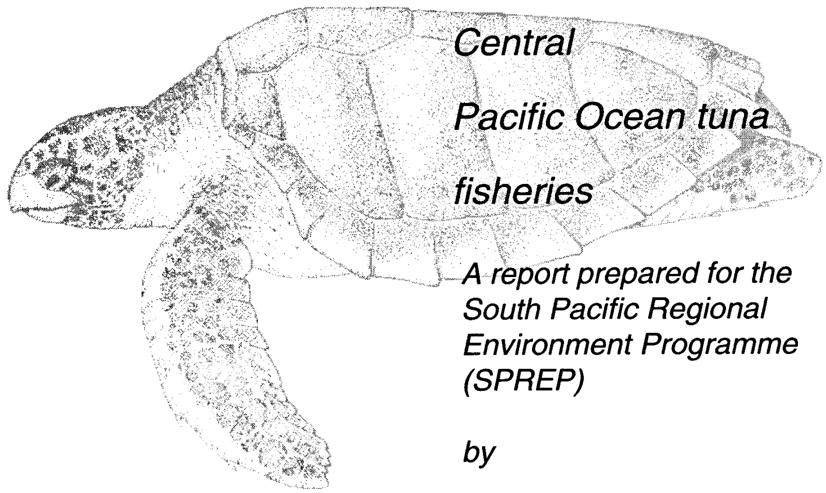
RMTCP
Regional Marine Turtle Conservation Programme

A Review of Turtle By-catch in the Western and Central Pacific Ocean tuna fisheries



A report prepared for the South Pacific Regional Environment Programme (SPREP)

by

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Contents

Foreword

SPREP's Regional Marine Turtle Conservation Programme vision for turtles in the Pacific islands region states that:

'We see a future where generations of Pacific island people will have choices about how they use and interact with sea turtles. This dream will come true if we take action now to ensure that sea turtle populations recover to become healthy, robust and stable. Sea turtles will be fulfilling their ecological role and being harvested by Pacific island people on a sustainable basis to meet their cultural and nutritional needs.'

The Pacific Islands Region is a globally significant area for marine turtles breeding and migration. The coastal populations of the Pacific islands have exploited marine turtles for their meat, eggs, shell, and oil for centuries. Cultures and traditions, which historically managed sustainable use and promoted ecological balance are degrading. The loss of traditional values combined with the negative effects of unregulated adult and egg harvest, habitat degradation, commercial trade and mortalities through incidental capture in fishing gear has accelerated the decline of marine turtle populations. The latter half of the 20th Century has been marked by catastrophic decline of sea turtle populations throughout the Pacific Region. Having existed for thousands of years, most marine turtles are now categorized as 'Critically Endangered', 'Endangered', 'Threatened' or 'Vulnerable' on the Red List of the World Conservation Union.

Key issues for turtle survival are unsustainable harvesting and habitat degradation. Both these causal factors are primarily due to human activities. In the last 10 years, concern for turtle conservation and wise-use has grown in the region with an increasing number of initiatives being undertaken at the local, national and regional levels. This has resulted in the establishment of the Regional Marine Turtle Conservation Programme (RMTCP) and associated active network of government and NGO agencies working together to effect turtle conservation and sustainable use.

This report is a review of the issue of incidental catch of marine turtles in the Western and Central Pacific Ocean Tuna Fisheries. Marine turtles can become entangled in fishing gear. Incidental injuries and deaths result from fishing where turtles are taken as by-catch in activities targeting other species. We believe that this review highlights the issue of incidental catch especially to the fishing industry and that mitigation measures maybe taken by the industry in reducing marine turtle mortalities.

I wish to acknowledge the Ocean Fisheries Programme of the Secretariat of the Pacific Community (SPC) for undertaking this review and I wish us all well in our continuing efforts to sustainably manage and conserve the marine turtles in our region.

Tamari'i Tutangata

Executive summary

The western and central Pacific Ocean (WCPO–Pacific Ocean west of 150°W) currently supports the largest industrial tuna fishery in the world, with much of the catch coming from the Exclusive Economic Zones (EEZs) of Pacific-island countries. Marine turtles are sometimes taken as by-catch within this wide area.

This review focuses on the issues of incidental marine turtle catch in the WCPO tuna fisheries based on information currently available to the Oceanic Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC). Various forms of tuna fishery information and data held by the OFP have been compiled, analysed and presented in a form providing some indications of the extent of marine turtle encounters in the WCPO tuna fisheries.

The review uses three sub-areas of the SPC Statistical Area, the western tropical Pacific (WTP, 10°N–10°S), the western sub-tropical Pacific (WSP, 10°S–35°S) and the western temperate Pacific (WTeP, 35°–45°S), to describe marine turtle by-catch in the WCPO tuna fisheries.

Annual tuna catches in the WCPO have averaged about 1.5 million metric tonnes over the past decade. Around 60 per cent of the catch is taken by purse-seine vessels which comprise a fleet of more than 200 purse seine vessels that set large nets around entire schools of tuna. These vessels operate almost exclusively in tropical waters (i.e. 10°N–10°S), originate from a variety of fishing nations and catch a high-volume product (mainly skipjack and yellowfin) for the canned tuna market. A fleet of several thousand longline vessels catch individual tuna on anywhere up to 3,000 baited hooks per line. These vessels operate throughout the waters of the WCPO from around 45°N to 45°S with their catch mostly destined for the high-priced Japanese sashimi markets. This review concentrates on marine turtle by-catch in the longline and purse seine fisheries, as by-catch in the other fisheries is either considered non-existent (e.g. pole-and-line, troll) or there is no information available (e.g. ring-net).

Information from studies elsewhere suggests that marine turtles spend some part of their life cycle in the epipelagic layer of the open ocean. Interactions with tuna fisheries are therefore thought to occur during the period when they are in the open ocean, drifting with or without debris and prior to association with inshore feeding grounds. Certain species of marine turtles are more prevalent in oceanic waters than others. Marine turtles rely on their visual senses in their search for food, but need to surface at regular intervals to breathe. They also exhibit some preference for distinct thermal regimes. These basic attributes have certain implications for potential interaction with tuna fishing gear.

Incidental catch in the longline fishery occurs when opportunistic-feeding marine turtles encounter baited longline hooks or when they are accidentally entangled with longline gear. When turtle mortalities occur they are directly related to entanglement or hooking with longline gear and typically result in drowning. If marine turtles are hooked or entangled not long before being hauled on board, they normally survive. Statistics on the life status of the marine turtle encounters varies by area however conclusions cannot be drawn from available data at this stage. There are rare reports of marine turtles being kept for crew consumption on longline vessels as most of the observed catch is typically released. It is worthwhile to note that improving crew awareness and handling has contributed to reducing marine turtle mortalities in the Hawaii-based longline fishery.

Observers have covered most of the fleets throughout the SPC Statistical Area with at least one trip, despite the overall low coverage level (<1 per cent). There are three longline fleets, for which observer data collection (in regards to marine turtle encounters) is lacking. They are therefore of some priority. These longline fleets are the Japanese and Korean distant-water longline fleets operating in the eastern areas of the WCPO, and the recently-established Australian swordfish fishery operating in waters off the eastern Australian coast (i.e. the western WSP).

Observer-reported encounters clearly show that tropical areas have more turtle encounters. Of the various factors thought to affect the level of marine turtle encounters in the **WTP longline fishery**, the depth of set appears to be the most important factor. Analysis of available observer data suggests that bait used, and whether gear is set in water during day or night, does not have as

marked an effect as the strategies to set the longline gear at either shallow or deep. Estimates from observer data and studies elsewhere (e.g. the Hawaii-based longline fishery) show that marine turtle encounters on shallow-set vessels are an order of magnitude higher than encounters by those vessels utilising a deep-set strategy. Analysis of observer data shows that when marine turtle encounters occur on deep-setting vessels, they are almost always on the shallowest hooks. *This suggests that there is probably a critical depth range of hooks where most marine turtle encounters would be expected to occur in the WTP longline fishery.*

A very preliminary estimate of 2,182 marine turtle encounters per year in the WTP longline fishery has been determined from available data, of which an estimated 500–600 are expected to result in mortality. This estimate, however, is expected to have wide confidence intervals since observer coverage has been very low (<1 per cent).

Marine turtle encounters in the **purse seine fishery** occur when turtles are found within the pursed net after the operation of encircling a school of tuna. Marine turtles are frequently found near logs and other drifting debris, and are attracted by the diverse prey items in the vicinity as well as the protection the debris offers. Purse seine vessels search and set on tuna schools that are often associated with drifting debris.

Turtle mortalities in the purse seine fishery are due to drowning as a result of entanglement in a net or, in rare instances, to being crushed during the process of loading the net on board. In most cases, turtles are encountered alive in the net and are subsequently scooped up and released overboard. Observers reported a 17 per cent mortality rate in the WCPO purse seine fishery, but a breakdown of factors for mortality rates was not possible with available information.

Marine turtle encounters in the purse seine fishery appear to be more prevalent in western areas of the WTP. The main factor affecting marine turtle encounters in the WCPO purse seine fishery is set type. Animal-associated, drifting log and anchored-FAD sets have the highest incidence of marine turtle encounters, compared to drifting FAD set on free-swimming schools (unassociated sets).

A very preliminary estimate of 105 marine turtle encounters per year in the WCPO purse seine fishery has been determined from available data. It is expected that less than 20 of these encounters would result in mortality given the current level of awareness in this fishery area. As with WTP longline fishery, this estimate has wide confidence intervals since observer coverage is less than 5 per cent.

The review suggests specific measures that might mitigate turtle by-catch and mortality, identifies gaps in the present knowledge base and recommends where future work might be directed. Specific recommendations include: (i) the introduction and adoption by Pacific island countries of a formal mechanism to advise all (longline and purse seine) fishing fleets of their responsibilities regarding the live discard of protected species, and (ii) the introduction of initiatives focusing on crew awareness and training in regards to reducing marine turtle mortalities.

Acknowledgements

A review of turtle bycatch in the western and central Pacific Ocean tuna fisheries is commissioned by SPREP's Regional Marine Turtle Conservation Programme and undertaken by Ocean Fisheries Programme of the Secretariat of the Pacific Community.

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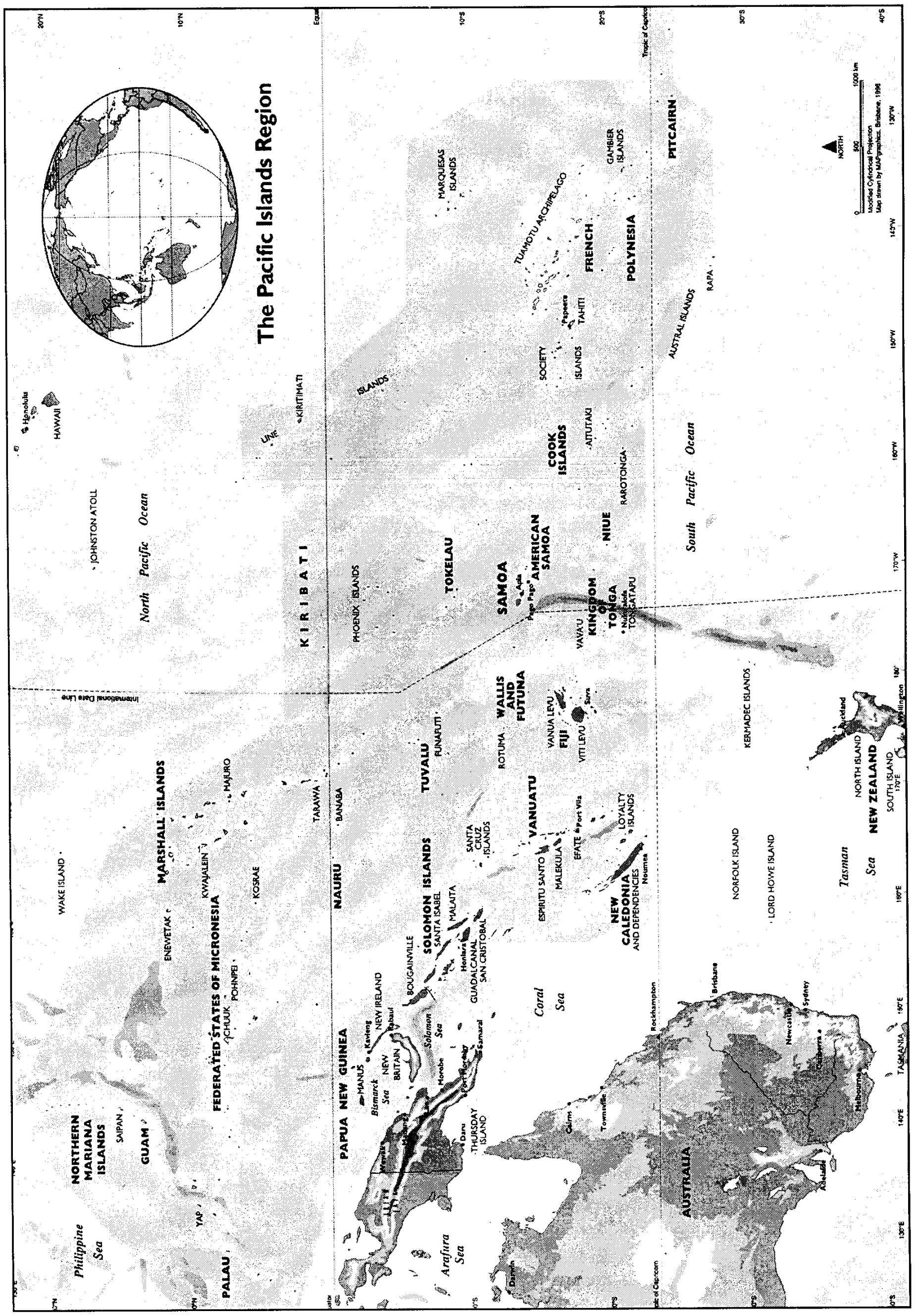
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Philippine Sea
PALAU
NORTHERN MARIANA ISLANDS
SAIPAN
GUAM
YAP
FEDERATED STATES OF MICRONESIA
CHUUK
POHNPEI
KOSRAE
MARSHALL ISLANDS
ENEWETAK
KWAJALEIN
MAJURO
WAKE ISLAND
JOHNSTON ATOLL
North Pacific Ocean
HAWAII
Honolulu
KIRIBATI
TARAWA
BANABA
NAURU
PHOENIX ISLANDS
LINE ISLANDS
KIRITIMATI
PAPUA NEW GUINEA
MANUS
Bismarck Sea
NEW IRELAND
NEW BRITAIN
Solomon Sea
BOUGAINVILLE
SOLOMON ISLANDS
SANTA ISABEL
MALAITA
GUADALCANAL
SAN CRISTOBAL
SANTA CRUZ ISLANDS
Arafura Sea
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VANUA LEVU
VITI LEVU
Suva
NEW CALEDONIA AND DEPENDENCIES
Noumea
LOYALTY ISLANDS
KINGDOM OF TONGA
VAVA'U
TONGATAPU
NIUE
COOK ISLANDS
AITUTAKI
RAROTONGA
SOCIETY ISLANDS
TAHITI
Papeete
TUAMOTU ARCHIPELAGO
MARQUESAS ISLANDS
GAMBIER ISLANDS
FRENCH POLYNESIA
AUSTRAL ISLANDS
RAPA
PITCAIRN
South Pacific Ocean
KERMADEC ISLANDS
NORFOLK ISLAND
LORD HOWE ISLAND
Tasman Sea
NEW ZEALAND
NORTH ISLAND
SOUTH ISLAND
Auckland
Wellington
AUSTRALIA
Darwin
Cairns
Townsville
Rockhampton
Brisbane
Newcastle
Sydney
Canberra
Melbourne
Adelaide
TASMANIA
International Date Line
Equator
Tropic of Capricorn
NORTH
Modified Cylindrical Projection

1. Introduction

The western and central Pacific Ocean (WCPO–Pacific Ocean west of 150°W) currently supports the largest industrial tuna fishery in the world, with much of the catch coming from the Exclusive Economic Zones (EEZs) of Pacific island countries, bounded by the Secretariat of the Pacific Community (SPC) statistical area (Figure 1; Lawson 2000).

The WCPO tuna fisheries are described in detail in a number of documents produced by the Oceanic Fisheries Programme (OFP) of the SPC, for example, Hampton et al. (2001), Lawson (2000) and Bailey et al. (1996). The lattermost study provides a detailed review of by-catch and discards in the WCPO tuna fisheries, and divides the SPC Statistical Area into three distinct sub-areas representing broad divisions of target tuna fisheries. As this review deals with a by-catch of the WPCO tuna fisheries, it has been deemed appropriate to use these three sub-areas (Figure 1) in this review. These areas are, respectively, the western tropical Pacific (WTP, 10°N–10°S), the western sub-tropical Pacific (WSP, 10°S–35°S) and the western temperate Pacific (WTeP, 35°–45°S). The northern areas of the WCPO have not been dealt with in this review, but similar studies have been undertaken in some of these adjacent areas (for example, the Hawaii-based longline fishery).

Marine turtle encounters in commercial tuna fisheries throughout the world have been documented to varying degrees. The need for more reliable information on the level of marine turtle encounters in tuna fisheries has become increasingly important. This is due to the recent closure of the Hawaii-based longline fishery due to perceived detrimental impacts on turtle populations. While further review of the Hawaii situation is currently being undertaken via an in-depth Environmental Impact Statement (EIS) update, the ramifications of these events suggest a need to have a better understanding of the extent of marine turtle interaction in WCPO tuna fisheries.

There is currently no regional management regime that brings together the coastal states and all fishing nations involved in the WCPO tuna fisheries. However, preliminary high-level discussions related to the establishment of an arrangement have now been completed and a preparatory conference dealing with the administrative aspects that should lead to the formation of the WCP Fisheries Commission was in April 2001. The OFP has been the focal point for research on the status of WCPO tuna stocks over the past 20 years with the consensus that the WCPO tuna stocks are generally in a healthy state (Hampton et al., 2001). This has meant that there has yet to be any biologically-driven management measures introduced in these fisheries. However, the past 5–10 years has seen an increase in the importance of by-catch monitoring in the WCPO tuna fisheries, with some emphasis on sharks and marine turtles, as a reaction to consideration of management measures required in line with the United Nations Implementing Agreement (UNIA) and the Food and Agricultural Organisation's (FAO) International Plans of Action (IPOAs).

This review provides: (i) an overview of tuna fisheries throughout the WCPO, (ii) a brief review of the biology and ecology of marine turtle species in the region, (iii) an overview of tuna fisheries monitoring undertaken by the OFP relevant to marine turtle encounters, and (iv) a summary of information available on the incidental capture, survival and factors affecting marine turtle encounters in the WCPO longline and purse seine tuna fisheries. Finally, this review suggests measures that might mitigate turtle by-catch and mortality, identifies gaps in the present knowledge-base and recommends where future work might be directed.

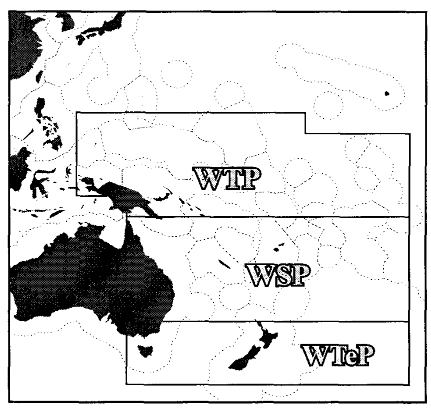


Figure 1. The SPC Statistical Area, showing sub-areas of the tropical (WTP), the sub-tropical (WSP) and the temperate (WTeP) WCPO

2. Tuna fisheries in the western and central Pacific Ocean

2.1 Overview

The WCPO tuna fisheries constitute the largest of any ocean region, providing approximately 50 per cent of the world's current tuna production. Since 1990, annual catches have averaged about 1.5 million tonnes (Lawson, 2000). The most important species, by weight of landings, are skipjack tuna (*Katsuwonus pelamis*) – 65 per cent of total 1990–1999 landings, yellowfin tuna (*Thunnus albacares*) – 24 per cent, bigeye tuna (*Thunnus obesus*) – 6 per cent, and albacore tuna (*Thunnus alalunga*) – 5 per cent.

The WCPO tuna fisheries involve several gear types. A fleet of more than 200 **purse-seine** vessels set large nets around entire schools of tuna, originate from a variety of fishing nations and catch a high-volume product (mainly skipjack and yellowfin) for the canned tuna market. A fleet of more than several thousand **longline** vessels catch individual tuna on anywhere up to 3,000 baited hooks per line. These vessels catch smaller quantities of yellowfin and bigeye for the high-priced Japanese raw fish (*sashimi*) market and albacore for the canned 'white meat' tuna market. **Pole-and-line** vessels catch tuna from schools feeding on live bait with poles that have a short line and a barbless hook and lure. This fishery was once the most common, but now numbers less than 100 large vessels. Catch these days consists mainly of skipjack for the premium-quality canned tuna and lower-quality sashimi markets. A **driftnet** fishery operated in the temperate waters of the South Pacific during the late 1980s targeting albacore with long, large-mesh nets, several kilometres in length. This fishery was eventually closed in 1991 as a result of concerns for the effects this gear had on the albacore population and bycatch. The SPC bycatch review (Bailey et al., 1996) documents marine turtle interaction with the driftnet gear, but this fishery will not be dealt with further in this review as it has been closed for more than a decade.

The purse-seine, longline and pole-and-line fleets collectively represent the ***industrial*** tuna fishing capability in the western Pacific. Tuna catches by small-scale ***artisanal*** fishers in the Pacific islands are relatively small, and total less than 10,000 tonnes per year. There are also numerous small-scale commercial and artisanal vessels catching tunas in the waters of south-east Asian countries, particularly eastern Indonesia and the Philippines. These fleets utilise a variety of gears (e.g. **handline**, **ringnet**, **troll**, **small-scale driftnet** and **bagnet**) to catch a substantial amount of tuna (averaging around 300,000 tonnes per year over the past decade) and operate in archipelagic waters in proximity to known feeding and nesting areas of marine turtle species. Unfortunately, information on bycatch from these fleets is virtually non-existent, left to speculation, based on information from adjacent areas inside the SPC Statistical Area.

In essence, it has not been possible to cover marine turtle encounters in the complete range of WCPO artisanal fisheries in this review.

The SPC review on bycatch and discards (Bailey et al., 19 96) identified three gears where encounters with marine turtles have been documented – longline, purse seine and driftnet fisheries. For reasons mentioned earlier, this review deals with only longline and purse seine.

2.2 Longline gear

The longline fishery targets adult tunas dispersed over a large area (contrary to purse seining which target juvenile and mature tunas in a more concentrated tropical area). The longline operation is conducted from fishing vessels ranging in size from 12m (with a crew of 3) up to 45m (with a crew of around 20). Depending on the size of vessel, between 500 and 3000 hooks may be set over a total distance of about 25 to 100 km. Basically a longline structure consists of the mainline and a series of floats attached to the mainline via floatlines. The floats serve to suspend the mainline as a series of catenary curves in the water column. Branchlines, with baited hooks, are attached to the suspended mainline at regular intervals (see Figure 2).

Setting the longline can take between two and six hours depending on the number of hooks and the rate of deployment from the vessel. During the setting process, baiting, branchline attachment and gear deployment can be done manually or facilitated by mechanical equipment (e.g. line-throwing devices). In certain areas, special devices are used during the setting process to avoid interaction with protected and endangered species (e.g. bait throwers, bird scaring lines and additional weights on branchlines). The bait used are commonly 'oily' fish (e.g. mackerels, scads or clupeids), squid (associated with lightsticks when targeting swordfish), and in some specific instances, live milkfish (*Chanos chanos*).

The gear drifts over a wide area for a number of hours. To ensure location in the event of a broken mainline, radio buoys are deployed at strategic places along the line. Each radio buoy has a unique morse-code signal, which can be located with the help of radio direction finder equipment. The vessel then leaves the gear to 'soak' for a period of two to ten hours, although soak time for an individual hook could be between two to more than 15 hours, if the first hook set was the last hook hauled. Weather conditions, the amount of catch and line entanglement also determine the soak time for a hook. The hauling process may take between four to more than 15 hours depending primarily on the number of hooks set, but may also be influenced by the factors mentioned above.

The depth at which longline hooks lie in the water column is influenced by many factors, such as the distance between hooks, the number of hooks between floats, the vessel speed relative to line-throwing speed during setting, the length of floatlines and branchlines and the influence of currents. A basic indication of the depth of setting is the number of hooks (branchlines) set between successive floats. It is possible to configure the gear to reach a depth of 500 m, but more often the deepest hooks lie at between 100 and 300 m, depending of the species targeted and the area fished.

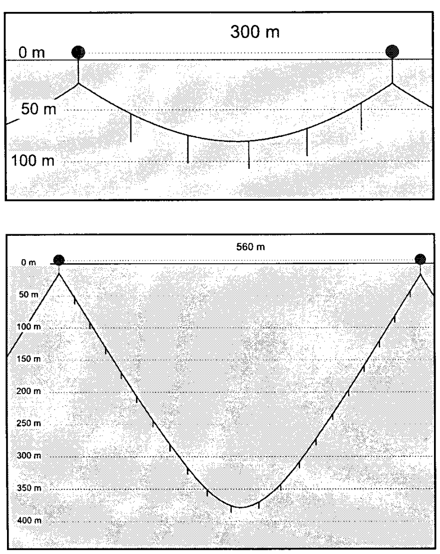


Figure 2. Artist's impression of shallow-set (top) and deep-set (bottom) longline gear

The longline fishery involves two main types of operation:

- large (typically >250 GRT) freezer vessels that undertake long voyages (months) and operate over large areas of the region. They typically target yellowfin and bigeye tuna in the tropics, and albacore in the subtropics/temperate areas;
- smaller (typically <100 GRT) vessels that are usually domestically-based, with ice or chill capacity, and serving fresh or air-freight sashimi markets. They operate mostly in tropical areas, targeting mostly bigeye and yellowfin.

There have been significant changes in fleet operations during the past two decades. For example, a feature of the 1980s was a change in targeting practices in order to capitalise on a higher price for bigeye tuna over yellowfin tuna. The gradual increase in the number of Pacific island domestic vessels, and entrance of the smaller 'offshore' sashimi longliners of Taiwan and mainland China into the fishery during the past decade is also noteworthy. There has also been a trend in some fleets towards flexibility in which species are targeted, notably those fleets with ultra-low temperature freezing capacity, and the capability of some fleets to shift operations between oceans.

Figure 3 shows the distribution of longline effort with distant-water fleets operating throughout the WCPO, targeting bigeye and yellowfin in tropical waters for the frozen sashimi market, and albacore

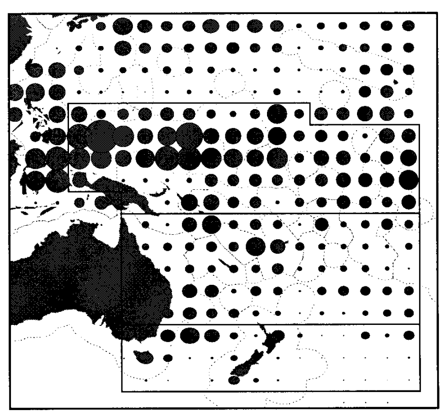


Figure 3. Distribution of longline effort in the WCPO

in the subtropical waters for canning. In contrast, the offshore fleets are primarily restricted to the tropical waters of the Federated States of Micronesia, Indonesia, Marshall Islands, Palau and Solomon Islands, and adjacent international waters, where they target bigeye and yellowfin for the fresh sashimi market.

During 1999, there was a diverse longline fleet operating in the WCPO composed of ~ 4,700 vessels. These vessels can be divided into four components largely based on the area of fishing operations:

- over 400 vessels domestically-based in the Pacific Islands with the recently-established Samoa alia fleet representing half of these vessels;
- approximately 3,000 vessels domestically-based in non-Pacific Island countries such as Japan and Taiwan;
- about 750 large distant-water freezer vessels from Japan, Korea and Taiwan that operate over large areas in the region; and
- about 450 offshore vessels based in Pacific Island countries. The offshore fleet is composed of equal numbers of vessels from mainland China, Japan and Taiwan.

Of the three large-scale commercial fishing methods (i.e. longline, pole-and-line purse-seine), longline fishing is the least selective and therefore catches the most non-target or bycatch species. The longline catch is typically composed of the target tunas, tuna-like fish, billfish, sharks and other fishes. Approximately half of the bycatch species may be retained, while other species are discarded for several reasons: undesirable species with limited commercial value, no space available, damaged fish, difficulty to land, or due to catch being a protected species (marine turtle or mammal). Bycatch levels vary due to several factors, but observer data indicate that bycatch account for about half of the catch in number for the area 10°N–10°S compared to a quarter of the catch in higher latitudes (10°S–35°S).

In recent years, there have been formal restrictions introduced in some domestic fisheries throughout the Pacific to limit the take of certain bycatch species, specifically species such as marlin, sea birds and turtles. These restrictions consist of time closures, longline exclusion zones or gear modifications, such as 'tori poles' to reduce seabird bycatch in the southern bluefin tuna fishery.

2.3 Purse seine gear

Purse seine vessels predominantly target surface tunas that form dense, mobile schools in the tropical waters of the WCPO. The purse seine vessel actively searches for schools of free-swimming tunas with a variety of manual (e.g. binoculars), mechanical (e.g. helicopter) and electronic (e.g. sonar) equipment. Once a school has been found, the vessel chases and then attempts to intercept the school. Alternatively, purse seine vessels may also rely on drifting objects such as logs or flotsam to aggregate schools of tunas; purse seine vessels may also deploy their own drifting or anchored FADs (fish aggregating devices) to attract schools of tuna over a period of several weeks/months.

Once encountered, the schools of tuna are surrounded by the purse-seine net which is composed of panels of vertically-hung nets, with rings (purse rings) along its lower edge (Ben-Yami, 1994). A cable is passed through the purse rings enabling the vessel to close off the lower section of the netting (i.e. 'purse') from below. The top section of the net is supported by floats that serves to keep the wall of netting vertical when it is deployed and throughout the entire setting and brailing process. Skill and timing is required by the crew in utilising a small, fast skiff to take one end of the net and surround the school of tuna with the net, and then return to the vessel. Once this is done, the net is 'pursed' by retrieving the cable that is threaded through the rings on the lower section of the net. This process is typically performed by large, mechanically-driven winches through power blocks, but may also be done manually on small-scale ring-net vessels (e.g. those that fish in the Philippines). The bowl-like structure that results acts to enclose the school of tuna, preventing them from escape. The catch is then transferred from the purse seine to the vessel via smaller brail nets that scoop up to five tons of the catch at a time from the pursed net and places them on the deck of the vessel. The catch is then sorted and transferred to storage wells.

The industrial purse-seine fishery has accounted for around 60 per cent of the WCPO total (DWFN) fleets – Japan, Korea, Taiwan and USA – but with an increasing contribution from the growing number of Pacific island domestically-based vessels. Skipjack tuna regularly account for 70–75 per cent of the purse-seine catch, and the WCPO purse-seine fishery is essentially a skipjack tuna fishery, unlike those of other ocean areas.

During 1999, the purse-seine fleet comprised 223 vessels in WCPO fishery. The fleet structure was 159 distant-water vessels, 31 domestic Pacific island vessels and 33 domestic non-Pacific island vessels. WCPO purse-seine activity occurs almost exclusively in the equatorial waters within 10°N–10°S (Figure 4). There is a shift in activity relative to the *Warm Pool* (an ocean area with sea surface temperature > 28°C). The fleets typically fish farther to the east during warm El Niño events, when the warm pool expands eastwards; conversely, the purse-seine fishery contracts westward during La Niña or cool events. For example, the western Pacific experienced a La Niña event throughout 1999, with most of the fleets restricted to the east fishing the waters of FSM and PNG. This is in contrast to the previous two years when an El Niño event was in force and most fleets extended their activities into the waters of Kiribati and Marshall Islands waters. A noted exception was the US fleet, which remained east of the other fleets and fished almost exclusively on drifting FADs.

There has been some environmentally-related concerns regarding the recent increased use of drifting FADs in the fishery. Schools associated with logs and FADs are considered to have higher levels of by-catch relative to free-swimming schools encountered by purse seine vessels, with most (if not all) of the by-catch discarded. Drifting FADs also produce relatively higher catches of juvenile bigeye, which could later adversely affect catch rates of adult fish in the longline fishery. The percentage of by-catch relative to target catch in the WCPO purse seine fishery is generally very low in comparison to most other fisheries throughout the world.

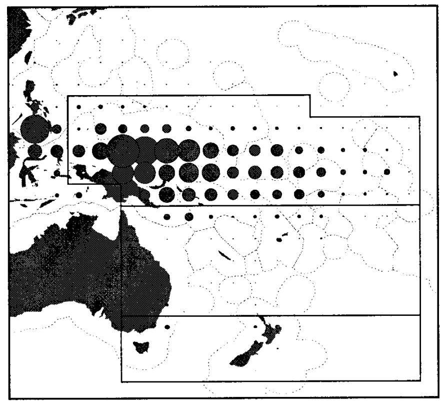


Figure 4. Distribution of purse seine effort in the WCPO

3. Monitoring, research and assessment of the WCPO tuna fisheries

3.1 Overview

The collection of appropriate data from the WCPO tuna fisheries has been a long-term priority of the OFP. Since its inception in 1981, the OFP has maintained catch and effort, tagging, size composition and, more recently, observer and recreational fisheries databases. These databases have been used extensively by research scientists conducting tuna stock assessment analyses, and are made available for other related activities, for example economic analyses of the fisheries.

In the past five years, a dedicated effort has been made to standardise tuna fisheries data collection forms throughout the region (SPC 2001).

Catch logsheets provide most of the information on the catch of target tuna species and are issued by the coastal states forming bilateral arrangements with fishing nations for access to their exclusive economic zones (EEZs). There is also one multilateral arrangement currently in force that allows US purse-seine vessels to fish throughout the region. However, while there is a requirement to provide accurate details for the target tuna catch, there has never been any strict obligation or enforcement to report bycatch. Further, logsheets used by fleets in the WCPO have never had the specific provision to report marine turtle encounters, although a column is available to fill in the name of the bycatch species and reported catch. Despite this, there has never been a marine turtle encounter recorded on a catch logsheet.

It has been long acknowledged that the only reliable indications on the level of marine turtle encounters in the WCPO tuna fisheries have been obtained by observers.

3.2 Scientific observer data collection

Observer programmes have only gained prominence in the WCPO tuna fisheries during the past decade. Prior to 1990, only two compliance-related observer programmes were operational in the tropical waters of the WCPO (i.e. the WTP); both programmes tended to become more involved in scientific data collection during the 1990s.

The establishment in 1995 of a five year European Union (EU)-funded project operating in association with the work programme of the OFP, the *South Pacific Regional Tuna Resource Assessment and Monitoring Project (SPRTRAMP)*, has seen an increase in observer activities throughout the region. With assistance from SPRTRAMP, national scientific observer programmes have been established in Fiji, Marshall Islands, Papua New Guinea, Palau and the Solomon Islands in recent years and further national programmes are expected in the future.

Major observer programmes have been established in Australia and New Zealand since the 1980s. These programmes have primarily covered the activities of foreign longline fleets provided access to target southern bluefin tuna (*Thunnus maccoyii*) in the WTeP, and albacore, yellowfin and bigeye elsewhere. This review has benefited from the provision of substantial observer data provided by government bodies in each country, that is the Australian Fisheries Management Authority (AFMA), and the Ministry of Fisheries and National Institute of Water and Atmospheric Research (NIWA) in New Zealand.

The National Marine Fisheries Service (NMFS) has conducted an observer programme in the Hawaii-based longline fishery since the early-mid 1990s. With observer coverage generally at 3–6 per cent since 1994, this data no doubt provides useful comparisons with observer data collected elsewhere in the WCPO longline fisheries. Unfortunately, the Hawaii-based longline observer data is not currently available to the OFP, but several publications and documents summarising this data have been used in this review.

Scientific observers are trained to collect catch and effort data from longline, pole-and-line and purse seine vessels operating in the region. Unlike logbook data collection, observers collect very detailed information on the components of fishing effort and individual catch from each fishing operation. Table 1 shows the type of effort and catch information collected by observers onboard longline vessels. Table 2 (following page) shows the type of information collected onboard purse seine vessels.

Observer data collection forms, ongoing training, manuals and species identification guides are provided to national observer programmes by the OFP. This fosters regional standardisation of data collection. Ongoing review of national observer programmes throughout the region has been achieved by the placement of scientific observers (employed by the OFP through SPRTRAMP) in countries to review and advise on observer data collection matters. A distinct improvement in the identification of marine turtle species by national observers has been the result of such initiatives in recent years. To ensure the integrity of the data collected, data from each observer trip is carefully screened. Data quality indicators for fishing activity, target catch, by-catch, species identification and size composition are assigned as necessary. Observers throughout the region are expected to complete a written report after each trip and these reports provide qualitative information on the fishing operation and the catch, and complement the quantitative information collected on the observer data collection forms. Observers are specifically instructed to include a section on protected species interactions in their trip report narrative.

3.3 Observer data quality and coverage issues

Observer data is the only source of quantitative data that can be used for this study. However, since the establishment of a regional programme (1995), observer data have covered less than 1 per cent of the longline effort annually, and at best 4 per cent of the purse seine effort in the WCPO (Lawson, 2001). This level of coverage is clearly insufficient for obtaining accurate estimates of marine turtle encounters. It has been estimated that, in order to increase observer coverage to around 20 per cent, 200 full-time observers need to be recruited with an operating budget far in excess of what has been required to date.

Observer data collection has been hampered by problems with species identification in the early years of the regional programme. These problems were mainly due to a lack of training of national observers before they embarked on trips.

Table 1: Observer data collected for each longline fishing operation

Effort information	Catch information
Detail of gear used by the vessel in the setting process. For example, all dimensions of the longline gear used in the set, bait species used and setting speed parameters.	Time when individual catch is taken and the hook number between successive floats that this catch was encountered.
Detailed positional and temporal information of the setting and hauling process.	Name of species (target and by-catch) encountered.
Environmental conditions (e.g. sea temperature, sea condition, etc.) during the set and haul.	Length and weight of individual catch. Note that different length and weight measurements are taken depending on the species and the processing (fate) undertaken onboard.
	The fate of the catch. That is, whether the catch, or part of the catch, was retained or discarded, and the reasons for retaining or discarding the species catch. The categories for discard includes 'discarded – protected species' (as is the case with marine turtles).
	Life status (condition) of the individual catch at the time of landing. There are six categories: A0 Alive (not categorised further) A1 Alive and healthy A2 Alive – injured or distressed A3 Alive – but dying D Dead U Condition unknown
	Sex of the individual catch.

Table 2: Observer data collected for each purse seine fishing operation

Effort information	Catch information
Detail of gear used by the vessel in the setting process	Name of species (target and by-catch) encountered
Detail of searching activity leading up to the fishing set	Number and weight of species taken (methods are employed to estimate weight for catch which is typically measured in the metric tonnes for target tuna species)
Location and time of the set	The fate of the catch. That is, whether the catch, or part of the catch, was retained or discarded, and the reasons for retaining or discarding the species catch
Tuna school association information	Weight range of individuals in that species catch / fate combination. (for example, target catch may be discarded due to being too small)
Environmental conditions (e.g. sea temperature, sea condition, etc.)	Life status (condition) of the species catch. This is relevant for protected species, for example, marine reptiles and marine mammals
Time taken for each sub-activity in the setting process	Size composition sample of the catch (Target and by-catch)

4. Biology and ecology of marine turtles

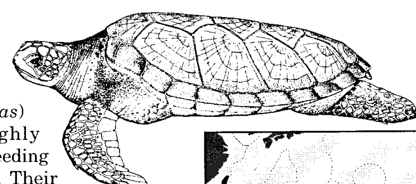
4.1 Overview

There have been many detailed research projects, including turtle tagging and tracking activities and population modelling, that have established the current information-base available on marine turtles. The following is a very brief and general overview of the biology and ecology of marine turtles that complements the sections that follow.

After hatching from beach nesting sites, young turtles are subject to dehydration and predators, such as sharks, during the time they attempt to swim offshore. The hatchlings remain in offshore currents, drifting and feeding in the epipelagic layer of the ocean. They generally return to inshore feeding grounds as immature adults when they are about 20cm (Straight Carapace Length–SCL). When they attain sexual maturity, which may be up to 30 years for some species, they return to the open ocean, once again embarking on long migration routes to breeding and nesting sites. Interactions with tuna fisheries are therefore thought to occur during the period when young turtles are in the open ocean, drifting with or without debris. This occurs prior to association with inshore feeding grounds, as non-breeding adults and also when sexually-mature adults are migrating to breeding/nesting sites. Certain species of marine turtles are more prevalent in oceanic waters than others. They rely on their visual senses in their search for food and need to surface at regular intervals to breathe. They also exhibit some preference for distinct thermal regimes. These basic attributes have certain implications for potential interaction with tuna fishing gear.

The description of each marine turtle species that follows is in no way comprehensive, but serves to provide an overview of each species with possible inference to interactions with tuna fisheries. Most of the following has been summarised from Marquez (1990).

4.2 Biology and ecology of marine turtle species



4.2.1 Green turtle

The green turtle (*Chelonia mydas*) is a circumglobal and highly migratory species, nesting and feeding in tropical/subtropical regions. Their range can be defined by a general preference for water temperature above 20°C.

This species is known to live in pelagic habitats as post hatchlings/juveniles, feeding at or near the ocean surface. The non-breeding range of this species can lead a pelagic existence many miles from shore. The breeding range primarily live in bays and protected shores and are rarely found in the open ocean. Most migration from rookeries to feeding grounds is via the coastal environs with females migrating to breed only once every two years or more.

The green turtle is a primarily herbivorous species and typically feeds during the day in shallow-water seagrass beds. Nesting season occurs throughout the year in the WCPO, with peaks in summer months where water temperature is typically over

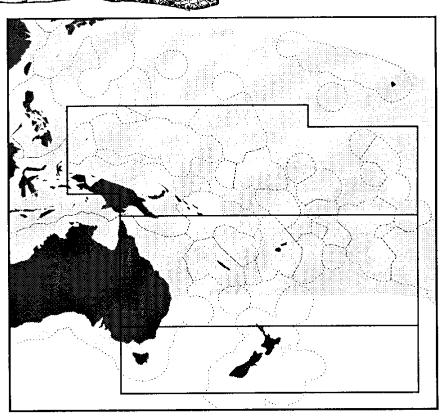
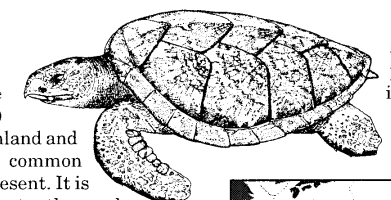


Figure 5. Geographic range of the green turtle throughout the WCPO. Adapted from Marquez (1990).

25°C. The range of age at first maturity has been estimated to range from between 6 and 13+ years, depending on the author. Some studies also show that these animals commence reproducing when in captivity less than 10 years. The green turtle is currently listed as 'endangered' under the 2000 IUCN–World Conservation Union red list of threatened species and 'threatened' under the U.S. Endangered Species Act (ESA).

4.2.2 Hawksbill turtle



The hawksbill turtle (*Eretmochelys imbricata*) lives in littoral waters of mainland and island shelves and is more common where reef formations are present. It is the most tropical of all sea turtles and nesting is confined between 25°N and 35°S.

Juveniles exhibit some degree of residential or non-migratory behaviour. Adults are capable of undertaking both short and long-distance migrations.

Nesting season occurs mostly toward the end of spring and throughout summer. Age at first maturity is not entirely clear; the female is estimated to reach maturity at sizes between 68 and 80 cm (SCL) and at body weights from 40 to 56 kg depending on the locality. The hawksbill turtle is a benthic feeder and its diet consists principally of corals, tunicates, algae and sponges.

The hawksbill turtle is currently listed as 'critically endangered' under the IUCN red list of threatened species and 'endangered' under the ESA. Throughout the Pacific, this species is rapidly approaching extinction primarily due to harvesting for its meat, eggs and shell, as well as destruction and disruption of its nesting habitat.

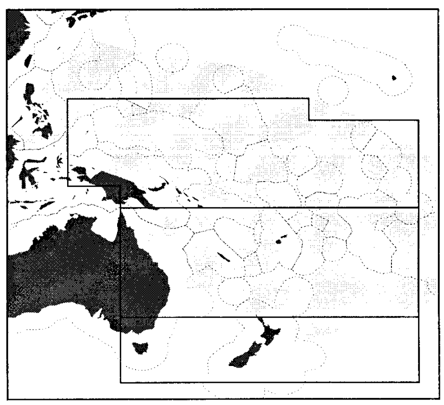
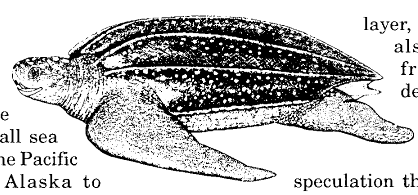


Figure 6. Geographic range of the hawksbill turtle throughout the WCPO.
Adapted from Marquez (1990)

4.2.3 Leatherback turtle



The leatherback turtle (*Dermochelys coriacea*) is the most widely distributed of all sea turtles and can be found in the Pacific Ocean from the Gulf of Alaska to Tasmania and New Zealand. It is a highly pelagic species that approaches coastal waters only during the nesting season. They are the largest of the marine turtles and may span 270 cm (SCL) length as an adult.

It is assumed that this species is carnivorous throughout its life cycle. The adults feed mainly on jellyfish, tunicates and other soft-bodied invertebrates that are abundant in the epipelagic layer, although observations have also found that the animal frequently descends into deeper waters. Rare nocturnal feeding within the deep scattered layer has been observed, with some speculation that leatherbacks may locate pyrosomas (salps) due to their bioluminescence. Maximum depths for dives have been reported to beyond 500 metres, but the majority of dives in one experiment with transmitters were less than 150 metres.

Migratory routes and nesting populations in the WCPO are not fully known; major nesting sites listed include Indonesia and the Solomon Islands, with scattered sites in Australia, Fiji and PNG. This species appears to grow faster than any other marine turtle and is believed to reach sexual maturity after a minimum of 9 years, at a size of about 125 cm (SCL).

The leatherback turtle is currently listed as 'critically endangered' under the IUCN red list of threatened species and 'endangered' under the ESA. Primary threats to this species are coastal and high seas fishing and, to a lesser extent, the disruption and destruction of nesting sites.

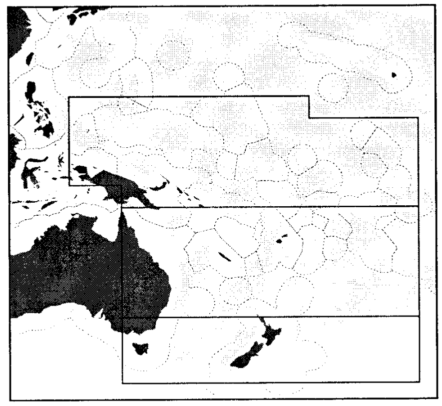
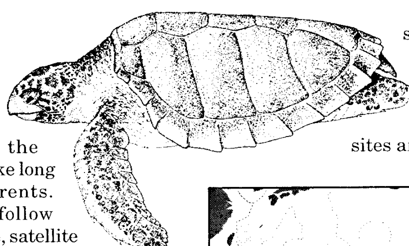


Figure 7. Geographic range of the leatherback turtle throughout the WCPO. Adapted from Marquez (1990).

4.2.4 Loggerhead turtle



The loggerhead turtle (*Caretta caretta*) is widely distributed in temperate and subtropical waters throughout most of the world, and is known to undertake long migrations using warm currents. There is some tendency to follow temperature fronts, for example, satellite telemetry studies in Hawaii showed individuals following the 17°C and 20°C isotherms.

Nesting has been observed from Japanese waters in the north to New Caledonia in the south, with major sites in Australia. Summer surface temperature for nesting must be over 20°C.

Both juvenile and sub-adults forage in open ocean pelagic habitats. As adults, this carnivorous species feeds in coastal bays and estuaries, as well as in the shallow waters along continental shelves. The diet of this species shows some preference to benthic fauna such as shellfish, crabs, shrimps and small fish. Age at first maturity has not been clearly determined and data from studies of individuals in captivity suggest this to be between 6 and 20 years. The loggerhead turtle is currently listed as 'endangered' under the IUCN red list of threatened species and 'threatened' under the ESA. Primary threats to this species are the disruption and destruction of nesting sites and commercial fishing.

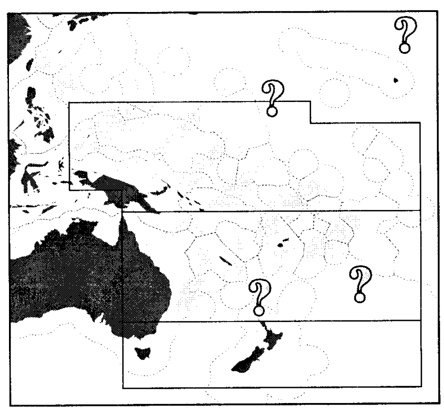
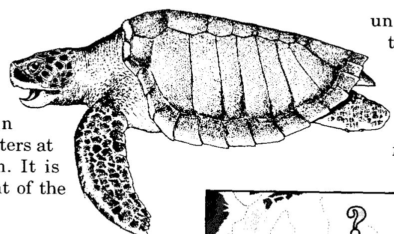


Figure 8. Geographic range of the loggerhead turtle throughout the WCPO. Adapted from Marquez (1990).

4.2.5 Olive ridley turtle



The olive ridley turtle (*Lepidochelys olivacea*) is a pantropical species, living principally in the northern hemisphere, but limited to waters at or above the 20°C isotherm. It is considered the most abundant of the world's sea turtles.

The geographic extent of this species is not as well documented in the WCPO as in other ocean areas, although it is known elsewhere to rarely frequent oceanic islands with major nesting colonies found primarily in the continental coastal waters.

Adults are mostly neritic, travelling or resting in surface waters, but turtles diving and feeding to a depth of 200m have been reported. The olive ridley is an omnivorous turtle, feeding on crustaceans, mollusks and tunicates.

In general, the nesting season is in the summer and autumn months. Large nesting aggregations with massive arrivals of thousands of females on the beach have been reported. Age at maturity is considered to be six to eight years, with studies suggesting an average size of 62 cm (SCL). The olive ridley turtle is currently listed as 'endangered' under the IUCN red list of threatened species and 'threatened' under the ESA, although most concern relates to the over-harvesting of the Mexican nesting population.

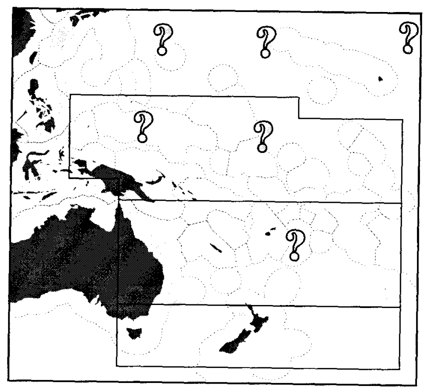


Figure 9. Geographic range of the olive ridley turtle throughout the WCPO. Adapted from Marquez (1990).

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5. Overview of marine turtles encountered in the WCPO longline fishery

5.1 Description of marine turtle capture and fate in WCPO longline fishery

Observers active in the region have described the capture of turtles by the longline gear in both quantitative and qualitative form. Marine turtles are caught when they have attempted to take the baited hook of the longline gear, although cases of accidental hooking in areas other than the mouth and entanglement with the fishing gear have also been reported regularly.

Incidental catch in the longline fishery occurs when opportunistic-feeding marine turtles encounter baited longline hooks or when they are accidentally entangled with the longline gear. Marine turtles presumably drift, float, dive or swim in the epipelagic layers of the ocean, with or without debris concentrated at current and temperature fronts, and simply approach and take the baited hook once encountered, or simply become entangled in the gear by accident.

Turtle mortalities, when they occur, are directly related to entanglement or hooking with the longline gear and typically results from drowning. Marine turtles that are hooked shortly before being hauled on board survive. Marine turtles have also been known to drag the branchline to the surface, when the gear is shallow, in order to breathe prior to being hauled on board. Post-release mortality can occur due to hook ingestion, that is, if the ingested hook pierces internal organs, despite the animal being released in an apparent healthy state. However, several recent studies have also shown that the hook can often pass through the digestive system of the marine turtle without any adverse effects (e.g. Aguilar et al., 1995).

There have only been two observed reports of a marine turtle being kept for crew consumption on longline vessels in the WCPO, although this may be more common on vessels without observers. Observers are instructed to inform the captain and crew of their obligations regarding protected and endangered species, even though there may not be any formal requirement to do so in their fishing access agreement.

Statistics on the condition (life status – Table 3) of marine turtles on landing varies and no conclusions can be drawn from the available data at this stage, although it is clear that most marine turtles encountered by observers are typically released alive. There was only one instance where a dead turtle was retained for crew consumption in the WTP, and a similar incident in the WSP. There was no explanation for the retention of marine turtles in the WTeP. In the Hawaii-based tuna and swordfish fisheries, turtle mortality was estimated to be 29 per cent for marine turtles that ingested the hook, but on average 17.5 per cent when considering all marine turtle encounters regardless of take (e.g. ingested hook, hooked elsewhere on body, entangled in the line, etc.) (Aguilar *et al.*, 1995; Kleiber, 1998; McCracken, 2000). This compares to a reported 27 per cent mortality for the WTP and 18 per cent for the WSP, regardless of take. It is worthy to note that improving crew awareness and handling has contributed to reducing marine turtle mortalities in the Hawaii-based longline fishery.

Table 3: Life status of marine turtle encounters observed in WCPO longline sets (based on observer data, 1990–2000)

Area	Observed sets	Turtles	Release (%)	Alive %			Dead (%)
				Healthy	Injured/ stressed	Barely alive	
WTP (10°N–10°S)	2,143	83	99%	58%	8%	6%	27%
WSP (10°S–35°S)	2,502	12	92%	73%	9%	–	18%
WTeP (south of 35°S)	5,908	7	71%	n/a	n/a	n/a	n/a

5.2 Spatial and temporal trends in marine turtle encounters in the WCPO longline fishery

5.2.1 Distribution

Table 4 and Figures 10–12 provide some indication of observed marine turtle encounters throughout the three sub-areas of the SPC Statistical Area. It should be noted that observer effort does not cover the eastern areas of the SPC Statistical Area and is therefore not representative of the longline effort (compare Figure 10 with Figure 3). Further, it is clear that a disproportionate amount of observer effort has been undertaken in the temperate areas than elsewhere. Nonetheless, the following observations have been drawn from these data:

- The distribution of observer-reported encounters clearly show that tropical areas (WTP) have higher incidence of turtle encounters. It is apparent that tuna-targeting fleets in the WSP do not have as high a number of marine turtle encounters as in the WTP, despite having more observer effort expended. This is accentuated further when comparing encounters in the WTeP tuna fisheries.

- The relatively fewer marine turtle encounters in Papua New Guinea are probably related to the lack of longline activity in the past decade (since 1987 when the Japanese longline fleet was last licensed to fish there).

- Unfortunately, a large proportion of the turtle encounters could not be identified to the species level. Green turtles and olive ridley turtles constituted the majority of marine turtles identified to the species level, but due to poor coverage this should not be taken as an indication of the relative turtle species composition in the WCPO longline fisheries. The olive ridley encounters were mostly in the northern hemisphere, with green turtle encounters more common in tropical waters and off the east coast of Australia.

- Observers have covered most of the fleets throughout the SPC Statistical Area with at least one trip (Lawson, 2001). The three longline fleets, for which observer data collection (in regards to marine turtle encounters) is currently lacking, and therefore of some priority, are the Japanese and Korean distant-water longline fleets operating in the eastern areas of the WCPO, and the recently-established Australian swordfish fishery operating in waters off the eastern Australian coast (i.e. the western WSP).

5.2.2 Sea surface temperature and seasonality

The biology of marine turtles suggests that they are restricted in distribution by water temperature. Clearly, there are relatively fewer turtles encountered in longline fisheries in progressively higher latitudes (Figure 10). Seasonal changes in water temperature outside of the WTP mean that marine turtles may only be encountered for a portion of the year in the more temperate areas. The seasonality of marine turtle encounters, according to observers, show that turtles have been observed in every month in the tropical areas, but more frequently in the austral summer–autumn months in the temperate zones, a period which coincides with months of highest sea surface temperature in these areas.

Table 4: Marine turtle encounters observed in WCPO longline sets (based on observer data, 1990–2000)

Area	Observed sets	Turtles	Incidence (%)	Nominal CPUE	Mean CPUE	SE	CV
WTP (10°N-10°S)	2,143	83	3.69%	0.02633	0.0389656	0.004599	11.8%
WSP (10°S-35°S)	2,502	12	0.48%	0.00218	0.0031200	0.000943	30.2%
WTeP (south of 35°S)	5,908	7	0.12%	0.00051	0.0006723	0.000263	39.1%

Notes

- The boundaries representing the sub-areas of the WCPO have not been strictly adhered to in cases where catch and effort is thought to be better associated to one sub-area over another. For example, it was convenient to have the boundary between the WTP and WSP moved from 10°S to 11°S.
- **Incidence** is the percentage of sets encountering turtles
- **Nominal CPUE** and **Mean CPUE** are expressed as number of marine turtles per 1,000 hooks; sets were used as replicates for determining Mean CPUE
- **SE** is the standard error in the estimate of **Mean CPUE**
- **CV** is the coefficient of variation, i.e. the ratio of SE to the mean CPUE

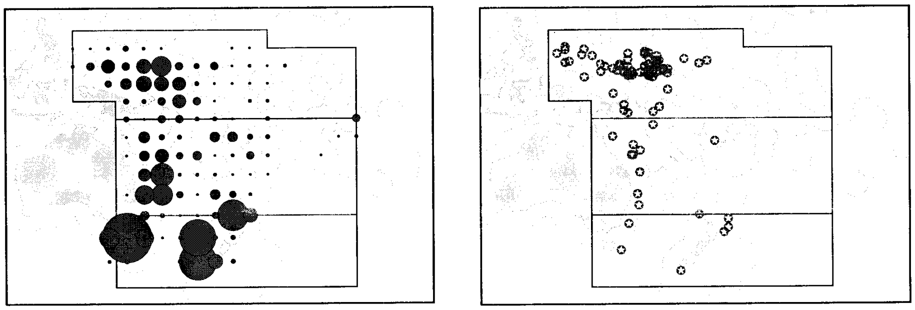
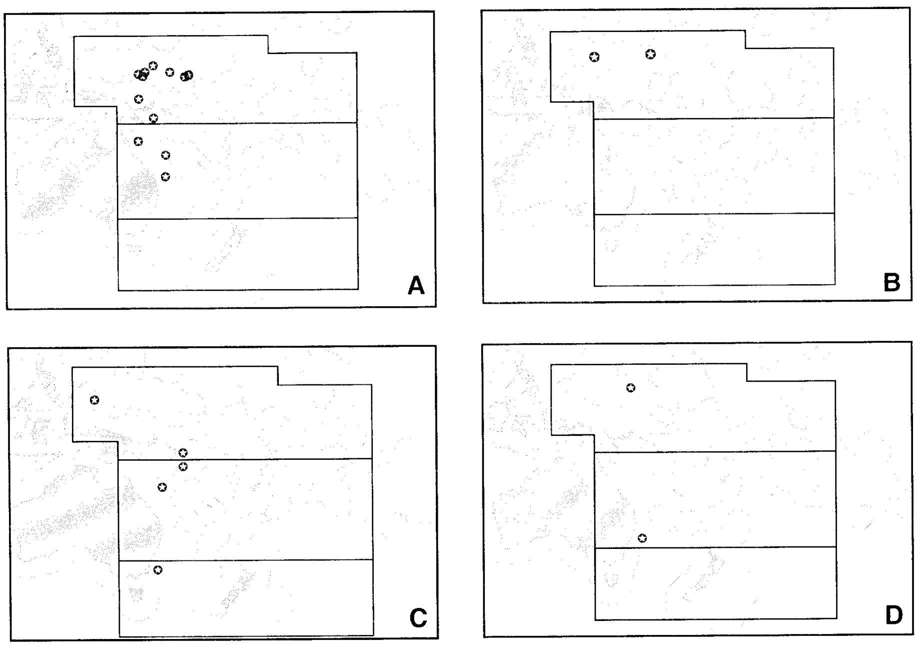


Figure 10: Distribution of observer effort (observed sets) on longline vessels in the WCPO, 1990–2000 (left), and marine turtle encounters by observers on longline vessels (right)



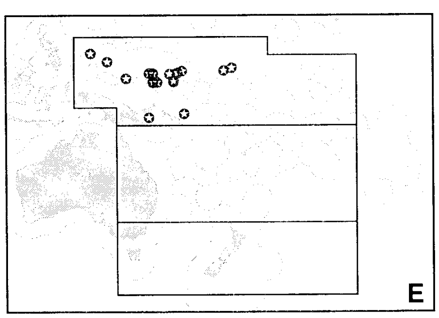


Figure 11: Marine turtle species encounters by observers on longline vessels. ***A****–green turtle;* ***B****–hawksbill;* ***C****–leatherback turtle;* ***D****–loggerhead turtle;* ***E****–olive ridley turtle.*

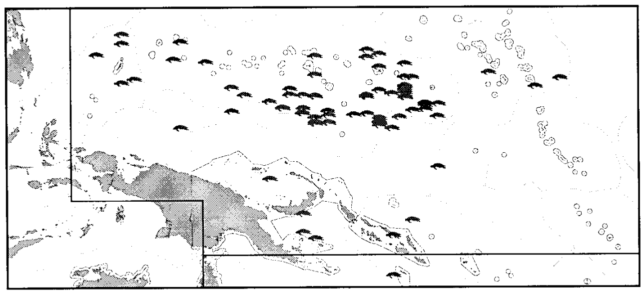


Figure 12: Distribution of observed marine turtle encounters in the WTP longline fisheries

Seasonality of occurrence is also related to periods of migration for marine turtle species and may be an important factor affecting interaction in the WCPO longline fisheries. Unfortunately, there is insufficient marine turtle observer data at the species level to be able to pursue this further at this stage.

5.3 Factors affecting turtle captures in the WCPO longline fishery

Longline vessels operating in the WCPO employ a variety of fishing strategies when attempting to optimise the catch of target tuna species. These include, for example, varying the depth of the gear in relation to knowledge of the preferred temperate levels for target species, real-time information from other vessels in the vicinity, the types of bait used, setting strategies involving diurnal and lunar cycles, and knowledge of geographic and oceanographic features.

An in-depth study looking at the effects of fishing strategies, environmental, geographic and oceanographic features on encounters with marine turtles in the longline fishery is beyond the scope of this report due to current low levels of observer coverage. Instead, the following provides a description of certain factors that are believed to play some part in marine turtle encounters in the WCPO longline fishery.

5.3.1 Depth of set

Variations in the vertical profile of water temperature and knowledge of the biology and ecology of marine turtles suggest that marine turtles are restricted to the epipelagic layers of the ocean. Longline vessels vary the depth of their gear to target certain species of tuna. For example,

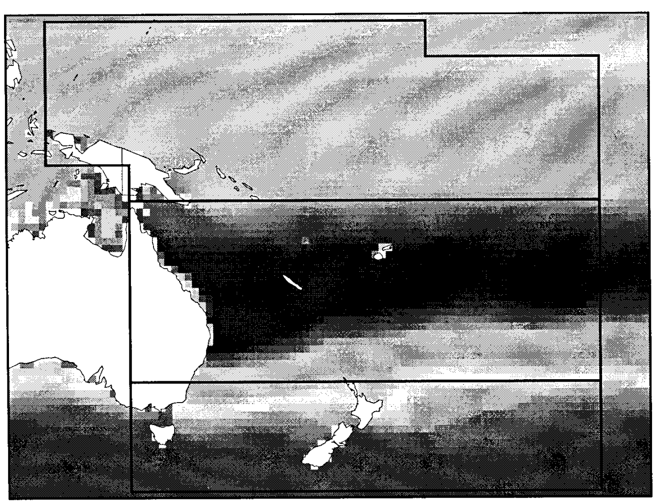


Figure 13: Distribution of the mean depth of the 15°C isotherm. Dark blue indicates a depth greater than 350 metres; light blue: 250–350 metres; green: 100–250 metres, and red: < 100 metres

bigeye tuna (considered the primary target species because of their value) is generally taken at greater depths than yellowfin, with one of the prime factors being that bigeye prefer a lower temperature range (10°–15° C) than yellowfin (Suzuki et al., 1977). Figure 13 shows the distribution of the mean depth of the 15°C isotherm throughout the WCPO, and therefore some indication of the depth required for longline gear targeting bigeye tuna.

Longline vessels targeting bigeye at greater depths would be less prone to encounter marine turtles than shallower gear. Longline vessels targeting bigeye in the sub-tropical areas (i.e. WSP) typically set between 15 and 25 hooks between floats to fish at depths of up to 400 metres. At these depths, the water is cooler and light is limiting, and therefore considered not to be the optimal environment for the marine turtles. This is perhaps why there have been relatively fewer reported marine turtle encounters in observer trips undertaken in the sub-tropical areas (WSP), despite there being a considerable number of known nesting sites throughout this broad area.

In contrast, the thermocline is shallower in the tropical waters and vessels targeting bigeye do not fish as deep as in the sub-tropical waters. Throughout the WTP, three longline fleets accounted for most of the observer activity over the past decade – the offshore fleets of China, Japan and Taiwan. Table 5 shows a breakdown of gear-setting strategies within these fleets; note that there is a distinct separation in depth of fishing (based on area fished) within one of these nations, hence the presentation of four fleets. There is a clear distinction between the fishing strategy of the shallow-set offshore fleets from China and Taiwan (operating in Micronesia), and that of the deep-set fleets of Japan and Taiwan (operating in Solomon Islands waters). The shallow-set fleets have adopted a strategy of fishing in the weeks either side of the full moon, setting their gear very shallow and (generally) letting it soak during the night, apparently as a means of better targeting bigeye. In contrast, the Japanese vessels, for example, tend to soak their gear during the day and at greater depths.

Table 5: Gear-setting strategies of the most frequently observed longline fleets operating in the WTP

	Observed Sets	Hooks between Floats			
		Avg	Range	Depth range	Desc
Fleet #1	482	5	4–6	< 100m	Shallow
Fleet #2	434	5	4–9	< 100m	Shallow
Fleet #3	115	19	15–21	150–300m	Deep
Fleet #4	294	18	15–20	150–300m	Deep

Table 6 shows the breakdown of marine turtle encounters by setting strategy, and clearly shows by comparison of nominal catch per unit effort (CPUE) that the shallow-set strategy would expect to account for approximately an order of magnitude more marine turtle encounters than deep sets.

Table 7, showing the hook number between successive floats where turtles that was encountered for deep-setting longline vessels, is

Table 6: Marine turtle encounters by setting strategy for WTP longline sets. Categories for setting strategy have been ranked in descending order of nominal CPUE (according to observer data)

Setting strategy	Observed sets	% shallow sets	Turtles	Incidence (%)	Nominal CPUE	Mean CPUE	SE	CV
Shallow – Night set	1,029	100%	60	5.4%	0.06617	0.06276	0.00852	13.6%
Night set	1,071	96%	61	5.1%	0.06344	0.06103	0.00822	13.5%
Shallow set	1,223	100%	69	5.3%	0.06129	0.06084	0.00767	12.6%
Shallow – Day set	174	100%	9	5.2%	0.04713	0.05643	0.01924	34.1%
Deep – Night set	42	0%	1	2.4%	0.01827	0.01860	0.01860	100.0%
Day set	1,072	16%	22	2.1%	0.01006	0.01694	0.00403	23.8%
Deep set	919	0%	14	1.5%	0.00692	0.00990	0.00303	30.6%
Deep – Day set	878	0%	13	1.5%	0.00659	0.00948	0.00305	32.2%

Notes

- **Incidence** is the percentage of sets encountering turtles
- **Nominal CPUE** and **Mean CPUE** are expressed as number of marine turtles per 1,000 hooks
- **SE** is the standard error in the estimate of **Mean CPUE**
- **CV** is the coefficient of variation

further evidence that shallow hooks tend to account for marine turtle encounters. Only two out of eleven records (where observers were able to record hook number) were not among the shallowest hooks, and only one of these was close to the deepest hook(s). It is interesting to note, with reference to Figure 2, that the shallowest hooks of the deep-setting vessels are in the same depth range (i.e. ~ 50–100 metres) as all hooks for the shallow-setting vessels. In fact, if the effort of the shallowest hooks of the deep-setting fleets only was considered, the calculation of nominal CPUE would no doubt be closer to that of the shallow-setting fleets instead of being considerably lower. ***This suggests that there is probably a critical depth range of hooks where most marine turtle encounters would occur in the WTP longline fishery.***

5.3.2 Soak time

The period that the longline gear is soaking and actively fishing in the water can be anywhere from around six to more than 15 hours. Some longline fleets strategically set their gear so that it is actively fishing during the daylight hours while others target during the night. For most of the soak time, the gear fishes at a depth where it has settled after deployment, but for a relatively shorter period during the hauling, the baited hooks will be pulled up shallower and hence may become more available to marine turtles. Unfortunately, it is impossible to determine whether marine turtle hooking occurs more frequently during the hauling process without the widespread use of time-depth recorders.

Table 7: Breakdown of marine turtle encounters by hook number between successive floats for deep-setting longline vessels in the WTP

Number of hooks between floats	Deepest Hook(s)	Hook with turtle encounter	Comments
17	9	1	Shallowest hook
19	10	2	2nd shallowest
17	9	15	2nd shallowest
17	9	4	
15	8	2	2nd shallowest
20	9,10,11	2	2nd shallowest
23	12	23	Shallowest hook
20	9,10,11	7	
20	9,10,11	1	Shallowest hook
20	9,10,11	20	Shallowest hook
25	13	2	2nd shallowest

Table 8: Comparison of primary bait used and bait taken by turtles for selected fleets in the WTP longline fishery (according to observer data)

Fleet # 1

	Sets used		Sets taking turtles	
Primary Bait	**No.**	**%**	**No.**	**%**
Clupeidae	1	0%	0	0%
Squid	467	97%	15	88%
Stolepherus spp.	1	0%	0	0%
(Blank)	13	3%	2	12%

Fleet # 2

	Sets used		Sets taking turtles	
Primary Bait	**No.**	**%**	**No.**	**%**
Clupeidae	28	10%	1	17%
Decapturus spp.	161	55%	4	67%
Mackerel scad	76	26%	1	17%
Amberstrip scad	1	0%		0%
Saury (Sanma)	6	2%		0%
Blank	22	7%		0%

Fleet # 4

	Sets used		Sets taking turtles	
Primary Bait	**No.**	**%**	**No.**	**%**
Frigate tuna	7	2%		0%
Kawakawa	1	0%		0%
Decapturus spp.	38	9%	2	5%
Milkfish	2	0%		0%
Mackerel scad	29	7%	4	9%
Skipjack	19	4%	1	2%
Squid	293	68%	32	74%
Yellowfin	1	0%		0%
(Blank)	44	10%	4	9%

Table 6 suggests that the shallow-versus-deep setting strategy is probably more of a determinant for marine turtle encounters than the day-versus-night soak time strategy, although the available data show that night sets are predominantly shallow (96%) and day sets are predominantly deep (84%), with only a few samples for combinations of 'shallow–day' and 'deep–night' sets.

5.3.3 Bait used

The baits used by longline vessels attract certain opportunistic-feeding marine turtle species. Table 8 shows the frequency of bait used and the frequency of that bait taking a marine turtle for three WTP longline fleets with differing baiting strategies. These summaries show that the type of bait does not appear to be a factor since the proportion of bait used in each case is about the same as that taken by the turtles. For example, Fleet #2 fishes 'shallow' and has a relatively high nominal CPUE for marine turtles and the percentage of bait usage roughly reflects the percentages that took marine turtles. For Fleet #4, mackerel scad was the most popular bait and resulted in the most turtle takes. In summary, and in the absence of detailed analyses, there does not appear to be any clear preference for bait based on the data presented in Table 8.

5.4 Estimates of turtle captures in the WCPO longline fishery

There has been some concern regarding the level of marine turtle encounters in the WCPO and what likely effect this has on the western and central Pacific Ocean turtle populations. Unfortunately, it is not currently possible to provide reliable estimates of marine turtle encounters throughout the entire WCPO longline fisheries due to the low observer coverage. However, the information presented provides some indications of where most encounters are likely to occur and factors likely to affect the level of marine turtle encounters.

Table 9 provides a very preliminary estimate of annual marine turtle encounters by major fleet categories for the WTP **only**; the catch rates estimated in this process have been based on observer data. It should be stressed that these estimates are based on very low observer coverage and therefore have wide confidence intervals.

It should be noted that these estimates assume that the relative abundance of marine turtles encountered in the eastern areas of the WTP is the same as in the western areas, where observer effort has been concentrated. In fact, it is understood that there would be relatively fewer marine turtles encountered in the east since it is far from known nesting and feeding sites, in which case the values presented below are probably over-estimated to some degree for those DWFN fleets predominantly fishing in the east.

Estimates from the Hawaii-based longline fishery show that marine turtle encounters in the shallow-set swordfish fishery have a similar order-of-magnitude difference to marine turtle encounters in the deep-set tuna-target fishery (NMFS Observer data summarised in the NMFS Draft Biological Opinion, March 2001). Applying the estimates of

Table 9: Estimates of turtle encounters in the WTP longline fishery (based on observer data)

Fleet characteristics	Estimated Annual Effort (100s of hooks)	Observed sets	Nominal Turtle CPUE	SE	CV	Estimated encounters per year	Confidence Interval
Offshore/fresh tuna vessels (Shallow-Night sets)	243,128	1,223	0.06129	0.007672	12.6%	1,490	± 376
Offshore/fresh tuna vessels (Deep-Day sets)	185,840	909	0.00692	0.003035	30.6%	129	± 79
DWFN freezer vessels (Deep-Day sets)	814,452	287	0.00692	0.003035	30.6%	564	± 345
						2,183	

Notes

- **Nominal CPUE, SE** and **CV** were obtained from Table 6.
- The very low number of observed sets with CPUE greater than zero and the variation in individual set effort meant that Nominal CPUE was considered a better approximation than Mean CPUE. For this reason, we have used **Nominal CPUE** (instead of Mean CPUE) with **SE** and **CV** in this table.
- The nominal CPUE for DWFN freezer vessels, according to observer data, is actually 0.000, but we have assumed that it would be, at most, the level of the offshore fleet using a Deep-Day setting strategy.

mortality (Table 3) to the estimated encounters (Table 9) suggests around 500–600 marine turtle mortalities may occur in the WTP longline fishery per year given the current level of awareness in this fishery.

5.5 Suggestions for measures which may mitigate turtle captures in the WCPO longline fishery

In general, the respective government fishing bodies of Pacific Island countries should adopt a formal mechanism to advise all fishing fleets of their responsibilities regarding the live discard of protected species.

Suggestions for measures to mitigate marine turtle captures are currently being evaluated in the Hawaii-based longline fishery. To date, measures such as area and season closures have been used, but the process is ongoing. Clearly, there is a difference in the level of marine turtle encounters between shallow-set and deep-set gears and this may be an area for review in the event mitigation is required in the future.

Crew awareness and training have been the focus of observer work in the Hawaii-based longline fishery in recent years. Longline vessels in this fishery have been provided with guides showing how to best deal with captured turtles, and while this does not specifically reduce the number of turtle encounters, it does help to reduce post-capture mortalities.

6. Overview of marine turtles encountered in the WTP purse seine fishery

6.1 Description of marine turtle capture in the WTP purse seine fishery

As with the longline fishery, observers have described the capture of turtles by the purse seine gear in both quantitative and qualitative form. Encounters in the purse seine fishery occur when turtles are found within the pursed net after the operation of encircling a school of tuna. Marine turtles are frequently found near logs and other drifting debris, attracted by the diverse prey items in the vicinity and the protection the debris offers.

Turtle mortalities in the purse seine fishery, when they occur, are due to drowning as a result of entanglement in the net or, in rare instances, to being crushed during the process of loading the net on board. In most cases, turtles are encountered alive in the net and are subsequently scooped up and released over the side. The problems related to ingested hooks in the longline fishery do not occur in the purse seine fishery.

There is some motivation by the crew to identify and then release turtles found in the net before the net is hauled through the power blocks and thus avoiding damage to the gear. Observers are usually in a good position to observe the early stages of set and see whether turtles have been discarded prior to brailing. Unfortunately, it is often difficult to identify turtles released in these instances from the deck of the purse seine vessel.

There has yet to be an observed report of a marine turtle being kept for crew consumption on purse seine vessels, although, as in the longline fishery, this may no doubt occur on vessels without observers. Observers are instructed to inform the captain and crew of their obligations regarding protected and endangered species, even though there may not be any formal requirement in their fishing access agreement.

The current level of coverage provided by observer data is acknowledged to be low and not sufficient to provide definitive estimates of marine turtle encounters in WCPO purse seine fisheries.

6.2 Trends in marine turtle encounters in the WTP purse seine fishery

6.2.1 Distribution

Figure 14 (following page) shows the distribution of observer effort on purse seine vessels and observed marine turtle encounters throughout the WTP. The following observations have been drawn from these data:

- Observer effort generally covers the extent of purse seine activity in the WTP (Figure 4). Observer effort for the US purse seine fleet has been as much as 20% per year, over the past five years.
- Marine turtle encounters in the purse seine fishery appear to be more prevalent in the western areas of the WTP. The distribution of effort by set type shows that log sets are more prevalent in the west and drifting FAD sets are more prevalent in the east. Anchored FADs are rarely used in the SPC Statistical Area outside the archipelagic waters of PNG and the Solomon Islands. The fact that marine turtle encounters in the purse-seine fishery are fewer in the east, despite uniform spatial observer coverage throughout the WTP, has significance to the longline estimates presented in this review.
- Longline observer effort is almost non-existent in the east (despite substantial longline activity), yet the estimates provided in this review have assumed that the relatively higher encounter-rate in the west (where observer activity has been concentrated) is maintained in the eastern areas of the WTP, which is probably not the case.

While there are no observer data available for the fisheries in Philippines and Indonesia to the east of the WTP, one can speculate that there would be marine turtle encounters for their purse seine and ring-net fleets fishing predominantly on arrays of anchored FADs in these waters.

6.2.2 Temporal trends

As the purse seine fishery is restricted to the tropical band (WTP) of the WCPO, seasonal trends in turtle encounters are likely to be related to species migration periods. At this stage, there is insufficient data to explore this relationship further, although the observer data show that almost half the encounters were in the months June and July.

El Niño events and its effect in extending the warm pool and natural debris eastwards may also be a factor in the distribution of marine turtles throughout the WTP.

6.3 Factors affecting turtle captures in the WTP purse seine fishery

Purse seine vessels operating in the WCPO employ a variety of fishing strategies when attempting to optimise the catch of target tuna species. These include, for example, the use of sophisticated equipment such as helicopters and electronic equipment to detect schools of tuna. They may also deploy artificially-made drifting FADs or mark naturally-floating logs with electronic radio-beacons in the expectation that they will eventually attract schools of tunas. They also use their knowledge of temperature fronts and oceanographic features that provide nutrient-rich upwellings that provide food for tuna prey (e.g. ocean anchovies).

An in-depth study looking at the effects of fishing strategies, climactic and oceanographic features on capture of marine turtles in the purse seine fishery is beyond the scope of this report due to the current low level of observer coverage. Instead, the following provides a description of certain factors that are believed to play some part in marine turtle encounters in the WTP purse seine fishery.

6.3.1 Type of set

Table 10 shows the breakdown of marine turtle encounters in the WTP purse seine fishery by set type and species category and Table 11, by set type for all turtle species combined. The following observations have been drawn from these data:

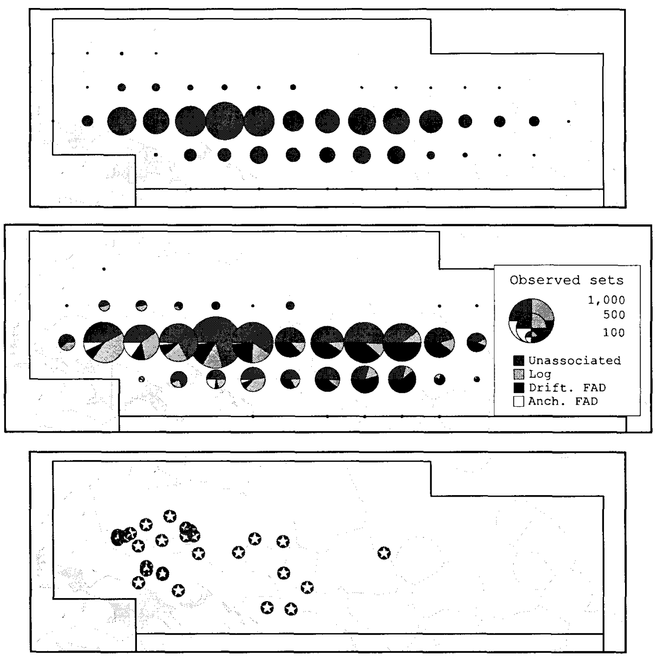


Figure 14: Distribution of purse seine observer effort (top), purse seine observer effort by set type (middle) and marine turtle encounters by observers on purse seine vessels (bottom)

- Animal-associated, drifting log and anchored-FAD sets have the highest incidence of marine turtle encounters, with 1.115, 0.807 and 0.615 encounters per 100 sets respectively, according to observer reports.

- In contrast, drifting FAD sets were reported to have only 0.07 encounters per 100 sets, despite being used in a similar manner to drifting logs in their mechanism for attracting schools of tuna. One hypothesis suggests that drifting FADs do not spend the same length of time in the ocean compared to drifting logs, and hence do not have the same amount of time to 'attract' certain by-catch, such as marine turtles. It may also be related to the notion that natural debris are more influenced by currents and are aggregated at current lines, a place where marine turtles may also tend to be more abundant. Alternatively, the area where drifting FADs are more prevalent (i.e. the eastern areas of the WTP) may simply not have as high an abundance of marine turtles as in the western areas (where drifting FAD sets are not as prevalent).

- Sets on free-swimming schools (unassociated sets) yield about 0.11 marine turtle encounters per 100 sets according to observer data. Unassociated sets, by their nature generally undertaken on fast, free-swimming pure schools of tuna, rarely have any by-catch, and marine turtle encounters are therefore expected to be very rare.

6.3.2 Crew awareness

Anecdotal reports from observers suggest that marine turtles accidentally encircled in the net have been quickly released by crew on the skiff or may be released later if they have been entangled in the net. As mentioned earlier, there is some motivation in ensuring an entangled turtle is not hauled through a power block and thus causing gear

Table 10: Marine turtles encountered in the WTP purse seine fishery, *by set type and species category* (based on observer data, 1990–2000)

		Marine turtles (unspec.)		Green turtle		Hawksbill turtle		Olive ridley turtle	
School association	Observed sets	No.	Nominal CPUE	No.	Nominal CPUE	No.	Nominal CPUE	No.	Nominal CPUE
Unassociated/Feeding on Baitfish	5,582	6	0.10749	–	–	–	–	–	–
Drifting log, debris, dead animal	2,107	10	0.47461	–	–	3	0.14238	4	0.18984
Drifting Raft, FAD or Payao	2,975	1	0.03361	–	–	–	–	1	0.03361
Anchored Raft, FAD or Payao	325	1	0.30769	1	0.30769	–	–	–	–
Animal–associated	307	–	–	–	–	1	0.32573	2	0.65147
Total	11,296	18	0.15935	1	0.00885	4	0.03541	7	0.06197

Notes

- **Nominal CPUE** is expressed as numbers per 100 sets.

Table 11: Marine turtles encountered in the WTP purse seine fishery, *by set type* (according to observer data, 1990–2000)

School association	Observed sets	Turtles	Incidence (%)	Nominal CPUE	SE	CV
Unassociated/Feeding on Baitfish	5,582	6	0.090%	0.10749	0.05065	47.1%
Log	2,107	17	0.807%	0.80683	0.19494	24.2%
Drifting FAD	2,975	2	0.067%	0.06723	0.04753	70.7%
Anchored FAD	325	2	0.615%	0.61538	0.43447	70.6%
Animal-associated	307	3	1.115%	1.11524	0.64148	57.5%

Notes

- **Incidence** is the percentage of sets encountering turtles
- **Nominal CPUE** (effectively Mean CPUE) is expressed as number of marine turtles per 100 sets
- **SE** is the standard error in the estimate of **Nominal CPUE**
- **CV** is the coefficient of variation

damage. Table 12 shows the observer-reported condition and fate of marine turtles encountered in the WTP purse seine fishery. Marine turtles appear to generally survive encounters with the purse seine gear, with all observed encounters resulting in the turtle being discarded. However, the crew reaction to marine turtle encounters when an observer is not on board may be different. Unfortunately, details on fleet practices on encountering turtles are not currently available.

6.4 Estimates of turtle captures in the WCPO purse seine fishery

As with the longline fishery, it is not currently possible to provide definitive estimates of marine turtle encounters in the WTP purse seine fishery, due to the low observer coverage. However, the information presented above has hopefully provided an indication of the circumstances involving marine turtle encounters.

Table 13 attempts to quantify annual marine turtle encounters by set type. The nominal catch rates used in this process have been based on observer data and therefore should be used as an indication only and not as definitive estimates. As in the longline fishery, species identification problems make it impossible to present a similar breakdown by species at this stage. The relatively high percentage of survival (Table 12) suggests that the WCPO purse seine fishery may account for less than 20 marine turtle mortalities per year given the current level of awareness in this fishery.

6.5 Suggestions for measures which may mitigate turtle captures in the WCPO purse seine fishery

As with the longline fisheries, the respective government fishing bodies of Pacific Island countries should adopt a formal mechanism to advise all fishing fleets of their responsibilities regarding the discard of protected species, especially as almost all are encountered alive in this fishery.

Table 12: Condition (life status) and fate of marine turtles encountered by observers in the WTP purse seine fishery

Area	N	Discard (%)	Alive % Healthy	Alive % Injured/ stressed	Alive % Barely alive	Dead (%)
Marine turtles (unspecified)	18	100%	94%	–	6%	–
Green turtle	1	100%	100%	–	–	–
Hawksbill turtle	4	100%	100%	–	–	–
Olive ridley turtle	7	100%	43%	–	–	57%
Total	**30**	**100%**	**83%**	**–**	**4%**	**13%**

Table 13: Estimates of turtle encounters in the WCPO purse seine fishery (based on observer data)

School association — Set type	Estimated Annual Effort (sets)	Observed sets	Nominal Turtle CPUE	SE	CV	Estimated encounters per year	Confidence Interval
Unassociated/Feeding on Baitfish	15,306	1,835	0.107488	0.050655	47.1%	16	± 16
Drifting log, debris or dead animal	9,257	1,650	0.806834	0.194941	24.2%	75	± 36
Drifting Raft, FAD or Payao	3,696	2,493	0.067227	0.047529	70.7%	2	± 4
Anchored Raft, FAD or Payao	1,707	221	0.615385	0.434471	70.6%	11	± 15
Animal-associated	78	307	1.115242	0.641478	57.5%	1	± 1
						105	

Notes

- **Incidence** is the percentage of sets encountering turtles
- **Nominal CPUE** (effectively Mean CPUE) is expressed as number of marine turtles per 100 sets (Table 11)
- **SE** is the standard error in the estimate of **Nominal CPUE**
- **CV** is the coefficient of variation

7. Recommendations for improving knowledge on marine turtle encounters

The following are recommendations for improving our knowledge of marine turtle encounters in the WCPO tuna fisheries.

- As observer data collection provides some indication of the abundance of marine turtles throughout the ocean, they are a useful complement to data collected on populations of marine turtles at nesting and feeding sites (i.e. in coastal areas). Therefore, efforts should continue to collect pertinent information from observer programmes. In particular, observers should be instructed to ensure they can:
  - Identify the species of turtle;
  - Obtain the straight carapace length (SCL) of the turtle;
  - Correctly identify the condition of the turtle on landing and on discard;
  - Correctly document the fate of the turtle. Table 14 provides a description of the detail required by observers active in the Hawaii-based longline fishery. This protocol for data collection could be adopted by observers active in the WCPO;
  - Remind vessel captains and crew of the obligation regarding the discarding of protected species.
- The depth of longline gear appears to be critical to the level of marine turtle encounters. To obtain a more accurate idea of the critical depth range, observers could utilise time-depth records to collect more accurate information related to turtle encounters with depth;
- Enhance crew awareness by providing guides showing how to deal with turtle captures and how to treat injured turtles; in this respect, the material prepared for the Hawaii-based longline fishery could be adopted for the WCPO tuna fisheries;
- Logbook data collection programmes in other oceans have specific provisions for recording marine turtle interactions. There should be some consideration for introducing this into the standard logbook forms used by fleets operating in the WCPO tuna fisheries. Despite acknowledged problems with non-reporting, this implementation might highlight the importance of marine turtle bycatch to the fishing industry.

Table 14: Definitions used to characterise the fate of sea turtles taken by Hawaii-based longliners (source: NMFS Hawaii-based longline observer programme)

Fate	Definition	Codes
Alive [Released unharmed]	An animal removed from the fishing gear that can swim normally. The animal is likely to have minor cuts and abrasions from being entangled. **This applies to entangled sea turtles only.**	EOK = entangled, okay
Injured	An animal released from the fishing gear with obvious physical injury or with gear attached. An injured animal may lie at the surface, breathing irregular, or swim in an abnormal manner. **If an animal is impaled on a hook, it is considered injured.** 'Internal' refers to the hook being ingested, 'external' implies that the turtle was hooked in the head, beak, flipper, carapace, or plastron.	HII = hooked, internal, injured HEI = hooked, external, injured HUI = hooked, unknown, injured EI = entangled, injured
Dead	An animal removed from the fishing gear in a post-mortem state (i.e. the animal died due to injuries incurred during fishing operations or was returned to the sea while comatose). Animals will show a lack of muscular activity and may float passively at or below the water's surface.	HID = hooked, internal, dead HED = hooked, external, dead HUD = hooked, unknown, dead HUU = hooked, unknown, dead ED = entangled, dead
Unknown	An animal lost, released or escaped from the fishing gear whose condition was not determined.	HIU = hooked, internal, unknown HEU = hooked, external, unknown HUU = hooked, unknown, unknown EU = entangled, unknown

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