Marine Turtle Mitigation in Australia's Pelagic Longline Fishery

C. M. Robins, E. J. Bradshaw and D. C. Kreutz

Australian Government
Australian Fisheries Management Authority

Australian Government
Fisheries Research and Development Corporation

Project No. 2003/013
September 2007

ISBN 978-0-646-47960-6

The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a statutory authority within the portfolio of the federal Minister for Agriculture, Fisheries and Forestry, jointly funded by the Australian Government and the fishing industry.

Citation: Robins, C. M., Bradshaw, E. J. and Kreutz, D. C., (2007) Marine Turtle Mitigation in Australia's Pelagic Longline Fisheries. Fisheries Research and Development Corporation Final Report 2003/013, Canberra, Australia.

Table of Contents

List of Tables and Figures

2003/013 Marine Turtle Mitigation in Australia's Pelagic Longline Fisheries

INVESTIGATORS: Carolyn M. Robins[1], Emma J. Bradshaw[1] and David C. Kreutz[2]

ADDRESSES: [1]Belldi Consultancy Pty Ltd
PO Box 459
Eumundi QLD 4562

[2]OceanWatch Australia Ltd.
Locked Bag 247
Pyrmont NSW 2009

OBJECTIVES:

1. Coordination of a team, primarily via email, of marine turtle scientists, industry representatives, fishery management and government officers, and Non-Government Organisation (NGO) representatives to determine suitable research components.
2. Attendance of as many fishers as possible from the Australian pelagic longline fleets at workshops covering marine turtle conservation awareness, marine turtle handling and logbook data collection.
3. Production of a DVD outlining marine turtle handling and logbook data collection guidelines, with distribution to all Australian pelagic longline vessels.
4. The collection of biological data and samples by trained volunteer fishers from the Australian pelagic longline fleets to be used in national and international research projects, including research using morphological measurements, conventional tagging, Platform Transmitter Terminal (PTT) tagging, genetic samples, and fishing operational modifications in a specialised marine turtle logbook.
5. Testing a selection of dip-nets, linecutters and dehookers in the Australian pelagic longline fisheries and recommending approaches and/or designs most suitable for Australian longline operations.
6. To produce an educational DVD, suitable for all ages, covering marine turtle ecology, biology and conservation, featuring Australian marine turtle research.

Non-Technical Summary

OUTCOMES ACHIEVED TO DATE:

- An expansion of the knowledge of the marine turtle issue for Australian longline fisheries. Some assumptions made in the past have been inaccurate, but verified data is now available that helps the fishing industry work towards addressing the turtle bycatch issue.
- An appreciation by the Australian fishers of the need to address marine turtle bycatch that has led to voluntary modifications in gear configurations resulting in the fisheries becoming more turtle-friendly.
- An increased awareness of the marine turtle issue (and possible implications for fisheries) by fishery managers and policy makers.
- A better understanding by fishers, in Australia and around the world, of correct handling and release techniques for turtles hooked or entangled during longline operations.
- Acceptance of *Crossing the Line* handling DVD as a key learning tool within the Australian longline fleet and many international longline fisheries, and also as a training aid for observers.
- The collection of data and samples that will benefit marine turtle research, and ultimately turtle stocks.
- The determination of the most suitable dehookers and linecutters for longline fisheries. This has led to the supply of suitable release equipment sets to all Australian longline vessels (funded by the National Heritage Trust).
- An increased awareness (through an educational DVD and worksheets) by children, students and educators of the challenges faced by marine turtles throughout the world and an understanding of the possible actions by individuals that may help marine turtles.
- An appreciation by many scientists and managers, nationally and internationally, that the Australian longline fisheries are addressing marine turtle issues and helping many fisheries throughout the rest of the world in the process.

There are seven species of marine turtle, six of which occur in Australian waters, the loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), olive ridley (*Lepidochelys olivacea*), hawksbill (*Eretmochelys imbricata*) and the endemic flatback (*Natator depressus*). All are considered to be threatened or endangered.

The incidental capture, called bycatch, of marine turtles in pelagic longline fisheries targeting tunas and billfishes is one of many anthropomorphic activities impacting these long-lived and late-maturing species worldwide. The interaction may involve entanglement in the gear, external hooking to the body, hooking in the mouth or deep ingestion of the hook. Once caught, turtles may be released unaffected, or suffer from injury and infection and have their feeding, breeding or nesting activities compromised, or may die as a result, all of which can contribute to diminution of current and future populations.

Hooking or entanglement that results in death during the interaction can be quantified, given accurate data from fishers or observers on the vessels. Deaths after release but caused by accidental capture (called 'cryptic mortality') are less well understood.

Fisher educational programmes on choice of gear (particularly the use of large circle hooks instead of J-hooks or tuna hooks), choice of bait, and turtle handling and release techniques have been shown to have substantial beneficial effects on turtle bycatch in several longline fisheries. In association with management, researchers and other stakeholders, Australian longline fisheries have endorsed a number of proactive initiatives to reduce the risk of capture and mortality of marine turtles in Australian waters. These initiatives include: education (training workshops, educational and instructional publications); improved data collection strategies; and the adoption of new gears and methodologies in everyday fishing activities.

The resources available to specific fisheries to develop and implement turtle bycatch mitigation measures vary considerably between countries. As marine turtles are migratory, the efforts of one country or fishery to reduce turtle bycatch will be ineffective should they not be adopted on a global scale. Because of this, Australian initiatives have been made available to other longline fisheries internationally, to reduce the global impact of longline fisheries on marine turtle populations.

This publication details the issue of marine turtles interacting with the Australian pelagic longline fisheries, lists steps taken by this fishery to address the issue, reviews the numerous bycatch mitigation methods being trialled internationally to reduce turtle bycatch including research results on circle hook trials and other mitigation ideas, and recommends a way forward for fishers, scientists and managers continuing the battle to reduce the impact of pelagic longline fisheries on endangered marine turtles.

KEYWORDS: **Marine (sea) turtles, longline fishery, bycatch mitigation, circle hooks.**

Acknowledgements

This research was funded primarily by the Fisheries Research and Development Corporation (FRDC) and in part by the Australian Fisheries Management Authority (AFMA).

The authors would like to thank the participating fishers from the Australian longline fisheries and the scientific observers who work in these fisheries. Without their assistance, enthusiasm and diligence this project would not have succeeded. Also supporting the project were many longline vessel owners, fleet masters and fishers. Without the continued interest and commitment to marine turtle conservation by the commercial fishers of Australia, and the rest of the world, the development and adoption of successful marine turtle bycatch mitigation techniques would be virtually impossible.

Special thanks go to the owners, master and crew of *FV Ocean Dawn*. These 'fisher actors' along with their 'turtle co-stars' made the filming of *Crossing the Line* enjoyable and worthwhile. Also thanks to the owner, master and crew of *FV Clover Bay* and the AFMA Observer Section for the provision of fishing footage included in the film.

Both DVDs, *Crossing the Line* and *One in a Thousand,* were expertly made by an Australian Company, Hatchling Productions, with the principal team of Jeff and Sam Canin, and Cathy Henkel. A special mention goes to underwater photographer David Hannan. Without his amazing footage of various sea creatures, the DVDs would not have been as fascinating, captivating or inspiring.

Reviewing of the draft report by Marie Robins and Rusty Strickland (Rustib Consultancy Services Pty Ltd) and cover design by Qld Media Print is appreciated.

Dr Colin Limpus and his team from the Queensland Environmental Protection Agency deserve a special mention. Without their expertise and encouragement this project, and many other marine turtle projects in Australia, would not have been possible.

Vale *Lance Ferris 'Pelican Man'*

Co-Founder of AUSTRALIAN SEABIRD RESCUE

(www.seabirdrescue.org)

A MESSAGE FROM MARNY BONNER - 14th October 2007

Today, the pelicans lost their best friend. At 3.25am on Sunday the 14th of October, our beloved Lance died in my arms at Lismore Base Hospital.

He suffered a stroke late Saturday morning at the Centre and was conveyed to Ballina Hospital by ambulance, before being transferred to Lismore around 1pm.

He was able to communicate for several hours whilst the dedicated nursing staff in Emergency worked on the man they knew had spent so much of his life saving lives ... the pelican needed Ivomec, the turtle needed squid, 2 turtles were tagged and could be released, and something about a silver gull and an entangled loggerhead at Evans Head....

Lance was so proud of ASR, the new crews who have expanded the network and extended our work, and all our achievements. I don't know how to find the words to honour the man who was so hard to love but yet gave so much.

Lance exhausted himself for the ASR mission. If, now, you ask yourself, "What can I do?" then my answer is, whatever you can to honour that mission, his vision.

With love and the deepest sorrow....

Marny.

"If pelicans could cry, there would be a wailing
around the nation that could not be ignored."

Background

Bycatch is one of the most significant issues affecting commercial fisheries, nationally and globally. On many occasions the bycatch of marine turtles by commercial fisheries has been singled out as a major threat to various marine turtle populations (Robins *et al.*, 2002a), especially as some species of marine turtle are considered vulnerable to local or global extinction due to declining numbers (IUCN, 2006). Although many turtle populations face other threats that far outweigh mortality resulting from fishing operations where turtles are a bycatch, the reduction of all sources of mortality remains critical when endeavouring to rebuild marine turtle populations (Gilman *et al.*, 2005b). Appendix 3 contains information on various anthropogenic events that negatively impact marine turtles around the world.

Because of their migratory nature, most species of marine turtles are an internationally shared resource and all relevant countries must do their best to prevent marine turtles stocks from further decline. This includes addressing the incidental catch and death of marine turtles during commercial fishing operations.

In addition to the issues of fishing operations contributing to turtle population decline, turtles are charismatic creatures the fate of which often arouses emotional public concern (Harris and Ward, 1999). Hence, their incidental capture may indirectly have negative socio-economic impacts upon fisheries (Bache *et al.*, 2000). For commercial fisheries to remain acceptable in terms of public-image they need to be deemed 'turtle-friendly'.

Marine Turtles

There are seven species of marine turtles in the world. Six occur in Australian waters:

- Loggerhead turtle *Caretta caretta*,
- Green turtle *Chelonia mydas*,
- Hawksbill turtle *Eretmochelys imbricata*,
- Olive ridley turtle *Lepidochelys olivacea*,
- Flatback turtle *Natator depressus,* and
- Leatherback turtle *Dermochelys coriaceae*.

Appendix 4 contains information and photographs of each of these marine turtle species. The seventh species, Kemp's ridley turtle *Lepidochelys kempii,* occurs only in the Gulf of Mexico and northwest Atlantic (Limpus, 1998). Appendix 5 contains a report on the generalised life cycle of marine turtles.

The magnitude of the impact of commercial fishing on specific turtle stocks depends on many factors, including: the status of the population in question, the rate of immediate and eventual mortality, other threats faced in that area and the life stage of the turtles removed by the capture events (Western Pacific Regional Fisheries Management Council, 2002).

Australian Marine Turtle - Longline Review Project

The possibility of marine turtles interacting with longline gear in Australian waters has been recognised for over a decade (Miller, 1993). Because the magnitude of the problem was unknown a review project, funded by the Fisheries Resource Research Fund (Department of Agriculture, Fisheries and Forestry), was completed in 2002. Robins *et al*. (2002a) documented the available information on marine turtle bycatch in Australian pelagic longline fisheries. It reviewed scientific research, policy responses and legal information relating to longline turtle bycatch, based on evidence from North, Central and South America, the Mediterranean and elsewhere. The possible usefulness of mitigation measures and policy responses adopted overseas were examined in order to establish a set of monitoring and mitigation measures that may be suitable for implementation in Australian domestic fisheries. This report is available through www.brs.gov.au (Robins, C. M., Bache, S. J. and Kalish, S. R. (2002a) *Bycatch of Sea Turtles in Pelagic Longline Fisheries – Australia*. Bureau of Rural Sciences. Final Report to the Fisheries Resources Research Fund, AFFA, Canberra, Aus.).

Recommendations from that project, included:

- *Handling guidelines and species identification charts*
    - Handling guidelines and species identification charts be laminated and distributed to all Australian longliners, possibly through the logbook system, for hanging in the wheel house, galley and anywhere else the crew considers to be appropriate,
    - Fishers receive handling training, including resuscitation techniques, at port workshops,
    - An instructional DVD on marine turtle handling guidelines, species identification and awareness of marine turtle conservation issues be made available to all Australian longliners.
- *Monitoring of turtle take*
    - Provide information to fishers on marine turtle data that would be most useful to report in logs,
    - Introduce a voluntary marine turtle specialist log for interested fishers, including photographing captured turtles,
    - Routinely conduct observer programs in Australian longline fisheries.
- *Fisher training and research*
    - Marine turtle research to include the formation of a strategy group to coordinate marine turtle activities,
    - Marine turtle research program be implemented in Australian longline fisheries (including morphological measurements, conventional tagging, PTT tagging, satellite and archival tagging, genetic samples, and fishing operational modifications),
    - Home-port workshops be conducted to train fishers in scientific protocol, data collection and increase marine turtle conservation awareness throughout the fishing community,
    - Research activities should not significantly impact on fishing operations.

- *Recovery planning*
    - Australia to complete and publish its Marine Turtle Recovery Plan,
    - The issue of longline marine turtle bycatch be discussed and appropriate actions highlighted in the Recovery Plan.
- *U.S. technology and laws*
    - Developments in both United States (U.S.) laws and gear modifications should be closely monitored in order to prevent any U.S. actions from negatively impacting on Australian longline fisheries,
    - Where applicable to the Australian situation, gear modifications developed abroad to minimise marine turtle capture and mortality should be considered for adoption in Australian fleets,
    - Monitoring of any potential U.S. and international organisation application of eco-labels to longline fisheries, in particular in relation to marine turtle bycatch.
- *Equipment*
    - Australian longliners carry linecutters to release hooked marine turtles without trailing line and dip-nets to retrieve small hooked turtles for treatment, where appropriate,
    - Fishery managers monitor dehooking studies while interested Australian fishers trial these devices.
- *Regional action*
    - Australia should participate in appropriate forums to encourage a harmonised and regional response to mitigating longline marine turtle bycatch, including where applicable, the fishing industries.

Australian Pelagic Longline Fisheries

There are two fisheries in the Australian Fishing Zone that target pelagic fish using longlines and have a marine turtle bycatch – the Eastern Tuna and Billfish Fishery (ETBF) and the Western Tuna and Billfish Fishery (WTBF). Skippers from these fisheries, interviewed in 2001, reported a marine turtle catch that ranged from 0 to 20 turtles/year. The average annual turtle catch rate from fisher interviews was 0.024 turtles/1000 hooks, which equates to an estimated total annual catch of 402 individuals (with 95% confidence limits of 360 – 444) using the 2001 fishing effort of around 17 million hooks for both fisheries. Although these data are not precise they did provide an estimate of marine turtle catch rates in these fisheries (Robins *et al.,* 2002a).

Since 2002 however, many operational aspects of these fisheries have changed significantly. These include various management regulations, shifts in targeting practices (such as changes in bait and hooks used and changes in the depth the gear is set), gear changes due to mitigation measures adopted for other bycatch species, the number of boats fishing and the number of hooks set. Consequently, it would be expected that marine turtle catch rates may also have changed.

Accurate estimation of post-hooking survival for longline caught marine turtles is important when developing fishery management plans and ultimately, for the worldwide conservation of marine turtles (Parker *et al.*, 2001). Although few verified data on mortality rates exist, it is reasonable to assume that survival is high for leatherbacks, the most commonly caught species. This is due to most encounters being their entanglement in gear only and the turtles being released healthy (Robins *et al.*, 2002a). It is less rational to make the same general assumption of very low mortality for other species of marine turtles. The types of encounters for these species vary, ranging from internal hooking to entanglement, and although most turtles are reported as released healthy, others are reported as injured upon release. A small number of shelled turtles are also reported as dead as a result of the encounter. Additionally, even though a high percentage of logbooks and observer records report that most turtles are released alive, their eventual fate is unknown. Further research is needed before any definitive conclusion can be drawn on marine turtle mortality rates as a result of capture by Australian longline fishers.

The migratory nature of marine turtles and their pelagic life-stage results in them being subject to a particular threat through pelagic longline operations. But it also means as interactions are not always in national waters, but rather on the high-seas, the issue is often not the responsibility of one country. Australia, however, has the obligation under a range of agreements to mitigate the bycatch of marine turtles. It also has the moral responsibility to assist countries with fewer resources to help solve their turtle issues.

Other Fisheries

In recent years, pelagic longline fisheries have been condemned worldwide for being a significant contributor to marine turtle population decline (Crowder and Myers, 2001; Lewison *et al.*, 2004). However, there has now been a number of reports questioning whether pelagic longline fisheries deserve the reputation of being the principal cause of turtle population declines (Kaplan, 2005; Lewison and Crowder, 2006). In the absence of additional and substantial research it is difficult to accurately quantify the risk faced by individual turtle populations as a result of specific fisheries, or indeed any other significant source of anthropomorphic mortality. What is known is that in order to rebuild marine turtle populations all threats to these populations should be addressed (Gilman *et al.*, 2005b).

Various methods have been used to estimate and report marine turtle interaction rates in longline fisheries. The differences in what constitutes an interaction (hooking only, hooking and entanglement, mortality only, landed on deck) and the diversity of scales (catch/1000 hoods, total catch, mortality rates) and time frames makes the comparison between fisheries difficult. The most common interaction rate reported is the number of turtle encounters (hooked or entangled)/1000 hooks set. Another issue is the differences in the accuracy of interaction rates ranging from anecdotal, non-confirmed information to verified observer data.

In March 2004, an Expert Consultation on Interactions between Sea Turtles and Fisheries within an Ecosystem Context, convened by the Food and Agriculture Organisation (FAO), was held in Rome, Italy (FAO, 2004). This meeting brought together a panel of marine turtle, fishing gear and fisheries management experts to provide expert technical input into the Technical Consultation on Sea Turtles Conservation and Fisheries, Bangkok Thailand 2004 (FAO, 2005). It was attended by 28 members of the FAO (including

Australia) and by observers from three inter-governmental and four international NGOs. Drafted and agreed upon at this Technical Consultation was a 'Guidelines to Reduce Sea Turtle Mortality in Fishing Operations' (Appendix 6).

Marine Turtle Mitigation Research

Prawn Trawl Fisheries

Prawn trawl fisheries around the world found their 'silver bullet' for marine turtle bycatch many years ago – Turtle Exclusion Devices or TEDs. This invention enabled many prawn trawl fisheries to continue operating without impacting turtles.

TEDs are devices sewn into trawl nets to separate large unwanted animals, generally marine turtles but also other large organisms like sharks and rays, from the smaller target species, generally prawns. They enable the large animals to exit the net before reaching the cod-end while prawns continue into 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, either on the upper side or the lower side of the trawl net (Figure 1).

Initially developed by fishers in the 1960s, TEDs were further refined by the U.S. National Marine Fisheries Service (NMFS) in the late 1970s. Over the last 30 years the designs have changed significantly (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 evaluation in different fisheries has been recognised repeatedly.

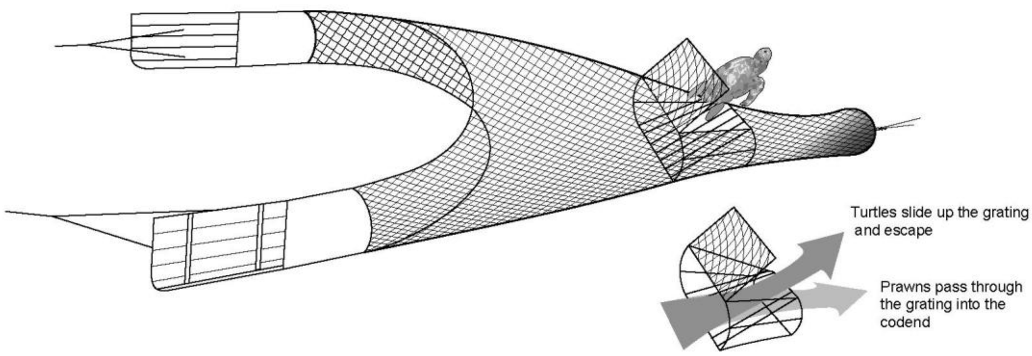


Figure 1 Diagram of One Style of TED (from Robins et al., 2002)

Following many years of domestic discord in the U.S. – regulations, challenges, lawsuits and court cases, amendments, public hearings, injunctions, and delays (examples in Oravetz, 1988 and 1992) – in 1996 the issue of marine turtle mortality 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 marine 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).

Currently, TED use is routine in many countries (Brewer *et al*., 1998; Anon, 2001). Various other nations' trawl fisheries do not pose a threat to marine turtles and, according to the U.S. embargo, do not require the use of TEDs (Anon, 2001).

Longline Fisheries

Is there a 'silver bullet' for longline fisheries? Over the last decade there have been studies developing and testing turtle mitigation measures in many longline fisheries around the world.

To date, the most successful mitigation measure investigated is the use of large circle hooks in conjunction with whole fish bait. To some researchers and fishers this is the solution. To others, it is just part of the solution.

The other fundamental part of the solution is to minimise immediate and long-term injury to the turtle by adopting good marine turtle handling and release techniques and by having the correct equipment and tools. These techniques involve ways to:

- Retrieve the turtle without further injuring the animal,
- Caring for the animal while it is on the deck of the boat including moving and restraining the animal, the recovery position, removing fishing gear and recognising and treating comatose animals, and
- Releasing the animal safely.

Possible injuries from gear that is not removed includes tissue damage, infection, blockages in the gut, internal organ damage and limb damage from trailing line (Watson *et al*., 2005). The U.S. has conducted extensive research (Epperly *et al.,* 2004) to determine the best turtle release tools and all U.S. longliners must carry and use a specific set of tools and equipment.

U.S. Actions

On several occasions the U.S. has unilaterally applied trade sanctions to further its environmental agenda by influencing the management policies of other countries and to 'level the playing field' for its industry. One example, as mentioned above, is the turtle-shrimp case. Though the application of embargoes is irregular, and its impact on Australia varies from product to product, U.S. trade and sanction policies will continue to have a major influence on Australian fisheries with disruptions to international trade having the potential to significantly, and increasingly, impact upon the Australian fishing industry.

With respect to longline fisheries, in the late 1990's it was advised that marine turtles were taken as bycatch in the North-East Distant Fishery, or NED, which includes the Grand Banks fishing grounds. Yeung (2001) reported that between 1992 and 1999 Atlantic pelagic longline fisheries interacted with an estimated 7891 loggerheads and 6363 leatherbacks. A significant proportion of these animals were taken in the NED (Read, 2007). As a result, in 2000 NED fishing grounds were partly closed to U.S. longline vessels when a Biological Opinion found that this fishery jeopardised the continued existence of loggerhead and leatherback turtles. The whole NED was completely closed for the 2001, 2002 and 2003 fishing seasons (Read, 2007).

In 2001, an extensive research program was started by the NMFS in cooperation with the fishing fleet, to develop and evaluate methods to reduce the interaction rate between marine turtles and longline vessels (Read, 2007). Amongst many other findings was the important result that the use of large circle hooks and whole-fish bait, compared with smaller J-hooks and squid bait, significantly reduced the catch of marine turtles and also decreased the rate of deep-hooking in loggerheads resulting in less harmful hooking events (Watson *et al*., 2005).

The identification that the use of large circle hooks and whole-fish bait as a suitable gear modification allowed the NED fishery to reopen in 2004. Vessels were permitted to fish but were required to:

- Possess onboard and/or use 18/0 or larger circle hooks with an offset not exceeding 10 degrees,
- Use only whole Atlantic mackerel and squid bait,
- Only use hooks offset by the manufacturer,
- Carry and use marine turtle release equipment, and
- Comply with specified marine turtle handling and release protocols.

(National Marine Fisheries Service, 2004b).

Other U.S. pelagic longline fisheries have also experienced closures as a result of inappropriate marine turtle bycatch levels. In April 2001, after many years of court cases and changes in fisheries regulations, the U.S. closed significant areas of the North Pacific Ocean (Hawaiian) pelagic longline fishing grounds to U.S. longliners. Not surprisingly, one aspect of the response to the decision to close this fishery and related gear modification requirements, has been the call for extension of this U.S. domestic law to countries whose longline fisheries bycatch includes marine turtles, in particular those countries that export longline caught products to the U.S..

In 2004, as a response to the mitigation research in the Atlantic, the North Pacific longline swordfish fishery was re-opened to American fishers. The fishery, however, was subject to various regulations:

- An annual fleet-wide effort limit of 1120 sets,
- Use 18/0 circle hooks or larger and mackerel-type bait only,
- Annual limits on the number of interactions with leatherbacks (16) and loggerheads (17). Upon reaching either limit the fishery is closed for the remainder of the calendar year,
- A requirement for 100% observer coverage, and
- Vessels to carry and use specified dehooking devices.

(National Marine Fisheries Service, 2004a).

On 20 March 2006, the fishery was again closed due to the annual interaction limit of 17 loggerheads being reached. There was no significant difference between turtle CPUE between the first quarters of 2005 and 2006, however; so it has been concluded that the increase in turtle catch was a result of increasing effort and not as a result of increasing loggerhead capture rates (Gilman *et al*., 2006a). This fishery reopened in 2007 and by 2 July interactions had occurred with six leatherbacks and 14 loggerheads (http://www.fpir.noaa.gov/SFD/SFD_turtleint.html, accessed 09/07/07).

The U.S. continues to advocate the need for all pelagic longline fleets around the world to trial and implement turtle-safe fishing practices. The focus is primarily on the universal adoption of large circle hooks and whole fish bait as the most appropriate mitigation measure to reduce the impact of longline operations on marine turtles.

On June 11, 2007 NMFS and the National Oceanic and Atmospheric Administration (NOAA) posted an 'Advance notice of proposed rulemaking; request for comments' in the Federal Register 'Certification of Nations Whose Fishing Vessels Are Engaged in Illegal Unreported, or Unregulated Fishing or Bycatch of Protected Living Marine Resources' (National Marine Fisheries Service, 2007).

This notice advises that NMFS is 'developing certification procedures to address illegal, unreported, or unregulated (IUU) fishing activities and bycatch of protected living marine resources'. It includes certifying nations and/or vessels engaged in IUU fishing or fishing that result in the bycatch of protected living marine resources, including marine turtles, and alludes to the possibility of trade embargos. The notice advises that import certification may be achievable for longlining if 'such imports were harvested by practices that do not result in bycatch of a protected living marine resource, or were harvested by practices that: (A) are comparable to those of the U.S., taking into account different conditions, and which, in the case of pelagic longline fishing, includes mandatory use of circle hooks, careful handling and release equipment, and training and observer programs; and (B) include the gathering of species-specific data that can be used to support international and regional stock assessments and conservation efforts for protected living marine resources' (National Marine Fisheries Service, 2007).

Need

Politically

There is a pressing need for the issue of marine turtle bycatch in Australian longline fisheries to be addressed, with the impetus coming from conservation and fisheries agreements. Globally, there have been many resolutions issued by expert-based bodies that call for a worldwide reduction in turtle captures by longlines. Of great concern is the indication in June 2007 by the U.S. to place an embargo upon longline fisheries that do not adopt what the U.S. considers to be turtle-safe practice. In Australia there are requirements to protect marine species under the Environmental Protection and Biodiversity Act (EPBC Act), which imposes high standards upon fishing activities in Australian waters. There is increased attention on the need for better data collection and bycatch management as demonstrated in the Bycatch Action Plans, and with the EPBC Act placing a strong emphasis on validated data. Additionally, the Australian Marine Turtle Recovery Plan documents the importance of addressing turtle bycatch issues by commercial fisheries.

Morally

Many fishers from the ETBF and WTBF recognise the need for their fisheries to be 'turtle-friendly', not only to achieve and demonstrate ecologically-sustainable fisheries, but as a personal responsibility not to harm or kill endangered species. The best way for fishers to achieve this is to be educated about marine turtles and relate this to their fishing operations. They need to understand the life cycles and the differences between the species; to understand why all species of turtle are currently considered threatened or endangered; keep up-to-date on mitigation research; and in some ways, most importantly, develop initiatives that will reduce their impact on the species. The involvement of fishers in marine turtle research is an educational opportunity that improves the awareness of turtle conservation issues throughout the fishing community.

Economically

There are economic incentives to minimise marine turtle bycatch. The catching of non-target species increases the cost of fishing, in that every hook and bait that is taken by an unwanted animal does not result in a profitable catch. Also the time taken to deal with animals that are to be discarded would be better spent dealing with animals that are marketable. Evidence suggests that the Australian pelagic longline fisheries may have what U.S. authorities consider a significant take of turtles (Robins *et al*, 2002a). Following a range of restrictions placed on U.S. domestic longliners, including fishery closures, there have been calls for the extension of their domestic laws to other nations. Australia's ability to pre-empt, or respond to, any threat of trade action is vital considering the very real chance that the U.S. will impose trade measures, such as import embargoes, on fleets and vessels that are not considered to be managing their marine turtle bycatch.

Objectives

1. Coordination of a team, primarily via email, of marine turtle scientists, industry representatives, fishery management and government officers, and NGO representatives to determine suitable research components.

2. Attendance of as many fishers as possible from the Australian pelagic longline fleets at workshops covering marine turtle conservation awareness, marine turtle handling and logbook data collection.

3. Production of a DVD outlining marine turtle handling and logbook data collection guidelines, with distribution to all Australian pelagic longline vessels.

4. The collection of biological data and samples by trained volunteer fishers from the Australian pelagic longline fleets to be used in national and international research projects, including research using morphological measurements, conventional tagging, PTT tagging, satellite and archival tagging, genetic samples, and fishing operational modifications in a specialised marine turtle logbook.

5. Testing a selection of dip-nets, linecutters and dehookers in the Australian pelagic longline fisheries and recommending approaches and/or designs most suitable for Australian longline operations.

6. To produce an educational DVD suitable for all ages covering marine turtle ecology, biology, and conservation and featuring Australian marine turtle research.

Methods

The intent of the report is to not only document the results and implications of the project objectives, but to also provide an information resource for fishers. The Appendices contain topics that may be of interest to fishers wishing to learn more about marine turtles and their associations with longline fishing operations.

Objective 1 Steering Committee

A Steering Committee was formed by email comprised of marine turtle scientists, industry and NGO representatives and other interested parties. This Committee commented on the research being undertaken, reviewed draft results and will review publications resulting from the project.

Objective 2 Training Workshops

Marine Turtle Conservation and Awareness Workshops were held in the key fishing ports of Mooloolaba, Ulladulla and Fremantle. Fishers were notified about these half-day workshops via personal invitation from SeaNet Australia liaison officers – Elton Robinson, David Kreutz and Carl Bevilacqua, and notices were distributed to fishers and/or vessels while in port. The workshops were attended by approximately 60 fishers.

The workshops covered turtle awareness and conservation; mitigation research results; turtle biology, handling and release guidelines; research with which fishers could become involved; and data to record. A session was included on seabird handling upon request from fishers. Handouts were provided of each session for those unable to attend. Questions were asked throughout the talks and the presentation format was kept casual. Appendix 7 is the general agenda for the workshops.

After the workshop, fishers wanting further involvement were provided with a 'Turtle Backpack'. This contained the equipment and information needed to record data for the project and collect samples. Fishers also received a Turtle t-shirt and lunch.

Objective 3 Handling DVD

Crossing the Line was filmed by a documentary film-maker on the longline vessel, *FV Ocean Dawn* at the Mooloolaba wharfs. Extra fishing footage of the *FV Clover Bay* was obtained from the AFMA Observer Section and underwater footage was donated by cinematographer David Hannan (www.davidhannan.com.au). The actors were Dr Colin Limpus from Queensland Environmental Protection Agency (EPA) and the crew of the vessel. The turtles were provided by Queensland EPA. The script followed along the lines of the workshop agenda (except for the seabird session) and was written to provide the necessary information, but still be enjoyable for fishers to watch. Also included on the DVD was a detailed lecture given by Dr Limpus to fishers on the life cycle of marine turtles.

The DVD was distributed by SeaNet liaison officers during port visits and each permit holder received a copy from the AFMA. Copies were also provided to fleet managers and owners, distributed at numerous fishery and turtle meetings in Australia and overseas, and provided to anyone who showed an interest in obtaining a copy.

Objective 4 Data and Sample Collection

Longline fishers were invited to record data on turtle interactions and to collect various samples from the turtles. Data collected included information on the fishing operation, on the circumstances of the interaction and on the turtle itself. Appendix 8 contains the data sheet that was completed by the fishers.

Fishers had the option to participate in scientific studies, including flipper tagging and satellite tagging, genetic sampling, and returning dead turtles for sample analysis by Queensland EPA. All turtles were measured (curved carapace length) and information provided on the health status upon capture and release.

Disposable cameras were provided to allow the fishers to photograph the turtle so species identification was not required. All the necessary equipment was provided to fishers including pre-paid and addressed envelopes for return of data sheets and samples.

Data was considered to be anecdotal and turtle interaction rates were estimated using verified Observer Records. Appendix 9 is a mid-project report provided to fishers.

Objective 5 Release Equipment

Thirteen sets of release equipment were purchased (in conjunction with SeaNet) from ARC Dehookers (www.dehooker4arc.com). Elton Robinson (Seanet Australia) was responsible for this section of the project. Each kit, supplied in a canvas bag, consisted of:

1. 16" Sportsman Deep-Hooked Dehooker
2. 16" J-style Handheld Dehooker
3. 16" Bite-Blocked Dehooker
4. 12' Pole Big-Game Dehooker
5. 12' NOAA LaForce Linecutter
6. 30" Thin PVC Conduit
7. 30" Thick PVC Conduit

Fishers interested in trialling the dehookers were provided with the necessary equipment, trained in using the equipment and completing the Dehooker and Linecutter Report Form (Appendix 8) during the Turtle Handling Workshops. If a fisher failed to complete the form all equipment was retrieved and given to another interested fisher.

As the trial was conducted during regular fishing operations, it was not practical to request that a certain tool be used, as would be necessary if a strict experimental design was applied. The fisher decided which tool to use and subsequently, as soon as a certain style was found to be preferable, no others were used. Consequently, data was not statistically analysed and is considered anecdotal.

Objective 6 Student Education Kit

One in a Thousand, an educational kit aimed at primary school students, was produced by Hatchling Productions (www.hatchling.com.au). Filming was conducted on Ballina Beach, at the Australian Seabird Rescue (www.seabirdrescue.org) Headquarters (Ballina), and at Mon Repos Marine Turtle Information and Research Centres (Bundaberg). Footage was used from the *Crossing the Line* film.

The film follows the story of Sam, a young girl who finds a turtle stranded on a beach and calls for help. This leads her on a journey of discovery into the miraculous life of the marine turtle and the many dangers and threats they must overcome in the oceans and on the beaches.

The kit consists of:

- A DVD containing a 30 minute film *One in a Thousand*, short extras on marine turtle biology and research, and underwater footage,
- Teachers' notes on marine turtles, and
- Ten worksheets for each of the three levels (Ages 5-7, 8-10, over 11).

The Kit was officially launched in August 2005 by Senator the Hon. Eric Abetz (Minister for Fisheries, Forestry and Conservation) in Brisbane, Queensland.

Copies of the Kit were offered free of charge to all individuals, organisations or schools who had previously purchased the FRDC's Seafood Kit. The Kit was also provided free of charge to all persons who contributed to the project.

One in a Thousand is for sale on the FRDC website (www.fdc.com.au) for AUD$20. A donation of $5 from the sale of each kit will be donated to the Marine Turtle Program of the Queensland EPA.

Results/Discussion

The Results/Discussion is presented in five sections:

1. Australian Pelagic Longline Fisheries
2. Results of Each Objective
3. Marine Turtle Interaction Rates
4. Mitigation Methods
5. Future Research.

1. Australian Pelagic Longline Fisheries

Although the two Australian pelagic longline fisheries, the ETBF and the WTBF, are classified as two fisheries, in actual fact the ETBF, in particular, could be considered as many fisheries in one. In order to evaluate the 'marine turtle interaction potential' or the 'likelihood of each of the sectors to interact with marine turtles' each sector needs to be considered separately. Unfortunately, as the observer coverage is relatively low at less than 5%, very little verified turtle interaction information is available at the sector level. Each sector can be described in terms of fishing grounds, fishing method, target catch, fishing effort, bait, hook type and bycatch, but each factor should not be contemplated independently when determining probable interaction potential of the sector. The evaluation of each of the factors, however, can be regarded as contributing to the interaction potential of that particular fleet.

The ETBF could be reasonably split into five sectors:

- Area E – fleet based out of Cairns, North Queensland, targeting tuna with mainly sardine bait with specific management regulations,
- Offshore Brisbane grounds – fleet of large vessels (>18m) on long-duration trips based out of South East Queensland targeting mainly swordfish with squid bait and using lightsticks,
- Inshore Brisbane grounds – fleet of generally small vessels (<18m) based out of South East Queensland targeting tuna (yellowfin, bigeye) and seasonally swordfish with a mix of squid and self-caught bait,
- Southern grounds – fleet of small vessels (<18m) based out of New South Wales ports targeting tuna (primarily yellowfin and seasonally striped marlin) using self-caught bait,
- Deep-set fishery – fleet of a mix of vessels that previously fished in the other sectors, and still cross between sectors depending on market-demand, in all areas except Area E targeting albacore and other tunas using a deep-set technique at night, primarily with circle hooks and sardine fish bait.

Although similar in many ways to the ETBF, the WTBF is not so easily segregated due to its contraction of effort and grounds in recent years.

Fishing Grounds

'The ETBF extends from Cape York, Queensland, to the South Australian/Victorian border. Fishing occurs in both the Australian Fishing Zone (AFZ) and adjacent high seas. Major ports used by the fleet include Cairns, Mooloolaba, Coffs Harbour, various south coast New South Wales ports and Hobart' (http://www.afma.gov.au/fisheries/tuna/etbf/at_a_glance.htm, accessed 10-06-07).

'The WTBF extends westward from Cape York Peninsula (142°30'E) off Queensland to 34°S off the west coast of Western Australia (WA). It also extends eastward from 34°S off the west coast of WA, across the Great Australian Bight to 141°E at the South Australian/Victorian border' (http://www.afma.gov.au/fisheries/tuna/wtbf/default.htm, accessed 10-06-07).

Both the ETBF and the WTBF (Figure 2) overlap with known marine turtle habitats. Each sector of the fisheries however, is expected to interact with different species proportions and with different abundance levels of each species. At this time it is not possible to map turtle abundance levels by area due to lack of knowledge and changes in oceanographic conditions that would be expected to influence abundance levels. Current knowledge does not allow for 'turtle hot spot' or 'turtle highways' to be identified within the Australian fishing grounds.

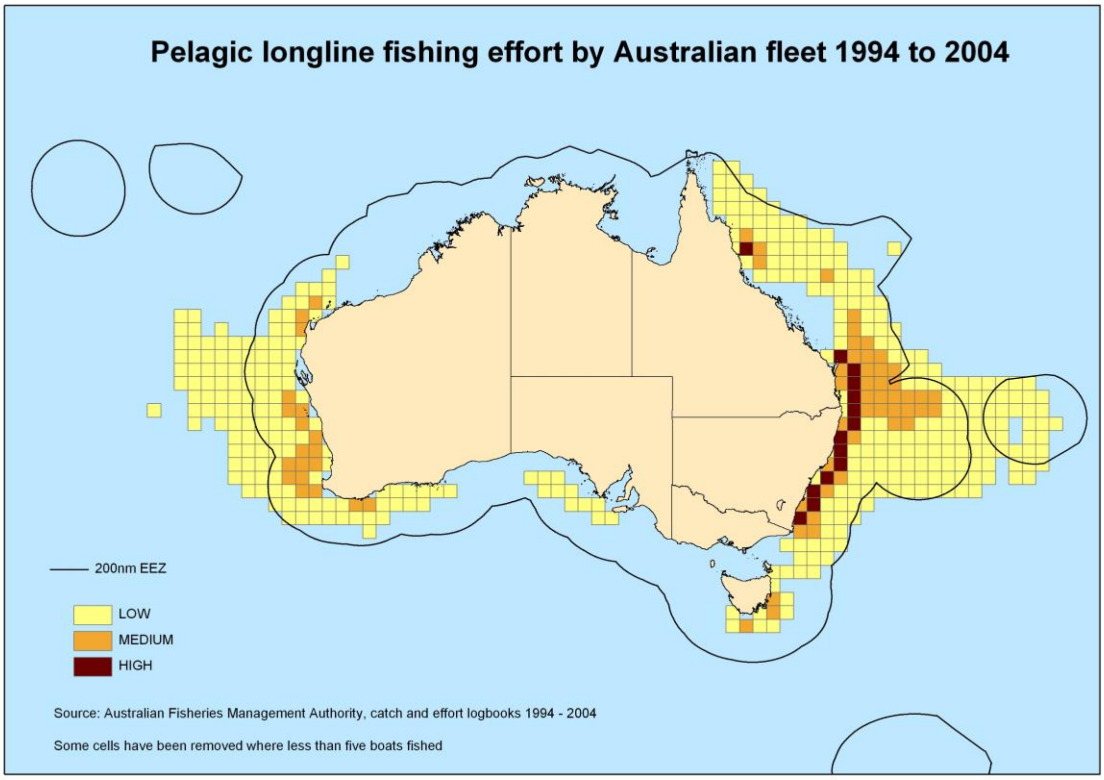


Figure 2 Pelagic Longline Fishing Effort in the ETBF and WTBF 1994 to 2004

Fishing in the ETBF and the WTBF occurs where loggerhead, green, olive ridley and hawksbill juveniles are believed to inhabit during the first 15 to 20 years of their lives. This pelagic stage of life, called the 'Lost Years', is after the hatchlings leave the beach for the first time to when the sub-adults move into their feeding habitat. It is commonly referred to as the 'Lost Years' due to the lack of knowledge about marine turtles during this phase of their life. Additionally, some adult turtles of these species migrate through the fishing grounds when traveling from their feeding habitats to breeding/nesting habitats and possibly at other times as well. Leatherbacks are also regularly observed in these fishing grounds.

Fishing Method

The methods of fishing used to target tuna and billfish in the ETBF and WTBF are pelagic longline, trolling, hand-lining and rod and reel fishing. 'Pelagic longlines are set near the surface of the water and can be many kilometres long carrying thousands of hooks. These baited hooks are attached to the longline by short lines called snoods that hang off the mainline. Pelagic longlines are not anchored and are set to drift near the surface of the ocean with a radio beacon attached so that the vessel can track them to haul in the catch. Pelagic longlines are usually used to catch large tuna and billfish species' (http://www.afma.gov.au/information/students/methods/pelagic.htm, accessed 10-06-07).

Marine turtles are known to interact with longline hooks through biting the bait and becoming internally hooked, swimming into the hook and becoming externally hooked, and swimming into the gear and becoming entangled. They can die as a direct result of the capture event or at a later date because of injuries received or from carrying gear. Turtles that are released with trailing gear and/or embedded hooks may have their swimming, foraging, migratory and/or breeding behaviours compromised.

Observer results from many pelagic longline fisheries, including the ETBF and WTBF, demonstrate that the shelled species of marine turtle are more likely to bite the hook and bait and become internally hooked than the only non-shelled species, the leatherback. This species usually becomes entangled or externally hooked. It is believed this may be due to the body shape and attraction to gelatinous animals such as squid, possibly lightsticks, and fishing gear such as floats. Shelled turtles can also become externally hooked and hooked/entangled (National Marine Fisheries Service, 2005).

Target Catch

'ETBF fishers target yellowfin tuna, bigeye tuna, albacore, broadbill swordfish and striped marlin'
(http://www.afma.gov.au/fisheries/tuna/etbf/at_a_glance.htm, accessed 10-06-07).

'The principal target species for the WTBF are broadbill swordfish, bigeye tuna and albacore tuna'
(http://www.afma.gov.au/fisheries/tuna/wtbf/at_a_glance.htm, accessed 10-06-07).

The demonstrated link between target catch and marine turtle bycatch varies with the gear configuration used to target swordfish versus tuna species. Various studies have shown that turtle interaction rates tend to be greater in shallow-set swordfish fisheries compared with deep-set tuna fisheries (Gilman *et al.,* 2005b, Oceanic Fisheries Programme, 2001). This link is further discussed on Page 55.

It has been demonstrated in the Hawaiian longline fishery that some vessels within a fleet tend to catch more turtles than others, even though they showed no significant increase in swordfish catch (Gilman *et al.,* 2006a). Research into reasons why this occurred is needed in order to identify strategies to maintain target catch rates while decreasing turtle catch rates.

Additionally, target catch must be considered when evaluating marine turtle mitigation measures. If target catch declines as a direct result of a mitigation measure there is little chance of that measure being successfully adopted by the fishers, even if made mandatory.

Fishing Effort

Fishing effort in pelagic longline fisheries is generally measured by the annual number of sets or the annual total number of hooks set. Alternative, but rarely used, measures of effort are days set and number of active vessels. Operational and target catch details of the ETBF and the WTBF are in Table 1.

Table 1 Operational Details and Target Catch of the ETBF and WTBF

Operational	ETBF		WTBF	
details	2001-2002	2004-2005	2001	2003
No. active vessels	143*	113*	43~	7
No. sets	12 874*	9 864*	5 492~	
Total hooks (millions)	11.80*	9.37*	6.17~	3.90+
Ave. hooks set/vessel ('000)	82#	82*	143~	
Ave. hooks/set		950	1 120~	1 269+
Yellowfin catch (t)	2 460*	1 946*	557~	191+
Bigeye catch (t)	1 018*	824*	386~	205+
Swordfish catch (t)	2 336*	1 638*	2 135~	1 184+
Other species catch (t)	2 523*	2 035*	243~	160+

*Lynch, 2005; # Perdrau and Lynch, 2003; ~ Perdrau, 2002; + Lynch, 2004

Note: Differing year formats between the ETBF and the WTBF are due to different reporting formats and 2003 is the most recent WTBF Data Summary due to a small number of vessels operating.

In recent years, both the ETBF and WTBF have experienced a decline in fishing effort. In the east this is primarily due to changes in management arrangements and economic factors, while many fishers in the west have been operating in other fisheries due to declines in their fish catches and/or economic factors.

The relationship between fishing effort and marine turtle interaction rate is more than the obvious 'less hooks in the water will catch less turtles'. Particularly relevant factors may be how the hooks are set (for example, depth of set), where the hooks are set (for example, near where turtles are aggregating), and when the hooks are set (for example, in times when turtles are migrating). Nevertheless, a measure of fishing effort is essential in estimating marine turtle interaction rates and the effectiveness of mitigation measures.

Bait

In 2004/05 around 76% of hooks set in the ETBF were baited with bought-bait, generally frozen squid or pilchards. The remaining 24% of hooks were baited with self-caught bait (i.e. live bait - mainly yellow-tail scad and blue mackerel). The choice of bait is associated with the target species. Tuna and striped marlin are believed to prefer live bait and swordfish seen to prefer squid (Lynch, 2005).

Although yet to be documented, as of 2007 a higher proportion of the fleet is now using frozen sardine/pilchards due to many more vessels targeting albacore using deep-set gear. This change in target species and operational style is partly as a result of a Total Allowable Catch (TAC) having been applied to swordfish catch. There are also fewer operators using self-caught bait due to a government fishery buy-out.

A number of studies have demonstrated that bait may be a fundamental factor influencing turtle interaction rate. Bait type is discussed on Pages 51 and 61.

Hook Type

A variety of hook styles – circle hooks, tuna hooks, and J-hooks – sometimes within the same set, are used in the Australian longline fishery. As with most types of fishing, the choice of hook depends on the target species, bait type and size, personal preference, hook availability and/or cost. In recent years there has been a shift towards a more widespread use of circle hooks. This is primarily due to the change in fishing operations as a result of vessels targeting albacore. These vessels tend to set gear deeper (to 400m) and use circle hooks as it is believed that these hooks result in better retention and an improvement in quality of the fish.

Since July 2006, circle hooks have been trialled in the ETBF through a National Heritage Trust funded project run by the Bureau of Rural Sciences and Belldi Consultancy. This research is due for completion in 2008. Promising results of the pilot study were reported in Ward *et al*. (2005). Similar catch rates were reported for circle hooks and traditional tuna hooks and more fish were mouth-hooked than gut-hooked when circle hooks were employed.

Hook type is probably the most significant, and often most obvious, factor to consider when developing mitigation strategies for any hook-fishery. The research based on hook type and the links to marine turtle interaction rates in longline fisheries is expanded on Pages 47 and 58.

Bycatch

The most commonly recorded bycatch species caught in both the ETBF and the WTBF are blue shark and lancet fish. There are also significant numbers of crocodile shark discarded in the WTBF and sunfish in the ETBF (Lynch, 2004; 2005).

The impact of any potential mitigation measure on all bycatch species – especially those of concern such as seabirds, marine mammals and sharks – must be considered if it is to be appropriate.

2. Results of Each Objective

Objective 1 Steering Committee

The steering committee determined the possible scientific components for fishers to conduct to be:

- Interaction data reporting – fishing operation (hook use, date, bait, lightstick use, weather conditions), and turtle interaction (time and position of capture, hook, lightstick presence/absence and colour, snoods to lightstick and float, depth of hook, position in longline, type of capture, part of body, species, length, tag details, health at capture and release, treatment and gear status on release),
- Flipper tagging for all boated turtles,
- Morphological measurements – curved carapace length and tail length,
- Photographing all turtles,
- Genetic sample from boated turtles and possibly also turtles left in the water if provided with a biopsy pole,
- Trailing release equipment, and
- Return of dead turtles for necropsy.

Additionally, observers could be considered for the return of data for all the above components plus the deployment of satellite tags.

Objective 2 Training Workshops

Although the training workshops were a success, there were some issues encountered that need to be addressed if port workshops are used in either these fisheries again or in similar fisheries (Figure 3). These included:

- Less fishers attended than expected due to problems in determining a suitable time when most fishers would have been in port. Many fishers who accepted invitations went to sea shortly before the day of the workshop or had not returned in time for the workshop. For longline fisheries without a concise in-port/fishing timeframe a better option would possibly have been more small group workshops rather than a few large group workshops,
- Difficulties in finding a suitable venue that was close enough to the fishing port for fishers to be able to walk to the meeting from where the vessels were moored,
- These fisheries have a very high turn over rate of crew and workshops need to be conducted at least annually in order to have a reasonable proportion of fishers in the fleet adequately trained, and

- The ETBF has a high proportion of Indonesian crew members who need specialised workshops to cater for language difficulties.

Figure 3 WTBF Fishers at Turtle Workshops

Objective 3 Handling DVDs

The implementation of correct handling procedures following marine turtle interactions with longline fishing gear has been proven to greatly improve post release survival (Epperly *et al.*, 2004). The provision of handling equipment and guidelines should be associated with an education package incorporating handling guidelines with detailed instructions and species identification guides. Largarcha *et al.* (2005) noted the importance of workshops to empower fishers in becoming involved in bycatch strategies such as mitigation measure trials, and also to broaden their awareness of the turtle bycatch issue.

The educational DVDs produced in Australia and used by the Australian longline fleet at workshops include *Crossing the Line* and *Hooks Out and Cut the Line* (Figure 4). These DVDs have been presented at turtle handling workshops and AFMA bycatch workshops, and distributed to all vessels in Australia's pelagic longline fisheries. With individual copies aboard each vessel, skippers are able to train new crew members in correct handling procedures and refresh the understanding of existing crew over time.

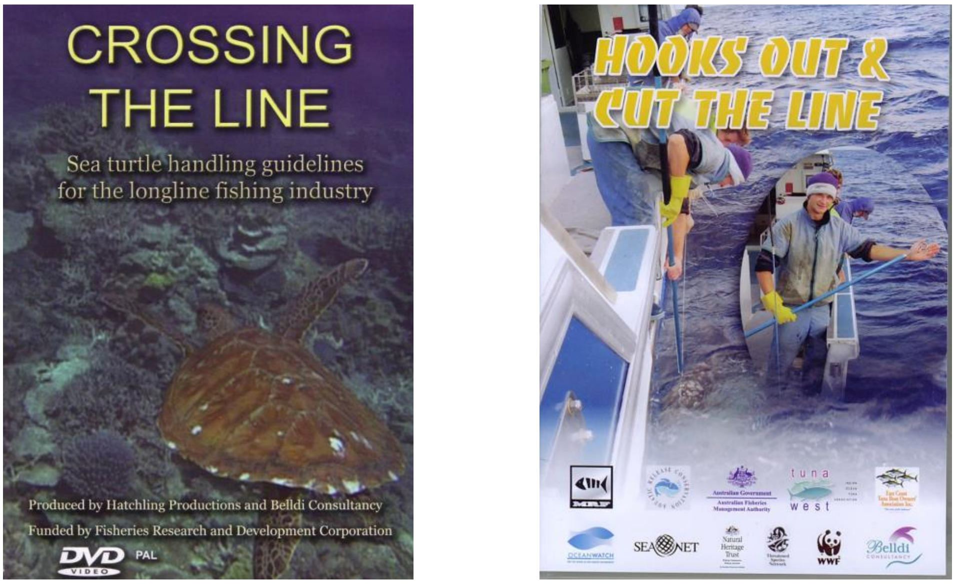


Figure 4 *Crossing the Line and Hooks Out and Cut the Line DVDs*

Crossing the Line

Crossing the Line, the marine turtle handling and release instructional DVD, was released in 2005 for use by Australia's pelagic longline fleet. It was developed to assist industry minimize impacts on marine turtle populations. It explains how to use dehooking devices on deck and on turtles still in the water, how to safely bring turtles aboard and handle them on deck, promote the recovery of comatose turtles and correctly release them back into the water. It also explains how to flipper tag, measure and identify different species of turtle.

It was determined that a locally produced film would be more readily accepted by the fishers to engender their support so Australian fishers appeared in the film with live turtles. *Crossing the Line* discussed their responsibilities as fishers interacting with endangered species, demonstrated correct handling procedures including dehooking turtles and covered research towards which fishers could make valuable contributions.

This DVD has been used throughout the world and in 2007 it was voiced-over in the Bahasa dialect (Indonesia) by World Wide Fund for Nature (WWF). Although the voice-over is effective it would have been more so if *Crossing the Line* had been refilmed using local people (in this case Indonesian fishers). With its simplicity and universal message this film lends itself as a framework to be converted into any language. For the guidelines and training DVDs to be effective fishers should attend training workshops. This provides a means for practical demonstrations and allows fishers to ask questions to experienced turtle handlers and scientists.

Hooks out and Cut the Line (Produced by OceanWatch Australia through National Heritage Trust funding)

This film illustrates step by step how to quickly and safely release target and non-target catch in a variety of situations utilising dehooking and line cutting tools. These include how to remove hooks that are swallowed and lodged in the mouth, throat or oesophagus of marine turtles, marine mammals, sea birds and fish. It also demonstrates how to remove hooks that are embedded in the body, flippers or lip of large fish, marine mammals, marine turtles and sea birds without touching or removing the catch from the water. Methods to remove gear from entangled animals in the water are also addressed.

Objective 4 Data and Sample Collection

Most fishers attending the workshops volunteered to collect data and samples. However, the number actually returning data and samples was much less. A small number of fishers continue to provide interaction data and turtle samples after the project officially finished.

Flipper Tags (Figure 5)

Six turtles were flipper tagged during the project. The low rate of flipper tagging was partly due to over half the turtles reported being leatherbacks, possibly also due to fishers wishing to get healthy turtles back into the water as quickly as possible, and plus the high rate of fisher-turnover. After one year a very small number of fishers that attended workshops were still participating in the fishery.

No turtles tagged during the project have been re-caught.

Figure 5 Flipper Tagging Demonstration

Necropsies (Figure 6)

Five turtles were returned dead for necropsies: three green, one hawksbill and one olive ridley. The turtles were necropsied at the Mon Repos Turtle Research Station, Bundaberg. Genetic samples, stomach contents and various other samples were taken and the turtles provided an opportunity for training workshops on turtle necropsy and anatomy.

All green turtles had significant amounts of plastic in their intestinal tract. One green shell was preserved and kept for education purposes. The olive ridley had consumed a large number of pelagic crabs, the first sighting of pelagic crab of this species in a turtle intestinal tract, and the skeleton became a museum specimen.

Figure 6 Various Stages of the Turtle Necropsies

Genetic Results

Genetic samples were taken from 11 turtles: two live leatherbacks, three shelled turtles released alive, one turtle that was satellite tagged and the five dead turtles returned for necropsy. Data returned from James Cook University includes:

- Green 43cm, caught 8 Dec 2003 haplotype C13 (this haplotype has only been found once in New Caledonia),
- Green 43cm, caught 9 Dec 2003, haplotype A2 (most common from the Southern Great Barrier Reef and secondly the Coral Sea),
- Green 43.2cm, caught 11 Dec 2003, haplotype B1 (primarily a Northern Great Barrier Reef haplotype),
- Green, caught Dec 2003 (sample still to be analysed),
- Green 103.5cm, caught 11 Feb 2004, haplotype A2 (most common from the Southern Great Barrier Reef and secondly the Coral Sea),
- Leatherback, caught 12 Mar 2004 (sample still to be analysed),
- Leatherback, caught 12 Jul 2004 (sample still to be analysed),
- Hawksbill, caught 28 Sep 2004 (sample still to be analysed),
- Green, caught 1 Dec 2004, satellite tagged (sample still to be analysed),
- Olive ridley, caught Dec 2004 (sample still to be analysed),
- Green, caught Dec 2005 (sample still to be analysed).

Satellite Tagging

An olive ridley was satellite tagged on 1 December 2002 by AFMA observer Andrew Bayne (Figure 7). *Andy's Travels* report (see end of Appendix 9) was distributed widely throughout the fleet and during many workshops and meetings.

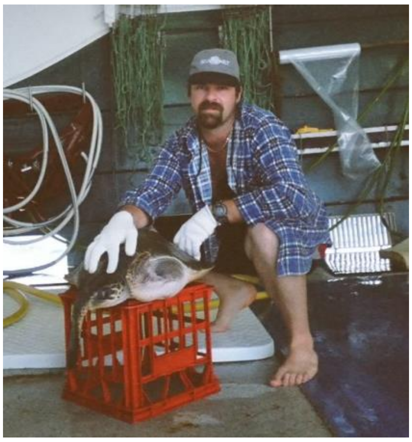
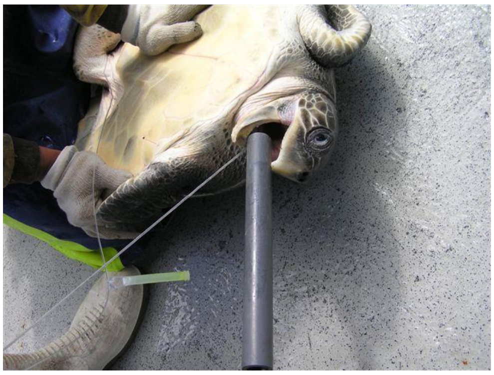


Figure 7 Andrew Bayne and Andy the Satellite Tracked Turtle

Objective 5 Release Equipment

The U.S. has conducted extensive research (Epperly *et al.,* 2004) to determine the best turtle release tools including dehookers, linecutters and turtle retrieval tools (Figure 8). All U.S. longliners must carry and use these tools (www.dehooker4arc.com).



Possible injuries from gear that is not removed includes tissue damage, infection, blockages in the gut, internal organ damage and limb damage from trailing line (Watson *et al*., 2005). Parties at the FAO Technical Consultation on Sea Turtles Conservation and Fisheries (FAO, 2005:27) agreed that 'in order to reduce injury and improve chances of survival' all fishing vessels should retain and use the appropriate release equipment (including dehooking, line cutting and dip-nets) when interacting with a turtle.

Figure 8 Hook Being Removed from a Turtle Using a Bite-Blocked Dehooker

However, these tools and techniques will only assist in reducing mortality if fishers are willing to take the time to release the turtle using the recommended procedures and don't retain the turtle for human consumption (Gilman *et al*., 2005b).

There are various opinions, both domestically and globally, on the effectiveness of the currently recommended dehookers when circle hooks are employed. Opinions range from 'they don't work' to 'they are still effective'. An Australian modification to ARC dehookers of a groove in the pigtail of the dehooker has been shown to make the dehooking of circle hooks more effective (Kreutz, 2007 *pers. comm.)*. This modification has been improved for use by U.S. fishers. NMFS announced the availability of a revised list of approved equipment models for the careful release of marine turtles caught in hook and line fisheries, (Media Release 8 February 2007, Office of Sustainable Fisheries, Silverspring, Maryland, US).

ETBF and WTBF Trials

Fishers of the ETBF trialled various handling and release tools to determine which styles were the most appropriate for use in Australian longline fisheries. Interest generated through the trials exceeded all expectations with many fishers wanting to take part. Consequently, the tools were swapped between vessels after a few weeks. Over 100 fishers participated in the trial.

Some completed data sheets were returned to the SeaNet Liaison Officer at the start of the project. However, as soon as the fishers identified the most suitable tools, the sheets were no longer completed and returned. Nevertheless, it was evident that the appropriate tools, as obtained through data sheets and via interviews from participating fishers (Figure 9), were the:

- 16" Bite-Blocked Dehooker,
- 12' Pole Big-Game Dehooker, and
- 12' NOAA La Force Linecutter.

Figure 9 Release Equipment

Implications of Trial Results

In 2005, SeaNet Australia and AFMA with funding from the National Heritage Trust provided every ETBF and WTBF commercial pelagic longliner with a set of handling and release equipment. Their correct use was demonstrated at bycatch workshops and they continue to be used by fishers and observers (Figure 10).

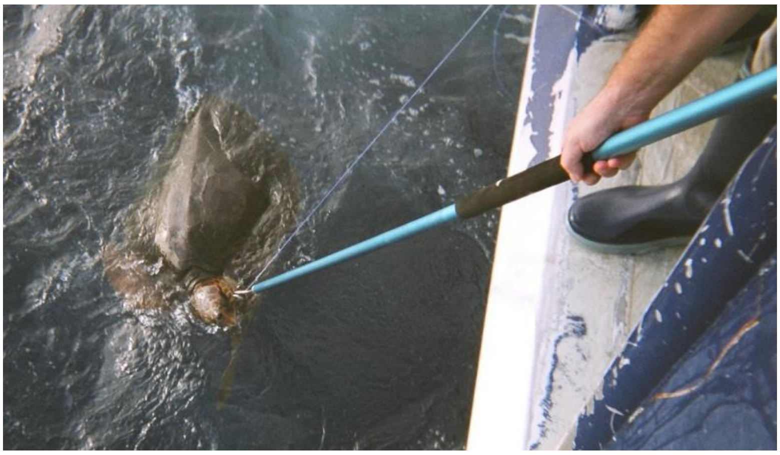


Figure 10 Turtle Being Dehooked While Still in the Water

Crossing the Line and *Hooks Out and Cut the Line* DVDs both cover in detail how to use these release tools. These tools were distributed to the fishers as a release tool for all species, not only turtles. The intention was for the equipment not to be packed away due to lack of use, but for the fishers to use the equipment with confidence with turtles should the need arise.

Objective 6 Student Education Kit

One in a Thousand – the miraculous life of the marine turtle, an Education Kit with DVD developed for Australian junior schools, was produced by Hatchling Productions and Belldi Consultancy in association with Dr Colin Limpus (Figure 11). The film takes students on a journey with an Australian teenager who finds a turtle stranded on a beach and follows her dream to learn more about these fascinating creatures. The film introduces students to important information about marine turtles, their biology, environment, life-history, threats to their survival and activities to help to reduce those threats. The DVD also includes lectures and mini documentaries on the biology of marine turtles and conservation techniques used in Australia. These have been developed so students can learn more about the life cycle of marine turtles and marine turtle research.

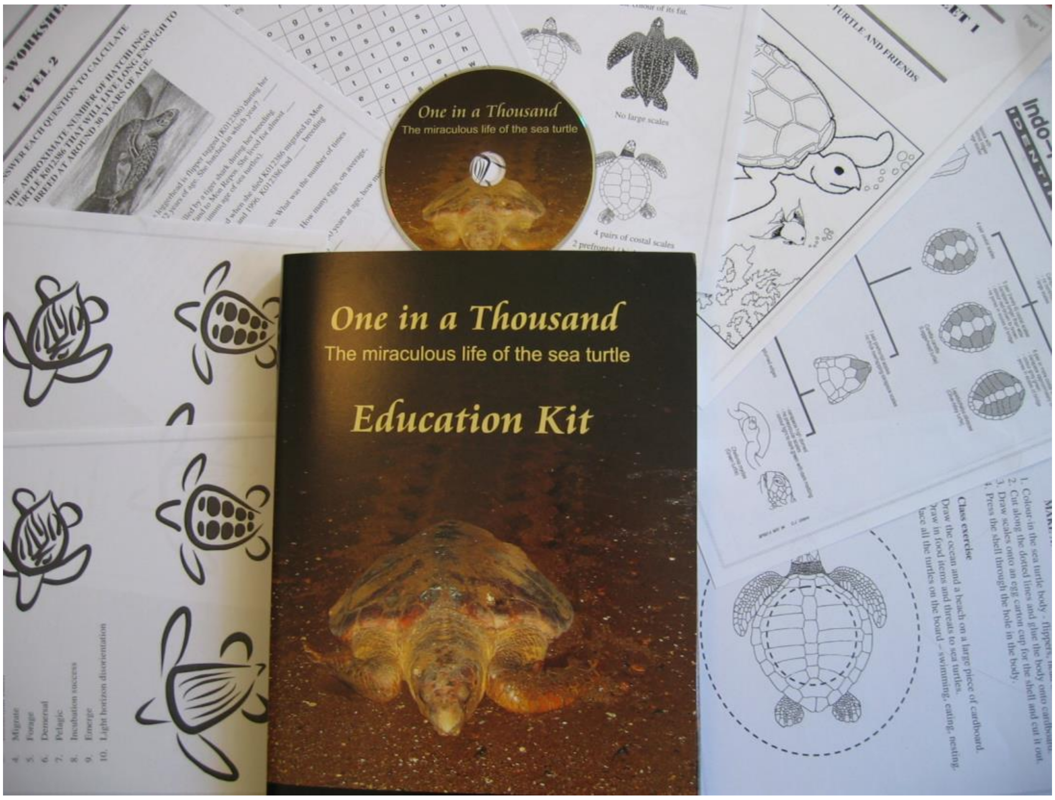


Figure 11 'One in a Thousand' Education Kit

Ten activity sheets were developed for application in the classroom for each of the three education levels:

- Level 1 – 5 to 7 years old,
- Level 2 – 8 to 10 years old, and
- Level 3 – over 11 years old.

Principal actors, in order of appearance, include:

- Jeff Canin (Father),
- Sam Lara Canin (Daughter),
- Lance Ferris (Australian Seabird Rescue),
- Marnie Bonner (Australian Seabird Rescue),
- John Meech (Queensland EPA Ranger),
- Col Limpus (Queensland EPA Turtle Scientist),
- James Limpus (young marine turtle researcher), and
- Gina Limpus (young marine turtle researcher).

The film was shot on location on a beach, at Australian Seabird Rescue Headquarters (Ballina, New South Wales) and at the Mon Repos Visitor Centre and Turtle Research Centre (Bundaberg, Queensland).

The kit was launched in Brisbane by the Honourable Senator Eric Abetz, Federal Minister for Fisheries, Forestry and Conservation on August 3rd, 2006. The FRDC supplied kits free of charge to schools and other interested parties who answered a magazine advertisement or responded to a letter sent to all people that had previously purchased the FRDC Seafood Kit. As of 30 June 2007, almost 1000 kits have been distributed to schools, tourist operators, environmental groups, and government officials, plus other stakeholders in Australia and overseas. Seafood processors and markets 4SEAS, Mooloolaba (Brett Taylor) and Samies Girl Seafood, Hamilton (Kristina Georges) have donated kits to their local schools.

The kits have been extremely well accepted and examples of feedback and responses received are provided in Appendix 10.

3. Marine Turtle Interaction and Mortality Rates

Interaction Rates

Reported marine turtle catch rates range from very low (for example, 0.007 turtles/1000 hooks) to relatively high (for example, 6.4 turtles/1000 hooks). Appendix 11 lists many turtle interaction rates that have been documented for pelagic longline fisheries around the world.

Turtle interaction rates depend on many factors, including:

- Gear type (hooks, bait, depth, lightsticks etc) and how it is set/used,
- Time of day and length of time the gear is fishing,
- Fishing grounds relative to the breeding and feeding grounds of turtles,
- Time of year,
- The oceanographic conditions (fronts, water temperature, food source),
- Whether the gear is set near or on migration routes of turtles, and
- The species of turtle in the vicinity to the fishing gear.

It can be expected that the links and relationships between these factors are complex and at times subject to rapid and significant changes. Currently, not enough is known about each factor in isolation to even consider analysing the relationships between them. What is known and demonstrated on a number of fishing grounds around the world, is that shallow-set squid and light-stick fisheries (setting gear less than 100m) tend to have higher interaction rates than deep-set (setting gear over 100m) fisheries using circle hooks and/or fish bait (Gilman *et al.*, 2005b). A reasonable assumption may be higher catch rates for fleets adopting the former fishing style and lower catch rates for fleets adopting the latter. Additional factors recognised as contributing to high turtle catches are setting around the full moon, using squid bait and lightsticks, setting without using a line-setter, and fishing near thermal fronts (Beverly and Chapman, 2007).

The methods used to estimate marine turtle interaction rates in longline fisheries vary depending on the accuracy of available data. In many cases, fishery-independent data, such as observer reports and some research surveys, are considered to be more accurate than fishery-dependant data, such as logbooks. This is due to observer data being regarded as accurately recorded by independent, unbiased and adequately trained observers. However, the use of observer data to estimate rarely caught species can be misleading when the level of coverage is low and/or coverage is patchy and/or the distribution of the species of concern is patchy.

While logbook programs tend to have higher coverage rates than observer programs, the problem with using these data to estimate the catch of rare or endangered species is that fishers may fail to accurately report interaction events if they consider it may harm their fishery. Inaccurate reporting can also be due to:

- Lack of a data collection system to capture the interaction event,
- Traditionally logbooks covered target species only and some fishers may think that they are only required to report target catches,
- Communication issues (possibly cultural or attitudinal) between master and crew resulting in the crew discarding the animal and the master (whom generally is responsible for the logbook) not realising that an interaction event has occurred, and
- Turtles being eaten, and therefore it was not considered necessary to report, or not wanting to report it in case they can no longer be eaten.

A further issue with the reporting of marine turtle interaction rates is that there are differences in what constitute an interaction. The turtle counts used to estimate 'catch rates' or 'interaction rates' are ambiguous and can mean:

- Turtles seen dead as a result of interacting with the gear, or
- Turtles hooked and landed on the boat, or
- Turtles interacting with the gear in any way.

The most common interaction rates reported are the number of turtle encounters (hooked or entangled)/1000 hooks set and the total turtles caught annually by a fleet. At times it is problematic to compare interaction rates between fisheries due to variations in assumptions and other differences in the estimation procedures used.

ETBF and WTBF Estimates Using Observer Reports

The total catch of marine turtles in the ETBF estimated from observer records (July 2004 to June 2005) for all species combined is 222 individuals (95% CI percent of estimate: leatherbacks 69%, green 112%, olive ridley 186%) (Dambacher, 2005). This estimate refers to all turtles interacting with the gear, either hooked or entangled. Therefore, the estimated marine turtle interaction rate for 2004/2005 with 9.37 million hooks set is 0.02 turtles/1000 hooks.

A pilot observer program in the WTBF from April 2003 to June 2004 reported that five turtle were caught (two leatherbacks, two loggerheads and one olive ridley) with 134 755 hooks observed. All were released in a healthy state. The estimated marine turtle interaction rate is 0.037 turtles/1000 hooks. This estimate, however, is based on a small sample (Ward, 2007 *pers. comm.)*.

ETBF and WTBF Estimates Using Logbooks

ETBF logbooks are believed to be unreliable in estimating catches of rare and endangered species, specifically marine turtles. Only 25 turtles were reported in logs from July 2004 to June 2005 (Evans, 2006).

ETBF AND WTBF Estimates Using Fisher Interviews

A 2002 review project on Australian longline fisheries and marine turtle interactions (Robins *et al*., 2002a) used fisher interviews in the ETBF and WTBF to estimate a marine turtle catch rate of 0.024 turtles/1000 hooks (standard deviation of 0.027).

This equates to an estimated total interaction rate for 2001 of 402 individuals (with 95% confidence limits of 360 to 444) for both fisheries, or assuming 1000 hooks are set per day fishing it equates to one turtle interaction for every 40 days fishing by each vessel (using days fished as reported in logbooks for 2001). The confidence interval surrounding the estimate from the fisher interviews should be considered an underestimate as it takes into account the sample size, but not the possible inaccuracy of the data from the fisher interviews (Robins, *et al*., 2002a).

Comparison Between Sources

A comparison between using observers to estimate marine turtle interaction rates and using logbooks reveal an obvious discrepancy indicating the inadequacy of logbook data for this purpose. Fisher interviews, however, seemed in this case to be a suitable way to estimate marine turtle interaction rates in that they closely align to rates found by observers. A probable issue with using fisher interviews as the only means of estimating the interaction rate with rare or endangered species is that there may be a perceived problem of fishers misrepresenting the truth in order to benefit their fishery or their own fishing operations. This does not seem to be the case in this fishery.

Irrespective of the data source all estimates provide evidence that marine turtles do interact with longline fishing operations in Australian waters. Although the incidence is relatively rarely compared too many other fisheries in the world these interactions need to be addressed by the fishing industry.

Marine Turtle Mortality

The actual magnitude of the impact of commercial fishing on specific marine turtle stocks depends on many other factors in addition to the number that interact with the fishing gear. These can include:

- The status of the turtle population in question,
- Other threats to the turtles,
- The life stage of the turtles removed by the capture events, and
- The marine turtle mortality rate following the interaction events.

Marine turtle interactions with longline fishing gear are not always fatal. It has been noted that most animals are alive upon capture and at release, especially in shallow-set gear (Read, 2007). In media coverage, marine turtle interaction rates are often confused with marine turtle mortality rates. Mortality rate could be considered as:

1. Turtles dead on the deck of the boat, or
2. Turtles in 1) plus those considered to be unable to survive the interaction, or
3. Turtles in 2) plus those released but carrying gear, or
4. Turtles in 3) plus a pre-determined proportion of all others released, or
5. All turtles that interact with the gear.

The most obvious mortality event is a turtle that leaves the vessel dead after the interaction. A less obvious mortality event is 'cryptic mortality'. This is a turtle that leaves the vessel alive but dies at a later date. These mortality events may be impossible to monitor as a turtle may die in the open ocean and the body never recovered. A difficult question to answer is 'what is a reasonable length of time after an interaction event to consider the interaction to be the cause of death?' There is little data available on the true level of post-release cryptic mortality (Swimmer *et al.,* 2002; Watson and Kerstetter, 2006).

Immediate death may be caused by injuries from the interaction event or forced submergence. If a marine turtle cannot reach the surface to breathe, obviously, its chance of drowning or becoming comatose increases. Deep-set gear, although shown in general to result in fewer turtle catches, may cause a higher mortality rate due to the inability of a caught turtle reaching the surface (Boggs, 2005 from National Marine Fisheries Service, 2005). Although marine turtles can intentionally remain submerged for considerable lengths of time, the stress of hooking and struggling against forced submergence may raise the risk of drowning (Kleiber and Boggs, 2000). Increased mortality rates may also occur if a turtle is caught along side, or entangled with, a large fish on the next hook (Ferreira *et al*., 2001). This situation was noted when a turtle was caught and killed during an observer program in the Mediterranean (Laurent *et al*., 2001) and from an ETBF fisher report regarding a turtle that died while being hooked by longline gear.

Cryptic mortality may be due to injuries received during the interaction event, such as from swallowing the hook or as a result of gear left on the animal after release. Trailing line, including entangled fishing line or line attached to an embedded hook, can:

- Be ingested at a later date and may cause death due to the digestive tract being compromised,

- Reduce mobility through the flipper being restricted and possibly increasing the probability of predation, and

- Cause loss of a flipper as a result of the line cutting through it that may restrict breeding, migration, foraging behaviours (National Marine Fisheries Service, 2005).

ETBF and WTBF Mortality Estimates

In the ETBF very few turtle deaths are reported as a direct result of the interaction event according to observer records and fishery reports. Of the 14 turtles reported by observers from July 2004 to June 2005, none were reported dead. Two, however, were classified as sluggish-alive (Dambacher, 2005).

Of the 39 turtles reported during this project by fishers in voluntary reports for the ETBF and the WTBF (2003 – 2005) 36 were considered to be released healthy and three died. These data are derived from a relatively small number of reports so should be considered as indicative only. A pilot observer program in the WTBF from April 2003 to June 2004 reported that all of the five turtles caught (two leatherbacks, two loggerheads and one olive ridley) were released in a healthy state (Ward, 2007 *pers. comm.*).

Global Mortality Estimates

Although little or no mortality data exist on many longline fishing fleets around the world, there has been some research that estimated turtle mortality rates following interactions with longline fishing gear. There have also been a small number of publications focusing on global or ocean-wide mortality estimates. In all cases these estimates have been based on extrapolating limited fisheries data. These include:

- Lewison *et al.* (2004) estimated that globally more than 200 000 loggerheads and 50 000 leatherbacks were likely to interact with pelagic longline fishing gear in 2000. Although it was noted that not all interactions resulted in the death of the turtle, they estimate that thousands of turtles die annually as a result of these interaction.

- In the Pacific basin, Kaplan (2005) examined the two most likely, and often documented causes of the decline of leatherback stocks: bycatch by longline fishing vessels and coastal harvesting of eggs and females on or near nesting beaches. One estimate of the eastern stock is a decline from 91 000 females in 1980 to 1690 in 2000 (Spotila *et al.*, 1996, 2000). The western Pacific stocks exhibit similar declines (Spotila *et al.,* 1996). Annual mortality rates for the western and central Pacific as a result of longlining and coastal harvesting is estimated at 12% and 13%, respectively. In the eastern Pacific the longline mortality rate estimate is 5%, compared with 28% for coastal sources. Consequently, it is noted that international efforts should not be focused solely on longline bycatch, but rather in the reduction of coastal harvesting and also other sources of mortality such as bycatch by inshore gear (gillnets).

- Observer records from the Western Tropical Pacific (10ºN – 10ºS) clearly show that longline vessels fishing in tropical areas, rather than sub-tropical or temperate areas, tend to encounter more turtles. A preliminary estimate of 2182 marine turtles interact with longlines in the Western Tropical Pacific each year of which 500 to 600 were expected to die as a result of the interaction. This estimate, however, has wide confidence intervals due to very low observer coverage (Oceanic Fisheries Programme, 2001).

Individual Fishery Estimates

Individual fishery estimates of mortality vary greatly (Swimmer *et al*., 2002a), both in what is actually reported and how it is reported. Most estimates include turtles that are dead on the deck of the boat and not those turtles that die at a later date as a result of the interaction – 'cryptic mortality'. Published reports that estimate mortality or report numbers retrieved dead as a result of the interaction for individual fisheries include:

- The Hawaiian shallow-set longline fishery, both before and after the introduction of a range of turtle mitigation measures were introduced, demonstrated a low drowned mortality rate of less than 1%. It was noted that this low rate of turtles drowned during the capture event was expected due to the fishery being a shallow-set longline fishery compared with a deep-set weighted gear fishery (Gilman *et al*., 2006a).
- Observers from the Hawaiian deep-set longline fishery from 1994 – 2004 reported that of 63 turtles observed 45 were immediate mortalities and 18 were released either alive or injured. Of the 18 released, nine were released without all of the gear removed and two had hooks still in their oesophagus (Boggs, 2005 from National Marine Fisheries Service, 2005).
- During 2000, 166 leatherback and 6000 other turtles were estimated to have been caught by Japan's longline fishery in the Eastern Pacific Ocean and of these, 25 and 3000, respectively, were dead (IATTC, 2006a).
- In 1994 and 1995, scientific observers monitored the catch of target and bycatch species on Mexican longliners in the Gulf of Mexico (Ulloa Ramírez and González Ania, 1998). The majority of turtles were entangled in monofilament fishing line and 66.7% were released alive.
- In 1999 and 2000, observers in the Mexican swordfish longline fishery reported that 0.44% of trips interacted with turtles and all were released without apparent harm (Instituto Nacional de la Pesca, 2001).
- Observer reports in the Peruvian artisanal longline fishery (2003 and 2004) reported a high turtle mortality rate as turtles were rarely released and were often retained for consumption or sale (Alfaro-Shigueto *et al*., 2005).
- Petersen (2005) reported that in the South African domestic longline fishery for 2000 to 2003, 85% of turtles captured were released alive.
- Yeung (2001) reported that between 1992 and 1999 Atlantic pelagic longline fisheries interacted with an estimated 7891 loggerheads and 6363 leatherbacks, although most of these turtles were released alive.

- A capture rate of 1.8 turtles/1000 hooks for longliners in the South West Atlantic Ocean (Uruguayan waters) in 1994 and 1996 was estimated from observer cruises (Achaval *et al.*, 1998). The turtles caught were loggerheads and leatherbacks. Most were released alive (98.1%) but with the hook still embedded.
- Molony (2005) estimated from observer records that in the Western and Central Pacific 6962 ± 22 567 marine turtles were captured by commercial longline and purse seine fishing operations each year. The estimated mortality is 931 ± 7329 turtles/year. The highest catches were in the tropical shallow longline (15ºN – 10ºS, < 10 hooks between floats); however the highest mortalities were in the tropical deep longline fisheries (15ºN – 10ºS, 10 or more hooks between floats). The suggested reason for the higher catch in the former was due to the gear fishing at depths where turtles spend most time (less than 120m) and the suggested reason for the mortality in the latter was that most turtles were unable to make it to the surface to breathe after hooking due to the increased depth of the gear.

Estimating Mortality

Since longline mortality of marine turtles has been recognised, the mortality rates have been estimated in various ways. The initial, and obvious, mortality estimate is the number of turtles returned to the water dead. For cryptic mortality it is necessary to adopt more complex estimation techniques. Accurate estimates of mortality, both direct and cryptic, are vital if managers are to make sound management decisions concerning marine turtle bycatch (Southwood and Swimmer, 2006).

An example is the post-hooking mortality criteria developed by U.S. NMFS in February 2001. They used a constant fraction to interaction events to estimate the rate of mortality, as follows:

No hooking, no injury, disentangled completely	0%
Hooked externally or entangled, line left on animal (hook does not penetrate internal mouth structure, e.g., lip hook)	27%
Mouth hooked (penetrates) or ingested	42%
Dead	100%

These estimation methods were revised and refined in a workshop in 2004 (Ryder *et al.*, 2006). The workshop was attended by experts on marine turtle biology, anatomy/physiology, veterinary medicine, satellite telemetry and longline gear deployment. The participants considered the 2001 criteria, relevant research and other available information to develop new post-hooking interaction mortality criteria, as shown in Table 2. The new criterion expands on the categories of interaction events, recognises the differences between leatherbacks and shelled turtles, and also considers the improvement in survival when all gear is removed from the turtle before release. These criteria were applied to data from the Atlantic NED experiments in Epperly and Boggs (2004).

One method of researching turtle mortality is through satellite telemetry, conventional PTT satellite tagging and pop-up satellite archival tagging (PSAT). Both methods allow the animal to be tracked over a long period, and possibly provide a record of long-term migration. The PSAT tags can additionally differentiate between the death of the turtle and the loss of the tag (Swimmer *et al.*, 2002a). This is one of the main issues with conventional PTT satellite tags.

Satellite tracking turtles is used to provide information on post-hooking mortality through an understanding of the behaviour of marine turtles following their interactions with longline fishing gear. Results published to date show that hooking events can modify the turtle's behaviour including differences in dive dept and frequency and possibly changes in migration and movement. Transmitter and attachment failure are frequently noted in research results as issues that need to be addressed and which may confound data interpretation (Ryder *et al.*, 2006). Various research projects that have used this technology include:

- In 1998, eight juvenile loggerheads, three of which were caught by longliners through mouth hooking and five captured using dipnets, had satellite transmitters attached to their shells, their movements were followed and their diving behaviour was recorded. At time of the report (Bjorndal *et al.,* 1999), all transmitters were still active, but it was noted that the longline caught turtles had significantly fewer dive counts than dip-net caught turtles.
- Data was presented at the workshop documented in Ryder *et al.* (2006) on a study to assess post-hooking mortality of loggerhead turtles captured in the Azores. Following capture on longline fishing gear six turtles were satellite tagged and released with ingested hooks and 18 inches of attached line. A further 12 control turtles were independently netted and satellite tagged. The hooked turtles made more shallow dives than the control animals and spent the vast majority of their time just below the surface. The control animals dived to 150m to forage. The hooked turtles also stopped orientating and floated with the current and did not continue to forage in the area where they were released, unlike the control turtles. Additionally, half the hooked turtles began to show more regular movement and dive patterns approximately 8 – 10 months after release. It was assumed these animals took many months to recover from the hooking event.
- In a 40 turtle satellite tracking program (Chaloupka *et al.*, 2004), found that lightly hooked turtles had significantly longer transmitter time-to-failure than deeply hooked turtles. As the reason for transmitter failure was unknown and the sample size was small, strong inferences should not be drawn.
- Swimmer *et al.* (2002a) reports on development of an attachment method for PSATs on marine turtles and the successful use of a PSAT on olive ridleys after interacting with longline gear in Hawaii. The first turtle was hooked in the mouth and the hook was not retrievable. Following deployment the turtle was tracked for 82 days before the tag was shed. The PSAT on another turtle that was tagged came to the surface after four days and commenced downloading data. The fate of the turtle was unknown.
- PSATs were deployed on longline caught turtles off Costa Rica (2001 to 2003). Nine olive ridley and one green turtle that were longline hooked and five hand-caught turtles were fitted with PSATs. The average distance travelled per day was

similar for longline and control turtles. Dive behaviour data suggested that there was no caught-effect and appeared to be correlated to oceanographic conditions. The PSATs show that the olive ridley turtles survived their interaction with longline gear for at least two months post-release (Swimmer *et al.*, 2004b).

- In 2001, 16 loggerheads were satellite tagged (PSAT) and released in the NED Atlantic fishing grounds: two entangled, two flipper hooked, three lightly mouth hooked and nine had ingested the hook. Of the turtles entangled or lightly hooked: one failed to transmit, one died, four were undetermined (premature release) and one survived. Of the turtles that ingested hooks: five failed to transmit, three were undetermined (premature release) and one survived. It was suspected that the turtle carrying internal hooks may have been more susceptible to predation resulting in the undetermined status (Watson *et al.,* 2003a).
- From 1997 to 2000, 54 turtles were released following capture by longline fishing gear in the North Pacific (Parker *et al.*, 2001). It was found that there was no significant difference between lightly-hooked or deeply-hooked turtles in terms of duration and distance travelled. It was suggested that mortality rate may be around 20% to 40% considering the failure of 15 of the transmitters. Although it was noted that some of these may have been due to transmitter failure and not turtle death.

Table 2 Criteria for Assessing Marine Turtle Post-Interaction Mortality After Release From Longline Gear (U.S.)

Percentages shown for hard-shelled turtles, followed by percentages for leatherbacks (in parenthesis) (Ryder et al., 2006)

Nature of Interaction	**Released with hook and with line greater than or equal to half the length of the carapace**	**Release with hook and with line less than half the length of the carapace**	**Released with all gear removed**
Category	**Hardshell (Leatherback)**	**Hardshell (Leatherback)**	**Hardshell (Leatherback)**
I Hooked externally with or without entanglement	20 (30)	10 (15)	5 (10)
II Hooked in upper or lower jaw (not adnexa) with or without entanglement	30 (40)	20 (30)	10 (15)
III Hooked in cervical oesophagus, glottis, jaw, jaw joint, soft palate, or adnexa (and the insertion point of the hook is visible when viewed through the mouth) with or without entanglement	45 (55)	35 (45)	25 (35)
IV Hooked in the oesophagus at or below level of the heart (includes all hooks where the insertion point of the hook is not visible when viewed through the mouth) with or without entanglement	60 (70)	50 (60)	NA (Per veterinary recommendation hooks would not be removed if the insertion point of the hook is not visible through the open mouth)
V Entanglement only	Released entangled 50 (60)		Fully disentangled 1 (2)
VI Comatose/resuscitated	NA (assumes that resuscitated turtles will always have the line cut to a short length)	70 (80)	60 (70)

Studying the long-term health of turtles with hook injuries as a result of an interaction with longline fishing gear assists in the estimation of cryptic mortality. The clinical long-term effects of a hook lodged in their oesophagus were monitored for 11 turtles over two years by Alegre *et al*. (2006). The turtles, although carrying hooks, behaved normally and it was decided not to operate to remove the hooks. Five of the turtles spontaneously expelled the hook, four animals required endoscopy surgery and two required an oesphagotomy to remove the hooks. It was concluded that a turtle that has a hook lodged in the oesophagus and has the line cut off short may suffer minimal damage and distress in the long term.

Reducing Mortality

The chance that a marine turtle will die following an interaction event with a longline fishing operation is dependant on many factors, including but not limited to:

1. If the turtle was incorrectly handled on the vessel, for example a turtle returned to the sea comatose will probably drown,
2. If the turtle was hooked or entangled,
3. If hooked, was it internally (gut, throat or mouth) hooked or externally hooked (flipper, neck, shoulder),
4. If hooked, was the hook removed before release,
5. If entangled, was all line removed before release,
6. If any other injuries were obtained through the interaction event, and
7. Factors about the animal itself such as species, age, health status.

Marine Turtle Species

Before any determination can be made of the impact of longline fishers on marine turtle populations it is necessary to know the proportion of each species that interact with a fishing fleet. Species composition is not wholly dependant on the numbers of each species in the area that is fished. Other factors are varied and may include bait type, gear configuration and turtle behaviour.

ETBF and WTBF

The most common species recorded in observer and fisher reports (2003 – 2005) is the leatherback (Figure 12). From July 2004 to June 2005 10 of the 14 turtles reported by observers in the ETBF were leatherbacks (Dambacher, 2005). Of the 39 turtles reported in the ETBF by fishers 22 were leatherbacks (56%). Additionally, an earlier review project conducted by Robins *et al*. (2002a) reported that according to fisher interviews approximately 60% of turtle encounters involved leatherbacks.

Figure 12 Leatherback on ETBF Line (Source: S. Hall, AFMA)

The species composition of shelled species is less conclusive. Observer records (June 2004 – July 2005) report small numbers of greens and olive ridleys. Of the 39 turtles reported by fishers too few animals were identified or photos returned to specify the species composition. However, there were verified captures of hawksbills, greens, loggerheads and olive ridleys (Figure 13).

Figure 13 Loggerhead and Hawksbill Caught in the ETBF (Sources: AFMA Observer Section and Jim Driscoll)

Other Longline Fisheries

The turtle species most often reported as interacting with longline fishing gear are leatherbacks and loggerheads (Gilman *et al.*, 2006b). As a result of many U.S. fleets interacting with these species, the bulk of research has involved leatherbacks and loggerheads. Examples of fisheries and/or fishing grounds (as listed in Appendix 11) that report catching leatherbacks and/or loggerheads include the Antigua/Barbuda longline fishery, Azores surface longline fishery, Canadian swordfish longline, the Mediterranean fisheries, fleets in the Atlantic Ocean and the North Pacific, fleets in Urguayan and Brazilian waters. The Costa Rican longline fishery is reported to interact with olive ridley and green turtles. Some fisheries operating in the South Pacific report a variety of species, along with fisheries in the Gulf of Mexico and those in South African waters.

Classification of Interaction Events

The most common information used to help determine turtle mortality rates as a result of interactions with longline fishing gear is the type of interaction event and turtle health upon release. Types of interaction events as defined by National Marine Fisheries Service (2005) include:

- Hooked externally with or without entanglement,
- Hooked in the upper or lower jaw (not adnexa) with or without entanglement,
- Hooked in the cervical oesophagus, glottis, jaw, jaw joint, soft palate, or adnexa (and the insertion point of the hook is visible when viewed through the mouth) with or without entanglement,
- Hooked in the oesophagus at or below level of the heart (includes all hooks where the insertion point of the hook is not visible when viewed through the mouth) with or without entanglement, or
- Entanglement only.

ETBF and WTBF

Leatherbacks are usually entangled, and may, or may not also be externally hooked as recorded in observer data, from fisher reports, personal interviews and logbook records from the ETBF and WTBF. There have been reports that shelled turtles have interacted with longline gear in all of the listed ways. There is inadequate data from any of these sources to accurately determine the proportional occurrence for each type of interaction event in the Australian fisheries.

An additional problem is the recognition of whether an animal is hooked or entangled. A turtle that is either too large to retrieve, such as a leatherback, or if the weather or any other factor prohibits retrieval of the animal, it may be impossible to distinguish if the turtle is hooked: by mouth, internally, externally, or only entangled.

Other Longline Fisheries

Widely demonstrated in many fisheries is that loggerheads tend to become hooked either internally or externally, when interacting with longline gear. It is assumed the loggerheads tend to bite the bait. Leatherbacks, on the other hand, tend to become entangled and occasionally externally hooked (Swimmer *et al*., 2002a; Read, 2007).

Careful Release Protocols

Extensive research was conducted in the NED Fishery in the Atlantic by a committed team of U.S. government officers, industry participants and academic scientists. A complete strategy was developed that incorporated turtle handling guidelines and release equipment. It has now become a mandatory requirement for all U.S. longliners to carry and use an extensive set of release tools and receive training on their use in compulsory annual workshops. Epperly *et al*. (2004) documents detailed Careful Release Protocols as summarised here.

Part 1: Vessel's responsibility upon sighting a sea turtle

- Scan mainline as far ahead as possible during gear retrieval to sight turtles in advance and to avoid getting ahead of the main line
- Upon sighting the turtle:
    - Slow vessel and main line reel speed
    - Move towards the turtle
    - Minimize tension on the main line and branch line
    - Retrieve branchline slowly keeping a gentle and consistent tension on the line
- When turtle is along side the vessel:
    - Stop and put the vessel in neutral
    - Do not use gaffs or other sharp objects in direct contact with the turtle to control it
    - A gaff may be used to control the line
    - Assess the condition and size of the turtle

    - Assess if hooked and/or entangled and location of hook
    - Make a decision of whether the turtle can be safely brought on board
        - If turtle cannot be brought on board – go to Part 2
        - If turtle can be brought on board – go to Part 3
    - An attempt must be made to remove all gear
    - All efforts should be made to release the turtle with minimal injury and minimal remaining gear

Part 2: Sea turtles not boated

- If a turtle is too large to be boated or condition prevent it all gear must be removed while the turtle remains in the water
- Bring the turtle as close as possible to the side of the vessel
    - But first, if necessary, allow the turtle to calm down for a short time
- Remove gear using appropriate equipment
    - Turtle tether – help control the animal whilst in the water
    - Long-handled linecutter – to cut monofilament line as close as possible to the hook while turtle is still in the water
    - Monofilament cutters – to cut the monofilament line when the turtle can be reached by hand
    - Long-handled dehooker for internal hooks (ARC Pole Model Deep-Hooked Dehooker) – to remove internal or external hooks from turtles that cannot be boated. It is noted that hooks that have been swallowed beyond where the insertion point of the barb is visible should not be removed
    - Long-handled dehooker for external hooks (J-style dehooker) – to remove external hooks from turtles that cannot be boated.
    - Long-handled device to pull an 'Inverted V' during disentanglement – after the animal has calmed, engage the monofilament leader closest to the hook with a gaff, boat hook or J-dehooker and pull the line up into an inverted V to enable easier removal of the hook

Part 3: Sea turtles boated

- Never pull the turtle out of the water using the branch line and use the appropriate equipment to board the animal
    - A dip-net if the turtle is small enough
    - A large turtle hoist, particularly for leatherbacks,
- Holding the turtle
    - Keep moist and in the shade

    - Safely isolate and immobize the turtle on a cushioned surface (for example an automobile tyre for small turtles – the right way up if possible)
    - If the turtle is tagged, note the number and species and report the interaction to the address on the tag
    - Remove all gear immediately
        - Remove hooks – all external hooks should be removed; mouth hooks when they are visible should be removed
        - If you believe the removal of the hook will cause more damage do not remove the hook; never remove a hook that has been swallowed or when the insertion barb is not visible
        - Cut the line as close as possible to the eye of the hook if the hook is not removed
        - Use bolt-cutters to cut off and remove the visible part of the hook if it is visible but cannot be removed
    - If the turtle is lethargic leave it on the deck for up to 24 hours and monitor its condition
    - If the turtle is comatose
        - Place it on its plastron and elevate the hindquarters several inches to drain the lungs
        - Do not give up as some will take up to 24 hours to recover
        - Keep the turtle moist by covering with a wet towel and periodically spraying with water or applying petroleum jelly to the skin and carapace
        - If after 24 hours the turtle shows no signs of recovery, return the body to the water
- Opening the mouth – try the following techniques
    - Block the nose to make the turtle breathe through its mouth
    - Tickle the throat or pull upward on throat skin
    - Cover the nostrils and carefully apply pressure to the corner of the eye (not the eye itself) with one hand and apply pressure to the throat with the other hand
    - Use a mouth-gag (rope loops covered in plastic or the avian speculum) to lever the mouth open – also useful to hold the mouth open for dehooking
    - Keep the mouth open using a block of wood placed in the corner of the mouth, canine mouth gags, dog chew bones, a hank of rope or a PVC splice couplings

- Equipment to remove hooks

    - Needle-nose or long-nose pliers – if deep in the animals flesh or sometimes if mouth-hooked
    - Bolt-cutters – cut off the eye and push through or back out the hook, and if the hook cannot be removed it should be cut off
    - 16″ Hand Held Bite Block Deep-Hooked Turtle ARC Dehooking Device for internally hooked turtles – to prevent damage to the turtle's beak
    - Short-Handled J-Style Dehooker or Flipstick for external hooks
    - Scotty's Dehooker for when hooks are visible in the front of the mouth or beak and the barb is not visible or the hook is external
- Releasing the turtle
    - In similar water temperature to when caught
    - Preferable in a non-fishing area
    - Lower the turtle over the aft position of the vessel when the gear is not in use and the engines are in neutral
    - Monitor and record the turtle's behaviour after release.

4. Mitigation Methods

Over the last decade there have been studies developing and testing turtle mitigation measures in many longline fisheries. The research has focused on exploring options that have the potential to reduce the capture of turtles (avoidance strategies) and to increase their survivorship during capture and after release (handling guidelines).

A problem for fishers is that many people and governments seem to assume if the longline fishers eliminated their threat to turtle populations the 'species will be saved'; however, this will probably not be the case (Kinan and Dazell, 2005). There are many other threats that are equally, or more, detrimental to turtle populations. Nevertheless, reducing marine turtle mortality events as a result of longline operations is still important as fishers need to have the lowest impact possible to give marine turtle populations the best chance to improve. The actual magnitude of the impact of commercial fishing on specific stocks of turtles depends on many more additional factors including:

- The status of the turtle population in question,
- The rates of immediate and eventual mortality following interactions,
- Other threats to the turtles, and
- The life stage of the turtles removed by the capture events.

For any turtle mitigation measure to be effective it must satisfy two criteria:

- *Successfully mitigate* against interactions between turtles and fishing operations, and

- *Be commercially viable*. If this criterion is not satisfied there will be little chance that the measure will be adopted into the fishing fleet. It is also crucial to consider economic and social impacts of potential mitigation measures (Gilman *et al.*, 2006b).

It is difficult to generalise the current research results due to differences in the trials (experimental design, sample sizes, result presentation), the fisheries (gear, fishing effort, level of marine turtle interaction, target species) and the issue of confounding factors confusing the impact of each mitigation measure (Dalzell and Gilman, 2006; Gilman *et al.*, 2006a). Outlines of the relevant research results, which have been used in this section, are in Appendix 12.

Scientific research conducted onboard fishing vessels testing various mitigation measures may ultimately result, directly or indirectly, in providing solutions. There is the expectation that there may not be only one solution that is suitable for all longline fisheries, but rather a raft of possible measures that need to be modified to suit each fishery. To date however, the most successful mitigation measure investigated has been the adoption of circle hooks.

Circle Hook Definition

Circle hooks have been used in recreational fisheries for many years to potentially improve survivorship of fish hooked and then released. Interestingly, hooks made of seashells that were similar to today's circle hooks were found when excavating graves from pre-Columbia Indians in Latin America. Japanese fisherman made circle hooks out of reindeer horn, and Pacific Coast Native Americans, New Zealand Maoris and Easter Islanders all used a type of circle hook (Bolton and Bjorndal, 2003). Commercial longline fishers, however, have been credited with originally developing the modern circle hook (http://saltfishing.about.com/od/tackleandaccessories/a/aa990627a.htm downloaded 1 April 2007).

Circle hooks are considered by many in the recreational fishery fraternity to be a conservation measure for catch-and-release fishing. Many reports professing the success of circle hooks can be found on the World Wide Web. For example: 'Circle hooks are becoming increasingly popular among conservation-minded anglers fishing for billfish. Many South Florida sailfish tournaments require anglers to fish with circle hooks because the hooks with backswept points snag less soft tissue inside fish than traditional J-hooks and improve a fish's chance of surviving after being released'.
(http://www.palmbeachpost.com/recreation/content/entertainment/recreation/outdoors/fishing/bass_hooks.html downloaded 1 April 2007, dated 21 Dec 2004).

Many studies focusing on target fish in commercial and recreational fisheries demonstrate that fish caught using circle hooks have a lower release mortality rate due to less deep hooking and more mouth and jaw hooking (Bolton and Bjorndal, 2003). One example listed was a study by Lukacovic (2001) who reported mortality results from 859 striped bass caught with circle or J-hooks. The rate of deep-hooking was substantially lower for those fish caught on circle hooks, 5.6% and 15% for circle and J-hooks, respectively. The predicted mortality rate was 1.9% for fish caught with circle hooks and 9.1% for J-hook caught fish. Trials using pop-up satellite archival tag technology on white marlin demonstrated that survival was significantly higher for fish caught on circle hooks compared with those caught on J-hooks (Horodysky and Graves*,* 2005).

Although there are many styles of circle hooks in circulation they are generally considered to be hooks with the barb point turned back perpendicular to the shank (Bolton and Bjorndal, 2003). These hooks act and fish differently to other hooks used during longline fishing: the J-hook and the Japanese tuna hooks (also known as tuna hooks). Figure 14 is an example of two different sizes of circle hooks (top), a J-hook and a tuna hook (bottom). The principle behind the circle hook is simple. If the hook is swallowed by the fish the inward direction of the barb will allow the hook to come out of the stomach without engaging. The unique shape causes the hook to slide towards the point of resistance and embed itself in the jaw or in the corner of the fish's mouth.

Figure 14 Circle Hooks, J-Hook and Japanese Tuna Hook

Why Circle Hooks Mitigate Turtle Bycatch

Experiments have shown that large circle hooks are effective for mitigating turtle bycatch for a number of reasons including:

For internally hooked turtles (primarily shelled-turtles):

- *A reduction in the probability of a marine turtle being caught on a* hook due to the large size of the hook being unable to be swallowed by a turtle. Obviously a hook bigger than a turtle’s mouth will not be so readily taken.

  Large circle hooks have been shown in most fisheries in which they have been trialled, to reduce the number of turtles taking a hook and bait (Gilman *et al.,* 2005b; Watson *et al.,* 2005; Swimmer *et al*., 2006b; Boggs and Swimmer, 2007). This has been primarily demonstrated on loggerhead turtles, although it could be assumed this will apply for all shelled turtles. The success of using a hook too large to fit into a turtle’s mouth will obviously depend on the size of the hook relative to the size of turtles being hooked internally (Watson *et al*., 2005). An analysis of observer data in the Hawaiian longline fishery after the introduction of stringent regulations in 2004, which included the mandatory adoption of circle hooks, showed a reduction in the loggerhead turtle capture rate of 90% (Gillman *et al.,* 2006b, Dazell and Gilman, 2006, Gilman and Kobayashi, 2007). It was shown during trials in the western North Atlantic Ocean fishing grounds that the use of circle hooks in conjunction with whole fish bait resulted in a reduction in loggerhead turtle interaction rates of also 90% (Watson *et al*., 2005).

- *A reduction in the severity of the hooking event* as circle hooks tend to mouth-hook and not deep/gut-hook.

Large circle hooks have been shown in most fisheries in which they have been trialled to reduce the proportion of turtles becoming gut-hooked and therefore increasing their chance of survival (Watson *et al.,* 2003b; Bolton and Bjorndal, 2005; Gilman *et al.,* 2005b; Dalzell and Gilman, 2006; Swimmer *et al*., 2006a; Boggs and Swimmer, 2007)). The inward-facing design of the barb is thought to help prevent the barb engaging as it comes back out of the turtles gut after being swallowed. Reports on an analysis of the data from the U.S. pelagic longline fishery in the Western Atlantic NED Waters by Epperly and Boggs (2004) found that the animals tend to be hooked in the side/hinge of the mouth - a much less dangerous position than in the oesophagus or gut (Read, 2007). They demonstrated that circle hooks reduced the mortality (proportion of hooked turtles dying as a result of the interaction) of loggerheads by half (0.33 to 0.17). In the Hawaiian longline fishery after the mandatory adoption of circle hooks there was a decline in the proportion of deeply hooked turtles from 60% to 22%. Although single factor effects on observed changes in marine turtle interactions were not determined, it was noted that these results were consistent with previously conducted control experiments (Gillman *et al.,* 2006b, Dazell and Gilman, 2006). In the first quarter of 2007 in that fishery all 14 marine turtles caught were lightly hooked (Gilman and Kobayashi, 2007).

- *The use of large circle hooks may result in fewer turtles being released with terminal tackle still attached.*

  Dazell and Gilman (2006) demonstrated that before large circle hooks were mandatory in the Hawaiian longline fishery, 40% of hooked turtles were released after removing all gear. After circle hooks were routinely used in the fishery, 67% were released free of all gear. This effect is predicted to be a function of more turtles being mouth-hooked than gut-hooked and therefore the gear being easier to remove. In the first quarter of 2007, 13 of the 14 turtles caught were released after all gear was removed. One leatherback was released with a hook and line externally attached to its front flipper (Gilman and Kobayashi, 2007).

For externally hooked and/or entangled turtles (primarily leatherbacks):

- *A reduction in the probability of a marine turtle becoming foul-hooked or snagged following entanglement (*Boggs and Swimmer, 2007).

  In the Hawaiian longline fishery after the mandatory adoption of circle hooks there was a significant decline in the catch rate of leatherbacks of 82.8% (Gillman *et al.,* 2006b, Dazell and Gilman, 2006). It was shown during trials in the western North Atlantic Ocean fishing grounds that the use of circle hooks in conjunction with whole fish bait resulted in a reduction in leatherback turtle interaction rates of 65% (Watson *et al*., 2005).

This effect is believed to be due to two reasons:

- The inward-facing barb of circle hooks not tending to foul hook the flipper of the animal as it swims into the gear, and
- The shorter distance between the tip of the barb and the shank of the hook will not allow the flipper to become wedged.

Size of Circle Hooks

To date, most research on circle hooks has been conducted using large (16/0 and 18/0) hooks. This is possibly due to the fisheries in which the trials have been conducted using relatively large hooks and compatible sized circle hooks were therefore chosen. Consequently, the effect of using a smaller circle hook has not been statistically tested. It could be assumed that the reasoning that 'large circle hook catch fewer turtles due to the large size of the hook relative to the size of the turtles mouth' may not be true. However, the reasoning that 'circle hooks reduce gut hooking' could reasonably be assumed true irrespective of the size of the hook.

Anecdotally, Australian longline fisheries have successfully used small circle hooks (13/0 and 14/0) to target albacore in the ETBF. These size hooks were chosen due to the smaller size of the target fish (albacore) compared to swordfish or other tuna. The effect of the hooks has not been tested due to turtles being rarely encountered in this fishery and observer coverage being relatively low at less than 5%.

Results from research that incorporates the size of hook were varied and the idiosyncrasies for each fishery are assumed to have contributed to that variation. Consequently, each fishery should be treated as a separate case and studies should be undertaken to determine the best size of hook for that fishery. Gilman *et al*. (2006b) and Read (2007) point out that fishery-specific research is needed to be conducted in each fishery to determine effectiveness of the measure and commercial viability and that large (16/0 or 18/0) hooks may not be appropriate for every target species (especially mahi mahi or albacore) in every longline fishery.

Degree of Offset in Circle Hooks

A further complicating factor is the impact of amount of offset. Offset hooks are those with the barb bent sideways in relation to the shank of the hook. It is believed by many fishers that offset hooks will engage more effectively and are also easier to bait (Watson *et al.,* 2005; Boggs and Swimmer, 2007). Information is scarce on the effect of the degree of offset in circle hooks and further research is needed in this area.

Information on the success of offset circle hooks includes:

- The degree of offset and a comparison on target catch is reported in the Azores eastern Atlantic longline fishery. In 2002, the highest to lowest blue shark CPUE was non-offset 16/0, offset 18/0, offset 16/0 circle. (Bolton *et al.,* 2001; Bolton and Bjorndal, 2002 and 2004).

- Experiments in the NED have demonstrated that circle hooks with a 10º offset are better, or equally as good, at catching fish and have an equal effect on the turtles. The degree of offset and the overall shape of the hooks require further investigation. (Watson *et al.,* 2004b and 2005).

- Trials in Costa Rica demonstrate that there was no differences in the frequency of turtle interactions or mahi mahi catch between a non-offset 14/0 circle hook and a 10 degree offset 14/0 circle hook.

Whole Fish Bait and Circle Hooks

The use of whole-fish bait versus squid to reduce the catch of shelled turtles was tested during research in the Atlantic (Watson *et al.,* 2004b) and in the Mediterranean (Rueda *et al*., 2006). Both trials demonstrated that mackerel bait tends to catch fewer shelled turtles than squid bait. Additionally, during the latter study, swordfish catch was not significantly different between the two bait types. Trials in the Atlantic reported by Watson *et al*. (2005) demonstrated that the use of whole fish bait also resulted in a reduction in leatherback catches by 65% and 66% for circle hooks and J-hooks, respectively. The use of fish bait instead of squid has been demonstrated in field trials in Spain to have the potential to improve swordfish catch (Boggs and Swimmer, 2007).

Captive turtle trials have shown that when a turtle feeds on fish bait, the fish will usually break off and be eaten without the hook being touched. Squid bait with associated hook, by comparison, will tend to remain whole and the turtle keeps feeding until the squid and hook is swallowed as one piece. Additionally, if the large fish used as bait are bigger than the turtle's mouth, the turtle will tend to chew on part of the bait and not come into contact with the hook (Gillman *et al*., 2006a; Stokes *et al*., 2006).

Research into the Effect of Circle Hooks on Target Catch

There were varied outcomes in respect of the catch of target fish when circle hooks were adopted by longline fleets. It is difficult to generalise results, as not only are they reported in different ways but also treatments and controls vary greatly. For this reason, it is important for each fishery to be considered separately when it comes to impact on target catch, although it could be assumed that similar fisheries may produce similar results.

The basic results of projects (with more detailed results of projects in Appendix 12) using circle hooks over J-hooks (unless specifically stated) that considered fish catch are:

(Note: sword = swordfish, mack = mackerel and n-o = non-offset)

Equador (Largacha *et al.,* 2005)

- Tuna catch similar
- Mahi-mahi catch around a third less (but there is a belief that over time the fishers will learn how to fish better with circle hooks)

Shallow-set swordfish fishery in the Strait of Sicily (Boggs and Swimmer, 2007)

- No differences between number and total weight of target swordfish (16/0 circle vs J-hook with offset – all mackerel)

U.S. Western Atlantic NED Waters (each is a separate trial) (Read, 2007)

- 2002 sword down 29%, bigeye up 26% (18/0 circle-squid vs J-squid)
- 2002 sword up 30%, bigeye down 81% (18/0 circle-mack vs J-squid)
- 2002 sword up 63%, bigeye down 90% (J-mack vs J-squid)
- 2003 sword down 29%, bigeye up 20% (18/0 circle-squid vs J-squid)
- 2003 sword up 9%, bigeye down 88% (18/0 circle-mack vs J-squid)
- 2003 sword up 8%, bigeye down 90% (20/0 circle-mack vs J-squid)

U.S. north Pacific (2002) (Boggs, 2003 and 2004)

- Circles 40% as effective at catching swordfish (squid on both)
- Circles 98% as effective at catching tuna (squid on both)

U.S. north Pacific (1994-2206) (Gilman *et al*. 2006a)

- Pre-regulation 13.29 sword/1000 hooks (J-hooks, lightsticks and squid)
- Post-regulation 15.42 sword/1000 hooks (circle-hooks, no lightsticks and mackerel)

Venezuela Caribbean longline tuna fishery (Falterman and Graves, 2002)

- Yellowfin catch 2.5 times better with circle hooks (live scad)

Brazil longline fishery (Boggs and Swimmer, 2007)

- Similar weights of individual swordfish on both circle and J-hooks
- Capture rates of swordfish slightly higher for J-hooks over circle hooks
- Tuna CPUE similar for circle an J-hooks

Azores eastern Atlantic swordfish catch/1000 hooks (each is a separate trial) (Bolten and Bjorndal, 2003 from Read, 2007)

- 2000: n-o J 8.30, offset J 7.41, circle 5.7
- 2001: n-o J 6.91, 16/0 n-o circle 7.49, 18/0 n-o circle 4.66
- 2002: 16/0 n-o circle 8.50, 16/0 offset circle 6.83, 18/0 offset circle 8.14
- 2003: 16/0 n-o circle 8.96, 18/0 n-o circle 6.61, tuna hook 10.14
- 2003: 16/0 n-o circle 8.45, 18/0 n-o circle 7.77

Japan northwest Pacific (circle hooks vs tuna hook - each is a different trial)

- Sword and tuna CPUE not different (Kiyota *et al*., 2003)
- Bigeye, albacore, yellowfin and sword not different (Nakano, 2004)

U.S. Hawaiian longline fishery (Dalzell and Gilman, 2006)

- After marine turtle regulations came into effect (large circle hooks and whole fish bait - May 2004)
- Sword CPUE was significantly higher by 16% and
- 'Combined tuna species' and 'combined mahi mahi, opah and wahoo' CPUE was significantly lower by 50% and 34.1%, respectively.

Anecdotal Information on the Effect of Circle Hooks on Target Catch

Some believe that circle hooks are not as effective in catching swordfish as J-hooks or tuna hooks. More recently however, it has been shown that circle hooks can be as equally effective for catching this species. Since the Hawaiian longline fleet has adopted large (18/0) circle hooks and fish bait, and stopped using lightsticks the swordfish CPUE has risen from 13.29 to 15.42 swordfish/1000 hooks (Gilman *et al.*, 2006a). In recent field trials in the Spanish shallow-set longline swordfish fishery the use of fish bait instead of squid has been demonstrated to have the potential to improve swordfish catch (Boggs and Swimmer, 2007).

Anecdotally, the problem may be that fishers need to haul the gear differently if using circle hooks. As the circle hooks tend to mouth hook and swordfish have 'soft' mouths compared to many tunas, it is relatively easy to tear the hook from the swordfish mouth if the line is hauled aggressively. It has been noted that after adopting circle hooks that many fishers may over time learn how to fish with circle hooks (Largacha *et al.,* 2005). An example from the World Wide Web of instructions for recreational fishers using circle hooks is – 'There is only one technique: DON'T SET THE HOOK. Steadily and slowly reel in the slack in the line until the hook sets itself in the fish. This requires some patience and restraint. Patience to make sure the fish has had time to swallow the bait and restraint in the initial urge to violently set the hook' (http://edis.ifas.ufl.edu/SG042).

There has been concern that setting the gear deeply may result in much longer hauling times than the traditional shallow-setting. However, some Australian fishers have reported that when deep-setting for albacore hauling times are no longer than standard setting. This is due to the adoption of a steady haul technique rather than stopping and starting (Kreutz, 2007 *pers. comm.*).

A number of Australian fishers report that using circle hooks when deep-setting (200 to 400m) for albacore results in better retention of fish due to the positioning of the hook in the jaw of the fish resulting in increased catch rate and better quality fish.

Additionally, Australian fishers have identified a correlation between fish size and circle hook size. Anecdotally, 13/0 circle hooks catch more 16 – 25 kg albacore compared with the smaller Japanese tuna hook and 18/0 circle hooks catch more 40 – 120kg swordfish than 9/0 J-hooks (Kreutz, 2007 *pers. comm.*). Swimmer *et al.* (2006b) demonstrated in the Brazil longline fishery that the use of 18/0 circle hooks caught larger swordfish than 9/0 J-hooks.

Effect of Circle Hooks on Other Bycatch

An important, but often forgotten, issue with any mitigation measure is how its adoption will impact on other bycatch. One species that has been noted as being effected by the use of circle hooks are sharks. There does not appear to be any published results on the impact of circle hooks on seabirds or marine mammals (Read, 2007).

The increased catch of blue shark on circle hooks was noted in trials in the Azores (Bolton and Bjorndal, 2005). A hypothesis is that there may be more animals being mouth hooked and unable to 'bite-off' as they often do if gut hooked (Watson *et al.,* 2005). Although sample sizes are low this effect has also been seen in the Australian circle hook trial (Ward, 2007 *pers. comm.*). However, this theory requires further investigation as results have varied between trials.

In contrast, a trial by the Japanese Fisheries Research Agency did not demonstrate any difference in blue shark catch or mortality rates using conventional tuna hooks or circle hooks (Yokota *et al*., 2006a). Dazell and Gilman (2006) show that shark CPUE was significantly lower after circle hooks and whole fish bait were made compulsory in the Hawaiian longline fishery. This could be due to other measures adopted in the fishery at the same time. Gilman *et al*. (2006a) theorize that this may be due to the adoption of whole fish bait instead of squid.

Of particular interest is a modelling study by Kaplan *et* al. (2007) that considered tropic interactions (trade-offs), catchability rates and survival levels of different species in the North Pacific Ocean. They reported that adopting reasonable levels of shark and marlin catchability and survival rates as a result of circle hook use and with a policy of release of these animals, the models show an increase in shark and marlin abundance. Their study highlights the need for considering catchability rates, survival rates and trophic trade-offs between species when determining the effect of adopting circle hooks and also the need for good release and handling skills and equipment.

The actual impact on the shark population of bringing more live sharks to the boat has been debated. If more sharks can be released unharmed versus sharks that have bitten off and carry significant amounts of gear it may be advantageous for the shark population. Alternatively, if more shark are killed by the crew or released fatally injured, it may result in a higher mortality rate. This requires further investigation before definite conclusions can be drawn.

For other fish species, some trials have demonstrated that the use of circle hooks can result in more live-on-line fish, due to more fish being mouth-hooked than gut-hooked. Therefore a higher proportion of undersized fish could be released alive, possibly promoting the re-building of depleted stocks (Kerstetter and Graves, 2006). Horodysky and Graves (2005) demonstrated that the use of circle hooks resulted in higher survival rates (100%) of white marlin following capture by recreational fishing compared with those caught using J-hooks (65%).

Effect of Circle Hooks on Fishery Profitability

Before considering the adoption of any mitigation measure, it is important to consider the net costs and benefits to the fishery (Read, 2007). Fishers may be able to absorb extra costs or accept reductions in target catches if the adoption of the mitigation measure allows them to fish in an otherwise closed area. Additionally, the possible reduction in target catch volume may be compensated by the increase in value of the target catch.

Australian fishers have reported that deep-set caught albacore, which die easily when gut-hooked, are of a better quality when landed with circle hooks as compared to the more traditionally used Japanese tuna hook.

Hook Exchange Programs

A hook exchange program (exchanging circle hooks for the conventional J-hooks or tuna hooks at no cost to the fisher) has been underway in Ecuador since 2003 and was expanded into Peru, Columbia, Panama, Costa Rica, El Salvador and Guatemala in 2004 and 2005 (IATTC, 2006b). The goal of the program is to allow fishers to test the circle hooks during real fishing operations but still have the confidence that they can get their old hooks back if they decide circle hooks are ineffective.

This is a useful tool in fisheries once the correct hook for the fishery has been identified and when fishers are uncertain if the 'new' hook will still catch fish. Advantages to the fishers is that it has low cost implications and gives a mentoring system – in that the person providing the hooks and doing the workshops is an advisor if the fisher requires further help. Problems can be overcome in cooperation between the scientist and fisher before the fisher becomes disillusioned and refuses to use the gear. But the fisher still feels he has an 'out' if the gear is a failure so is more likely to participate.

The experimental hook substitution in Peru showed that a hook-swap 'could be an effective tool to reduce marine turtle bycatch, if attention is paid to crucial details and to differences with Atlantic fisheries' (Valqui *et al.*, 2006 pg. 270). In this case the smaller size of turtle catch and smaller size of target catch made it necessary to use smaller circle hooks. This created difficulties in storing, handling and baiting the hooks.

Other Mitigation Measures That Show Promise

Favourable mitigation measures undergoing assessment with research trials and during actual fishing operations, include:

- *Setting gear deeper to minimise the time that baited hooks are present at depths where turtles occur in high densities* (Bartram and Kaneko, 2004).

  The relationship between marine turtle catch rate and depth of hook has been explored as an option in reducing marine turtle take in longline fisheries (Itano, 2004). Research results supporting this theory include:

  - It has been discovered that loggerheads rarely dive deeper than 75 feet (23m) and, consequently, captures may be reduced if longlines are deeply set (Altonn, 2001).

- The vertical habitat of turtles was examined when two loggerheads and two olive ridleys were fitted with satellite transmitter and depth recorders following capture by the Hawaiian-based longline fishery. The loggerheads made relatively shallow dives and tended to spend about 40% of their time at the surface and 90% of their time above 40 m. In contrast, the olive ridleys spent only 20% of their time at the surface and 40% below 40m (Polovina *et al.,* 2002).

- Observer reports from the Western Tropical Pacific Ocean from 1990 to 2000 suggested that shallow-set gear would be expected to catch 10-times more turtles than deeply-set gear (Oceanic Fisheries Programme, 2001).

- Observer data also indicate that all loggerheads caught in the Hawaiian-based longline fishery were in shallow sets (Polovina *et al.,* 2002). The turtle mortality rate that occurred during the capture event was less than 1% and considered a result of the shallow depth of set (Gilman *et al.,* 2006a).

- Leathbacks spend the majority of their time near the surface (Eckert *et al*., 1989 from Beverly and Chapman, 2007).

- The position of the hook within the set may be related to turtle catch rates for that hook. Hawaiian observer data show that the shallowest hooks in a set, those closest to the floats, caught significantly more leatherbacks and loggerheads than hooks in other positions within the set. These types of observations could imply that the turtles are attracted to floats or the float-lines. Alternatively, the shallower hooks may be more likely to catch marine turtles due to their depth (Kleiber and Boggs, 2000).

- An observer program on Italian longliners in the Mediterranean showed that most turtles caught during fishing for albacore, which had hooks set to approximately 20m, were caught in the top 5m of the water column. It was also reported 41% of all turtles captured were caught on the hooks set closest to the float (Laurent *et al*., 2001).

In the past, depth of set was used to mitigate turtle bycatch in the Hawaiian longline fishery. After a number of years of closures and regulations in that fishery in June 2001, an emergency interim rule implementing temporary measures, including those related to depth, was announced (National Marine Fisheries Service, 2001a). Measures were effective from June 2001 to December 2001, then extended to 9 June 2002 (National Marine Fisheries Service, 2001b). These regulations (as they related to depth) included: a ban on the targeting of swordfish north of the equator in the Pacific; a requirement that the deepest point between any two floats is at least 100m beneath the surface; the float line suspending the main longline beneath a float be at least 20m long; and a requirement that at least 15 branchlines are deployed between any two floats. These regulations prevent the setting of shallow longline gear, typically used to catch swordfish, to avoid or minimise the takes of loggerhead turtles in the fishery.

Changing the mitigation rules slightly, but still achieving a somewhat similar outcome of using depth to prevent turtle interactions were adopted in 2002. This legislation prohibited Hawaiian longliners from fishing north of 26º North latitude and prevents vessels that fish north of the equator from retaining more than 10 swordfish/fishing trip. These regulations are expected to geographically remove longline operations from loggerhead turtle habitat and to remove economic incentives to use shallow set gear, thereby minimising the take of loggerhead turtles (National Marine Fisheries Service, 2002).

The U.S. placed restrictions on gear configuration on their longliners fishing in the Atlantic, requiring sufficient slack line to allow caught turtles to surface. The regulation, which came into effect on 1 August 2001, requires that 'for longline sets in which the combined length of the float-line plus the gangion is 100m or less, the length of the gangion must be at least 110% the length of the float-line'. This regulation does not apply to sets over 100m in depth (Federal Register: July 12, 2001; Vol. 66, No. 135).

In many fisheries there is clear evidence that deep-set longlines catch fewer turtles than shallow-set fisheries (Gilman *et al.,* 2006b). The National Marine Fisheries Service (2005, p101) notes that 'marine turtle interaction rates are typically at least ten times greater in shallow-set swordfish longline fisheries than in deep-set tuna fisheries'. However, the impact on a fishery of setting gear deeply is fishery-specific. Before considering this option it would be necessary to conduct research on the effectiveness of the measure, the feasibility of being able to actually set the gear to the required depths and the commercial viability of adopting the measure. Beverly *et al.* (2004) reports that landings of tuna using deep-set gear in a small-scale developmental longline fishery achieved much higher Hawaiian market prices due to improved quality. This paper also reports weighted (deep-set) gear showed an improvement of 42% in the main target tuna species CPUE with swordfish CPUEs unaffected, although the paper did note that further testing would be required.

The decision on whether or not to deep-set is obviously dependant on many factors including impact on target catch and the ability to achieve the required depths. Techniques developed to set gear deeply include those by Beverley *et al.*, (2004) and Itano (2004). Both these methods use weights on the mainline to sink the gear quickly and easily.

- *Reducing the probability of turtle capture by moving the snood away from the float line*

Previous studies considered the hypothesis that turtles are more likely to become hooked on snoods close to the float. It was thought that either the turtle may be attracted to the float and become hooked (National Marine Fisheries Service, 2005), or that the hooks closest to the float fish at shallow depths and were more likely to hook turtles. Dalzell and Gilman (2006) reported that in the Hawaiian longline fishery (after the turtle regulations came into effect in 2004) there was no significance difference in turtle CPUE between hooks set next to floats and those that were not. In an earlier (2001) trial on captive turtles more turtles occurred in an area containing an orange bullet float than in a control (no float) area. In the same series of trials turtles conditioned to feed under floats swam in the float-area more than in the no-float control area (Hataway and Mitchell, 2002).

- *Minimising gear-soak during the day to allow hooks to fish during times when turtles tend not to actively feed (or get the gear below that level through the day)*

  Watson *et al.* (2005) found that total soak time was highly significant for loggerhead catch rate, but not for leatherbacks. Bolten and Bjorndal (2003) found a significant increase in loggerhead catch rate with increased length of daylight hauling. For this measure to be adopted fishery specific research would be required on its effectiveness and the practicalities of adoption (Gilman *et al.*, 2005b).

- *Hook design aimed at minimising the rate of being hooked and/or the probability of deep-hooking*

  - Minimising the rate of being hooked by a hook design that prevents a turtle from being physically able to take the hook or become externally hooked has been successfully trialled with captive turtles using the Weedless style hook guard. This is a stainless steel fishing leader connected to the shank and running in a loop to the barb of the hook (Hataway and Mitchell, 2002).

    Another modification that has been successful is adding a wire appendage to the hooks eye effectively making the hook seem wider. In 2007 this was tested in the Costa Rican longline fishery for sharks and mahi mahi on 16/0 circle hooks. Preliminary data indicate the success of this mitigation measure with over 24 thousand hooks tested and around 29% of turtles being hooked on hooks with the added wire and around 69% on hooks without the wire (Boggs and Swimmer, 2007)

  - Reducing the probability of deep-hooking or a hook design that allows the hook to come out of the gut without engaging once swallowed has been demonstrated with the circle hook.

  - Various devices attached to the hook or line that deters the turtle from interacting with the hook show promise in captive trials. Examples include devices placed above the bait include circular flat discs, a football shaped bait stopper, a clear soda bottle with the bottom cut out, and a funnel. A novel idea was the use of a predator-shaped shark model to deter turtles (Hataway and Mitchell, 2002).

    Captive reared turtles tested in tank trials for avoidance strategies to replica sharks were inconclusive with no significance difference between the time taken to eat a squid in the presence or absence of the shark. Some turtles, although initially avoiding the shark, eventually acclimated and bit on the replica shark itself (Higgins, 2006).

  - An example of a modification to monofilament line to reduce hooking or entanglement was a captive trial that showed that the stiffer (3.0mm and 3.6mm versus 2.6mm) monofilament line resulted in fewer entanglements (Hataway and Mitchell, 2002).

- Weighted line has been shown to result in fewer entanglements in captive turtle trials. The turtles tended to flick the weighted line off their flipper as they swam through before encountering the hook (Hataway and Mitchell, 2002).

- *Reducing the use of lightsticks to make the gear less attractive to turtles*

  Chemiluminescent lightsticks used by fishers to attract target fish have also been shown to attract turtles (Levenson *et al.*, 2006). In lightstick attraction trials captive-reared juvenile turtles and wild-caught post-hatchling loggerheads were attracted to lightsticks due to their illumination only and not another cue, such as chemical (Wang *et al.*, 2007). These results provided evidence that illumination from lightsticks is one of the stimuli that attracts turtles to longline gear. Since 2004 lightsticks have been banned in the U.S. Hawaiian swordfish longline fishery and the NED swordfish fishery in the Atlantic.

  The development of a lightstick that does not attract turtles but still attracts fish would be advantageous for many longline fisheries around the world and various studies have been conducted to determine the visual, and other sensory, capabilities of turtles. Eckert *et al.* (2006) used visual spectral sensitivity to examine nesting leatherback turtles to determine the light wavelengths that leatherbacks could detect. Levenson *et al.* (2006) conducted similar investigations on captive green and loggerhead turtles. Other related research includes:

  - Wang *et al.* (2006 pg 272) demonstrated using captive-reared juvenile loggerheads, that 'lightsticks that flash intermittently, or have wavelengths between 540nm and 600nm, or project only downwards may be potential strategies that limit the attractiveness of lightsticks to juvenile turtles'. Also reported in Wang *et al.* (2007) was that the juvenile loggerheads were attracted to green, blue and yellow chemical lightsticks and LED-based Electrolume lightsticks.

  - Research is being conducted into the flashing timing and sequence not attractive to turtles but will still attract the target fish. There are also developments into the design of a new type of lightstick for daytime fisheries that takes advantage of the fact that fish may be able to recognise certain flickering lights that are seen as a constant light to turtles. This is through a concept of flicker-fusion perception abilities (Lohmann *et al.*, 2006).

  - Fritsches and Warrant (2006) report on the visual capabilities of turtles and fish to investigate the possibility of identifying differences to design species-specific fishing gear. Results include longer wavelengths (such as red) are invisible to swordfish but not turtles, turtles can possibly detect UV light while fish cannot, fish and turtles have different flicker-fusion frequency and fishes vision changes dramatically between day and night.

- *Area and seasonal closures, including avoiding areas of high marine turtle concentrations (real-time and fleet-wide communication protocols)*

- Avoiding areas of high marine turtle concentrations,
- Effort restrictions to reduce the number of turtles caught,
- Interaction cap that closes a fishery/area when a pre-determined number of interactions occur. An important point when considering fishing closures is having the ability to communicate within the fleet and between managers and the fleet, so regulations can be immediately enforced when caps are reached and so closure boundaries can be adjusted.

While this measure sounds workable, before considering a fishery closure – spatially or temporally – it is necessary to understand turtle abundance levels over time and area (Dazell and Gilman, 2006). If fishery closures are to be in real-time (ie whole fleets move away from specific grounds when a certain number of turtles are reported) it is important that fleet-communication protocols are efficient and timely (Gilman *et al*., 2005a).

An imperative issue to consider is whether the closure will increase turtle deaths through another fleet, possibly with less-effective turtle mitigation measures, increasing effort in the closed area or will the effort be displaced into other, and possibly worse, turtle-catching grounds. A possible example is when the U.S. pelagic longline swordfish fleet in the Northwest Atlantic was closed. It is believed that there may have been negative consequences for some turtle populations by displaced longline effort moving to alternative grounds such as the South Atlantic (Kotas *et al*., 2004 from Gilman *et al*., 2006b).

Another scenario is that a fishery closure designed to protect marine turtles could indirectly result in an increased turtle take due to markets previously met by the closed fishery being replaced with fish sourced from fisheries with higher associated turtle takes. This was noted by Bartram and Kaneko (2004) as possibly occurring following the Hawaiian longline fishery closure from 2001 to 2004.

Environmental conditions have been found to influence where turtles live. They are often associated with oceanographic discontinuities, such as fronts and driftlines, which are areas of high productivity and in waters of certain temperatures (National Marine Fisheries Service, 2005). Consequently, with adequate research and data, area and seasonal closures can likely be designed for most pelagic longline fisheries to avoid longline fishing in peak areas and periods of marine turtle foraging, nesting, and migration (Polovina *et al*., 2000).

- *Stealth gear or the reduced detection of bait and gear by turtles*

  Australian fishers, and also fishers and scientists elsewhere, have noted that turtles are often associated with floating objects (National Marine Fisheries Service, 2005), and similarly may be attracted to fishing gear. The possibility of fishers being able to 'camouflage' their gear to turtles but not the target fish species is appealing and is possibly a cost effective solution to the issue of turtle bycatch.

  Ideas tested in a Hawaiian study, Boggs (2003), included:

  - counter-shaded floats (the underside of the floats painted blue),
  - dark grey float lines (mainline, branchline and float lines),

- dulled hardware (painted to remove metallic shine),
- shaded lightsticks (shaded on upper section so the light is directed downwards),
- narrow-frequency lightsticks (yellow electronic LED), and
- branchline design (move hooks further away from floats).

These ideas were operationally ineffective, but considered promising and in need of further refinement. It was found that swordfish revenue made by the vessel using the stealth fishing gear, as listed here, was 39% less than of the control vessel (Boggs, 2003).

Johnsen (2006) mathematically modelled the visual abilities of turtles and fish with the eventual intention of designing fishing gear, including lures that are invisible to turtles but seen by fish. The results indicate that possibly the most likely strategy to succeed for daytime fishing may be a flashing lure of two colours that when blended matched the ocean colour, and for night fishing a lure with rapidly flashing lights.

There may be other ways that fishers can modify their gear to make it less visible to turtles but without any negative impact on target catch. Fishers may be able to invent other stealth gear measures and trial their ideas themselves. By their nature, many fishers are inventive and any ideas should be considered and possibly trialled before being dismissed.

- *Bait type*

  In some trials mackerel have been shown to catch fewer turtles than squid (Rueda *et al.*, 2006). Although this measure is generally called 'mackerel' there is no evidence to suggest the fish must be mackerel. Trials in the Atlantic demonstrate differing results with regards to squid versus mackerel bait. Watson *et al*. (2004b) found no significant difference between turtle takes on 18/0 circle hooks baited with squid or mackerel. But mackerel bait was shown to result in fewer turtle interactions compared to squid bait when trialled using both bait types on J-hooks (Watson et al., 2005). Garrison (2003) reported that leatherback bycatch rate was significantly lower for J-hooks baited with sardines versus squid. It was noted, however, that there may have been other confounding factors.

  On a similar line Piovano *et al.* (2004) used captive loggerheads to test if turtles were attracted to bait due to the smell, and therefore, if it would be possible to develop artificial lures that do not attract turtles. They found that all of the turtles tested were attracted to artificial lures that were coupled with a scomber-odour and concluded that it may be possible to develop artificial lures without a scomber-odour that will not attract turtles. However, to be a realistic mitigation method, trials considering the effect of the artificial lures on the target catch are required.

  Interestingly, trials in the Western Atlantic NED Waters demonstrated that mackerel bait caught significantly fewer (31% – circle hooks and 40% – J-hooks) blue sharks than J-hooks baited with squid (Read, 2007).

  Currently, for many fisheries including those in Australia, squid is cost effective and convenient to purchase. Whole fish may be less accessible as markets need to be developed in some countries. However, if fishers start using fish it could be expected that new fisheries may develop to supply the fish bait. A possible option to source fish is through fishers catching their own 'live bait' or catching their own bait and using it fresh by keeping it on an ice-slurry.

- *Bait threading*

  Single-hooked bait (hook pushed through bait once) has been shown to catch fewer turtles than multiple-threaded bait (hook pushed through bait more than once to hide hook within bait). It has been demonstrated in tank trials that turtles can more easily remove the single-threaded bait, most notably mackerel bait, without touching the hook (Watson *et al.,* 2004a; Stokes *et al*., 2006). Also reported was that single-hooked fish baits on circle hooks seemed to result in higher swordfish catches than if the bait was multiple-threaded (Watson *et al*., 2002).

- *Tangle-proof float-line*

  Beverly and Chapman (2007) document a new design of float-line that may prevent entanglements of leatherback turtles. To date the idea has not been tested. 'The tangle-free float-line is made from the same material as a normal float-line with an eye at the top for attaching a float and a longline snap at the other end for attachment to the mainline. Two things are added to the normal float-line: a string of small pressure resistant cylindrical hard plastic net floats and a 2kg lead weight. The upward pressure exerted by their floatation keeps the float-line rigid. The lead weight at the bottom end keeps the line straight and vertical in the water column. The cylindrical floats roll on the line like little wheels' (Beverly and Chapman, 2007: 46).

Other Mitigation Measures Deemed Ineffective

- *Blue-dyed bait to reduce the turtles attraction to bait*

  All trials demonstrate that this idea is not worth pursuing (Swimmer and Brill, 2001; Swimmer *et al*., 2004; Gilman *et al*., 2006b; Watson *et al*., 2002).

  Sales et al. (2006) reported on feeding trials with captive loggerheads in Brazil. Four turtles were fed natural squid with an oil/resin scent, blue-dyed squid, and blue-dyed squid with an oil/resin scent. The trials were ended after a few days as all turtles ate all of the squid that was offered irrespective of the treatment. Wild-caught animals also appeared not to differentiate between blue-dyed and natural squid.

- *Deterrents to discourage turtles from eating baited hooks*

  Swimmer *et al*. (2006a) reported on behavioural trials on turtles and tuna to determine the effect of soaking bait in various substances with known or suspected properties that repel or conceal food (lactic acid, quinine hydrochloride, chlorhexidine gluconate, aromatic bitters, citric acid, urea – shark smell, squid ink, garlic, chilli, cilantro, sea-hair ink, wasabi oil, noxious secretions from the sea hare). Both the turtles and the tuna ate all items presented.

  Southwood *et al*. (2006) used captive turtles to explore the mechanisms by which turtles locate prey and to assess if chemical manipulation of squid bait would reduce the turtle's ability to locate prey. They tested squid treated with various chemicals and found no significant difference in the number of turtles that located and ate squid from all of the treatment groups and the control.

- *Acoustic deterrents to deter turtles from approaching longlines*

  Bartol and Ketten (2006) used electrophysiological techniques to test the hearing capabilities of turtles and yellowfin tuna in order to determine if acoustic deterrents repel turtles from longline gear. However, preliminary data suggests that both species are low-frequency specialists and both would potentially hear the same deterrent.

5. Future Research

The success of any mitigation measure, particularly gear modifications, will in most cases be specific to a fishery. This has often been noted in respect of the adoption of circle hooks in longline fisheries (Gilman *et al*., 2006b; Dalzell and Gilman, 2006; Read, 2007; FAO, 2004) and will depend on many factors, including: the turtles interacting with the fishery, the specific operational aspects of the fishery, the compatibility of the measure with the current fishing style, the target catch, the mindset of the fishers and the determination of the fishers, scientists and managers to solve the issue.

Additionally every mitigation measure must be commercially viable in each fishery for it to succeed (Gilman and Moth-Poulsen, 2007). There is little chance of a mitigation measure being adopted in the long-term if it is not commercially viable, even if made mandatory. Many longline fleets fish in the open ocean and ensuring compliance may be difficult unless the measure works for the animal of concern and for the fisher. Mitigation measures with the best chance of success are those that actually improve profitability or improve operational efficiency. If this is the case it may not be necessary to introduce any regulations to ensure the measure is adopted throughout the fleet. (Gilman *et al.,* 2006b). Good ideas tend to migrate within and amongst fishing fleets, without the need of an extensive dissemination program.

The most cost effective, and possibly the most likely to succeed, method to encourage fishing industries to modify fishing practices is to provide fishers with good reasons why they should modify their gear. Allowing fishers to personally evaluate the workability of a mitigation measure and refine its operational efficiency, as necessary, to ensure the measure is practically, operationally and economically viable is vital before it is made mandatory. Fishers are inventive and resourceful and in many cases already understand aspects on target and non-target species, and possibly most importantly, their own gear and operational style. To not utilize this important resource is illogical and foolish.

The international SmartGear competition is an initiative of WWF U.S. to encourage innovative, practical and cost-effective initiatives that allow fishers to fish 'smarter' and better target their intended catch while reducing bycatch. In 2006, the competition received 99 entries from 28 countries, far exceeding the number received in the inaugural competition in 2005, demonstrating an international commitment to reduce bycatch in commercial fisheries. Numerous entries addressed turtle bycatch in both years, with Steve Beverly of the Secretariat of the Pacific Community (SPC) receiving first prize in 2005 for his technique of setting longlines below 100m to avoid turtle interactions while maintaining target catch. Information brochures on the technique were produced and distributed to WWF in Washington DC, the Western Pacific Regional Fisheries Management Council and the Hawaii Longline Association, plus various other organizations including OceanWatch Australia for distribution to Australia's longline fleets. The brochure has been widely distributed internationally and is available on the SmartGear website (www.smartgear.org) in English, Spanish and French.

In terms of priority it is prudent that a high priority should be designated to turtle mitigation research in those fleets that are impacting on the most threatened turtle populations and also those fleets that result in turtle mortalities (Gilman *et al.,* 2006b). However, it may not be possible to put this into practice as research funds are generally provided for specific fisheries and not available to other fisheries or nations. Other high priorities include:

- Why some vessels within the same fleet record high turtle captures and some low. Is it gear, is it how the gear is used, is it fishing grounds or something else not yet identified? This knowledge may lead to the identification of new strategies to reduce interaction rates (Dazell and Gilman, 2006).
- Research on cryptic mortality: a largely an imprecise aspect of marine turtle interactions with longline fishing gear (Read, 2007).
- The issue of satellite transmitter failure is central in solving the cryptic mortality issue. Did the turtle die or did the transmitter fail? (Read, 2007).
- The negative and positive impacts of circle hooks on other bycatch.
- The effect of the degree of circle hook offset on turtle and target catch catchability (Boggs and Swimmer, 2007).
- The routine adoption of whole fish bait in terms of economical and operational viability (Gilman *et al.,* 2006b).
- The effectiveness of small circle hooks.
- Other possible mitigation measures (for example different hook designs, baiting techniques, bait type, stealth gear, lightstick design and smart hooks).

At this stage in the development of a solution to marine turtle bycatch in longline fisheries, researchers are focusing on strategies that may reduce the interaction rate and strategies to increase turtle survivorship during capture or after release. Although the currently preferred mitigation method is the adoption of large circle hooks, the effect of hook style may be one in a suite of factors. Research projects need to continue to address the fundamental issue of what is the possible assembly of strategies that will best mitigate turtle catches in longline fisheries around the world.

As with any migratory animal, generally neither one fishery nor even one country has sole ownership of turtle stocks that occur in their waters. As juveniles, marine turtles possibly move vast distances and, as adults migrate from foraging to breeding habitats. So over its lifetime, a single turtle may pass through the fishing grounds of several fisheries, longline and others, and cross the jurisdictional boundaries of many countries (Steering Committee, Bellagio Conference on Marine Turtles, 2004). Surviving its journey across one fishery using good mitigation measures, will not protect it in the next fishery in which mitigation measures are not adopted (Watson *et al*., 2005). Every fishing fleet that interacts with marine turtles has the responsibility to every other fleet to protect these endangered animals. This is just as applicable in regard to research results. The diffusion of successful technologies within and across fleets, without the need for mandatory regulations, is probably the fastest and most cost effective method for the successful adoption of a mitigation approach. Fishers, scientists and managers from longline fisheries around the world need to work together to produce effective and workable solutions to their own bycatch issues.

Benefits and Adoption

The Australian pelagic longline fisheries have benefited directly from this research. This has been through a number of means, including:

- *The increase in fisher awareness of the importance of the industry to adequately address marine turtle bycatch*. This is not only through fishers attending workshops, or watching the DVD, but also participating in marine turtle research.
- *The continual dissemination of correct handling and release techniques when a marine turtle is encountered*. The fishers who attended training workshops and/or watched the handling DVD will pass on their knowledge to other crew when a turtle is caught. These fishers in turn will pass on the skills to new crew.
- *The positive consequence of the trial of release tools was for the National Heritage Trust to purchase a set of equipment for all Australian pelagic longline vessels*.
- *The collection of samples and data expanded fishers' knowledge of marine turtles during their pelagic life stage*.
- *An appreciation by governments, both national and global, that Australian longline fisheries are working together with turtle scientists and fishers managers to address turtle bycatch issues.*

Many other longline fisheries around the world have benefited from this research through the extensive distribution of the handling DVD, *Crossing the Line*. It is being used in various countries for fisher and observer training. It was dubbed into Bahasa by WWF so it can be more useful in Indonesia and by Indonesian crew in Australian longline fisheries.

The Student Education Kit benefits students through a better understanding of marine turtles and the threats they face. Other Australian fisheries, such as state trawl fisheries, will benefit to some extent in terms of the Australian public appreciation of the efforts taken in the past to address their turtle bycatch issues, for example the adoption of TEDs.

All these situations will in the long-term, benefit marine turtle populations.

Further Development

This project was the first step in addressing the turtle bycatch issue in Australian longline fisheries. Through the findings of this project it is recommended that:

- A series of compulsory workshops be prepared and delivered at major tuna ports, to inform fishers of international developments in fishing practices and standards regarding turtle bycatch and mitigation measures along with implications these may have to Australian fisheries and exports.
- Through these workshops, a specific 'Turtle Protection Strategy' should be adopted and introduced by industry.
- Import certification into the U.S. be investigated and achieved by demonstration of the adoption of best practice by Australia in pelagic longline fishing operations with regard to turtle protection.
- Further research is needed to help determine mortality rates of marine turtles as a result of capture by Australian longline fisheries. It is suggested that an on-going satellite tagging study be undertaken.
- Fishers are given the opportunity to participate in marine turtle research to improve knowledge of marine turtles in the pelagic phase of their life-cycle, and possibly, contributing to solving the turtle bycatch issue.
- Australian scientists disseminate results of any mitigation trials to other longlining nations and assist, when possible, other fishers in their quest to solve marine turtle bycatch issues.
- Australian fishers and scientists continue to refine current strategies and possibly develop effective new strategies that may result in longline fisheries reducing their impact on marine turtles in Australia and around the world.

Planned Outcomes

Outcome 1. This study will educate fishers in issues concerning marine turtles and train them in safe release and handling procedures of turtles.

Many Australian longline fishers attended handling and conservation workshops and most fishers questioned have watched the handling DVD, *Crossing the Line*, at least once and are confident they know how to correctly respond should they encounter a turtle. These techniques are expected to be continually disseminated throughout the fleet. If a vessel has one fisher knowledgeable in turtle handling and release techniques and a turtle is encountered, he will pass on his expertise to the other crew, and these fishers in turn will pass on their skills to new crew. The recommended techniques are not difficult and this form of knowledge dispersal is invaluable. However, with the rapid turnover in crew ongoing education may still be necessary.

Outcome 2. This project will act to reduce the mortality of bycaught turtles.

The implementation of correct handling procedures following marine turtle interactions with longline fishing gear has been proven to greatly improve post release survival (Epperly *et al.*, 2004). Therefore the routine use of correct handling procedures and release equipment in Australian longline fisheries would have improved survival of marine turtles interacting with fishing operations.

Outcome 3. It will provide information so as to allow better management decisions, and potentially the development of improved bycatch mitigation or marine turtle recovery gear and methods.

This project has provided the most up-to-date knowledge on marine turtle interactions with longline fishing gear and on the situation within the Australian longline fishing industries. In order to better inform both managers and fishers, this report lists relevant research results, the advantages and disadvantages of the currently-preferred mitigation method (circle hooks), possible issues with other mitigation measures and future high-priority research needs.

Outcome 4. This study and its outcomes are of great importance to the community, given the public's fondness for marine turtles as with other large and charismatic marine species.

Through the successful fulfilment of Outcomes 1, 2 and 3, this Outcome has been achieved. Additionally, the production of the Education Kit improves public knowledge, through education of children, on the threats faced by marine turtles and what we can all do to help. This not only benefits the children due to their enhanced interest in marine turtles, but also to the industry in terms of the image of fishermen and their product as 'environmentally friendly'.

Outcome 5. This project will comply with Australia's obligations under the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA).

The Education Kit was released as Australia's contribution to the IOSEA Year of the Sea Turtle.

Conclusion

Marine turtles, one of the ocean's charismatic fauna and as such hold a particular fascination for many, are in global decline. With the increased exposure of these animals to the general public through the media, aquariums and educational institutes, awareness of their plight has grown, and as a result, so too has the pressure on those responsible for these threats to take remedial action.

In recent years, pelagic longline fisheries have come under worldwide pressure from governments, conservation organisations and the public to reduce their contribution to global marine turtle population decline (Crowder and Myers, 2001; Lewison *et al.*, 2004). However, of late the extent of the impact of longlining operations on turtles has been questioned (Kaplan, 2005; Lewison and Crowder, 2006). A problem is that without additional and substantial research it is difficult to accurately quantify the risk faced by individual turtle populations as a result of specific fisheries, or indeed any other significant source of anthropomorphic mortality. What is known is that in order to effectively improve the status of marine turtle populations, all threats will need to be addressed (Gilman *et al.*, 2005b).

Of the seven species of marine turtles in the world, six live in Australian waters and five of these, excluding the flatback, live and migrate across Australian longline fishing grounds. It is estimated from observer data that around 200 turtles interact with ETBF fishing gear in 2004-2005. There have been no valid estimations of turtle catch for the WTBF due to the contracting nature of the fishery.

The types of encounters vary, ranging from internal hooking to entanglement, and although most turtles are reported as released healthy, some are reported as being injured upon release. A small number of shelled turtles are also reported as dead as a result of the encounter. Additionally, even though a high percentage of logbooks and observer records report that most turtles are released alive, their eventual fate is unknown. The most obvious mortality event is a turtle that leaves the vessel dead after the interaction event. A less obvious and relatively unmonitored mortality event is 'cryptic mortality': a turtle that leaves the vessel alive but dies at a later date.

Over the last decade there have been many studies developing and testing turtle mitigation measures in longline fisheries around the world. The research has focused on measures with the potential to either reduce the capture of marine turtles, to increase their survival during the interaction with longline gear, or to increase their survival after release.

To date the most successful turtle mitigation measure investigated is the use of large circle hooks in conjunction with whole fish bait. To some researchers and fishers this is the solution. To others it is just part of the solution.

Considerable research has also gone into handling and post-release strategies to reduce turtle injury and death. Possible injuries from gear that is not removed includes tissue damage, infection, blockages in the gut, internal organ damage and limb damage from trailing line (Watson *et al.*, 2005). Fishers of the ETBF trialled various handling and release tools to determine what styles were the most appropriate for use in the Australian longline fisheries. In 2005, Seanet Australia and AFMA with funding from National

Heritage Trust provided every ETBF and WTBF commercial pelagic longliner with a set of handling and release equipment. Their correct use was demonstrated at turtle handling workshops and in the handling DVD, *Crossing the Line*.

Every mitigation measure must be commercially viable in each fishery for it to succeed. There is little chance of a mitigation measure being adopted in the long-term if it is not commercially viable, even if made mandatory. Although the currently preferred mitigation method is the adoption of large circle hooks, the effect of hook style may be one in a suite of factors. Research projects need to continue to try to answer the fundamental issue of the best possible assembly of strategies which will most effectively mitigate turtle catches in longline fisheries around the world.

Australian fishers, in conjunction with government, management agencies and conservation organisations have taken a pro-active approach to reduce their impacts on these populations and by association, secure the future of their industry and livelihood. Fishers have a genuine commitment, through personal conviction to 'do the right thing' and maintain/improve productivity. The incidental capture of marine turtles reduces 'active' fishing time and fouls and damages gear, reducing the potential catch of target species. Adherence to national and international legislation ensures continuation of the fishery.

The industry has adopted a number of activities to maximise survival of marine turtles including avoidance strategies, handling strategies and post release strategies. These include:

- Attendance at specifically convened workshops to learn about turtles as a species, handling strategies and participation in data collection and research. Regular repeated training is required to reinforce understanding of the messages for long term crew and introduce new crew to these activities.
- The widespread and voluntary adoption of tools (circle hooks, dehooking and linecutting devices) to ensure efficient handling and release of turtles.
- The supply to crew of *Crossing the Line* to provide an on-board ready reference on the use of release tools and techniques while fishing.

As with any migratory animal, generally neither one fishery nor even one country, has sole ownership of turtle stocks that occur in their waters. As juveniles they are possibly moving vast distances and, as adults migrating from foraging habitat to breeding habitat. So over its lifetime one turtle may wander the fishing grounds of several fisheries, longline and others, and cross the jurisdictional boundaries of many countries. Surviving its journey across one fishery using good mitigation measures will not protect it in the next fishery in which mitigation measures are not adopted (Watson *et al*., 2005). Every fishing fleet that interacts with marine turtles has a responsibility to every other fleet to protect these endangered animals. This is just as applicable with regards to research results. The diffusion of successful technologies within fleets and across fleets, without the need for mandatory regulations, is probably the fastest and most cost effective way for the successful adoption of a mitigation approach. Fishers, scientists and managers from longline fisheries around the world need to work together to produce effective and workable solutions to their own bycatch issues.

References

Achaval, F. and Yamandu H. M. (1998) Incidental Capture of Sea Turtles in Swordfish Long Line Fishery. In: *Proceedings of the 17th Annual Sea Turtle Symposium*. Epperly, S. P. and Braun, J. (Compilers). U.S. Dept. Commer. NOAA Tech. Memo. NMFS–SEFSC–415, 294 pp.

Achaval, F., Marín, Y. H. and Barea, L. C. (2000) Incidental Capture of Turtles with Pelagic Longline. In: *Proceedings of the 18th International Symposium on Sea Turtle Biology and Conservation, Mazatlan, Sinaloa Mexico 3–7 March*. Abreu-Grobois, F. A., Briseno-Duenas, R. Márquez, R. and Sarti, L. (Compilers), 261.

Aguilar, R., Mas, J. and Paster, X. (1995) Impact of Spanish Swordfish Longline Fisheries on the Loggerhead Sea Turtle *Caretta caretta* Populations in the Western Mediterranean. In: *Proceedings of the 12th Annual Workshop on Sea Turtle Biology and Conservation.* Richardson, J. L. and Richardson, T. H. (Compilers). NOAA Tech. Memo. NMFS–SEFSC–361, 274 pp., 1–6.

Alegre, F., Parga, M., del Castillo, C. and Pont, S (2006) Study on the long-term effect of hooks lodged in the mid-oesophagus of marine turtles. In: *Frick, M., Panagopoulou, A. Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006.*

Alfaro-Shigueto, J., Mangel, J., Diaz, P., Seminoff, J. and Dutton, P. (2005) Longlines and sea turtle bycatch in Peru. Poster presentation given at the *25th Annual Symposium on Sea Turtle Biology and Conservation, January 16–22, 2005, Savannah, Georgia.*

Altonn, H. (2001) Study finds deep-set lines could spare most turtles. *Starbulletin Sunday July 22, 2001.*

Anon. (1997) Legal Briefs. *Marine Turtle Newsletter 76, 25–30*.

Anon. (1999) And they have tears in their eyes: Marine turtles – Connecting and reflecting our actions across the Earth. *A.M.C.S. Bull. (Turtle Insert),* 20(4), 4–9.

Anon. (2001) Turtles Safe from Shrimp Trawl in 43 Countries. *Marine Turtle Newsletter 94, 23–27.*

Anon. (2006) Cook Islands national tuna fishery report. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia.*

Arauz, R. (2000) Impact of high-seas longline fishing operations on shark and sea turtle populations in the Economic Exclusive Zone of Costa Rica. *Sea Turtle Restoration Project. Unpub Report.*

Arauz. R. (2001) Impact of high seas longline fishery operations on shark and sea turtle populations in the Economic Exclusive Zone of Costa Rica – A Second Look. In: *Proceedings of the 21st Annual Symposium on Sea Turtle Biology and Conservation, February 24–28, 2001, Philadelphia, Pennsylvania*.

Arauz, R., Roderiguez, O., Vargas, R.and Segrura, A. (2000) Incidental Capture of Sea Turtles by Costa Rica's Longline Fleet. In: *Proceedings of the 19th Annual Symposium on Sea Turtle Conservation and Biology. Kalb, H. and Wibbels, T. (Compilers). NOAA Tech. Memo. NMFS–SEFSC–443, 62–64.*

Ariz, J., Delgado de Molina, A., Ramos, M. L. and Santana, J. C. (2006) Checklist and catch rate data by hook type and bait for bycatch species caught by Spanish experimental longline cruises in the South-Western Indian Ocean during 2005. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia.*

Bache, S., Haward, M. and Dovers, S., (2000) *Economic, environmental and trade instruments — Their impact on Australian Fisheries Policy*. Report to the Fisheries and Aquaculture Policy Branch of the Department of Agriculture, Forestry and Fisheries — Australia, July 2000.

Balazs, G. H. (1996) Behavioural changes within the recovering Hawaiian green turtle population. In: *Proceedings of the 15th Annual Workshop on Sea Turtle Biology and Conservation.* Keinath, J. A., Barnard, D. E., Musick, J. A. and Bell, B. A. (Compilers). U.S. Dept. Commer. NOAA Tech. Memo. NMFS–SEFSC–387, 355 pp.

Bartol, S. M., Kettem, D. R. (2006) Turtle and tuna hearing. In: *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques* to reduce sea turtle bycatch in longline fisheries. *NOAA Tech. Memo. NMFS–PIFSC–7.*

Bartram, P. K. and Kaneko, J. J. (2004) *Catch to bycatch ratios: Comparing Hawaii's pelagic longline fisheries with others*. PacMar Inc, Honolulu, Hawaii.

Beverly, S., Robinson, E. and Itano, D. (2004) Trial setting of deep longline techniques to reduce bycatch and increase targeting of deep-swimming tunas. *Presented at the Seventeenth Meeting of the Standing Committee on Tuna and Billfish, 9–18 August 2004, Majuro, Republic of the Marshall Islands. SPC, Noumea, New Caledonia*

Beverly, S. and Chapman, L. (2007) Interactions between sea turtles and pelagic longline fisheries. Presented at the *Third Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 13–24 August 2007, Honolulua, U.S.*

Bjorndal, K. A., Bolten, A. B. And Riewald, B. (1999) Development and use of satellite telemetry to estimate post-hooking mortality of marine turtles in the pelagic lonlgnie fisheries. *Southwest Fisheries Science Center Admin. Rep. H–99–03C.*

Boggs, C. H. (2003) *Annual Report on the Hawaii Longline Fishing experiments to reduce sea turtle bycatch under ESA* Section 10 Permit 1303. US NMFS, Honolulu, HI, USA.

Boggs, C. H. (2004) Pacific research on longline sea turtle bycatch. In*: Proceedings of the International Technical Expert Workshop on Marine Turtle Bycatch in Longline Fisheries* (eds. K. J. Long and B. A. Schroeder) US Department of Commerce. NOAA Technical Memorandum NMFS–F/OPR–26, Silver Springs, MD, USA.

Boggs, C. H. (2005) Average sea turtle mortality rates for predicting mortality of future takes by the Hawaii-based, deep-set longline fishery. *Pacific Islands Fishery Science Center Internal Report IR–05–010. June 10, 2005.*

Boggs, C. (2007) Developments (2006-2007) in scientific research on the use of modified fishing gear to reduce longline bycatch of sea turtles. Presented at the *Third Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 13–24 August 2007, Honolulua, U.S.*

Bolton, A., Martins, H., Isidro, E. et al. (2001) Preliminary results of experiments to evaluate effects of hook type on sea turtle bycatch in the swordfish longline fishery in the Azores. In: *First Mediterranean Conference on Marine Turtles, 24–28 October 2001* (ed. D. Margaritoulis) IUCN/SSC Marine Turtle Specialist Group and Istituto Centrale Ricerca Applicata al Mare (ICRAM), Nicosia, Cyrus.

Bolton, A. and Bjorndal K. (2002) *Experiment to evaluate gear modification on rates of sea turtle bycatch in the swordfish longline fishery in the Azores*. Final Project Report submitted to the US NMFS. Archie Carr Centre for Sea Turtle Research, University of Florida, Gainesville, FL, USA.

Bolton, A. B. and Bjorndal, K. A. (2003) Circle hook definition and research issues. *Special Report No 77 of the Atlantic States Marine Fisheries Commission*.

Bolton, A. B. and Bjorndal, K. A. (2004) *Experiment to evaluate gear modification on rates of sea turtle bycatch in the swordfish longline fishery in the Azores – Phase 3* Final Report Submitted to NMFS. Archie Carr Center for Sea Turtle Research, University of Florida, USA.

Bolton A. B. and Bjorndal, K. A. (2005) *Experiment to evaluate gear modification on rates of marine turtle bycatch in the swordfish longline fishery in the Azores – Phase 4.* NOAA Award Number NA03NMF4540204.

Bravo, C. M., Sara, S. K. And Velez-Zuazo, X. (2006) Impact of the common dolphin fish longline fishery on sea turtles along the Peruvian Coast between 2003 and 2005. In: *Frick, M., Panagopoulou, A, Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006*

Brewer, D.T., Rawlinson, N., Eayrs, S. and Burridge, C. Y. (1998) An Assessment of Bycatch Reduction Devices in a Tropical Australian Prawn Trawl *Fishery Fisheries Research. 36, 195–215*

Burger, J. and Garber, S. D. (1995) Risk assessment, life history strategies, and turtles: Could declines be prevented or predicted? *Journal of Toxicology and Environmental Health* 46, 483–500.

Caminas, J.A. (1996) Capturas accidentales de tortuga boba (Caretta caretta, L. 1758) en el Mediterraneo Occidental en la pesqueria de palangre de superficie de pez espada (*Xiphias gladius* L.). *SYMP/96/031: 446–455*

Caretta, J. V. (2003) An analysis of sea turtle take rates in the high seas longline fishery in the eastern Pacific Ocean. *Southwest Fisheries Science Centre, NMFS, La Jolla, CA.*

Chaloupka, M. and Limpus, C. (2001) Trends in the abundance of sea turtles resident in Southern Great Barrier Reef waters. *Biol. Cons.* 102(3), 235–249.

Chaloupka, M., Parker, D. and Balazs, G. H. (2004) Modelling post-release mortality of pelagic loggerhead sea turtles exposed to the Hawaii-based longline fishery. *Mar. Ecol. Prog. Ser.* 280: 285–293.

Cheng I. J. (2003) Sea turtle by-catchment by the Taiwanese high-seas longline fishery in the eastern Pacific Ocean. *Southwest Fisheries Science Centre, NMFS , La Jolla, CA.*

Clarke, S. (2004) Preliminary modelling of Japan's Research Cruise Data on sea turtle bycatch reduction measures. National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Japan. Presented at the *Workshop to plan a joint Japan-Hawaii sea turtle and seabird experiment to reduce bycatch and injury in pelagic longline fisheries, Honolulu, HI USA. 13–17 September 2004. US NMFS PIFSC and WPRFMC, Honolulu, HI, USA.*

Craig, P. (2002) Rapidly approaching extinction: Marine turtles in the Central South Pacific. Presented at the *Western Pacific Marine turtle Cooperative Research and Management Workshop. 5–8 February 2002, Honolulu, Hawaii*

Crouse, D. T., Crowder, L. B., Caswell, H. (1987) A stage-based population model for loggerhead sea turtles and implications for conservation. *Ecology 68(5), 1412–1423*.

Crouse, D. T. (1997) Pacific leatherback postscript. *Marine Turtle Newsletter 76, 12–14.*

Crowder, L. B. and Myers, R. A. (2001) *A comprehensive study of the ecological impacts of the worldwide pelagic longline industry*. 2001 First Report to the Pew Charitable Trusts, Philadelphia, PA, USA.

Dalzell, P. and Gilman, E. (2006) Turtle bycatch mitigation in the Hawaiian Longline Fishery. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia.*

Dambacher, J. M. (2005) The analysis of AFMA observer data July 2004–June 2005. Presented at the *Eastern Tuna and Billfish Resource Assessment Meeting. 17–18 November 2005, Hobart, Australia.*

Deep-Sea Fisheries Research and Development Centre (2005) Tuna fisheries status report of Chinese Taipei in the Western and Central Pacific Region. Presented at the *First Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 8–19 August 2005, Noumea, New Caledonia. WCPFC, Pohnpei, Federated States of Micronesia*.

Delflorio, M., Aprea, A., Corriero, A., Santamaría, N., De Metrio, G. (2005) Incidental captures of marine turtles by swordfish and albacore longlines in the Ionian sea, *Fish. Sci*. 71, 1010.

Dellinger, T. and Encarnaçâo, H. (2000) Accidental Capture of Sea Turtles by Fishing Fleet Based at Madeira Island, Portugal. In: *Proceedings of the 19th Annual Symposium on Sea Turtle Conservation and Biology.* Kalb, H. and Wibbels, T. (Compilers). U.S. Dept. Commer. NOAA Tech. Memo. NMFS –SEFSC–443, 218.

Dobbs, K. (2001) General impacts of human activities on marine turtles. In *Marine Turtles in the Great Barrier Reef World Heritage Area*. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Donoso, M. and Dutton, P. (2006) Distribution and stock origin of marine turtles caught incidentally in the Chilean longline fishery for swordfish, 2001–2004. In: *Frick, M., Panagopoulou, A, Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006.*

Echwikhi, K., Jribi, I., Nejmeddine, M and Bouain, A. (2006) Interaction of marine turtles with longline fisheries in the region of Zarzis (Gulf of Gabes, Tunisia). In: *Frick, M., Panagopoulou, A, Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006.*

Ekert, S. A. (1997). Distant fisheries implicated in the loss of the World's largest leatherback nesting population. *Marine Turtle Newsletter* 78, 2–7.

Eckert, S. A., Eckert, K. L., Pongamia, P. and Koopman, G. H. (1989) Diving and foraging behaviour of leatherback sea turtles*. Can. J. Zool*. 67:2834–2840.

Eckert, K. L. and Luginbuhl, C. (1988) Death of a giant. *Mar. Turtle Newsl*. 43, 2–3.

Eckert, S., Levenson, D. H. and Crognale, M. A. (2006) The sensory biology of sea turtles: What can they see, and how can this help them avoid fishing gear. In: *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques* to reduce sea turtle bycatch in longline fisheries. *NOAA Tech. Memo. NMFS–PIFSC–7.*

Environment Australia (1998) *Draft recovery plan for marine turtles in Australia*. Environment Australia, Canberra.

Epperly, S. P. and Boggs, C. (2004) *Post-hooking mortality in pelagic longline fisheries using J-hooks and circle hooks. Application of new draft criteria to data from the Northeast Distant Experiments in the Atlantic*. Internal document PRD–03/04–04 of the Southeast Fisheries Science Centre.

Epperly, S., Stokes, L. and Dick, S. (2004) Careful release protocols for sea turtle release with minimal injury. *NOAA Tech. Memo. NMFS–SEFSC–524*.

Evans, S. K. (2006) *Eastern Tuna and Billfish Fishery Data Summary 2004–2005* . Data Group, AFMA, Canberra.

Fairfield Walsh, C. and Garrison, L. P. (2006) Estimated bycatch of marine mannels and turtles in the U.S. Atlantic Pelagic Longline Fleet During 2005. *NOAA Tech. Memo. NOAA NMFS–SEFSC–539: 52p.*

Fallabrino, A., Bager, A., Estrades, A. and Achaval, F. (2000) Current Status of Marine Turtles in Uraguay. *Marine Turtle Newsletter* 87, 4–5.

Falterman, B., and Graves, J. E. (2002) A comparison of the relative mortality and hooking efficiency of circle and straight shank ("J") hooks used in the pelagic longline industry. *Amer. Fish. Soc. Symp*. 30:80–87.

FAO (2004) Expert consultation on interactions between sea turtles and fisheries within an ecosystem context. Rome, Italy, 9–12 March 2004. *FAO Fisheries Report* No 738. Rome, FAO. 37pp.

FAO (2005) Report of the Technical Consultation on Marine Turtle Conservation and Fisheries. Bangkok, Thailand, 29 November–2 December 2004. *FAO Fisheries Report* No 765. Rome, FAO. 31pp.

Ferreira, R.L., Martins, H. R., Da Silva, A. A. and Bolton, A. B. (2001) Impact of Swordfish Fisheries on Sea Turtles in the Azores. Arquipelago. *Life and Marine Sciences 18A, 75–79.*

Frazer, N. B. (1992) Sea turtle conservation and halfway technology. *Cons. Biol*. 6, 179–184.

Fritsches, K. A. and Warrant, E. J. (2006) Differences in the visual capabilities of sea turtles and blue water fishes – Implications for bycatch reduction. In: *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques* to reduce sea turtle bycatch in longline fisheries. *NOAA Tech. Memo. NMFS–PIFSC–7.*

Fuller, J. E., Eckert, K. L. and Richardson, J. I. (1992) Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST), Sea Turtle Recovery Action Plan for Antigua and Barbuda. *Caribbean Environmental Programme, United Nations Environment Programme, Technical Report* 16, 88 pp. Kingston, Jamaica.

Garrison, L. P. (2003) Summary of target species and protected resources catch rates by hook and bait type in the pelagic longline fishery in the Gulf of Mexico 1992–2002. *SEFSC Contribution #: PRD–02/03–08.*

Garrison, L. P. (2005) Estimated bycatch of marine mammals and turtles in the U.S. Atlantic pelagic longline fleet during 2004. *NOAA Tech. Memo. NMFS–SEFSC–531, 52p.*

Gerrior, P. (1996) Incidental Take of Sea Turtles in Northeast US Waters. In: *Pelagic Longline Fishery–Sea Turtle Interactions. Proceedings of an Industry, Academic and Government Experts, and Stakeholders Workshop, Silver Springs, Maryland, 24–25 May 1994. Williams, P., Anninos, P. J., Plotkin, P. T. and Salvini, K. L. (Compilers). U.S. Dept. Commer. NOAA Tech. Memo. NMFS–OPR–7, 14–31.*

Gilman, E., Dalzell, P. and Martin, S. (2005a) *Reducing fisheries bycatch through fleet communication programs: Recommended design for a pilot fleet communication program for the Hawaii Longline Tuna and Swordfish Fisheries*. Report prepared for the Western Pacific Regional Fishery Management Council.

Gillman, E., Watson, J., Boggs, C., Epperly, S., Zollet, E., Beverly, S., Nakano, H., Swimmer, Y., Davis, K., Shiode, D., and Kinan, I. (2005b) *Review of the state of knowledge for* *reducing marine turtle bycatch in pelagic longline gear*. Western Pacific Regional Fishery Management Council, Honolulu, Hawaii.

Gillman, E., Kobayashi, D., Swenarton, T., Dalzell, P., Kinan, I. and Brothers, N. (2006a) *Efficiency and commercial viability of regulations designed to reduce marine turtle interactions in the Hawaii-based longline swordfish fishery*. Western Pacific Regional Fishery Management Council, Honolulu, Hawaii.

Gilman, E., Zollett, E., Beverly, S., Nakano, H., Davis, K., Shiode, D., Dalzell, P. and Kinan, I. (2006b) Reducing marine turtle by-catch in pelagic longline fisheries. *Fish and Fisheries* 7:2–23.

Gilman, E. and Kobayashi, D. (2007) Sea turtle interactions in the Hawaii-based longline swordfish fishery. First quarter 2007 and comparison to previous periods. *Draft Report 3 July 2007.*

Gilman E. and Moth-Poulsen, T. (2007) Review of measures taken by intergovernmental organisations to address sea turtle and seabird interactions in marine capture fisheries. *FAO Fisheries Circular No 1025. Rome , FAO.*

Harley, S. J. and Kendrick, T. (2006) New Zealand annual report to the Commission: Part 1 – Information on fisheries, research and statistics. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia.*

Harris, A. and Ward, P. (1999) Non-target species in Australia's Commonwealth Fisheries. A critical review. Bureau of Rural Sciences, Canberra.

Hataway, D. and Mitchell, J. (2002) *Report on gear evaluations to mitigate sea turtle capture and mortality on pelagic longlines using captive reared sea turtles*. NOAA, NMFS , Southeast Fisheries Science Centre. Internal Report.

Heppell, S. S., Limpus, C., Crouse, D. T., Frazer, N. B. and Crowder, L. B. (1996) Population model analysis for the loggerhead sea turtle, *Caretta caretta*, in Queensland. *Wildlife Research* 23, 143–159.

Higgins, B. (2006) Shark decoy experiments. In: *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques* to reduce sea turtle bycatch in longline fisheries. *NOAA Tech. Memo. NMFS–PIFSC–7.*

Hillstead, H. O., Richardson, J. I., McVea Jr., C. and Watson Jr., J. M, (1981) Worldwide incidental capture of sea turtles. In: *Biology and Conservation of Sea Turtles. Proceedings of the World Conference on Sea Turtle Conservation*. Bjorndal, K. A. (ed.). Smithsonian Institutional Press, Washington, D.C., 489–495.

Hitipeuw, C., Mustofa, I. and Pet Soede L. (2006) Preliminary assessment of marine turtle interactions with Indonesian fisheries. In: *Frick, M., Panagopoulou, A, Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006.*

Horodysky, A. Z. and Graves, J. E. (2005) Application of pop-up satellite archival tag Technology to estimate post-release survival of white marlin (*Tetrapturus albidus*) caught on circle and straight-shank (J) hooks in the Western North Atlantic Recreational Fishery. *Fish. Bull*. 103:84–96.

Hutchinson, J. and Simmonds, M. (1991) A review of the effects of pollution on marine turtles. *A Greenpeace Ecotoxicilogy Project.*

IATTC (2006a) Interactions of fisheries in the eastern Pacific Ocean and marine turtles. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia*.

IATTC (2006b) The sea turtle bycatch mitigation program for the coastal longline fleets and preliminary results of circle hook experiments. Presented at the *Inter-American Tropical Tuna Commission Working Group on Bycatch, 24 June 2006, Busan, Korea.*

IOTC (2006) *Report of the Second Session of the IOTC Working Party on Bycatch. 31 Ju;y – 1 August 2006, Seychelles. IOTC, Seychelles.*

Instituto Nacional de la Pesca (Canainpesca, seccion especializada de pez espada fidemar) (2001) Estudio de la pesqueria de pelagicos mayors que opera red y palangre de superficie en el oceano Pacifico oriental. *Informe preliminary de investigacion.*

Itano, D. (2004) Hawaiian-0style small-scale deep setting longline technique used on seamounts. *SPC Fisheries Newsletter # 111* October/December 2004.

Ito, R. Y. and Machado, W. A. (2001) Annual report of the Hawaii-based longline fishery for 2000. *Adm. Report H–01–07, NOAA/NMFS, Southwest Fisheries Science Center, Honolulu Laboratory, Honolulu, HI.*

Ito, R., Hamm, D., Coan, A. L. Jr. and Childers, J., (2005) Summary of U.S. fisheries for highly migratory species in the Western and Central Pacific 2000-2004. Presented at the *First Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 8–19 August 2005, Noumea, New Caledonia. WCPFC, Pohnpei, Federated States of Micronesia*.

IUCN (2006) 2006 IUCN Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on 15 July 2007.

Javitech Limited (2002) *Report on sea turtle interactions in the 2001 pelagic longline fishery*. Dartmouth, Nova Scotia.

Javitech Limited (2003) *Report on sea turtle interactions in the 2002 pelagic (offshore) longline fishery, February 14, 2003*. Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, Canada.

Johnsen, S. (2006) Mathematical model of the visual abilities of sea turtles and pelagic fishes. In: *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques* to reduce sea turtle bycatch in longline fisheries. *NOAA Tech. Memo. NMFS–PIFSC–7.*

Kaplan, I. C. (2005) A risk assessment for Pacific leatherback turtles (*Dermochelys coriacea*). *Can. J. Fish. Aquat. Sci*. 62:1710–1719.

Kaplan, I. C., Cox, S. P. and Kitchell, J. F. (2007) Circle hooks for Pacific longliners: Not a panacea for marlin and shark bycatch, but part of the solution. *Transaction of the American Fisheries Society 136:392–401.*

Kerstetter, D.W., and J.E. Graves (2006) Effects of circle versus J-style hooks on target and non-target species in a pelagic longline fishery. *Fisheries Research, 80:239–250.*

Kim, S-.S., Moon, D.-Y., An, D.-H. and Koh, J.-R. (2006) Comparison of circle hooks and J-hooks in the catch rate of target and bycatch species taken in the Korean Tuna Longline Fishery. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia.*

Kinan, I. (ed.) (2002) *Proceedings of the Western Pacific Sea Turtle Cooperative Research and Management Workshop*. 5–8 February 2002, Honolulu Hi, USA. WPRFMC.

Kinan, I. and Dazell, P. (2005) Sea turtles as a flagship species: Different perspectives create conflicts in the Pacific Islands. *MAST 3(2) and 4(1): 195–212.*

Kiszka, J. and Muir, C, (2006) Incidental catch of non-targeted marine species in the Western Indian Ocean: Problems and mitigation measures. *Workshop Proceedings Mayotte France, 13–15 November 2006, 111p.*

Kiyota, M., Nakano, H., Matsunaga, H. and Minami, H. (2003) Research activities and fishery management for the solution of incidental catch of sharks, seabirds and sea turtles in Japanese Tuna Longline Fishing. *National Research Institute of Far Seas Fisheries, Fisheries Research Japan. 16th Meeting of the Standing Committee on Tuna and Billfish Working Paper NNRG–10. Mooloolaba, Australia, 9–16 July 2003*.

Kleiber, P. (1998) Estimating Annual Takes and Kills of Sea Turtles by the Hawaiian Longline Fishery, 1991–97, from Observer Program and Logbook Data. *SWFSC Administrative Report H–98–08,* 21pp.

Kleiber, P. and Boggs, C. (2000) Workshop on reducing sea turtle takes in longline fisheries, Miama, August 31–September 1 1999. *US NMFS SWFSC Adin. Rep. H-00-09. Honolulu Laboratory, Honolulu, HI.*

Kobayashi, D. R. and Polovina, J. J. (2005) Evaluation of time-area closures to reduce incidental sea turtle take in the Hawaii-based longline fishery: Generalised additive Model (GAM) development ands retrospective examination. NOAA *Tech. Memo. NMFS–PIFSC–4*.

Kotas, J. E., Santos, S., de Azevedo, V., Gallo, B. and Barata, P. (2004) Incidental capture of loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) sea turtles by the pelagic longline fishery off southern Brazil. *Fishery Bulletin 102: 393–399*.

Largacha, E., Parrales, M., Rendon, L., Velasquez, V., Orozco, M. and Hall, M. (2005) Working with the Ecuadorian fishing community to reduce the mortality of sea turtles in longlines:the first year March 2004–March 2005. *Unpublished document. Western Pacific Regional Fishery Management Council.*

Laurent, L., Lescure, J., Excoffier, L., Bowen, B., Domingo, M., Hadjichristophorou, M., Kornaraki, L. and Trabuchet, G. (1993) Genetic Studies of Relationships Between Mediterranean and Atlantic Populations of Loggerhead Turtle (*Caretta caretta*) with a Mitochondrial Marker. *Animal Biology and Pathology* 316, 1233–1239.

Laurent, L., Camiñas, J. A., Casale, P., Deflorio, M., De Metrio, G., Kapantagakis, A., Margaritoulis, D., Politou, C. and Valeiras, J. (2001) *Assessing Marine Turtle Bycatch in European Drifting Longline and Trawl Fisheries for Identifying Fishing Regulations.* Project-EC-DG Fisheries 98–008, Joint Project of BIOINSIGHT, IEO, IMBC, STPS and University of Bari, Villeurbanne, France, 267 pp.

Lawson, T. (2006) Scientific aspects of observer programs for tuna fisheries in the Western and Central Pacific Oceans. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia*

Levenson, D., Eckert, S., Crognale, M., Deegan, J. and Jacobs, G. (2006) Electroretinographic and genetic examination of sea turtle visual pigments. In: *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques* to reduce sea turtle bycatch in longline fisheries. *NOAA Tech. Memo. NMFS–PIFSC–7.*

Lewison, R. L., Freeman, S. A. and Crowder, L. B. (2004) Quantifying the effects of fisheries on threatened species: The impact of pelagic longlines on loggerhead and leatherback marine turtles. *Ecology Letters, 7:221–231.*

Lewison, R. L. and Crowder, L. B. (2006) *Putting longline bycatch of marine turtles into perspective.* Conservation Biology Online Early.

Limpus, C. J. (1982) The Status of Australian Sea Turtle Populations. In *Biology and Conservation of Sea Turtles. Proceedings of the World Conference on Sea Turtle Conservation. Bjorndal, K. A. (ed.). Smithsonian Institutional Press, Washington, D.C., 297–303.*

Limpus, C. J. (1995) Conservation of marine turtles in the Indo-Pacific Region. Queensland DEH. *Unpub Report to ANCA*.

Limpus, C. (1998) Overview of marine turtle conservation and management in Australia. In: *Marine turtle conservation and management in Northern Australia. Proceedings of a Workshop Held at the Northern Territory University, Darwin, 3–4 June 1997, Centre for Indigenous Natural and Cultural Resource Management and Centre for Tropical Wetlands Management, Northern Territory University, Darwin. Kennett, R., Webb, A., Duff, G., Guinea, M. and Hill, G. (eds).*

Lohmann, K. J., Wang, J. H., Boles, L. C., McAlister, J. and Lohmann, C. M. F. (2006) Development of turtle-safe light sticks for use in longline fisheries. In: *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques* to reduce sea turtle bycatch in longline fisheries. *NOAA Tech. Memo. NMFS–PIFSC–7.*

Lopez-Mendilaharsu, M., Sales, G., Griffon, B., Miller, P., Niemeyer Fiedler, F. and Domingo, A. (2007) Distributión y composición de tallas de las Tortugas marinas (*Caretta caretta* y *Dermochelys coriacea*) que interactuan con el palangre palegico en et Atlantico Sur. *Col. Vol. Sci. Pap. ICCAt 60(6): 2094–2109*.

Lukacovic (2001) An Evaluation of deep hooking rates and relative hooking efficiency of several styles of circular configured hooks. *In: Weinrich, D. R., Piavis, P. G., Pyle, B. H., Jarzynski, A. A., Walstrom, J. C., Sadzinski, R. A., Webb, E. J., Rickabaugh, H. W., Zlokovitz, E., Mower, J. P., Lukacovic, R. n y composiciand Whiteford, K. A. Stock assessment of selected resident and migratory recreational finfish species within Maryland's Chesapeake Bay. Federal Aid Project F–54–R. Annual Report, Department of the Interior, Fish and Wildlife Service.*

Lynch, A. W. (2004) *Southern and Western Tuna and Billfish Fishery Data Summary 2003*. Logbook Program, Australian Fisheries Management Authority, Canberra

Lynch, A W. (2005) *Eastern Tuna and Billfish Fishery Data Summary 2004–2005*. Data Group, Australian Fisheries Management Authority, Canberra

McCracken, M. L. (2000) Estimation of Sea turtle Take and Mortality in the Hawaiian Longline Fisheries. *SWFSC Admin. Rep. H–00–06*, 29pp.

Miller, J. D. (1993) Longline fishery interactions with sea turtles in Australia: A brief overview. In: *Research Plan to Assess Marine Turtle Hooking Mortality: Results of an Expert Workshop Held in Honolulu, Hawaii, November 16–18 1993. NOAA– SWFSC Administrative Report H–93–18, 76–80.*

Minami, H., Yokota, K. and Kiyota, M. (2006) Effect of circle hooks and feasibility of de-hooking devices to reduce incidental mortality of marine turtles in the Japanese Longline Fishery. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia*

Molony, B. (2005) Estimates of the mortality of non-target species with an initial focus on seabirds, turtles and sharks. Presented at the *First Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 8–19 August 2005, Noumea, New Caledonia. WCPFC, Pohnpei, Federated States of Micronesia.*

Moon, D-Y., Kim, S-S. and Koh, J-R. (2005a) A Summary of the Korean Fishery Observer Program for the Pacific Ocean (2004–2005). Presented at the *First Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 8–19 August 2005, Noumea, New Caledonia. WCPFC, Pohnpei, Federated States of Micronesia.*

Moon, D-Y., Kim, S-S. and Koh, J-R. (2005b) Tunas and billfishes in the Eastern Pacific Ocean in 2004 IATTC. Presented at the *First Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 8–19 August 2005, Noumea, New Caledonia. WCPFC, Pohnpei, Federated States of Micronesia.*

Moon, D-Y., Hwang, S-J., An, D-H., and Kim, S-S. (2006) National report of the Republic of Korea: Part 1. Information on fisheries, research and statistics. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia*.

Nakano, H. (2004) Research on the mitigation and conservation of sea turtles by the Fisheries Research Agency. National Research Institute of Far Seas Fisheries, Japan Fishery Research Agency, Shimizu, Shizuoka, Japan. Presented at *the Second Western Pacific Sea Turtle Cooperative Research and Management Workshop 17–21 May 2004. WPRFMC, Honolulu, HI, USA.*

Nakano, H., Kiyota, M., Minami, H., Yokota, K. and Clarke, S. (2004) Report on sea turtle and seabird bycatch research, National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Japan. Presented at the *Workshop to plan a joint Japan-Hawaii sea turtle and seabird experiment to reduce bycatch and injury in pelagic longline fisheries, Honolulu, HI USA. 13–17 September 2004. US NMFS PIFSC and WPRFMC, Honolulu, HI, USA.*

National Marine Fisheries Service and U.S. Fish and Wildlife Service (1998) *Recovery Plan for U.S. Pacific populations of the loggerhead turtle (Caretta catetta)*. NMFS, Silver Spring, MD.

National Marine Fisheries Service (1999) Our Living Oceans. Report on the Status of U.S. Living Marine Resources, 1999. *U.S. Dept. Commer. NOAA Tech. Memo. NMFS–F/SPO*–41.

National Marine Fisheries Service (2001a) Fisheries off West Coast States and in the Western Pacific; Western Pacific Pelagic Fisheries. Hawaii-based Pelagic Longline restrictions and seasonal area closure, and sea turtle and sea bird mitigation measures. *Federal Register* 66, 31561–31565.

National Marine Fisheries Service (2001b) Fisheries off West Coast States and in the Western Pacific; Western Pacific pelagic fisheries. Hawaii-based Pelagic longline restrictions and seasonal area closure, and sea turtle and sea bird mitigation measures. *Federal Register* 666 63630–63632.

National Marine Fisheries Service (2002) Fisheries off West Coast States and in the Western Pacific; Western Pacific pelagic fisheries. Pelagic longline gear restrictions, seasonal area closure, and other sea turtle take mitigation measures. *Federal Register* 67, 40232–40238.

National Marine Fisheries Service (2204a) Fisheries off West Coast States and in the Western Pacific; Western Pacific pelagic fisheries. Pelagic longline fishing restrictions, seasonal area closure, limit on swordfish fishing effort, gear restrictions, and other sea turtle take mitigation measures. *Federal Register* 69, 17329–17354.

National Marine Fisheries Service (2204b) Atlantic Highly Migratory Species (HMS); Pelagic Longline Fishery. *Federal Register* 69, 40733–40758.

National Marine Fisheries Service (2005) Endangered Species Act – Section 7 Consultation Biological Opinion and Incidental Take Statement. *Pacific Islands Region, Protected Resources Division, October 2005.*

National Marine Fisheries Service (2007) Certification of Nations Whose Fishing Vessels Are Engaged in Illegal, Unreported, or Unregulated Fishing or Bycatch of Protected Living Marine Resources. *Federal Register* 72, 32052–32055.

National Marine Fisheries Service, Southeast Fisheries Science Centre (2001) Stock assessments of loggerhead and leatherback sea turtles and an assessment of the impact of the Pelagic Longline Fishery on the loggerhead and leatherback sea turtles of the Western North Atlantic. *NOAA Tech. Memo. NMFS–SEFSC–455*, 343pp.

Nishimura, W. and Nakahigashi, S. (1990) Incidental Capture of Sea Turtles by Japanese Research and Training Vessels: Results of a Questionnaire. *Marine Turtle Newsletter* 51, 1–3.

Oceanic Fisheries Programme (2001) *A review of turtle bycatch in the Western and Central Pacific Ocean Tuna Fisheries*: A report prepared for the South Pacific Regional Environmental Programme (SPREP). Apia, Samoa.

Oldenburg, L. (2005) Hawaii Longline Association initiatives to reduce fisheries bycatch. *Proceedings of the International Tuna Fishers Conference on Responsible Fisheries and Third International Fishers Forum, July 25–29, 2005, Yokohama, Japan.*

Oravetz, C. A. (1988) Status of Federal Regulations to Reduce the Incidental Capture and Mortality of Sea Turtles from Shrimp Trawling. In: *Proceedings of the 8th Annual Symposium on Sea Turtle Conservation and Biology*. Schroeder, B. A. (Compiler). U.S. Dept. Commer. NOAA Tech. Memo. NMFS–SEFSC–214, 75–77.

Oravetz, C. A. (1992) The Status of Revisions to the TED Regulations and Implementation of Public Law 101-162 (The Sea Turtle Conservation/Shrimp Embargo Bill). In: *Proceedings of the 11th Annual Symposium on Sea Turtle Conservation and Biology*. Salmon, M. and Wyneken, J. (Compilers). U.S. Dept. Commer. NOAA Tech. Memo. NMFS–SEFSC–302, 87–88.

Oravetz, C. A. (1999) Reducing Incidental Catch in Fisheries. In: *Research and Management Techniques for the Conservation of Sea Turtles.* Eckert, K. L., Bjorndal, K. A., Abreu-Grobois, Donnelly, M. (Eds). IUCN/SSC Marine Turtle Specialist Group Publication No. 4, 235 pp.

Pandav, B. and Choudhury, B. C. (1999) Can the Olive Ridley turtles in Orissa, India be saved – A review of the scientific facts available. In: *Proceedings of the 19th Annual Symposium on Sea Turtle Conservation and Biology. Kalb, H. and Wibbels, T. (Compilers). U.S. Dept. Commer. NOAA Tech. Memo. NMFS–SEFSC–443, 71–73.*

Panou, A., Tselentis, L., Voutsinas, N., Mourelatos, C. H., Kaloupi, S., Voutsinas, V. and Moschonas, S. (1999) Incidental catches of marine turtles and surface longline fisheries in the Ionian Sea, Greece. *Contributions to the Zoogeography and Ecology of Eastern Mediterranean Region* 1, 435–445.

Parker, D. M., Balazs, G. H., Murakawa, S. K. K. and Polovina, J. P. (2001) Post-hooking survival of sea turtles taken by pelagic longline fishing in the North Pacific. In: *Proceedings of the 21st International Symposium on Sea Turtle Biology and Conservation,* 24–28 February 2001, Philadelphia, US.

Perdrau, M. (2002) *Southern and Western Tuna and Billfish Fishery Data Summary 2001*. Logbook Program, Australian Fisheries Management Authority, Canberra.

Perdrau, M. and Lynch, A W. (2003) *Eastern Tuna and Billfish Fishery Data Summary 2001–2002*. Data Group, Australian Fisheries Management Authority, Canberra.

Petersen, S. (2005) Incidental mortality of seabirds, turtles and sharks: A review of data collected east of 20 degrees by South African observers. *First Meeting of the IOTC Bycatch Working Party, Phuket, 20 July 2005.*

Piovano, S., Balletto, E., Di Marco, S., Dominici, A., Giacoma, C. and Zannetti, A. (2004) Loggerhead turtle (Caretta caretta) bycatches on longlines: The importance of olfactory stimuli. *Ital. J. Zool., Suppl*. 2:213–216.

Polovina, J. J., Kobayashi, D. R., Parker, D. M., Seki, M. P. and Balazs, G. H. (2000) Turtles on the edge: Movement of loggerhead turtles (*Caretta caretta*) along oceanic fronts, spanning longline fishing grounds in the Central North Pacific, 1997–1998. *Fish. Oceanogr.* 9(1), 71–82.

Polovina, J., Howell, E., Parker, D. and Balazs, G. (2002) Dive-depth distribution of loggerhead (Caretta caretta) and olive ridley (Lepidochelys olivacea) in the Central North Pacific: Might deep longline sets catch fewer turtles? *Fishery Bulletin* Vol *101 No 1:189–193).*

Prieto, R., Ferreira, R. Silva, A. (2000) Turtle bycatch study in the longline fisheries of the Azores. In: *Workshop to design an experiment to determine the effects of longline gear modification on sea turtle bycatch rates. NMFS–OPR–19. NOAA Tech. Memo. Pg.22–28. 50pp.*

Queensland Department of Environment and Heritage (1994) *A matter of time. Sea turtles of Queensland*. Queensland Department of Environment and Heritage, Queensland.

Read, A. J. (2007) Do circle hooks reduce the mortality of sea turtles in pelagic longlines? A review of recent experiments. *Biological Conservation* 135:155–169.

Robins, C. M., Bache, S. J. and Kalish, S. R. (2002a) *Bycatch of sea turtles in pelagic longline fisheries – Australia*. Bureau of Rural Sciences. Final Report to the Fisheries Resources Research Fund, AFFA, Canberra, Aus.

Robins, C. M., Goodspeed, A. M., Poiner, I. and Harch, B. D. (2002b) Monitoring the catch of turtles in the Northern Prawn Fishery. *Fisheries Research and Development Corporation Final Report FRDC Project 1998/202*, April 2002.

Robins, C. M. and Kreutz, D. C. (2005) *Circle hook research in pelagic longline fisheries.* Unpublished Report. Belldi Consultancy, Eumundi Aus.

Ruckdeschel, C., Shoop, C. R. and Zug, G. R. (2000) Sea turtles of the Georgia Coast. *Occas. Publ. Cumberland Isl. Mus.*, Georgia, 100 pp.

Rueda, L., Sagarminaga, R. J., Baez, J. C., Caminas, J. A., Eckert, S. A. and Boggs, C. (2006) Testing mackerel bait as a possible bycatch mitigation measure for the Spanish Mediterranean swordfish longline fleet. In *Frick, M., Panagopoulou, A., Rees, A. and* Williams, K (2006) *Book of Abstracts of the 26th Annual Symposium on Marine Turtle Biology and Conservation*, Island of Crete, Greece, 3–8 April 2006.

Ryder, C. E., Conant, T. A. and Schroader, B. A. (2006) Report of the Workshop on Marine Turtle Longline Post-Interaction Mortality. US Dept of Commerce, NOAA Tech. Memo. NMFS–F/OPR–29, 36p.

SAGARPA, Instituto Nacional de la Pesca (2003) Atención a solicitud de información del INP sobre: Captura incidental de tortuga en las pesquerías de tiburón, palangre de atún y picudos. http://www.inp.sagarpa.gob.mx/SoilicInforma/Solicitudes.htm .

Sales, G., Marcovaldi, M. A. and Giannini, F. (2006) Testing mitigation measures to reduce sea turtle incidential capture in longline fishing gear in Brazil. In *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques to reduce sea turtle bycatch in longline fisheries. NOAA Tech. Memo. NMFS –PIFSC–7.*

Shah, A., Watson, J., Foster, D. and Epperly, S. (2004) *Experiments in the Western Atlantic Northeast Distant waters to evaluate sea turtle mitigation measures in the pelagic longline fishery, Summary of statistical analysis.* NMFS , Pascagoula, MS, USA.

Southwood, A., Higgins, B., Brill, R. and Swimmer, Y. (2006) Chemoreception in loggerhead sea turtles: An assessment of the feasibility of using chemical deterrents to prevent sea turtle interactions with longline fishing gear. In: *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques to reduce sea turtle bycatch in longline fisheries. NOAA Tech. Memo. NMFS –PIFSC–7.*

Southwood, A. and Swimmer, Y. (2006) Refining post-release mortality estimates for sea turtles caught in fishing gear: An assessment of the impacts of entanglement on physiology and behavior. In *Frick, M., Panagopoulou, A, Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006* .

Spotila, J., Dunham, A., Leslie, A., Steyermark, A., Plotkin, P. and Paladino, F. (1996) Worldwide population decline of Dermochelys coriacea: are leatherback turtles going extinct? *Chelonian Conservation Biology* 2. 209–222.

Spotila, J. R., Reina, R. D., Steyermark, A. C., Plotkin, P. T and Paladino, F. V. (2000) Pacific leatherbacks face extinction. *Nature* 405, 529–530.

Steering Committee, Bellagio Conference on Marine Turtles (2004) *What can be done to restore Pacific turtle populations?* The Bellagio Blueprint for Action on Pacific Marine turtles. 24pp.

Steiner, T and Arauz R. (1998) Turtle-Safe Shrimp ™: Can It Help Save the Sea Turtles? *NOAA Tech. Memo. NMFS –SEFSC–415, 37–40.*

Stokes, L., Hataway, D., Epperly, S., Belskis, L., Bergmann, C., Watson, J. and Higgins, B. (2006) Evaluation of injury potential in incidentally captured loggerhead marine turtles (Caretta caretta) relating to hook size and baiting technique. In *Frick, M., Panagopoulou, A, Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine Turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006* .

Stone, H. H. and Dixon L. K. (2001) A Comparison of catches of swordfish, *Xiphias gladius*, and Other Pelagic Species from Canadian Longline Gear Configured with Alternating Monofilament and Multifilament Nylon Gangions. *Fish. Bull.* 99, 210–216.

Swimmer, Y. and Brill, R. (2001) Abstract. Methods aimed to reduce marie turtle interactions with longline fishing gear. In: *Proceedings of the 21st Annual Workshop on Sea Turtle Conservation and Biology. US NMFS , Pascagoula, MS, USA.*

Swimmer, Y. and Brill, R. (2002) Determining survival, migration, and diving patterns of sea turtles released from longline fishing gear using pop-up satellite archival transmitters. Presented at the *Fifteenth Meeting of the Standing Committee on Tuna and Billfish, 22–27 July 2002, Honolulu, Hawaii.. SPC, Noumea, New Caledonia.*

Swimmer, Y., Brill, R. and Laurs, M. (2002a) Behaviour and physiology experiments aimed at reducing pelagic longline interactions with marine turtles. Presented at the *Meeting of* *the American Society of Limnology and Oceanography. Victoria, British Columbia, Canada, 10–14 June 2002.*

Swimmer, Y., Brill, R. and Musyl, M. (2002b) Quantifying sea turtle mortality with PSATs. *Pelagic Fisheries Research Program PFRP Newsletter April–June 2002, 7(2):1–5.*

Swimmer, Y., Arauz, R., Ballestero, J., McNaughton, L., Higgins, B., McCracken, M. and Brill, R. (2004) Effects of bait colour on marine turtles-longline fishing gear interactions: Can blue bait reduce turtle bycatch in commercial fisheries? Presented at the *Seventeenth Meeting of the Standing Committee on Tuna and Billfish, 9–18 August 2004, Majuro, Republic of the Marshall Islands. SPC, Noumea, New Caledonia.*

Swimmer, Y., Arauz, R., Musyl, M., McNaughton, L. Ballestero, J. and Brill, R. (2004) Survivorship and dive behaviour of olive ridley (*Lepidochelys olivacea*) sea turtles after their release from longline fishing gear off Costa Rica. Presented at the *Seventeenth Meeting of the Standing Committee on Tuna and Billfish, 9–18 August 2004, Majuro, Republic of the Marshall Islands. SPC, Noumea, New Caledonia.*

Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques to reduce sea turtle bycatch in longline fisheries. *NOAA Tech. Memo. NMFS–PIFSC–7.*

Swimmer, Y., McNaughton, L. M., Southwood, A. and Brill, R. (2006a) Tests of repellent bait to reduce turtle bycatch in commercial fisheries. In *Swimmer, Y. and Brill, R. (2006) Sea turtle and pelagic fish sensory biology: Developing techniques to reduce sea turtle bycatch in longline fisheries. NOAA Tech. Memo. NMFS–PIFSC–7.*

Swimmer, Y., Sales, G., Guffoni, B. and Thome, J. C. (2006b) Marine turtles and longline fisheries interactions in Brazil. An update on field trials and post-release mortality and movements. *In Frick, M., Panagopoulou, A., Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006*.

Ulloa Ramírez, P. A. and González Ania, L. V. (1998) Incidence of Marine Turtles in the Mexican Longline Tuna Fisheries in the Gulf of Mexico. In: *Proceedings of the 18th International Symposium on Sea Turtle Biology and Conservation, Mazatlan, Sinaloa Mexico 3–7 March.* Abreu-Grobois, F. A., Briseno-Duenas, R. Márquez, R. and Sarti, L. (Compilers), 110.

Valqui, M., Cruz, A., Alfaro Shigueto, J.,Kelez Sara, S., Pajuelo, M., Mangel, J. and Melly, P. (2006) First year results of the hook substitution experiment to reduce marine turtle bycatch in Peru. In *Frick, M., Panagopoulou, A, Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006* .

Wang, J. H., McAlister, J., Fuxjager, M., Higgins, B. and Lohmann, K. J. (2006) Light sticks used in longline fisheries attract juvenile loggerhead marine turtles: Potential mitigation strategies. In: *Frick, M., Panagopoulou, A, Rees, A. and Williams, K (2006) Book of Abstracts of the 26th Annual Symposium on Marine turtle Biology and Conservation, Island of Crete, Greece, 3–8 April 2006.*

Wang, J. H., Boles, L. C., Higgins, B. and Lohmann, K. J. (2007) Behavioral responses of sea turtles to lightsticks used in longline fisheries. *Animal Conservation* 10: 176–182.

Ward, P., Robins, C. and Kreutz, D. (2005) *The Effect of Circle Hooks on Target and Non-Target Catches in Australia's Longline Fisheries. Stage 1: Feasibility of Experimental Approach.* Unpub' report. Bureau of Rural Sciences, Canberra.

Watson, J. W., Foster, D. G., Epperly, S. and Shah, A. (2002) *Experiments in the Atlantic northeast distant waters to evaluate sea turtle mitigation measures in the pelagic longline fishery.* Draft report on experiments conducted in 2001. NOAA Fisheries, May 23 2002.

Watson, J. W., Foster, D. G., Epperly, S. and Shah, A. (2003a) *Experiments in the Atlantic northeast distant waters to evaluate sea turtle mitigation measures in the pelagic longline fishery.* Report on experiments conducted in 2001 and 2002. NOAA Fisheries. March 5, 2003.

Watson., J. W., Hataway, B. D. and Bergmann, C. E. (2003b) *Effect of hook size on ingestion of hooks by loggerhead sea turtles.* Report of NOAA NMFS , Pascagoula, MS, USA.

Watson, J., Bergmann, C., Shah, A., Foster, D. and Epperly, S. (2004a) *Evaluation of 18/0 circle hook in the Gulf of Mexico Tuna Fishery: Report on experiments conducted in 2004.* NOAA Fisheries.

Watson, J. W., Foster, D. G., Epperly, S. and Shah, A. (2004b) *Experiments in the Atlantic northeast distant waters to evaluate sea turtle mitigation measures in the pelagic longline fishery.* Report on experiments conducted in 2001-2003. NOAA Fisheries. February 4, 2004.

Watson, J. W., Epperly, S. P., Shah, A. K. and Foster, A. G. (2005) Fishing methods to reduce sea turtle mortality associated with pelagic longlines. *Can. J. Fish. Aquat. Sci.* 62: 965–981.

Watson, J. W. and Kerstetter, D. W. (2006) Pelagic longline fishing gear: A brief history and review of research efforts to improve selectivity. *Marine Technology Society Journal, 40 (3) 6:11.*

Wetherall, J. A., Balazs, G. H., Tokunaga, R. A. and Yong, M. Y. Y. (1993) Bycatch of marine turtles in North Pacific high-seas driftnet fisheries and impacts on the stocks. *North Pacific Commission Bulletin* 53, 519–538.

Western Pacific Regional Fishery Management Council (2002) *Measures to reduce the incidental catch of sea turtles in the pelagic fisheries of the Western Pacific Region*. A regulatory amendment under the Pelagic Fishery Management Plan of the Western Pacific Region. Western Pacific Regional Fishery Management Council, January 31, 2002.

Witzell, W. N. (1984) The incidental capture of sea turtles in the Atlantic US Fishery Conservation Zone by the Japanese Tuna Longline Fleet, 1978–81. *Marine Fisheries Review* 46(3), 56–58.

Witzell, W. N. (1999) Distribution and relative abundance of sea turtles caught incidentially by the U.S. pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. *Fish. Bull*. 97:200–211.

Yeung, C. (1999) Estimates of Marine Mammal and Marine Turtle Bycatch by the U.S. Atlantic Pelagic Longline Fleet in 1998. *NOAA Tech. Memo. NMFS–SEFSC–430*, 26pp.

Yeung, C. (2001) Estimates of Marine Mammal and Marine Turtle Bycatch by the U.S. Atlantic Pelagic Longline Fleet in 1999–2000. *NOAA Tech. Memo. NMFS–SEFSC–467*, 43pp.

Yokota, K., Kiyota, M. and Minami, H. (2006a) Shark catch in a pelagic longline fishery: Comparison of circle and conventional tuna hooks. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia*.

Yokota, K., Minami, H. and Kiyota, M. (2006b) Measurement-points examination of circle hooks for pelagic longline fishery to evaluate effects of hook design. Presented at the *Second Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–18 August 2006, Manila, Philippines. WCPFC, Pohnpei, Federated States of Micronesia* .

Appendix 1: Intellectual Property

Crossing the Line DVD

- Produced by Hatchling Productions and Belldi Consultancy
- Funded by Fisheries Research and Development Corporation
- © FRDC, Hatchling Productions and Belldi Consultancy 2005

One in a Thousand DVD

- Produced by Hatchling Productions and Belldi Consultancy
- Funded by Fisheries Research and Development Corporation
- © Hatchling Productions, Belldi Consultancy and FRDC 2006

One in a Thousand Education Kit

- Written by Carolyn Robins and David Kreutz
- Funded by Fisheries Research and Development Corporation
- © FRDC and Belldi Consultancy 2006

Appendix 2: Staff

Carolyn Robins, Belldi Consultancy

David Kreutz, SeaNet Extension Program, OceanWatch Australia

Emma Bradshaw, Private Consultant

Appendix 3: Threats Faced by Marine Turtles

(Source: Robins *et al*., 2002a)

All species of marine turtle have high egg and hatchling mortality, but low adult mortality, excluding human-induced mortality events (Limpus, 1998). Historically, marine 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; Western Pacific Regional Fishery Management Council, 2002). 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. Spotila *et al*. (1996), when considering leatherbacks, argued that egg and hatchling; and also adult protection is vital for the survival of the species.

Frazer (1992) suggests that rather than looking only at marine turtle conservation as an issue of too few turtles, thereby solving the problem by releasing more hatchlings in the oceans, effort should also be directed at addressing each contributing factor separately, thereby reducing the negative impacts of human activities on turtle populations. These anthropogenic threats are varied. Examples, in no particular order, from Hutchinson and Simmonds (1991), Wetherall *et al*. (1993), Burger and Garber (1995), Limpus (1998), National Marine Fisheries Service (1999), Anon. (1999), Ruckdeschel, *et al.* (2000), and Dobbs (2001) include:

- Negative effects of pollution (pesticides, heavy metals, organochloride compounds, sewage effluent) sourced from the land and from boats, including pollution affecting feeding grounds and contributing to increases in disease,
- Ingestion of, and entanglement in, debris, including plastic bait bands, possibly causing injury, internal blockages, drowning, ulcers and toxic effects,
- Deaths from recreational fishing, including hooking and entanglement,
- Ingestion of, and coating in, oil droplets and tar in the water and on beaches, possibly causing choking, inhibition of movement and sub-lethal effects,
- Harvesting of meat and eggs for human consumption – commercial, subsistence and 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 marine turtles for fun or sport,
- Predation of eggs and hatchlings and destruction of beach dunes by feral, domestic 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, introduction of exotic vegetation and shading nest sites,
- Dredging and sand mining,
- Degradation of foraging habitats, including coral reefs and sea grass beds,
- Dynamite fishing,
- Marina, dock and jetty development,
- Human activity on nesting beaches, including vehicles and furniture, tourists disrupting nesting females and collapsing nests, injuries from discarded refuse, beach cleaning, compaction of sand, formation of tracks,
- Light pollution on nesting beaches,
- 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,
- Religious, ceremonial and other traditional uses,
- 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, injury, changes in movement and behaviour, and
- Boating strikes, including propeller and vessel collisions – recreational and commercial.

Appendix 4: Marine Turtles in Australian Waters

(Source: Robins *et al*., 2002b)

Loggerhead turtle (Caretta caretta)

Loggerheads have a distinctive large head compared to other marine turtles, five pairs of costal scales and generally a reddish-brown shell. 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 (Wetherell *et al*., 1993; Queensland Department of Environment and Heritage, 1994).

In Australia, loggerheads migrate from feeding areas around the north of Australia to nest sites along the eastern and western coastlines. They also range greater distances 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 and in Shark Bay, Western Australia. Little is known about male loggerheads (Queensland Department of Environment and Heritage, 1994; Environment Australia, 1998).

(Source: AFMA Observer Program)

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. Similar declines are occurring elsewhere in the world (Ruckdeschel *et al*., 2000). There have been, however, some positive trends in recent years.

Loggerheads, like all species of marine turtles, face many threats throughout their lifetime. These include mortality through commercial and recreational fishing, boat strikes and ingestion of discarded fishing line and rubbish, predation at rookeries by feral animals, indigenous harvesting, and coastal development negatively affecting 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). Although this impact has reduced due to the adoption of TEDs. The U.S. loggerhead turtle recovery plan in the Pacific (National Marine Fisheries Service and U.S.

Fish and Wildlife Service, 1998) notes that commercial fisheries, particularly longlining and net fisheries, pose serious threat to this species.

Leatherback turtle *(Dermochelys coriacea)*

Leatherbacks are the largest living species of marine turtle, sometimes weighing more than 500 kg with a carapace span of up to two metres. One specimen had a reported body mass of 916 kg (Eckert and Luginbuhl, 1988). Unlike all other marine turtle species that are 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.

Leatherbacks spend considerable amounts of time basking on the surface of the water, are able to live in colder waters and dive to greater depths in search of prey items than most other reptiles. They have species adaptations to manage high pressure and maintain a higher core body temperature higher than the surrounding water (Wetherall *et al.*, 1993; Queensland Department of the Environment and Heritage, 1994; Ruckdeschel *et al.*, 2000).

(Source: Doug Hazell AFMA Observer)

Leatherbacks migrate down both the Western Australian and Queensland coasts in considerable 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, recorded 1367 leatherbacks nesting there in 1988-1989 and by 1998–1999, this number had fallen to 117 individuals (Spotila *et al.*, 2000). Disastrous collapses have been seen elsewhere in the Pacific, with dramatic declines in numbers on many beaches and even disappearances of entire nesting colonies. A nesting colony in Mexico has fallen from 70 000 individuals in 1982 to less than 250 in 1998–99 (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, 2001). A nesting colony at Terengganu, Malaysia, has declined from over 3 000 nesting females in 1968 to two 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 contributes to 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 repeatedly blamed in recent years (Spotila *et al*., 2000).

Green turtle *(Chelonia mydas)*

Green turtles are the largest of the hard-shelled species, with adults often measuring over one metre 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 Environment and Heritage, 1994; Anon., 1999 Environment Australia, 1998). The green turtle is the only genuinely herbivorous marine turtle, feeding almost exclusively on seaweeds and seagrasses. However immature greens can be carnivorous. Unfortunately their herbivory makes the adults popular in 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 marine 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.

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 fishing operations, indigenous harvesting, boat strike and 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

with 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 endemic to the Australian continental shelf and occur in Queensland and the Northern Territory. 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. 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 marine 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). The species exhibits a unique mass nesting strategy or 'arribada'. In these 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 marine 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, while longliners in Coast Rica also annually kill thousands of individuals annually (Arauz, 2000).

Hawksbill turtle *(Eretmochelys imbricata)*

The most distinctive feature of the hawksbill turtle is its overlapping classic tortoiseshell-patterned shell, ranging from light amber to brown-black. Other features include a distinctive parrot-like beak, four pairs of costal scales and tow pairs of prefrontal scales (Queensland Department of Environmental and Heritage, 1994; Limpus, 1998; Ruckdeschel *et al*., 2000). 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 observed in more temperate regions down to northern New South Wales. Their diet is primarily sponges (Limpus, 1998), but they will also feed on seagrasses, soft corals and shellfish, 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 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, jewellery and souvenirs including stuffed specimens. There are also considerable numbers of eggs harvested on beaches, killing for meat, and mortality from drowning in fishing gear, boat strike and ingestion of marine debris. Although no definite research into population status has been conducted, the Australian population of hawksbill is suspected to be in decline (Limpus, 1998; Ruckdeschel *et al*., 2000).

Appendix 5: Generalised Life Cycle

(Report prepared by Dr Colin J. Limpus, Turtle Research, Queensland EPA)

Seven species of marine turtles are well recognised worldwide and five species have a global distribution in tropical and temperate waters. Two species have a restricted distribution: the flatback turtle is confined to the waters of the Australian continental shelf while the Kemp's ridley turtle occurs in the Gulf of Mexico and the north-western Atlantic Ocean. While some aspects of the nesting biology have been understood for centuries, since 1980 there have been major advances in many other aspects of marine turtle biology: stock identification with population genetics; temperature dependent sex determination; geomagnetic imprinting of hatchlings to the area of their birth; oceanic dispersal of post hatchlings; extended life to first breeding; fidelity of adult turtles to both their feeding and nesting areas; migratory dispersal of adults and population modelling.

Marine turtles have many common features in their life cycles that are summarised below.

Marine turtles utilise feeding grounds often far removed from the nesting beaches. With the onset of the breeding season adult males and females migrate to copulate near the nesting area. There is no pair bond between individuals and copulation may occur with several different partners during the mating season. At courtship the female stores the sperm from her mate(s) for use later in the breeding season. At the completion of mating the males depart, presumably returning to the distant feeding grounds. Each female moves to an area adjacent to her selected nesting beach and commences making eggs, fertilising them from her sperm store. Because of the mixture of sperm she carries, several males may contribute to the fertilisation of any one clutch. The female comes ashore, usually at night, to nest several weeks after her first mating. For those beaches fronted by reef flats, nesting coincides with the higher tidal levels. Within the one nesting season each female typically lays several clutches at about two-week intervals. During that two-week period she does not need to find a new mate, she moves just offshore from the nesting beach to make the next clutch of eggs, again fertilising them from her sperm store. The breeding turtles do not feed, or else feed to only a limited extent, while migrating, courting or making eggs at the nesting beach area. They live off the stored fat reserves they accumulated before the breeding season began.

Each female usually chooses to return to the same beach or island to lay several clutches within the one nesting season. However, several percent of females can be expected to lay on more than one beach within a few hundred kilometres of the initial nesting site. At the completion of the nesting season the females do not use the adjacent shallow water habitats as year round feeding grounds but return to their respective distant feeding grounds, each to the same area that she left at the start of her breeding migration. After two to eight years many of these females will make yet another breeding migration, each generally returning to nest on the same beach as before. This behaviour and the annual use of traditional nesting beaches have led to the assumption that a marine turtle returns to nest on the precise beach of her birth. In reality the homing is probably not that exact. Genetic studies suggest that the female returns to breed in the general region of her birth. For example, a turtle born in the southern Great Barrier Reef, when it grows up, should return to breed in the southern Great Barrier Reef or a turtle born in the Hawaiian Islands should return to breed in the Hawaiian Islands.

Females lay their eggs high up on the beach usually within the vegetated strand. No parental care is exercised. The incubation period, incubation success and the sex of the resulting hatchlings are a function of the temperature of the surrounding sand. A warm nest at mid incubation results in all or mostly female hatchlings while males come from cool nests. The eggs hatch about 7 - 12 weeks after laying (Miller, 1985). The hatchling turtles dig their way unaided and as a group through the 50cm or more of sand to the surface. On surfacing they immediately cross the beach to the sea. This hatchling emergence is almost entirely nocturnal. During the beach crossing they orient towards low elevation bright horizons. The hatchlings are imprinted to the dip and strength of the earth’s magnetic field at the beach. For most turtle rookeries only a small percentage of hatchlings is lost to terrestrial predators during the beach crossing. Immediately the hatchlings reach the water they begin oriented swimming into the wave fronts that takes them away from the beach and into deep water. The hatchling at this stage is living off a yolk-sac internalised just prior to hatching. Hatchlings do not feed while on the beach or while swimming out to sea. In coral reef areas when the hatchlings are crossing the reef flat, they are probably exposed to the greatest level of depredation during their life cycle. This is a period of transfer to predatory fish of nutrients derived from adult turtles via eggs and hatchlings. For all except flatback turtles, the hatchlings, on reaching the deep water areas, continue to swim out to sea and this activity presumably brings them under the influence of the open ocean currents where they drift for the first few years of their lives. The post-hatchling flatback turtles remain over the continental shelf. Post-hatchling turtles do not feed nor take up residence in the vicinity of where they were born.

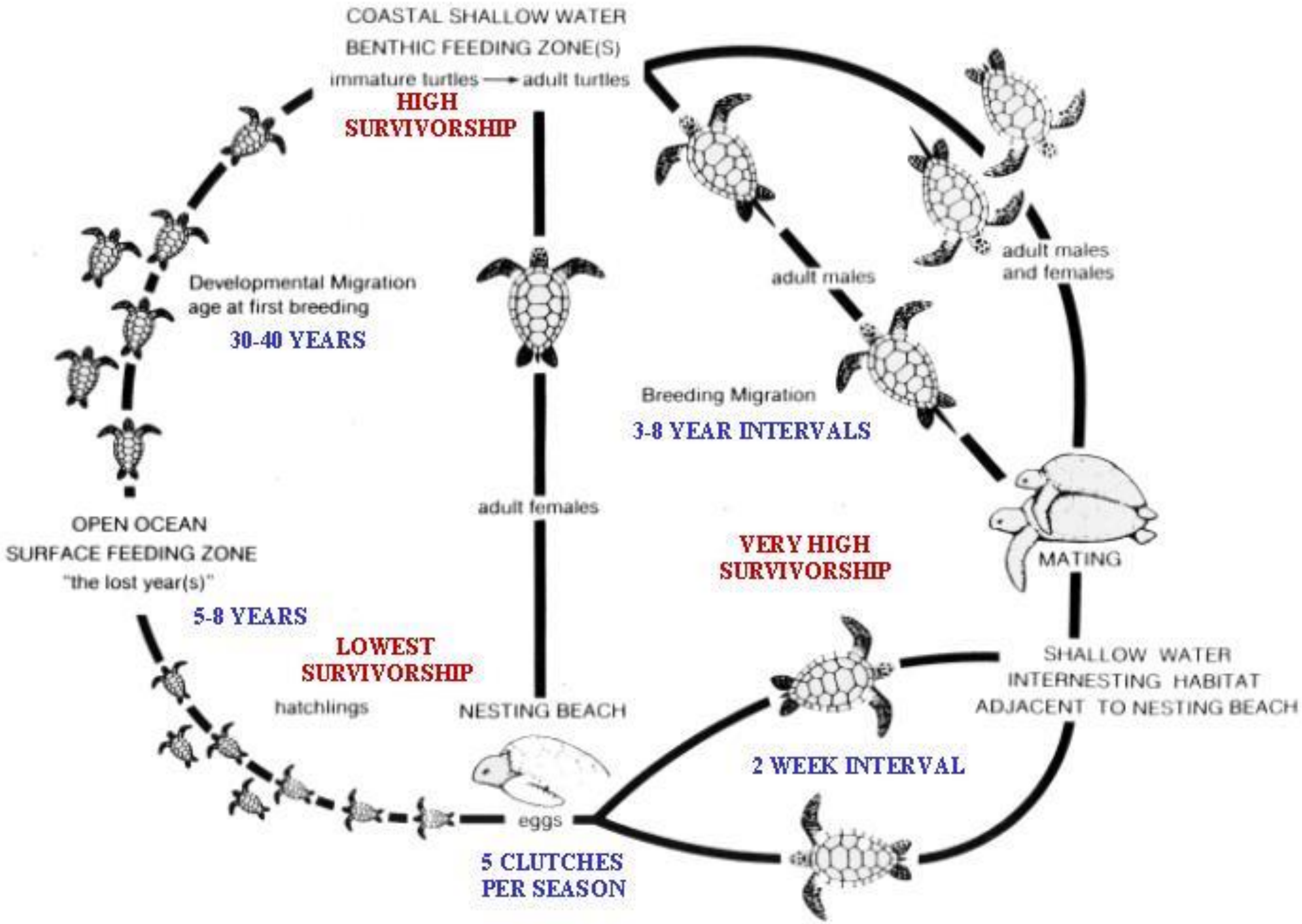
When the hatchlings disperse from the nesting beach they are virtually lost to study for the next few years. While in this drifting phase the turtles presumably feed on the macro-planktonic animals and/or algae at the surface. The young of all marine turtles except the leatherback turtle 'reappear' at about the size of a large dinner plate (curved carapace length 35-40cm, age undetermined but possibly 5-10 yr old). Loggerheads recruit at a larger size, >70cm in carapace length. At this size they take up residence in the shallow water habitats of the continental shelf, feeding principally at the bottom on plants and animals depending on the turtle species. Green turtles feed mostly on seaweed, sea grass, and mangrove fruits. Loggerhead turtles feed mostly on shellfish and crabs. Flatback turtles feed mostly on soft corals and sea pens. Olive ridley turtles feed mostly on small species of crab and shellfish. Hawksbill turtles feed mostly on sponges and seaweeds. These turtles will also eat jellyfish and Portuguese man-of-war on occasions. These immature turtles may remain in the one feeding ground for extended periods, perhaps years, before moving to another major area. Several such shifts may occur in the life of the turtle in this coastal shallow water benthic-feeding phase. The offspring of a particular female will not all recruit to the same feeding area but are expected to recruit throughout the entire region occupied by the breeding unit. The leatherback turtle, which remains an inhabitant of oceanic waters for almost all its life, feeds mostly on jellyfish.

Tagging studies of turtles living within the Great Barrier Reef show that they are many decades old at first breeding and can have a breeding life spanning many more decades. At no stage in their life are marine turtles free of depredation. The young to adult sized turtles are potential prey to large cod, grouper, sharks, crocodiles, and killer whales. However in Australia and the neighbouring countries of South East Asia and the western Pacific Ocean, human actions continue to be the most significant threat to survival of our marine turtles.

Studies in the Great Barrier Reef indicate that marine turtles have very high annual survivorship throughout their lives in the absence of human impacts. This high annual survivorship appears to be essential for marine turtles to maintain population stability. Small increases in annual mortality over extended periods at any stage of the life cycle can be expected to cause population declines.

Green and olive ridley turtles have been harvested in large numbers especially for meat. The hawksbill turtle has been hunted excessively for tortoiseshell. All species are hunted for leather, oil and their eggs. Incidental capture in fishing gear can also cause significant mortalities of marine turtles, especially in prawn trawls, drift-nets, large mesh set-nets and long-lines. Terrestrial predators such as pigs, foxes, dogs and varanid lizards can cause the excessive loss of turtle eggs. In some areas, ingestion of plastic and other debris has been identified as a significant cause of mortality. Boat strikes are common in shallow areas with high density boating activity. Wherever there has been organised large-scale harvesting or killing of the turtles and/or their eggs over several decades, the turtle population has undergone significant decline. No one has ever successfully managed marine turtles at stable population levels while subjecting them to large-scale mortalities.

Generalised marine turtle life cycle



Appendix 6: FAO Guidelines to Reduce Marine Turtle Mortality

Drafted and agreed upon at the Technical Consultation on Sea Turtle Conservation and Fisheries, Bangkok, Thailand, 29 November-2 December 2004 (FAO, 2005)

Preamble

The FAO Code of Conduct for Responsible Fisheries calls for sustainable use of aquatic ecosystems and requires that fishing be conducted with due regard for the environment. Some marine turtle stocks are seriously impacted by fishing and require urgent attention. Because of the critical status of these stocks a broad suite of measures is recommended that includes reduction of fishery-related mortality in addition to other conservation measures.

Because of the concern regarding the status of marine turtles and the possible negative effects of fishing on these populations, the twenty-fifth Session of the FAO Committee on Fisheries (2003) raised the question of marine turtle conservation and interaction with fishing operations and requested that a Technical Consultation be held on the subject matter to consider, inter alia, the preparation of guidelines to reduce marine turtle mortality in fishing operations. These guidelines respond to the request of the Committee on Fisheries (COFI) and have been developed on the basis of the report of the Expert Consultation, held in Rome in March 2004.

These guidelines are intended to serve as input to the preparation of FAO Technical Guidelines as well as to offer guidance to the preparation of national or multilateral fisheries management activities and other measures allowing for the conservation and management of marine turtles. These guidelines are voluntary in nature and non-binding. They apply to those marine areas and fisheries where interactions between fishing operations and marine turtles occur or are suspected to occur. They are global in scope but in their implementation national, subregional and regional diversity, including cultural and socio-economic differences, should be taken into account.

These guidelines are directed towards members and non-members of FAO, fishing entities, subregional, regional and global organizations, whether governmental or nongovernmental concerned with fisheries management and sustainable use of aquatic ecosystems.

All activities associated with these guidelines should be undertaken with the participation and, where possible, cooperation and engagement of fishing industries, fishing communities and other affected stakeholders.

Implementation of the guidelines should be consistent with the Code of Conduct for Responsible Fisheries as well as with the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem with regard to ecosystem considerations and based on the use of best available science.

1. Fishing operations

A. Appropriate handling and release.

In order to reduce injury and improve chances of survival:

(i) Requirements for appropriate handling, including resuscitation or prompt release of all bycaught or incidentally caught (hooked or entangled) marine turtles.

(ii) Retention and use of necessary equipment for appropriate release of bycaught or incidentally caught marine turtles.

B. Coastal trawl

(i) In coastal shrimp trawl fisheries, promote the use of turtle excluder devices (TEDs) or other measures that are comparable in effectiveness in reducing marine turtle bycatch or incidental catch and mortality.

(ii) In other coastal trawl fisheries, collect data to identify marine turtle interactions and conduct where needed research on possible measures to reduce marine turtle bycatch or incidental catch and mortality.

(iii) Implementation of successful methodologies developed as a result of B(ii).

C. Purse seine

(i) Avoid encirclement of marine turtles to the extent practical.

(ii) If encircled or entangled, take all possible measures to safely release marine turtles.

(iii) For fish aggregating devices (FADs) that may entangle marine turtles, take necessary measures to monitor FADs and release entangled marine turtles, and recover these FADs when not in use.

(iv) Conduct research and development of modified FADs to reduce and eliminate entanglement.

(v) Implementation of successful methodologies developed as a result of C(iv).

D. Longline

(i) Development and implementation of appropriate combinations of hook design, type of bait, depth, gear specifications and fishing practices in order to minimize bycatch or incidental catch and mortality of marine turtles.

Recent research has shown positive results for:

- Use of large circle hooks with no greater than a 10 degree offset, combined with whole fish bait. These measures have shown to be effective in reducing marine turtle interactions and mortality;

- Arrangement of gear configuration and setting so that hooks remain active only at depths beyond the range of marine turtle interaction; and

- Retrieval of longline gear earlier in the day and reducing soak time of hooks.

(ii) Research should include consideration of the impact of various mitigation measures on marine turtles, target species and other bycaught or incidentally caught species, such as sharks and seabirds.

(iii) Retention and use of necessary equipment for appropriate release of bycaught and incidentally caught marine turtles, including de-hooking, line cutting tools and scoop nets.

E. Other fisheries

(i) Assessment and monitoring of marine turtle bycatch or incidental catch and mortality in relevant fishing operations.

(ii) Research and development of necessary measures for reducing bycatch or incidental catch or to control mortality in other fisheries with a priority on reducing bycatch or incidental catch in gillnet fisheries.

(iii) In other setnet fisheries, collect data to identify marine turtle interactions and conduct when needed research on possible measures to reduce marine turtle bycatch or incidental catch and mortality.

(iv) Implementation of successful methodologies developed as a result of E (ii) and (iii).

F. Other measures as appropriate for all fishing practices

(i) Spatial and temporal control of fishing, especially in locations and during periods of high concentration of marine turtles.

(ii) Effort management control especially if this is required for the conservation and management of target species or group of target species.

(iii) Development and implementation, to the extent possible, of net retention and recycling schemes to minimize the disposal of fishing gear and marine debris at sea, and to facilitate its retrieval where possible.

2. Research, monitoring and sharing of information

A. Collection of information and data, and research

(i) Collection of data and information on marine turtle interactions in all fisheries, directly or through relevant regional fishery body (RFBs), regional marine turtle arrangements or other mechanisms.

(ii) Development of observer programmes in the fisheries that may have impacts on marine turtles where such programs are economically and practically feasible. In some cases financial and technical support might be required.

(iii) Joint research with other states and/or the FAO and relevant RFBs.

(iv) Research on survival possibilities of released marine turtles and on areas and periods with high incidental catches.

(v) Research on socio-economic impacts of marine turtle conservation and management measures on fishers and fisheries industries and ways to improve communication.

(vi) Use of traditional knowledge of fishing communities about marine turtle conservation and management.

B. Information exchange

(i) Sharing and dissemination of data and research results, directly or through relevant RFBs, regional marine turtle arrangements or other mechanisms.

(ii) Cooperation to standardize data collection and research methodology, such as fishing gear and effort terminology, database development, estimation of marine turtle interaction rates, and time and area classification.

C. Review of the effectiveness of measures

(i) Continuous assessment of the effectiveness of measures taken in accordance with these guidelines.

(ii) Review of the implementation and improvement of measures stipulated above.

3. Ensuring policy consistency

A. Maintaining consistency in management and conservation policy at national level, among relevant government agencies, including through inter-agency consultations, as well as at regional level.

B. Maintaining consistency and seeking harmonization of marine turtle management and conservation-related legislation at national, sub-regional and regional level.

4. Education and training

A. Preparation and distribution of information materials such as brochures, manuals, pamphlets and laminated instruction cards.

B. Organization of seminars for fishers and fisheries industries on:

- Nature of the marine turtle-fishery interaction problem
- Need to take mitigation measures
- Marine turtles species identification
- Appropriate handling and treatment of bycaught or incidentally caught marine turtles
- Equipment to facilitate rapid and safe release
- Impacts of their operations on marine turtles
- Degree to which the measures that are requested or required to adopt will contribute to the conservation, management and recovery of marine turtle population.
- Impacts of mitigation measures on profitability and success of fishing operations
- Appropriate disposal of used fishing gear

C. Promotion of awareness of the general public of marine turtle conservation and management issues, by government as well as other organizations

5. Capacity building

A. Financial and technical support for implementation of these guidelines in developing countries.

B. Cooperation in research activities such as on status of marine turtle incidental catch in coastal and high seas fisheries and research at foraging, mating and nesting areas.

C. Establishment of a voluntary support fund.

D. Facilitation of technology transfer.

6. Socio-economic and cultural considerations

A. Taking into account :

(i) socio-economic aspects in implementing marine turtle conservation and management measures.

(ii) cultural aspects of marine turtles interactions in fisheries as well as integration of cultural norms in marine turtle conservation and management efforts.

(iii) marine turtle conservation and management benefits to fishing and coastal communities, with particular reference to small-scale and artisanal fisheries.

B. Promotion of the active participation and, where possible, cooperation and engagement of fishing industries, fishing communities and other affected stakeholders.

C. Giving sufficient importance to participatory research and building upon indigenous and traditional knowledge of fisherfolk.

7. Reporting

Reporting on the progress of implementation of these guidelines as part of Members' biennial reporting to FAO on the Code of Conduct for Responsible Fisheries and, as appropriate, and, voluntarily, to other relevant bodies such as regional marine turtle conservation and management arrangements.

8. Consideration of other aspects of marine turtle conservation and management

Fishers, research institutions, management authorities and other interested parties dealing with fisheries conservation and management should collaborate with relevant

conservation and management bodies, at national, sub-regional and regional level, in the following subject matters:

A. Collection and sharing of information on marine turtles relative to:

(i) Biology and ecology (population dynamics, stock identification, behaviour, diet selection, habitats, breeding, nesting, foraging, migration patterns/areas, nursery grounds, etc).

(ii) Sources of mortality other than fisheries.

(iii) Status of marine turtle populations, including human-related threats.

B. Improvement and development of conservation and management measures applied throughout the marine turtle life cycle (habitat/ nesting beach protection, enhancement of marine turtle populations).

C. Promotion, as appropriate, of participation in regional marine turtle conservation and management arrangements with a view to cooperate on marine turtle conservation and management.

Appendix 7: General Workshop Agenda

Topic	Time	Presenter
Introduction and welcome	5 mins	Organiser

- Why are we here – turtles and fisheries
- Introduce presenters
- Agenda

Biology of marine turtles	20 mins	Turtle scientist

- Evolution
- Characteristics – body shape and use
- Migration
- Breeding

Threats and endangered status	15 mins	Turtle scientist

- Hatchling vs adult mortality
- Mortality events and scales where possible
- Gear types
- Solutions – TEDs (embargo), closure etc
- Mitigation vs survival

Scientific research to date	10 mins	Mitigation researcher

Who has done research and where it has occurred

- Mitigation
  - Bait dying, type and threading
  - Hook type and depth
  - Gear configuration
  - Scare tactics (floats etc)
- Mortality and behaviour
  - Mortality results
  - Satellite tagging

Morning tea	15 mins	

Seabird handling	10 mins	Bird vet

- Handling
- Dehooking
- Retrieving

General marine turtle handling	10 mins	Turtle scientist

- Safety – biting and flippers
- Picking up – number of crew and where to hold
- Effect of injuries – feeding and breeding problems
- Comatose/drowned turtles
- Recovery position

Handling Guidelines	20 mins	Liaison Officer

- Spotting the turtle
- Retrieving the turtle to the boat
- Assess options to lift or release

- Small turtles
    - How to lift
    - Remove gear (not detailed)
    - Record
    - Release
- Large turtles
    - How to restrain
    - Remove gear
    - Record
    - Release

Handling gear - demo — 15 mins — Liaison Officer

- Lifting gear
- Linecutters
- Dehookers
- Data sheets

Species identifications — 15 mins — Turtle scientist

- Instructions
- Examples and wrong IDs
- Testing

Lunch — 30 mins

Scientific research — 35 mins — Turtle scientist

- Measuring
- Tagging
    - Conventional
    - Satellite
- Genetic analysis
    - Whole carcasses – stomach etc
    - Hatchling

Recording — 20 mins — Data Analysist

- Importance of reporting capture event
- Information to record
- Tag details
- Photos

Wrap up — 10 mins — Organiser

- What to do now
- Contact numbers

Appendix 8: Data Sheets

To be completed for each shot and if a turtle is sighted or caught

DATE **NAME** **BOAT**

GEAR DETAILS TO BE COMPLETED FOR EACH TRIP/SHOT

Type of hooks used ________ ________ ________ ________
(circle/tuna/J, size, stainless or not)

Percentage of each type ______% ______% ______% ______%
Bait ________ ________ ________ ________
(include size if relevant)

Percentage of each type ______% ______% ______% ______%

Lightsticks (circle) none 100% of hooks % of hooks ☐

Colours (circle) all Blue Green Yellow Orange Pink Other ____________

Design (circle) standard / not standard – describe the design or draw picture

Water temp ________ Water depth __________ Other info ________________

Weather conditions ____

CAPTURE DETAILS TO BE COMPLETED WHEN A TURTLE IS SIGHTED OR CAUGHT
Position of capture ____________ lat ____________ lon

Time of capture ________ am / pm Time taken to release ____hrs ____ mins

Hook of capture type ____________ size _______ stainless steel yes/no

Lightstick on capture hook yes / no Blue Green Yellow Orange Pink Other ________

If no, number of snoods to nearest lightstick ________

Snoods to nearest float ________ metres and/or _________ number

Estimated depth of hook ________ metres

Position in longline on hauling (circle) first ¼ second ¼ third ¼ last ¼

Type of capture (circle) mouth hooked throat or gut hooked entangled exter. hooked

Part of body (circle) mouth neck head front flipper hind flipper shell tail other ________

TURTLE DETAILS TO BE COMPLETED WHEN A TURTLE IS SIGHTED OR CAUGHT
Species (circle) leatherback loggerhead olive ridley flatback green hawksbill
unknown shelled turtle unknown species

Carapace length measured / estimated _________ cm Tail length _______ cm

Tag number/s _____________________ Photo (label with date) yes / no

Health status on capture (circle) healthy dead injured comatose

Health status on release (circle) healthy dead injured comatose

Treatment (circle) all gear removed retaining hook trailing _____metres of line

Genetic samples taken (circle) yes / no Number on vial _____

Dehooker/ Linecutter report form

Vessel	Port	Skipper	Moon Phase	Bait	

Date	**Person**	**Tool used** 1 - 8 (see below)	**Hook type/ size**	**Animal**	**Size** (estimated)		**Type of hooking** Deep, throat, mouth, fin, body	**Dead / Alive** removing hook (circle)	**Hook out** (circle)	**Time taken** min:sec	**Kept/ Return** (circle)	**Life Status** If return 0 - 5	**Ease of use** Rated 1 - 5 easy - hard	**Other**
					Length (cm)	Weight (kg)								
								D / A	YES NO		K / R			
								D / A	YES NO		K / R			
								D / A	YES NO		K / R			
								D / A	YES NO		K / R			
								D / A	YES NO		K / R			
								D / A	YES NO		K / R			
								D / A	YES NO		K / R			
								D / A	YES NO		K / R			
								D / A	YES NO		K / R			

Tools

1. Yellow Line cutter
2. Blue Dehooker (12')
3. J-Style Dehooker (16")
4. Bird Dehooker (16")
5. Turtle Dehooker (16")
6. Thick PVC Conduit
7. Thin PVC Conduit
8.
9.

'Life Status' Codes

0 = Dead and damaged
1 = Dead and in rigour (stiff)
2 = Dead and flexible
3 = Alive, just
4 = Alive and sluggish
5 = Alive and vigorous

Masters' Signature

Date

Appendix 9: Fisher Information Handout

Marine turtle research in Australia's longline fisheries

Carolyn Robins (0418 463 099)

David Kreutz (0432 683 147)

October 2005

Marine turtle populations have declined worldwide over the last century. Even though turtles are rarely caught in many fisheries, some populations are considered to be in danger as a result of high mortality rates associated with interactions with fishing gear. Over the last decade, pelagic longline fisheries have received considerable attention and criticism over unacceptable levels of bycatch, including marine turtles. Some longline fisheries around the world are catching and killing significant numbers of marine turtles during their fishing operations. Many of these deaths can be prevented through education in correct handling/release techniques and through an appreciation of why fishers need to do all they can to prevent these deaths.

Although the levels of turtle interactions in our fisheries are relatively low, the potential exists for current interaction levels to be considered unacceptable in the national and international arena. There is a pressing need for verified data concerning Australian longline interactions with turtles and for the issue of turtle bycatch to be addressed.

(Photo: Doug Hazell - observer)

Aim of this information paper

The aim of this paper is to provide information to the ETBF and WTBF fishers on the marine turtle project currently underway in Australia. This Fisheries Research and Development Corporation (FRDC) and AFMA funded project, which commenced in July 2003, is due for completion in December 2005. A final report with a full analysis of fisher and observer data will be available from FRDC or the authors.

The objectives of the project are to:

1. Conduct port workshops covering marine turtle conservation awareness, marine turtle handling and data collection.
2. Produce a DVD demonstrating marine turtle handling guidelines.
3. Collect biological data and samples by trained volunteer fishers from the Australian pelagic longline fleets (national and international research projects).
4. Test a selection of handling tools (linecutters and dehookers) and recommend designs most suitable for the Australian longline operations.

Progress to date

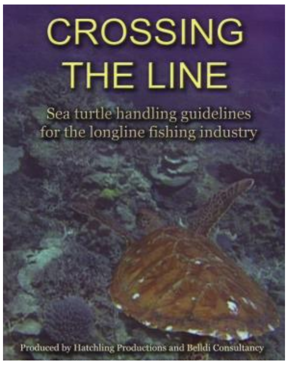
Port workshops

Marine turtle port workshops have been held in Mooloolaba, Fremantle and Ulladulla. These workshops covered the 'marine turtle-longline' issue (nationally and internationally), turtle biology and conservation, safe on-board and in-water handling guidelines, collection of data and samples, mitigation measures.

Workshops were attended by around 60 fishers including permit holders, skippers and crew. At the Mooloolaba workshops Col Limpus from Qld National Parks led informative and entertaining discussions on the life-cycle of turtles and threats they face. The workshops were well received by the fishers, but unfortunately fewer fishers attended than expected. The turtle expert for Perth workshops was Bob Prince from the Western Australian Department of Conservation and Land Management.

If anyone has a question on what to do with a turtle or problems with correct handling either call Carolyn or David for assistance. This includes if you have, or find, an injured turtle when returning to port and wish bring it back for veterinary treatment. A copy of the recommended turtle handling guidelines is attached.

Training film



Crossing the line, a DVD that covers everything you need to know about marine turtles, has been produced (by Belldi Consultancy and Hatchling Productions) and distributed (by AFMA) to owners and skippers. The film provides information on turtle handling techniques that are easy to adopt and safe for the crew and the turtle. The intention is for all fishers, especially new crew, to watch the film so they know what to do if a turtle is caught.

The DVD has also been distributed to many other nations and is being used to educate fishers, observers and government officials in a number of countries that have their own longline fleets. The DVD will help many turtle populations around the world. With fishers from other fisheries, especially those that catch and kill high numbers of turtles, better educated in turtle handling techniques - more turtles will survive the hooking event. WWF will be providing funding to dub the film into Bahasa (Indonesian). This will allow the messages conveyed in the film to reach even more fishers around the world.

Special thanks go to Bernie Manston, Josh Hamlet, Warrick Allen, Chris Waghorn and all those at DeBretts who assisted during the making of the film.

A special thanks to Col Limpus (Qld National Parks), one of the most respected turtle scientists in the world, who has been invaluable to the project in too many ways to list.

If you wish to obtain a copy call Carolyn or David. Don't forget to check-out the Slideshow for photos on the making of the film and if you want to know more go to 'Life History of Marine Turtles' in the special-features menu. Please note that the DVD needs either external speakers or headphones to play on computers.

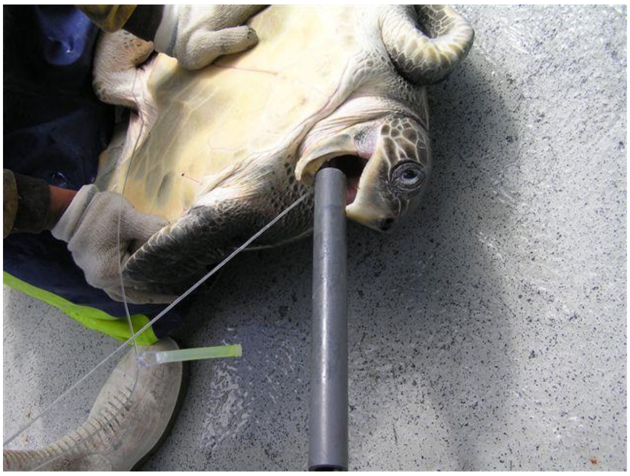
Samples collected

After attending workshops some fishers and the observers agreed to flipper-tag, record extra data and collect genetic samples from turtles they catch.

- Eight turtles have been tagged with the information sent to Qld National Parks,
- One turtle has been tracked using a satellite tag (see Andy's travels below),
- Six genetic samples have been taken from live turtles,
- Two dead turtles have provided stomach contents and genetic samples, and
- Thirty-nine turtles were reported (33 interacting and 6 sighted but not caught).

Handling tools

In conjunction with Seanet we purchased thirteen sets of different styles of dehookers and linecutters for trial in the fishery (by fishers and observers). Very quickly the participating fishers determined the most suitable tools for our fisheries. These were the PVC-covered short dehooker, the 3-piece long dehooker and the 3-piece linecutter.



Although some fishers were sceptical of their usefulness, with practice most are now using them during routine fishing operations. They have been found to be effective for not only safely releasing turtles, but also for handling target catch, byproduct and other bycatch.

The trial was so successful AFMA and Seanet (with National Heritage Trust funding) purchased a set of release equipment for each Australian longline vessel. The correct use of the devices is demonstrated in two DVDs – *Crossing the Line* and *Hooks Out Cut the line* – produced by Seanet.

Achievements and where to from here

The project has been successful and has made a number of achievements including:

- An expansion of our knowledge of the marine turtle issue for the Australian longline fisheries. We now have data on marine turtle interactions that helps your industry to address the turtle bycatch issue.
- An increased awareness of the marine turtle issue (and possible implications for our fisheries) by fishery managers and policy makers.
- A better understanding by fishers of correct handling and release techniques for hooked or entangled turtles through workshops and the DVD. This is not only Australian fishers, but many from around the world.
- Data and sample collection that will benefit marine turtle research, and ultimately turtle stocks.
- The determination of the most suitable dehookers and linecutters for our fisheries. This has led to the supply of release equipment sets to all Australian vessels.
- An appreciation by many scientists and managers, nationally and internationally, that the Australian longline fisheries are addressing their marine turtle issues and helping many fisheries throughout the rest of the world in the process.

Even though this project is almost completed fishers still need to:

- Accurately record every turtle interactions in your log with information on the event. This should include type of interaction (hooking or entanglement) and position of hook (mouth, gut, flipper etc), health of turtle on release and if it retains any gear, turtle length (including method of measuring), tag numbers and any information you think may also be important.

- Ensure all crew are ‘turtle aware’ by watching the film and reading literature to make sure they know what to do if turtle interaction occurs.
- Continue to use dehookers and linecutters so you become proficient in their use.
- Assist the observers who will continue to collect data and samples for research projects.
- If you wish to tag turtles or take genetic samples from live turtles contact Carolyn for instructions and equipment. An important thing to remember is that the only practical and cost-effective way to collect data and samples from turtles in the open ocean is through cooperative fisher-scientist projects.
- If possible, supply dead turtles that have been caught or hatchlings that have been found in fish stomachs to Dr Colin Limpus (Qld National Parks) for genetic research. The samples need to be frozen in a plastic bag and labelled with the date and position of capture. **Call Carolyn for a permit to hold turtle samples before you freeze the turtles and before you return to port with samples for collection**. It is illegal to hold a dead turtle on your boat without a permit.
- Remain involved with mitigation research in your fleet. We all have the same ultimate purpose – a long-term, sustainable and profitable Australian longline fleet. We cannot achieve this without adequately addressing our bycatch issues.

Andy's travels

ANDY is a large immature olive ridley turtle (51cm curved carapace length) that was captured by the longline vessel '*Ocean Dawn'* during Dec 2004. She/he was flipper tagged (K29784), had a small skin sample removed for genetic analysis and had a satellite tag fitted before release.

Andy was named after AFMA observer Andrew Bayne, who connected the sat tag to his/her shell. Andrew continues to conduct marine turtle research on top of his regular observer duties.

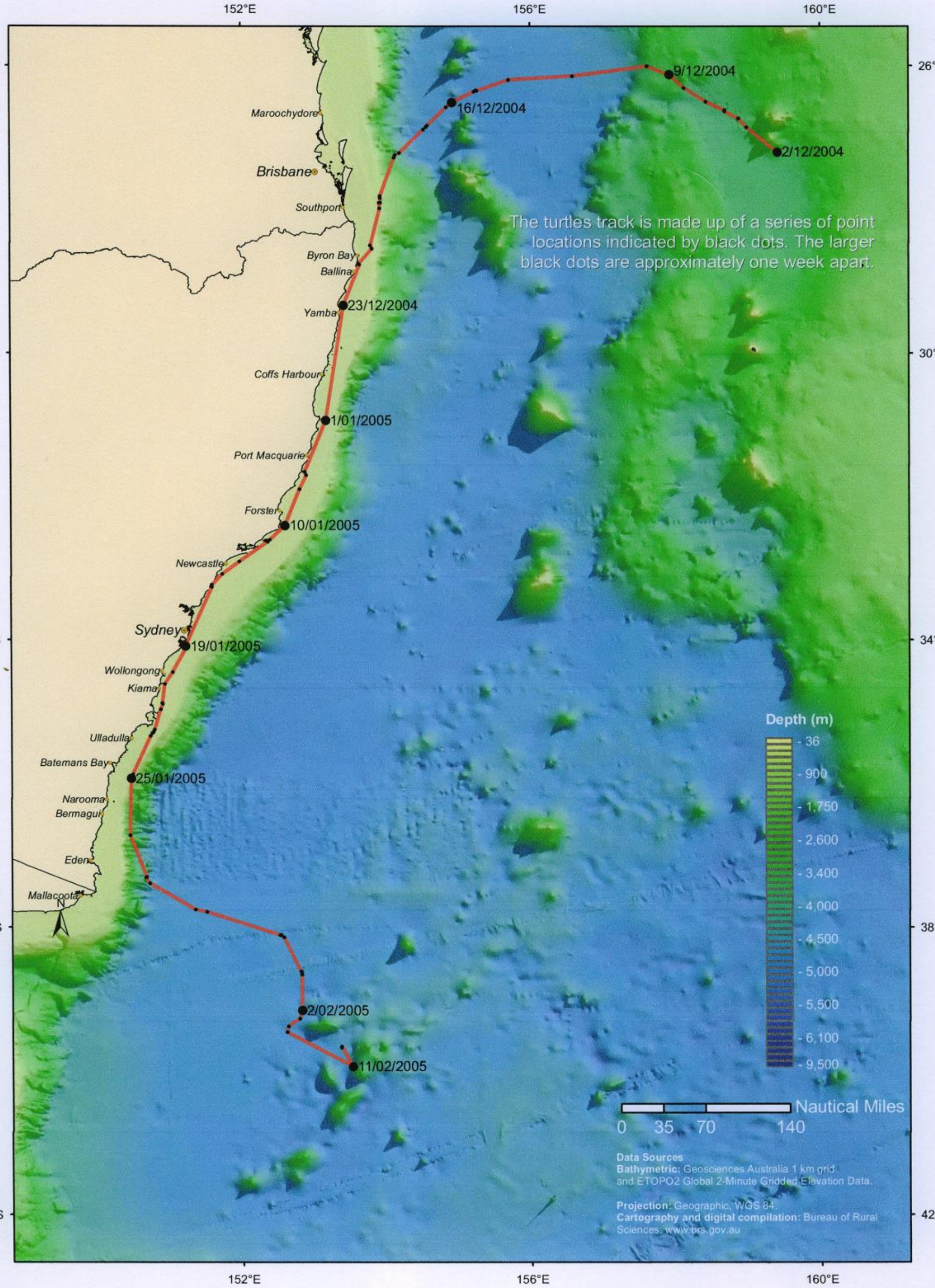
In Andy's case, the turtle was captured by superficial hooking on the flipper on 1 Dec 2004. Following successful removal of the hook on board the vessel and data recording, the turtle was fitted with a Sirtrack 0.5 watt transmitter powered by 4 AA cell batteries.

Andy was released on 3 Dec over the Gifford seamount in the Coral Sea off Queensland, moved west into continental shelf waters and continued to move south along the NSW coast. By 31 Jan, Andy had moved offshore into the Tasman Sea! On 14 Feb the tag failed and transmission ceased, probably due to the tag getting detached from the shell.

Andy traveled over 4,000 kilometers in a ten week period. Scientists consider it amazing that an Olive Ridley could move so fast in so short a time and also travel so far south.

We have applied for funding to purchase more satellite tags for observers and fishers can continue to be involved in this type of research. The movement patterns of oceanic-pelagic foraging marine turtles off the eastern Australian coast are virtually unknown and every turtle tracked during this stage of their life improves the gaps in our knowledge of these amazing creatures.

Andy the Turtle



Appendix 10: Sample of Reviews Received on *Crossing the Line* DVD

I would like to thank you for the Marine Turtle Education kits you sent to be used at our district science forum in November. They are a wonderful resource and were very much appreciated. Have a great Christmas!

Kind regards

Wondai State School P – 10, Queensland

Yesterday I visited a school doing a turtle talk, with freshwater turtles and your DVD. The DVD was received well and the school is thinking of getting a copy. Lots of photos were taken of happy little kids and a star stuck turtle.

Thank you very much for your help Ric.

Today we received Education Kit + DVD of "One in a Thousand". Thank you very much, we hope it will increase community awareness in turtle conservation in Pangumbahan.

Best regards,

iskandar

Turtle Conservation Group of Pangumbahan – West Java Indonesia,

Indonesia

Just a note to say the kit was very successful - the children loved the DVD footage regarding the hatchlings, laying of the turtle eggs and the underwater scenes - a great background to build on regarding their awareness of the plight of the turtle. This resource will be used by the older children in the future as it is to be kept in the library.

Thanks again

Christine

Nairne Primary School

Nairne SA 5252

ps

The coloring pages I enlarged & they were a hit also!

Good evening, just a few words to let you know I have received One in a Thousand DVD and Education Kit. Thank you so very much for sending it to me and I am really delighted with it. For someone who is passionate about sea turtles and your country, this was a wonderful birthday gift (it arrived the day after). Thank you so very much once again and keep up the good work for the turtle's sake. Warmest Regards, Leonor

Maria Leonor Sardinha

BELGIUM (Costa Rica nesting beach volunteer)

I received the DVDs and had a quick chance to watch them. I think they indeed will be beneficial to the project. Thank you very much for sending them to me it's a great help for the project, as well as all the teacher notes and extras on the DVDs. I will have to see how the translation thing goes but it may indeed be ok to show to the schools around the project.

thanks again

Adrian

Baan Talae Nork Sea Turtle Workshop (Thailand)

Thanks for sending the Marine Turtle Education Kit. I plan to use it in some of the integrated learning programs for next year so it will be very useful.

Thanks again.

Sue

Northern Territory Open Education Centre
CASUARINA NT 0811

Thanks Thanks thanks..

Very beautiful the Marine Turtle education Kit.

Abrazo

Regards

Ale

Karumbé, Uruguay

Thank you so much for the turtle education kit you sent. It is very interesting and I am sure it will be useful in our education work. Thank you again.

Regards,
Rahayu WWF-Malaysia

Thanks for the marine turtle DVD. The whole package is great, and my daughter, who is 20mths and has never really shown any interest in TV, loves the DVD too much - she has seen it so many times now and sits glued to the screen each time.

Cheers
Mark (Darwin)

Appendix 11: Pelagic Longline Fisheries Marine Turtle Interaction Rates

Sections based on either fishing grounds, nation's fleet or fishery may include information from more than one publication. Different estimates may consider different time frames, be derived from different data sources or be estimated using different data analysis methods, or be updated estimates.

Antigua/Barbuda longline fishery

- The longline fishery in Antigua/Barbuda is estimated to catch over 100 loggerheads and leatherbacks/year (Fuller *et al.,* 1992 cited in National Marine Fisheries Service Southeast Fisheries Science Center, 2001).

Australian Eastern Tuna and Billfish Fishery

- A 2002 review project on Australian longline fisheries and marine turtle interactions (Robins *et al.*, 2002a) used fisher interviews in the ETBF and WTBF to estimate a marine turtle catch rate of 0.024 turtles/1000 hooks (with a standard deviation of 0.027). This equates to an estimated total interaction rate for 2001 of 402 individuals (with 95%confidence limits of 360 to 444) for both fisheries, or assuming 1000 hooks are set/day fishing, this equates to one turtle caught for every 40 days fishing by each vessel (using days fished as reported in logbooks for 2001). The confidence interval surrounding the estimate from the fisher interviews should be considered an underestimate as it takes into account the sample size, but not the possible inaccuracy of the data from the fisher interviews.
- The total estimated catch of marine turtles in the ETBF from observer records (4% coverage) (July 2004 to June 2005) for all species combined is 222 individuals (95% CI percent of estimate: leatherbacks 68%, green 112%, olive ridley 186%). Of the 14 turtles reported by observers from July 2004 to June 2005, none were reported as dead. Two, however, were classified as sluggish-alive (Dambacher, 2005).

Azores surface longline fishery

- In 1998 a small pilot study in the Azores demonstrated high leatherback and loggerhead turtle bycatch rates of around 0.753 turtles/1000 hooks in the longline fishery in the Azores (Prieto *et al.*, 2000 from Read, 2007).
- The swordfish longline fishery around the Azores, a surface fishery (hooks are set at 15 to 50m), has an incidental catch of marine turtles (Ferreira *et al.*, 2001). The most common species hooked or entangled was the loggerhead, but an occasional leatherback was also caught. A mean catch rate for loggerheads of 0.27 turtles/1000 hooks was estimated from observer data, equating to an estimated annual catch of 4190 individuals.

Brazilian and Uruguayan pelagic longline fisheries

- Observers on board the Brazilian and Uruguayan pelagic logline vessels in the Atlantic Ocean reported 1693 loggerheads and 238 leatherbacks with an observed 2 643 851 hooks (López-Mendilaharsu *et al.*, 2007).

Canadian swordfish longline

- The Canadian longline fishery, which extends from Georges Bank to the Flemish Cap in the north Atlantic, incidentally catches marine turtles. A comparison of catches between different longline fishing gear showed that 66 turtles were captured over 10 sets with an average of 1440 hooks/set, to give an estimated 4.6 turtles/1000 hooks (Stone and Dixon, 2001). Turtles were the fifth most common species caught and loggerheads were the only species of marine turtle reported.

Cook Islands longline fishery

- There has been little observer data recorded from 2003 to 2005 from the Cook Islands longline fleet in terms of non-target, associated and dependent species. However from the small amount of observer data held by the Oceanic Fisheries Program and the Cook Islands Ministry of Marine Resources, it appears there has been no recorded catches of marine turtles (Anon., 2006).

Costa Rican longline fishery

- Arauz *et al.* (2000) reported on observer data from two longline fishing cruises in Costa Rica's Exclusive Economic Zone during 1997 and 1998. The incidental catch was relatively high, with 34 turtles caught from 1750 hooks set by an industrial vessel (CPUE = 19.4 turtles/1000 hooks) and 26 turtles caught from 1804 hooks set by a research vessel (CPUE = 14.4 turtles/1000 hooks). The industrial vessel's turtle catch was 55% olive ridleys and 45% green marine turtles and the total mortality was 8.8%. The research vessel caught only olive ridleys, all of which were released alive. It was noted that although the mortality rate at release was quite low, in reality total mortality may be substantially higher as a result of fishers attempting to retrieve hooks from turtles.
- More recent estimates from this fishery, but in a different area, using observer data collected from August 1999 to February 2000, are reported in Arauz (2001). These data indicate that olive ridleys were commonly hooked, with an estimate 6.4 turtles caught/1000 hooks. This species is second only to the target fish, maji-maji (mahi-mahi). There were also smaller numbers of green turtles.

European longline fishing fleets in the Mediterranean

- In 2000, observer reports were used to estimate the catch rate and, when effort estimates were available, the total catch of marine turtles by longliners in the Mediterranean (Laurent *et al.*, 2001). In the Greek swordfish fishery, the marine turtle catch rate was estimated to be 0.63±0.38 turtles/1000 hooks, or 6158±3521 marine turtles annually. In the Italian swordfish fishery, the estimated catch rate/1000 hooks was 0.22±0.12 and 0.71±0.14, in the northern and southern Ionian Sea, respectively. The Spanish catch rate from the swordfish fishery was estimated to be 1.15±0.73. In the albacore fishery marine turtle catch rates/1000 hooks was 0.50±0.19 and 0.20±0.06 from the Italian fleet and 3.27±4.03 from the Spanish fleet.

- Lewison *et al.* (2004) estimated 60 000 – 80 000 loggerheads and 250 – 10 000 leatherbacks were caught in the Mediterranean in 2000. These estimates were based on observer reported fishing effort, 80% for loggerhead bycatch and 6% for leatherbacks.

Gulf of Gabes (southern part) longline fisheries

- The longline fisheries (shark – pelagic longline and groupers – bottom longline) in the southern part of the Gulf of Gabes, an important wintering and foraging area for the loggerhead turtle, was observed from June to September in 2004 and 2005. A total of 57 loggerheads were caught over 57 trips. The estimated interaction rate for the pelagic fishery was 0.823±0.385 turtles/1000 hooks and 0.278±0.229 turtles/1000 hooks for the bottom longline fishery. Consequently, the total turtle catch is estimated to be 486.486±160.083 turtles/year and 732.89±439.27 turtles/year for the pelagic and bottom longline fisheries, respectively. Total direct mortality for the surface longlines was considered to be nil and 91.61±20.01 was the estimated mortality for the bottom longliners (Echwikhi et al., 2006).

Indonesian longliners

- WWF-Indonesia conducted a preliminary assessment of turtle catch on Indonesian longliners and trawlers using semi-structured interviews. Most respondents from the Indonesian tuna longline fleet (1000 to 2000 hooks; depth of 60 – 75m; targeting yellowfin, albacore, bigeye, marlin and swordfish) confirmed that they usually encounter at least one turtle/fishing trip (Hitipeuw *et al.,* 2006).

Ionian Sea, Greece longline fishery

- Fisher records by longliners based in Kefalonia Island, Ionian Sea, Greece, give an estimated average of 0.2 turtles caught/trip (or 7.7 turtles/year/vessel) (Panou *et al.,* 1999). This equates to possibly 80 turtles caught annually by this fleet of 10 vessels. If this estimated catch rate is applied to all fishing fleets in the Ionian Sea, excluding amateur and small-scale coastal vessels, up to 280 turtles may be caught every year. All but one turtle caught (a total of 157), was identified as a loggerhead. The majority of turtles taken were immature.
- In 1999 and 2000, 200 marine turtles were caught (198 loggerhead and two green), by swordfish and albacore vessels fishing Italian waters off the Ionian Sea. These figures comprised 0.5–15.7% of the total catch in number of individuals. Estimates of marine turtles caught by the total fishing effort of both fisheries were 1,084 in 1999 (95% CI = 667–1502) and 4447 in 2000 (95% CI = 3189–5705) (Delflorio *et al*., 2005).

Japanese longline fleet in the Atlantic U.S. Fishery Conservation Zone

- The estimated incidental capture of 330 turtles/year (126 in the Atlantic and 204 in the Gulf of Mexico) by the Japanese longline fleet in the Atlantic U.S. Fishery Conservation Zone was obtained using observer and logbook records from 1978 to 1981 (Witzell, 1984). The catch rate varied by area, with 0.7388 caught/1000 hooks in the Atlantic from a total of 17 million hooks set, and 1.8047/1000 hooks in the Gulf of Mexico from 11 million hooks set. It was noted that most leatherbacks were entangled or hooked in the flipper-shoulder area whereas many loggerheads ate the bait and became mouth hooked.

Japanese research and training vessels

- In 1988 and 1989 a questionnaire was sent to 72 Japanese research and training vessels (Nishimura and Nakahigashi, 1990). Of the 41 respondents, 61% reported an incidental catch of marine turtles, mainly on tuna longliner and bottom trawlers. Around 58% of the respondents reported that turtles were alive upon capture then released and 42% reported that they were dead.

Japanese longline line in the Eastern Pacific Ocean

- During 2000, 166 leatherback and 6000 other turtles were estimated to have been caught by Japan's longline fishery in the Eastern Pacific Ocean and of these, 25 and 3000, respectively, were dead (IATTC, 2006a).

Korean longline Pacific fishery

- In 2005, two observers were deployed to two Korean longliners fishing the Western Central Pacific Ocean and Eastern Pacific Ocean. During the 43 day trip in the Western Central Pacific Ocean, 32 longline sets were monitored with a total of 78 093 hooks. Three olive ridleys were caught and released alive, two were mouth hooked, one hooked in the oesophagus. During the 42 day trip in the Eastern Pacific Ocean, 35 longline sets were monitored with a total of 92 312 hooks. No turtles were captured (Moon *et al.*, 2006).

Madagascar and Mauritius longline fisheries

- Green turtles are reported as caught in the main industrial longline fishery in Madagascar. Both green and loggerheads are considered to be at risk by longline gear in Mauritius (Kiszka and Muir, 2006).

Mexican longline fishery in the Gulf of Mexico

- In 1994 and 1995 scientific observers monitored the catch of target and bycatch species on Mexican longliners in the Gulf of Mexico (Ulloa Ramírez and González Ania, 1998). They reported an average marine turtle catch rate of five turtles/100 trips. Most of the turtles were entangled in the monofilament fishing line and 66.7% were released alive. During the study, 18 leatherbacks (85.7%), two hawksbills (9.5%) and one loggerhead (4.8%) were caught.
- The Mexican longline fishery has been observed since 1994 and the estimated rate of capture/1000 hooks each year was 1994 – 0.6968, 1995 – 0.1598, 1997 – 0.2515, 1998 – 0.1750, 2000 – 0.2458, 2001 – 0.0218, 2002 – 0.2473, 2003 – 0.6092 (SAGARPA, Instituto Nacional de la Pesca, 2003 from National Marine Fisheries Service, 2005).
- In 1999 and 2000, observers in the Mexican longline swordfish fishery reported that 0.44% of trips interacted with marine turtles and all were released without apparent harm (Instituto Nacional de la Pesca, 2001).

New Zealand longline fishery

- A total of 11 turtles were reported by observers (coverage of 10%–20%) in the New Zealand longline fishery (2001–2005). There were seven leatherbacks, two greens (one dead), one loggerhead and one unidentified (Harley and Kendrick, 2006).

Peruvian longline fishery

- Observer reports in the Peruvian artisanal longline fishery in 2003 and 2004 reported a marine turtle catch rate of 0.597 turtles/1000 hooks in the mahi mahi fishery and 0.356 turtle/1000 hooks in the shark fishery. The mortality rate was high as turtles are rarely released being retained for consumption or sale (Alfaro-Shigueto *et al*., 2005).
- Bravo et al. (2006) reported on turtle interactions in the Pervian longline fishery targeting common dolphin fish (mahi mahi) from 2003 to 2005. The average CPUE of turtles was 0.349 turtles/1000 hooks (77 turtles captured with 221 447 hooks observed). There were 50% greens, 27.4% loggerheads and 12.9% olive ridleys. With regards to the type of interactions 38.5% were mouth-hooked, 30.8% flipper-hooked, 12.3% oesophagus-hooked, 1.5% plaston-hooked and 16.9% entangled.

Portuguese deep pelagic longliners targeting black-scabbard fish

- Dellinger and Encarnaçâo (2000) estimated that at least 500 marine turtles were taken annually by deep pelagic longliners based at Madeira Island, Portugal, targeting black-scabbard fish (*Aphanopus carbo*). This estimation was based on fishermen questionnaires and by quantifying catch at local harbours and from onboard data sheets.

South African pelagic longline fisheries for swordfish and tuna

- The average marine turtle bycatch rate reported by observers for the South African pelagic longline fisheries from 1998 to 2005 was 0.1 and 0.05 turtles/1000 hooks for the swordfish and tuna fisheries, respectively (IATTC, 2006b). The species included leatherbacks (35.3% and 53%), loggerheads (14.7% and 13%), hawksbill (2.9% and 0%), green (2.9% and 0%) and (44.1% and 33%) unidentified.
- Petersen (2005) reported that from 2000 to 2003 the South African domestic longline fishery had an average turtle catch rate of 0.05 turtles/1000 hooks. These consisted on 39% loggerheads, 23% leatherbacks, 3% greens, 3% hawksbill and 32% unidentified. It was noted that in 85% of cases the turtles were released alive.

South Atlantic (South African shallow-set longline fishery)

- Bartram and Kaneko (2004) used Taiwanese distant-water longline fishery data from Cheng (2003) to estimate a turtle take of 5.95/10 000 hooks in the South African shallow-set longline fishery in the South Atlantic.

Spanish surface longline fishery

- The Spanish longline fishery targeting swordfish, catches large numbers of loggerheads in the West Mediterranean (Laurent *et al.,* 1993).
- Greenpeace observers on board these vessels in the early 1990s, and fisher interviews, indicate that this fishery had a very high marine turtle capture rate of around 9.8 turtles/day/vessel. This equates to more than 20 000 sub-adult loggerhead turtles possibly being caught every year (Aguilar *et al.,*1995).

- A 1996 study of turtle bycatch in the Spanish longlining fleet estimated total capture rates of 1953 in 1993 and 23 886 in 1990 (Caminas, 1996).

U.S. longline fisheries in Atlantic waters

- Observer records were used to estimate the 1998 marine turtle capture by U.S. longliners in the Atlantic Ocean (Yeung, 1999). An estimated 728 (95% CI of 337–1824) marine turtles were caught and of these, 708 (95% CI of 324–1788) were assumed to have died as a result of the interaction. Most were caught on the Grand Banks fishing grounds. Of the 20 turtles caught while an observer was present, 15 were identified as loggerheads, four as leatherbacks and one as a hawksbill.
- Yeung (2001) reported that between 1992 and 1999 Atlantic pelagic longline fisheries interacted with an estimated 7891 loggerheads and 6363 leatherbacks, although most were released alive.
- A total of 112 and 87 marine turtles captures were reported by observers in the U.S. longline fisheries in Atlantic waters in 1999 and 2000, respectively (Yeung, 2001). Approximately, 2000 turtles were estimated to have been caught by the fleet in both years. In 1999 there were similar numbers of loggerheads and leatherbacks, but in 2000 there were twice as many loggerheads as leatherbacks.
- Garrison (2005) reported that in 2004 the U.S. Atlantic pelagic longline fleet interacted with an estimated 1358 leatherback turtles and 734 loggerhead turtles.
- Fairfield Walsh and Garrison (2006) reported that in 2005 the U.S. Atlantic pelagic longline fleet interacted with an estimated 351 (233-529 95%CI) leatherback turtles and 247 (195-384 95% CI) loggerhead turtles. It is noted that parts of the Atlantic were subject to management regulation such as the use of circle hooks.

Including U.S. longline fisheries in Northeast Atlantic waters

- From Northeast Fisheries Science Centre observer data, estimates of turtle catches by longliners in the Northeast Atlantic have been developed. Gerrior (1996) reported on available data from 1991, 1992 and 1993. Longliners, targeting swordfish, tuna and shark, have a substantial incidental catch of marine turtles (leatherbacks, loggerheads, green and hawksbills). Over the three years and a total of 54 observed trips 85 turtles were caught. Of these 65% were leatherbacks, 18% loggerheads, 12% greens, 1% hawksbills and 4% were unidentified. The nature of the capture ranged from hooking in different parts of the body, including internally, to entanglements with the monofilament line and mainline.

And including U.S. longline fisheries in the Western North Atlantic Ocean

- The U.S. longline fisheries in the western North Atlantic Ocean generally target swordfish at night using lightsticks or tuna in the day without lightsticks (Witzell, 1999). Logbook records from 1992–1995 indicated an average annual leatherback catch of 316 and a loggerhead catch of 334. Both species were more abundant during summer and autumn and catch varied by area.
- From logbook records for the period 1992–1999, between 293 and 2439 loggerheads and 308 and 1054 leatherbacks were estimated to have been taken

annually by U.S. longliners in the Western North Atlantic (National Marine Fisheries Service Southeast Fisheries Science Center, 2001).

U.S. vessels in the Hawaiian longline fishery

- An observer program has been in place in the Hawaiian longline fishery since 1994 as a result of the Biological Opinion issued under the Endangered Species Act (ESA). This data, along with logbook data from 1994 to 1997, was used to estimate total turtle captures and mortality by species (Kleiber, 1998). It was assumed that if a turtle was internally hooked the mortality rate would be approximately 30% and if externally hooked it would survive. Catch estimates ranged between 150 and 558/year, with mortality of between 23 and 103 individuals.
- Ito and Machado, 2001 from Bartram and Kaneko (2004) reported that from 1994–1999 the sub-tropical central North Pacific (bigeye and yellowfin tuna fishery) had an estimated take of 0.051 turtles/10 000 hooks. Ito and Machado (2001) and Caretta (2003) were used by Bartram and Kaneko (2004) were used to estimate the turtle take from 1994–2001 in the sub-tropical and temperate central North Pacific (Hawaii swordfish longline fishery) to be 1.7 turtles/10 000 hooks.
- Observer data was used to estimate that between 88 and 132 leatherbacks, (average of 112) may have been taken annually from the Hawaiian–based longline fishery and of these an average of nine were killed (McCracken, 2000). The estimated annual average take of loggerheads was 418, with an estimated mortality of 73 individuals. Olive ridleys were also caught, with an estimated annual take of 146 individuals, of which, 49 were estimated to die as a result of the capture.

Uruguayan and Brazilian waters longline fisheries

- A capture rate of 1.8 turtles/1000 hooks for longliners in the South West Atlantic Ocean (Uruguayan waters) in 1994 and 1996 was estimated from observer cruises (Achaval *et al.*, 1998), comprising loggerheads and leatherbacks. Most were released alive (98.1%) but with the hook still embedded.

- There has also been some - mainly anecdotal - information on marine turtle and fishery interactions in Uruguayan and Brazilian waters. There have been leatherback and loggerhead strandings that cannot unequivocally be linked to fisheries, but were assumed to be a result of negative fishery interactions. In addition, there was evidence that over a two-week period one longliner in Brazil caught between 70 and 75 turtles, 70% of which were loggerheads and 30% leatherbacks (Fallabrino *et al.,* 2000).

Western temperate Pacific longline fisheries

- Observer reports in the western temperate Pacific were used to estimate an annual turtle take of 1 490±376 turtles (0.06 turtles/1000 hooks) by vessels fishing with shallow-night sets, 129±79 turtles (0.007 turtles/1000 hooks) by the deep-day setting fresh tuna vessels and 564±345 turtles (0.007 turtles/1000 hooks) by the deep-day setting freezer vessels (Oceanic Fisheries Programme, 2001).
- Kotas *et al.* (2004), reports the capture of loggerhead and leatherbacks and catch per unit effort (CPUE) in the surface longline fishery off the southern coast of Brazil

in 1998. From a total of 34 sets, 33 650 hooks, 145 loggerhead (CPUE=4.31/1000 hooks) and 20 leatherback (CPUE=0.59/1000 hooks) marine turtles were captured. The majority of loggerheads were hooked in the mouth or oesophagus, with a small number hooked in the flipper or entangled in the line. Leatherbacks were entangled in the line or hooked in the flipper, carapace or mouth. As the leatherbacks were unable to be hauled aboard, the incidence of oesophageal hooking could not be determined.

Western and Central Pacific longline fisheries

- Bartram and Kaneko (2004) reported of bycatch per unit effort (BPUE – Bycatch Per Unit Effort of turtle takes/10 000 hooks) for the various longline fisheries in the Pacific and Atlantic:

  Central and Western Pacific deep-set

  - Sub-tropical South Pacific – none caught in 54 000 observed hooks
  - Western Tropical Pacific – 0.0692 BPUE
  - Sub-Tropical central North Pacific – 0.051 BPUE.

  Central and Western Pacific shallow-set

  - Western Tropical Pacific (Taiwan, yellowfin) – 0.6129 BPUE
  - Western Tropical Pacific (Peoples Republic of China) – 0.6129 BPUE
  - Eastern Australia – 0.24 BPUE.

  Sub Tropical and temperate central North Pacific

  - Hawaii – 1.7 BPUE.

  Eastern Pacific shallow-set

  - Tropical eastern Pacific (Costa Rica offshore) – 66.7 BPUE
  - Tropical eastern Pacific (Costa Rica near nesting beaches)– 194 BPUE
  - Temperate eastern Pacific (California) – 1.8 BPUE.

  South Atlantic shallow-set

  - South Atlantic (Brazil offshore) – 18 PBUE
  - South Atlantic (Brazil near nesting beaches) – 116 BPUE
  - South Africa – 5.95 BPUE.

- Molony (2005) estimated from observer records that in the Western and Central Pacific 6962 ± 22 567 marine turtles were captured by commercial longline and purse seine fishing operations each year in the Western and Central Pacific. The estimated mortality is 931±7 329 turtles/year. The highest catches were in the tropical shallow longline (15ºN–10ºS, <10 hooks between floats); however the highest mortalities were in the tropical deep longline fisheries (15ºN–10ºS, 10 or more hooks between floats). The suggested reason for the catch rates in the shallow fishery was due to the gear fishing at depths where turtles spend most time (i.e. less than 120m). The explanation of catch rates in the deep fishery was that most turtles were unable to reach the surface to breathe once hooked, due to the increased depth of the gear.

Appendix 12: Research on Turtle Mitigation

Circle hook research

Date: 2005 and 2006

Fishery: Shallow-set swordfish fishery in the Strait of Sicily, Mediterranean Sea

Study Size: 20 000 hooks, 20 sets

Treatment: 16/0 circle hook with frozen mackerel bait, lightsticks on every branchline

Control: J-hooks 20 degree offset with frozen mackerel bait, lightsticks on every branchline

Results:

- Seventeen turtles were hooked
- Circle hooks accounted for 17.6% of turtle hookings while J-hooks were responsible for 82.4%
- 88.2% of turtles were mouth hooked and 11.8% swallowed (all J-hooks)
- No difference between swordfish catch (number and total weight)

(Boggs and Swimmer, 2007).

Date: 1992 –2002

Fishery: U.S. Gulf of Mexico longline tuna and swordfish fishery

Study Size: 864 000 hooks, 1729 sets

Treatment: None

Control: Analysis of observer data: 16/0 circle hooks, 7/0, 8/0 and 9/0 J-hooks with squid and sardine bait

Results:

- Bait type, night vs day setting and depth confounded assessment of hook type
- Leatherback bycatch rate significantly lower for J-hooks + sardine + day setting versus J-hooks + squid + night setting
- Leatherback bycatch rate lower for circle hooks + sardine + day setting versus circle hooks + squid + night setting

(Garrison, 2003).

Date: 2004

Fishery: U.S. Gulf of Mexico longline yellowfin tuna fishery

Study Size: 29 570 hooks, 61 sets

Treatment: 16/0 circle hooks with sardine bait

Control: 18/0 circle hooks with sardine bait

Results:

- 18/0 circle hooks with sardine bait less effective for yellowfin than 16/0 circle hooks with sardine bait
- 25.7% reduction in total yellowfin on 18/0 versus 16/0 circle hooks ($p=0.0025$)
- 25.7% reduction in weight for marketable yellowfin tuna on 18/0 versus 16/0 circle hooks ($p=0.0183$)

(Watson *et al.,* 2004a).

Date: 1999

Fishery: Venezuela Caribbean longline tuna fishery

Study Size: 2 105 hooks, 6 sets, 1 trip

Treatment: 16/0 circle hook with live bigeye scad bait

Control: 7/0 J-hook with live bigeye scad bait

Results:

- Target species CPUE with circle hooks was 2.5 times greater at 3.33 yellowfin tuna/100 hooks than with conventional 7/0 J-hooks at 1.33 yellowfin tuna/100 hooks

(Falterman and Graves, 2002).

Date: 2000

Fishery: Azores Eastern Atlantic longline swordfish and blue shark fishery, Phase 1

Study Size: 138 121 hooks, 93 sets

Treatment: Non-offset Mustad 16/0 circle hook with squid bait, 25° offset and non-offset 9/0 J-hooks with squid bait

Control: None

Results:

- No significant difference in total number of turtles caught with each hook type
- Significant difference between hook types in location of turtle hookings
- 57% of loggerheads caught on the J-hooks were hooked in the oesophagus
- 81% of loggerheads caught on circle hooks were hooked in the mouth
- Circle hooks caught significantly fewer swordfish than J-hooks
- Offset J-hooks caught significantly fewer blue sharks than the other two hook types
- Turtle capture rate increased significantly as the hour of day of gear hauling increased

(Bolten and Bjorndal, 2003).

Date: 2001

Fishery: Azores Eastern Atlantic longline swordfish and blue shark fishery, Phase 2

Study Size: 88 150 hooks, 60 sets

Treatment: Non-offset Mustad 16/0 and non-offset 18/0 circle hooks with squid bait, non-offset 9/0 J-hook with squid bait

Control: None

Results:

- No significant difference in number of loggerheads caught between hooks
- When data from Phase 1 was considered, there was a significant difference in the position of turtle hooking for each hook type
- 60% of loggerheads caught on J-hooks and 9% of loggerheads caught on circle hooks were hooked in the oesophagus
- No significant difference in the number of blue sharks caught between 16/0 and 18/0 circle hooks
- The non-offset J-hook caught significantly fewer blue sharks than the two circle hooks

(Bolten and Bjorndal, 2003).

Date: 2002

Fishery: Azores Eastern Atlantic longline swordfish and blue shark fishery, Phase 3

Study Size: 75 511 hooks, 48 sets

Treatment: Offset and non-offset Mustad 16/0 circle hooks and offset 18/0 circle hook with squid bait

Control: None

Results:

- No significant difference in the number of loggerheads caught between hook types
- With reference to Phase 1 and Phase 2 (above), turtles were captured in clusters with a significant difference in position of turtle hooking for each hook type
- 60% of loggerheads ingesting J-hooks
- 12% of loggerheads ingesting circle hooks were hooked in the oesophagus
- Significant difference in the number of blue sharks caught on the three hook types
- Non-offset 16/0 circle hooks had a higher blue shark CPUE than offset 18/0 circle hooks, which had a higher blue shark CPUE than offset 16/0 circle hooks

(Bolten and Bjorndal, 2004).

Date: 2003

Fishery: Azores Longline Fishery, Phase 4

Study Size: 73 sets, 114 417 hooks,

Phase 4a: 27 sets

Phase 4b: 43 sets

Treatment: 16/0 non-offset circle hook (Mustad # 39960), 18/0 circle hook non-offset (Lingren Pitman), Japanese tuna hook 3.6mm S/S (Ocean Producers International #OPI023) with squid bait

Phase 4a: all three hook types tested,

Phase 4b: circle hooks only (Japanese tuna hooks discontinued due to the high catch rate and high proportion of throat-hooked turtles)

Control: None

Results:

- A total of 143 loggerhead and five leatherback turtles caught
- Significantly more turtles captured by the Japanese tuna hook vs. circle hooks: Phase 4a, 62 with Japanese tuna hook versus 16 by 18/0 circle hooks and 26 by 16/0 circle hooks, NB: Japanese tuna hooks discontinued due to the high catch rate and high proportion of throat-hooked turtles
- No significant difference between location of hooking site between circle hooks, but significant difference between Japanese tuna hooks and both circle hook types
- In all 73 sets fewer turtles were caught with the 18/0 circle hook than the 16/0 circle hook

(Bolton and Bjorndal, 2005).

Date: 2000

Fishery: U.S. California/Hawaii Eastern Pacific longline swordfish fishery

Study Size: 16 065 hooks

Treatment: 16/0 circle hook with squid bait

Control: 9/0 J-hook with squid bait

Results:

- Ten swordfish on circle hooks (4.5/1000 hooks) and 119 on J-hooks (8.6/1000 hooks)
- Four tuna on circle hooks (0.5/1000 hooks) and seven on J-hooks (1.8/1000 hooks)

(Gilman *et al.,* 2006b).

Date: 2001–2002

Fishery: Canadian Northwest Atlantic longline tuna and swordfish fisheries

Study Size: 534 057 hooks: 283 057 in 2001 and 251 000 in 2002

Treatment: None

Control: Analysis of observer data. Offset and non-offset 9/0 J-hooks and non-offset 16/0 circle hooks with squid, mackerel and herring bait

Results:

- The nine hook and bait configurations did not allow independent assessment of hook or bait effect on turtle bycatch
- 2001: 28 leatherbacks caught – 42.8% entangled, 29.3% foul hooked, 3.6% mouth hooked, 0% swallowed the hook
- 2001: 199 hard shelled turtles caught – 92.5% mouth hooked, 4.5 % swallowed the hook, 2.5% foul hooked or entangled
- 2002: 33 leatherbacks caught – 12% mouth hooked, 27% swallowed the hook, 6% foul hooked, 53% entangled
- 2002: 145 hard shelled turtles caught – 32% mouth hooked, 66% swallowed the hook, 1% entangled

(Javitech Ltd. 2002, 2003 from Gilman *et al.,* 2006b).

Date: 2001–2003

Fishery: U.S. Northwest Atlantic longline swordfish fishery

Study Size: 486 554 hooks

Treatment: 10° offset Lingren-Pitman 18/0 circle hooks and mackerel bait

Control: 25° offset 9/0 J-hooks with squid bait

Results:

- Leatherback and loggerhead capture rates were reduced by 63% and 88%, respectively
- Swordfish CPUE increased by 19%
- Bigeye tuna CPUE decreased by 80% compared to the control using 25° offset 9/0 J-hooks with squid bait
- Loggerheads were more likely to be hooked in the mouth with the experimental treatment, and more likely to swallow the hook with the control
- 60.2% of loggerheads caught on J-hooks swallowed the hooks
- 80.0% of loggerheads caught on circle hooks were caught in the mouth and 20.0% swallowed the hooks
- 96.5% of leatherbacks caught on J-hooks and 85.7% on circle hooks were hooked externally

(Watson *et al.*, 2003a, 2004b, 2005; Shah *et al.,* 2004).

Date: 2001 - 2003

Fishery: U.S. Northwest Atlantic longline swordfish fishery

Study Size: 225 191 hooks

Treatment: Non-offset Lingram-Pitman 18/0 circle hooks with squid bait

Control: 25° offset 9/0 J-hooks with squid bait

Results:

- Significant reduction in leatherback and loggerhead capture rates (75% and 74%, respectively)
- Swordfish CPUE reduced 25%
- Insignificant increase in bigeye tuna CPUE
- 60.2% of loggerheads caught on J-hooks swallowed the hook
- 14.3% of loggerheads caught on circle hooks swallowed the hook
- 75% of loggerheads caught on circle hooks were mouth hooked
- 96.5% and 75% of leatherbacks were caught externally on J-hooks and circle hooks respectively

(Watson *et al.,* 2003a, 2004b, 2005; Shah *et al.,* 2004)..

Date: 2002

Fishery: Pelagic Longline Fishery - Western Atlantic Northeast Distant Waters

Study Size: 13 vessels, 489 sets, 427 385 hooks

Treatment: 0° offset 18/0 circle hooks and 10° offset 18/0 circle hooks with mackerel bait and 25° – 30° offset 9/0 J-hooks with mackerel bait

Control: 25° – 30° offset 9/0 J-hooks with squid bait

Results:

- Circle hooks (offset and non-offset combined) with squid bait reduced the catch rates of loggerhead turtles, leatherback turtles and swordfish by 86%, 57% and 29% respectively and increased bigeye tuna catch by 26%
- Circle hooks with mackerel bait reduced catch rates of loggerhead turtles, leatherback turtles and bigeye tuna by 90%, 65% and 81% respectively and increased swordfish catch by 30%
- J-hooks with mackerel bait reduced the catch rates of loggerhead turtles, leatherback turtles and bigeye tuna by 71%, 66% and 90% respectively and increased swordfish catch by 63%
- Circle hooks with squid caught from 8 (non-offset) and 9% (offset) more blue shark
- Both types of hooks baited with mackerel caught 31 (circle hooks) and 40 (J-hooks) percent fewer blue shark than those baited with squid

(Watson *et al.,* 2005).

Date: 2003

Fishery: Pelagic longline fishery - Western Atlantic Northeast distant waters

Study Size: 11 vessels, 539 sets, 578 050 hooks

Treatment:

Swordfish sets: Non-offset 18/0 circle hooks with squid bait, and 10° offset 18/0 circle hooks with mackerel bait, 10° offset 20/0 circle hooks with mackerel bait, 10/0 non-offset (Mustad # 9202SR) tuna hook (J-hook) with mackerel bait

Tuna sets: 18/0 non-offset 18/0 circle hook with squid bait

Control:

Swordfish sets: 25° – 30° offset 9/0 J-hooks with squid bait

Tuna sets: 10° offset 16/0 circle hooks with squid bait

Results:

- Interactions: 92 loggerhead, 79 leatherback and one olive ridley turtle
- 18/0 non-offset circle hooks with squid bait reduced the catch rates of loggerhead turtles, leatherback turtles and swordfish by 65%, 90% and 29% respectively and increased bigeye tuna catch by 20%
- 10° offset 18/0 circle hooks with mackerel bait reduced the catch rates of loggerhead turtles, leatherback turtles and bigeye tuna by 86%, 56% and 88% respectively and increased swordfish catch by 9%
- 10° offset 20/0 circle hooks with mackerel bait reduced the catch rates of loggerhead turtles, leatherback turtles and bigeye tuna by 91%, 72% and 90% respectively and increased swordfish catch by 8%

(Watson *et al.,* 2004b).

Date: 2003 - 2004

Fishery: U.S. Atlantic coastal pelagic longline fishery

Study Size: 85 sets

Treatment: 16/0 0 º offset circle hooks

Control: 10º offset 9/0 J-hooks

Results:

- Although not significant, the circle hooks caught fish in the mouth more frequently than j-hooks, which hooked more fish in the throat or gut
- Suggestion that 0 º offset circle hooks in the coastal pelagic longline fishery will increase the possibility of survival for bycatch species with minimal effects on target catch

(Kerstetter and Graves, 2006).

Date: 2002

Fishery: U.S. Hawaii longline swordfish fishery

Study Size: 78 071 hooks, 95 sets, seven trips

Treatment: Non-offset Lingren-Pitman 18/0 circle hooks with squid bait

Control: Non-offset 9/0 J-hooks with squid bait

Results:

- The 18/0 circle hooks were only 40% as effective as the control (J-hooks) for catching swordfish and 94% as effective for catching tuna
- Catch from the deep-daylight trials (below 240m) for swordfish was 85% less than the control gear, but the catch of other species was similar
- Swordfish revenue made by the vessel using stealth fishing gear (counter-shaded floats, dark grey lines, dulled hardware, shaded lightsticks, narrow-frequency lightsticks, branchline design) was 30% less than that made by the control vessel

(Boggs 2003, 2004).

Date: 2003

Fishery: Captive loggerhead turtles

Study Size: 45 hooks

Treatment: Modified 16/0 circle hook (4.6cm narrowest width) with squid bait

Control: Modified 9/0 and 10/0 tuna hooks and 9/0 J-hooks (3.3–4.0cm narrowest width) with squid bait

Results:

- 16/0 circle hook significantly reduced swallowing of baited hook by loggerheads 44-58.8cm straight line carapace length

(Gilman *et al.,* 2006b).

Date: 2003

Fishery: Japan Northwest Pacific shallow set longline tuna and swordfish fisheries

Study Size: 28 000 hooks, 33 sets, one trip

Treatment: Tankichi type 3.8 sun circle hook

Control: Japanese tuna hook 3.8 sun

Results:

- No data available on loggerhead bycatch rates and target species CPUE between experimental and control treatments
- Ratio of mouth to oesophagus-hookings was higher for the circle hook than the tuna hook
- Loggerhead turtles mouth hooked: 52% Japanese tuna hook, 67% circle hooks

- Loggerhead turtles oesophagus hooked: 40% Japanese tuna hook, 25% circle hooks
- Loggerhead turtles flipper hooked: 8% both hook types
- Target catch rates (swordfish, bigeye, albacore and yellowfin tuna) were not significantly different between hooks

(Nakano, 2004; Nakano *et al.,* 2004).

Date: 2004

Fishery: Japan Northwest Pacific shallow set longline tuna and swordfish fishery

Study Size: 40 000 hooks, 47 sets, two trips

Treatment: 18/0 10° offset and non-offset, circle or ring hooks, Tokkan type 5.5 sun circle hook, and Tokkan type 4.3 sun circle hook

Control: Japanese tuna hook 3.8 sun

Results:

- Nominal difference in tuna and swordfish CPUE between Japan 3.8 sun tuna hooks and Tokkan type 4.3 sun circle hooks

(Kiyota *et al.,* 2003; Nakano, 2004; Nakano *et al.,* 2004).

Date: 2004

Fishery: U.S. Gulf of Mexico longline tuna fishery

Study Size: 29 570 hooks

Treatment: Non-offset 18/0 circle hook with sardine bait

Control: Non-offset 16/0 circle hooks with sardine bait

Results:

- Three leatherback turtles were foul hooked:18/0 circle (two) and 16/0 circle (one)
- 18/0 circle hooks resulted in a 25.7% reduction in the number and weight of target yellowfin tuna captured compared to 16/0 circle hooks

(Watson *et al.,* 2004a).

Date: 2004

Fishery: Tuna and Mahi Mahi fisheries – Equador

Study Size: 15 000 + circle hooks, 115 vessels

Treatment: 18/0 and 16/0 circle hooks in tuna fishery and 14/0 and 15/0 in mahi mahi fishery

Control: Traditional J-hooks

Results:

- Circle hooks were found to reduce turtle interactions by 44% to 88% in the tuna fishery and by 16% to 37% in the mahi mahi fishery
- Less harmful hookings on circle hooks
- Estimated total turtle mortality of 63% to 93% in the tuna fishery and 41% to 93% in the mahi mahi fishery
- Catch rates of target species similar in the tuna fishery and fishers preferred the 16/0 circle hook
- Catch rates of target species lower in the mahi mahi fishery

Largacha *et al.,* 2005).

Date: 2005

Fishery: Spanish longline in the South-Western Indian Ocean

Study Size: Two vessels; 539 sets; 531 916 hooks

Treatment: Circle hooks - 18/0 metallic and 18/0 blue in the fixed part and 18 J-0 metallic

Control: 16/0 conventional metallic and blue

Results:

- Catch rate of 0.047 turtles/1000 hooks
- 76% entangled, 16% bit hook and 2% unknown capture type
- Three turtles bit conventional hooks and 1 bit circle hooks
- Most turtles caught associated with squid bait
- 68% of turtles were leatherbacks

(Ariz *et al.*, 2006).

Date: 2004

Fishery: Colimo shark longline fleet, Gulf of Mexico

Study Size:

Treatment: 6/0 circle hook 10º offset (Mustard 39966 DT), 9/0 Japanese tuna hook (Mustard 9202 SKR) and 9/0 J-hook (Eagle 9015) mackerel or skipjack bait

Control:

Results:

- 16/0 circle hook most efficient for sharks
- Circle hook caught no fewer turtles, but turtles caught on circle hooks received fewer injuries
- Fishers involved in the trial have switched permanently to circle hooks

(National Fisheries Institute, 2005 from Robins and Kreutz, 2005).

Date: 2004

Fishery: Gulf of Mexico Yellowfin tuna fishery

Study Size: Three vessels, 61 sets, seven trips, 29 570 hooks

Treatment: 18/0 circle hooks, Mustard #39960, sardine bait (no lightsticks)

Control: Non-offset 16/0 circle hooks, sardine bait

Results:

- No loggerhead turtles were caught with either hook
- Two leatherback turtles externally caught on the 18/0 hook and one on the 16/0 hook
- Yellowfin catch: 205 and 347 for 18/0 and 16/0 hooks respectively
- 18/0 circle hooks with sardine bait less efficient for yellowfin tuna than 16/0 circle hooks with sardine bait

(Watson *et al.*, 2004a).

Date: 2005

Fishery: Japanese longline fishery

Study Size: 48 600 hooks, 52 sets, 2 vessels

Treatment: Mutsu Hokubei type 4.3 and 5.2 sun (~ 18/0) circle hooks

Control: 3.8 sun tuna hook

Results:

- 74 loggerhead turtles caught
- No significant difference in hooking rates of loggerhead turtles between tuna hook and 4.3 sun circle hooks
- 5.2 sun circle hooks significantly reduced the catch rate of loggerhead turtles of average carapace length 70.3cm
- 3.8 sun tuna hooks were ingested most frequently, the 5.2 sun circle hooks ingested the least
- Circle hooks had no significant effect on catch rates of bigeye tuna but the 5.2 sun circle hooks showed negative impacts on billfish catch

(Minami *et al.,* 2006).

Date: 2005

Fishery: Spanish experimental longline fishery- Southwest Indian Ocean

Study Size: 531 916 hooks, 539 sets, two vessels

Treatment: Metallic 18/0 circle hook, blue 18/0 circle hook, J-O 18/0 hook

Mackerel

Control: Conventional 16/0 metallic J-hook and conventional 16/0 blue J-hook
Squid (usually green-dyed)

Results:

- 25 turtles caught – mostly leatherback (17)
- Interaction rate 0.047 turtles/1000 hooks
- 76% of turtles entangled; 16% took the hook; 2% unknown
- Turtles that 'bit the hook' – three on conventional hook and one on circle hook

(Ariz *et al.,* 2006).

Date: 2005

Fishery: Korean tuna longline fishery – eastern Pacific Ocean

Study Size: 44 100 hooks, 21 sets, 2 vessels

Treatment: Size 15 circle hook and size 18 circle hook

Control: Traditional 4.0 tuna hook

Results:

- Large circle hooks (size 18) had the lowest catch rate for tunas and for other fishes
- Small circle hook (size 15) had the lowest rate for billfish and sharks

(Kim *et al.,* 2006).

Date: 2006

Fishery: Japanese longline fishery – western North Pacific Ocean

Study Size: 44 100 hooks, 21 sets, 2 vessels

Treatment: Size 15 circle hook and size 18 circle hook

Control: Traditional 4.0 tuna hook

Results:

- No difference in hooking rate of loggerheads between tuna and small circle hooks
- Ingestion of circle hooks occurred less frequently than tuna hooks
- Little effect on catch of tuna; large circle hooks showed reduced billfish catch

(Minami *et al.,* 2006).

Date: 2005

Fishery: Japanese longline fishery – western North Pacific Ocean

Study Size: 44 100 hooks, 21 sets, 2 vessels

Treatment: Circle hooks (4.3-sun and 5.3-sum)

Control: Conventional tuna hooks (3.8-sun)

Results:

- Blue shark catch rates did not differ
- Proportion of dead blue shark did not differ
- Conclude that hook type in the study had little impact on catch and mortality rates of blue shark

(Yokota *et al.,* 2006a).

Date: 2002 and 2003

Fishery: Western North Atlantic recreational fishery

Study Size: 41 white marlin (Tetrapturus albidus) pop-up satellite archival tag after capture by recreational fishing

Treatment: Mustard Demon Fine Wire 7/0 5ºoffset circle hook and Eagle Claw Circle Sea 7/0-9/0 non-offset circle hook

Control: 7/0 Mustard straight0shank J-hooks

Results:

- Survival was significantly higher for whiter marlin caught on circle hooks compared with those caught on J-hooks

(Horodysky and Graves, 2005).

Date: 2002 – 2005

Fishery: Brazil longline fishery

Study Size: 9 trips; approx. 50 000 hooks

Treatment: 18/0 circle hooks

Control: 9/0 J-hook

Results:

- 18/0 circle hooks catch fewer turtles than 9/0 J-hooks
- Productivity of the fishery is not negatively influenced by the adoption of 18/0 circle hooks
- Swordfish sizes are larger when 18/0 circle hooks are used compared with 9/0 J-hooks
- The circle hooks improve survivorship of loggerheads due to less ingesting hook and more jaw-hooked

(Swimmer *et al.,* 2006b).

Date: 2006-2007

Fishery: Brazil longline fishery

Study Size: 3 trips; 16 500 hooks (not entire set)

Treatment: 18/0 circle hooks 10 degree offset with mackerel bait

Control: 9/0 J-hook with mackerel bait

Results:

- J-hooks responsible for 66% of the 30 turtles caught
- Circle hooks responsible for 34% of turtles caught
- J-hooks were swallowed 59% of the time while circle hooks were swallowed 13% of the time
- Swordfish catch slightly lower for circle hooks (60 vs. 65)
- Tuna species catch on each type of hook similar
- Similar weights of swordfish (individuals) on both hook styles

(Boggs and Swimmer, 2007).

Date: 2007

Fishery: Uruguay surface longline fishery

Study Size: 1 vessel; 66 sets; 38 000 hooks

Treatment: 18/0 circle hook 10 degree offset

Control: Portuguese 9/0 J-hook no offset

Results:

- 29 loggerhead turtles caught
- 62% of turtles caught on J-hooks and 38% on circle hooks

(Boggs and Swimmer, 2007).

Date: 2005

Fishery: Australian Eastern Tuna and Billfish Fishery – Feasibility Study

Study Size: 3 trips; approx. 9961 hooks

Treatment: Trip 1 – 16/0 circle hooks with squid

Trip 2 – 13/0 circle hooks with live bait

Trip 3 – 16/0 circle hooks

Control: Japanese Tuna Hooks

Results (observations only due to low sample size):

- Total target fish catch rates using circle hooks almost equal to tuna hooks

- Circle hooks caught fewer bigeye and striped marlin but similar numbers of the other species
- Bycatch of Ray's bream and escolar higher with circle hooks
- Bycatch of mahi mahi lower with circle hooks

(Ward *et al.,* 2006).

Date: 2007

Fishery: Indonesian tuna fishery off the coast of Benoa (Bali)

Study Size: 1 vessel; 36 sets

Treatment: 16/0 circle hook with rings

Control: Traditional style tuna hook with rings

Results:

- Circle hooks responsible for 53.5% of total catch with no turtle interactions
- Circle hooks caught 12% more target fish and resulted in 14.63% less discards than the traditional tuna hook

(Boggs and Swimmer, 2007).

Date: 2004 and 2005

Fishery: Taiwanese longline fishery – Pacific Ocean

Results:

- No turtle hooked
- No significance difference in baiting time and bigeye hooking rate between circle and J-hooks
- Survival rate of the catch greater with circle hooks

(IOTC, 2006).

Handling Research

In the U.S., handling and release protocols developed by NOAA Fisheries Southeast Science Centre must now be used by all Atlantic vessels with pelagic longline gear (Epperly *et. al.,* 2004). These protocols are based on 1214 trials of various dehooking and monofilament cutting tools on 32 vessels in the Western Atlantic NED pelagic fishery between 2001-2003 (Watson *et. al.*, 2004b). Interviews were conducted with captains and observers after every trip to collate feedback to improve tools and methodologies. Gear design and handling requirements were subsequently modified and adopted.

Training workshops have been conducted for all captains and owners, with significant improvement in handling proficiency. Regulations have recently been endorsed that require mandatory training and refreshers every two years. Improvements are measured by the observer program that documents the success or failure of crew to handle animals and remove gear.

Minami, *et al*. (2006) reported on experiments conducted on the effectiveness of dehooking devices on board Japanese longline vessels. They found that some commercially available dehookers did not easily remove hooks due to their inability to grip the hook, while others were considered too expensive to be commercially practical. Successfully developed and tested were a set of pliers with gaps in the jaws that fitted the diameter of the hook.

Captive studies on turtle post-hooking survival demonstrated that safe handling and release techniques are effective in reducing marine turtle mortality following interactions with longline gear (Minami, *et al*., 2006).

Other mitigation measures research

Setting gear deeper to avoid the depths where turtles are in high densities

Date: 2001

Fishery: Hawaiian longline fishery in central North Pacific

Results:

- Two loggerhead and two olive ridley turtles fitted with a satellite-linked depth recorder after capture
- Turtles spent more time at the surface during the day than at night
- Loggerheads – 40% of time in top meter and all time above 100 m
- Olive ridleys – 20% of time in top meter and 90% of time above 100m

(Polovina *et al.,* 2002).

Date: 1990–2000

Fishery: Western tropical Pacific longline tuna fisheries

Study Size: 7 387 054 hooks, 6 408 sets

Treatment: None

Control: Analysis of observer data

Results:

- Shallow (< 100m) hooks set primarily at night resulted in a turtle bycatch rate of 0.061 captures/1000 hooks
- Deep (>150m) hooks set primarily during the day resulted in a turtle bycatch rate of 0.012 captures/1000 hooks

(Oceanic Fisheries Programme, 2001).

Date: 2001

Fishery: U.S. Northwest Atlantic longline swordfish fishery

Study Size: 164 429 hooks, 186 sets

Treatment: Branch lines set 60m from buoy lines

Control: Branch line directly under each buoy

Results:

- Increase in leatherback turtle capture and no significant difference in loggerhead turtle capture rate (Watson *et al.,* 2002)
- The experimental treatment deviated from the planned research design, placing the shallowest hooks deeper than the control shallowest hooks, but leaving more baited hooks above 40m than the control (Boggs 2003)

(Watson *et al.,* 2002; Boggs, 2003, 2004).

Date: 2002

Fishery: U.S. Hawaii longline swordfish fishery

Study Size: 52 618 hooks, 66 sets

Treatment: Deep daytime sets

Control: Shallow nightime sets

Results:

- No turtles caught on deep daytime sets
- One turtle caught on regular shallow night sets
- Daytime sets reduced swordfish catch by 85% and overall revenue by 71% as compared to the control
- Hooks on the deep set gear only reached 244m, the research design required hooks set to a mean depth of 400m

(Boggs, 2003 and 2004).

Date: 2004

Fishery: East coast Australian longline tuna and billfish fishery

Study Size: 6270 hooks, six sets

Treatment: Gear with lead weights and portions of the main line used as float lines

Control: Gear suspended between two floats sagging in a curve (conventional design)

Results:

- Experimental treatment hooks reached depths between 120m and 340m, control treatment hooks reached depths between 0m and 300m

- CPUE of target species were unchanged or enhanced by the experimental treatment compared to the control

(Beverly *et al.*, 2004).

Date: 2004

Fishery: Japan longline tuna fishery

Study Size: 15 hooks, three baskets

Treatment: Gear with one or two mid-water floats attached to the main line

Control: Gear without mid-water floats

Results:

- A difference of 4.9m between shallowest and deepest hook on gear with two mid-water floats, 26.2m with one mid-water float and 55.1m on the control gear
- Demonstrates the possibility to set all hooks in a basket at approx. the same depth
- No significant difference in hook sink rates: experimental and control treatments

(Shiode *et al.,* in press – presented at Third International Fisheries Forum, 25 – 29 July 2004, Yokohama, Japan).

Minimising gear-soak during the daytime

Date: 2002

Fishery: U.S. Northwest Atlantic longline swordfish fishery

Study Size: 427 385 hooks

Treatment: Shorter daytime gear-soak time

Control: Longer daytime gear-soak time

Results:

- Highly significant effect of total soak time on catch rate of loggerheads
- The effect of daylight soak time on loggerhead capture was inconclusive
- Total and daylight soak time had no sig' effect on catches of leatherbacks

(Watson *et al.,* 2005).

Reduced detection of bait and gear by turtles (stealth gear)

Date: 2002

Fishery: U.S. Hawaii longline swordfish fishery

Study Size: 53 483 hooks, 66 sets

Treatment: Counter-shaded floats (blue below, orange above), dark grey lines, hardware painted to remove metallic shine, down-welling narrow-frequency yellow electronic diode lightsticks and blue-dyed bait

Control: Orange buoys, uncoloured monofilament lines, unpainted hardware, green fluorescent lightsticks, and untreated bait (conventional gear)

Results:

- No turtles were caught on experimental gear, one loggerhead turtle was taken on the control gear
- Experimental gear caught significantly fewer swordfish than the control, reducing revenue by 39%

(Boggs, 2003 and 2004).

Hook and bait design – artificial lures and placing a device over or near a hook to physically prevent the turtle from taking the bait and hook

Trials on captive turtles reported in Hataway and Mitchell (2002) include:

> *Hooking deterrent. - a device attached to the hook or line that deters the turtle from interacting with the hook*. Examples of promising devices placed above the bait in captive trials include circular flat discs, a football shaped bait stopper, a clear soda bottle with the bottom cut out and a funnel. A novel idea, although unsuccessful in trials was considered to be promising, is the use of a predator shaped (shark) model to deter turtles away from longline gear.
>
> *Modifications to monofilament line to reduce hooking or entanglement*. An example was a captive trial that showed that the stiffer (3.0 and 3.6mm versus 2.6mm) monofilament line resulted in fewer entanglements.
>
> *Weighted line has been shown to result in fewer entanglements in captive turtle trials*. The turtles tended to have the ability to flick the weighted line off their flipper as they swim through before encountering the hook.

Bait threading – single-hooked fish bait has been shown to catch fewer turtles than multiple-threaded fish bait

Date: 2006

Fishery: Captive reared loggerhead turtles

Study Size: 20 individuals, 45cm, 55cm and 65cm (straight carapace length)

Treatment: Modified Mustad 39960D 14/0, 16/0, 18/0 and 20/0 circle hooks: barbs removed, points wrapped, single hooked and threaded, squid and sardine bait

Results:

- Threaded baits were more likely to be swallowed than single baited hooks in all cases except for 65cm turtles with 14/0 hooks (small sample)
- Threaded squid bait made it more difficult to strip from the hook
- Serious injury may be diminished through the use of large hooks, singly baited with finfish

(Stokes *et al.,* 2006).

Date: 2005

Fishery: Spanish Mediterranean swordfish longline fishery

Study Size: 15 sets

Treatment: Mackerel bait

Control: Squid bait

Results:

- 27 loggerheads caught with squid and 11 with mackerel
- No significant difference in swordfish catch (74 fish in total) between baits

(Rueda *et al.,* 2006).

Fishery: Captive-reared juvenile loggerhead turtles

Treatment: Various styles of ligthsticks

Results:

- The is potential in lightsticks that flash intermittently and
- In lightsticks that have wavelengths between 540nm and 600nm and
- In lightsticks that only project downwards

(Wang *et al.,* 2006).

Acoustic deterrents and soaking bait in various substances

Date:

Fishery: Captive green turtles

Treatment: Bait soaked in alternative substances - quinine hydrochloride, lactic and citric acid, urea, squid ink, garlic, chilli extract, cilantro, sea hare (*Aplysia* sp.) ink

Control: Untreated bait

Results:

- No difference in feeding behaviour between experimental and control treatments

(US National Marine Fisheries Service, Pacific Islands Fisheries Science Center, unpub. data).

Blue-dyed bait to reduce the turtles attraction to bait

Date: 2001

Fishery: Captive green and loggerhead turtles

Treatment: Blue-dyed squid bait

Control: Untreated squid bait

Results:

- Green and loggerhead turtles did not attempt to eat the blue-dyed bait for up to 10 days, after which they ate both dyed and non-dyed bait at the same rate

(Swimmer and Brill, 2001; Swimmer *et al.,* 2002a)..

Date: 2004

Fishery: Captive loggerhead turtles

Treatment: Squid bait treated with 2-phenylethanol, tiger shark skin extracts, compound VR, an experimental shark repellent

Control: Untreated squid bait

Results:

- Turtles showed limited ability to locate squid in complete darkness
- No difference between time taken to locate control or treatments

(Southwood *et al.,* 2006).

Date: 2001

Fishery: U.S. Northwest Atlantic longline swordfish fishery

Study Size: 164 429 hooks, 186 sets

Treatment: Blue-dyed squid bait

Control: Untreated squid bait

Results:

- No significant difference between treatment and control in capture rates of loggerhead and leatherback turtles

(Watson *et al.,* 2002).

Date: 2003

Fishery: Japan Northwest Pacific shallow set longline swordfish and tuna fishery

Study Size: 18 000 hooks, 19 sets, one trip

Treatment: Blue-dyed squid and mackerel bait

Control: Untreated squid and mackerel bait

Results:

- No significant difference between treatment and control

(Clarke, 2004).

Date: 2003

Fishery: Costa Rica longline dolphin fish (mahi mahi) fishery

Study Size: 12 834 hooks, 22 sets

Treatment: Blue-dyed squid bait

Control: Untreated squid bait

Results:

- No significant difference between treatment and control in capture rates of olive ridley and green turtles
- 8.4 and 8.1 turtle captures/1000 hooks for untreated and blue bait respectively

(Swimmer *et al.*, 2004).

Appendix 13: Acronyms

AFMA	Australian Fisheries Management Organisation
AFZ	Australian Fishing Zone
COFI	Committee on Fisheries
ETBF	Eastern Tuna and Billfish Fishery
EPA	Environmental Protection Agency
EPBC Act	Environmental Protection and Biodiversity Act
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organisation
FRDC	Fisheries Research and Development Corporation
IOSEA	Indian Ocean and South-East Asia Marine Turtle Memorandum of Understanding
IUU	Illegal, Unreported, or Unregulated (Fishing Operations/Vessels)
NOAA	National Oceanic and Atmospheric Administration
NED	North-East Distant Fishery
NGO	Non-Government Organisation
NMFS	National Marine Fisheries Service
PSAT	Pop-up Satellite Archival Tagging
PTT	Platform Terminal Transmitter
RFB	Regional Fishery Body
SPC	Secretariat of the Pacific Community
TAC	Total Allowable Catch
TED	Turtle Exclusion Device
US	United States
WA	Western Australia
WTBF	Western Tuna and Billfish Fishery
WWF	World Wide Fund for Nature