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

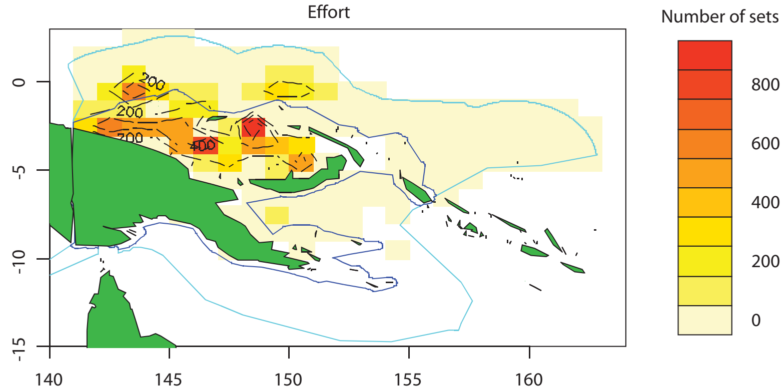

Figure 15. Average distribution of purse seine effort on anchored fish aggregation devices in the Papua New Guinea exclusive economic zone, 2000–07
Source: log-sheet data held at SPC

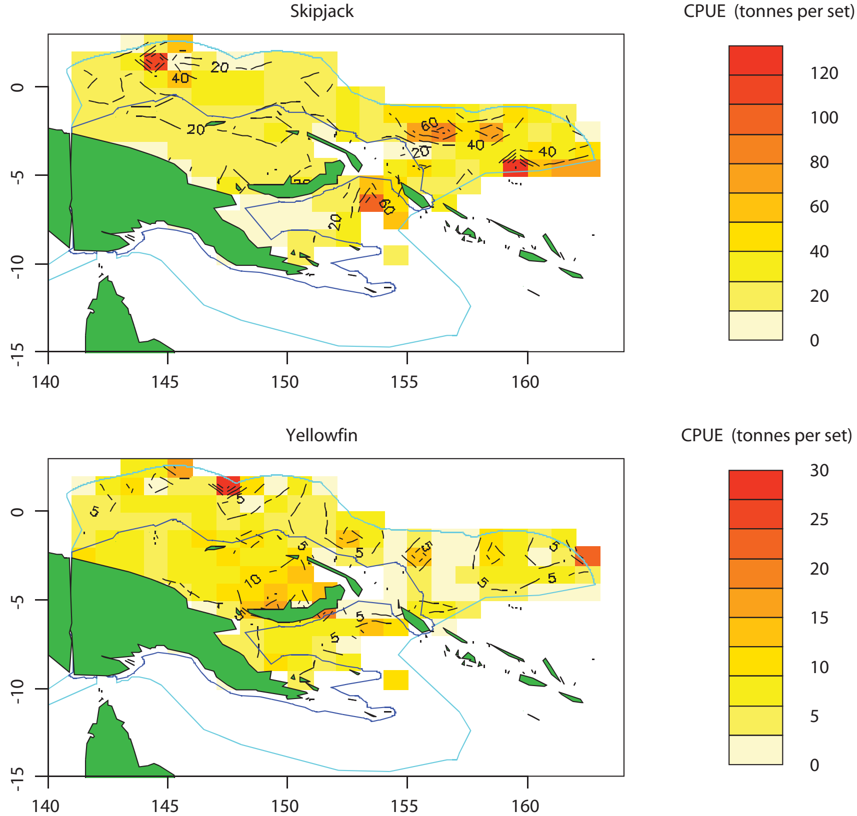

Figure 16. Distribution of purse seine catch per unit effort (CPUE) on anchored fish aggregation devices for skipjack (upper figure) and yellowfin (lower figure) tuna in the Papua New Guinea exclusive economic zone, 2000–07
Source: log-sheet data held at SPC

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

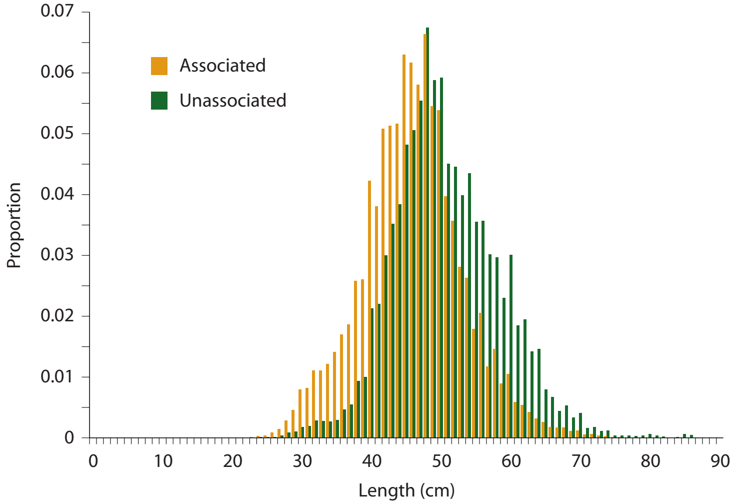

Figure 17. Amalgamated skipjack length frequency (proportion of fish numbers) for the years 1998–2007 for associated and unassociated sets in the Papua New Guinea exclusive economic zone
Source: SPC observer data

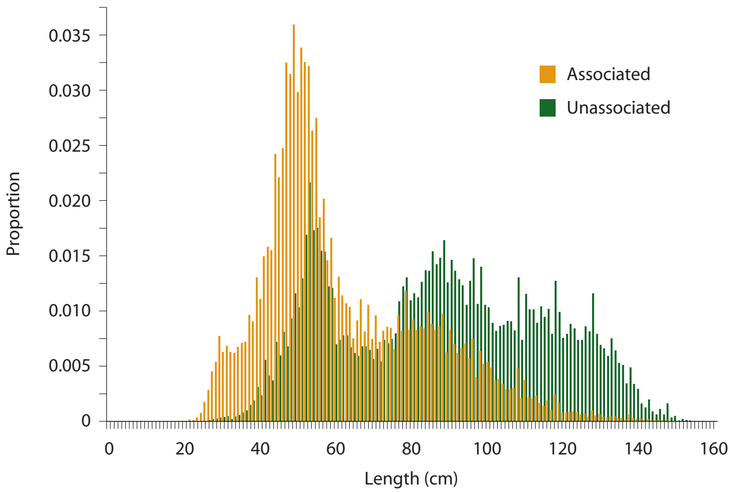

Figure 18. Amalgamated yellowfin length frequency (proportion of fish numbers) for the years 1998–2007 for associated and unassociated sets in the Papua New Guinea exclusive economic zone
Source: SPC observer data

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.

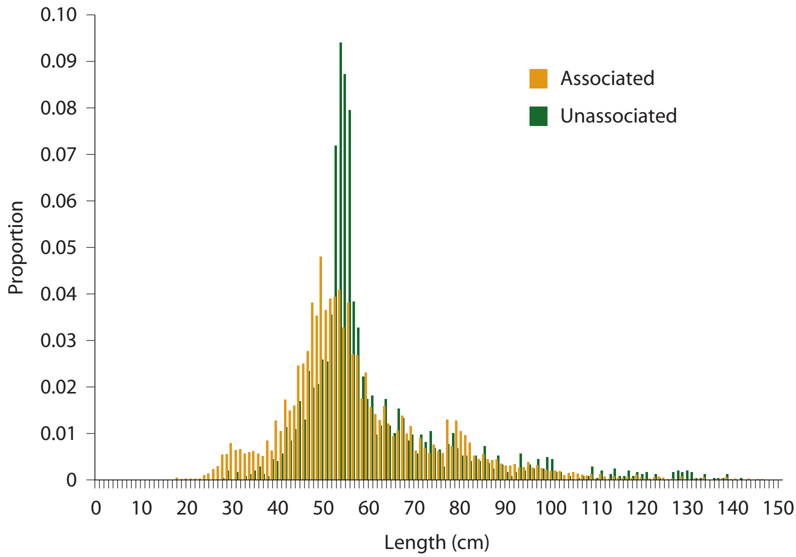

Figure 19. Amalgamated bigeye length frequency (proportion of fish numbers) for the years 1998–2007 for associated and unassociated sets in the Papua New Guinea exclusive economic zone
Source: SPC observer data

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

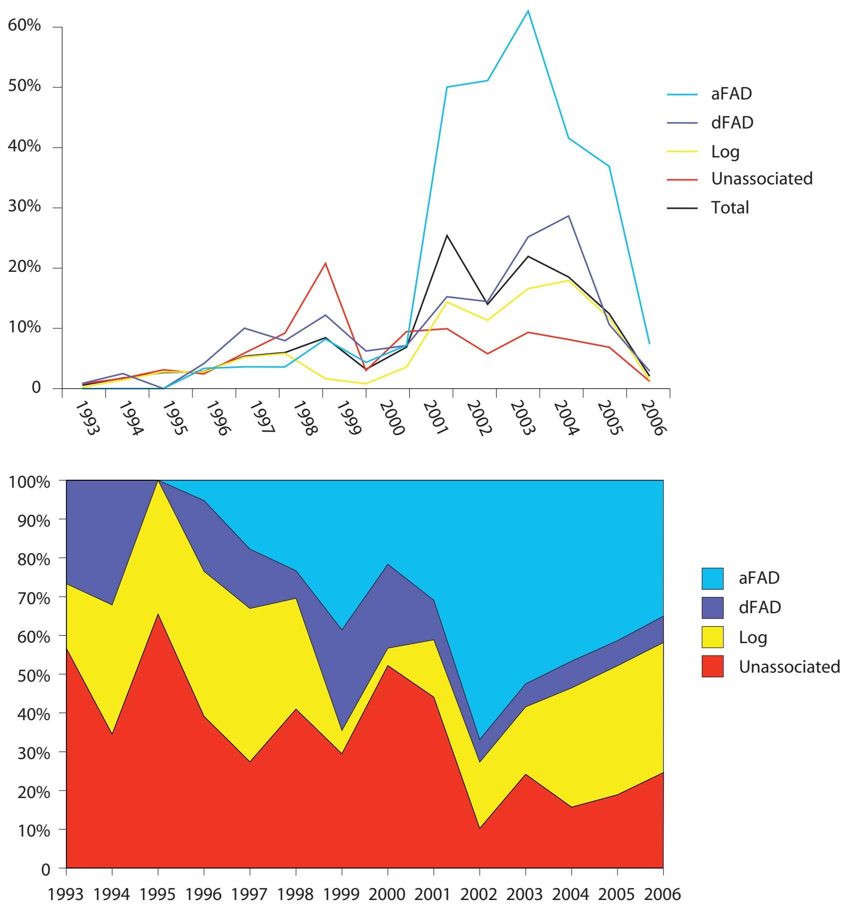

Figure 20. Observer coverage by set type as percentage of total effort (top panel) and total observer coverage (lower panel) in the Papua New Guinea exclusive economic zone
Source: SPC observer data
Note: aFAD = anchored fish aggregation device; dFAD = drifting fish aggregation device

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.

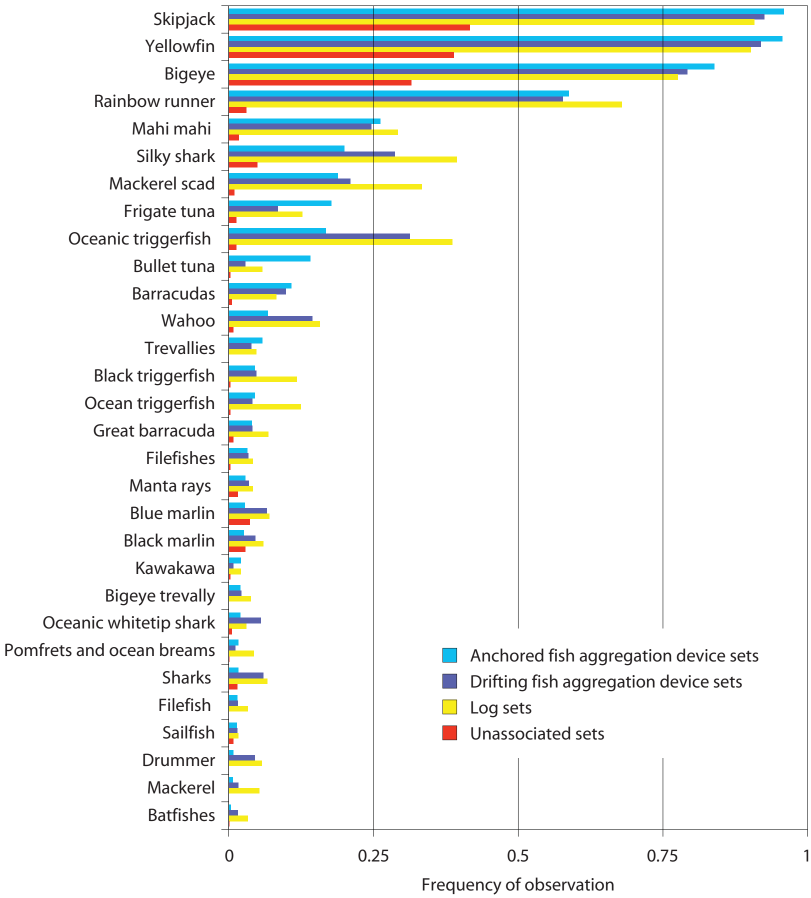

Figure 21. Frequency of species observed in observer data records for the 30 most common species in the Papua New Guinea exclusive economic zone
Source: SPC observer data
Code: black bars = anchored fish aggregation device sets; yellow bars = drifting fish aggregation device sets; red bars = log sets;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

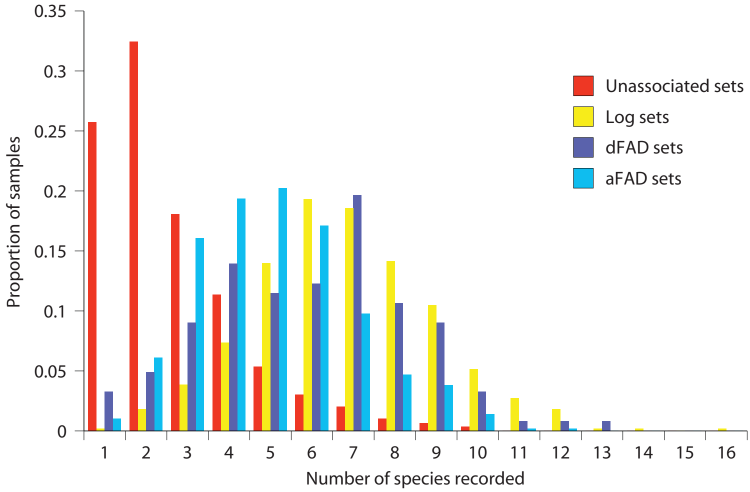

Figure 22. Number of species recorded by set type as a proportion of the total number of sets observed in the Papua New Guinea exclusive economic zone
Source: SPC observer data
Note: dFAD = drifting fish aggregation device; aFAD = anchored fish aggregation device

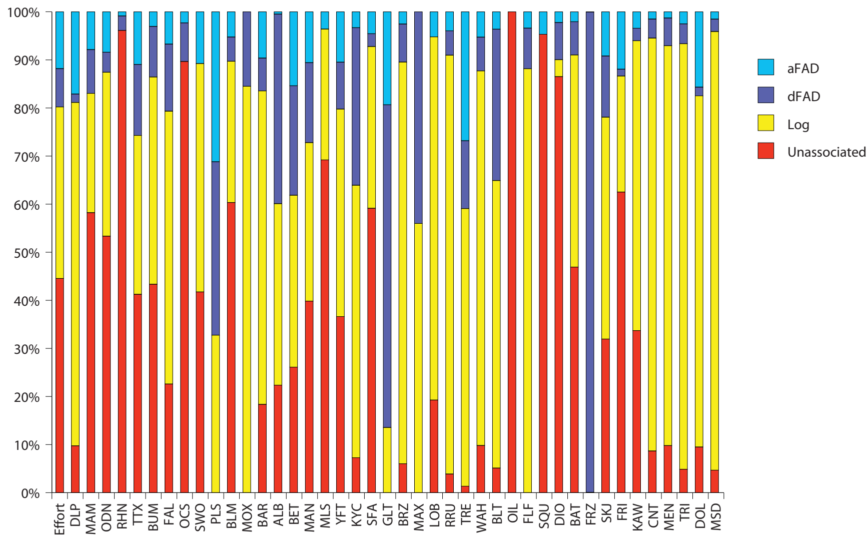

Figure 23. Attribution of catch by set type in the Papua New Guinea exclusive economic zone
Source: SPC log-sheet data
Note: Fishing effort is the first column on the left; thereafter, species are ranked left to right by their productivity risk score. Refer to Table 1 for species codes.
aFAD = anchored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

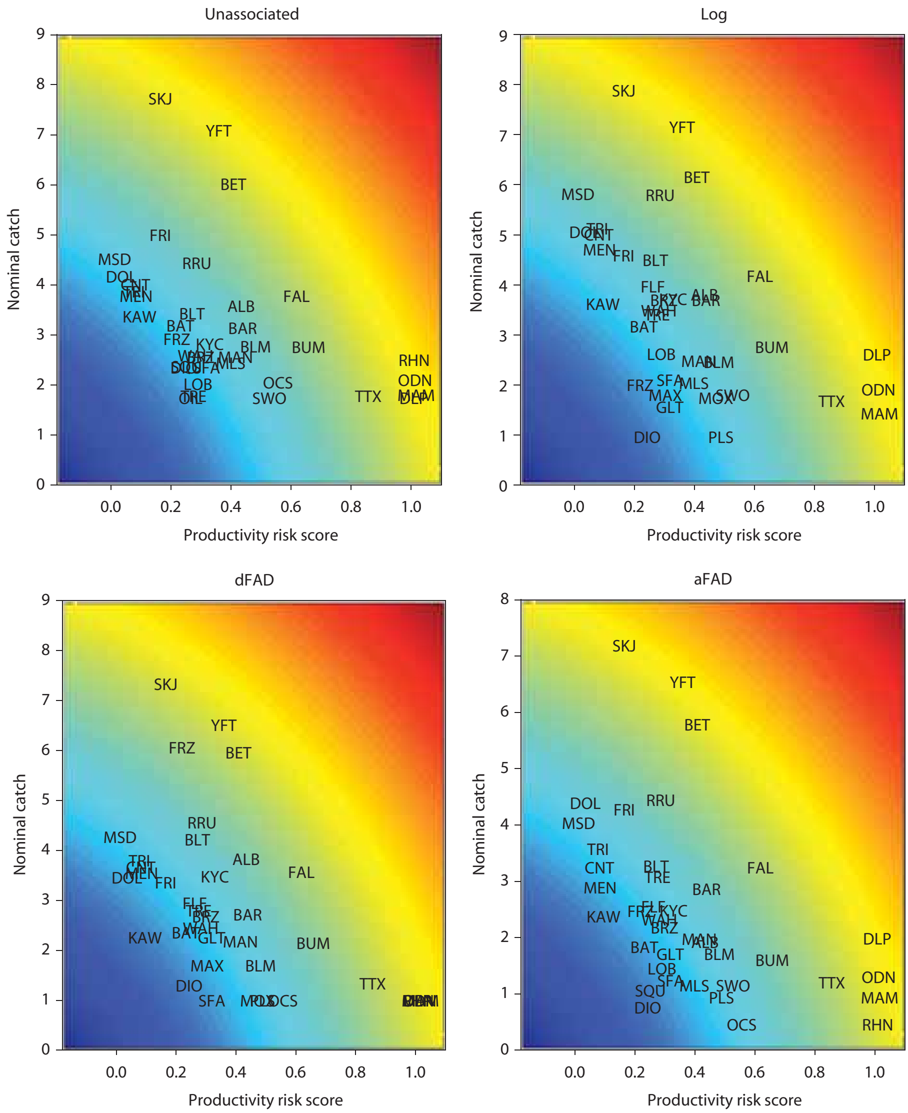

Figure 24. Productivity-susceptibility analyses by set type, using nominal catch (individuals per set type, on a logarithmic scale) as the susceptibility score (y-axis) in the Papua New Guinea exclusive economic zone
Source: SPC log-sheet data
Note: Refer to Table 1 for species codes; aFAD = anchored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

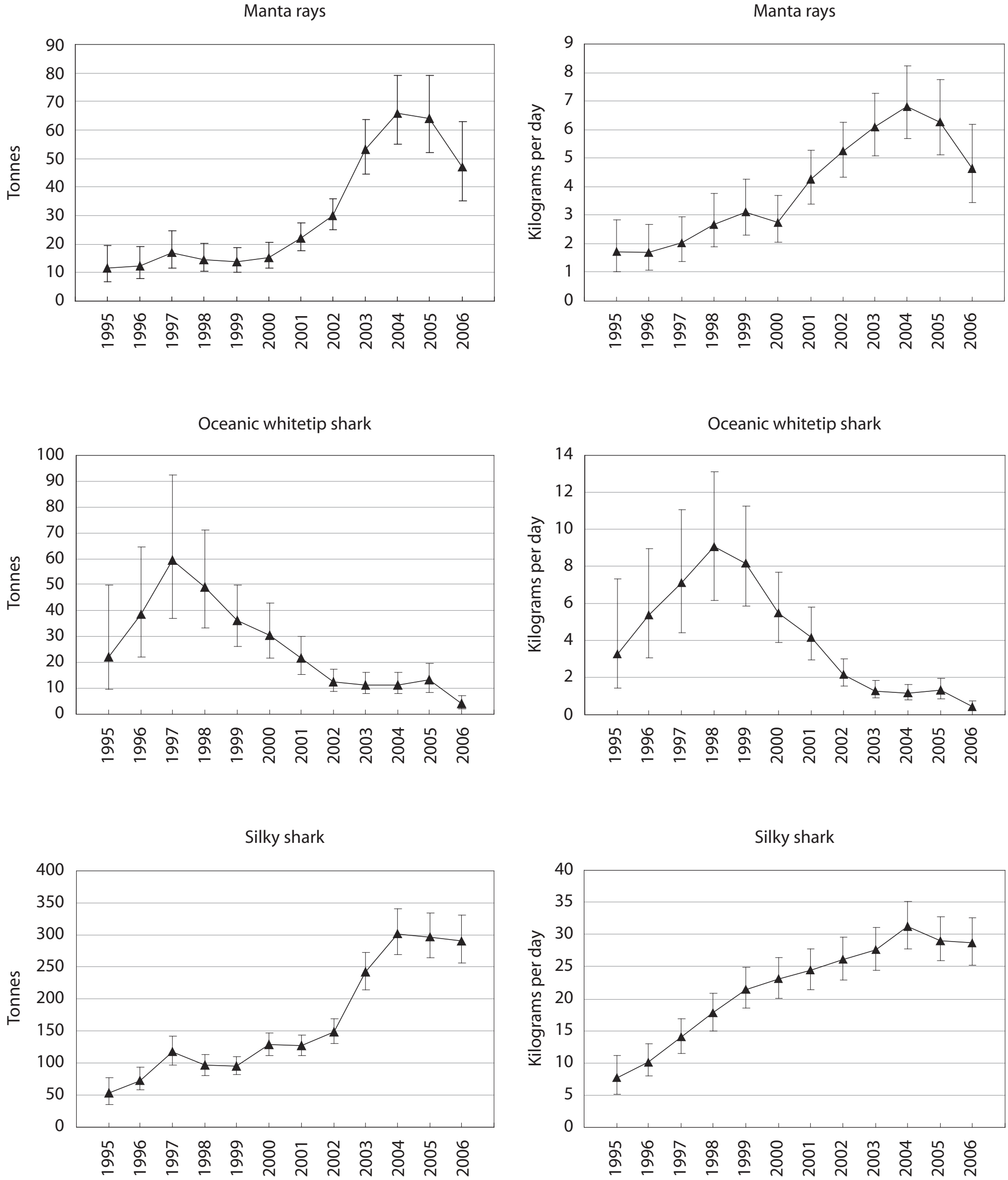

Figure 25. Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

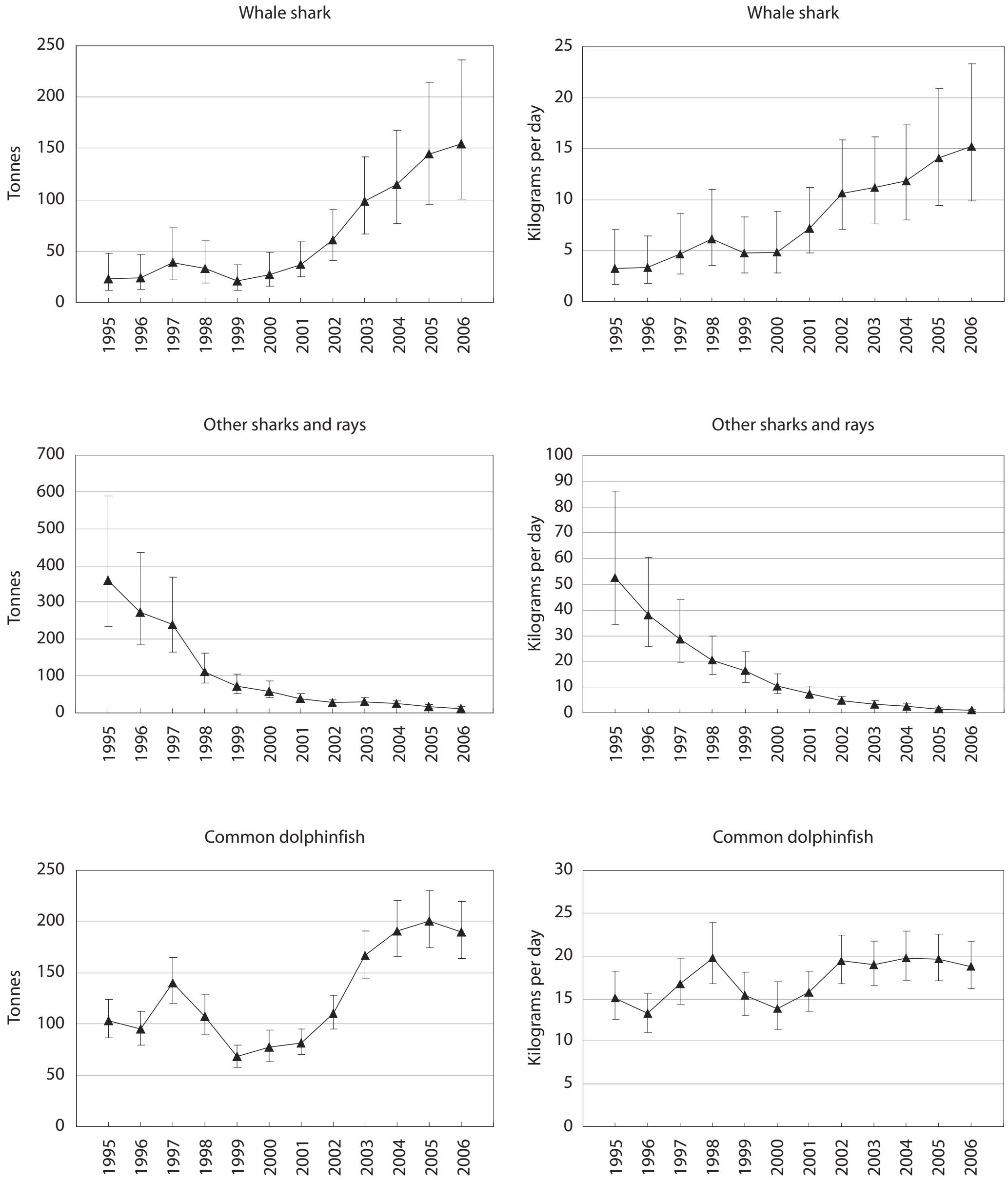

Figure 25. (Cont'd) Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

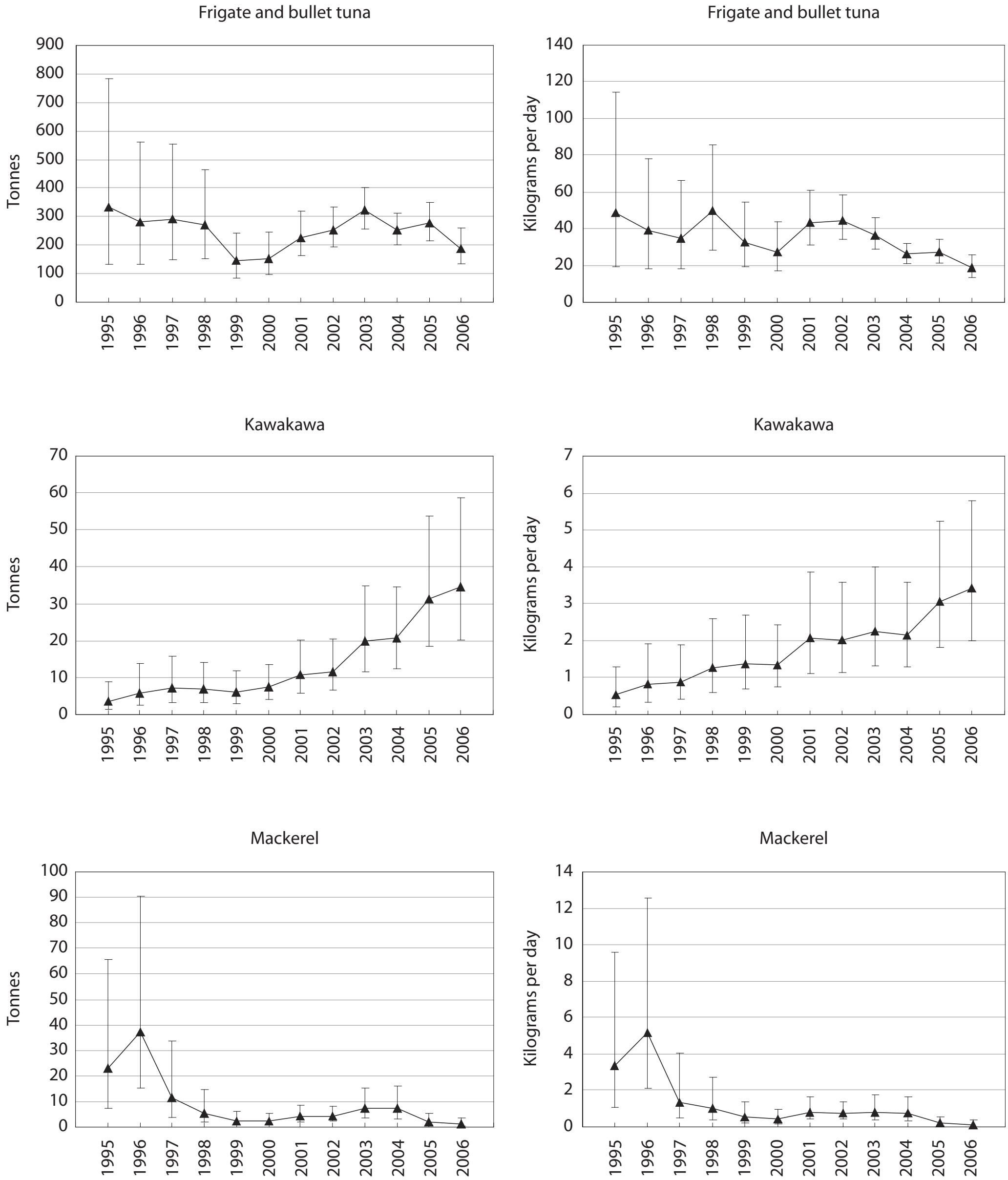

Figure 25. (Cont'd) Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

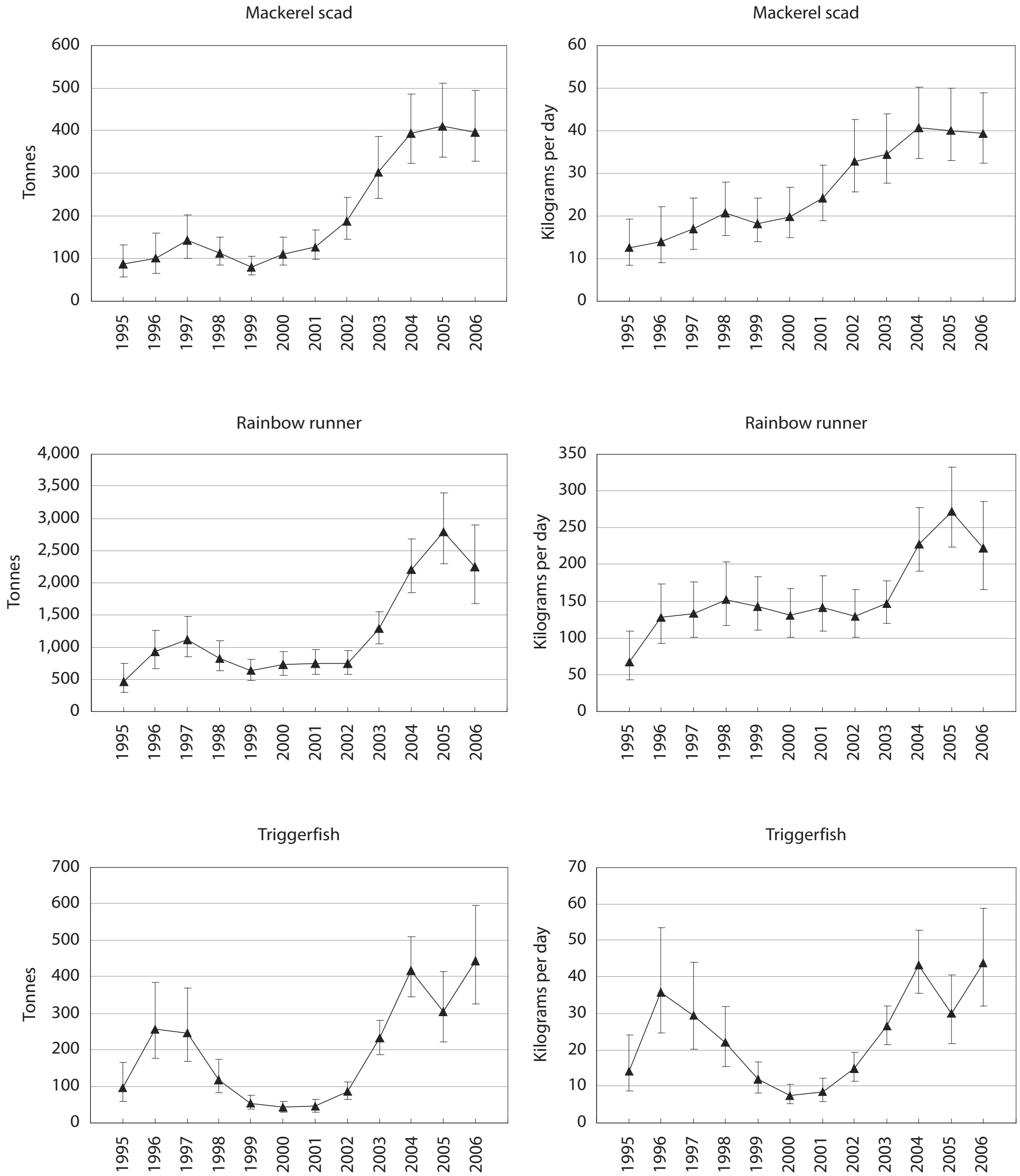

Figure 25. (Cont'd) Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

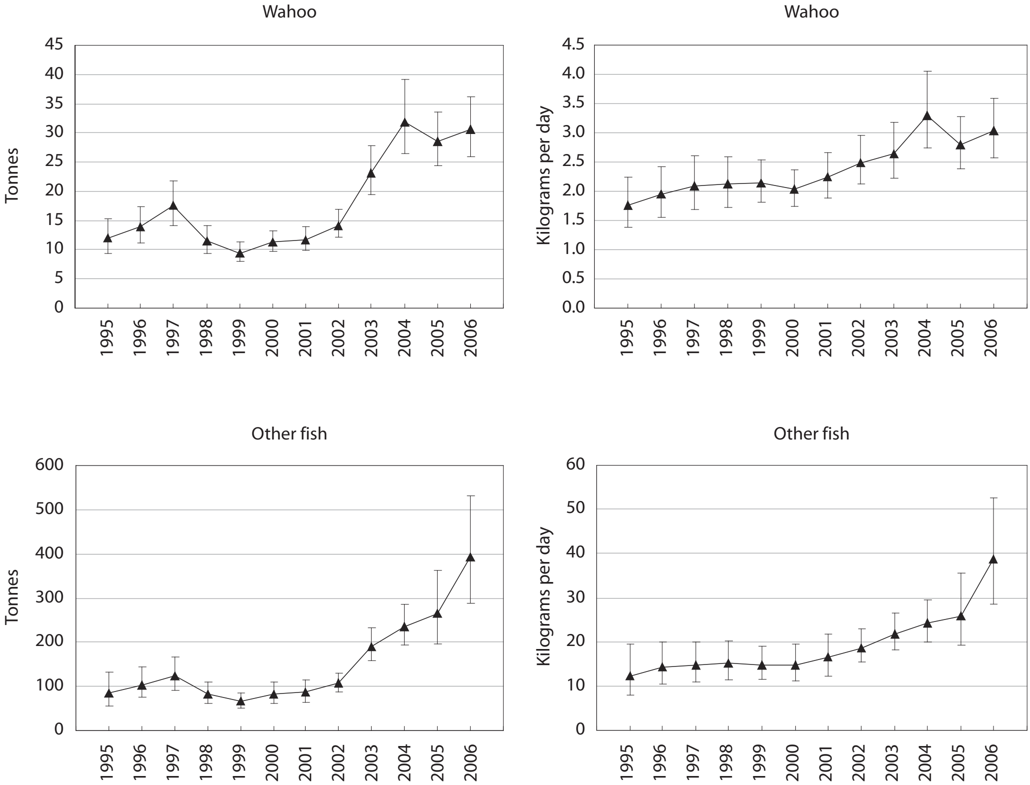

Figure 25. (Cont'd) Catches and catch rates of non-target species by purse seiners from associated sets in the waters of Papua New Guinea

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

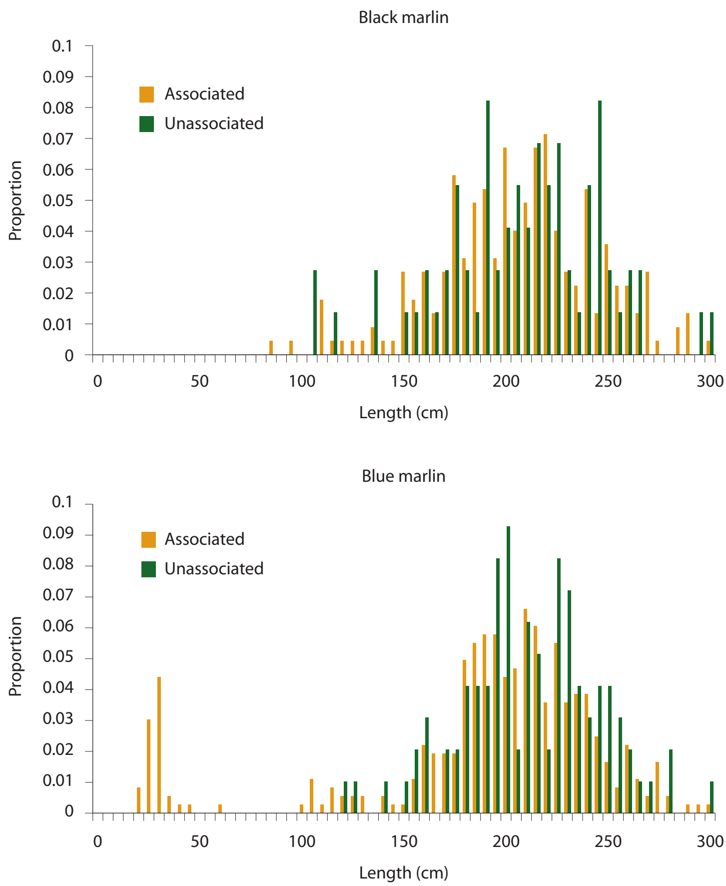

Figure 26. Amalgamated black marlin (upper panel) and blue marlin (lower panel) length frequency (proportion of fish numbers) for 1998–2007 for associated and unassociated sets in the Papua New Guinea exclusive economic zone
Source: SPC observer data

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.

References

Heppel S., Crowder L. and Menzel T. 1999. Life table analysis of long-lived marine species with implications for conservation and management. American Fisheries Society Symposium 23, 137–148.

Itano D. and Fukofuka S. 2005. Handbook for the identification of yellowfin and bigeye tunas in fresh, but less than ideal condition. Information Paper FT-IP-1. 1st meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Noumea, New Caledonia, 8–19 August 2005.

Kirby D.S. 2008. Ecological risk assessment (ERA) progress report (2007/8) and workplan (2008/9). Working Paper EBSWG-WP-1. 4th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Port Moresby, Papua New Guinea, 11–22 August 2008.

Kumoru L. and Koren L. 2006. Tuna Fisheries Report – Papua New Guinea. Working Paper FR-WP. 2nd meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Manila, the Philippines, 7–18 August 2006.

Kumoru L. and Koren L. 2007. Tuna Fisheries Report – Papua New Guinea. Working Paper AR-WP-23. 3rd meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Honolulu, United States of America, 13–24 August 2007.

Kumoru L. 2008. Tuna Fisheries Report – Papua New Guinea. Working Paper AR-WP-23. 4th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Port Moresby, Papua New Guinea, 11–22 August 2008.

Langley A., Hampton J., Kleiber P. and Hoyle S. 2008. Stock assessment of bigeye tuna in the western and central Pacific Ocean, including an analysis of management options. Working Paper SA-WP-1. 4th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Port Moresby, Papua New Guinea, 11–22 August 2008.

Lawson T. 2003. Status of data collection, compilation and dissemination. Working Paper SWG-1. 16th meeting of the Standing Committee on Tuna and Billfish, Mooloolaba, Australia.

Lawson T. 2007. Estimates of annual catches in the WCPFC Statistical Area. Information Paper SWG-2. 3rd meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Honolulu, United States of America, 13–24 August 2007.

Lawson T. 2008. Factors affecting the use of species composition data collected by observers and port samplers from purse seiners in the western and central Pacific Ocean. Working Paper ST-WP-3. 4th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Port Moresby, Papua New Guinea, 11–22 August 2008.

Lehodey P., Bertignac M., Hampton J., Lewis A. and Picaut J. 1997. El Niño Southern Oscillation and tuna in the western Pacific. Nature 389, 715–718.

Oksanen J., Kindt R., Legendre P. and O'Hara B. 2007. The vegan package. Version 1.8-5, 11 January 2007. At: <http://cc.oulu.fi/~jarioksa/>. Accessed 20 February 2007.

R Development Core Team. 2007. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. At: <http://www.R-project.org>.

Shono H. and Ogura M. 1999. The standardized skipjack CPUE including the effect of searching devices, of the Japanese distant water pole and line fishery in the Western Central Pacific Ocean. ICCAT-SCRS/99/59. International Commission for the Conservation of Atlantic Tunas, Standing Committee of Research and Statistics.

Shono H., Matsumoto T., Ogura M. and Miyabe N. 2000. Preliminary analysis of effect of fishing gears on catch rate for the Japanese purse seine fishery. 13th meeting of the Standing Committee on Tuna and Billfish, Noumea, New Caledonia, 5–12 July 2000.

Stobutzki I., Miller M. and Brewer D. 2001. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. Environmental Conservation 28, 167–181.

Williams P. and Terawasi P. 2008. Overview of tuna fisheries in the western and central Pacific Ocean, including economic conditions – 2007. Working Paper GN-WP-1. 4th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Port Moresby, Papua New Guinea, 11–22 August 2008.