BYCATCH ASSOCIATED WITH THE ARTISANAL TUNA FISHERY OF BUNAKEN NATIONAL PARK, NORTH SULAWESI, INDONESIA

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ABSTRACT

An investigation into the bycatch produced by the artisanal tuna fishery of Bunaken National Park was undertaken between May and July 2001. The fishery employs two types of gear: pole and line and purse seine. Mahi mahi (*Coryphaena hippurus*) was the most common bycatch species of the pole and line gear, while juvenile trevally (*Carangoides* spp.) dominated the bycatch associated with the purse seine gear. Both biomass transfer efficiency (BTE) and bycatch per unit effort (BpUE) were very low for both gears. Bycatch and wastage was very low at <1% of the catch, a stark contrast to many commercial tuna fishing operations which create high bycatch. This research supports the hypothesis that certain artisanal fishing practices can relieve local anthropogenic pressure on finfish populations in the form of bycatch and wastage and can be generally more selective in comparison to more industrial fishing methods.

Introduction

Discards and bycatch of non-target species, or undersized target species form some component of the catch of almost all fishing activities (Alverson, 1999). Alverson *et al.* (1994) estimated that 27 million tons were discarded annually, based on an annual target catch of 77 million tons. Bycatch is a very general term for every species or individual organism captured by a fishing operation that is not the intended target species. Bycatch can be categorized dependent on its fate after landing. McCaughran (1992) defined all retained catch of non-target species of marketable or use value as incidental catch while discarded catch is that portion of the catch returned to the sea as a result of economic, legal, or personal consideration.

The world's tuna fisheries have been well documented within fisheries literature (Fonteneau *et al.,* 2000; Gales *et al.,* 1998; Garcia & Hall, 1996; Hall, 1996; Shomura *et al.,* 1996). Non-target species include, but are not limited to elasmobranches (FAO, 1994; Williams, 1999; Francis *et al.,* 2001), seabirds (Brothers, 1991; Brothers *et al.,* 1999; *Gales et al.,* 1998), and marine mammals (Balazs & Pooley, 1994; Hall, 1996). The Eastern Pacific tuna fishery was subjected to considerable public pressure for its apparent disregard of the high mortality of dolphins *Stenella attenuata* and *S. longirostris*, prior to the introduction of the Marine Mammal Protection Act by the United Sates during the early 1990s.

Literature dealing with the issues of tuna bycatch contains several methods used to describe and assess the bycatch produced by a particular tuna fishery. Several authors have used descriptive statistics to describe bycatch species composition and ratio of bycatch organisms to target species (Alverson *et al.,* 1994; Hall, 1996; Garcia & Hall, 1996). Hall *et al.* (2000) introduced the idea of establishing a biomass transfer efficiency (BTE) for a catch, therefore gaining a total figure in kilograms (kg) of catch needed to be attained by the fishery to gain 1 kg of marketable target species. Bycatch per unit effort (BpUE) is described for shark bycatch from the Pacific tuna fishery by Francis *et al.* (2001) and Williams (1999). Using the total weight of the bycatch produced and the effort invested for a day's fishing enables the BpUE to be calculated, thus both BTE and BpUE figures give an indication as to the selectivity of the gear employed within any given fishery.

Pelagic fishing effort accounts for 80% of the total production for capture fisheries in North Sulawesi (Kahn & Fauz, 2001). The principal target species are bonito tuna (*Sarda sarda*), big eyed scad (*Selar crumenophthalmus*), mackerel scad (*Decapterus* spp.), skipjack tuna (*Katsuwonus pelamis*), and yellowfin tuna (*Thunnus albacares*). Both *K.*

pelamis and *T. albacares* are prized for canning and sashimi and provide considerable in-country commerce. Asian Pacific marine fisheries land approximately three million tons of fish annually, about 65% of the world's catch (Shomura *et al.*, 1996). In North Sulawesi alone annual marine fish production from capture fisheries amounts to 176,000 metric tons/ yr^{-1}, with 32.8% of this comprising *K. pelamis,* valued at US$ 352 million (Kahn & Fauz, 2001). Citing a lack of research centered on these fisheries, FAO (1997) recommended increased effort to collect both catch and bycatch data for small scale fisheries. Such fisheries account for 90% of the fishing effort in Indonesia (Kahn & Fauz, 2001). This study aims to investigate the bycatch and subsequent fate of all non-target species associated with the artisanal pole and line and purse seine tuna fishery of Bunaken National Park, by comparing the BTE and BpUE of each gear.

Study Area and Methods

Bunaken National Park is located in the province of Minahasa, North Sulawesi, Indonesia (Fig. 1), positioned in the Wallacea bioregion, the global center of marine biodiversity (Kahn & Fauz, 2001). The Park is principally made up of the five islands: Bunaken, Siladen, Manado Tua, Mantehage, and Nain (Fig.1), plus the adjacent coastal area. There are 15 villages located on the five islands within the Park, which have conducted subsistence fishing and farming for over 100 years. Park resources generate $3.8 million per annum for the local population (Kahn & Fauz, 2001). The artisanal pelagic pole and line and purse seine tuna fishery is the principal local livelihood, with boats operating out of most villages within the park. Pole and line fishing for tuna dates back hundreds of years (Fonteneau *et al.,* 2000) and is considered to be one of the traditional tuna fishing methods. Since the 1950s pole and line has been increasingly replaced by purse seine gear (Hall, 1999).

Throughout a period of seven weeks between May and July 2001, 20 pole and line and 20 purse seine boats were chosen at random from the artisanal tuna fishing fleet within the Park, and accompanied by an observer for fishing trips. Total time at sea and number of fishers per vessel were recorded. The total weight of target species was gained when the catch was sold at the end of each day's fishing. As bycatch taxa were landed, each individual animal was positively identified and weighed, then noted if the fishers retained the specimen or returned it to the sea. Specimens removed by the fishers from deployed "in water" fishing gear, as in the case of purse seining for bait, were not recorded.

Results

The pole and line vessels fish the waters around small pelagic fish aggregating devices (FADs), anchored in 200-4,000m of water, within or just outside the park boundaries (Fig. 2). The feeding characteristics of the tuna are exploited by chumming the water directly behind the boat with live bait, typically, shorthead anchovy (*Encrasicolus hetroloba*). Sprinklers are used to create the illusion of a greater number of bait fish, creating a tuna feeding frenzy. Bait is collected on route to the fishing grounds using a seine net over seagrass beds or more often from lift net pontoons used to supply the pole and line fishing fleet. Alternatively, vessels using purse seine gear are also active in and around the park boundaries. FADs are also employed, along with the use of a "fish eye", a member of the crew who reaches the FAD some hours before the main fishing vessel, and watches the behavior of the aggregating tuna or scad from the water or the FAD platform. On the command of the fish eye, who decides when the maximum number of target species are within the vicinity of the FAD, the purse seine is deployed. Major characteristics of each type of fishing vessel are summarized in Table 1.

Of the landed pole and line biomass, 99.62% was target species, with the remaining 0.38% bycatch. Comprising 23 species, this bycatch included six pelagic fish species, 11 reef fish species, three molluscs, two cephalopods, three echinoderms, and one crustacean (Table 2). The total bycatch produced by the purse seine fishery was slightly greater, totaling 0.61% of the harvested biomass. This included 10 species of pelagic fish and 1 undersized target species, with the remaining 99.39% of the catch consisting of target species.

Mahi mahi (*Coryphaena hippurus*) comprised 40% of the pole and line bycatch with five other pelagic fish species making up the remaining bycatch (Fig. 3). Incidentally, 26% of the non-target biomass is captured during the bait fishing process. Bait collection often captured sessile benthic fauna. Molluscs, predominantly the clams *Tridacna* spp. and *Hippopus hippopus*, contributed 14% of the bycatch biomass. Small species of reef fish made up 6% of the bycatch (Table 2), and commonly included guineafowl puffer (*Arothron meleagris*), cornetfish (*Fistularia commersonii*), and insular half beak (*Hyporhamphus affinis*). Juvenile trevally (*Carangoides* spp.) was the most abundant form of bycatch resulting from purse seine deployment, comprising 33% of the bycatch biomass. Juvenile (<25 cm) rainbow runner (*Elagatis bipinnulata*) accounted for 25% of the purse seine bycatch (Fig. 4).

A mean BTE of 1.013kg (i.e. on average 0.013kg of bycatch being produced with every kg of target species landed) was recorded for the pole and line gear. The BTE of the purse seines had a slightly greater mean value of 1.016kg. There was a significant difference in the BTE of the pole and line gear and the purse seine gear, (one way ANOVA, p=0.034). The BpUE of the two gears showed a strong significant statistical variation (one way ANOVA, p=0.004). The pole and line gear supported a mean BpUE of 0.017kg/man hour, compared to 0.042 kg/man hour for purse seines.

Every item of bycatch produced by the purse seine fishers was treated as incidental catch and was either sold or utilized by the fishers. All of the pelagic species caught by the pole and line fishers were utilized by the fishers or sold. The only discards occurred when the pole and line fishers caught their own bait. During bait fishing, after setting the nets in less than 1m of water, three or four fishers snorkeled within the nets removing all visible, sessile, non-target species, such as echinoderms, molluscs, and crustaceans (Table 2). All other bycatch were removed when the net had been landed before the bait fish was transferred to the hull of the boat and stored as live bait. Everything that was deemed non-edible by the fishers, for example toxic guineafowl puffer (*A. meleagris*) and small reef fish, was returned to the sea (Table 2). Certain species were graded according to size, such as insular half beak (*H. affinis*) and cornetfish (*F. commersonii*). Larger individuals were retained as incidental catch to be utilized by the fishers as food, while smaller individuals were returned to the sea. Cephalopods were retained as welcomed incidental catch. Twenty six percent of the pole and line bait fishing bycatch was discarded; only 0.48% of the whole catch was discarded as a result of using this gear.

Discussion

As expected, purse seine fishing generated more bycatch (0.61% of the total catch) due to the less selective nature of the fishing gear. Before the net was deployed, the "fish eyes" informed the fishers on the boat when they believed the highest number of target species had aggregated under the FAD. However, as soon as the gear was deployed, the fishers had no influence on the species moving into the path of the net. Indeed, the capture of many species that coexisted with the target species was unavoidable. The pole and line gear produced less bycatch (0.38%) due to the fishers exploiting the feeding characteristics of the tuna, therefore creating a very target specific fishing method. It is evident from the calculated BTE's that pole and line gear was significantly more selective than purse seine. When fishing effort was considered, BpUE for the purse seine gear was also significantly greater than that for the pole and line gear.

It is worth noting that total bycatch for the pole and line gear would be slightly greater than results suggest due to the fishers removing some of the larger sessile animals from the fishing gear. This was undertaken while the gear was still in the water and happened on the few occasions that the bait fish were caught by the fishers. Discussions with the fishers revealed that they only employed bait fishing on approximately 5% of the fishing trips. Despite larger animals such as *Tridacna* sp. making up most of the bycatch removed by hand, the infrequency of the bait fishing activity suggests that this missed bycatch would add little to the total biomass of the bycatch produced by this gear.

Both fisheries generated very little bycatch in comparison to commercial tuna fishing efforts. Garcia and Hall (1996) stated that the tuna purse seine fishery of the Eastern Pacific recorded bycatch levels of other fish, marine reptiles, and invertebrates of up to 24.2% of the catch. Frances *et al.,* (2001) found that blue sharks (*Prionace glauca*) alone contributed to 32% of the catch from the New Zealand tuna long line fishery (Fig. 5). It is very difficult to compare BTE and BpUE as varying methods to describe effort are used throughout the literature, but the use of "fish eyes" by the purse seiners in this study could be one reason why the percentage bycatch is so low compared to the commercial purse seine efforts described by Garcia and Hall (1996).

Marine resource utilization in small-scale fishing communities is high (McGoodwin, 1990). In this study this was highlighted by the fact that 100% of the bycatch produced by the purse seine vessels was treated as incidental catch (Table 2) and utilized by the fishers. Some incidental catch, such as barracuda (*Sphyraena barracuda*) and (*S. qenie*), had a marketable value and was sold. Because discarded fish was considered a waste of edible protein and effort by the fishers, nothing was wasted. In comparison, Garcia and Hall (1996) report that 15-20% of the fish caught by the commercial purse seine tuna fishery of the Eastern Pacific was discarded.

The pole and line vessels generated some bycatch from its tuna fishing operation and occasionally from bait fishing. Pelagic species captured during tuna fishing were treated as incidental catch, with *C. hippurus* and *E. bipinnulata* being sold and all other retained species utilized by the fishers themselves. Stress and mortality among discarded species was low, due to careful handling by the fishers and limited time out of the water (pers. obs).

All fishing methods have ecological costs such as bycatch that need to be compared in order to assess their relative merits. It is evident that the more traditional pole and line gear was a more selective form of fishing. With bycatch of <1% of the total catch for both gears, compared to industrial tuna fishing efforts, the artisanal tuna fishers of the Park have a negligible effect on the non-target marine species of one of the most biodiverse regions of the world. The Indonesian government needs to encourage the use of the more environmentally sound traditional tuna fishing practices. The use of "fish eyes" on FADs, and chumming with pole and line gear to reduce the levels of bycatch need to be considered and recommended by decision makers. The increasing level of regulated and non-regulated fishing efforts by larger foreign vessels, using less selective long lining techniques within the Indonesian Exclusive Economic Zone, should also be given due consideration by national fishery authorities.

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* * *

In memory of my mother

Carolyn Clare Walker, 1948-2000

who grew up by the sea.

* * *

Literature Cited

Alverson, D.L. (1999). Some observations on the science of bycatch. *Marine Technology Science Journal.*, *33*, 6-12.

Alverson, D.L., Freeburg, M.H., Pope, J.G., & Murawski, S.A. (1994). A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper 339, Rome FAO.

Balazs, G.H., & Pooley, S.G. (1994). Research plan to assess marine turtle hooking mortality. In *Results of an Expert Workshop held in Honolulu, Hawaii, 16-18 November 1993* (p.166). NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-201.

Brothers, N. (1991). Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. *Biological Conservation*, *55*, 255-268.

Brothers, N., Gales, R., & Reid, T. (1999). The influence of environmental variables and mitigation measures on seabird bycatch rates in the Japanese tuna fishery within the Australian fishing Zone, 1991-1995. *Biological Conservation*, *88*, 85-101.

F.A.O. (1994). Overview of world elasmobranch fisheries. F.A.O. Fisheries Technical Paper. 341. Rome FAO.

F.A.O. (1997). Report on the Indonesia/FAO/DANIDA workshop on the assessment of the potential of marine fishery resources of Indonesia. FAO Technical Report. Rome FAO.

Fonteneau A., Aris, J., Gaertner, D., Nordstrom, V.,& Pallares, P. (2000). Observations in the species composition of tuna schools in the Gulf of Guinea between 1981 and 1999, in relation with fish aggregating device fishery. *Aquatic Living Resources, 13*, 253-257.

Francis, M.P., Griggs, L.H., & Baird, S.J. (2001). Pelagic shark bycatch in the New Zealand tuna longline fishery. *Marine and Freshwater Research, 52*, 165-178.

Gales, R., Brothers, N., & Reid, T. (1998). Seabird mortality in the Japanese tuna long line fishery around Australia, 1988-1995. *Biological Conservation, 86*, 37-56.

Garcia, M.A., & Hall, A.M. (1996). Spatial and seasonal distribution of bycatch in the purses seine tuna fishery in the Eastern Pacific Ocean. In *Fisheries Bycatch: Consequence and Management.* Alaska Sea Grant College Program Report No. 97-02, University of Alaska, Fairbanks.

Hall, M.A. (1996). Dolphins and other bycatch in the Eastern Pacific Ocean tuna purse seine fishery. In *Fisheries Bycatch: Consequence and Management.* Alaska Sea Grant College Program Report No. 97-02, University of Alaska, Fairbanks.

Hall, M.A., Alverson, D.L., & Metuzals, K.I. (2000). Bycatch: Problems and solutions. *Marine Pollution Bulletin,41*, 204-219.

Hall, S.J. (1999). The effect of fishing on marine ecosystems and communities. London: Blackwell.

Kahn, B.,& Fauz, A. (Eds.). (2001). Fisheries in the Sulu-Sulawesi Seas. Indonesian Country Report. WWF Wallacea Program.

McCaughran, D.A. (1992). Standardized nomenclature and methods of defining bycatch levels and implications. In: Proceedings of the National Industry Bycatch Workshop, February 4-6, 1992, Newport, Oregon. Schoning, RW, R.W. Jacobson, D.L. Alverson,, T.G. Gentle, and J. Auyong (Eds.) Natural Resources Consultants, Inc., Seattle Washington. 200 p.

McGoodwin, J.R. (1990). *Crisis in the world's fisheries*. USA: Stanford University Press.

Shomura, R.S., Majkowski, J., & Harman, R.F. (Eds.) (1996). Status of Interactions of Pacific tuna fisheries in 1995. Proceedings of the second FAO Expert Consultation of Pacific Tuna Fisheries. Shimizi, Japan, 23-31 January 1995. FAO Fisheries Technical Paper. No. 365. Rome, FAO. 612 p.

Williams, P.G. (1999). Sharks and related species catch in tuna fisheries of the tropical western and central Pacific Ocean. F.A.O. Technical Paper. 378. 860-880 pp.

APPENDIX

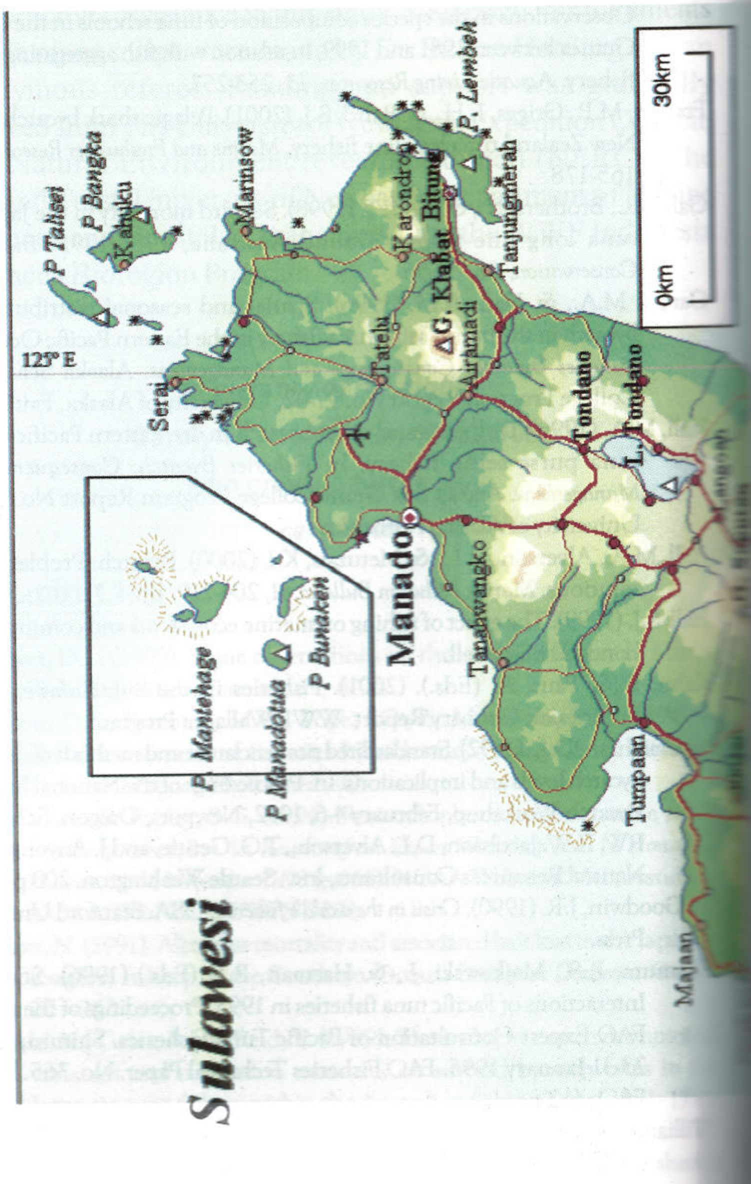

Figure 1. Bunaken National Park, North Sulawesi, with the fishing zone indicated within the northern region of the park (this page). North Sulawesi in relation to the rest of the Indonesian Archipelago (next page).


PHILIPPINES
Philippine Sea
NORTH PACIFIC OCEAN
PAPUA NEW GUINEA
IRIAN JAYA
Puncak Jaya
New Guinea
Biak
AUSTRALIA
Arafura Sea
Ambon
MOLUCCAS
Banda Sea
EAST TIMOR
Timor Sea
Kupang
Sulawesi (Celebes)
Celebes Sea
Pulau Ligitan
Pulau Sipadan
Makassar
Borneo
Equator
Kalimantan
BRUNEI
MALAYSIA
South China Sea
VIETNAM
Java Sea
JAKARTA
Semarang
Madura
Surabaya
Java
Denpasar
Cirebon
Cilacap
SINGAPORE
Gulf of Thailand
THAILAND
Strait of Malacca
Sumatra
Palembang
Pekanbaru
Medan
Andaman Sea
INDIAN OCEAN
0 200 400 km
0 200 400 mi
100
110
120
130
140
10

Figure 2. Artisanal pole and line fishers using sprinklers and bait fish to attract tuna.

Figure 3. Bycatch composition of the pole and line gear

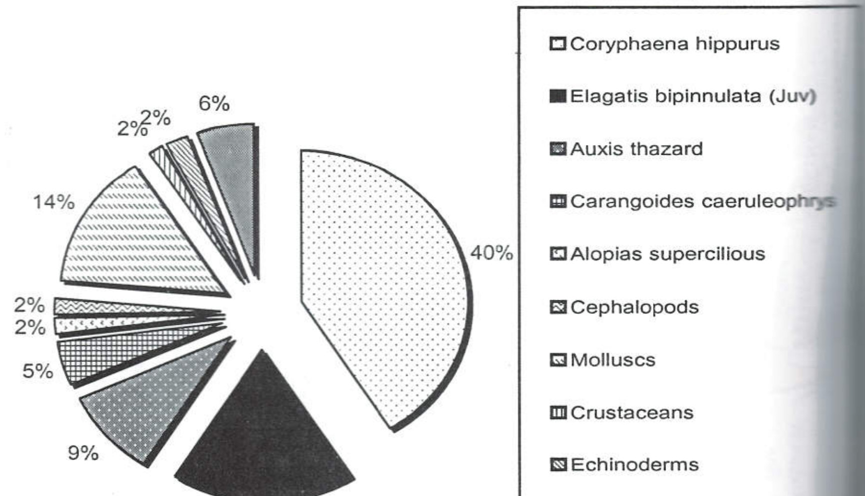

Figure 4. Bycatch composition of the purse seine gear

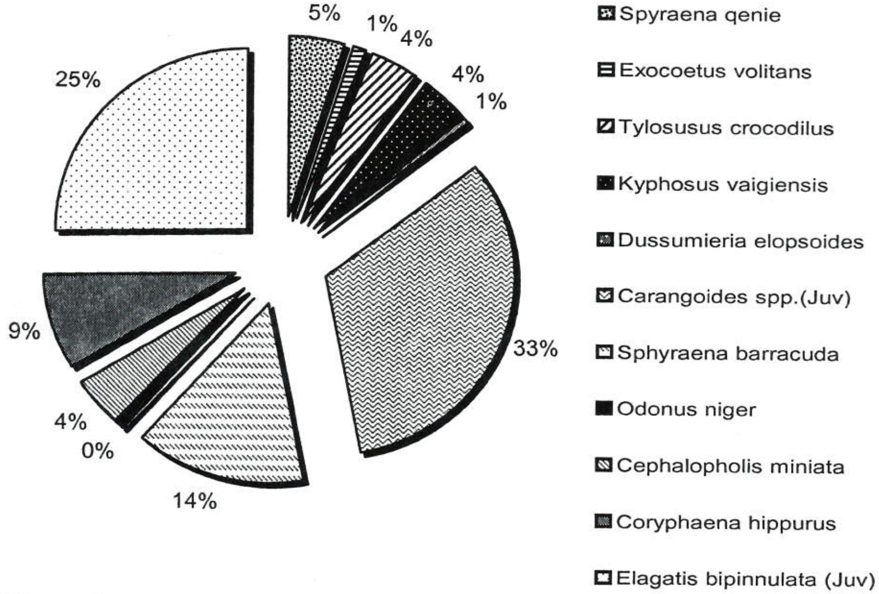

Figure 5. A comparison of data from this study vs the Eastern Pacific purse seine fishery (Garcia & Hall, 1996) and the New Zealand long line fishery (Frances *et al.*, 2001) * = data solely for blue shark *Prionace glauca* bycatch.

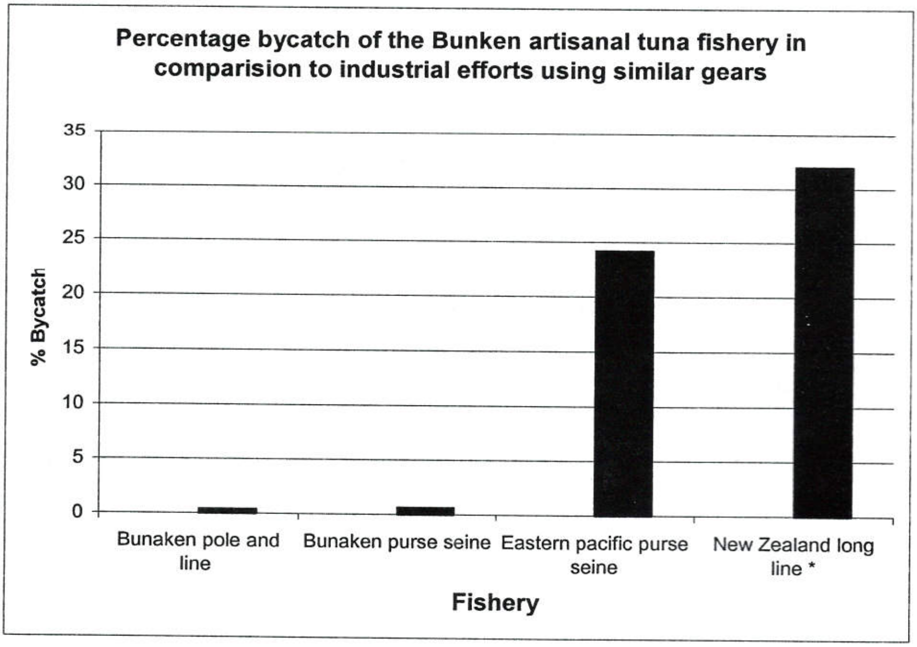

Table 1. Background information on the pole and line and purse seine tuna fishery, BNP.

	Pole & Line	Purse Seine
• Vessel length / weight	12m / 5-15 gross tonnes	15m / 10-15 gross tonnes
• Mean crew size	12	29
• Outboard engine size	3 x 40 horse power	3 x 40 horse power
• Navigation methods	Stars & visible land marks	Stars & visible land marks
• Operational distance from shore	20-40 km	3-15 km
• Daily fishing effort	15-18 hours	3-7.5 hours
• No. of days fished per week	6	6
• Target species	skipjack tuna *K pelamis* yellowfin tuna *T. albacares*	skipjack tuna *K pelamis* yellowfin tuna *T. albacares* bonito tuna *S. sarda* big eyed scad *S. crumenophthalmus* mackerel scad *Decapterus* spp. rainbow runner *Elagatis bipinnulata*
• Peak fishing months	April-July	December-January

Table 2. Bycatch species produced by each gear, and its out come (discarded or retained as incidental catch).

Non target species	**Gear**		**Bycatch**	
	Pole and line	Purse seine	Incidental catch	Discarded catch
Pelagic fish species				
Rainbow runner (>25cm)*Elagatis bipinnulata*	X		X	
Rainbow runner (<25cm) *Elagatis bipinnulata*	X	X	X	
Mahi Mahi *Coryphaena hippurus*	X	X	X	
Blue trevally *Carangoides caeruleophrys*	X		X	
Frigate mackerel *Auxis thazard*	X		X	
Big eyed thresher *Alopias superciliosus*	X		X	
Flying fish *Exocoetus volitans*		X	X	
Black fin barracuda *Spyraena qenie*		X	X	
Crocodile longtom *Tylosurus crocodiles*		X	X	
Low finned drummer *Kyphosus vaigiensis*		X	X	
Slender rainbow sardine *Dussumieria elopsoides*		X	X	
Trevally (Juv) *Carangoides spp.*		X	X	
Great barracuda *Sphyraena barracuda*		X	X	
Red toothed triggerfish *Odonus niger*		X	X	
Coral hind *Cephalopholis miniata*		X	X	
Reef fish				
Cornetfish (>55cm) *Fistularia commersonii*	X		X	
Cornetfish (<55cm) *Fistularia commersonii*	X			X
Insular half beak (>30cm) *Hyporhamphus affinis*	X		X	
Insular half beak (<30cm) *Hyporhamphus affinis*	X			X
Fan bellied filefish *Monacanthus chinensis*	X			X
Guineafowl puffer *Arothron meleagris*	X			X
Black blotched porcupinefish *Diodon liturosus*	X			X
Dash and dot goatfish *Parupeneus barberinus*	X			X
Black saddled toby *Canthigaster valentini*	X			X
Crescent wrasse *Thalassoma lunare*	X			X
Sculptured pipefish *Choeroichthys sculptus*	X			X
Reef needlefish *Strongylura incisa*	X			X
Orbicular batfish (Juv) *Platax orbicularis*	X			X

Molluscs				
Egg cowrie *Ovula ovum*	X			X
Giant clam *Tridacna sp.*	X			X
Hippopus clam *Hippopus hippopus*	X			X
Cephalopods				
Reef octopus *Octopus cyanea*	X		X	
Bigfin reef squid *Sepioteuthis lessoniana*	X		X	
Crustaceans				
Hermit crab *Dardanus spp.*	X			X
Echinoderms				
Sea urchin *Tripneustes gratilla*	X			X
Sea star *Linkia lavaegata*	X			X
Sea star *Protoreaster nodus*	X			X