details received a stubby holder and a cash prize.

Data verification

Data was double punched and any inconsistencies referred back to the tagger for correction. If possible, turtles were photographed using disposable cameras. A turtle-identification was not accepted as correct unless a photograph was provided or the tagger had shown in the past to be able to correctly recognise all species. All photographs were scanned and catalogued for future reference. A list of each turtle tagged and a photograph, if available, was forwarded to the Queensland Environmental Protection Agency for reference if the turtle is recaptured in the future.

Data analysis

Data analysis paralleled methods documented by Poiner and Harris (1996). All statistical analyses were implemented using SPLUS 2000 (Mathsoft Inc., 2000).

Fishery definitions

All data was split into banana prawn fishery and tiger prawn fishery. Each fishery was treated separately due to their different natures. Each fishing day was assigned to either the banana prawn or the tiger prawn season depending on the species distribution of the prawn catch reported in the logbooks. If over 50% in weight of the total prawns caught for the day were banana prawns or there was no prawn catch then that day was considered to be in the banana prawn season, otherwise it was considered a day in the tiger prawn fishing season. One special case was when the boat was fishing for Indian banana prawns in Joseph Bonaparte Gulf. As these prawns are caught using methods more similar to tiger prawn fishing than banana prawn fishing all days in this area were assigned as tiger prawn season days. Generally, from April to June most boats target banana prawns and from August to November they target tiger prawns. These months alone, however, do not reflect a fishery division that is accurate enough for analysis. Vessels occasionally fish for tiger prawns during the April to June season and fish for banana prawns during the August to November season.

TED classification

Turtle catch data were collected on vessels that did not have a TED installed in either net, referred to as ‘before TEDs’, and on vessels that had a TED installed in both nets, referred to as ‘after TEDs’. As TEDs became mandatory in 2000, in general, ‘before TED’ days were during 1998 and 1999, while ‘after TED’ days were during 2000 and 2001.

There were reporting days when a net containing a TED was being compared to a net without a TED on the same vessel. This occurred either when an observer was on the trawler or during the first two weeks of 2001 when some vessels participated in a separate TED evaluation project. The lack of information on which boats participated in these trials, and which net the turtles were caught in, makes these data unsuitable for use in catch rate and total catch analyses. Therefore, these data are excluded from the catch rate analyses and ignored in effort estimates for each fishery. Also not taken into account with these estimates is the period from 1 to 14 April 2000 when TEDs were not used in the fishery. Data from this time is considered to be ‘before TEDs’. These operations are not expected to impact substantially on the results.

Model

Catch Rates

As per Poiner and Harris (1996) the following equations were used for each fishery. The catches of turtles each day are assumed to be random variables and independent of each other. The calculated distribution of turtle catch per day spans the values of 0, 1, 2, 3, 4, 5, 6, 7 and 8, with the probability of capture being:

$$P_0 + P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 + P_8 = 1. \qquad (1)$$

The mean catch rate (μ_R) will be:

$$\mu_R = \sum_{i=0}^{8} iP_i = P_1 + 2P_2 + 3P_3 + 4P_4 + 5P_5 + 6P_6 + 7P_7 + 8P_8 \qquad (2)$$

with a variance (σ_R^2) of:

$$\sigma_R^2 = P_1 + 4P_2 + 9P_3 + 16P_4 + 25P_5 + 36P_6 + 49P_7 + 64P_8 - \mu_R^2 . \qquad (3)$$

Generalised linear model (GLM) methodology (McCullouch and Nelder, 1989) was used to calculate mean catch rates (μ_R) and their associated standard errors (σ_R), and conduct tests for significant differences:

- between observers and taggers (one-way GLM analysis; 2 levels – observer and tagger);
- before and after the introduction of TEDs;
- between banana prawn and tiger prawn fisheries (two-way GLM analysis; 2 levels – before and after; and banana and tiger), and
- amongst months (July 1998 to June 2001) (one-way GLM analysis; 11 levels/months).

Turtle catches were modelled assuming a Poisson distribution with a log-link function. A two-way factorial GLM analysis was pursued with a factor for fishery (2 levels – banana prawn fishery and tiger prawn fishery) and a factor for TED usage (2 levels – before and after).

Total Turtle Catches

The total number of turtles caught by each fishery (C) was estimated using:

$$C = \mu_R * T \qquad (4)$$

where μ_R is the mean catch rate and T is the total fishing effort for that fishery. The standard error of C (σ_c) is associated with both standard errors of μ_R and T. Total turtle catch estimates were calculated for each season from July 1998 to June 2001, therefore they include the second season of 1998, both seasons of 1999 and 2000, and the first season of 2001. Fishing effort in days was estimated from log records and followed the method explained above.

The 95% confidence limit of the total fishing effort was estimated to be between 90 and 110 %. Assuming μ_R and T are independent of each other, σ_c is estimated as (Meyer, 1980:1410):

$$\sigma_c = \sqrt{\mu_R^2 * \sigma_T^2 + \sigma_R^2 * T^2} . \qquad (5)$$

Catch Rate Differences

Any differences in catch and mortality rates before and after the introduction of TEDs and in species compositions, were tested by the χ^2 test for differences in probabilities (Conover, 1980).

AFMA logbook records

A comparison of turtle catch numbers between the AFMA logbook records and the tagger data was made by noting the relative percentage differences between the catch numbers. A statistical comparison was not undertaken because appropriate estimates of error were not available.

Results and discussion

From April 1998 to June 2001 a total of 810 turtles were reported as being caught by taggers (726 turtles) and observers (84 turtles). There were very few turtles caught more than once during the project, as determined from tagging data, so in these cases each capture was considered to be independent, i.e. treated as 2 separate captures. The number of days of recording for each component is in Table 1.

Table 1 Number of observer and tagger reporting days by the number of TEDs for the NPF banana prawn and tiger prawn seasons.

Reporter	TED classification	Total reporting effort (days)	Reporting effort in the banana prawn season (days)	Reporting effort in the tiger prawn season (days)
Observer	Before TEDs	124	4	120
	One TED	247	78	169
	After TEDs	1	0	1
Tagger	Before TEDs	2317	274	2043
	One TED	2	1	1
	After TEDs	905	127	778

Sea turtles were reported as being caught throughout all fished areas of the NPF, as seen in the banana prawn and tiger prawn fishery effort distribution maps over the time of the project – July 1998 to June 2001 (Figures 3 and 4), the corresponding sea turtle catch distribution maps – both before and after TEDs were used in the NPF (Figures 5 to 8) and sea turtle catch by species (Figures 9 to 14). The two turtles reported as being caught in the middle of the Gulf of Carpentaria (Figures 6, 10 and 14) are assumed to be incorrectly positioned.

Log records compared with photographs – 1997

In 1997, AFMA logbook officers distributed disposable cameras to NPF skippers with instructions on the importance of reporting sea turtle capture and the correct identification of species. This study will be referred to as Sachse (1997). It was an attempt to determine the validity of species identification by skippers and also an impetus for this turtle-monitoring project. Out of 129 boats in the fishery, 33 returned cameras. The films were developed and the photographs compared to records of turtles reported in logbooks.

Most photos could be linked to a log record (23 cameras or 78% of returned cameras). Of the remaining returned cameras: two contained less than three photos that could be matched; for five cameras it was not possible to link any of the photographs to corresponding log records; and for three cameras no turtles were reported in logs. Links were made using a variety of methods, including the skipper recording the photograph number against the log record, descriptions of matching photographs or other notes in the logs, all turtles in logs being photographed so they appear in the same order as log records, matched by lengths provided in logs or by species identification. These results demonstrate the difficulty of using photographs in order to verify species identifications. It would have been more useful to provide the skippers with a reusable data board (with boat or skipper name and the date) to place next to the turtle when photographed. This would have enabled the correct linking of turtle photographs to log records. In addition, there was a need for a better method for ensuring the cameras were returned.

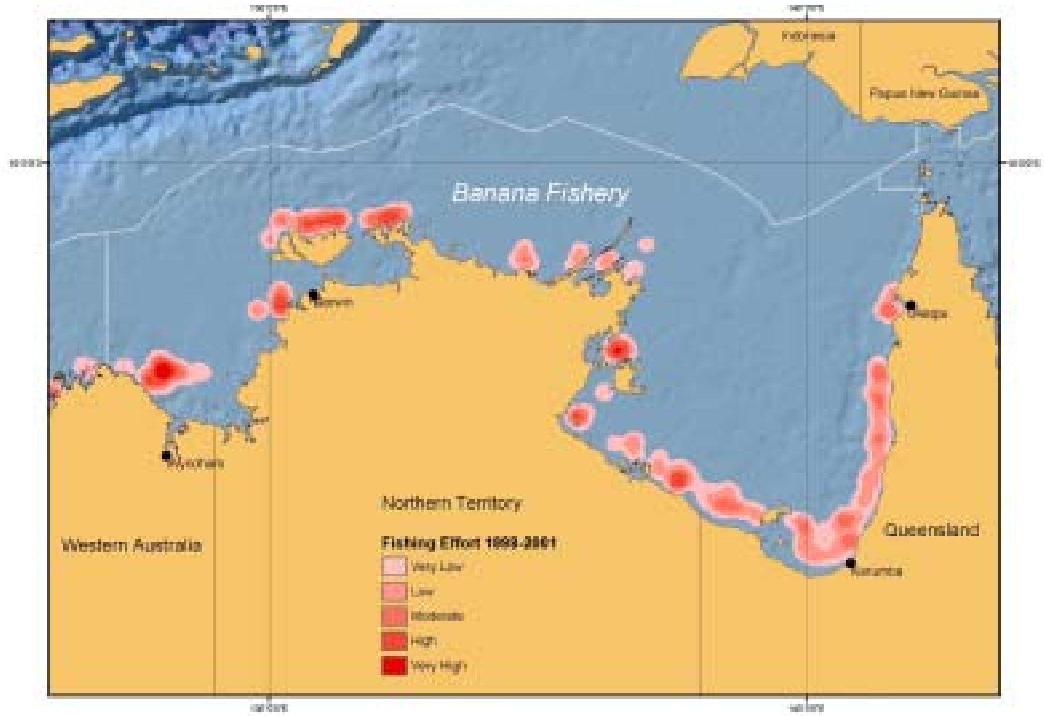


Figure 3 Banana prawn season effort from June 98 to July 01.

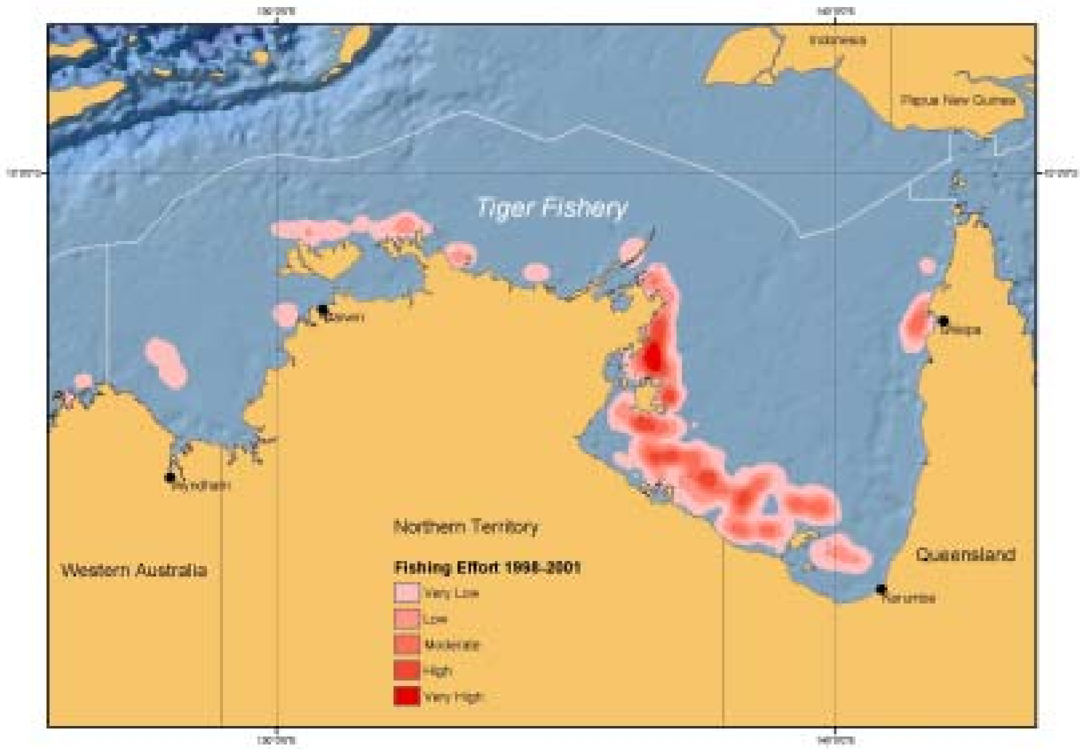


Figure 4 Tiger prawn season effort from June 98 to July 01.

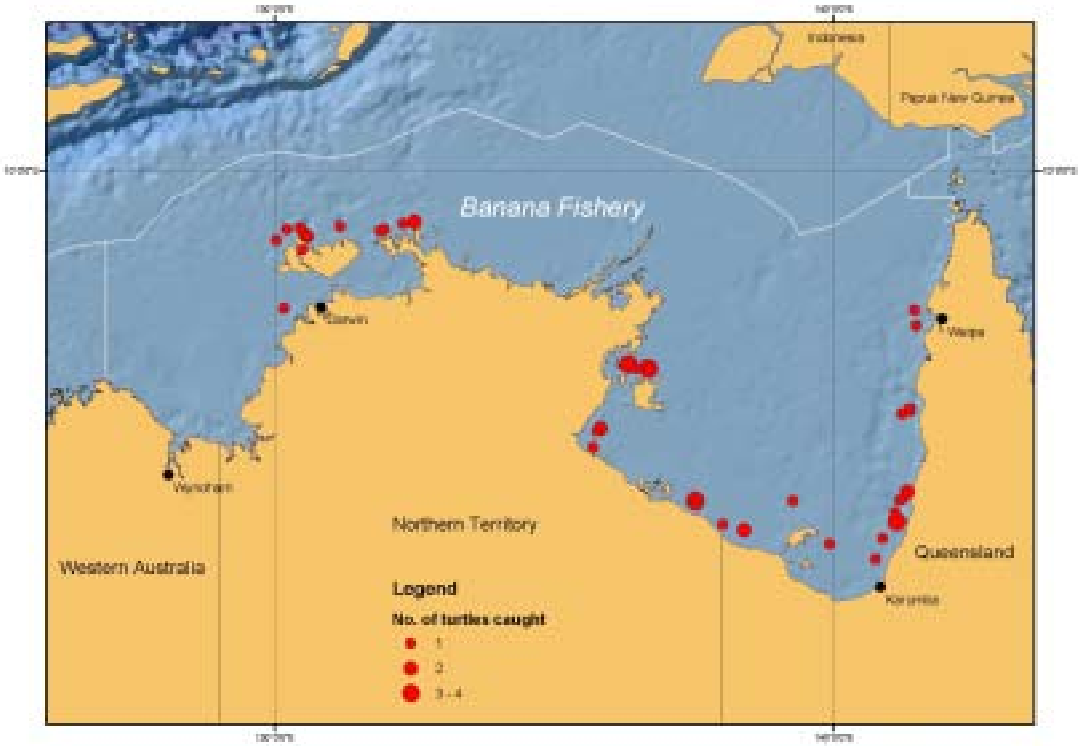


Figure 5 Sea turtle catch in the banana prawn season pre-TEDs (June 98 - July 01).

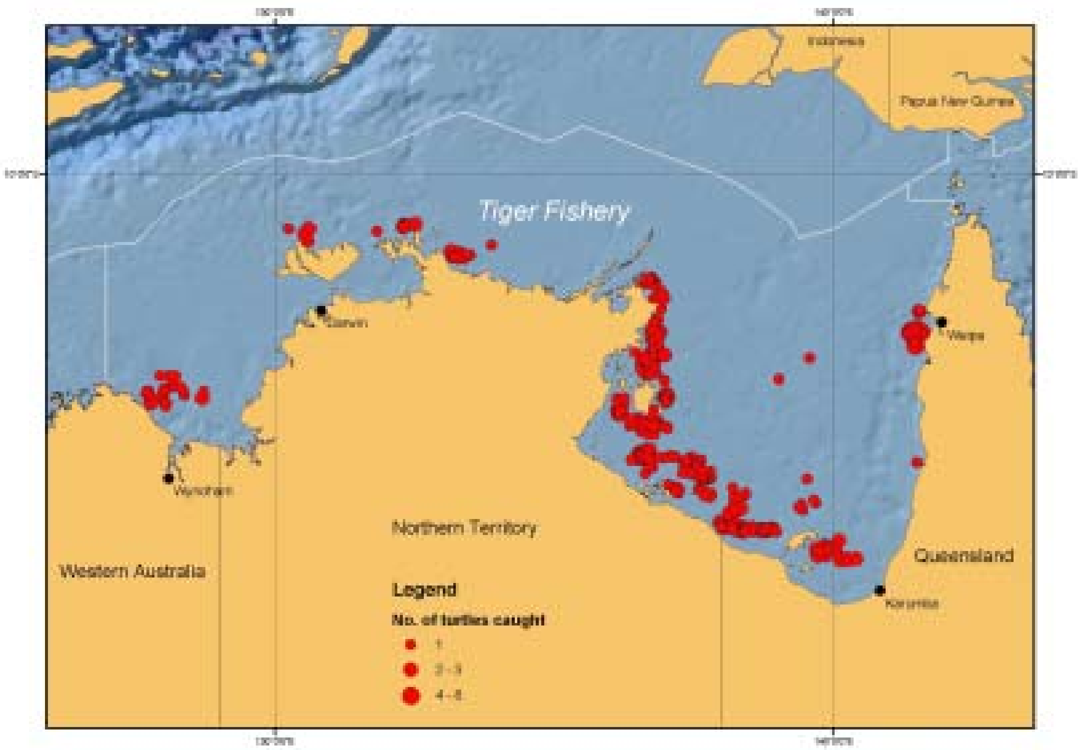


Figure 6 Sea turtle catch in the tiger prawn season pre-TEDs (June 98 - July 01).

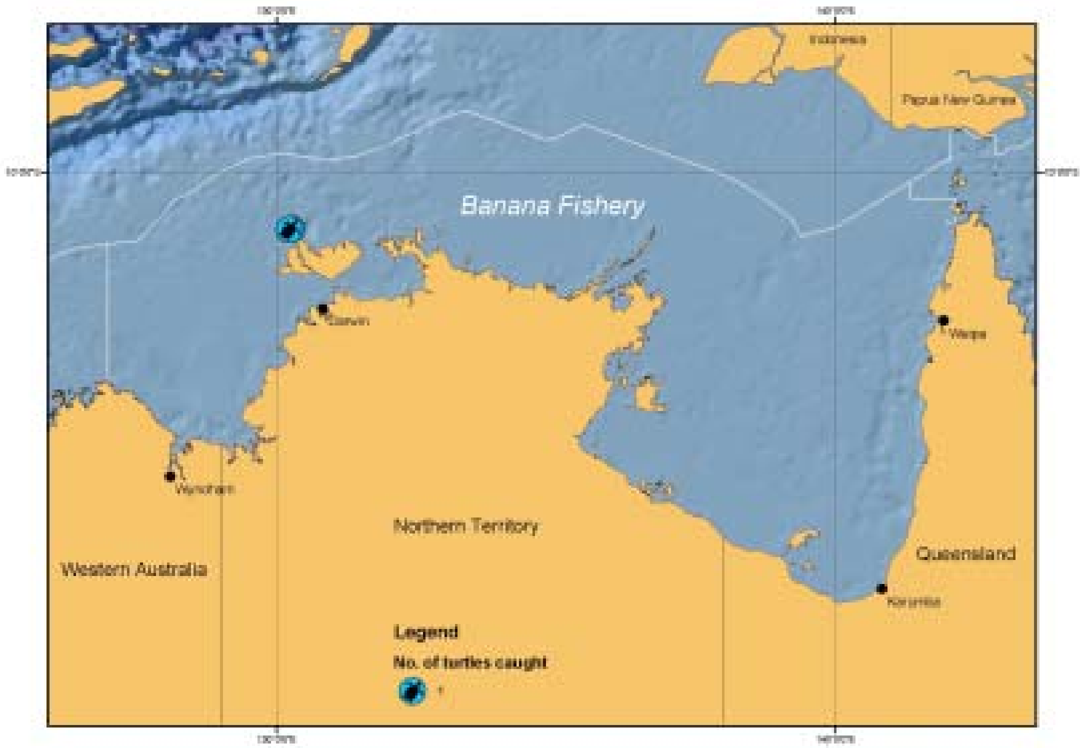


Figure 7 Sea turtle catch in the banana prawn season after TEDs (June 98 - July 01).

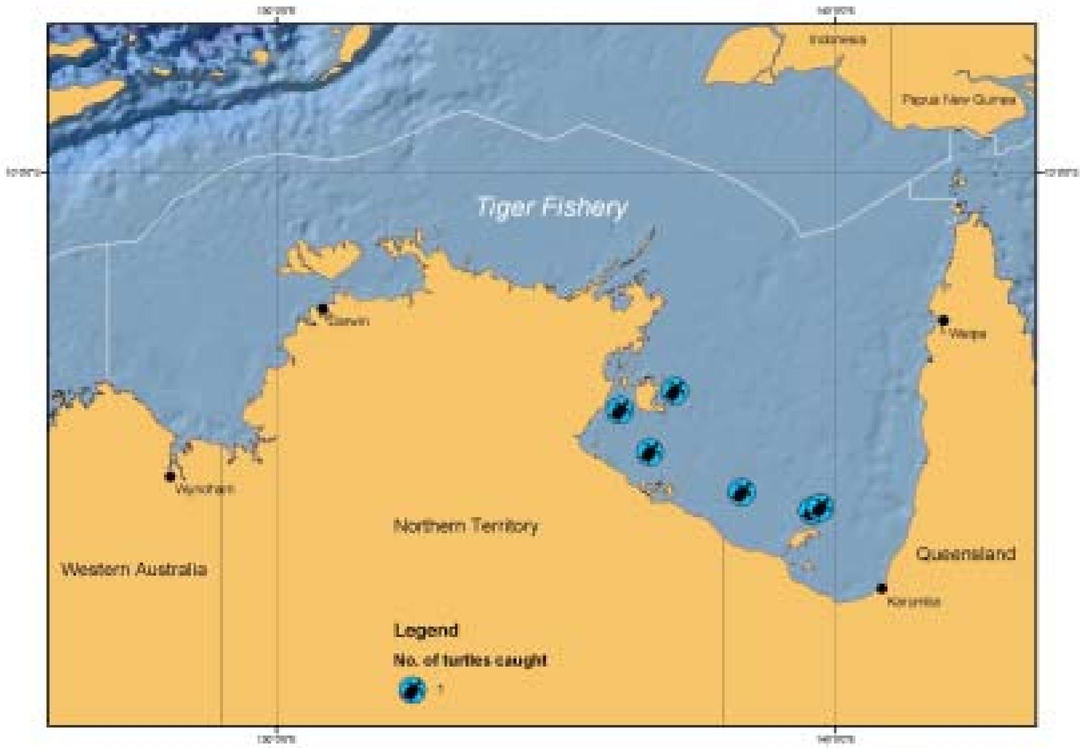


Figure 8 Sea turtle catch in the tiger prawn season after TEDs (June 98 - July 01).

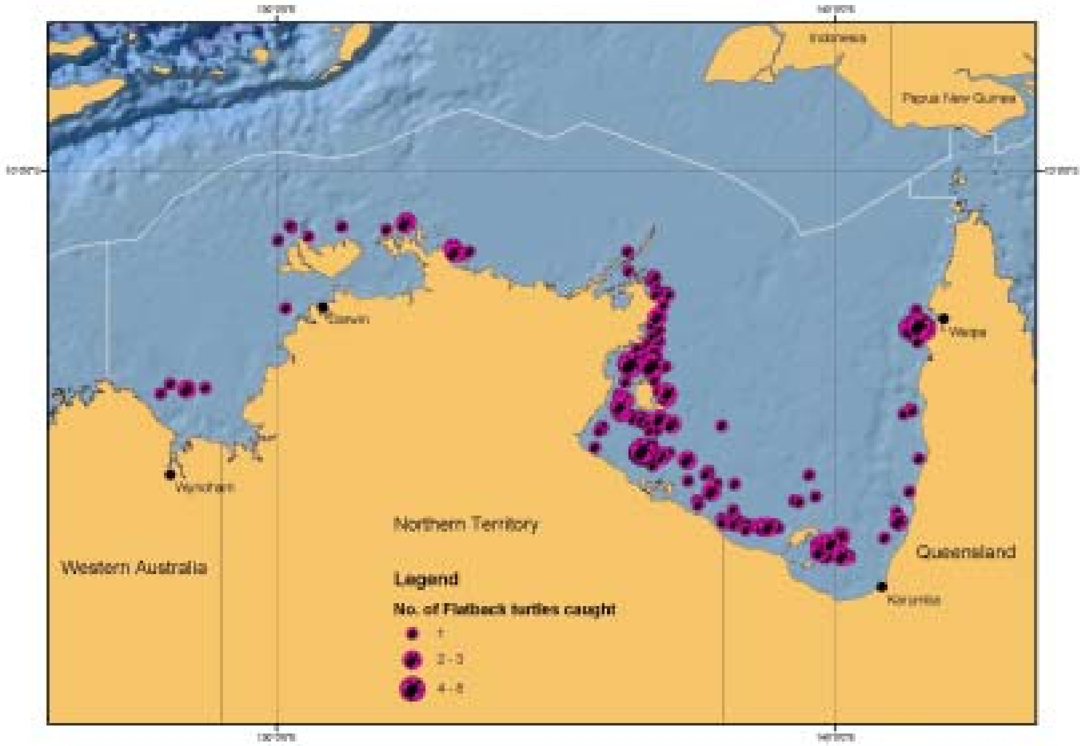


Figure 9 Flatback turtle catch from June 98 to July 01.

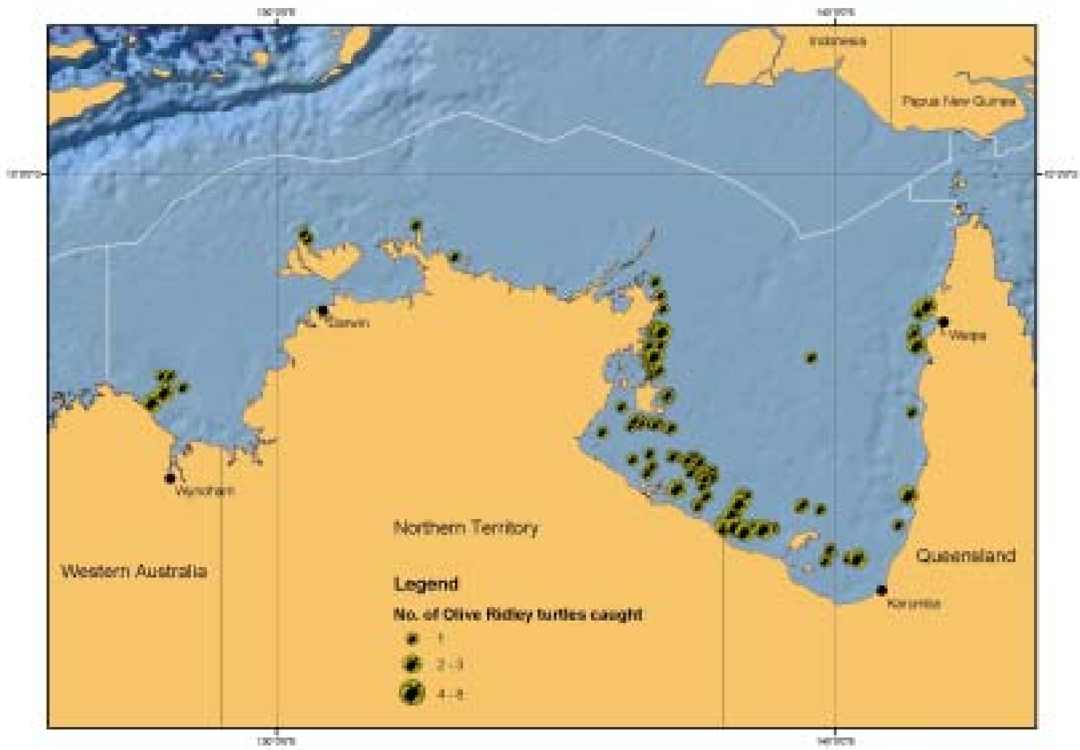


Figure 10 Olive ridley turtle catch from June 98 to July 01.

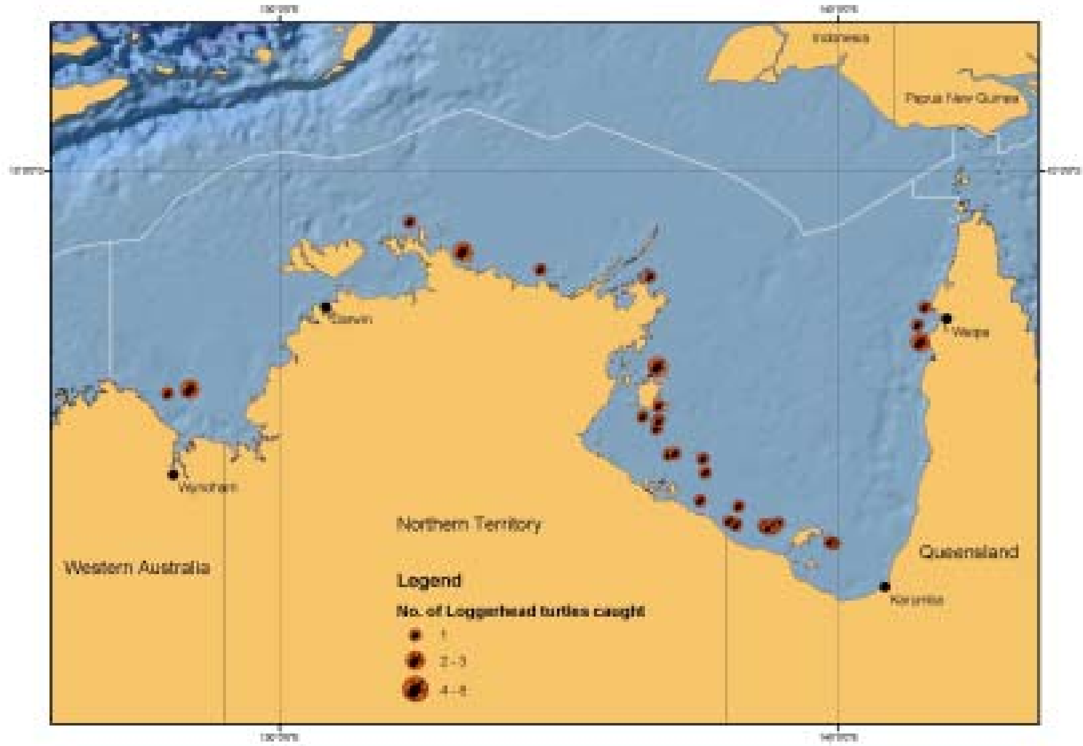


Figure 11 Loggerhead turtle catch from June 98 to July 01.

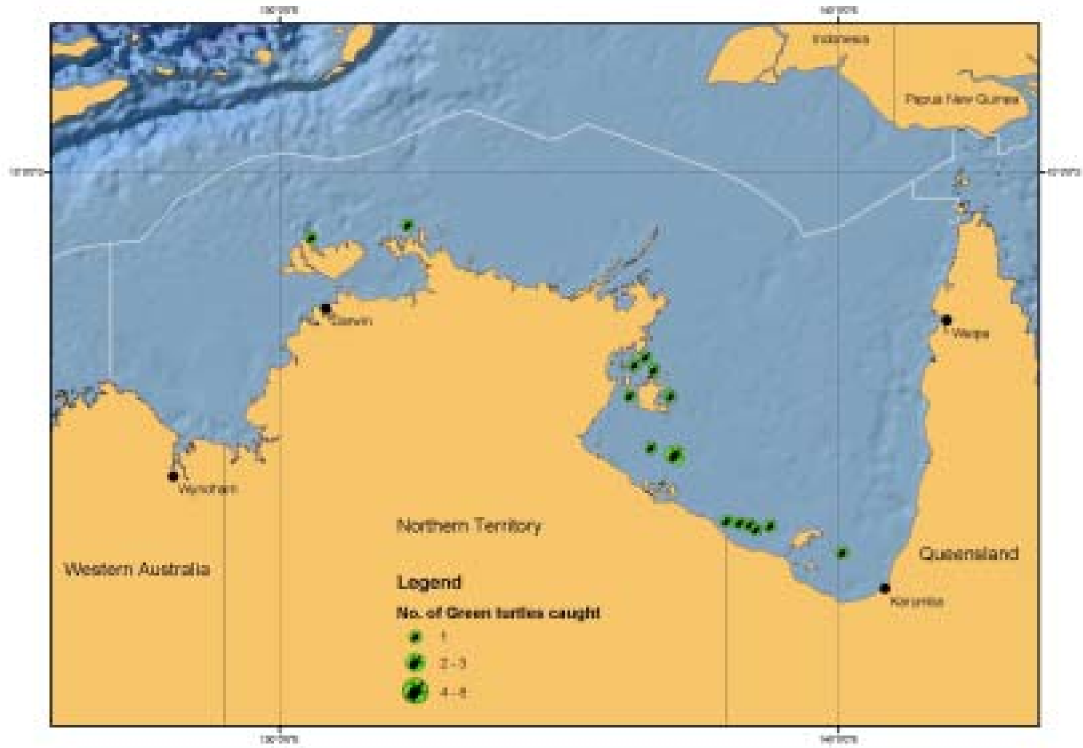


Figure 12 Green turtle catch from June 98 to July 01.

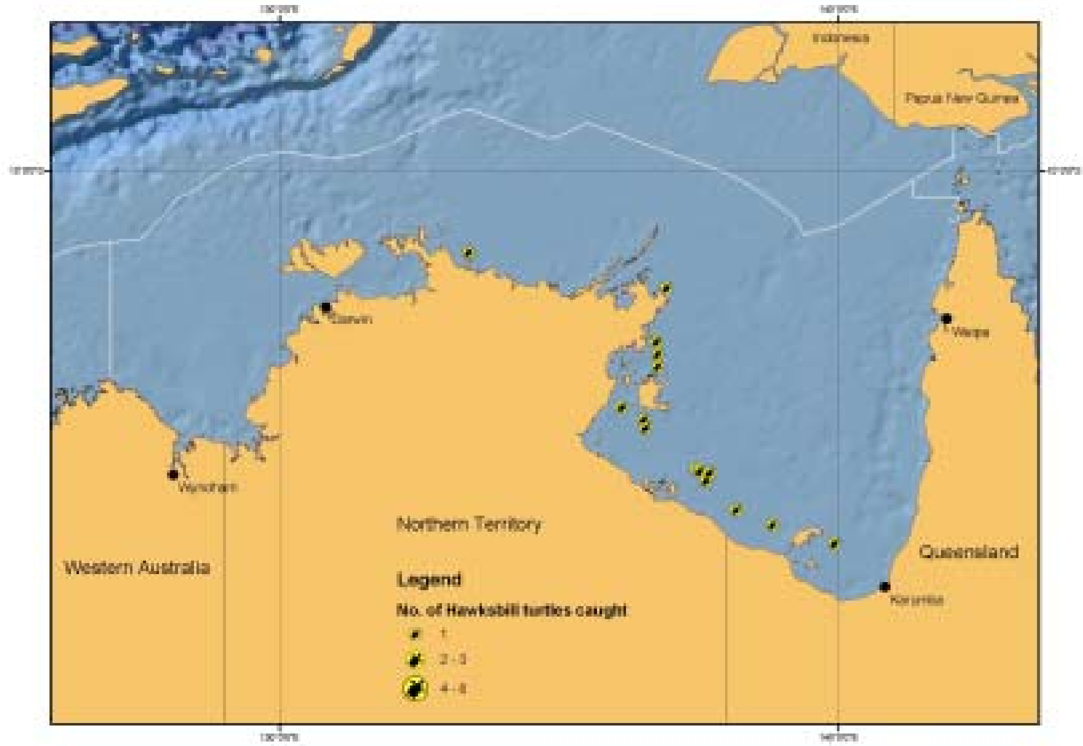


Figure 13 Hawksbill turtle catch from June 98 to July 01.

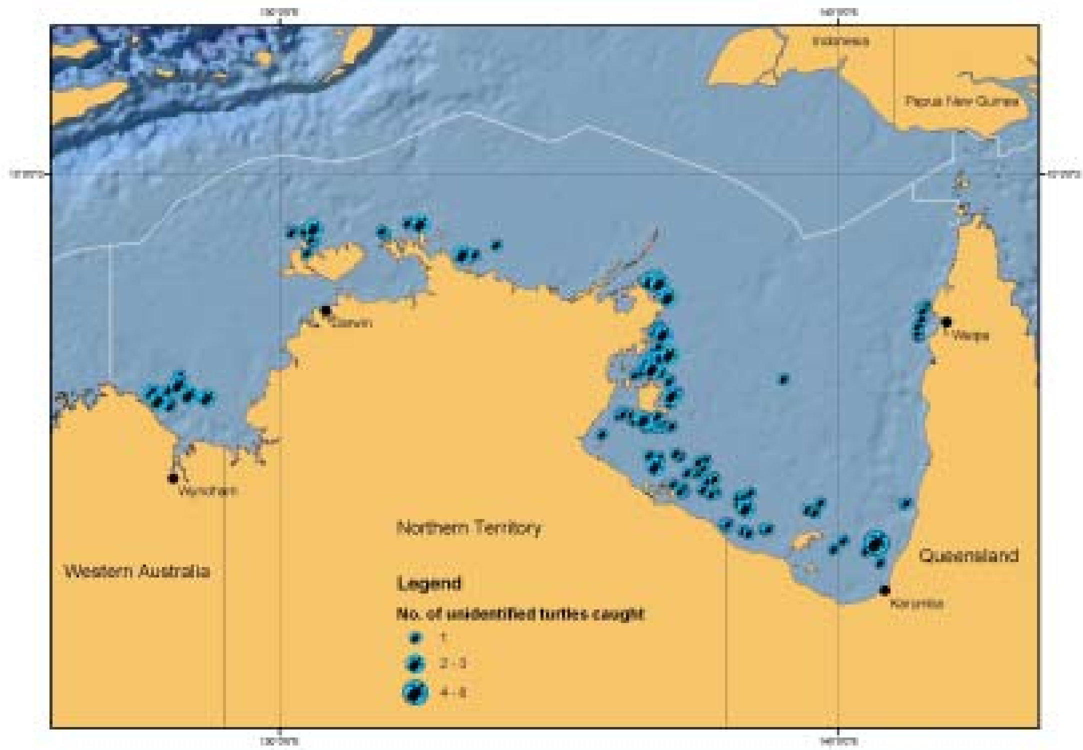


Figure 14 Unidentified turtle catch from June 98 to July 01.

Out of the 23 cameras that had photographs that could be linked to log records, nine skippers correctly identified all turtles; 10 skippers identified more than 50% correctly; three skippers were correct less than half of the time; and three identified all turtles incorrectly. Out of a total of 194 turtle photographs matched to log records, 134 (70%) were correctly identified in the logs, 50 (26%) were incorrectly identified and 10 (5%) were not identified in the log records. The relatively low frequency of correct identifications, given that some training and guidelines had been provided, demonstrates the importance of adequate species identification training and appreciation of the importance of providing correct data. Unless the skipper is properly trained and has an interest in getting it right, species identifications will always be questionable.

The species composition of the 252 turtle photographs is in Figure 15. All photographs were used irrespective of whether they were correctly identified in the logbooks. Around half of the turtles were flatbacks with olive ridleys making up another third. The next most abundant species photographed was the loggerhead and there were only small numbers of green and hawksbill turtles.

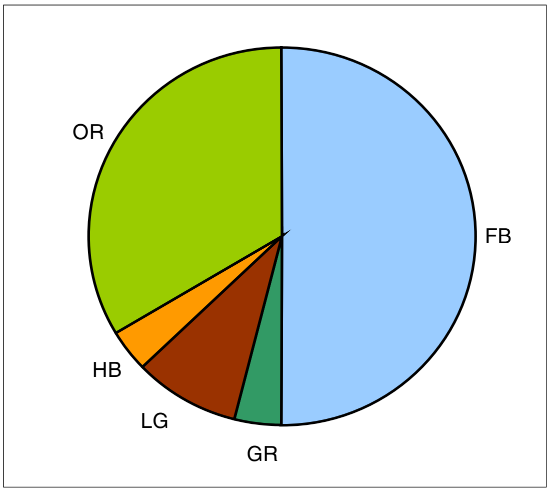


Figure 15 Species composition of sea turtles from 1997 photographs
(OR – olive ridley, HB – hawksbill, LG – loggerhead, GR – green, FB – flatback).

Sea turtle catch rate by fishery

The estimated sea turtle catch rates, using tagger data for each fishery and TED classification, are in Table 2. Catch rate from observer data was calculated only for the tiger prawn fishery before TEDs and these were used to verify corresponding tagger catch rates. To reduce bias when data is sparse, sectors with less than 10 weeks data were excluded from this analysis.

Table 2 Estimated catch rate (turtles/day) from observer and tagger data before and after introduction of TEDs for the NPF banana prawn and tiger prawn season.

		Estimated catch rate (turtles/day) ± standard error	
Reporter	**TED classification**	**Banana prawn season**	**Tiger prawn season**
Observer	Before TEDs	NA	0.342 ± 0.053
Tagger	Before TEDs	0.238 ± 0.029	0.302 ± 0.012
	After TEDs	0.007 ± 0.003	0.009 ± 0.003

Tagger catch rate verses observer catch rate

The sea turtle catch rate calculated from observer records in the tiger prawn season before TEDs were implemented is not significantly different to that estimated from tagger capture data ($p=0.45$). As expected, the standard error of the tagger catch rates is smaller (or more precise) than the observer catch rate – the standard error being a function of the number of trawl days. It is encouraging that the verified observer sea turtle catch rate agrees with the unverified tagger data.

Catch rate by fishery

The two-way factorial GLM analysis of the tagger data revealed no significant interaction between the fisheries (banana prawn and tiger prawn) and TED usage (before and after) ($p=0.281$). Significant main effect differences between the banana prawn and tiger prawn fisheries were found ($p=0.018$), with the overall catch rate for the banana prawn fishery smaller than that for the tiger prawn fishery. Likewise, significant main effect differences between before and after TEDs were found ($p<0.0001$), with the overall catch rate after the introduction of TEDs smaller than that before the introduction of TEDs.

Banana prawn season verses tiger prawn season

The higher turtle catch rate during the tiger prawn season compared to the banana prawn season is expected given the different modes of fishing operation adopted for each season. Trawls in the banana prawn season tend to be short, sometimes 15 minutes, targeting aggregating schools of banana prawns. Also, a substantial amount of time is spent searching for these schools of prawns. Consequently, the total time the gear is actually fishing and able to catch sea turtles is often quite short. For the tiger prawn season (generally August to November), even though vessels are restricted to only fishing at night, trawl shots tend to be longer and more continuous than when targeting banana prawns. The vessels tend to fish for as long as the management measures allow, possibly shooting away four or five times a night with each shot around three hours long. The target catch, tiger prawns, do not form concentrations to the same extent as banana prawns.

Before TEDs versus after TEDs

These data demonstrate that TEDs fitted in trawl gear significantly reduce the incidental catch of sea turtles in the NPF. There are, however, still small numbers of turtles being caught in nets with TEDs.

These findings are similar to other trawl fisheries in the world where TEDs have been found to be effective (Bisong, 2000). In some fisheries, turtles are, however, still being caught, and possibly killed, due to a number of factors. These factors may include injuries and increased stress from repeated capture and release from trawls with TEDs; being caught in TEDs that are not fitted or used correctly or are intentionally disabled; or capture in the try gear (small trawls that are not fitted with TEDs) (Caillouet *et al*., 1996; Shaver, 1998).

During this project, taggers and observers reported 20 turtles as being caught in a net fitted with a TED. The most logical and obvious reason for the capture, as decided by the tagger or observer, was reported. The most common reason for capture in a trawl net fitted with a TED was that the turtle had not reached the grid before the gear was winched on board (five turtles). Two turtles were captured because they were small enough to fit through the grid. One turtle was caught in the grid and another was caught because the TED became clogged with starfish. There were also six turtles caught in experimental TEDs; these were modified after the captures. Five turtles were reported as captured with no reason given for the capture.

A small number of turtles caught in nets with TEDs were reported as 'dead'– one caught in the experimental TED and one caught due to the clogged grid and one of the turtles small enough to fit through the grid. The cause of capture could not be determined for one dead turtle. Being caught before the grid, the most common reason for capture, would mean the turtle was captured during the later stages of the shot or during winching in of the gear and consequently would be in the net for a short period of time. These turtles are assumed to have a high chance of survival.

Over the whole project a further 35 turtles were caught in the trygear. These data are not included in the analysis. Trygear is a small trawl towed for short periods, designed to sample the abundance of prawns in the main gear. TEDs are not fitted to these nets. Turtles have also been noted as being captured in trawl trygear by Renaud *et al.* (1997). Although turtles were reported as being captured in the trygear both before and after the adoption of TEDs we do not recommend any changes to the current rules governing trygear usage in the fishery. None of the trygear-captured turtles were reported as dying as a result of capture. In the NPF, trygear is generally winched up every 15 to 30 minutes and this length of time in a trawl net would not be expected to drown a captured sea turtle.

Previously estimated turtle catch rate versus current result

For the tiger prawn fishery before the introduction of TEDs, a comparison of the estimated mean catch rate from Poiner and Harris (1996) with the current study, taking into account the standard errors (hence confidence intervals), suggests that the Poiner and Harris' (1996) catch rate per trawl (0.0509) is significantly lower than the current study's catch rate per trawl (0.0754) ($p<0.05$) (Table 3).

Table 3 Estimated mean catch rate for the tiger prawn fishery before the introduction of TEDs from Poiner and Harris (1996) and from the current study.

Study	n	Turtles per trawl (μ_r)[2]	Standard error (SE)	Confidence interval (95%)[3]
Poiner and Harris (1996) (1989 and 1990 pooled)	6406	0.051	0.003	±0.006
Current study (before TEDs; tiger prawn fishery)	8172 [1]	0.075	0.004	±0.008

Note: The current study's catch rate per day was converted to catch rate per trawl by dividing the catch rate per day by 4 (assuming 4 trawls per day as reported by taggers).

[1]8172 trawls=2043 days*4 trawls per day

[2]$V(1/4*\mu_R) = 1/4^2 * V(\mu_R)$ and $SE(1/4*\mu_R) = \sqrt{(V(1/4*\mu_R)/n)}$ where $n = 2043$

[3]95%CI=1.96*SE

The reason for the difference is not known although there were a number of modifications in management measures implemented and fishery operational changes made between 1990 and 1999 that may have affected the turtle catch rate. Differences that may have raised or lowered the probability of turtle capture include an increase in various area closures, a 30% decrease in total length of gear towed, a 35% fall in the number of boats fishing, a 50% decrease in total tiger prawn effort, an increase in average hours fished per day, a slight increase in engine power, an increase in average days fished per year and a contraction in area fished (Dichmont *et al.*, 2001). A further operational change from 1990 to 1998 was the utilisation of global positioning system and plotter technology by the fleet (Robins *et al.*, 1998). These technologies allowed gear to be trawled in a more precise manner (closer to, and between, rough grounds), over the same grounds more accurately, and finding previously successful, and plotted, grounds. The different sea turtle catch rate may also be related to turtle population changes with respect to fishing ground changes. Unfortunately due to the confounding nature of these changes it is impossible to separate factors that may have contributed to the increase in sea turtle catch rate.

Estimated sea turtle catch by fishery

Before NPF trawlers used TEDs the fleet was estimated to incidentally catch around 1000 and 4000 sea turtles during the banana prawn seasons and tiger prawn season, respectively (Table 4). After the introduction of TEDs these catches fell dramatically to less than 200 turtles for both seasons combined. The total sea turtles caught were estimated by fishery (banana prawn and tiger prawn) due to the differing nature of the fisheries and the variation in effort for each fishery between years. Total turtle captures were estimated only for the seasons during which data were collected: August 1998 to June 2001.

Table 4 Estimated total turtle catch rate for August 98 to June 01 by fishery.

TED use	Season	Fishery	Effort (days)	No. Turtles caught	SE	CI (95%)
Before TEDs	1998 second (Aug. to Nov.)	Banana	325	77	10	20
		Tiger	14260	4299	279	547
	1999 whole (Apr. to Jun. and Aug. to Nov.)	Banana	4287	1018	136	267
		Tiger	13900	4190	272	533
After TEDs	2000 whole (Apr. to Jun. and Aug. to Nov.)	Banana	2644	19	7	14
		Tiger	13277	122	41	80
	2001 first (Apr. to Jun.)	Banana	3372	24	9	18
		Tiger	1169	11	4	8

Sea turtle mortality rate by fishery

In estimating the mortality rate, it was assumed that comatose turtles had a high probability of dying if returned to the water in a comatose state (Gerosa and Casale, 1999). A U.S. workshop conducted in 1989 on trawl tow time verses sea turtle mortality concluded that 'while the fate of comatose turtles directly returned to the sea is unknown, a reasonable assumption is they will die' (Kemmerer, 1989:3). Also, the comments reported by taggers during this study on turtles designated as injured were examined to determine if the injury was likely to cause death; if no details were given then these turtles were also assumed to die on return to the water. If the description of the injury would not be expected to cause death then the turtle was assumed to survive after release. Unfortunately, the low numbers of turtles caught in nets fitted with a TED and the high proportion of turtles returned to the water in an unknown condition make it invalid to estimate a mortality rate for the turtles caught in a net fitted with a TED.

The mortality rate without TEDs fitted in gear was estimated to be around 22%. There was no significant difference found between the banana prawn and tiger prawn fisheries' mortality rates (∂^2 =0.8, df=1, p=0.37). There was also no significant difference between turtle species (∂^2 =3..5, df=2, p=0.17), although only flatback, loggerhead and olive ridley mortality rates could be compared due to lack of data for the other species. All turtles caught in try gear, both before and after TEDs were installed in the main gear, were returned to the water healthy.

In the early 1990's Poiner and Harris (1996) estimated a higher mortality rate of between 25 and 39%, depending on how many comatose turtles would survive on return to the water and how many injured turtles would eventually die. The difference between these estimates and the current study may be that in the earlier study a relatively high number (around half) of the comatose turtles were reported as being returned to the water in a comatose state. In the current project very few turtles were returned to the water comatose. Fishers now follow a recommended recovery procedure that is expected to improve a comatose turtle's chance of survival. Recovery procedures are in Appendix 10 and include retaining comatose turtles on the deck in the recovery position for up to 24 hours, raising the rear end slightly and possibly keeping the carapace moist.

Some estimated mortality rates from other trawl fisheries in the world differ from the mortality rate estimated here, while others are comparable. Observers on Italian trawlers operating in the North Adriatic Sea estimated that 57% of turtles that were captured were comatose and the remainder was made up of 14% each of healthy, injured and dead turtles (Laurent *et al*., 2001). A mortality rate of around 50% was estimated for Costa Rican trawlers (Arauz, 1998). The estimated mortality rate for sea turtles captured in Guyana and Suriname was 60% and 50%, respectively; these high mortality rates were attributed to long tow duration and lack of recovery techniques (Tambiah, 1994). Mortality rate for the Queensland east coast prawn fishery in Australia was estimated to be very low compared to other trawl fisheries (between 1.1 % and 6.8%) due to the relatively short tow duration of less than 80 minutes (Robins, 1995). The incidental capture of sea turtles by the industrial shrimping fleet off north-eastern Venezuela is 1 370 turtles per year with a mortality of 260 (approximately 20%; Marcano and Alio, 1998). Mortality rates for Louisiana, Florida and Alabama shrimp trawlers were estimated to lie between 21 and 25% (Hillestad *et al*., 1981).

Two factors, tow duration and recovery procedures, have been shown to have a significant impact on mortality rates (Ulrich, 1978; Henwood and Stuntz, 1987; Kemmerer, 1989; Tambiah, 1994; Robins, 1995; Laurent *et al*., 2001). The NPF has adopted an effective code-of-good-conduct with respect to handling sea turtles, and trawl length varies from 15-minute shots to relatively long trawls of 4 or more hours.

The increased probability of death as a result of multiple captures of the same turtle was noted by Hillestad *et al.* (1981) in his consideration of turtle captures by trawlers in the near shore waters of Georgia, USA. There was the suggestion that turtles that are captured more than once on the same day may be more likely to drown. Although the number of turtles recaptured in this project was very low, making statistical analysis inappropriate, there was no indication of this effect. Out of the six turtles that were recaptured the same day, only one was reported as healthy after the first capture and dead after the second capture.

Captured sea turtle length distribution

There are considerable differences in size between the five species of sea turtle regularly seen in the waters of northern Australia, from the relatively small olive ridleys to the large green sea turtles. In addition, the sea turtles reported as being captured by taggers or observers during this project ranged from hatchlings to adults (Figure 16).

Hillestad *et al* (1981) noted that mortality as a result of prawn trawling operations can be influenced by the size of the turtle – smaller turtles tending to drown more quickly than larger turtles. However, for the current project small samples precluded statistical analysis of the effect of turtle length on mortality or on the relationship between turtle length and TED usage.

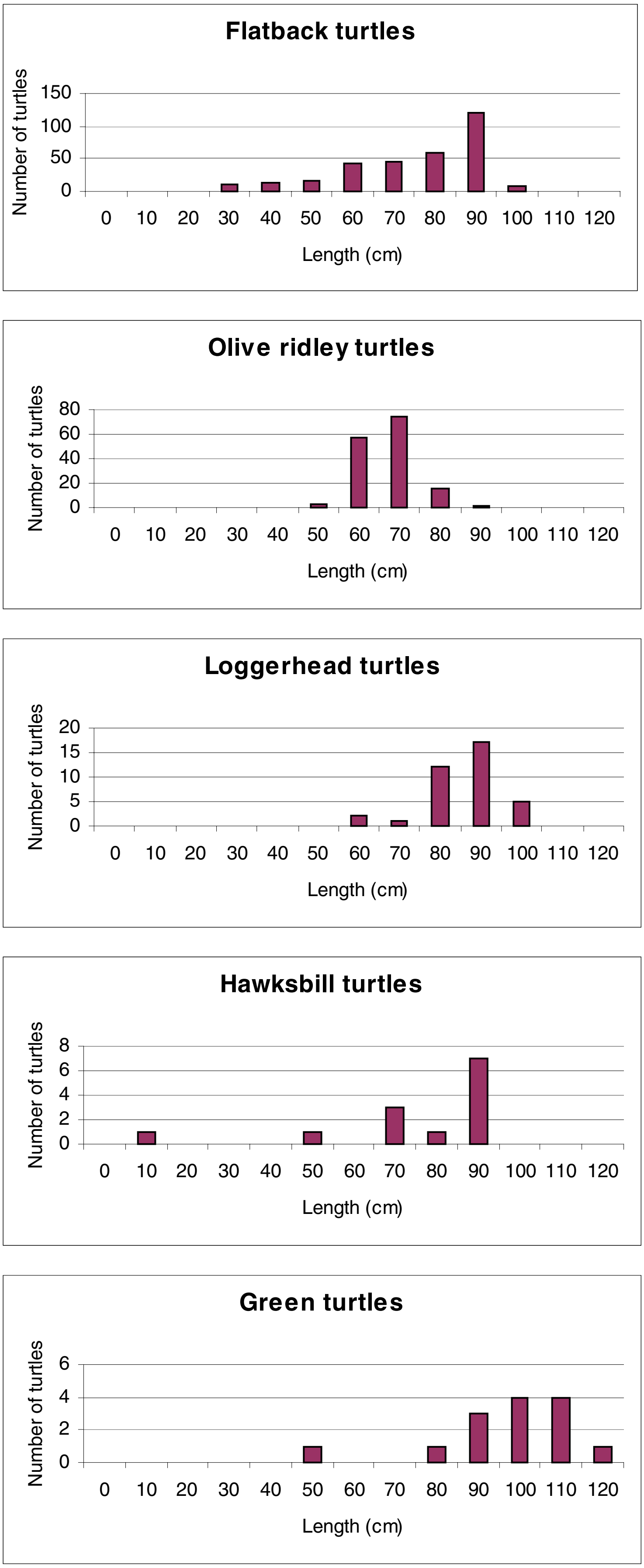


Figure 16 Turtle size composition by species

Catch rate by month

Sea turtle catch rates vary with time of year, with the highest catch rates occurring in August and September ($p<0.0001$) (Figure 17). The April 1999 catch rate is significantly lower than all other monthly catch rates ($p<0.05$), apart from November 1999 and April 2000 ($p>0.05$). The error associated with April 2000 is a consequence of the limited sample size for that month ($n=15$). A similar temporal distribution of turtle catch rate was found by Poiner and Harris (1996).

Sea turtle species composition

In order to estimate the species composition of sea turtles caught by NPF trawlers, all reported turtles with a verifying photograph or identification by a proven tagger were used. A proven tagger was one who had correctly identified turtles with verifying photographs during a previous season. Observer identifications were also assumed to be correct. This yielded 637 turtle identifications for analysis.

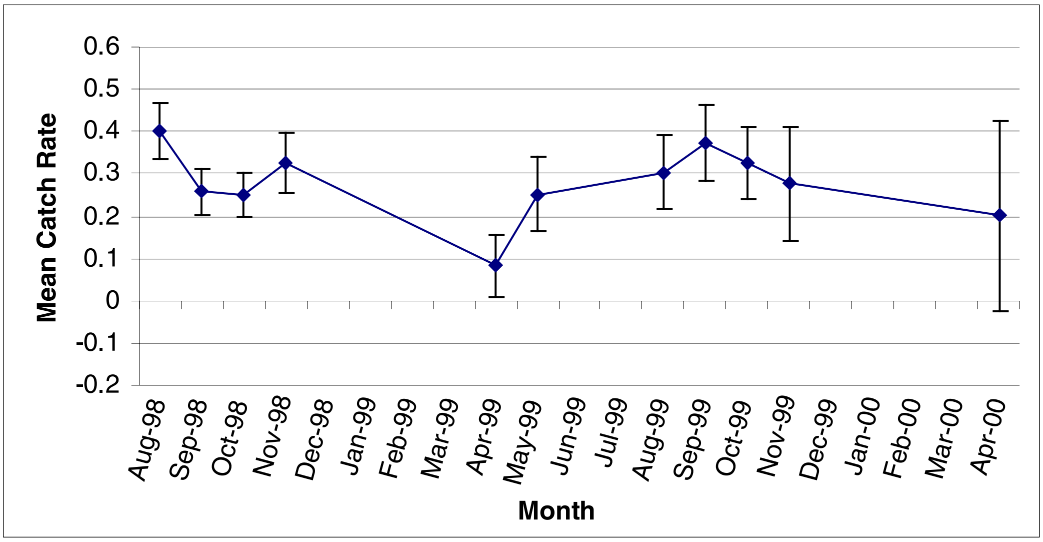


Figure 17 Estimated mean sea turtle catch rate reported by taggers before TEDs were introduced into the NPF fleet. Error bars represent ±95% confidence intervals.

The species most commonly captured was the flatback at 60%, followed by the olive ridley at 29%. The other species were caught rarely, with loggerhead at 6%, green at 3% and hawksbill at 2%. No leatherbacks were reported by taggers.

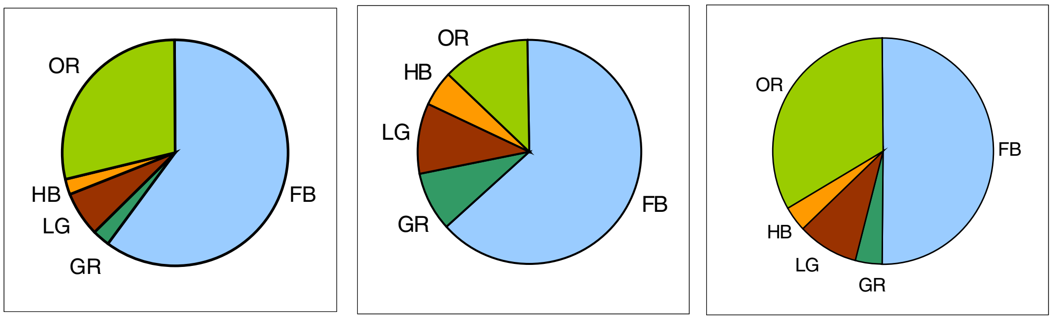
There have been a small number of leatherbacks, however, reported in log records each year, although these sightings have not been verified. A fisher trained as a tagger reported that they had definitely caught a leatherback in 1997 and released it healthy. Therefore, there is evidence that leatherbacks are caught in this fishery, although very rarely.

The species proportions found during two previous studies (Poiner and Harris, 1996; Sachse, 1997) and the current project are compared in Figure 18. The proportions of turtle species caught were not the same for all three studies (∂^2 =56.1, df=8, p<0.0001). More specifically, the study by Sachse (1997) found similar capture results across the species to those found in the current study (∂^2 =8.3, df=4, p=0.08), whilst results from Poiner and Harris (1996) were significantly different from those found by either Sachse (1997) (∂^2 =35.1, df=4, p<0.0001) or the current study (∂^2 =45.5, df=4, p<0.0001). The similarity between Sachse (1997) and the current study is expected due to identifications from both data sets being verified, i.e., turtles were photographed, and time frames being close, i.e., 1997 versus 1998–2001.

There are a number of possible reasons behind the difference between the current study and Poiner and Harris (1996). However, there are no data that could be used to accept or reject these hypotheses:

- A substantial number of species identifications for the earlier Poiner and Harris (1996) project (1989–1990) may have been incorrect. The turtle component of the study was minor, with the target species, prawns, being the main species of concern. Additionally, the turtle identifications were not verified;
- The sea turtle species abundance in the waters of the NPF has changed over the last 10 years; and/or

- Changing fishing methods and/or fishing grounds have resulted in catch rates of each species differing. Log records and gear sheets indicate that some fishing grounds and fishing methods have changed over the last 10 years, as noted in the 'Previously estimated turtle catch rate versus current result' section on page 31 and 32.



A *B* *C*

Figure 18 Sea turtle species composition from: A- this project (98–01), B- Poiner and Harris (1996) (89–90) project and C- the Sachse 1997 project.

Comparison with skippers' logs

Total sea turtle reported catches by the fleet

The total number of sea turtles reported in the AFMA logbooks by the whole NPF fleet before TEDs were installed in nets, i.e., during the 1998 second season (August to November) and both 1999 seasons (April to June and August to November), shows an alarming level of under-reporting (Table 5). There was a factor that may have attributed to this difference – some skippers ceased recording turtles while an observer or tagger was onboard. This, however, would not cause the magnitude of the difference between logged turtle catch and estimated turtle catch.

The under-reporting of turtle captures was not apparent in the data after TEDs were installed in nets, i.e., during both 2000 seasons (April to June and August to November) and the 2001 first season (April to June). It is not reasonable, however, for these data to be compared as logbook reported catches include turtles caught while TEDs were not being used from 1–14 April 2000 and while TEDs were being trialed from 1–14 April 2001. The catch estimates from tagger data do not take these operations into account.

Table 5 Comparison of turtle catch numbers reported in logbooks and estimated from the current study.

	1998	1999	2000	2001
	Second Season	**Both Seasons**	**Both Seasons**	**First Season**
Logbooks	734	883	68	52
Current project	4 376	5 208	141	35
Difference factor	6	6	2	Not applicable

Sea turtle catches reported by individual vessels

These data do not allow for a comparison of tagger and observer catches with skipper-recorded catches in the logbooks to look at compliance of skippers in completing sea turtle captures. From a preliminary analysis of the log data, in some cases, when a tagger or observer was present on the boat it seems likely that skippers ceased writing down captures. In these cases, turtles were reported before and after the tagger was on board but not while he was working in this project. It was assumed the skipper thought it was not useful to replicate the tagger or observer data. In other cases skipper-logged turtle captures appeared to agree somewhat with tagger-reported captures and in still others there seems to be no similarity between the two sets of data. As the reason for the differences is not known a statistical comparison by vessel between tagger-reported and skipper-logged turtle capture data is not possible.

This problem should be addressed in any future work of this type. The solution, however, is not an easy one. If the skipper is well briefed on what is expected with logbook data there may be a problem with respect to data independence. The skipper will know the logbook data is being compared with the tagger data and possibly ensure it is identical, irrespective of whether it is routine to complete sea turtle captures in logs. If the skipper is not instructed on completing logs the assumption may possibly be made that replication of data is not wanted.

Recommendations for the AFMA logbook monitoring of sea turtles

AFMA has included the catch of bycatch species in skippers' logbooks since 1996 and actively encouraged industry to routinely and accurately complete this section of the logs. Examples of current- and past-endangered species log pages are in Appendix 11.

The apparent high level of under-reporting of sea turtle catch in these analyses demonstrates the need for continued, and possibly increased emphasis on, awareness by fishers of the importance of reporting turtle captures accurately. In conjunction with this campaign, awareness in best-practice turtle recovery procedures should continue to be promoted irrespective of the reduced turtle catch.

Logbook designers always have the problem of providing space for all possible data while keeping the logbook simple and at a useable size. If the log is very complex and arduous to complete there is less chance that the skipper will want to or have time to complete it accurately. With respect to the endangered and rare species section it is necessary to ensure it applies to all species and not just sea turtles. However, the simplicity and the multi-species design of the NPF log can result in information that is easily misinterpreted. Some examples of problems encountered when raw log sheets were compared with punched data are:

- Fishers measuring animals without reporting the technique adopted, i.e., curved or straight carapace length.
- Unit of measure (centimeters or inches) not being punched correctly. This is due to the unit of measure not being described in the instructions because it is not requested, but some skippers consider it to be important to record.
- Two turtles being reported as one, and visa versa, due to the design of the logs. An example is when the health status (H) is written once but there are two measurements or two locations (probably indicating that two turtles were caught). With careful consideration it is possible to interpret that the skipper is reporting two turtles, but initially it could be interpreted as one turtle.

All of these problems can be corrected. It is impossible, however, to prepare for all possible misinterpretations. Verification and quality control processes should be implemented. Methods to minimise misinterpretations could include double punching data by different people, randomly checking that raw data matches correctly with punched data, and investigating unusual reports. Considering it's significance to sound fisheries management and to the conservation of animal populations, the importance of accurate rare and endangered bycatch data needs to be emphasised to industry by logbook staff so that it is not considered an unimportant addition to target catch data.

A recommendation is that AFMA staff continue to keep fishers aware of the importance of reporting sea turtle captures. One addition to the requested information could be a probable reason why the turtle was captured. This would enable researchers and fishers to identify problems with the TEDs and to modify either the design or fishing practice to achieve the optimum result of minimal captures of sea turtles by NPF trawlers.

Resuscitation techniques

The mortality rate of sea turtles as a result of capture in trawl nets has been shown to dramatically reduce if proper handling techniques are used. Shoop *et al*. (1990) found that sea turtles can become comatose when submerged in trawl nets: appearing dead, not breathing and with infrequent heartbeats. Some stranded comatose sea turtles, when protected from predators, recuperated after being allowed to recover, sometimes over weeks. As early as the late 1970s, Ulrich (1978) (cited in Murphy and Hopkins-Murphy, 1989) documented that recovery periods for comatose turtles were important. A U.S. workshop in 1989 on trawl tow time verses sea turtle mortality also recognised that the comatose condition of trawl-captured sea turtles depended on the handling procedures adopted (Kemmerer, 1989). The assumption, previously noted in Ogren at al. (1977), that these turtles would die if returned to the water before recovery was also endorsed. It was noted that comatose turtles should be allowed to recover on deck but need to be protected from the sun and other sources of injury, such as sliding around the deck, while on the boat (Figure 19). In addition, there will be an increased probability of mortality if a turtle is recaught following recovery from the comatose state (Kemmerer, 1989).

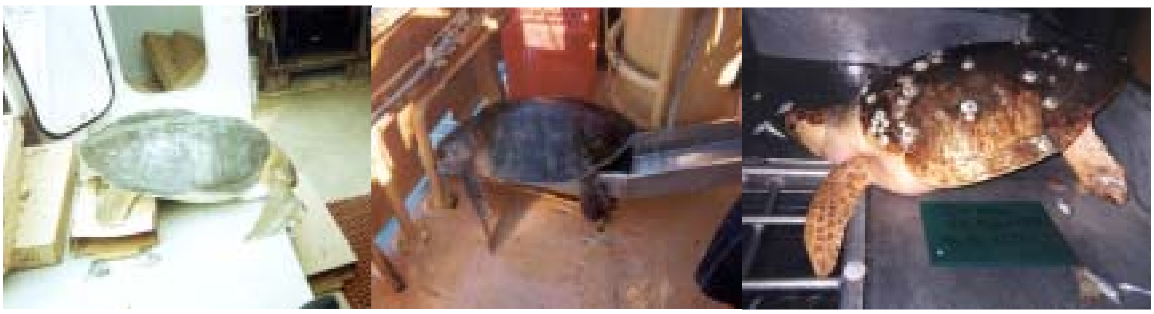


Figure 19 Sea turtles in the recovery position on NPF trawlers

Logbooks provided to the skippers on NPF trawlers contain sea turtle resuscitation guidelines that were prepared by the Queensland Commercial Fisherman's Organisation and the Queensland Department or Primary Industries (Appendix 10). In addition, AFMA logbook officers instructed skippers, and if possible the crew as well, on correct techniques to ensure they understood the guidelines.

Taggers were also trained to follow these guidelines. The taggers submitted ideas or techniques on their data sheets that they felt would improve the handling guidelines. These have not been statistically tested but are rather the opinions of people who handle these animals regularly. Such comments included: ensuring that the rear of the turtle is not raised too high resulting in the neck being kinked unnecessarily and covering the turtle with wet rags or allowing water to gently run across the turtle if it is left to recover on deck.

A small number of taggers tested a method of resuscitation that was suggested by Dr Colin Limpus (QEPA). If the turtle was considered dead the tagger placed a small plastic pipe down the turtles windpipe and gently blew into the pipe. Out of the 22 turtles treated using this technique, 12 recovered. A probable confounding factor was that some taggers applied this technique on all comatose turtles as quickly as possible, while others waited until the turtle seemed dead. Due to the small sample size and irregular procedures it is not possible to statistically test this resuscitation technique. However, this technique warrants further investigation and possible inclusion in handling guidelines (Table 6).

Tagging data

Sea turtles are tagged so that individuals, or cohorts, can be distinguished from each other. It is recognised as one of the most valuable research activities undertaken with these animals and has contributed to understanding of migration, growth, life cycles and mortality (Balazs, 1999).

A total of 654 sea turtles were tagged throughout this project (Figure 20). All tag records included a geographic location – either the tagger reported latitude and longitude or skippers' logs provided this data. Not all tagged turtles were measured, mainly because the turtle work was secondary to catching prawns. Only turtles with a corresponding photograph or tagged by taggers that had proven themselves in the field to correctly identify turtles were accepted as correctly identified to the species level. The exclusion of species identification for tagging records is somewhat inconsequential as it is hoped that the turtle can be correctly identified if recaptured.

This was the last chance for a significant number of sea turtles to be tagged and photographed on NPF trawlers due to the introduction of TEDs in 2000. The resultant data set is considered to be valuable for turtle conservation in Australia.

Figure 20 Tagging a sea turtle.

Although the tagging results were not used in these analyses, except to determine recapture rate, it became apparent that this activity played a vital role in the project. Tagging the turtles contributed to increased enthusiasm in the project by the taggers. Recording numbers on a data sheet does not hold the same attraction as actively handling, tagging and photographing the turtles. Also, reporting the migration routes of any turtles tagged during this project and recaptured elsewhere was of great interest to the taggers, especially to the person who actually did the tagging of that individual.

Table 6 Comments provided by taggers for all turtles given mouth-to-mouth resuscitation.

Comment	Outcome
Resuscitated by mouth to mouth (7 hours on deck).	healthy
Little movement in eyes when touched, so propped up back of turtle and inserted hose into throat, after 1hr 20 mins turtle was very lively so we released him.	healthy
Place hose in turtles throat and it recovered.	healthy
This one I didn't think would make it, put hose in throat and lifted back end up. Heaps of water came out.	healthy
Left on deck for 3hrs 25 mins with body on 45° angle and head handing over the side of the hatch, put hose in throat to drain water from lungs.	healthy
Put hose in throat and lifted up 45°.	healthy
Put hose in his throat and lifted up back of shell to let water drain out.	healthy
Left on deck with hose in throat.	healthy
Left on deck with hose in throat at 45°, heaps of water came out, for about 5 minutes.	healthy
Put hose in throat.	healthy
CPR needed (with hose).	healthy
Flatback was at first thought to be dead, but was resuscitated with a piece of plastic hose as shown by Col Limpus. Turtle appeared bruised and not in a good condition on release.	injured
Turtle seemed very lethargic, eyes closed and swollen shut but when pulled rear flipper – slight movement so placed on deck. After 3 hours black slime oozed from turtle. Tried to resuscitate with pipe but still nothing, no movement at all. Began to stink.	dead
Tried to resuscitate with pipe down throat and lifted rear to drain lungs but to no avail – stiffness had set in after 4 hours.	dead
Attempted resuscitation – no good.	dead
Attempted resuscitation – no go.	dead
Place hose in turtles throat but it didn't recover.	dead
Place hose in throat but didn't recover.	dead
Put hose in turtles throat, but I think this one was dead for a while before we caught him. But I tried anyway.	dead
Left on deck all day in shade with wet bags over carapace. Deck hose run on him. Lifted to 45° angle with head lower and hose in throat.	dead
Place hose in throat.	dead
No eye response – tried CPR to no avail.	dead

Sea snake and sawfish catch and mortality

In addition to sea turtles, taggers also reported sawfish and sea snake captures (Table 7). This data includes both tagger reported catch and observer reported catch and so includes catches with and without TEDs in the fishing gear. This data should not be adjusted up to the total effort as it needs further analysis before reasonable conclusions on catch rates and numbers caught can be made. A greater proportion of sawfish were reported as being returned to the water dead (77%) than were snakes (27%). The full analysis of sea snake and sawfish data is not included in this report.

Table 7 Sawfish and snake captures reported by taggers and observers and reporting effort.

		1998	1999	2000	2001
Sawfish	Catch (no. individuals)	187	47	36	17
	Effort (days)	1080	534	243	61
Snakes	Catch (no. individuals)	1053	237	301	81
	Effort (days)	841	358	213	50

Fishers as data collectors for the capture of rare bycatch species.

Without the help of volunteer fishers this project would not have been possible. One of the main advantages of enlisting fishers in these types of projects is the low cost. This project cost a fraction of the estimated cost had the project employed observers for the same length of time.

Many additional advantages became apparent during the running of this project. Particularly the greater cooperation between scientists and fishers. This resulted in an improvement in understanding, both for the fishers and the scientists. Fishers gained an appreciation of the difficulties of scientific research and scientists gained an appreciation of the role of fishers. It is hoped that the cooperative relationships cultivated by this project will benefit future research projects involving the industry.

Good timing is considered to be fundamental to the success of the project. TEDs were becoming mandatory in the NPF in 2000, so the research results would not negatively impact on their fishing operations. Consequently, the fishers had no qualms about reporting turtle catch accurately and completely. Fishers cannot be expected to provide evidence that may result in negatively affecting their fishery, or maybe even cause it’s closure.

There have been various lessons learned by the researchers during this project that should be considered for future research of this type, including:

Flexibility

The importance of remaining flexible was apparent. In order to be able to tag and report on turtles, while also completing their own work, each tagger tended to adopt their own procedures within the general guidelines. It was necessary to be supportive of their methods while ensuring that they met the requirements of the project, and to bear in mind that they were not employed by the project but rather by the fishing company. Examples of modifications to the methods were one tagger who preferred to stipulate days when not reporting turtles, rather than days when he was reporting turtles, and another who recorded turtles on week-days and snakes on weekends. Initially, the data sheets were examined in detail and if any information was not clear the tagger was called and queried on the methods used. Once a set of general ‘rules’ was established for each tagger it was relatively straightforward to interpret the data correctly.

Provision of equipment

The provision of equipment was important in allowing taggers to work efficiency. It was found that the taggers needed to have everything easily accessible or they could not carry out their tagging duties. They were therefore provided with a backpack with all the equipment, plus spares when possible. It was not easy to provide extra equipment as supplies were depleted during the season, so the taggers were initially given an excess of items such as turtle tags, pencils, data sheets and cameras.

Training and retraining

The training workshops were fundamental to the success of this project. The taggers were taught scientific data collection procedures and all the necessary skills in handling, measuring, tagging and resuscitating sea turtles. Turtle identification skills were taught with a short lesson on reading species identification keys, followed by practice and testing on preserved turtle shells. Measuring, tagging and handling skills were taught in a similar way – formal instruction, then practice and testing on real turtles, preserved and live, where possible. Data recording procedures were explained during classroom sessions, with informal testing throughout the day and at the end of the workshop. During the first workshop we found that written tests were not the most suitable method to check that taggers were clear on procedures. In order to adequately test the taggers the exams needed to be long and quite arduous for some of the volunteers. An informal approach was more suitable as it was less intimidating than a ‘formal exam’. A common request given in feedback questionnaires after each workshop was that they would prefer less classroom training and more fieldwork.

Sea turtle biology and conservation was presented to increase the volunteer’s appreciation and awareness of the global nature of bycatch problems, principally with respect to sea turtles. Many of the taggers were keen to learn more about sea turtles and readily participated in discussions on the various aspects, including behaviour, stock status and migration.

Workshops in the second and third years of the project were a review of the project so far. An exception was with new volunteers, who were trained on an individual basis before the general workshop. The review sessions were important to check that all taggers still followed the same guidelines, to check that the information from data sheets was interpreted correctly and to allow taggers to see the importance of the data they had collected.

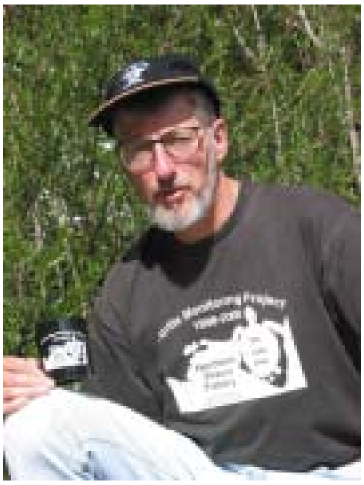
Workshop costs were completely covered as they were also considered to be an incentive for the taggers to continue with the project. The final workshop, focusing primarily on review of the project, included entry to a marine based theme park, Sea World, to tour the centre’s turtle rescue facilities.

Identification skills

The trained taggers’ proficiency at turtle species identification ranged from incompetent to proficient. This skill level was tested using photographs of turtles taken with disposable cameras. However, not all taggers returned cameras, making it impossible to determine their identification skills. Of the 18 taggers who returned cameras, seven were considered to be proficient with very few errors (at least 90% accuracy), three regularly made errors (less than 90% accuracy) and eight did not provide enough verifying photographs to determine their level of identification skill (at least two of each species correct). The latter group of people is a problem; they may not have returned photographs because they were unsure of their own identification skill. It may be possible to exclude species identifications from project methods and instead request that all turtles be photographed. This should solve the problem of taggers not taking photographs if they are unsure of the accuracy of their species identifications.

We found the use of disposable cameras to be invaluable in determining the correct species identification, and given the high level of incorrect identifications, this was particularly important. Photographs may also become significant if turtles are recaptured and a comparison of visible injuries can be made. The problem of unreturned cameras should be addressed in future projects that require fishers to identify species.

Encouragement rewards



Various gifts were given to participating taggers. T-shirts, caps, stubby holders, mugs and jackpot cash draws were designed to not only provide incentives to keep taggers in the project but also as a sign of our appreciation for their contribution (Figure 21). A tag reward consisting of a stubby cooler and a cash prize was provided to other fishers from the fleet returning tags. The encouragement rewards were a contributing factor in the success of the project.

An additional advantage of these rewards was that they were also promotional material. All items were printed with the project logo so were readily visible around the fleet. This could possibly have promoted discussions between crew members on sea turtles and encouraged other fishers to become turtle taggers.

Figure 21 An example of the encouragement awards.

Turtle injury comments

Taggers provided, in many cases, a description of anything about the turtles that they considered might be relevant, including both old and new injuries (Figure 22). This information may be useful if the turtle is captured again and injuries compared.

Other comments that were noted on the data sheets and may warrant further investigation are:

- Large congregation of flatbacks and olive ridleys in squid schooling area (14° 137 °) seen on the surface in the day a couple of miles either side of the position.
- We have more dead turtles when fish bycatch is high. Is the fish in the codend smothering them?

Figure 22 Captured sea turtle with injury report.
‘Piece missing out of back left hand side of carapace’.

Benefits

The NPF is the main beneficiary of this study. The effectiveness of TEDs, the primary management measure implemented to address the sea turtle bycatch issue, has been evaluated and found to significantly reduce sea turtle capture. In addition, the fishing industry has demonstrated a commitment to ensuring that NPF operations are not contributing to the global decline of sea turtles.

Fishers, scientists and managers of trawl fisheries in Australia and elsewhere in the world will benefit from the evidence of TEDs effectiveness. In addition, researchers considering the possibility of using fishers as primary data collectors on rare species may find value in this study.

Sea turtle research projects – for example, those dealing with migration patterns, growth rates, complex life cycles and mortality events – will benefit from information obtained from the significant numbers of turtles tagged during this project.

Further development

The results of this project will be presented in a report that is more concise and relevant to the NPF fishers, for dissemination into the NPF fishing fleet. The study will be further documented in scientific papers in sea turtle and fisheries journals.

Concluding remarks

These analyses suggest that in recent years and prior to the use of TEDs in trawl nets around 5 000 sea turtles were captured annually during NPF trawl operations; about 1 000 during the banana prawn season and 4 000 during the tiger prawn season. This is slightly lower than the tiger prawn fishery annual catch of between 5 000 and 6 000 turtles estimated by a study in 1989–1990 (Poiner and Harris, 1996). Changes in the fishery, including a substantial drop in effort, are likely to contribute to the difference. Differences between the studies also occur in the estimated catch rates and mortality rates. The earlier study demonstrated a catch rate during the tiger prawn season of 0.0509 turtles per trawl, while the current study showed a higher corresponding catch rate of 0.0754 turtles per trawl, assuming 4 trawls per night. Again changes in fishing operations and adoption of new technologies might account for this difference. Mortality rate was estimated to be up to 39% in the earlier study and during this study, but prior to the use of TEDs, at around 22%. This is assumed to be as a result of improved handling techniques adopted by fishers in the fleet over the last 10 years.

Since TEDs have been installed in NPF trawl nets the turtle catch rate has decreased to 0.0072 for the banana prawn season, or as low as 20 turtles per year for the whole fleet, and 0.0092 for the tiger prawn season, or as low as 100 turtles per year for the whole fleet. The small numbers of turtles that are still captured are taken primarily during the ‘winching-up of the gear’ stage of the fishing operation. These turtles are assumed to have a good chance of survival due to the short length of time they are in the gear. Consequently the mortality rate is assumed to be substantially less than the estimated 22% prior to the adoption of TEDs. The actual sea turtle mortality rate in gear containing TEDs, however, could not be estimated due the small number of sea turtles reported as caught in nets with TEDs.

In addition to minimising sea turtle catch, nets with a TED installed must also continue to catch the target species. If this is not demonstrated, the implementation of TEDs may be more difficult and possibly result in legal conflicts (Seidel and McVea, 1981). Other studies have noted that some TEDs, depending on the design, can result in a reduction of the catch of prawns (Anon., 2001b). However, damage to prawns caught in a net fitted with a TED is substantially reduced, by 6 to 35%, compared with a standard net without a TED (Anon., 2001b). As a consequence, the value of the catch can be improved and the bulk-packed damaged prawns that attract a low price are replaced with premium quality prawns attracting a much higher price. Research on the economic benefits of TEDs in the NPF is ongoing.

Over the last couple of years trawl fisheries have been the focus of sea turtle conservation concerns. This method of operation, however, is not the only cause of sea turtle mortality by commercial fisheries. Substantial numbers of deaths also occur as a result of other commercial fishing operations: longline; pound nets; gill-nets; purse seine; hook and line; and pot trapping operations (Crouse, 1984; Hillestad *et al*., 1981; National Marine Fisheries Service, 1999; Oravetz, 1999; Pierpoint, 2000). Crouse (1998:105) in a seminar titled, ‘After TEDs: What’s Next?’, presented at the 18th Annual Symposium on Sea Turtle Biology and Conservation, states ‘we were right to put such a heaving emphasis on reducing trawling mortalities first, even if TEDs are having an effect and some populations are beginning to increase, we cannot declare victory and go home’.

There is the need to start concentrating on these other sources of mortality resulting from commercial fishing activities, while continuing to monitor trawl fisheries at a lower level to ensure circumstances do not change. Even the deaths of sea turtles resulting from non-trawl commercial fishing operations is reported to be much fewer than for trawl operations, they may still be too great for the populations of sea turtles to sustain. Although this is point is debatable.

As yet there is no gear modification mechanism, such as TEDs, which can be used in many non-trawl commercial fishing operations. The solution employed by the U.S. government for their longline fisheries has been seasonal or complete closure of fishing grounds, generally not a good solution if fisheries are to remain viable.

More research funding to support cooperative research with the fishers themselves needs to be provided to find a practical solution to bycatch for all types of commercial fishing operations. There are many benefits of the participatory solution, that is, fishers, scientists and managers working together to address bycatch problems (Hall *et al*., 2000), including the possibility of avoiding conflict (Tucker *et al*., 1997). Now and into the future, fishers, with or without the help of others, will continue to refine their gear and fishing technique in their quest to catch more and/or better quality target species and less bycatch. Adequate funding and assistance will greatly benefit this advancement.

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APPENDIX 1

Intellectual property

There is no recognised intellectual property arising from this research.

APPENDIX 2

Project Staff

Principal Investigator	Carolyn M. Robins (BRS)
Co-investigators	Ian R. Poiner (CSIRO) and Amanda M. Goodspeed (AFMA)

Initially the principal investigator was Derek Staples (BRS) with Bruce Wallner (AFMA) and Ian Poiner (CSIRO) as co-investigators. However, project staff was modified over the course of the project. The project was initiated and originally conducted by Aubrey Harris (BRS) and Carolyn Robins (BRS) with fishery liaison assistance from Wendy O'Brien (AFMA). Colin Limpus (QEPA) assisted throughout the project.

APPENDIX 3

Sea turtles in general

Sea turtles are marine reptiles possibly dating back more than 100 million years. They belong to two families, the hard-shelled Cheloniidae, with six representatives, and the Dermochelyidae, with only one extant member, the leatherback sea turtle). Sea turtles live in coastal waters and the open ocean and some migrate vast distances from their foraging grounds to their breeding grounds. They are slow-growing, often taking decades to mature, and breed for many years. All species are well adapted to marine life, with strong flippers; light, streamlined shells; and salt glands to excrete excess salt (Limpus, 1998; Anon., 1999a).

Of the seven marine turtle species, six are found in the region. Significant populations of sea turtles, their nesting beaches and feeding grounds, occur in Australian and in adjacent waters. They are distributed across northern Australian and down the east and west coasts, occasionally as far south as Tasmania (Queensland Department of Environment and Heritage, 1994; Preen *et al*., 1997; Environment Australia, 1998; Limpus, 1998; Meylan and Meylan, 1999).

In contrast to sea turtles, there are around 180 species of land-dwelling, or freshwater, turtles. Australia has at least 20 species. These turtles tend to have webbed feet and low-domed shells. In addition, there are around 37 species of tortoise, none of which is found in Australia. Unlike turtles, tortoises have elephant-like feet and high-domed shells, a well-known example is the Galapagos tortoises *Geochelone elephantopus* (Queensland Department of Environment and Heritage, 1994).

Sea turtles exhibit a typical life cycle of hatchling moving offshore from nesting beaches to live in the open ocean feeding zone, referred to as the pelagic phase and, after a number of years, migrating to coastal shallow benthic feeding zones. Breeding males and females move to habitats near nesting beaches for mating. The males return to their feeding zones, while the females nest, possibly a number of times, before returning to their benthic-feeding zone. Some species, however, diverge from this pattern at various phases (Ruckdeschel *et al*., 2000)

Sea Turtles found in Australian waters

Loggerhead turtle (*Caretta caretta*)

Loggerheads have a distinctive large head relative to body size compared to the other sea turtles, five pairs of costal scales and generally have a reddish-brown shell (Wetherall *et al*., 1993; Queensland Department of the Environment and Heritage, 1994; Environment Australia, 1998). They are found in tropical to temperate waters of the world including those off Australia’s eastern, northern and western coastlines. Generally, they live around coral cays, bays and estuaries, and primarily feed on invertebrates, including jellyfish, crabs, shellfish and sea urchins. They will scavenge fish but are not considered to be fish eaters.

In Australia, loggerheads migrate from feeding areas around the north of Australia to nest sites along the eastern and western coastlines (Department of the Environment and Heritage, 1994; Centre for Marine Conservation, 1998; Environment Australia, 1998). They also travel further afield to and from islands in the Pacific Ocean and have occasionally been seen as far south as Tasmania. There are two genetically distinct populations within Australia, eastern and western, and the Australian nesting populations are assumed to be distinct from populations elsewhere in the world. Breeding occurs along the Bundaberg coastline of Queensland and adjacent islands and on Murion Island, along the Ningaloo Coast and in Shark Bay, Western Australia. Little is known about male loggerheads.

Serious concerns are held for the viability of the loggerhead turtle stock in southern Queensland. This drastically declining population is one of the most important loggerhead stocks in the Pacific region, so its decline is particularly alarming. Chaloupka and Limpus (2001) estimate that the nesting female loggerhead population declined 8% per year from 1985 to 1992 and continues to do so. Similar declines are occurring elsewhere in the world (Ruckdeschel *et al.*, 2000).

Figure 23 Loggerhead sea turtle.

Loggerheads, like all species of sea turtles, face many threats throughout their lifetime. These include mortality through commercial and recreational fishing, boat strike and ingestion of discarded fishing line and rubbish, predation at rookeries by feral animals, indigenous harvesting, and coastal development negatively effecting hatchlings and nesting females (Limpus, 1998). Trawling, in particular, has been implicated as contributing to the decline in loggerheads on the east coast of Australia (Heppell *et al.*, 1996) and down the west coast..

Leatherback turtle (*Dermochelys coriacea*)

Leatherbacks are the largest living species of sea turtle, sometimes weighing more than 500 kg and having carapaces spanning almost 2 m. One specimen had a reported body mass of 916 kg (Eckert and Luginbuhl, 1988). Unlike all of the other sea turtles that are hard bony-shelled, leatherbacks have a distinctly ridged and rubbery carapace. Their colour ranges from black to bluish-black and greyish-black, with the flippers and head sometimes mottled or spotted. They have seven ridges, including those along the side of the body, that run lengthways and end in a pointed terminal extension.

These jellyfish-eating oceanic travellers have a global distribution and migrate vast distances from temperate feeding grounds to tropical breeding grounds. They also spend considerable amounts of time basking on the surface of the water. Leatherbacks are able to live in colder waters and dive to greater depths in search of

Figure 24 Leatherback turtle caught by a prawn trawler and released alive in 1972.
Source (Tony Tomlinson, MG Kailis Gulf Fisheries. Aug/Sep 1972)

prey items than most other reptiles. They have specific adaptations to handle high pressure and to keep their core body temperature higher than the surrounding water temperature (Wetherall *et al*., 1993; Queensland Department of the Environment and Heritage, 1994; Ruckdeschel *et al*., 2000; Environmental Protection Agency, 2002).

Leatherbacks migrate down both the Western Australian and Queensland coasts in noticeable numbers but have no major nesting sites in Australia. Nesting does occur, although rarely, along southern Queensland beaches and across the top of Australia (Limpus, 1982). Nesting occurs in neighbouring countries and many major nesting beaches are also in the Atlantic (Queensland Department of the Environment and Heritage, 1994).

Globally, leatherback numbers are dwindling throughout their range (Spotila *et al*., 1996). In particular, the Pacific stock is predicted to be on the verge of extinction. Research in Playa Grande, Costa Rica, the fourth largest nesting colony of leatherbacks in the world, shows that between 1988–89 1 367 leatherbacks were nesting there and by 1998–99 the number had fallen to 117 individuals (Spotila *et al*., 2000). The Atlantic stock is also in serious decline. In 2000, increased strandings of dead leatherbacks were seen on beaches in the French Guianas (Anon, 2001a). A nesting colony at Terengganu, Malaysia, has declined from over 3 000 nesting females in 1968 to 2 individuals in 1994 (Spotila *et al*., 1996). It is assumed that a long history of egg harvesting, loss of nesting habitats, pollution and incidental capture in commercial fishing operations are to blame. All agree that the current rate of decline is not sustainable (Spotila *et al*., 1996; Crouse, 1997; Spotila *et al*., 2000). Spotila *et al*., (2000:530) states, 'We conclude that leatherbacks are on the verge of extinction in the Pacific'.

Leatherbacks face many challenges throughout their life, ranging from egg theft to death of adults in fishing gear (Eckert, 1997). The killing of gravid females while nesting is a historical practice that has decreased in recent years through protection of nesting beaches (Eckert, 1997). All causes of mortality have been held responsible for the depressing plight of these populations. The death of adults as a result of fishing operations, however, is very difficult to address and has been more readily blamed in recent years (Spotila *et al*., 2000). In Australian waters leatherbacks are caught and possibly killed in lobster pot gear, longlines and gillnets (Limpus, 1998, Robins *et al*., 2002).

Green turtle (*Chelonia mydas*)

Green turtles are the largest of the hard-shelled species, with adults often measuring over 1 m in length and weighing over 100 kg. They have four pairs of costal scales with a high domed and mottled light to dark olive-brown shell, although colour can vary greatly (Queensland Department of the Environment and Heritage, 1994; Anon., 1999a; Environment Australia, 1998). The green turtle is the only genuinely herbivorous sea turtle, dining almost exclusively on seaweeds and seagrasses. However immature greens can be carnivorous. Unfortunately their herbivory makes the adults a favourite for the turtle meat trade in many countries of the world.

Green turtles are found in tropical and subtropical waters world-wide and are known to undertake complex migrations. They are abundant on the Great Barrier Reef and along the northern coastline of Australia. They nest in the northern and southern Great Barrier Reef, the Gulf of Carpentaria, the islands on the north-west shelf and down the Western Australian coastline.

Green turtles continue to be exploited for the meat and egg human consumption trade. They are often considered to be the best-eating sea turtle. In fact, the name 'green turtle' is derived from the colour of their subdermal fat. Limpus (1995) (cited in Limpus, 1998) estimated around 100,000 green turtles breeding in Australia, mostly mature females, are harvested annually, primarily during migrations out of Australian waters. Along with providing food, green turtle shells are also used for ornaments and tourist items.

Figure 25 Green sea turtle.

As a result of exploitation, the species is already extinct in Bermuda and the Cayman Islands. There have been, however, promising signs of green turtle population recovery in Hawaiian waters (Balazs, 1996) and at Tortuguero, Costa Rica, nesting beaches (Bjorndal *et al*., 1999). In Australia, many deaths occur as a result of commercial fishing operations, indigenous harvesting, boat strike and from ingestion of marine debris. There is also a high incidence of fibropapilloma disease in green turtles in some areas of Queensland, including Moreton Bay (Limpus, 1998).

Flatback turtle (*Natator depressus*)

Flatback turtles have four pairs of costal scales, as do the hawksbill and green turtles, but have a characteristic low domed shell with upturned edges – hence the name 'flatback'. They tend to be olive-grey in colour. They are the only species that is endemic to the Australian continental shelf and occurs in Queensland, the Northern Territory and in Western Australia. Major rookeries for flatbacks are Crab Island at the tip of Cape York, some southern islands of the Great Barrier Reef and Greenhill Island in the Northern Territory, with minor nesting beaches in the Gulf of Carpentaria, Torres Strait and central to southern Queensland (Limpus, 1982). Flatbacks have a diet comprised mainly of soft corals and sea pens.

Figure 26 Flatback sea turtle.

Human induced mortality includes death through fishing operations, egg harvesting and also significant predation by feral pigs. It is suspected that the flatback turtle population is in decline (Limpus, 1998).

Olive ridley turtle (*Lepidochelys olivacea*)

Olive ridleys are easy to identify, not only are they the smallest species, they are the only species of sea turtle with six or more pairs of costal scales. Their olive-grey carapaces are also more circular than other species. They are found in tropical and subtropical areas of the world, including northern Australia and along the eastern and western coastlines. They live mainly in shallow protected waters and feed mostly on shellfish and crabs (Queensland Department of Environment and Heritage, 1994; Limpus, 1998; Environmental Protection Agency, 2002). The species exhibits a unique mass nesting strategy or 'arribada', where in some cases several thousand turtles migrate to nesting beaches to mate and nest simultaneously (Pandav and Choudhury, 1999). There are no major rookeries in Australia although low-density nesting has been recorded on Northern Territory and Queensland beaches. There is a genetically distinct population of olive ridleys that nest in Arnhem Land (Limpus, 1998).

Human induced mortality includes threats faced by all species of sea turtle: egg harvest, death in fishing nets and death from boat strike. The large numbers of olive ridleys in Indian waters are at threat from commercial fishing nets (Pandav *et al*., 1997), while longliners in Coast Rica also annually kill thousands of individuals (Arauz, 2000).

In 1995, 15 dead sea turtles, of which 12 were olive ridleys, were found on a beach in Fog Bay, Northern Territory – an area intensively fished by NPF trawlers targeting banana prawns. Guinea and Whiting (1997) implicated the NPF although there is no evidence to prove that these turtles died as a result of trawling activities.

Figure 27 Olive ridley sea turtle.

Hawksbill turtle (*Eretmochelys imbricata*)

The most distinctive feature of the hawksbill turtle is its overlapping classic tortoiseshell-patterned shell, ranging from light amber to browny-black. Other features include a distinctive parrot-like beak, four pairs of costal scales and two pairs of prefrontal scales (Queensland Department of Environmental and Heritage, 1994; Limpus, 1998; Ruckdeschel *et al*., 2000; Environmental Protection Agency, 2002). The trade in hawksbill shell – 'bekko' or tortoiseshell – although listed by CITES as banned, still continues today (www.turtles.org/hawksd.html, 5/11/01).

Hawksbills live in tropical tidal and sub-tidal coral and rocky reef areas but have been seen in more temperate regions down to northern New South Wales. Their diet is primarily sponges (Limpus 1998), but also will feed on seagrasses, soft corals and shellfish. They feed along the eastern, northern and western coastlines of Australia. Nesting is common in the Torres Strait and the northern Great Barrier Reef and occurs in low numbers on many islands and beaches throughout most of their northern feeding range.

The hawksbill sea turtle has undergone severe reductions in abundance in many areas with some significant nesting populations disappearing. The most significant threat is harvesting for tortoiseshell (Limpus, 1998), used in the manufacture of various items including hair-combs, eyeglass frames, pieces of jewellery and souvenirs, even stuffed specimens. There are also considerable numbers of eggs harvested on beaches, killing for meat, and mortality from drowning in commercial fishing nets, boat strike and ingestion of marine debris. Although no actual research into population status has been conducted, the Australian population of hawksbill is suspected to be in decline (Limpus, 1998; Ruckdeschel *et al*., 2000).

Figure 28 Hawksbill sea turtle.

APPENDIX 4

Threats faced by sea turtles

All species of sea turtle have high egg and hatchling mortality, but low adult mortality, excluding human-induced mortality events (Limpus, 1998). Historically, sea turtle conservation focused on the early stages of their life (Hillestad *et al*., 1981). By reducing the harvest of turtle eggs and increasing the preservation of nesting beaches, more hatchlings have the chance to make it to the water for their first swim.

The magnitude of adult mortality tends to remain somewhat hidden, with many deaths occurring in the oceans and few bodies being recovered. However, when considering declining populations it has been noted that, in some cases, the adult and sub-adult components of the population may make the greatest contribution to the recovery of the species (Crouse *et al*., 1987; Panou *et al*., 1999). This was demonstrated by Heppell *et al.* (1996:143) when modelling loggerhead population on the east coast of Australia. They found that for this stock the 'survival in the first year of life is relatively less important in these long-lived and slow-maturing animals'. They also predicted that the current anthropogenic-induced sources of adult and sub-adult loggerhead mortality, including significant kills by commercial fishing gear, could drive this stock to extinction in less than a century.

The relative importance of the contribution of different life phases to the recovery of turtle species, however, is not always agreed upon by sea turtle scientists. Spotila *et al*. (1996), when considering leatherbacks, argued that egg, hatchling and adult protection is vital for the survival of the species.

Frazer (1992), takes a slightly broader view and suggests that rather than only looking at sea turtle conservation as an issue of too few turtles, thereby solving the problem by releasing more hatchlings in the oceans, effort should also be concentrated on addressing each contributing factor separately, thereby reducing the negative impacts of human activities on turtle populations. These anthropogenic threats are varied. Examples from Hutchinson and Simmonds (1991), Wetherall *et al*. (1993), Burger and Garber (1995), Limpus (1998), National Marine Fisheries Service (1999), Anon. (1999b), Ruckdeschel, *et al.* (2000), and Dobbs (2001) include:

- negative effects of pollution (pesticides, heavy metals, organochloride compounds, sewage effluent) both sourced from the land and from boats, including pollution affecting feeding grounds and contributing to increases in disease;
- ingestion of, and possibly entanglement in, plastic and other debris, including plastic bait bands, possibly causing injury, internal blockages, drowning, ulcers and toxic effects;
- ingestion of, and coating in, oil droplets and tar in the water and on beaches, possibly causing choking, inhibition of movement and sublethal effects;
- deaths from recreational fishing, including hooking and entanglement in fishing line;
- deaths from commercial fishing – longlines, trawls, gillnets, lobster pot lines, pound-nets, purse seines;
- entanglement in discarded nets (ghost fishing), including trawl gear, set nets and the now-banned drift nets, possibly causing drowning, changes in movement and behaviour and injury;

- boating strikes, including propeller and vessel collisions – recreational and commercial;
- harvesting of meat and eggs for human consumption – commercial, subsistence and for ceremonial purposes;
- harvesting for leather and oil;
- shark netting and hooking programs along beaches;
- use of shells and other parts of the turtles for sale as souvenirs, including tortoiseshell (bekko) and stuffed specimens;
- deliberate killing, injuring and harassing sea turtles for fun or sport;
- predation of eggs and hatchlings and destruction of beach dunes by feral and native animals;
- nesting habitat loss and modification through coastal development that prevents females nesting or causes mortality to hatchlings, including changing beach architecture, beach erosion and erosion control;
- dredging and sand mining;
- degradation of foraging habitats, including coral reefs and seagrass beds;
- dynamite fishing;
- marina, docking and jetty development;
- human activity on nesting beaches, including light pollution, dogs, recreational vehicles and furniture, exotic vegetation, tourists disrupting nesting females, injuries from discarded refuse such as broken glass, beach cleaning, boats left overnight on beaches, people walking on and possibly collapsing the nest, shading nest sites altering the sex ratio of hatchlings, compaction of sand, and formation of tracks;
- mining and exploration, including underwater explosions;
- oil rigs causing an increase in predation of hatchlings as a result of attracting predators and also hatchlings beneath them;
- entrapment in water intake mechanisms of power plants; and
- religious, ceremonial and other traditional uses.

APPENDIX 5

Sea turtles on the endangered lists

Alarming declines in sea turtle numbers in recent years have resulted in the listing of most species as threatened or endangered, both nationally and globally (Crowder *et al*., 1994; Bisong, 2000). Various countries, including Australia and the U. S., have drafted recovery plans that attempt to address the issue of declining sea turtle populations. The Australian Northern Prawn Fishery, along with many other Australian Commonwealth fisheries, has drafted a Bycatch Action Plan.

Australia

Northern Prawn Fishery Bycatch Action Plans

The Second NPF Bycatch Action Plan, developed by the Northern Prawn Fishery Management Advisory Committee (NORMAC) to address growing concerns about bycatch, recognises the importance of reducing bycatch in this fishery. This plan, although independent of the strategic assessment, will be considered in making the assessment (see EPBC Act below). The first plan was developed in 1998 with the updated second plan released in 2001.

The primary aims of this plan, as listed in the Draft NPF Bycatch Action Plan 2001 (p 5), are to:

1. Eliminate to the greatest possible extent feasible the catch of:

    i. large animals such as turtles, sharks and stingrays
    ii. other protected species
    iii. other unsustainable species

2. Reduce the overall amount of bycatch in the fishery

3. Provide protection for areas that are important habitat for vulnerable species of marine life.

The strategies and actions as listed in the plan (p 5 and p 6) are to:

1. Modify fishing gear to minimise turtle and other bycatch

    1.1 Make the use of Turtle Excluder Devices (TEDs) and Bycatch Reduction Devices (BRDs) compulsory throughout the Fishery.

    1.2 Monitor the effectiveness of TEDs and BRDs and encourage ongoing innovation in the design and effectiveness of TEDs and BRDs.

    1.3 Monitor compliance with TED and BRD regulations.

2. Monitor bycatch in the fishery

    2.1 AFMA and NORMAC will implement in August 2002 a crew-based observer program to monitor and validate amounts and composition of bycatch, particularly in regard to protected species, in the fishery.

    2.2 AFMA and NORMAC will continue collecting information through logbooks and targeted research programs.

3. Manage the physical impacts of trawling

    3.1 Continue current permanent closures of critical fisheries habitats for the fishery, such as seagrass beds.

3.2 Initiate research to conduct a vulnerability assessment on species and habitats resulting from the impacts of trawling and implement new closed areas where required.

4. Ensure industry ownership and support in developing measures to address bycatch

4.1 Review the industry code of conduct by January 2002 and develop measures to ensure crew awareness and uptake of the code.

5. Develop measures to increase the survival of bycatch species

5.1 Regularly review and uptake advice on best practice handling of turtles accidentally caught in trawls, which is included with the logbook issued to all boats at the start of the season each year. Develop new information on the handling of sea snakes and sharks.

5.2 Encourage research to develop and assess the effectiveness of hoppers at increasing the survival of bycatch species after they are caught.

6. Make information regarding bycatch available to both fishers and the community

6.1 NORMAC will develop educational and information packages about bycatch, and promote awareness of what is being done to reduce the impacts of trawling.

7. Continue evaluating research needs and maintaining a high priority on research into ways to minimise bycatch

7.1 Maintain bycatch issues as a high priority in the five-year Strategic Plan for the fishery.

8. Review the implementation of measures in this Plan and incorporate new information to improve the fishery's performance with respect to bycatch in the future

8.1 NORMAC will monitor the implementation of this Plan and conduct a major review every two years.

All of the strategies and actions have either already been implemented or are in the process of being addressed by various scientific studies and industry-based monitoring schemes. The main strategies and actions with respect to sea turtle bycatch are 1.1, 1.2, 1.3, 2.1, 2.2 and 5.1. Strategy 1.2 (Monitor the effectiveness of TEDs) is directly addressed by this project.

The current status of the strategies and actions related to sea turtles are:

1.1 TEDs and BRDs were made compulsory for all vessels in the NPF in April 2000;

1.2 This project evaluates the effectiveness of TEDs, while various others dealing with BRDs are in progress;

1.3 TED and BRD compliance is routinely carried out by AFMA;

2.1 A data collection and monitoring program is being established with lessons learnt from this project being considered;

2.2 Bycatch captures are routinely reported in AFMA logbooks;

2.3 Handling guidelines are distributed in NPF logbooks.

Australian Environment Protection and Biodiversity Conservation Act 1999

All Commonwealth Fisheries are under national pressure to become ecologically sustainable. The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) 'establishes a new Commonwealth process for assessment of proposed actions that are likely to have a significant impact on matters of national environmental significance or on Commonwealth land' (http://www.ea.gov.au/epbc/publications/factsheets/actions.html [accessed 15 Jan 02]). The EPBC Act came into effect on 16 July 2000 with the requirement for all Commonwealth Fisheries to be strategically assessed within 5 years. This strategic assessment, conducted by AFMA, will also meet the requirements of Schedule 4 of the Wildlife Protection Regulation of Exports and Imports Act 1982 (WP (REI) Act). The NPF strategic assessment is expected to be out for comment mid-2002.

All sea turtle species found in Australian waters are protected by the EPBC Act and under state and Territory legislation. The olive ridley and the loggerhead sea turtles are listed as endangered, meaning that they may become extinct if threats continue. The leatherback, green, hawksbill and flatback sea turtles are listed as vulnerable, meaning that they may become endangered if threats continue.

Draft Recovery Plan for Marine Turtles

The Draft Recovery Plan for Marine Turtles (Environment Australia, 1998), released by Environment Australia in August 1998, contains recommendations on the key issues threatening the survival of sea turtles in Australian waters. Following extensive review and public consultation it is currently being considered by Senator Kemp, Minister for the Environment and Heritage, for approval.

The primary recovery plan objective is 'to reduce impacts on Australian stock of marine turtles and hence promote their recovery in the wild' (Environment Australia, 1998:17). The prescribed action for the NPF is to legislate for mandatory use of TEDs on all fishing vessels from 2000 with the criteria for success as 'Marine turtle capture and mortality to decline to levels approaching 5% of 89/90 levels and even less for loggerhead turtles' (Environment Australia, 1998, p18). The action was achieved, but evaluating the criteria for success is an objective of this project.

United States

Endangered Species Act

National Marine Fisheries Service (NMFS) responsibilities include the management of commercial fisheries of the U. S. and oversight of marine species that have been listed as threatened or endangered under the Endangered Species Act (ESA) (Dalzell, 2000). All species of sea turtles, except the flatback that is endemic to Australia, are protected under the ESA. If an interaction that occurs between these species during any enterprise, in this case commercial fishing, results in mortality of the protected species there is the requirement for the responsible agency, in this case NMFS, to produce a biological opinion. The biological opinion evaluates the level of interactions and may determine appropriate limits.

U. S. Sea Turtle Recovery Plans

Section 4 of the Endangered Species Act requires NMFS to publish a recovery plan for species listed as threatened and endangered. For sea turtles in the Pacific this includes the loggerhead, leatherback, green, East Pacific green, hawksbill and olive ridley recovery plans that were drafted in 1998. Plans were drafted for sea turtles in the Atlantic and Gulf of Mexico early in the 1990s.

U. S. recovery plans define reasonable actions that are believed to be required for the species of concern to be protected or to recover. They document background information on the species, evaluate threats, present recovery objectives and an implementation schedule. NMFS and the

U.S. Fish and Wildlife Service prepare them with assistance from recovery teams and require approval by the Assistant Administrator of Fisheries or the Regional Director. They are subject to modifications depending on new information, changes in species status and on the completion of tasks (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998a-f). Copies of the plans can be found on the NMFS website (http://www.nmfs.noaa.gov/prot_res/PR3/recovery.html).

One of the actions listed in all Pacific sea turtle recovery plans is the minimisation of incidental sea turtle mortalities by commercial fishing operations. Two additional actions that are partly related to research with longline caught turtles are the determination of population sizes and status in U. S. waters and the identification of stock home ranges using DNA analysis (National Marine Fisheries Service and U. S. Fish and Wildlife Service, 1998a-f).

International Organisations

2000 IUCN (World Conservation Union) Red List of Threatened Animals

The 2000 IUCN (World Conservation Union) Red List of Threatened Animals lists all animal species. In this listing the hawksbill is considered as critically endangered (high risk of extinction in the wild in the immediate future); the loggerhead, green, leatherback and olive ridley as endangered (not critically endangered but still facing a high risk of extinction in the wild in the near future); and the flatback as vulnerable (not critically endangered or endangered but still facing a high risk of extinction in the wild in the medium-term future) (http://www.redlist.org/ [accessed 14 Feb02]).

Convention on International Trade in Endangered Species of Wild Fauna (CITES)

All sea turtle species are also listed under Appendix 1 of the Convention on International Trade in Endangered Species of Wild fauna (CITES). These are species considered to be threatened with extinction and therefore commercial international trade in specimens except under exceptional circumstances is prohibited. (http://www.cites.org/ [accessed 14 Feb 02]).

Convention on the Conservation of Migratory Species of Wild Animals (CMS)

All sea turtle species, except the flatback that is not considered a migratory species, are a priority for conservation under the Convention on the Conservation of Migratory Species of Wild Animals (CMS) or the Bonn Convention (http://www.wcmc.org.uk/cms/ [accessed 14 Feb 02]). CMS provides a framework for countries to cooperate towards a common goal of conservation of migratory animals including the facilitation of intergovernmental agreements or treaties such as the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia. This Memorandum of Understanding (MOU) was agreed in June 2001 by bordering states, including Australia, with various actions that work towards protecting, conserving, replenishing and recovering marine turtles and their habitats in the Indian Ocean (CMS, 2001).

APPENDIX 6

The Northern Prawn Fishery (NPF)

The NPF is one of the most valuable fisheries resources in Australia, with the catch valued at around Aus$120 million in recent years (Caton and McLoughlin, 2000). It is a trawl fishery that extends from Cape York, Queensland (142°E) to Cape Londonderry, Western Australia (127°E) along several thousand kilometres of coastline. There are four main species groups caught: banana prawns (white banana prawn *Fenneropenaeus merguiensis*, Indian banana prawn *F. indicus*); tiger prawns (brown tiger prawn *Penaeus esculentus*, grooved tiger prawn *P. semisulcatus*); endeavour prawns (blue endeavour *Metapenaeus endeavouri*, red endeavour *M. ensis*); and king prawns (Blue-legged king prawn *Melicertus latisulcatus*, red-spot king *M. longistylus*) (Pownall, 1994).

The NPF is divided into a banana prawn fishery and a tiger prawn fishery. The banana prawn fishery, in which white banana prawns are targeted, is generally a daytime fishery that occurs from April to June each year depending on the abundance of prawns. The aggregating prawns are found using aerial searches, sounders and try-gear sampling the water so shots are generally short (10 to 30 minutes) and catches sporadic. The tiger prawn fishery from May to November, targets tiger prawns and Indian banana prawns and is generally a night-time fishery, with longer shots of up to four hours. Endeavour and king prawns are not generally targeted, making them a by-product of this fishery (Pownall, 1994).

The estimated NPF prawn catch for the 2000 season of 5 355 t, made by 121 vessels over 16 433 fishing days, was lower than the 1990s catch average of 8 052 t. Catch composition was 2 195 t of banana prawns, 2 190 t of tiger prawns, 958 t of endeavour prawns and 13 t of king prawns. Fishing days were split into 3 697 days of banana prawn fishing days and 12 736 days of tiger prawn fishing days. In 2000, vessels in the NPF were between 16 and 27 metres in length and towed twin-gear with a total length of from 16 to 32 fathoms (Malcolm and Bishop, 2001).

In 2001, the estimated total prawn catch improved to a 10 389 t due to an exceptional banana prawn catch of 7 245 t. There were 1 983 t of tiger prawns landed, 1 157 t of endeavour prawns and 4 t of king prawns. There were 16 687 fishing days over the year – 6 247 banana prawn days and 10 440 tiger prawn days (Garvey and Lilly, 2002)

Management regulations adopted over the history of the NPF have resulted in many changes to the fishery. Excluding the very early years, the number of trawlers fishing has decreased from a high of 286 boats in 1981 to the current low of 121 boats. Effort has decreased considerably from over 40 000 days to less than half this in recent years (Malcolm and Bishop, 2001). This is not only due to the decrease in the number of vessels fishing but also the extensions of seasonal closures. In addition, area closures, gear restrictions and daylight closures have been in place for several years.

The NPF has a comprehensive fishery data set in comparison to many other commercial fisheries in Australia and the world. Logbooks have been collected in various forms since the fishery began in the late 1960s and continue to be compulsory for all operators (Robins and Somers, 1994). Bycatch estimates, including sea turtle catch, however, have only been included since 1996. Target prawn species catch is verified through owner returns and also, in the earlier years, by processor returns; by-product information is recorded on transhipment records from 2001 onwards; but the bycatch remains largely unverified.

APPENDIX 7

Workshop programs, presenters and photographs

NPF TURTLE MONITORING WORKSHOP PROGRAM CSIRO Cleveland 13th-16th July 1998

Monday 13th	1400-1700 Participants arrive
Tuesday 14th	0915 Background (Ian Poiner) 0945 Catches of turtles in NPF (Aubrey Harris) 1015 The Commonwealth Bycatch Policy (Katrina Maguire) 1030 Morning Tea 1100 Turtles and TEDs (Julie Robins) 1130 Sawfish (Burke Hill) 1200 Snakes (Ted Wassenberg) 1230 Environment Australia (Andrew McNee) 1245 Lunch 1400 Recording the data (Carolyn Robins) 1430 Keeping in touch (Wendy O'Brien) 1500 Identification (Aubrey Harris, Burke Hill, Ted Wassenberg) 1530 AfternoonTea 1600 Identification (continues) 1630 General discussion 1700 End 1900 Workshop dinner
Wednesday 15th	0915 Organisational announcements 0920 Biology of turtles (Col Limpus and Duncan Limpus) 1030 Morning Tea 1100 Biology of turtles (continues) 1230 Lunch 1330 Field practical (Col Limpus and team) 1530 Afternoon Tea 1600 General discussion 1700 End 1900 Dinner - Grandview
Thursday 16th	0915 Organisational announcements 0920 Trial data recording (Carolyn Robins, Aubrey Harris) 1000 NPF bycatch issues - sustainability (Ilona Stobutski) 1030 Morning Tea 1100 BRD's in the NPF (Wendy O'Brien) 1130 The Turtle Recovery Plan (Mark Armstrong) 1200 GBR impacts of trawling (Roland Pitcher) 1230 Lunch 1330 Evaluation (Carolyn Robins, Aubrey Harris) 1400 General discussion 1430 Close (Aubrey Harris)

NPF TURTLE MONITORING WORKSHOP PROGRAM

CSIRO Cleveland 30 June to 2 July 1999

New taggers

Wed	pm	
	1.00	Background (Ian/Carolyn)
	1.30	Sustainability of Bycatch (Ilona)
	1.50	TEDs and BRDs 2000 (David)
	2.10	Scientific methods and reading id keys (Ted)
	2.40	BRD policy/ AFMA stuff (Mandy)
	3.00	Afternoon tea
	3.30	Instructions and data sheets (Carolyn)
	4.00	Keeping in touch etc (Mandy)
	4.30	Review instructions (Carolyn and Mandy)
	5.00	Workshop close
	7.00	RSL dinner

All taggers

Thur	am	
	10.00	Biology of turtles (Col)
	11.00	Morning tea
	11.30	Identification of turtles, snakes and swordfish -groups
	pm	
	1.00	Lunch
	2.00	Field practical
	4.00	Afternoon tea
	4.30	Turtle results for 1998 (Carolyn)
	4.50	Sawfish and snake results for 1998 (Ted)
	5.30	Workshop close
	7.00	Grandview dinner
Fri	am	
	10.00	Id evaluation and questions (Carolyn and Mandy)
	11.00	Morning tea
	11.30	Aquaculture talk and tour
	12.30	Lunch
	pm	
	1.30	Juvenile redlegs (Rob)
	1.50	Redleg tagging (David)
	2.10	General discussion and distribute packs
	3.30	Close

Monitoring the catch of turtles in the Northern Prawn Fishery

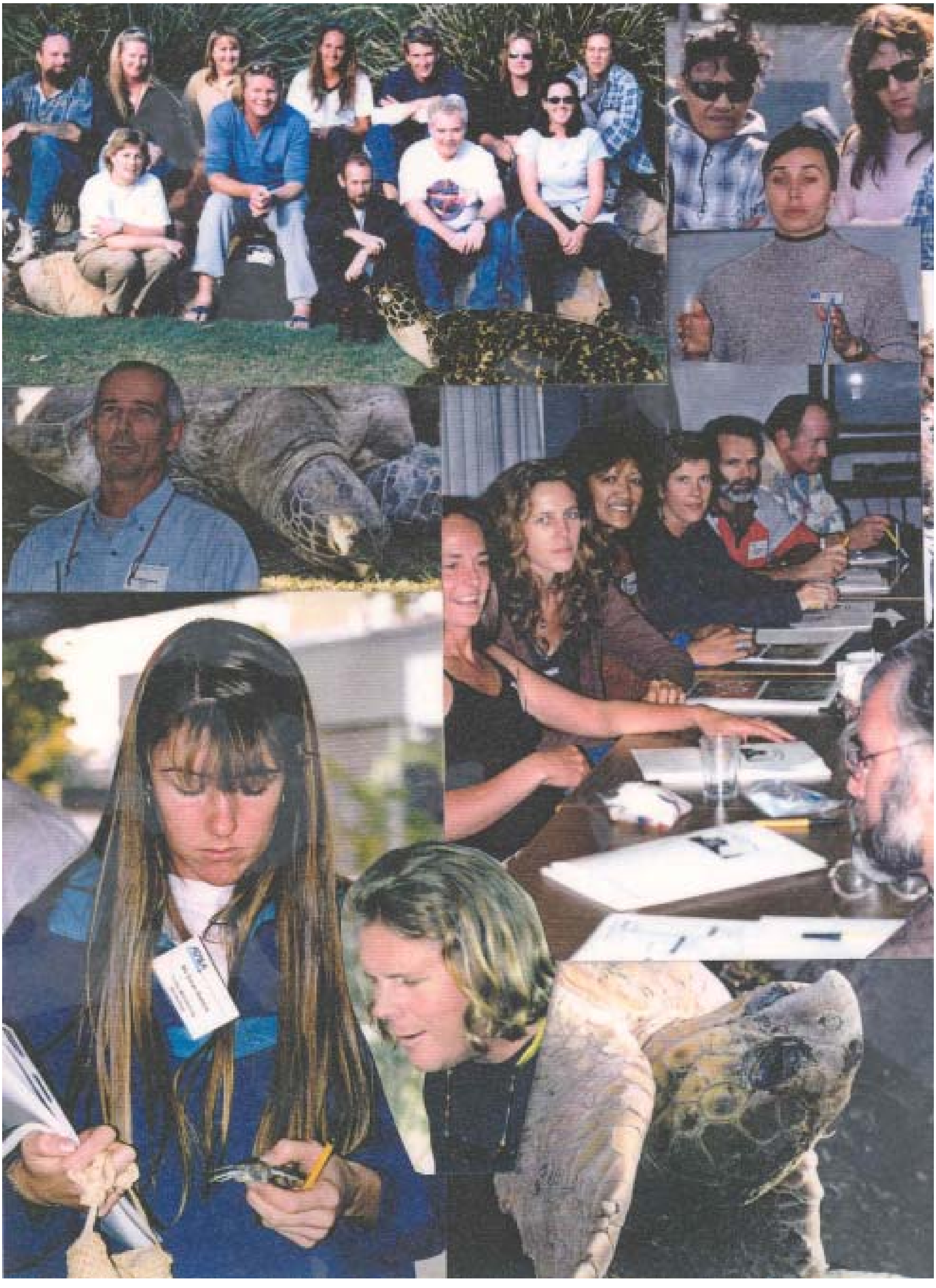
Final Workshop
Nara Resort, Gold Coast
9 and 10 June 2000

Friday 9 June 2000

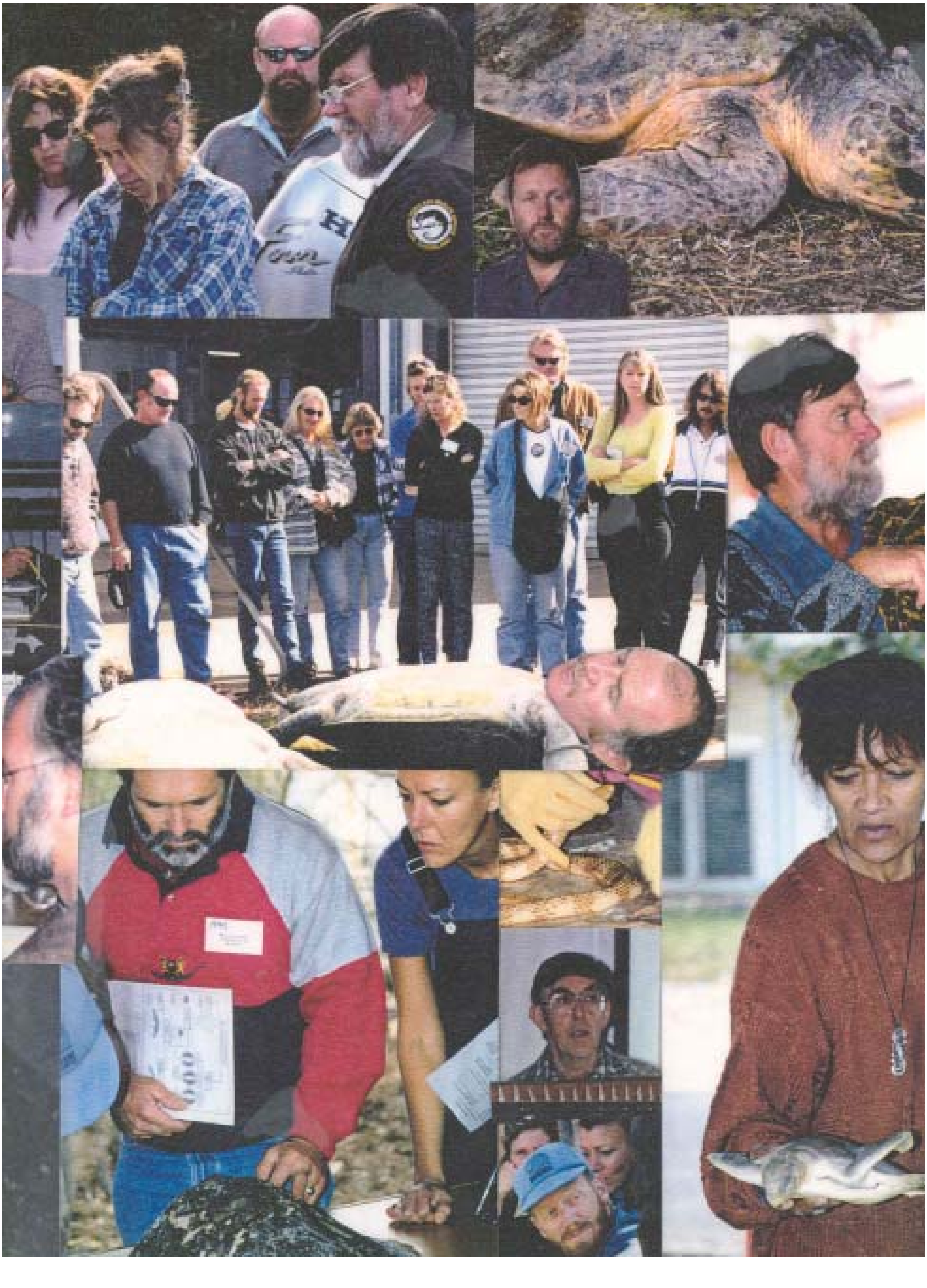
9.30 am	Bus arrives to Nara (leave bags at Reception)	
1 pm	Check–in to own room	
1.30 pm	Workshop starts in the Ocean North Room	
1.45 pm	Introduction	Dr Ian Poiner
2 pm	Results of this project	Carolyn Robins
2.30 pm	Tagging turtles in Australia	Dr Col Limpus
3 pm	Sawfish in the NPF	Burke Hill
3.15 pm	Snakes in the NPF	Ted Wassenburg
3.30 pm	Afternoon Tea	
4 pm	Political issues	EA
4.10 pm	FRDCs role in Australian fisheries	Patrick Hone
4.20 pm	NPF in the future	Ian Poiner
4.50 pm	Turtles around the world	Col Limpus
5.20 pm	Tagging next season	Mandy Goodspeed
6.30 pm	Happy Hour in the Ocean North Room	
7.30 pm	Dinner at the Shoreline Restaurant	

Saturday 10 June 2000

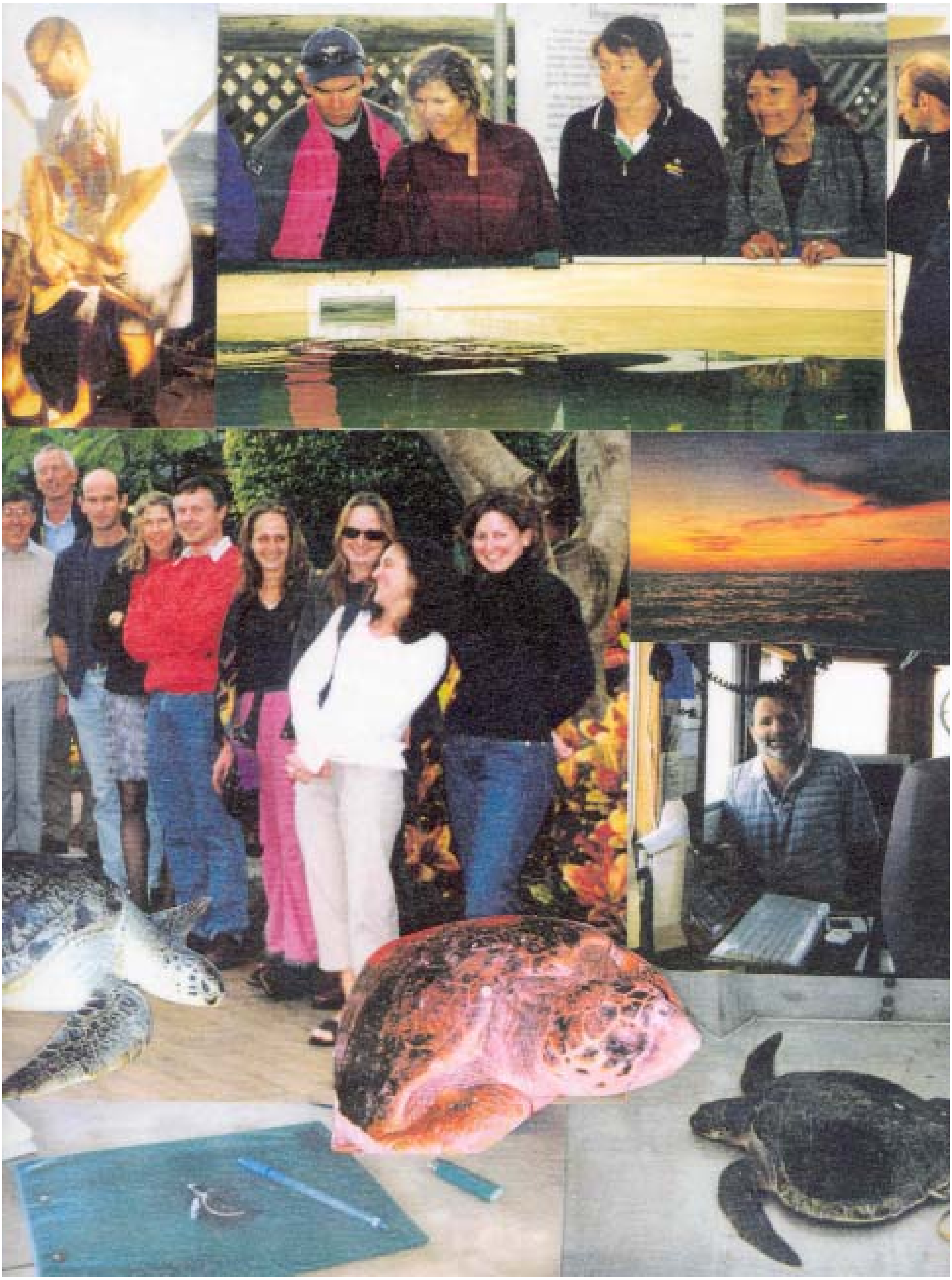
6.30 am	Breakfast at the Shoreline Restaurant
10 am	Meet in the foyer for entry into Seaworld
12 noon	Meet at Penguin Cove (near Skishow) - Turtle rescue centre
5 pm	Seaworld closed
5.30 pm	Meet in the foyer to catch a Taxi to the airport (if necessary)



1998 turtle tagging workshop



1999/2000 turtle tagging workshop



APPENDIX 8

Update reports

Monitoring the catch of turtles in the NPF

February 1999

For more information please contact -

Wendy O'Brien (AFMA) **02 6272 5632**

Carolyn Robins (BRS) **02 6272 4609**

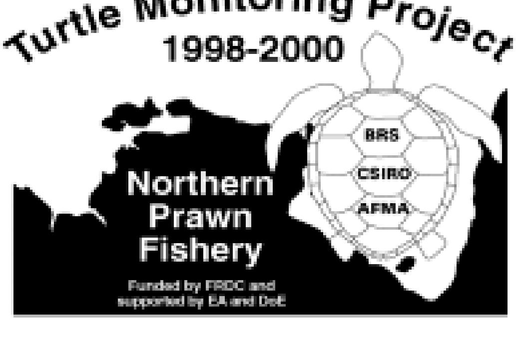
The Turtle Monitoring project is a collaboration between the Bureau of Rural Sciences (BRS), the CSIRO Division of Marine Research, the Australian Fisheries Management Authority (AFMA) and the NPF industry. The Fisheries Research and Development Corporation (FRDC) fund this project. It will collect information on turtles caught in the NPF so as to measure the impact of management changes over the last decade and to provide a baseline to assess the introduction of turtle excluder devices due to take place in 2000.

The first training workshop was held between 13th and 16th July 1998 at the CSIRO Marine Laboratories in Cleveland. During the workshop, selected volunteer fishers were trained to collect detailed information on turtles captured in the Northern Prawn Fishery. This included identifying the turtles, understanding their biology, assessing their condition on capture as well as tagging them to find out their movements across Northern Australia. Some data has also been collected on sea-snake and sawfish catches.

The response of the volunteer fishers following the workshop has been good. Of the 20 fishers trained, 17 have returned information. In addition the project is also receiving turtle catch information from Garry Day of the Australian Maritime College (AMC) who is assisting NPF fishers to try out TEDs as part of a separate FRDC project. The project also needs help from the whole NPF fleet, as details on captured turtles with tags are a vital component of the project. Data sheets can be obtained from the project organisers or any of the turtle taggers, and have been distributed to owners, skippers and barges.

So far there have been 394 turtles reported as caught, and of these 303 were tagged. There is, however, still more data to be received by AFMA. Around 80% of turtles caught were released healthy. We also received reports of 6 turtles with tags re-caught during the 1998 season.

There will be another workshop held during the 1999 mid-year seasonal closure. We are looking for more taggers to work the 1999 tiger prawn season and the 2000 banana prawn season. Any crew member wishing to become involved in this project should call either Carolyn (02 6272 4609) or Wendy (02 6272 5632).



Monitoring the catch of turtles in the Northern Prawn Fishery

Update December 2000

The Turtle Monitoring project (July 1998 to December 2001) is a collaboration between the Bureau of Rural Sciences (BRS), the CSIRO Division of Marine Research, the Australian Fisheries Management Authority (AFMA) and the NPF industry. The Fisheries Research and Development Corporation (FRDC) fund this project. It will collect information on turtles caught in the NPF so as to measure the impact of management changes over the last decade and to provide a baseline to assess the introduction of turtle excluder devices this year.

There were training workshops in 1998, 1999 and 2000. During the workshops, volunteer fishers were trained to collect detailed information on turtles captured in the Northern Prawn Fishery. This included identifying the turtles, understanding their biology, assessing their condition on capture as well as tagging them to find out their movements across Northern Australia. Some data has also been collected on sea-snake and sawfish catches.

The response of the volunteer fishers following the workshops have been good. Most taggers have returned significant amounts of data. In addition, the project also received turtle catch information from Garry Day of the Australian Maritime College (AMC) who has been assisting NPF fishers to try out TEDs as part of separate FRDC projects. In 2000, a further eleven fishers collected data on turtle captures but did not tag turtles. In the banana season of 2001 there will be seven observers from AMC also providing data. The project also received help from the whole NPF fleet, providing details on captured turtles with tags. There are rewards for all crew that participate in the project.

Summary of catches reported so far, although more data is expected for the 2000 seasons:

1998	1563 days recording from 18 taggers; 464 turtles reported with 362 tagged; 75% returned healthy.
1999	1203 days recording from 13 taggers; 320 turtles reported with 279 tagged; 78% returned healthy.
2000	1312 days recorded from 8 taggers and 6 other crew (excl. AMC); 41 turtles reported with 20 tagged; 80% returned healthy; Pre-TED - 98 days with 13 turtles caught (12 returned healthy); Post-TED - 1214 days with 28 turtles caught (21 returned healthy).

The most common reason for capture while the TEDs were installed was either the turtle being captured in the try net or as a result of the grid becoming blocked.

This project will continue into the 2001 banana prawn season and final reports produced in December 2001. For more information contact Carolyn Robins, BRS on 02 6272 4609 or Mandy Goodspeed, AFMA on 02 6272 5406.

APPENDIX 9

Data recording instructions, data sheets and recapture sheet

1998 and 1999 instructions

DATA RECORDING

1. Complete DATE, BOAT and RECORDER at the start of the recording week.
2. Decide what you will be recorded each day (turtles, snake and/or sawfish) and complete RECORDING box (T, SF or S).
3. On a recording day complete DATE, LATITUDE and LONGITUDE (degrees and minutes), HOURS TRAWLED, and NUMBER OF SHOTS.
4. On a non-recording day leave comments blank and if you are not fishing write NOT FISHING in comments column.
5. If none of that species are caught on a recording day - write NT (no turtle), NS (no snakes) or NSF (no sawfish) in comments column.
6. Request more tags or another camera before running out.
7. Send the completed sheet and camera to Mandy in prepaid envelope or fax as often as possible.

TURTLE RECORDING

For each turtle caught **(dead or alive)** on a turtle recording day:

1. Record shot away and winch up time,
2. Identify the species,
3. Measure the carapace length and depth of the turtle (if possible),
4. Assess the health when caught and released (dead, comatose, injured or healthy),
5. Estimate the length of time the turtle is on deck,
6. Tag the turtle (dead or alive) and record the number,
7. Take a photo with id board (INITIALS and TAG NUMBER) next to turtle,
8. If the turtle is alive, follow recovery procedures before returning to the water.

PRE-TAGGED TURTLES

If a turtle is already tagged, record all the regular information, take a photo and complete the TAGGED TURTLE sheet. Send this to Mandy so she can send you a stubby cooler. If the old tag is in danger of being ripped out or is unreadable - remove and re-tag (recording both tag numbers). If the old tag is fine then record the number and any other information (colour, shape, writing and address). Follow recovery procedures before returning the turtle to the water.

SAWFISH RECORDING

For each sawfish caught (on a sawfish recording day):

1. Record the date,
2. Identify the species (NA, DW, GR, WI or NI),
3. Assess the health (alive or dead) when released,
4. Estimate the length to the nearest metre.

SNAKE RECORDING

For each snake caught (on a snake recording day):

1. Record the date,
2. Record the trawl duration,
3. Count and record the number dead and alive (by species- if possible).

1998 and 1999 data sheet

Turtles **Fax to Wendy O'Brien 02 6272 4614** **Week starting / / 98**

Species (sp.): FB flatback; GR green; LG loggerhead; OR olive ridley; HB hawksbill; LT leatherback; NI no id
Turtle health (hlth): H healthy; I injured; C comatose; D dead

Boat	Recorder

	Lat	Lon		Shot away (24 hr)	Winch up (24 hr)	Sp.	Turtle length (cm)	Turtle depth (cm)	Hlth in	Hlth out	Deck time (hrs:min)	New tag number	Comments
Mon			1										
Hours trawled			2										
Number of shots			3										
Recording (T/S/SF)			4										
Tue			1										
Hours trawled			2										
Number of shots			3										
Recording (T/S/SF)			4										
Wed			1										
Hours trawled			2										
Number of shots			3										
Recording (T/S/SF)			4										
Thu			1										
Hours trawled			2										
Number of shots			3										
Recording (T/S/SF)			4										
Fri			1										
Hours trawled			2										
Number of shots			3										
Recording (T/S/SF)			4										
Sat			1										
Hours Trawled			2										
Number of shots			3										
Recording (T/S/SF)			4										
Sun			1										
Hours trawled			2										
Number of shots			3										
Recording (T/S/SF)			4										

Other Comments

2000 and 2001 instructions

DATA RECORDING

The data recording procedures are changing this year to make it easier for you. Rather than logging DAYS RECORDING EACH ANIMAL, it will be assumed that you are recording for all fishing days (except when noted on the sheet). This should not be difficult, as you should not catch many turtles. If, for any reason, you cannot record data note these dates on the sheet. If you don't catch a turtle all season then complete the BOAT and RECORDER and write 'no turtles' across the sheet before returning. We need all data sheets. If you are never going to record snakes or sawfish then write this on the first sheet. Remember if you are looking for turtles, snakes or sawfish then those count as recording days, even if you don't see any animals of interest. We will get the latitudes and longitudes from the skipper's logbooks.

TURTLE RECORDING

1. Complete BOAT and RECORDER at the top of each sheet.
2. Every day you are not fishing record the date in the 'DATES NOT FISHING' section. Every other day it is assumed you are watching for turtles.
3. If you cannot watch for turtles, for any reason, note this on the sheet.
4. When you catch a turtle (dead or alive) complete all usual trawl and turtle information, take a photo (very important if you don't have time to identify) and return it to the water (after resuscitation)
5. Send the completed sheet and camera to Mandy in prepaid envelope at the end of the season (use up the film during usual fishing operations)

PRE-TAGGED TURTLES

If a turtle is already tagged, record all the regular information, take a photo and complete the TAGGED TURTLE sheet. Send this to Mandy so she can send you a stubby cooler. If the old tag is in danger of being ripped out or is unreadable - remove and re-tag (recording both tag numbers). If the old tag is fine then record the number and any other information (colour, shape and address). Follow recovery procedures before returning the turtle to the water.

SNAKE RECORDING

1. Complete BOAT and RECORDER at the top of each sheet.
2. Every day you are not fishing or not recording snakes record the date in the 'DATES NOT RECORDING SNAKES' section.
3. When you catch snakes record the DATE, HEALTH STATUS, TRAWL TIME and NUMBER OF SNAKES and identify the species (optional).

SAWFISH RECORDING

1. Ensure BOAT and RECORDER at the top of the sheet is complete.
2. Every day you are not fishing or not recording sawfish record the date in the 'DATES NOT RECORDING SAWFISH' section.
3. When you catch a sawfish record the DATE, ID, HEALTH and SIZE to the nearest metre.

2000 and 2001 data sheet

Turtles

Species (sp.): FB flatback; GR green; LG loggerhead; OR olive ridley; HB hawksbill; LT leatherback; NI no id
Turtle health (hlth): H healthy; I injured; C comatose; D dead

Boat	Recorder

Date	Hrs trawled	No. shots	Shot away	Winch up	Sp.	Turtle length (cm)	Turtle depth (cm)	Hlth in	Hlth out	Deck time (hrs:min)	New tag number	Comments

Dates not recording turtles (all others are assumed to be 'turtle recording days', even if no turtles are caught)

Recapture sheet

TAGGED TURTLES

As part of a joint BRS/CSIRO/AFMA research project there will be 'turtle taggers' at work in the NPF fleet from the tiger season of 1998 to the banana season of 2001. For this project to be successful we need the whole fleet to return information on all captured tagged turtles.

If you catch a tagged turtle please complete this sheet and return to AFMA. It can be faxed directly to 02 6272 4614, sent in with your logsheets or send this information via your VMS. For each completed sheet returned you will receive a special stubby holder and the information known on that particular turtle. Your name will be entered into a lottery to be drawn at the end of each season.

If the tag number is unreadable then (1) dry and clean the tag, (2) place a small piece of paper over the tag, (3) rub over with a pencil to get an imprint, and (4) send this with the completed sheet. If the tag is still illegible after several attempts then remove the tag with a pair of pliers and return to AFMA. If the turtle has two or more tags and all are unreadable then remove and return only one tag.

If the turtle is dead do not remove the tag unless unreadable. Record the required details and return the dead turtle to the water. Also note in the 'other comments section' that the turtle is dead.

Name ____

Address to send the stubby holder and information

____

____

Boat name ____

Date____

Latitude and longitude for the night ______________________________

Shot away time of that trawl ______________________________

Winch up time of that trawl ______________________________

Tag number and tag description ______________________________

Other comments ____

____

____

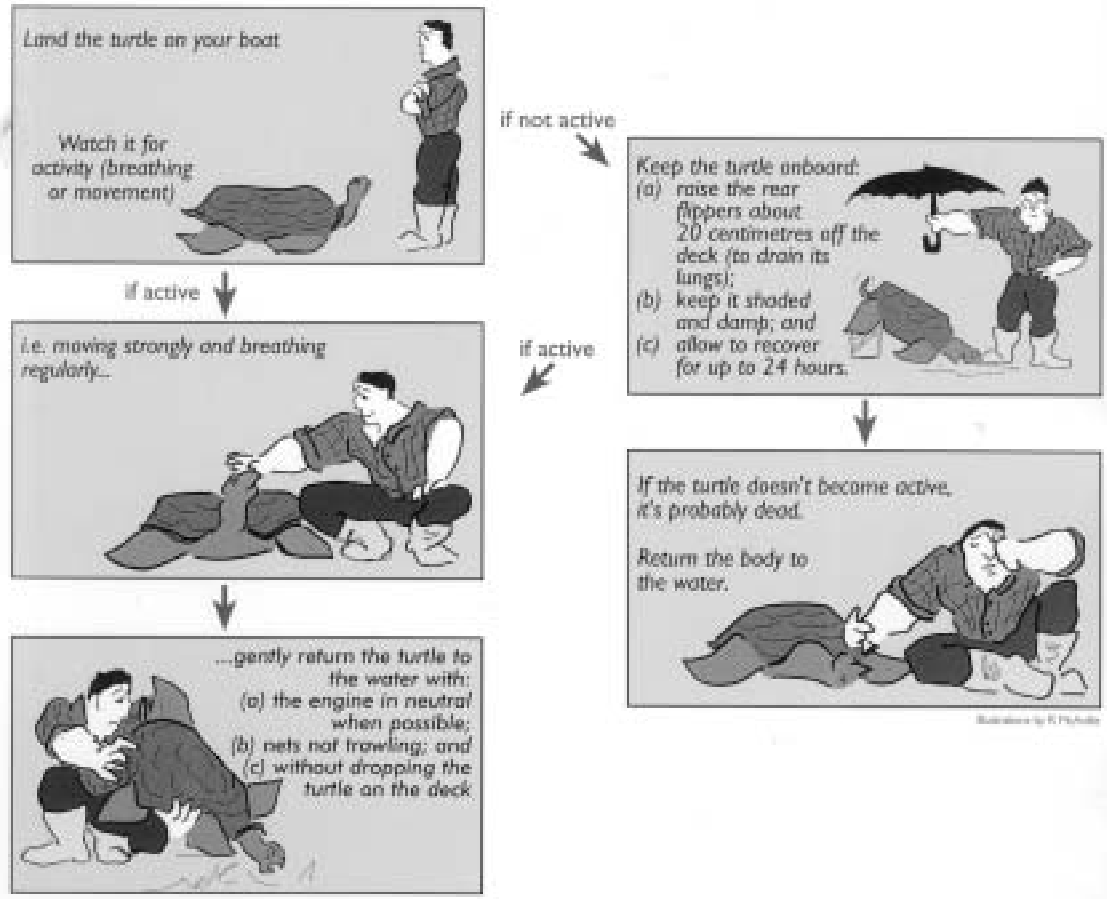
APPENDIX 10

Sea turtle identification, health status and recovery instructions

From QCFO, Queensland DPI, AFMA and FRDC Turtle Recovery Procedure Brochure

Turtle Recovery Procedures

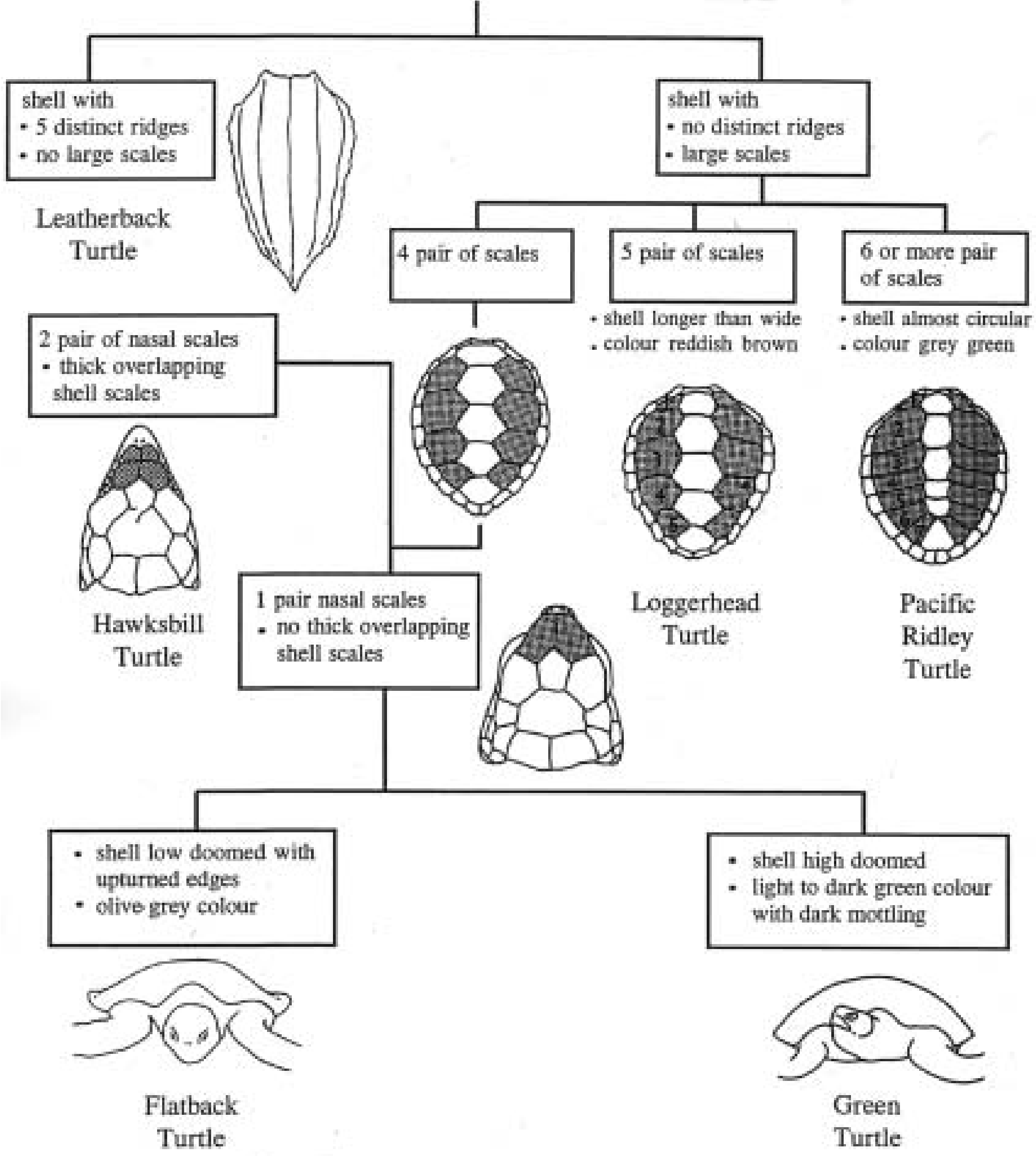
Sea turtles caught in trawl nets may be stressed. Most are conscious and able to swim away after removal from the net, but some may be tired or appear lifeless. Turtles that appear lifeless are not necessarily dead They may be comatose. Turtles returned to the water before they recover from a coma will drown. A turtle may recover on board your boat once its lungs have drained of water. This could take up to 24 hours. By following these steps you can help to prevent unnecessary turtle deaths:



Additional information

All records of turtle catches and deaths are important. If you catch a sea turtle record when, where, what species and what condition it was in when released. Record any tag numbers that may be on the front flippers of the turtle. This information should be recorded on your compulsory fishing log book or passed on to the Southern Fisheries Centre, telephone: (07) 3817 9500.

Guide to Sea Turtle Identification

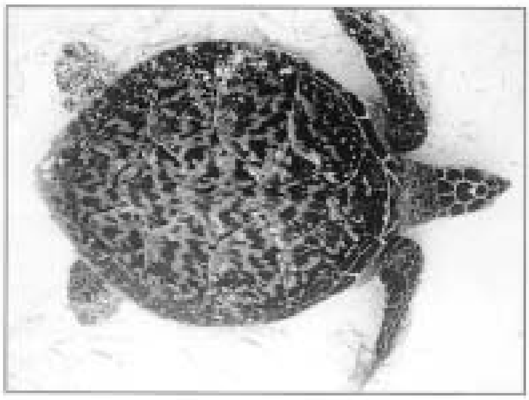


Note: The colour of the shell may vary within species.

For more information contact the Southern Fisheries centre on (07) 3817 9500

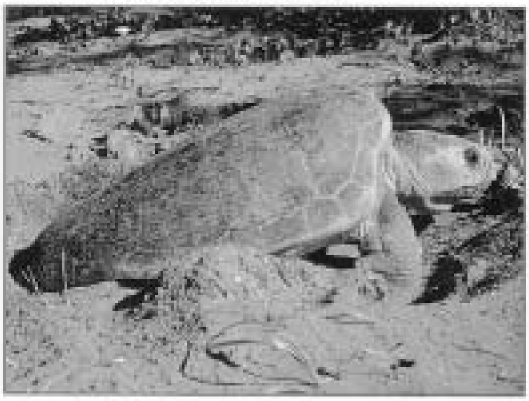
Sea Turtle Identification Chart

(Photos courtesy of Department of Environment)

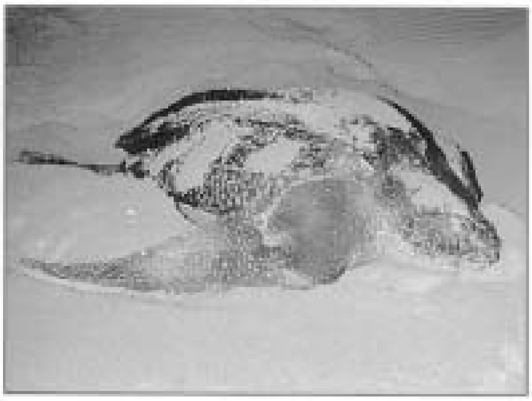


Hawksbill Turtle

Green Turtle

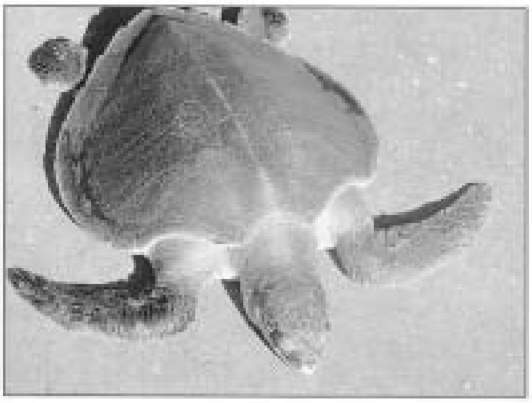


Loggerhead Turtle



Leatherback Turtle

Flatback Turtle



Pacific Ridley Turtle

QCFO
QUEENSLAND COMMERCIAL FISHERMEN'S ORGANISATION

DPI
QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

Code of Fishing Ethics: The Capture of Sea Turtles

Sea turtle mortality is caused by a number of factors including direct harvest by indigenous people, ingestion of marine debris, predation by introduced animals, fungal and bacterial infections of eggs, entanglement in shark nets, boat propellor strikes and incidental capture in fishing gear. Although trawl related mortality is minimal, the commercial fishing industry still needs to assist in the conservation of endangered sea turtles.

By following this code of fishing ethics, fishers can assist in minimising the impact of their trawling operations on sea turtles. Individual fishers are encouraged to adhere to the code of fishing ethics.

Refrain from trawling within 2 to 3 nautical miles of 'major' turtle nesting beaches during turtle nesting season.
Why: to minimise the possibility of nesting turtles being caught in trawl nets.

Limit trawl shots to less than 90 minutes in areas of high turtle numbers.
Why: to minimise mortality of turtles caught in trawl nets. Turtles caught in trawl nets have better chance of surviving if trawl shots are less than 90 minutes.

Apply recovery procedures when appropriate. Return lively turtles to the water as soon as possible. Why: to help the recovery of turtles accidentally caught in trawl nets thereby minimising unnecessary mortality.

Forward information on tagged or marked turtles caught to Southern Fisheries Centre.
Why: to help find out about basic turtle biology such as distance moved and life spans.

Participate in research programs monitoring the incidental capture of turtles in trawl nets. Why: to assist the collection of data to determine if trawling does/does not affect sea turtles.

Participate in research programs trialing by-catch excluding equipment. Why: through fishers participating in these trials an excluder device which is most suitable to your fishing grounds is more likely to be developed, something which will advantage fishers and turtles.

For further information contact:
QCFO (07) 3262 6855
or
Southern Fisheries Centre (07) 3817 9500

AFMA Australian Fisheries Management Authority

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

Australian Nature Conservation Agency

APPENDIX 11

Relevant information on AFMA bycatch log sheets

Logbooks NP10 to NP12 includes information relevant to sea turtles on:

1. Boat and master details
2. Date
3. Location (latitude and longitude)
4. Hours searched and trawled
5. Number of turtles caught (difficult to link the number of turtles to species code and condition if more than one turtle in a day)
6. Sea turtle species code
7. Sea turtle condition on release
8. Separate page for other comments

Representation of sea turtle section in logsheets:

	No. Turtles	Species Code	Condition of Release
Date			
Date			
Date			

Logbook NP13 includes information relevant to sea turtles on:

1. Boat and master details
2. Date
3. Location (latitude and longitude)
4. Hours searched and trawled
5. Species code (FBT-Flatback; HAW-Hawksbill; LGT-Loggerhead; GRN-Green; LBT-Leatherback; PRT-Pacific Ridley) (difficult to link the species code to the number caught and condition if more than one turtle in a day)
6. Number of turtles caught
7. Condition on release (A- Alive; J-Injured; D-Dead)
8. Separate page for other comments

Representation of sea turtle section in logsheets:

	Date	Date	Date
Species Code			
Number of Turtles and Condition of Release (eg 1D, 2A, 1J)			