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# Characterisation of the tuna purse seine fishery in Papua New Guinea

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*Simon Nicol, Tim Lawson, Karine Briand, David Kirby, Brett Molony, Don Bromhead,*
*Peter Williams, Emmanuel Schneiter, Ludwig Kumoru and John Hampton*

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Cover: Papua New Guinea National Fisheries Authority Observer, Lawrence Pero, undertaking length measurements of species captured during purse seine fishing in the Bismarck Sea, Papua New Guinea. Photo: Peter Sharples, Oceanic Fisheries Programme, Secretariat of the Pacific Community

# Foreword

The tuna fisheries in the western and central Pacific Ocean are important for the Pacific economy and the prosperity of Pacific island countries and territories. The fishery comprises a variety of fishing activities, the most important of which are the industrial-scale purse seine, longline and pole-and-line fisheries. Large catches from the same stocks are also made by numerous small fishing vessels employing a variety of fishing methods in the adjacent waters of the Philippines and Indonesia. The size of the fishery has increased through time and this is clearly evident in Papua New Guinea (PNG), which is an extremely productive tuna fishing area. In PNG catches are now dominated by purse seiners that target skipjack and yellowfin tuna. This technique is strongly dependent on the setting of nets on floating objects, in particular logs, and on drifting and anchored fish aggregation devices. In addition to target species, there is a significant catch of other species taken in these sets. Understanding the extent of this catch is important for managing this expanding fishery and the marine ecosystem upon which it is reliant, and meeting the obligations of international conventions.

The Australian Centre for International Agricultural Research (ACIAR) strongly supports the improvement in knowledge of regional and international fisheries and the adoption of evidence-based decision-making in natural resource management. The analysis reported in this publication focuses on characterising the target and non-target catch of the purse seine fishery in the PNG exclusive economic zone. It is anticipated that the approach adopted in this report will be broadly applicable to other Pacific island countries and territories, and will provide an example for current and future Australian-sponsored work in the region.

Peter Core.

Peter Core
Chief Executive Officer
ACIAR

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# Acknowledgments

In 2006 the Australian Centre for International Agricultural Research (ACIAR) funded a multi-year research project (FIS/2005/096) to assess the impact of the Papua New Guinea (PNG) purse seine fishery on bigeye, yellowfin and skipjack tuna stocks, with special focus on the impact of fish aggregation devices (FADs). The project was jointly undertaken by the Oceanic Fisheries Programme at the Secretariat of the Pacific Community (SPC), New Caledonia; the National Fisheries Authority (NFA), PNG; and the Pelagic Fisheries Research Program, University of Hawaii at Mānoa (UoH), United States of America. The Pelagic Fisheries Research Program is funded by Cooperative Agreement NA17RJ1230 between the Joint Institute for Marine and Atmospheric Research (JIMAR) and the National Oceanic and Atmospheric Administration (NOAA). The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subdivisions. The principal investigators for this research are Dr John Hampton (SPC), Dr Tony Lewis (SPC), Mr Augustine Mohiba (NFA) and Mr David Itano (UoH). PNG has implemented an extensive at-sea and port observer program, and the analysis presented would not be possible without this program and the efforts of the individuals involved

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# Abbreviations

| | |
|---|---|
| ACIAR | Australian Centre for International Agricultural Research |
| aFAD | anchored fish aggregation device |
| ANOSIM | analysis of similarity |
| CPUE | catch per unit effort |
| dFAD | drifting fish aggregation device |
| EEZ | exclusive economic zone |
| FAD | fish aggregation device |
| FL | fork length |
| NFA | National Fisheries Authority |
| PNG | Papua New Guinea |
| PSA | productivity-susceptibility analysis |
| SOI | Southern Oscillation Index |
| SPC | Secretariat of the Pacific Community |
| WCPFC | Western and Central Pacific Fisheries Commission |
| WCPO | western and central Pacific Ocean |
| ZILN | zero-inflated lognormal |

# Summary

In this report the purse seine fishery in the exclusive economic zone of Papua New Guinea (PNG) is characterised for both target and non-target species. Characterisation was based upon the different purse seine operating techniques used in the area, these being the setting of the net either on schools of tuna that were associated with a floating object (e.g. logs, whale sharks and fish aggregating devices (FADs)) or where the schools were not associated with any floating object. Characterisation of the target and non-target species catches was based on individual vessel log-sheet data as well as observer records for the non-target species. It comprised catch composition analysis, analysis of the vulnerability to fishing mortality, and estimation of catches and catch per unit effort for target and a subset of non-target species. The analysis demonstrated that the purse seine fishery in PNG has developed over the last 20 years in terms of both the total catch and the number of nations operating purse seiners within PNG's jurisdiction. Unassociated and log sets comprised the majority of effort within PNG, although anchored and drifting FAD sets comprised between 10% and 20% of all effort.

The fishery primarily targets skipjack and, to a lesser extent, yellowfin tuna. However, bigeye tuna are also caught, particularly from associated sets. The size composition on associated sets for the target species was lower than that observed on unassociated sets. The expansion of the purse seine fishery has resulted in an increase in the number of non-target species captured. The average estimated catch for non-target species per year was 2,740 tonnes. While the non-target species catch was higher on associated sets (67% of total catch), the majority of this mortality occurred on log sets. Based on restrictive assumptions, the analysis indicated that the purse seine fishery generally interacts with most non-target species infrequently by comparison with target species. For species where reported interactions are relatively high and biological productivity is low (e.g. silky shark and oceanic whitetip shark), and/or the life stage impacted is important for population growth (e.g. bigeye tuna), current levels of interaction with the fishery may be resulting in detrimental impacts upon their populations.

## Introduction

The tuna fisheries in the western and central Pacific Ocean (WCPO) produce approximately half of the world's tuna and are of high economic importance to Pacific island countries and territories. Throughout the WCPO, total annual catches of target tuna species (skipjack, yellowfin, bigeye and albacore tuna) are now above 2 million tonnes (t) (Williams and Terawasi 2008). The fishery comprises a variety of fishing activities, the most important of which are the industrial-scale purse seine, longline and pole-and-line fisheries. Large catches are also made by numerous small fishing vessels employing a variety of fishing methods in the adjacent waters of the Philippines and Indonesia.

While the overall fishery is distributed widely from about 40°N to 40°S, by far the majority of the catch occurs in equatorial waters between about 10°N and 10°S (Figure 1). In this region catches are dominated by purse seiners, catching mainly skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) tuna, with a smaller catch of bigeye tuna (*Thunnus obesus*). Purse seiners have two main operational modes—setting nets on schools associated with floating objects such as drifting logs, and anchored or drifting fish aggregation devices (FADs); and setting on free-swimming (or unassociated) schools of skipjack and medium-large yellowfin. These associated sets tend to catch larger quantities of small, juvenile yellowfin and bigeye tuna. Longliners target adult bigeye and yellowfin tuna in this region and at higher latitudes.

The waters comprising the exclusive economic zone (EEZ) of Papua New Guinea (PNG) are an extremely productive tuna fishing area. Catches in this zone have averaged about 250,000 t/year over the past decade, peaking at approximately 466,000 t in 2007 (Kumoru 2008). Most of this catch has been taken by foreign-licensed and locally based purse seiners, although a locally based longline fleet also operates in the southern part of the EEZ. The purse seine fishery operating in PNG waters is one of the largest in the WCPO, representing approximately 20% of recent purse seine catches from the entire WCPO. This fleet has been dominated by vessels operating under the Federated States of Micronesia (FSM) Agreement plus vessels from Korea, the Philippines, Taiwan, the United States of America (USA) and Vanuatu. The purse seine fishery in PNG is strongly dependent on sets on floating objects, in particular logs, and drifting FADs (dFADs) and anchored FADs (aFADs), collectively called 'associated sets' (Figures 2, 3). Fishing on associated sets results in a greater proportion of the catch consisting of juvenile yellowfin and bigeye tuna by comparison with unassociated sets. There is also significant catch of other species taken in all set types.

The National Fisheries Authority (NFA) of PNG implements an observer program, with high coverage rates of the purse seine fishery (86% in 2007; Kumoru 2008), that offers the opportunity to document levels and variability of catches of non-target species (i.e. species other than skipjack and yellowfin tuna) in purse seine sets. This report uses observer data, along with log-sheet data submitted by the fishing companies, to characterise the catches of target and non-target species from purse seine fishing in PNG. This includes:

- a summary of the purse seine fishery in PNG for the purpose of reviewing the operations and identifying any recent developments and trends
- estimates of time trends in catches and catch rates for a subset of non-target species or species groups
- a productivity-susceptibility analysis (PSA) to qualitatively rank the 'vulnerability' of all non-target species or species groups to the impacts of purse seine fishing.

This information will allow fishery managers to undertake a preliminary assessment of the impact of the fishery on non-target species, and will assist in the development of appropriate management responses if they are required.

# Methods

## Classification of set types

There are nine different set types recorded by scientific observers when describing purse seine fishing operations in PNG. These were generally grouped as follows for the analysis undertaken in this study:

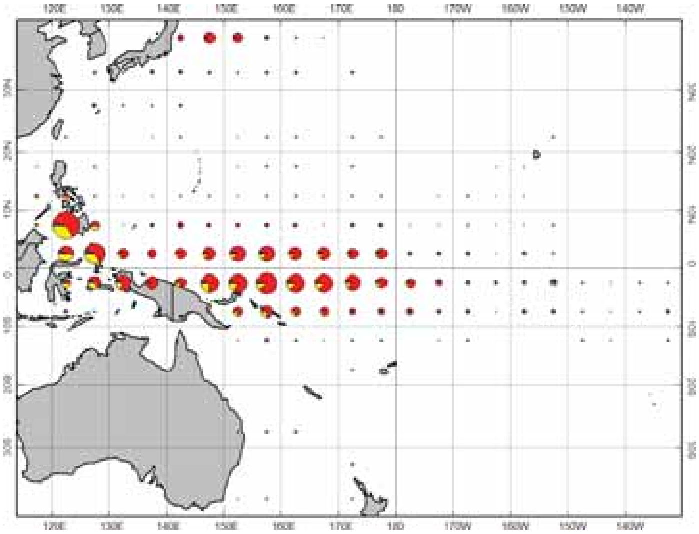

**Figure 1.** Distribution of skipjack (red), yellowfin (yellow) and bigeye (blue) tuna catch, 2000–07, in the waters of the western and central Pacific Ocean
Source: SPC aggregate public domain data

- unassociated sets and feeding on baitfish (combined)
- log sets
- drifting FADs
- anchored FADs.

Live whale, live whale shark, other and combined whale–whale shark–porpoise sets were generally excluded. The exception was during the estimation of nominal catch estimates for marine mammals (where sets on live whales are reported) and for turtles (where these set types have been aggregated as 'other' sets).

Where no information was provided on set type, the data were excluded from the analysis.

## Characterisation of target species and the PNG purse seine fishery operations

Characterisation of the purse seine fishery was based on individual vessel log-sheet data held by the Secretariat of the Pacific Community (SPC). During recent years the log-sheet coverage has been very high (>80%) for the main fleets operating within the PNG EEZ (Kumoru and Koren 2006, 2007; Kumoru 2008). However, prior to 1990, log-sheet coverage rates were lower and, consequently, the actual levels of catches and fishing effort for this period were likely to be underestimated by log-sheet data. Log-sheet data were considered complete up to the end of 2007. Only preliminary data were available from 2008, and these data were not used. Catch was summarised in tonnes (t) and effort as the number of successful sets. Catch rates (catch per unit effort (CPUE) as t/set) of the major tuna species were examined by fleet and set type. Information on aFAD locations was sourced from NFA.

## Non-target species characterisation

Characterisation of the non-target species associated with purse seine fishing in PNG was based on observer records that are contained within the SPC-managed Observer Database Query System. For the past 15 years PNG has implemented a program for the training of observers and their placement on board fishing vessels. Coverage as a proportion of effort has increased over recent years. In 2008 the parties to the Nauru Agreement, which includes PNG, agreed to implement 100% coverage of purse seine fisheries occurring in their EEZs.

Characterisation of the non-target species was undertaken in three parts:

1. catch composition analysis for 2006, the most recent year for which available observer data are considered to be comprehensive

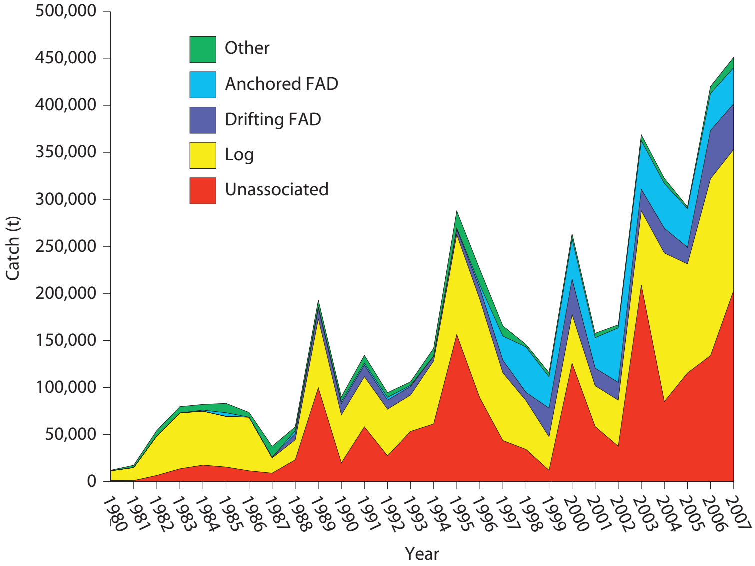

**Figure 2.** Purse seine catch in the Papua New Guinea exclusive economic zone by set type, 1980–2007
Source: SPC log-sheet data
Note: t = tonnes; FAD = fish aggregating device

2. an analysis of the vulnerability to fishing mortality (2006 observer data only)
3. estimation of catches and CPUE for a subset of non-target species, using observer data from 1995 to 2006.

*Catch composition analysis*

Data were extracted from the Observer Database Query System for 1995 to 2006 in order to summarise the observed catch composition in PNG and examine the frequency of encounter for each reported non-target species. Data from 2006 were used to assess species richness and compare species composition among set types. Differences in species composition between associated and unassociated sets were assessed using analysis of similarity (ANOSIM) to determine if differences in species assemblage were statistically significant. Data were square-root transformed and standardised using the Wisconsin double standardisation procedure. A matrix of pair-wise dissimilarities between the samples was constructed using the Bray-Curtis dissimilarity metric. The ANOSIM was computed with 1,000 permutations using the ‘R’ (R Development Core Team 2007) add-in package ‘vegan’ (Oksanen et al. 2007).

*Vulnerability posed by fishing mortality on non-target species*

The vulnerability of non-target species to fishing mortality was assessed using PSA (Stobutzki et al. 2001). PSA is a semi-quantitative, indicator-based method that uses biologically pertinent parameters and available fisheries data. It comparatively ranks the potential impact of a fishery on multiple species, given their biological characteristics and the extent and characteristics of their interactions with the fishery.

The *productivity* component of the analysis uses biological attributes for each species to derive an indicator of the species population’s resilience to fishing mortality. Animals that are long lived, slow growing, late maturing and have low natural mortality are considered to have low biological productivity (i.e. low population growth rates); whereas short-lived, highly fecund, early maturing animals with high natural mortality have higher biological productivity. Populations of particular species that have low biological productivity are assumed to be at greater risk of negative impacts due to additional mortality, such as that caused by fishing. In this analysis natural mortality, growth rate, maximum length, maximum age and age at

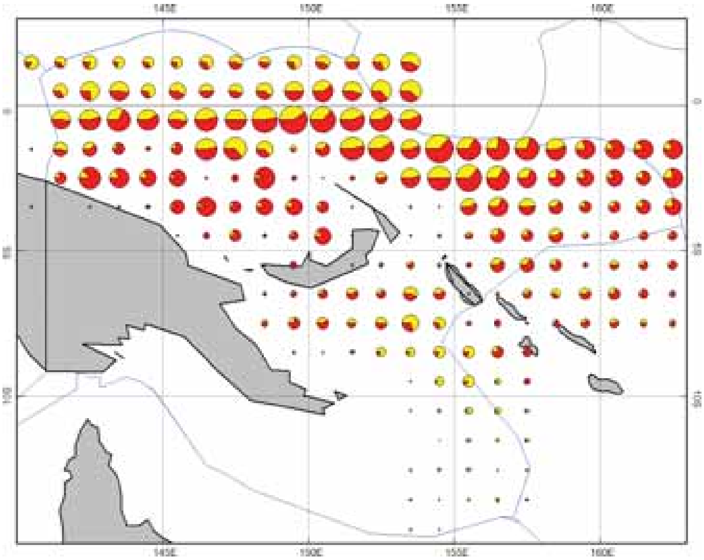

**Figure 3.** Distribution of purse seine catch by associated (red) and unassociated (yellow) sets in the Papua New Guinea exclusive economic zone, 2000–07
Source: SPC aggregate public domain data

maturity were used to generate a productivity score for each species observed in the purse seine fishery in 2006. These biological attributes were standardised between 0 and 1, and the average of the attributes used as a 'productivity score', such that species with high biological productivity have a low score and those with low biological productivity have a high score.

The *susceptibility* component for each species was the nominal catch estimate on a common log scale, based on the assumption that the likelihood and extent of negative impacts, on a scale from depletion to extinction, is correlated with catch. Ideally, statistical modelling methods would be used to account for the various sources of variability and error in the estimation of catch. However, multiple species analysis such as PSA requires that the same method be applied for each species in the analysis. Due to data limitations for most species, a statistical estimation procedure is not possible for all species. In this analysis, raised catch estimates were calculated from the number of observations, given that the per cent coverage of the fleets by observers is known.

*Raised catch estimate* = *number of observations* × 1/(*observer coverage*)

Ideally, calculation of the susceptibility score would also take into account:

- the proportion of the population encountering the gear/fishery, i.e. the horizontal and vertical range of the population, and the overlap of these with the fishery. These overlaps will vary on temporal scales (i.e. diurnal, seasonal, interannual, decadal)
- the life stage(s) caught and their relative importance for population growth
- the likelihood of death as a result of encountering the gear. This likelihood is determined by two factors:
  - capture likelihood once the gear is encountered, which is dependent on the behavioural tendency and physical capacity of the species to avoid the gear and the fishers' targeting ability in the presence of multiple species
  - mortality likelihood once the capture has occurred, which is dependent on retention rates (i.e. if the species has some economic value, including immediate subsistence of the fishers), condition at release (i.e. if the species has not been visibly damaged during capture or handling) and post-release mortality (i.e. if the species has not been invisibly damaged during handling)
- historical and other cumulative impacts (i.e. from other fisheries impacting on the same species population at the same time), and the relationship between the adult stock, the environment and recruitment levels for each species.

However, while these sources of variability and uncertainty are recognised, data allowing this level of detail to be incorporated for all species do not presently exist.

The productivity and susceptibility scores can be plotted against each other and the Euclidean distance from the origin of the graph (i.e. $\sqrt{S^2 + P^2}$) calculated for each species, giving an overall risk score. Species can then be ranked according to either their susceptibility or productivity scores or the overall risk score.

### *Catch and CPUE estimation*

While the observer coverage in PNG has improved over the last 5 years, the information available is currently insufficient to statistically estimate catches of non-target species with a high degree of confidence. To overcome this data limitation, a two-part modelling approach was applied.

In the first part, model-based predictors of the catch rate for each species reported as interacting with the PNG purse seine fishery were estimated for the entire Western and Central Pacific Fisheries Commission (WCPFC) Convention area using the observer data held by the SPC covering this area (Lawson 2007). The logistic and lognormal components of a zero-inflated lognormal (ZILN) model of the catch rate for each species or species group were fitted with the 'glm' function in the statistical analysis software 'R' (R Development Core Team 2007). The predicted variable was the logarithm of the catch rate for the observed trip, and predictors were school association (associated or unassociated), year, month, latitude, longitude, sea surface salinity, sea surface temperature and depth of the 20 °C isotherm. All numerical predictors were smoothed with cubic splines. The inclusion of predictors in the model, and the degrees of freedom for the smoothed predictors, were determined using a stepwise procedure that minimised the Bayesian Information Criterion. Where information was insufficient to estimate catch rates for particular species over the entire WCPFC Convention area, species data were combined into more general groups. Data limitations prevented the school association from being broken down to more specific categories.

In the second part, the ZILN models of catch rates were then applied to stratified effort data covering an area approximating the EEZ of PNG. Purse seine effort data were stratified by year, month, 2° of latitude, 5° of longitude and school association (associated or unassociated). For each time–area stratum, averages of the oceanographic variables were determined. Confidence intervals for the estimates of catches and catch rates were determined from a parametric bootstrap, i.e. from the 2.5% and 97.5% quantiles of catches and catch rates estimated by taking 1,000 random samples from the posterior distributions of estimates of the model coefficients. The median was taken to be the point estimate. The confidence intervals do not account for errors in the estimates of total effort and model uncertainty; hence, they underestimate the true uncertainty.

# Results

## Characterisation of PNG purse seine fishery operations and catches of target species

### *Fleet composition*

Purse seine vessels from 13 nations have fished in the PNG EEZ over the last 30 years (Figure 4). Vessels from Japan, Korea, Taiwan, the Philippines and the USA commenced fishing in the PNG EEZ in the early 1980s and dominated the purse seine fleet until the mid 1990s. The first PNG-flagged purse seine vessels commenced fishing in the EEZ in 1994. With ratification of the FSM Arrangement for purse seine fishing in 1995, fleets from certain other Pacific island nations commenced fishing in the PNG EEZ, including those from the FSM, Kiribati, Republic of the Marshall Islands and Solomon Islands. In recent years the purse seine fleet operating in the PNG EEZ has been dominated by vessels operating under the FSM Arrangement plus vessels from Korea, the Philippines, Taiwan, the USA and Vanuatu.

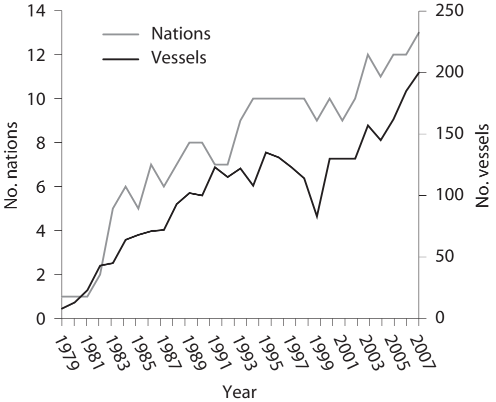

**Figure 4.** The number of purse seine nations and vessels by year in the Papua New Guinea exclusive economic zone, 1979–2007
Source: SPC log-sheet data

### *Fishing effort*

Purse seine effort, defined here as the number of successful sets, increased rapidly during the 1980s and is currently dominated by fleets from PNG, Taiwan, the Philippines, Korea, Japan and the FSM (Figure 5). There have been large inter-annual fluctuations in the number of sets and their proportion by set type within the EEZ. However, the number of sets from archipelagic waters of the Bismarck Sea has steadily increased from the early 1990s, and now typically comprises 10–20% of all sets (Figure 6).

The maintenance of relatively high levels of effort by most major fleets in archipelagic waters of the Bismarck Sea coincides with the installation and maintenance of aFADs in this area (Figure 7). However, other set types, particularly unassociated sets and log sets, still dominate the overall purse seine effort in the EEZ (Figure 8).

### *Catch of target species*

Purse seine catches in the PNG EEZ have been dominated by skipjack tuna (Figure 9), although significant quantities of yellowfin tuna have also been reported. While there have been fluctuations in purse seine catches from the PNG EEZ through time, they have generally increased and exceeded 200,000 t of skipjack since 2003. Catches have generally reflected the amount of effort in the EEZ, being dominated by the fleets of PNG, Taiwan and Korea in recent years. However, catches of tunas by the USA purse seine fleet have been significant in years when the fleet operated in the EEZ (Figure 10).

Catches of skipjack within archipelagic waters have been steadily increasing since 1997, exceeding more than 35,000 t in recent years (Figure 9). Catches of yellowfin within archipelagic waters have shown inter-annual variations; however, yellowfin catches from the Bismarck Sea have represented approximately 20–25% of total catches from the EEZ since 2000 (Figure 9). Catches of yellowfin from archipelagic waters have also steadily increased since 1997 and have averaged more than 10,000 t/year since 2000 (Figure 9). Catches of bigeye reported in log-sheet data have generally been less than 1,000 t/year. However, as

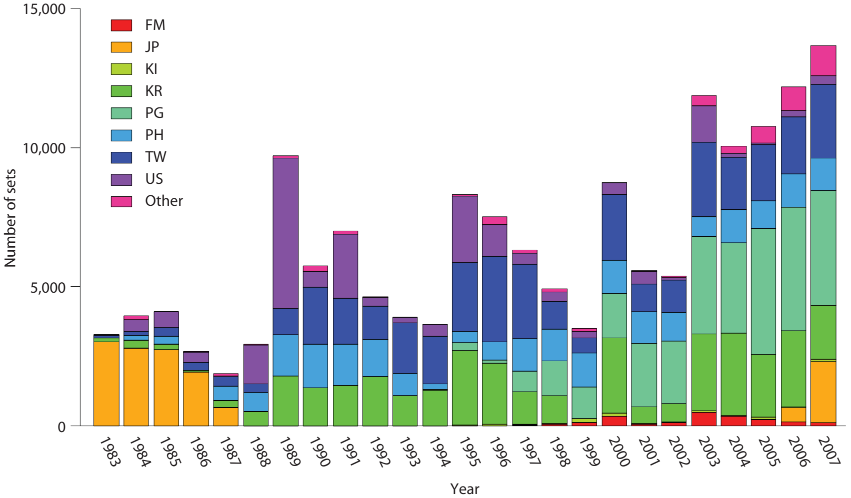

**Figure 5.** Annual numbers of sets by fleet for the purse seine fishery in the Papua New Guinea exclusive economic zone, 1983–2007
Source: raised log-sheet data held by SPC
Fleet codes: FM = Federated States of Micronesia; JP = Japan; KI = Kiribati; KR = Korea; PG = Papua New Guinea; PH = the Philippines; TW = Taiwan; US = United States; Other = vessels from Australia, China, Indonesia, Marshall Islands, Mexico, New Zealand, Soviet Union, Solomon Islands and Vanuatu

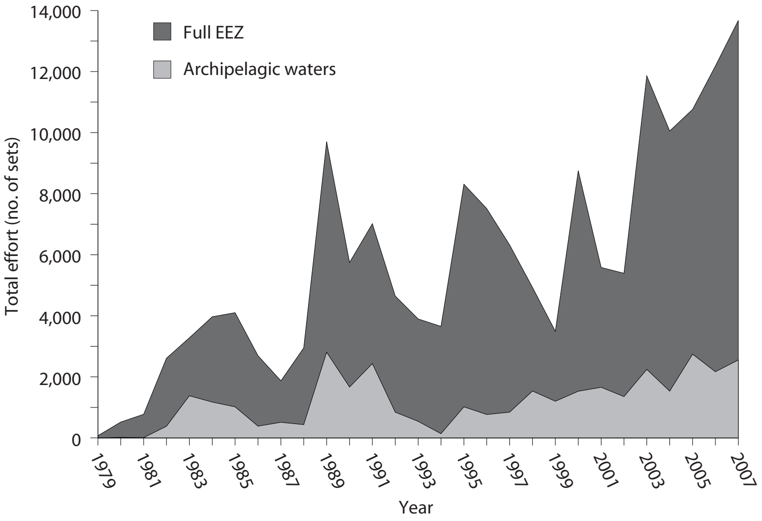

**Figure 6.** Annual number of sets from archipelagic waters and the entire Papua New Guinea exclusive economic zone (EEZ), 1979–2007
Source: SPC log-sheet data

most bigeye and a proportion of yellowfin captured from FAD sets are relatively small (less than 80 cm in length), they are often difficult to identify (Itano and Fukofuka 2005), and bigeye catches are likely to be grossly underestimated due to difficulties with identification (Lawson 2003). This is supported by observer records from purse seine vessels, where substantially higher proportions of bigeye were reported in catches in comparison to those recorded on the corresponding log-sheets (Figure 11). A similar situation exists in regard to yellowfin tuna, with evidence of significant under-reporting evident in log-sheet data supplied by some fleets. Furthermore, current observer sampling procedures result in a non-quantified bias in the species composition and length–weight data collected that significantly reduces the precision of this data (Lawson 2008). Consequently, purse seine catches of bigeye in the PNG EEZ have been estimated to be between 4,000 and 9,000 t/ year since 1997. Bigeye catches of this magnitude are very significant in the WCPO, where recent total catches of bigeye have been estimated to be between 80,000 and 100,000 t/year since 1997.

### *Catch rates of target species*

Skipjack CPUEs fluctuated around 20 t/set up to the early 1990s for most fleets (Figure 12) but, from the mid 1990s, steadily increased for the PNG and Taiwan fleets to 30 to 40 t/set. This increased CPUE coincided with the development of the aFAD fishery. CPUE has also increased but to a lesser extent for the Korean fleet, which has reported very low levels of FAD use. Skipjack CPUEs were generally highest from sets on dFADs and lower from sets on unassociated schools (Figure 13). Since the late 1990s, however, skipjack CPUEs from unassociated sets have increased to be similar to CPUEs from aFAD sets (Figure 13).

Yellowfin CPUEs have been lower than those for skipjack in all years, with catches by most fleets averaging around 10 t/set (Figure 12). Yellowfin CPUEs from aFAD sets have been relatively high and stable since the late 1990s, with catches from

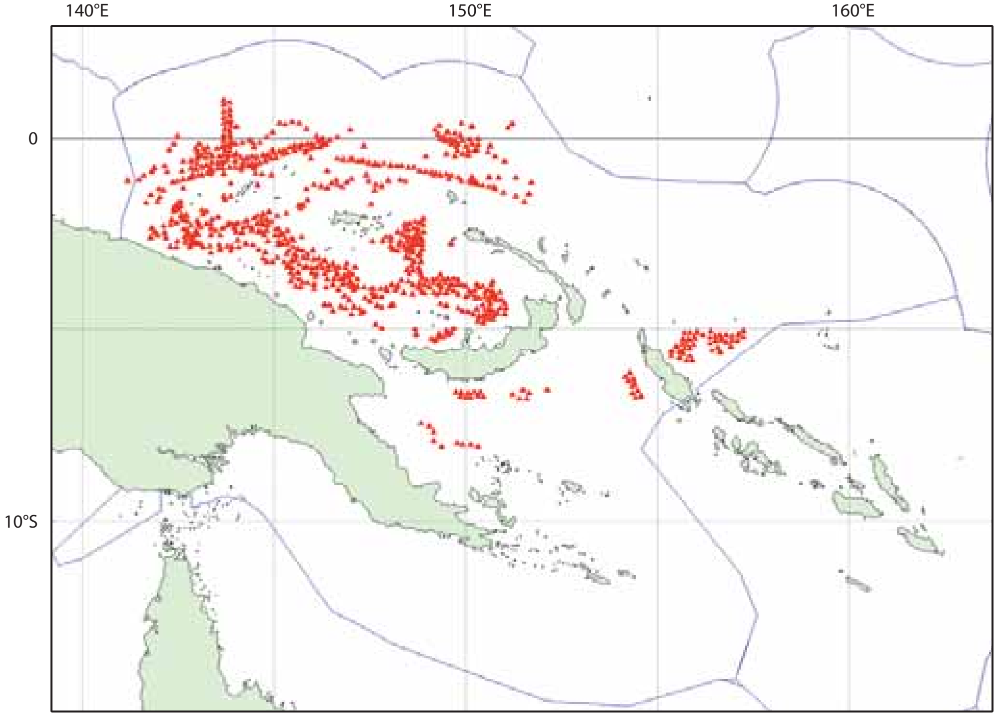

**Figure 7.** Position of licensed anchored fish aggregation devices in the Papua New Guinea exclusive economic zone (EEZ), 2007
Source: data supplied by NFA

aFADs being less variable than those from unassociated sets (Figure 13). There have been recent declines in yellowfin CPUE from dFAD and log sets (Figure 13). The results of the set type comparisons (Figure 13) of CPUEs showed that aFADs have been an important component of the PNG purse seine fishery for stabilising catch rates of both skipjack and yellowfin tuna.

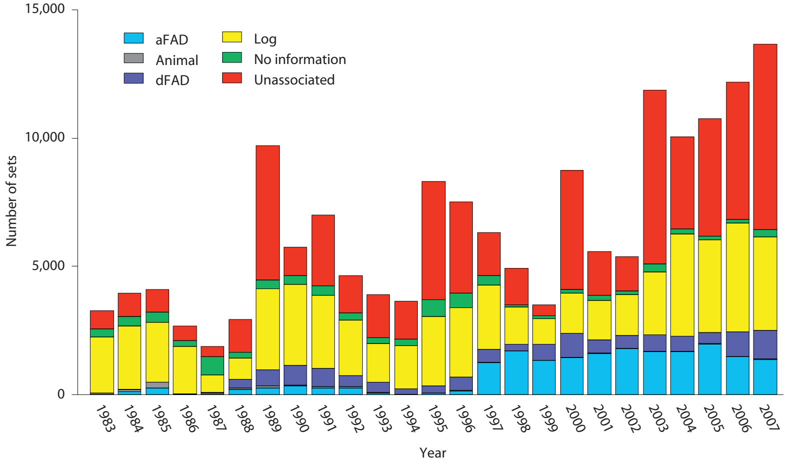

**Figure 8.** Annual numbers of sets by set type for the purse seine fishery in the Papua New Guinea exclusive economic zone, 1983–2007
Source: raised log-sheet data held by SPC
Set type codes: aFAD = sets on anchored fish aggregation devices; Animal = sets on whales, whale sharks and other live animals; dFAD = sets on drifting fish aggregation devices; Log = sets on logs; No information = no set type information recorded on the log-sheet; Unassociated = sets on unassociated tuna schools or tuna schools associated with baitfish

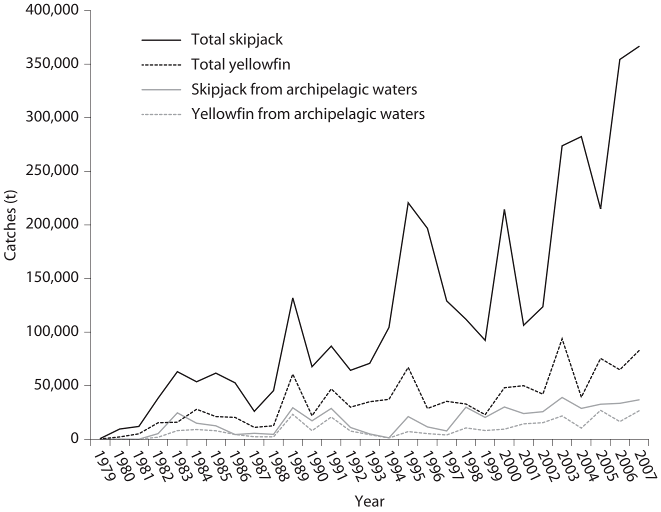

**Figure 9.** Total purse seine catches of skipjack and yellowfin tuna from archipelagic waters and the entire Papua New Guinea exclusive economic zone, 1979–2007
Source: SPC log-sheet data

Figure 14 demonstrates the shifting of the tropical convergence zone (approximated by the location of the 29 °C isotherm at the equator) seasonally and with shifts in climate state (El Niño – La Niña conditions), which are indicated by the Southern Oscillation Index (SOI). It also highlights correlations between these changes and movement of tropical purse seine fleets in the equatorial WCPO, and the subsequent impact of these movements on purse seine catch and effort inside the PNG EEZ.

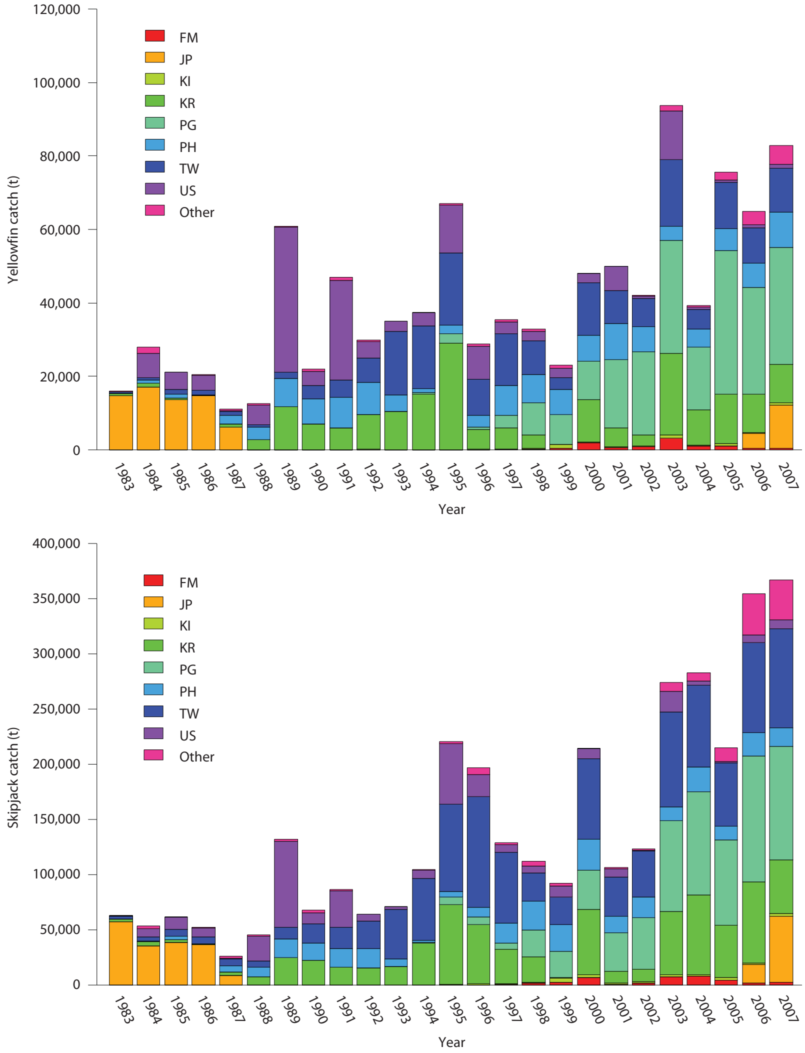

**Figure 10.** Annual catches of skipjack and yellowfin tuna (tonnes) by fleet for the purse seine fishery operating in the Papua New Guinea exclusive economic zone, 1983–2007
Source: raised log-sheet data held by SPC
Fleet codes: FM = Federated States of Micronesia; JP = Japan; KI = Kiribati; KR = Korea; PG = Papua New Guinea; PH = Philippines; TW = Taiwan; US = United States; Other = vessels from Australia, China, Indonesia, Marshall Islands, Mexico, New Zealand, Soviet Union, Solomon Islands and Vanuatu

*Anchored FAD fishery*

In the PNG EEZ, aFADs are licensed by individual fishing companies and the position of each aFAD is registered (NFA 2003). Most are located in the archipelagic waters of the Bismarck Sea (Figure 7) and a small number are deployed in the Solomon Sea immediately south of New Britain. The Morgado Square, to the north-west of New Ireland, has been designated as an area where aFADs are prohibited. Most purse seine sets on aFADs have been reported from the central regions of the Bismarck Sea, with far fewer sets in the northern areas of the Solomon Sea (Figure 15).

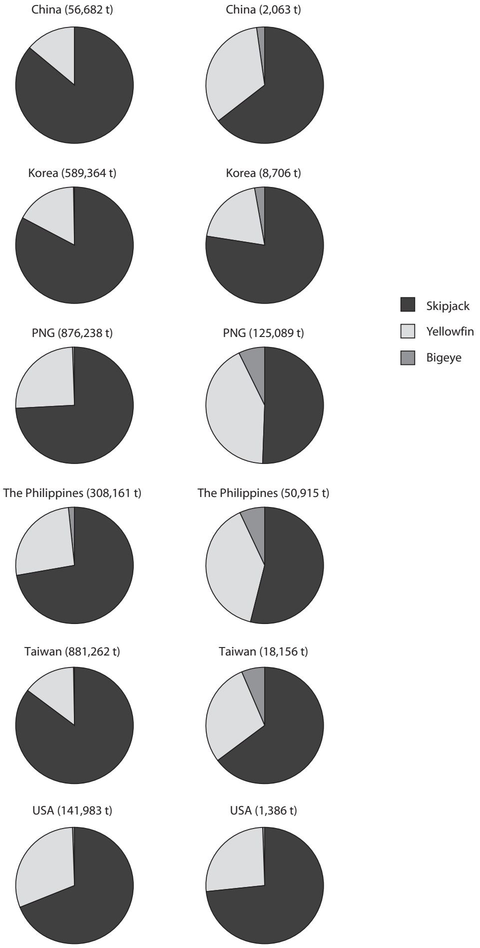

**Figure 11.** Species composition of log-sheet records (left-hand series) and observer records (right-hand series) of purse seine catches from the main fleets operating in the Papua New Guinea exclusive economic zone, 1998–2007, including total observed catch (tonnes, all species) for each fleet

Source: log-sheet and observer databases held at SPC

On average, the distribution of aFAD CPUE for skipjack is consistent across most of the PNG EEZ (Figure 16). The CPUE has been higher for skipjack in some small areas in the northern and eastern sectors of the EEZ. Yellowfin aFAD CPUE has, on average, been higher in the area to the immediate north of New Britain and some small areas along the northern border on the EEZ in comparison to all other areas in the EEZ (Figure 16).

*Length composition of target species*

Observer and port-sampling data were used to examine the length frequency of the major tuna species in purse seine catches from the PNG EEZ. The median size of skipjack has been larger for those captured in unassociated sets in comparison to associated sets (Figure 17). The modal size of skipjack has usually averaged 45–50 cm fork length (FL). Very few skipjack below 30 cm FL or above 70 cm FL have been captured.

Generally, the purse seine fishery captured two or more clear modes of yellowfin from the PNG EEZ (Figure 18). Catches from unassociated sets have been dominated by fish from three modal sizes—50–70 cm FL, 80–100 cm FL and 110–130 cm FL. In contrast, yellowfin catches from associated sets have been dominated by a strong mode at 50–60 cm FL. Larger yellowfin are captured less often from associated sets compared to unassociated sets. However, a second mode at 70–90 cm FL is present in associated sets.

Bigeye captured by the purse seine fishery in the PNG EEZ were generally less than 70 cm FL (Figure 19), with a large mode at approximately 50–60 cm FL. The size distributions of bigeye from both unassociated and associated sets are similar, although far fewer bigeye have been measured from unassociated sets.

## Characterisation of non-target species associated with the purse seine fishery in PNG

*Catch composition analysis*

Current observer coverage is biased towards aFADs given current effort (Figure 20). The number of unsuccessful sets reported by observers whereby the gear was set but no or limited tuna catch resulted was approximately 45% for unassociated sets and approximately 5% for associated sets.

A complete list of species observed to interact with the purse seine fishery is presented in Table 1. In each set type the target species dominated the observer records (Figure 21). Rainbow runners, mahi mahi, silky sharks, mackerel scad, frigate tuna, oceanic trigger fish, bullet tuna and barracudas were typically observed in >10% of observed associated sets, whereas the observation rate for non-target species in unassociated sets was typically <5% (Figure 21). The number of species recorded per set varied between set types (Figure 22). The median number of species recorded for unassociated sets was 2, aFAD sets was 5, dFAD sets was 6 and log sets was 7. On average, 33% of the catch of non-target species could be attributed to unassociated sets and 67% to associated sets, with log sets responsible for 46% of non-target fishing mortality (Figure 23). Statistically significant differences were detected among the species assemblages of unassociated sets, log sets, aFAD sets and dFAD sets (ANOSIM R statistics: 0.041, significance <0.001; however, the R statistic was small).

*Vulnerability of non-target species to fishing mortality*

The PSA confirms that skipjack, yellowfin and bigeye tuna are highly susceptible to purse seine fisheries (Figure 24, Table 2). Frigate tuna (FRZ) and rainbow runner (RRU) also scored highly on the susceptibility axis and were caught in a much higher proportion in associated sets than in unassociated sets. Marine mammals (toothed whale and dolphin), turtle and whale shark were the least productive groups on the productivity axis. Catches for these species were estimated to be relatively low (Table 3, Table 4). Silky shark (FAL) and blue marlin (BUM) were also ranked with low productivity; however, their capture was relatively high (>20,000 individuals per year) in all set types. Patterns in risk were evident between different set types. Log sets appear to pose the greatest risk to dolphins, while whale sharks were rarely encountered in association with aFADs.

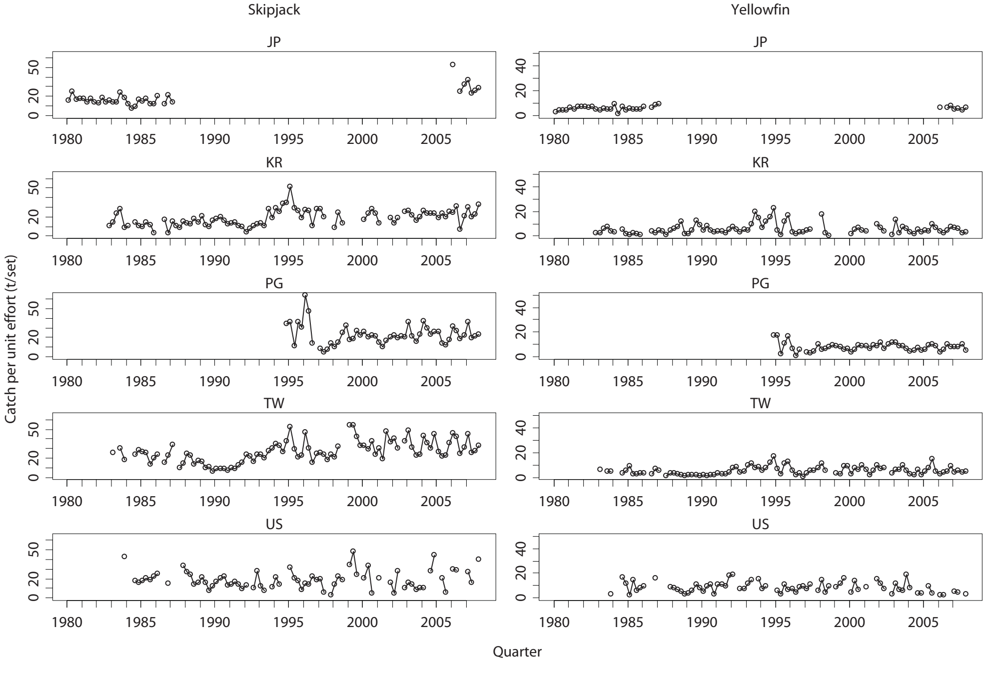

**Figure 12.** Average quarterly purse seine catch rates (tonnes per set) of skipjack and yellowfin tuna by major flags within the Papua New Guinea exclusive economic zone, 1980–2007
Source: log-sheet data held at SPC
Flag codes: JP = Japan; KR = Korea; PG = Papua New Guinea; TW = Taiwan; US = United States

**Table 1.** List of species observed to interact with the Papua New Guinea purse seine fishery

| Species code | Species name | Species scientific name | Species code | Species name | Species scientific name |
|---|---|---|---|---|---|
| ABU | Sargent major | *Abudefduf saxatilis* | COM | Spanish mackerel | *Scomberomorus commerson* |
| ALB | Albacore | *Thunnus alalunga* | CXS | Bigeye trevally | *Caranx sexfasciatus* |
| ALM | Unicorn leatherjacket | *Aluterus monoceros* | CZS | Bigeye trevally | *Caranx sexfasciatus* |
| ALN | Scribbled leatherjacket | *Aluterus scriptus* | DBO | Bottlenose dolphin | *Tursiops truncatus* |
| ALO | Shortsnouted lancetfish | *Alepisaurus brevirostris* | DCO | Common dolphin | *Delphinus delphis* |
| ALS | Silvertip shark | *Carcharhinus albimarginatus* | DGZ | Dog fishes | Squalidae |
| ALX | Longsnouted lancetfish | *Alepisaurus ferox* | DIY | Porcupine fish | *Diodon hystrix* |
| AMB | Greater amberjack | *Seriola dumerili* | DKK | Leatherback turtle | *Dermochelys coriacea* |
| AML | Grey reef shark | *Carcharhinus amblyrhynchos* | DLP | Porpoises (unidentified) | Delphinidae |
| AMX | Amberjacks | *Seriola* spp. | DOL | Mahi mahi | *Coryphaena hippurus* |
| BAC | Barracuda | *Sphyraena jello* | DOT | Dogtooth tuna | *Gymnosarda unicolor* |
| BAI | Rays, skates and mantas | *Batoidimorpha (Hypotramata)* | DRR | Risso’s dolphin | *Grampus griseus* |
| BAN | Barracuda | *Sphyraena putnamiae* | DSP | Spotted dolphins | *Stenella* spp. |
| BAO | Longfin batfish | *Platax teira* | DUS | Dusky shark | *Carcharhinus obscurus* |
| BAR | Barracudas | *Sphyraena* spp. | FAL | Silky shark | *Carcharhinus falciformis* |
| BAT | Batfishes | *Platax* spp. | FAW | False killer whale | *Pseudorca crassidens* |
| BET | Bigeye | *Thunnus obesus* | FLF | Filefishes | *Cantherhines(=Navodon)* spp. |
| BLM | Black marlin | *Makaira indica* | FLY | Flying fishes | Exocoetidae |
| BLR | Blacktip reef shark | *Carcharhinus melanopterus* | FRI | Frigate tuna | *Auxis thazard* |
| BLT | Bullet tuna | *Auxis rochei* | FRZ | Frigate and bullet tunas | *Auxis thazard, A. rochei* |
| BRA | Bramid species | *Brama* spp. | GBA | Great barracuda | *Sphyraena barracuda* |
| BRZ | Pomfrets and ocean breams | Bramidae | GEM | Gemfish | *Rexea solandri* |
| BSH | Blue shark | *Prionace glauca* | GLT | Golden trevally | *Gnathanodon speciosus* |
| BTH | Bigeye thresher | *Alopias superciliosus* | KAW | Kawakawa | *Euthynnus affinis* |
| BUK | Butterfly tuna / kingfish | *Gasterochisma melampus* | KIW | Killer whale | *Orcinus orca* |
| BUM | Blue marlin | *Makaira nigricans* | KPW | Pygmy killer whale | *Feresa attenuata* |
| BUP | Pacific rudderfish | *Psenopsis anomala* | KYC | Drummer (blue chub) | *Kyphosus cinerascens* |
| CCG | Galapagos shark | *Carcharhinus galapagensis* | LEC | Escolar | *Lepidocybium flavobrunneum* |
| CCP | Sandbar shark | *Carcharhinus plumbeus* | LEO | Olive ridley turtle | *Lepidochelys olivacea* |
| CEO | Rudderfish | *Centrolophus niger* | LMA | Long finned mako | *Isurus paucus* |
| CGX | Carangidae (trevallies) | *Carangoides* spp. and *Caranx* spp. | LOB | Triple-tail | *Lobotes surinamensis* |
| CNT | Ocean triggerfish | *Canthidermis maculatus* | MAK | Mako sharks | *Isurus* spp. |

**Table 1.** (Cont'd) List of species observed to interact with the Papua New Guinea purse seine fishery

| Species code | Species name | Species scientific name | Species code | Species name | Species scientific name |
|---|---|---|---|---|---|
| MAM | Marine mammal | Mammalia | SDX | Decapterus sp. – muroaji | *Decapterus* spp. |
| MAN | Manta rays | Mobulidae | SFA | Sailfish | *Istiophorus platypterus* |
| MAR | Marlin | *Makaira* spp. | SHK | Sharks | Elasmobranchii |
| MAX | Mackerel | Scombridae | SKJ | Skipjack | *Katsuwonus pelamis* |
| MEN | Black triggerfish | *Melichthys niger* | SKX | Sharks, rays, skates etc. | *Allothunnus fallai* |
| MLS | Striped marlin | *Tetrapturus audax* | SLT | Slender tuna | *Isurus oxyrinchus* |
| MOX | Ocean sunfish | *Mola mola* | SMA | Short-finned mako | *Sphyrna* spp. |
| MSD | Mackerel scad / saba | *Decapterus macarellus* | SNX | Snappers, jobfishes nei | Ommastrephidae, Loliginidae |
| NAU | Pilot fish | *Naucrates ductor* | SPN | Hammerhead sharks | *Tetrapturus angustirostris* |
| OCS | Oceanic whitetip shark | *Carcharhinus longimanus* | SQU | Squids | Dasyatidae |
| ODN | Toothed whales | Odontoceti | SRX | Rays, stingrays, mantas nei | *Xiphias gladius* |
| OIL | Oilfish | *Ruvettus pretiosus* | SSP | Short-billed spearfish | *Taractichthys longipinnis* |
| OTH | Other fish | Teleostii | STT | Rays (dasyatidae) | *Trachinotus baillonii* |
| PBF | Pacific bluefin tuna | *Thunnus orientalis* | SWO | Swordfish | *Alopias* spp. |
| PLS | Pelagic stingray | *Dasyatis violacea* | TAL | Big-scaled pomfret | *Caranx* spp. |
| PLZ | Right-eyed flounders | Pleuronectidae | TBA | Smallspotted dart | Balistidae |
| POA | Ray's bream | *Brama brama* | THR | Thresher sharks | *Taractichthys steindachneri* |
| PSC | Man-o-war fish | *Psenes cyanophrys* | TOE | Rays (torpedinidae, narkida | *Eretmochelys imbricata* |
| PSK | Crocodile shark | *Pseudocarcharias kamoharai* | TRE | Trevallies | Testudinata |
| PTH | Thresher | *Alopias vulpinus* | TRI | Oceanic triggerfish | *Chelonia mydas* |
| REL | Oarfish | *Regalecus glesne* | TST | Sickle pomfret | *Atule mate* |
| REM | Remora species | *Remora* spp. | TTH | Hawksbill turtle | Thunnini |
| RHN | Whale shark | *Rhincodon typus* | TTX | Marine turtle | *Acanthocybium solandri* |
| RMB | Giant manta | *Manta birostris* | TUG | Green turtle | *Thunnus albacares* |
| RMJ | Manta ray | *Mobula japanica* | TUM | Yellowtail scad | *Seriola rivoliana* |
| RMT | Chilean devil ray | *Mobula tarapacana* | TUN | Tuna | |
| RRU | Rainbow runner | *Elagatis bipinnulata* | WAH | Wahoo | |
| RZV | Slender sunfish | *Ranzania laevis* | YFT | Yellowfin | |
| SAP | Saury (sanma) | *Cololabis saira* | YTL | Longfin yellowtail | |
| SBF | Southern bluefin tuna | *Thunnus maccoyii* | | | |

**Table 2.** Scores used in the productivity-susceptibility analysis

| Species code | Species scientific name | Species name | Productivity | Unassociated | Log | dFAD | aFAD |
|---|---|---|---|---|---|---|---|
| DLP | Delphinidae | Dolphins/porpoises | 1.00 | 53 | 385 | 9 | 92 |
| MAM | Mammalia | Marine mammal | 1.00 | 60 | 26 | 9 | 8 |
| ODN | Odontoceti | Toothed whales | 1.00 | 120 | 77 | 9 | 19 |
| RHN | *Rhincodon typus* | Whale shark | 1.00 | 301 |  | 9 | 3 |
| TTX | Testudinata | Marine turtle | 0.85 | 57 | 45 | 20 | 15 |
| BUM | *Makaira nigricans* | Blue marlin | 0.65 | 542 | 539 | 132 | 38 |
| FAL | *Carcharhinus falciformis* | Silky shark | 0.61 | 5,680 | 14,258 | 3,507 | 1,686 |
| OCS | *Carcharhinus longimanus* | Oceanic whitetip shark | 0.55 | 105 |  | 9 | 3 |
| SWO | *Xiphias gladius* | Swordfish | 0.52 | 53 | 60 |  | 14 |
| PLS | *Dasyatis violacea* | Pelagic stingray | 0.48 |  | 9 | 9 | 8 |
| BLM | *Makaira indica* | Black marlin | 0.47 | 562 | 274 | 47 | 49 |
| MOX | *Mola mola* | Ocean sunfish | 0.46 |  | 51 | 9 |  |
| BAR | *Sphyraena* spp. | Barracudas | 0.43 | 1,315 | 4,668 | 489 | 688 |
| ALB | *Thunnus alalunga* | Albacore | 0.43 | 3,629 | 6,120 | 6,394 | 79 |
| BET | *Thunnus obesus* | Bigeye | 0.40 | 982,875 | 1,344,922 | 856,622 | 578,953 |
| MAN | Mobulidae | Manta rays | 0.40 | 341 | 282 | 142 | 90 |
| MLS | *Tetrapturus audax* | Striped marlin | 0.39 | 261 | 103 |  | 14 |
| YFT | *Thunnus albacares* | Yellowfin | 0.35 | 11,511,246 | 13,563,108 | 3,064,414 | 3,294,008 |
| KYC | *Kyphosus cinerascens* | Drummer (blue chub) | 0.32 | 631 | 4,915 | 2,840 | 287 |
| SFA | *Istiophorus platypterus* | Sailfish (indo-pacific) | 0.31 | 210 | 120 | 9 | 16 |
| GLT | *Gnathanodon speciosus* | Golden trevally | 0.31 |  | 34 | 169 | 49 |
| BRZ | Bramidae | Pomfrets / ocean breams | 0.29 | 341 | 4,721 | 447 | 144 |
| MAX | Scombridae | Mackerel | 0.29 |  | 60 |  |  |
| LOB | *Lobotes surinamensis* | Triple-tail | 0.28 | 100 | 393 | 47 | 27 |
| RRU | *Elagatis bipinnulata* | Rainbow runner | 0.28 | 26,139 | 585,351 | 33,965 | 26,566 |
| TRE | *Caranx* spp. | Trevallies | 0.27 | 57 | 2,428 | 592 | 1,128 |
| WAH | *Acanthocybium solandri* | Wahoo | 0.27 | 368 | 2,923 | 263 | 198 |
| BLT | *Auxis rochei* | Bullet tuna | 0.27 | 2,525 | 29,456 | 15,506 | 1,784 |
| OIL | *Ruvettus pretiosus* | Oilfish | 0.26 | 53 |  |  |  |
| FLF | *Cantherhines(=Navodon)* spp. | Filefishes | 0.26 |  | 8,727 | 837 | 336 |
| SQU | Ommastrephidae, Loliginidae | Squids | 0.24 | 221 |  |  | 11 |
| DIO | Diodontidae | Porcupine fishes | 0.23 | 210 | 9 | 19 | 5 |
| BAT | *Platax* spp. | Batfishes | 0.22 | 1,473 | 1,385 | 216 | 65 |
| FRZ | *Auxis thazard, A. rochei* | Frigate and bullet tunas | 0.21 | 789 | 94 | 1,081,380 | 282 |
| SKJ | *Katsuwonus pelamis* | Skipjack | 0.16 | 50,624,905 | 73,079,729 | 20,124,438 | 14,564,731 |
| FRI | *Auxis thazard* | Frigate tuna | 0.16 | 94,475 | 36,448 | 2,144 | 18,039 |
| KAW | *Euthynnus affinis* | Kawakawa | 0.08 | 2,208 | 3,949 | 169 | 225 |
| CNT | *Canthidermis maculatus* | Spotted triggerfish | 0.07 | 9,625 | 95,222 | 4,391 | 1,672 |
| MEN | *Melichthys niger* | Black triggerfish | 0.07 | 5,680 | 48,192 | 3,348 | 745 |
| TRI | Balistidae | Oceanic triggerfish | 0.07 | 6,995 | 126,840 | 5,924 | 3,597 |
| DOL | *Coryphaena hippurus* | Mahi mahi / dolphinfish | 0.02 | 14,148 | 108,728 | 2,708 | 23,338 |
| MSD | *Decapterus macarellus* | Mackerel scad / saba | 0.00 | 31,556 | 614,695 | 17,415 | 10,224 |

Note: The productivity score is an indicator based on a combination of standardised values for natural mortality, growth rate, maximum length, maximum age and age at maturity. A high productivity score denotes low biological productivity and therefore higher risk of adverse effects due to fishing. In this analysis the susceptibility score is simply the estimated total number of individuals caught by each set type in the fishery.

dFAD = drifting fish aggregation device; aFAD = anchored fish aggregation device

*Catches of non-target species interacting with the PNG purse seine fishery*

The degrees of freedom and other statistics for each of the ZILN models are presented in Table 5. The average degrees of freedom of model predictors and deviance explained were 5.5 and 19.3% respectively. In general, year was the most important predictor, followed by longitude, school association and latitude for the non-target species (Table 5).

The catch estimates for the purse seine fishery are presented in Table 6 and the trends in catch in Figure 25. The average estimated catch for non-target species per year was 2,740 t (Table 6). Over 90% of the estimated catch of non-target species was attributed to associated sets, with rainbow runner (45%) recording the largest biomass (Table 6). Frigate and bullet tuna (9%), mackerel scad (7%), trigger fish (7%), silky shark (6%) and mahi mahi (5%) also comprised a significant component of the catch (Table 6). Negative trends in estimated catch over time were detected for mackerel, frigate and bullet tuna, oceanic whitetip shark and the combined group of other sharks and rays (Figure 25).

Observer data were used to examine the length frequency of the non-target species in purse seine catches from the PNG EEZ. Data were sufficient (>50 records) to compare the length frequency between associated sets and unassociated sets for black marlin and blue marlin. There was no difference in the length frequency of associated versus unassociated sets for black marlin (Figure 26). The length frequency was also similar between the two set types for blue marlin; however, individuals less than 65 cm in length were observed in the associated sets (~10% of records, Figure 26).

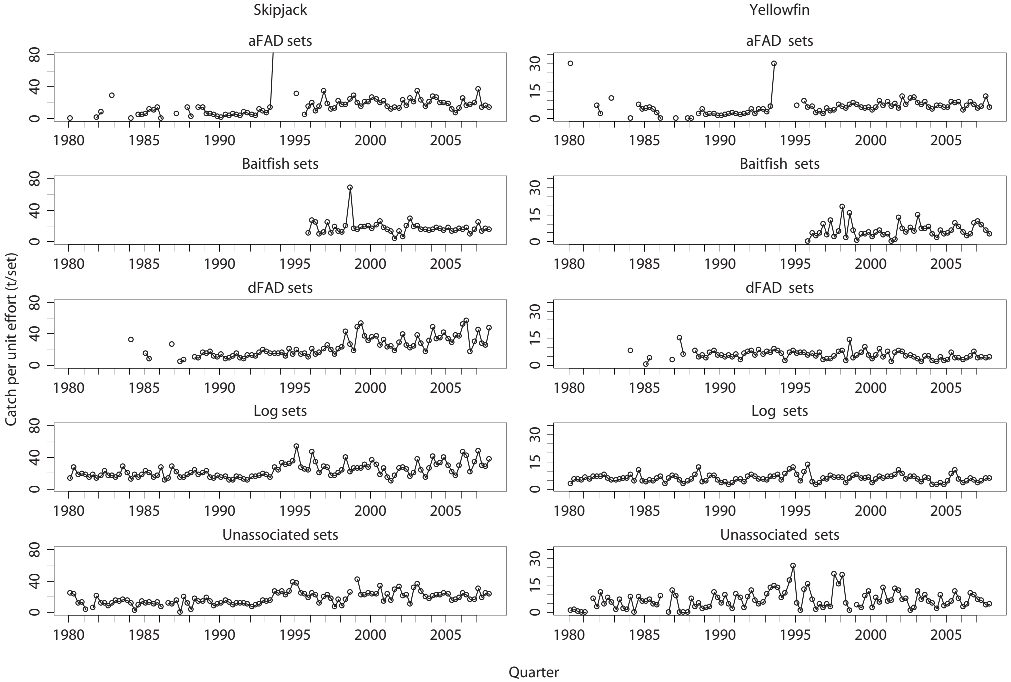

**Figure 13.** Average quarterly purse seine catch rates (tonnes per set) of skipjack and yellowfin tuna by set type within the Papua New Guinea exclusive economic zone, 1980–2007
Source: log-sheet data held at SPC
Set types: aFAD = anchored fish aggregation devices; Baitfish = sets on tuna schools associated with baitfish; dFAD = drifting fish aggregation devices; Log = sets on logs; Unassociated = sets on unassociated surface schools of tuna

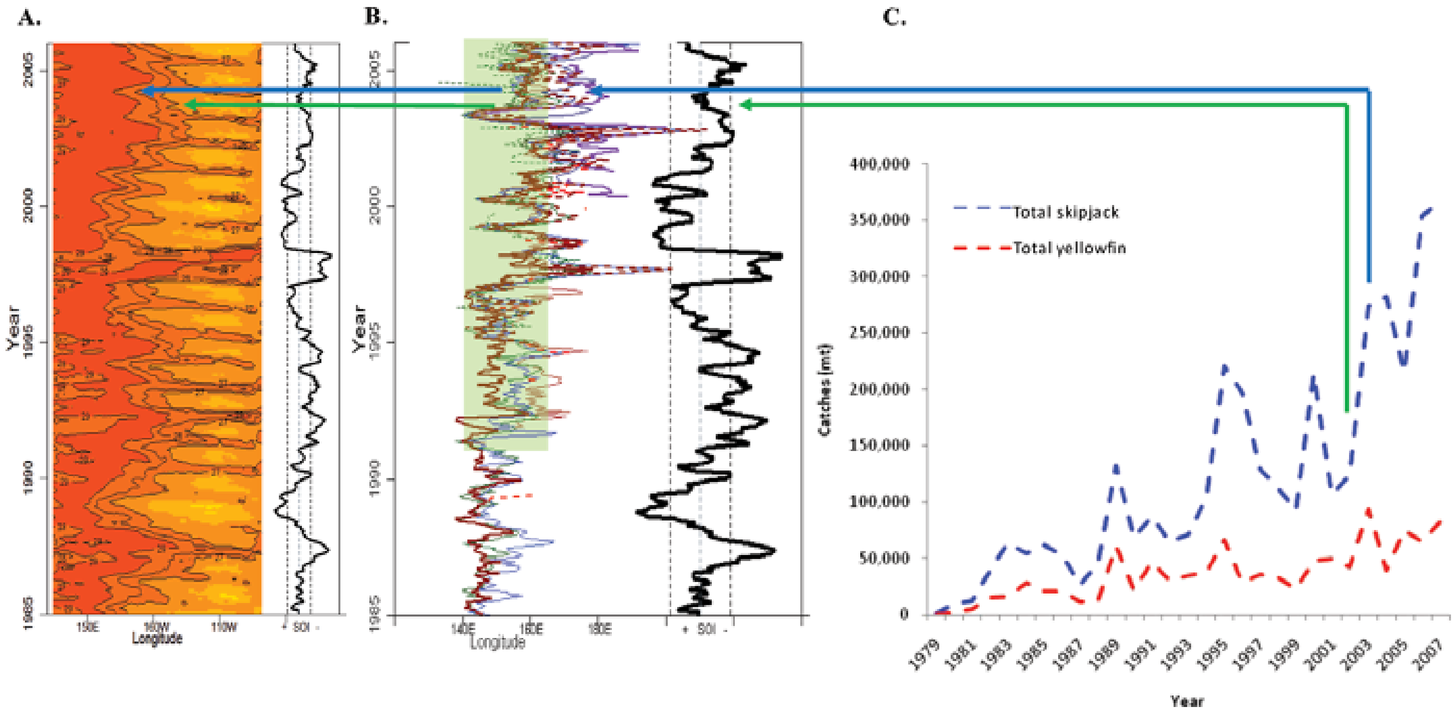

**Figure 14.** Sea surface temperature, Southern Oscillation Index (SOI) and tuna catches by year in the Papua New Guinea exclusive economic zone (EEZ)

Source: SPC log-sheet data

Note: (A) Average monthly equatorial sea surface temperature by longitude (left side of plot A) and SOI (right side of plot A) during the period 1985 to 2006, with isotherm lines representing the east–west movement of the 27 °C, 28 °C and 29 °C isotherms in equatorial waters. Warmer waters are denoted by darker shading (dark orange being waters 30 °C+) and cooler waters by lighter yellow shading. Strongly positive SOI values denote La Niña climate conditions and strongly negative SOI values denote El Niño climate conditions; (B) Shifts in the mean longitudinal centre of effort distribution for 'mobile' purse seine fleets operating in equatorial waters between 5 °N and 5 °S, plotted alongside the SOI. The green strip between 165 °E and 170 °E approximates the eastern and western edges of the PNG EEZ. Different 'fleets/flags' are denoted by different colours to show variability in longitudinal movement of fleets. Note that this figure does not indicate the latitudinal location of fleets; (C) Total annual skipjack and yellowfin catches (t) inside the PNG EEZ. Green and blue arrows indicate an example of correlation between high (and low) catch years, purse seine fleet movement with respect to the PNG EEZ, and shifts in the warm pool and the tropical convergence zone.

# Discussion

The purse seine fishery in PNG has developed over the last 20 years both in terms of the total catch and the number of nations operating purse seiners within PNG's jurisdiction. This development has also included the expansion of aFADs and dFADs. Although unassociated and log sets comprise the majority of effort within PNG, aFAD and dFAD sets now comprise between 10% and 20% of all effort. Stable fishing effort and catch rates are important for maintaining the supply of tuna to onshore processing facilities. The expansion of the FAD fishery has assisted in generating such stability in PNG.

**Table 3.** Observations of marine mammal and turtle interactions in the Papua New Guinea purse seine fishery

| Period | Species | Set type | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Unknown | Unassociated | Log | dFAD | aFAD | Live whale | Total |
| 1995 | MAM | | | 8 | | | | 8 |
| | LEO | 2 | | | | | | 2 |
| 1996 | TTX | | 1 | 1 | 1 | | | 3 |
| 1997 | MAM | 1 | | 15 | | | 6 | 22 |
| 1998 | MAM | | | | | 6 | | 6 |
| | TUG | | | | | 1 | | 1 |
| 1999 | MAM | 1 | | 1 | | 9 | | 11 |
| | TTX | | | | 1 | 2 | | 3 |
| 2000 | MAM | | 2 | | | | | 2 |
| 2001 | MAM | | | | 1 | | | 1 |
| | TTX | | | | | 1 | | 1 |
| 2002 | MAM | 21 | 32 | 7 | | 117 | | 177 |
| | TTX | 2 | 1 | 2 | 2 | 5 | | 12 |
| 2003 | DBO | | | | | 2 | | 2 |
| | MAM | 3 | 5 | 1 | | 117 | 2 | 128 |
| | TTH | | | | | 1 | | 1 |
| | TTX | | 4 | 5 | 1 | 10 | | 21 |
| | TUG | | 1 | | | | | 1 |
| 2004 | DBO | | | 28 | 1 | 13 | | 42 |
| | MAM | | 6 | 200 | 1 | 31 | 220 | 458 |
| | LEO | | | 1 | | | | 1 |
| | LTB | | | 1 | | | | 1 |
| | TTX | | 2 | 2 | | 9 | | 13 |
| 2005 | DBO | | 1 | | | | | 1 |
| | F43 | | 3 | 17 | | | | 20 |
| | MAM | | | 24 | | 31 | | 55 |
| | TTH | | 2 | | | | | 3 |
| | TTL | | 2 | 1 | 1 | | | 3 |
| | TTX | 2 | 1 | 4 | | 6 | | 13 |
| | TUG | | | 3 | | 1 | | 4 |
| 2006 | DBO | | 1 | 8 | | 30 | | 39 |
| | F43 | | 3 | 2 | | | | 2 |
| | MAM | | 1 | 3 | 1 | 3 | | 10 |
| | LEO | | | 3 | 1 | 1 | | 5 |
| | TTH | | | | | | | 1 |
| | TTL | | | 1 | | | | 1 |
| | TTX | | | | 1 | | | 1 |
| | TUG | | | | | 3 | | 3 |

Note: see Table 1 for species codes.
dFAD = drifting fish aggregation device; aFAD = anchored fish aggregation device

**Table 4.** Raised estimates[a] of marine mammal and turtle interactions in the Papua New Guinea purse seine fishery

| Period | Species | Set type | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Unknown | Unassociated | Log | dFAD | aFAD | Live whale | Total |
| 1995 | MAM | | | 267 | | | | 267 |
| | LEO | 68 | | | | | | 68 |
| 1996 | TTX | | 41 | 36 | 24 | | | 101 |
| 1997 | MAM | 14 | | 250 | | | 86 | 350 |
| 1998 | MAM | | | | | 150 | | 150 |
| | TUG | | | | | 28 | | 28 |
| 1999 | MAM | 9 | | 50 | | 113 | | 172 |
| | TTX | | | | 8 | 24 | | 32 |
| 2000 | MAM | | 67 | | | | | 67 |
| 2001 | MAM | | | | 14 | | | 14 |
| | TTX | | | | | 14 | | 14 |
| 2002 | MAM | 94 | 320 | 50 | | 234 | | 698 |
| | TTX | 13 | 10 | 14 | 13 | 10 | | 47 |
| 2003 | DBO | | | | 4 | 4 | | 4 |
| | MAM | 13 | 83 | 8 | | 213 | 9 | 327 |
| | TTH | | | | | 2 | | 2 |
| | TTX | | 69 | 44 | 14 | 20 | | 146 |
| | TUG | | 17 | | | | | 17 |
| 2004 | DBO | | | 165 | 4 | 21 | | 189 |
| | MAM | | 60 | 1,176 | 4 | 49 | 759 | 2,048 |
| | LEO | | | 6 | | | | 6 |
| | LTB | | | 6 | | | | 6 |
| | TTX | | 21 | 12 | | 14 | | 48 |
| 2005 | DBO | | 11 | 0 | | | | 11 |
| | F43 | | 33 | 85 | | | | 118 |
| | MAM | | | 120 | | 70 | | 190 |
| | TTH | | 25 | | 3 | | | 28 |
| | TTL | | 25 | 6 | | | | 30 |
| | TTX | 12 | 12 | 22 | | 14 | | 49 |
| | TUG | | | 17 | | 2 | | 19 |
| 2006 | DBO | | 11 | 62 | | 79 | | 152 |
| | F43 | | | 15 | | | | 15 |
| | MAM | | 43 | 23 | 9 | 8 | | 83 |
| | LEO | | | 26 | 9 | 3 | | 38 |
| | TTH | | 15 | | | | | 15 |
| | TTL | | | 9 | | | | 9 |
| | TTX | | | | 9 | | | 9 |
| | TUG | | | | | 8 | | 8 |

[a] Raised estimate = number of observations × 1/(observer coverage)
Note: see Table 1 for species codes.
dFAD = drifting fish aggregation device; aFAD = anchored fish aggregation device

**Table 5.** Statistics for zero-inflated lognormal (ZILN) models of purse seine catch rates

| Species or species group | Observed non-zero trips | | Model | School association | Year | Month | Latitude | Longitude | Sea surface salinity | Sea surface temperature | Depth of 20 °C isotherm | Total | Deviance explained (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trips | % | | | | | | | | | | | |
| Manta rays | 526 | 28.1 | Logistic | | 3 | | | | | | 3 | 6 | 2.7 |
| | | | Lognormal | | 1 | | | 3 | | | | 4 | 9.2 |
| Oceanic whitetip shark | 325 | 17.4 | Logistic | 1 | 5 | | | 1 | 1 | | | 8 | 13.3 |
| | | | Lognormal | 1 | 1 | | 1 | | | | | 3 | 16.2 |
| Silky shark | 965 | 51.6 | Logistic | 1 | 3 | | 1 | 1 | | | | 6 | 21.7 |
| | | | Lognormal | 1 | | | | 3 | | | | 4 | 16.8 |
| Whale shark | 98 | 5.2 | Logistic | | 1 | | | | | | | 1 | 1.9 |
| | | | Lognormal | 1 | | | | | | | 1 | 2 | 17.5 |
| Other sharks and rays | 843 | 45.1 | Logistic | 1 | 1 | | | 1 | | | 3 | 6 | 5.1 |
| | | | Lognormal | 1 | 1 | | | 4 | | | | 6 | 11.1 |
| Dolphinfish | 944 | 50.5 | Logistic | 1 | 1 | | 3 | | | 1 | | 6 | 32.7 |
| | | | Lognormal | 1 | | | | 3 | | | 1 | 5 | 12.8 |
| Frigate and bullet tuna | 458 | 24.5 | Logistic | 1 | 3 | | 3 | 1 | | | 1 | 9 | 25.6 |
| | | | Lognormal | | 1 | | 1 | 1 | | | | 3 | 10.4 |
| Kawakawa | 103 | 5.5 | Logistic | 1 | 1 | | | | | | | 2 | 6.2 |
| | | | Lognormal | | | | 1 | 1 | | | | 2 | 14.1 |
| Mackerel | 156 | 8.3 | Logistic | 1 | 5 | 1 | | 1 | | | | 8 | 17.2 |
| | | | Lognormal | | 1 | | | 1 | | 3 | | 5 | 19.8 |
| Mackerel scad | 625 | 33.4 | Logistic | 1 | 1 | | | 1 | | | 1 | 4 | 32.9 |
| | | | Lognormal | 1 | | | 1 | 4 | | | | 6 | 12.4 |
| Rainbow runner | 1,177 | 62.9 | Logistic | 1 | 1 | | | | | | | 2 | 42.1 |
| | | | Lognormal | 1 | 4 | | 3 | 3 | 1 | | | 12 | 32.7 |
| Triggerfish | 920 | 49.2 | Logistic | 1 | 1 | | 3 | 1 | | | | 6 | 35.5 |
| | | | Lognormal | 1 | 5 | | 1 | 4 | | | | 11 | 25.8 |
| Wahoo | 789 | 42.2 | Logistic | 1 | 1 | | | 1 | | | | 3 | 27.4 |
| | | | Lognormal | 1 | | 3 | 1 | 5 | 3 | | | 13 | 29.8 |
| Other fish | 1,173 | 62.7 | Logistic | 1 | 1 | | | 1 | | | | 3 | 28.3 |
| | | | Lognormal | 1 | 5 | | | | 1 | 1 | | 8 | 18.2 |

**Table 6.** Estimates of catches (tonnes) of non-target species of finfish by purse seiners in the waters of Papua New Guinea

| Species or species group | School association | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Average | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Manta rays | Unassociated | 15 | 9 | 6 | 7 | 2 | 16 | 11 | 12 | 52 | 32 | 39 | 36 | 20 | 0.7 |
| | Associated | 12 | 12 | 17 | 14 | 14 | 15 | 22 | 30 | 53 | 66 | 64 | 47 | 31 | 1.1 |
| | Total | 27 | 21 | 23 | 22 | 16 | 31 | 33 | 41 | 106 | 98 | 103 | 83 | 50 | 1.8 |
| Oceanic whitetip shark | Unassociated | 4 | 5 | 4 | 4 | 1 | 5 | 2 | 1 | 2 | 1 | 2 | 0 | 3 | 0.1 |
| | Associated | 22 | 39 | 60 | 49 | 36 | 30 | 22 | 12 | 11 | 11 | 13 | 4 | 26 | 0.9 |
| | Total | 26 | 43 | 63 | 54 | 37 | 35 | 24 | 13 | 13 | 12 | 15 | 5 | 28 | 1.0 |
| Silky shark | Unassociated | 5 | 5 | 4 | 5 | 1 | 17 | 8 | 9 | 44 | 28 | 35 | 39 | 17 | 0.6 |
| | Associated | 52 | 73 | 117 | 96 | 95 | 128 | 127 | 149 | 242 | 302 | 297 | 291 | 164 | 6.0 |
| | Total | 57 | 78 | 121 | 101 | 97 | 146 | 135 | 158 | 286 | 330 | 332 | 330 | 181 | 6.6 |
| Whale shark | Unassociated | 15 | 10 | 6 | 8 | 1 | 14 | 8 | 9 | 56 | 30 | 51 | 57 | 22 | 0.8 |
| | Associated | 23 | 24 | 39 | 33 | 21 | 27 | 37 | 61 | 98 | 115 | 144 | 154 | 65 | 2.4 |
| | Total | 38 | 34 | 44 | 41 | 22 | 41 | 45 | 70 | 154 | 145 | 195 | 211 | 87 | 3.2 |
| Other sharks and rays | Unassociated | 116 | 50 | 21 | 12 | 2 | 11 | 4 | 2 | 6 | 2 | 2 | 1 | 19 | 0.7 |
| | Associated | 359 | 274 | 239 | 111 | 73 | 59 | 38 | 27 | 30 | 25 | 16 | 10 | 105 | 3.8 |
| | Total | 474 | 323 | 260 | 123 | 75 | 70 | 42 | 29 | 36 | 27 | 18 | 12 | 124 | 4.5 |
| Dolphinfish | Unassociated | 3 | 2 | 1 | 2 | 0 | 2 | 1 | 1 | 6 | 4 | 6 | 7 | 3 | 0.1 |
| | Associated | 103 | 95 | 140 | 107 | 68 | 77 | 82 | 111 | 167 | 191 | 200 | 189 | 127 | 4.7 |
| | Total | 106 | 97 | 141 | 109 | 68 | 79 | 83 | 112 | 173 | 195 | 206 | 196 | 130 | 4.8 |
| Frigate and bullet tuna | Unassociated | 62 | 33 | 12 | 15 | 2 | 21 | 30 | 15 | 112 | 36 | 49 | 32 | 35 | 1.3 |
| | Associated | 333 | 281 | 289 | 269 | 144 | 151 | 227 | 254 | 320 | 251 | 277 | 187 | 249 | 9.1 |
| | Total | 395 | 314 | 301 | 284 | 146 | 172 | 257 | 269 | 433 | 287 | 327 | 219 | 284 | 10.4 |
| Kawakawa | Unassociated | 1 | 1 | 1 | 1 | 0 | 2 | 2 | 1 | 8 | 5 | 8 | 8 | 3 | 0.1 |
| | Associated | 4 | 6 | 7 | 7 | 6 | 8 | 11 | 12 | 20 | 21 | 31 | 35 | 14 | 0.5 |
| | Total | 5 | 7 | 8 | 8 | 6 | 9 | 13 | 12 | 28 | 26 | 40 | 43 | 17 | 0.6 |

**Table 6.** (Cont'd) Estimates of catches (tonnes) of non-target species of finfish by purse seiners in the waters of Papua New Guinea

| Species or species group | School association | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Average | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mackerel | Unassociated | 3 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.0 |
|  | Associated | 23 | 37 | 11 | 5 | 2 | 2 | 4 | 4 | 7 | 7 | 2 | 1 | 9 | 0.3 |
|  | Total | 26 | 42 | 12 | 6 | 2 | 2 | 4 | 5 | 8 | 8 | 2 | 1 | 10 | 0.4 |
| Mackeral scad | Unassociated | 1 | 1 | 1 | 1 | 0 | 2 | 1 | 1 | 8 | 4 | 8 | 9 | 3 | 0.1 |
|  | Associated | 86 | 101 | 143 | 112 | 81 | 110 | 126 | 187 | 302 | 393 | 410 | 397 | 204 | 7.4 |
|  | Total | 87 | 102 | 143 | 112 | 81 | 112 | 127 | 188 | 310 | 398 | 418 | 406 | 207 | 7.6 |
| Rainbow runner | Unassociated | 5 | 6 | 4 | 4 | 1 | 8 | 4 | 4 | 22 | 22 | 38 | 40 | 13 | 0.5 |
|  | Associated | 463 | 923 | 1,114 | 827 | 630 | 727 | 737 | 737 | 1,285 | 2,202 | 2,783 | 2,247 | 1,223 | 44.6 |
|  | Total | 468 | 929 | 1,118 | 831 | 631 | 735 | 741 | 741 | 45.1 | 1,308 | 2,224 | 2,822 | 2,287 | 1,236 |
| Triggerfish | Unassociated | 2 | 3 | 2 | 1 | 0 | 1 | 0 | 1 | 7 | 6 | 6 | 13 | 4 | 0.1 |
|  | Associated | 96 | 257 | 247 | 119 | 52 | 42 | 44 | 84 | 232 | 417 | 305 | 443 | 195 | 7.1 |
|  | Total | 98 | 260 | 248 | 120 | 52 | 43 | 45 | 85 | 238 | 423 | 312 | 456 | 198 | 7.2 |
| Wahoo | Unassociated | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0.0 |
|  | Associated | 12 | 14 | 17 | 12 | 9 | 11 | 12 | 14 | 23 | 32 | 29 | 31 | 18 | 0.7 |
|  | Total | 13 | 14 | 18 | 12 | 10 | 12 | 12 | 14 | 24 | 32 | 29 | 32 | 18 | 0.7 |
| Other fish | Unassociated | 13 | 11 | 6 | 4 | 1 | 13 | 5 | 5 | 36 | 21 | 33 | 56 | 17 | 0.6 |
|  | Associated | 84 | 103 | 123 | 82 | 66 | 82 | 86 | 107 | 190 | 234 | 264 | 392 | 151 | 5.5 |
|  | Total | 97 | 114 | 129 | 87 | 67 | 95 | 91 | 112 | 226 | 255 | 297 | 448 | 168 | 6.1 |
| Total | Unassociated | 245 | 140 | 67 | 65 | 13 | 114 | 76 | 61 | 362 | 193 | 278 | 300 | 160 | 5.8 |
|  | Associated | 1,671 | 2,239 | 2,562 | 1,843 | 1,298 | 1,471 | 1,575 | 1,789 | 2,981 | 4,267 | 4,836 | 4,427 | 2,580 | 94.2 |
|  | Total | 1,916 | 2,379 | 2,629 | 1,908 | 1,311 | 1,585 | 1,651 | 1,851 | 3,343 | 4,460 | 5,115 | 4,727 | 2,740 | 100.0 |

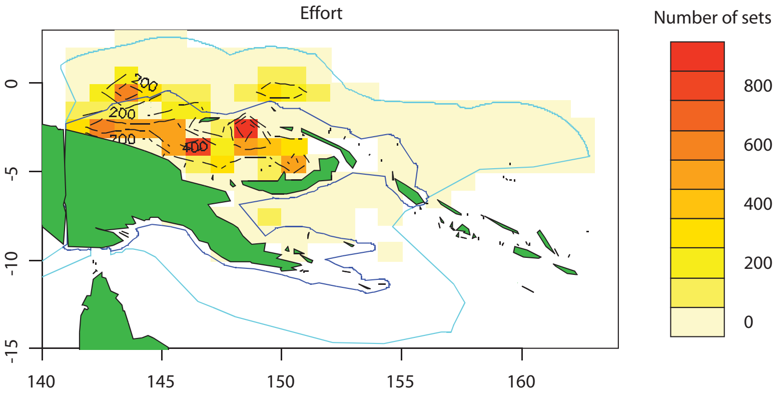

**Figure 15.** Average distribution of purse seine effort on anchored fish aggregation devices in the Papua New Guinea exclusive economic zone, 2000–07
Source: log-sheet data held at SPC

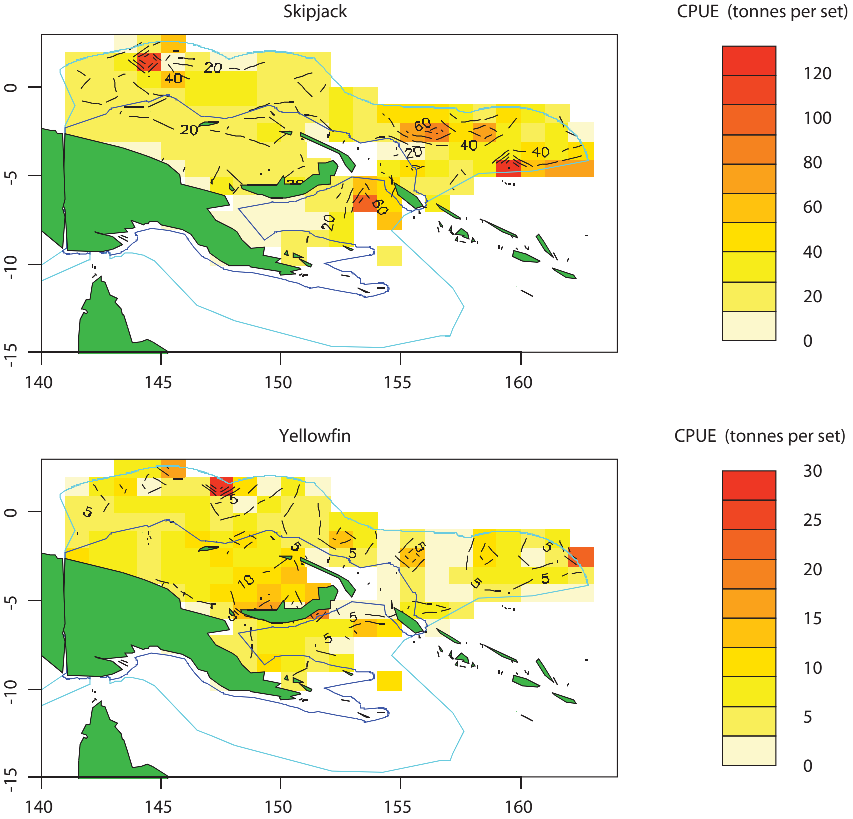

**Figure 16.** Distribution of purse seine catch per unit effort (CPUE) on anchored fish aggregation devices for skipjack (upper figure) and yellowfin (lower figure) tuna in the Papua New Guinea exclusive economic zone, 2000–07
Source: log-sheet data held at SPC

The fishery primarily targets skipjack and, to a lesser extent, yellowfin tuna. However, bigeye tuna are also caught, particularly from associated sets. The current 'overfishing' stock status of bigeye (Langley et al. 2008) and low market value for the small size classes caught by purse seine vessels indicate that this species should not be targeted in the purse seine fishery, and should be actively avoided where possible. The estimated catch and CPUE for juvenile bigeye from associated sets has been considered likely to be an underestimate due to the difficulties of accurately identifying these size

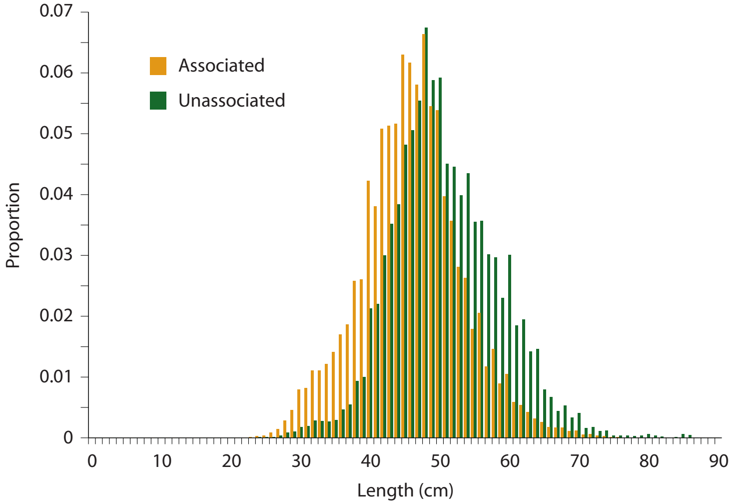

**Figure 17.** Amalgamated skipjack length frequency (proportion of fish numbers) for the years 1998–2007 for associated and unassociated sets in the Papua New Guinea exclusive economic zone
Source: SPC observer data

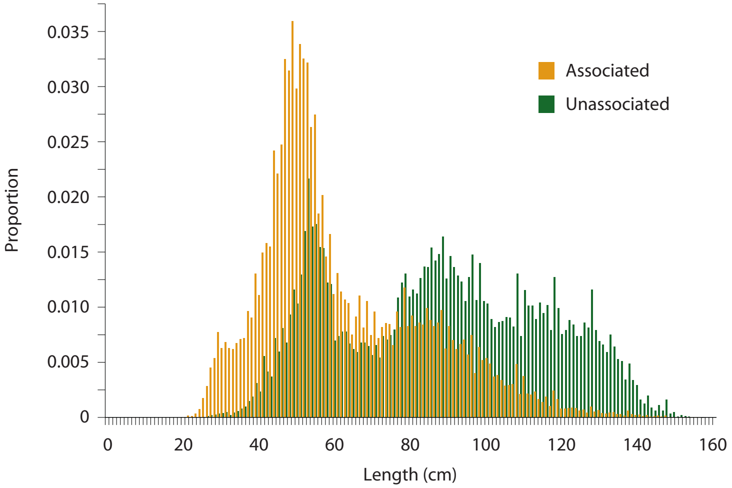

**Figure 18.** Amalgamated yellowfin length frequency (proportion of fish numbers) for the years 1998–2007 for associated and unassociated sets in the Papua New Guinea exclusive economic zone
Source: SPC observer data

classes from other tuna (Lawson 2003). This uncertainty has been reinforced by a recent study that examined bias in existing port and observer sampling data (Lawson 2008). The outcomes of this study for bigeye were that biases associated with length/weight and species composition sampling are likely to further reduce the precision in catch estimates for bigeye from purse seine fisheries. This uncertainty was included in the most recent stock assessment by modelling higher bigeye purse seine catches, resulting in considerably higher estimates of recent juvenile fishing mortality than previously considered. The stock status concerns for bigeye were also supported by the PSA, which indicated the particular vulnerability of this species to associated sets. Development of fishing technologies that restrict the catch of bigeye in associated sets is required to reduce the impact of the purse seine fishery on this vulnerable species.

The expansion of the purse seine fishery has resulted in an increase in the number of non-target species captured. While the non-target species catch is higher on associated sets (67% of total catch), the majority of this catch occurs on log sets. The analysis indicated that the purse seine fishery generally interacts with most non-target species infrequently by comparison with target species. For species where reported interactions are relatively high and biological productivity is low (e.g. silky shark and oceanic whitetip shark), and/or the life stage impacted is important for population growth (e.g. bigeye tuna), current levels of interaction with the fishery may be resulting in detrimental impacts upon their populations.

The reported species richness of non-target species was higher, on average, on associated sets than unassociated sets, with rainbow runner, mahi mahi, silky shark, mackerel scad, frigate tuna, bullet tuna, triggerfish, barracuda and wahoo the most frequently encountered and captured non-target species. All of these species, except for silky shark, were ranked with moderate or low vulnerability in the PSA. While these species are highly productive, they are often important for food security in coastal communities, and any local depletion caused by purse seine fisheries could have a negative impact on artisanal fisheries. Data on the catch and effort of the artisanal fisheries for these species is poor, and it is not possible to reliably estimate their reliance on these species.

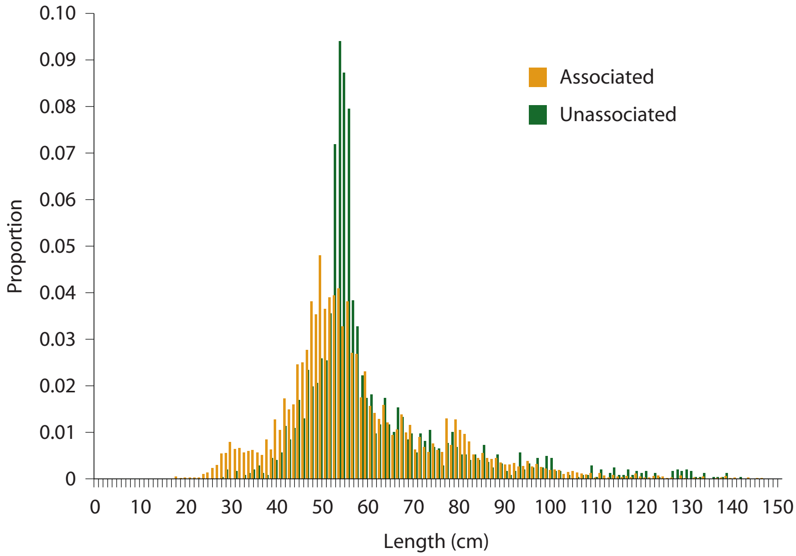

**Figure 19.** Amalgamated bigeye length frequency (proportion of fish numbers) for the years 1998–2007 for associated and unassociated sets in the Papua New Guinea exclusive economic zone
Source: SPC observer data

The PSA identified that, given the relatively high catch and low biological productivity of silky sharks, they are more likely to be vulnerable to population impacts from purse seine fishing than most of the species assessed. The catch analysis, however, did not indicate a declining CPUE, suggesting that this vulnerability may not be realised under current catch levels, or that historical depletion had already occurred prior to the period used for catch estimation. Increases in CPUE for skipjack are partially explained by improvements in fishing technology (e.g. deeper nets, stronger winches, better fish-finding technologies) (Shono and Ogura 1999; Shono et al. 2000), and it is quite likely that the factors increasing skipjack CPUE have also increased the catchability of some non-target species. The catch analysis undertaken does not include such technology-related trends, and declining trends in abundance may therefore not be reflected in nominal CPUE trends for some non-target species such as silky shark. Given that silky shark is also caught in large numbers in longline fisheries in the WCPO (Kirby 2008), and that PNG has also targeted shark fisheries, it would therefore be prudent to undertake more detailed scientific analysis for sharks in general and this species in

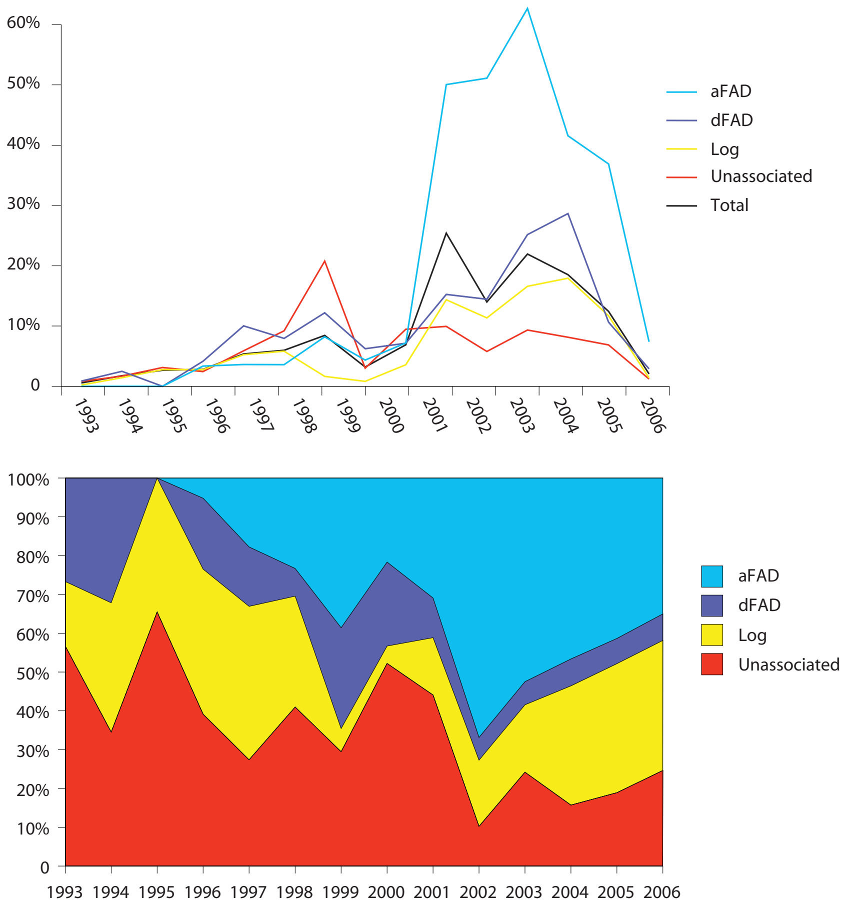

**Figure 20.** Observer coverage by set type as percentage of total effort (top panel) and total observer coverage (lower panel) in the Papua New Guinea exclusive economic zone
Source: SPC observer data
Note: aFAD = anchored fish aggregation device; dFAD = drifting fish aggregation device

particular. Further consideration could be given to developing enhanced monitoring systems for shark fisheries and shark bycatch in PNG.

The catch analysis indicated declining CPUE for oceanic whitetip sharks and the combined group of other sharks and rays, indicating that fishing may be impacting populations of these species. A sensitivity analysis of the ZILN models to the various sources of data is recommended to determine the influence of this and other data sources on the estimates of the models. It should be noted that an analysis of PNG observer data only should provide better estimates of non-target species catches when the time series of adequate observer coverage is sufficient.

Species identification errors may be responsible for the low values of observed and estimated catch rates for manta rays, oceanic whitetip sharks, silky sharks and whale sharks caught by purse seiners, and high values for 'other sharks and rays', during the early period of the time series. Data quality in observer programs covering offshore longline and purse seine fisheries has increased considerably since 1995. The reason for the exceptionally wide confidence intervals for certain estimates, e.g. oceanic whitetip shark and silky shark in 2002, is currently unknown.

Marine mammals, whale sharks and turtles were ranked with low biological productivity in the PSA.

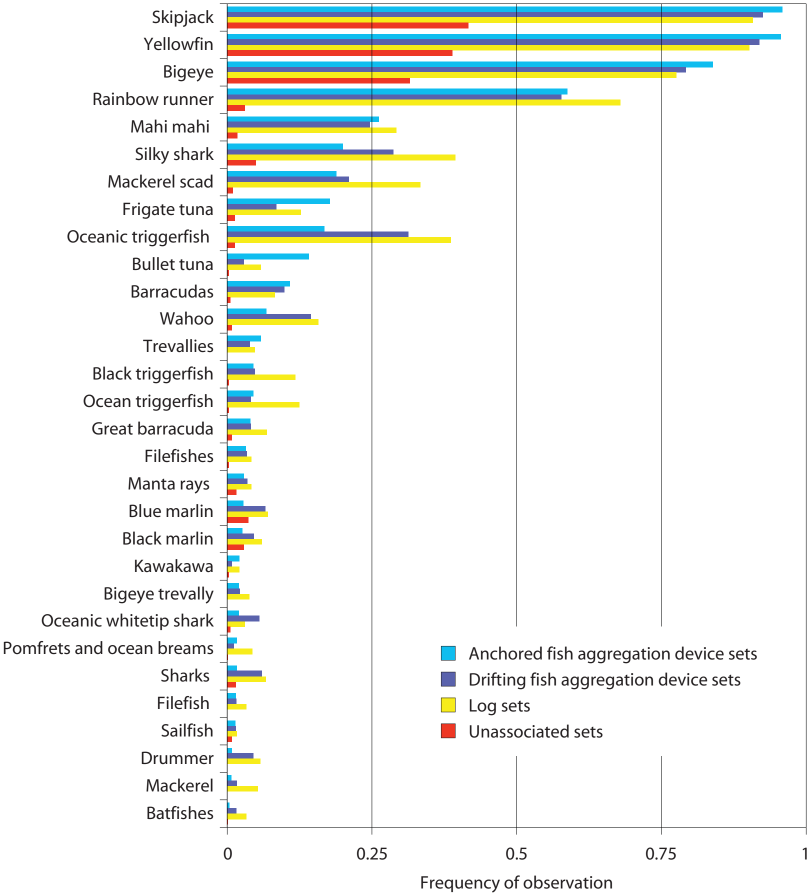

**Figure 21.** Frequency of species observed in observer data records for the 30 most common species in the Papua New Guinea exclusive economic zone
Source: SPC observer data
Code: black bars = anchored fish aggregation device sets; yellow bars = drifting fish aggregation device sets; red bars = log sets; green bars = unassociated sets

This reflects their delayed maturity, long life span, large maximum size and slow growth. There are also other aspects of purse seine fishery interactions with these species that are worth considering. For example, size/age-at-capture is an important determinant of the vulnerability to fishing of these species. Elasticity analysis for turtles has identified that adult mortality has more influence on population

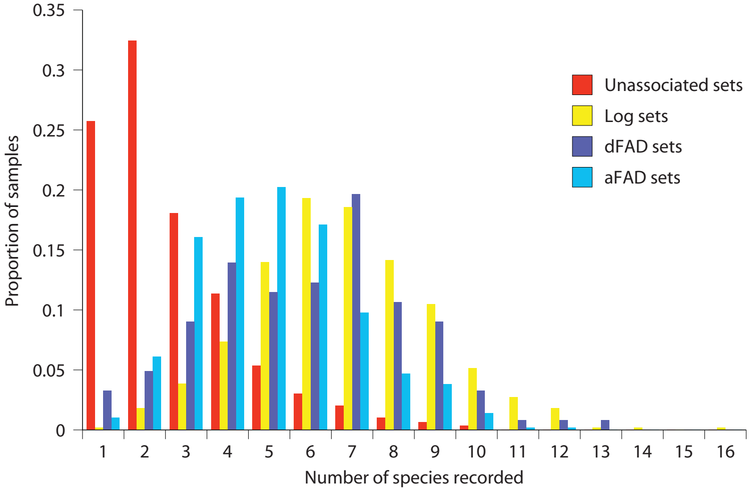

**Figure 22.** Number of species recorded by set type as a proportion of the total number of sets observed in the Papua New Guinea exclusive economic zone
Source: SPC observer data
Note: dFAD = drifting fish aggregation device; aFAD = anchored fish aggregation device

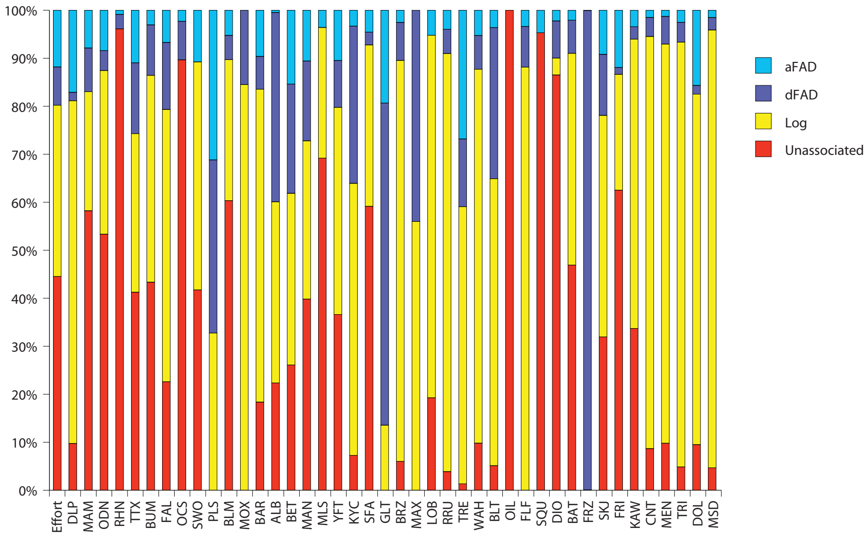

**Figure 23.** Attribution of catch by set type in the Papua New Guinea exclusive economic zone
Source: SPC log-sheet data
Note: Fishing effort is the first column on the left; thereafter, species are ranked left to right by their productivity risk score. Refer to Table 1 for species codes.
aFAD = anchored fish aggregation device; dFAD = drifting fish aggregation device

growth than juvenile survival (Heppel 1999). The current observer data for purse seine operations in PNG does not provide the information necessary to determine the age (or life stage) of these species, thus restricting the capacity for further inference. It is also plausible that many of the captures of these species result in releases back into the wild in unharmed condition, but this information is collected inconsistently in the observer data. More systematic collection of information on post-capture fate would expand the inference that could be applied to the impact of purse seine fishing on these species.

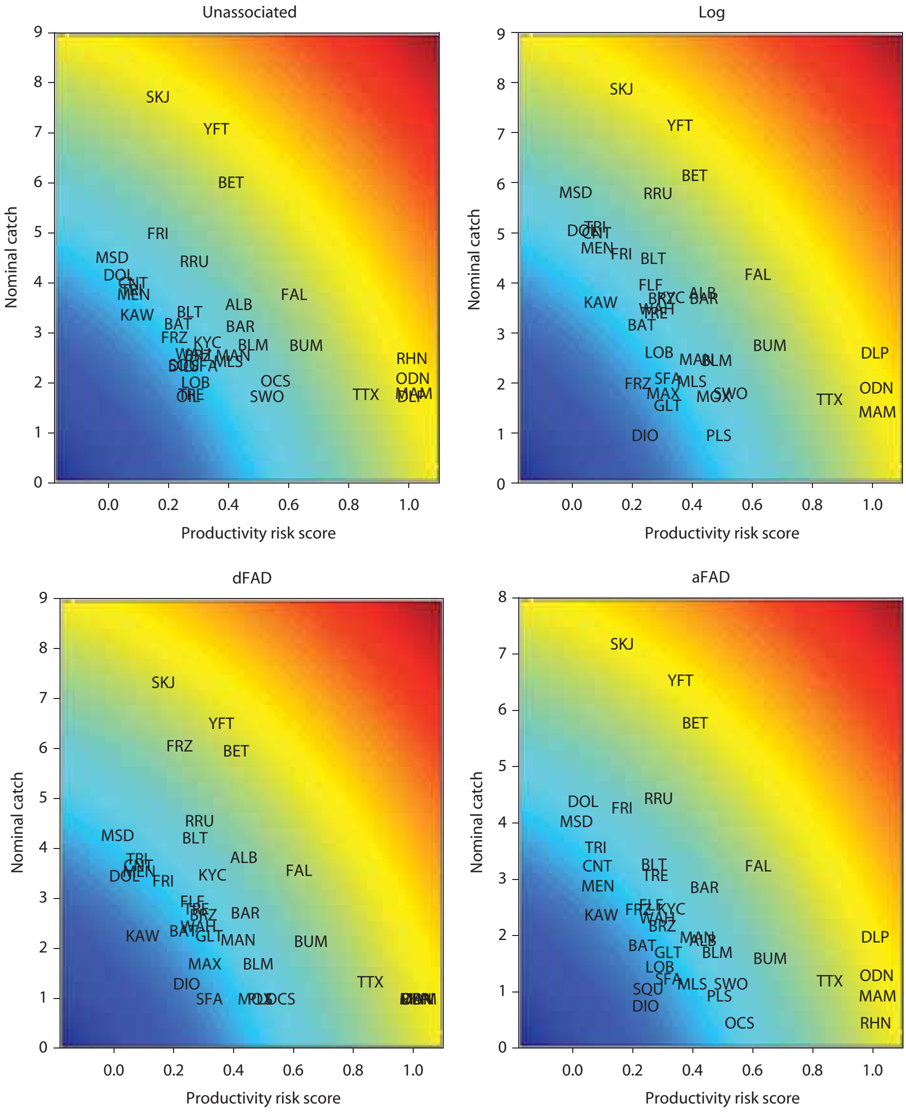

**Figure 24.** Productivity-susceptibility analyses by set type, using nominal catch (individuals per set type, on a logarithmic scale) as the susceptibility score (y-axis) in the Papua New Guinea exclusive economic zone
Source: SPC log-sheet data
Note: Refer to Table 1 for species codes; aFAD = anchored fish aggregation device; dFAD = drifting fish aggregation device

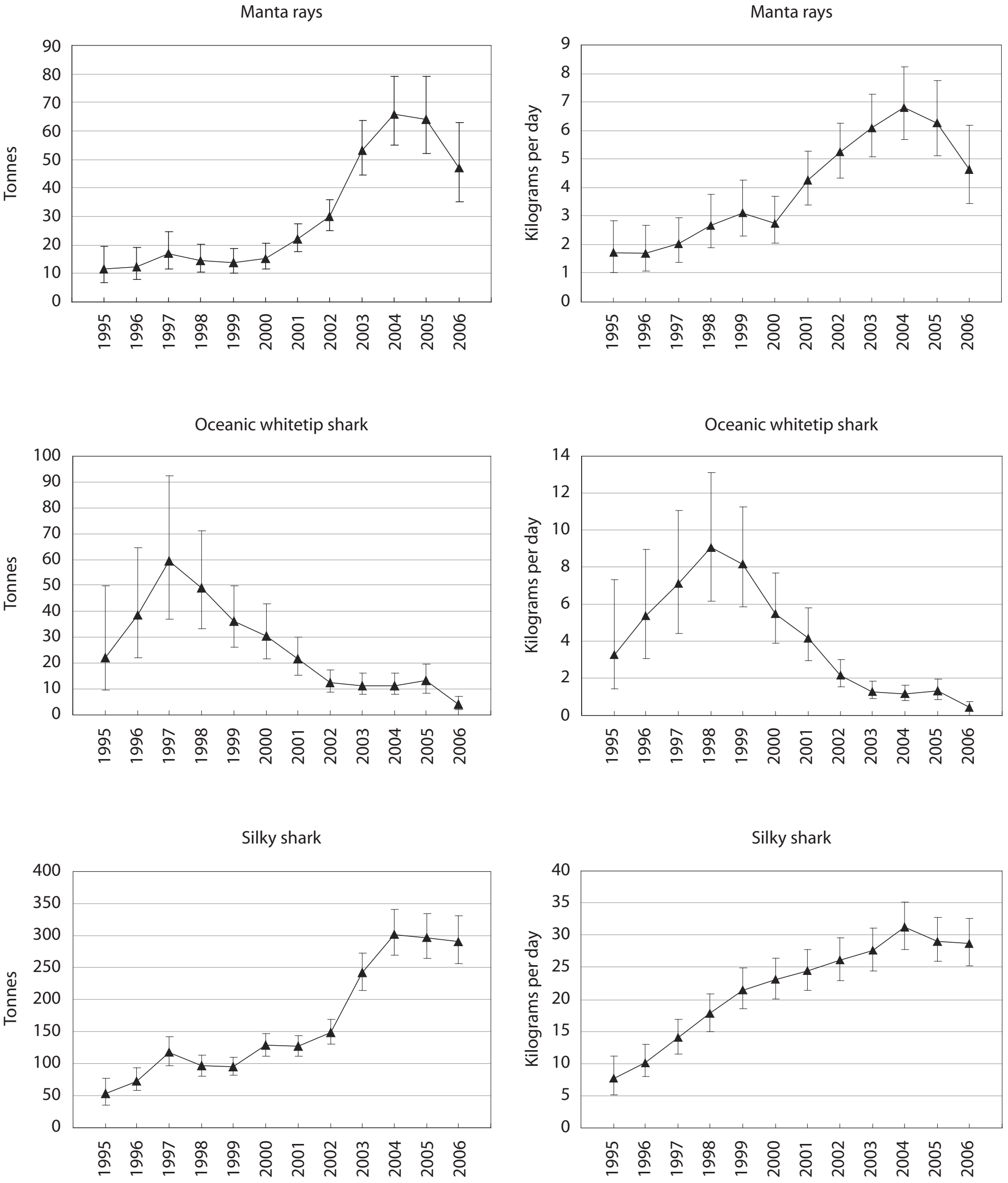

**Figure 25.** Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

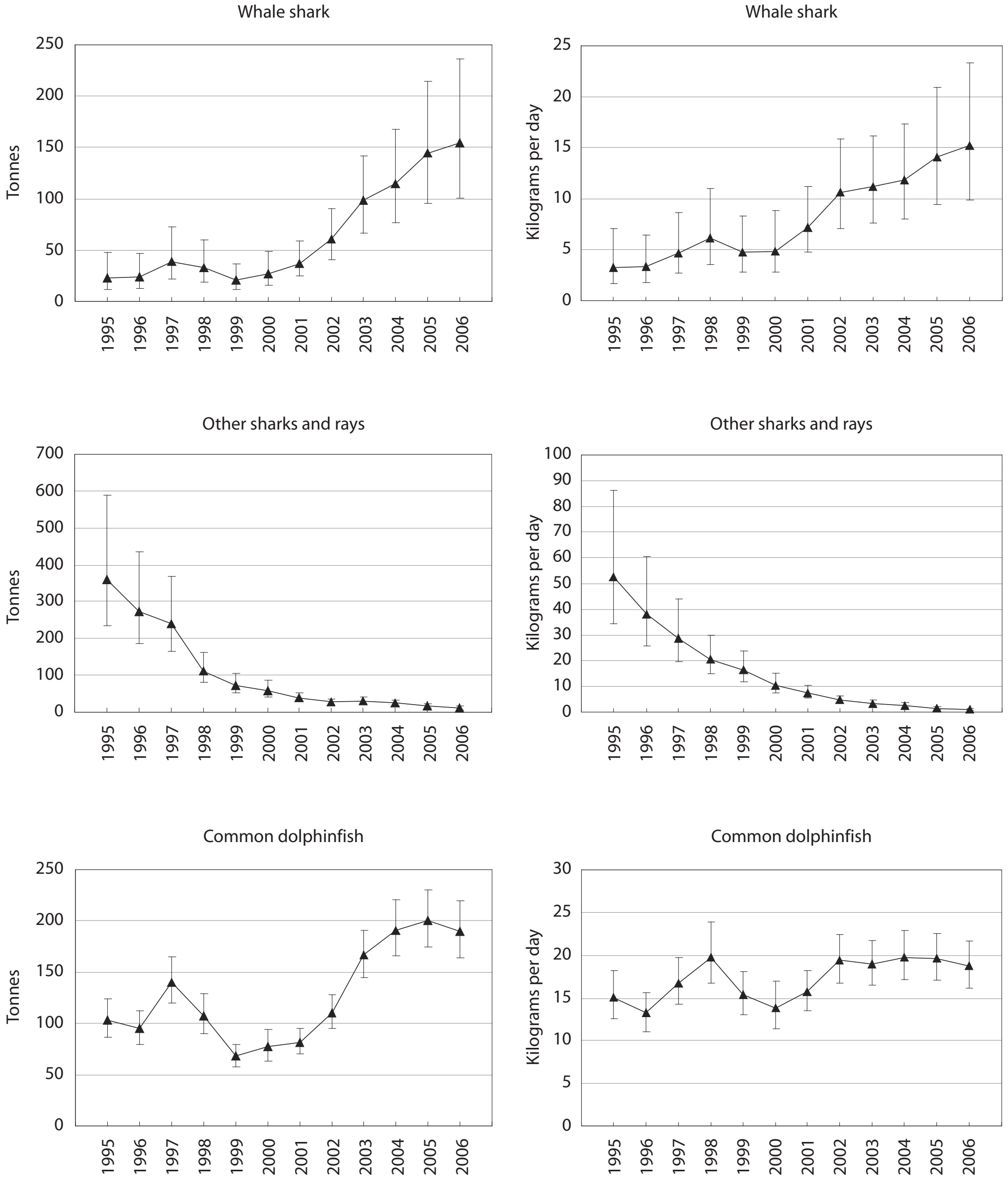

**Figure 25.** (Cont'd) Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

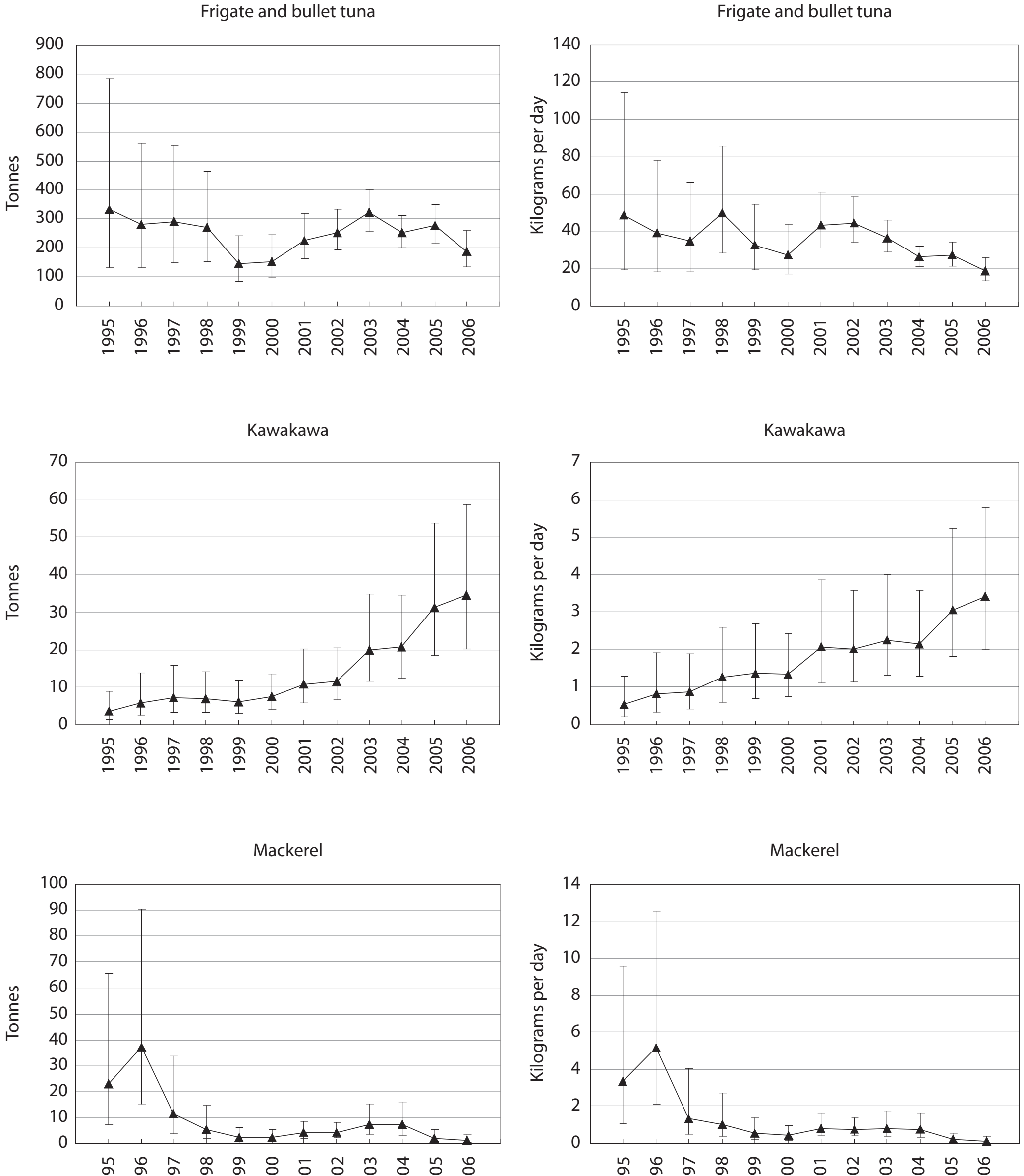

**Figure 25.** (Cont'd) Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

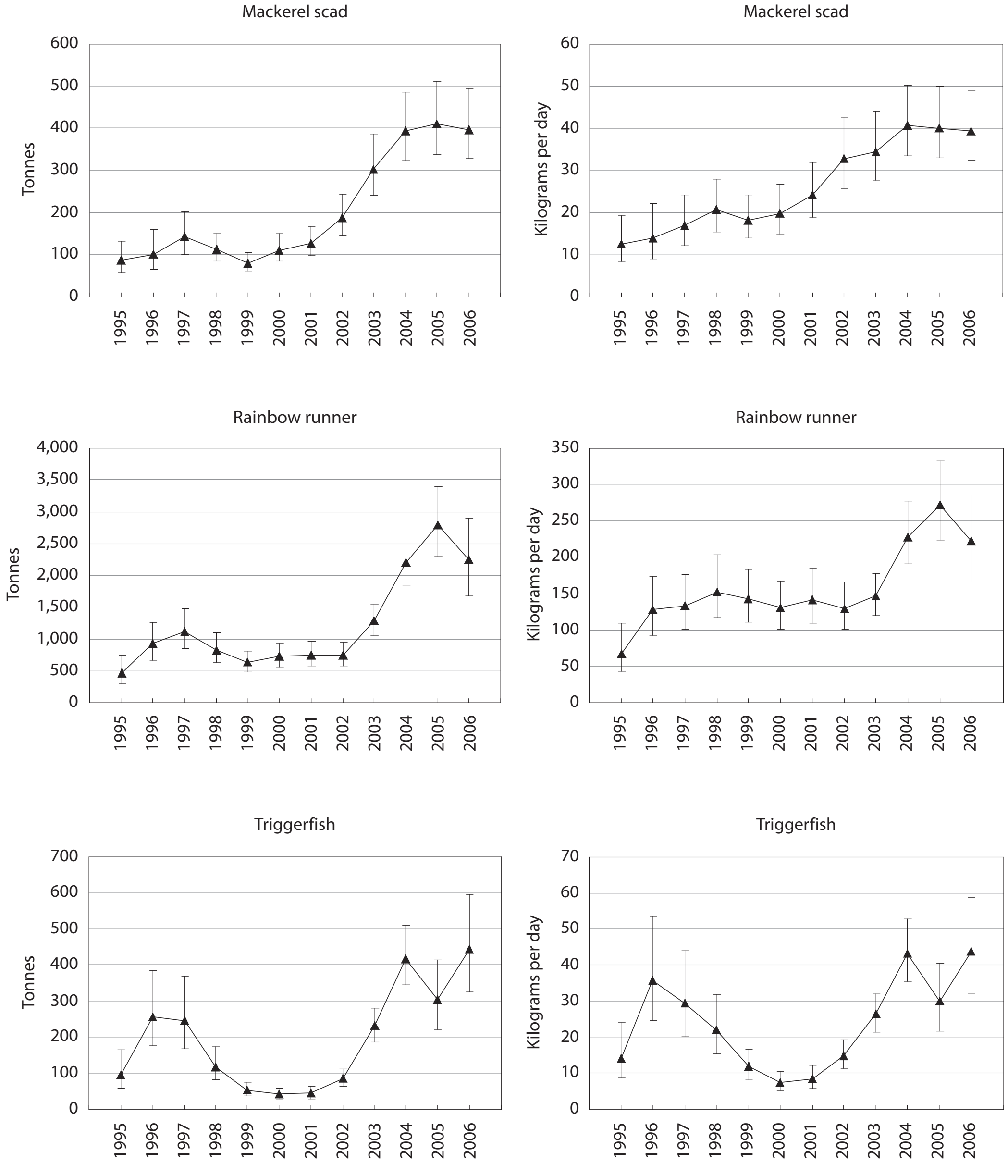

**Figure 25.** (Cont'd) Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

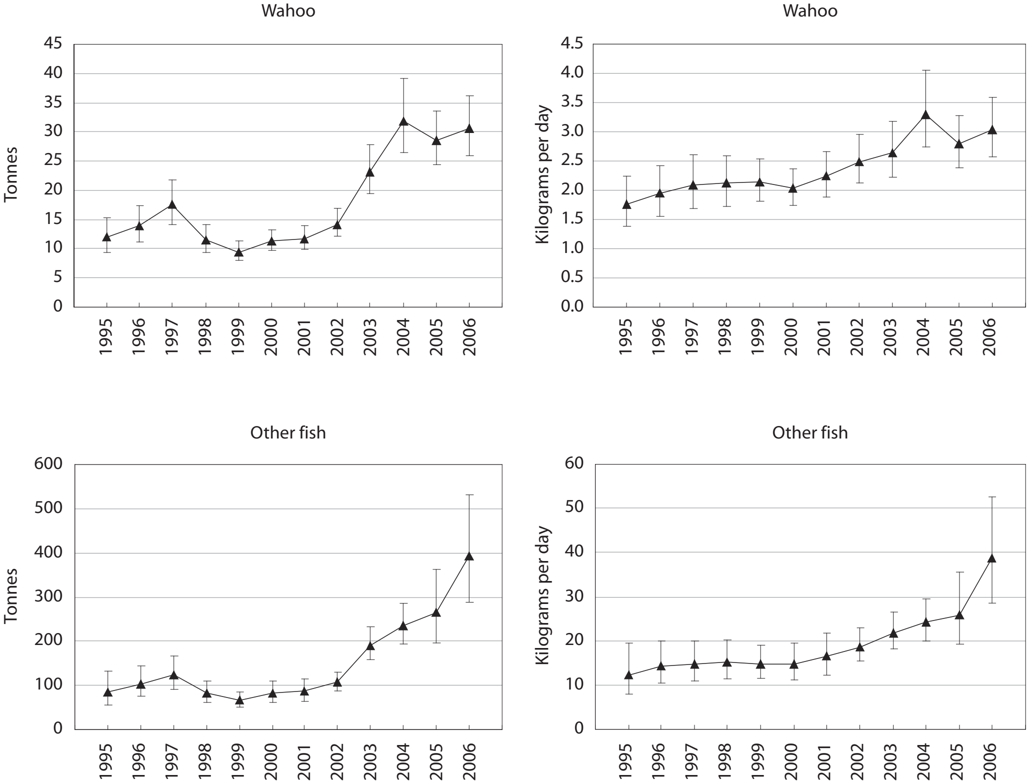

**Figure 25.** (Cont'd) Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

An important issue that has been identified in purse seine fisheries in the Indian Ocean, but not analysed in this study, is the potential for entanglement of marine turtles under FADs. Drifting FADs generally have about 20 m of netting hanging in the water column below the raft. This provides substrate to which algae etc. may attach, and also shelter for smaller fish. Pelagic organisms, especially tuna, are then attracted to the FADs. While scientific observers can accurately record the species composition of catches from sets made around FADs, they have no routine opportunity to record whether the netting attached to the FAD has itself been responsible for any direct catches. While the number of individual animals caught in this way is likely to be small, this may still be a significant source of mortality for small populations with low biological productivity, such as marine turtles. It is therefore recommended that monitoring of FAD design be enhanced and analysis undertaken as to patterns of use by FAD design type. Dedicated sampling under FADs would demonstrate the extent to which turtles are being entangled under FADs; however, even in the absence of this information, changes to FAD design may still be considered based on best practice in other purse seine fisheries.

It is worth noting that reductions that were apparent in the tuna catch data coincided with strong El Niño periods. Variations in the movement and fishing success of equatorial fisheries targeting tropical tunas are linked to variability in the spatial and temporal occurrence of areas of high ocean productivity (Lehodey et al. 1997). The occurrence of productive zones is driven by oceanographic processes that are, in turn, linked to climatic processes. Consequently, climatic variability influences the distribution of fishing effort, fishing success and the level of catch (Lehodey et al. 1997). In the equatorial WCPO, El Niño–Southern Oscillation climate phenomena are associated with large-scale east–west shifts in the warm pool, and the highly productive convergence zone between the warm pool and the cold tongue current originating from the eastern equatorial Pacific. During very strong La Niña events, the convergence zone and the cooler waters of the cold tongue can extend into the PNG EEZ, increasing productivity.

It is likely that catch of non-target species may also vary in response to such climatic patterns. In particular, although quantitative analysis has not been undertaken, it is plausible that the number and locations of floating logs will vary with El Niño–Southern Oscillation conditions, with floating logs expected to be more prevalent in La Niña years when higher rainfall is experienced in the region. An abundance of floating logs might lead to a greater proportion of associated sets and higher non-target species catch than during drier El Niño years, when logs are in lower abundance and fishers may switch to using predominantly unassociated sets (with low non-target species catch). An analysis that examines purse seine fishing sets and climatic variation may further assist the development of management guidelines to mitigate against capture of non-target species.

## Conclusion

Information on the impacts of fishing on non-target species is becoming an increasing priority at both national and international levels. For example, signatories to the WCPFC Convention have obligations towards minimising waste, minimising the risk of adverse effects on the marine environment, and

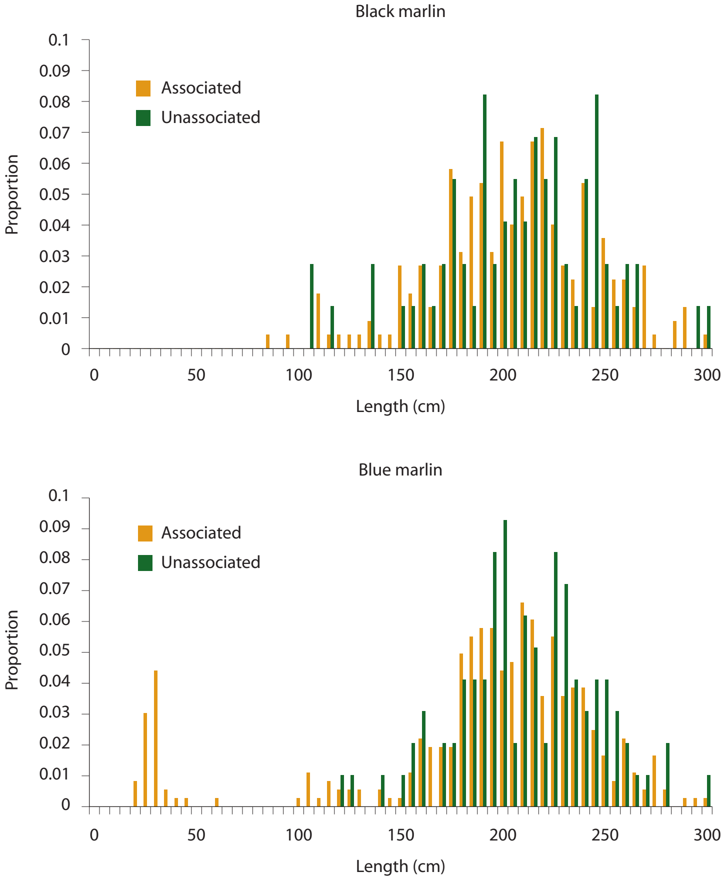

**Figure 26.** Amalgamated black marlin (upper panel) and blue marlin (lower panel) length frequency (proportion of fish numbers) for 1998–2007 for associated and unassociated sets in the Papua New Guinea exclusive economic zone
Source: SPC observer data

ensuring the 'sustainability' of both target and non-target species populations that interact with their tuna fisheries. The information available for estimating and forecasting the sustainability of non-target populations is often insufficient to undertake the analysis that is typically used to estimate sustainability for target species. The approach taken in this study presents the best available science concerning non-target species associated with purse seine fishing in PNG—it uses multiple lines of evidence that characterise the non-target species, identify those that may be of particular management concern, and incorporate the existing limitations and assumptions of the data available. This approach may be a useful tool for other studies that require characterisation of non-target species associated with fishing activities.

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