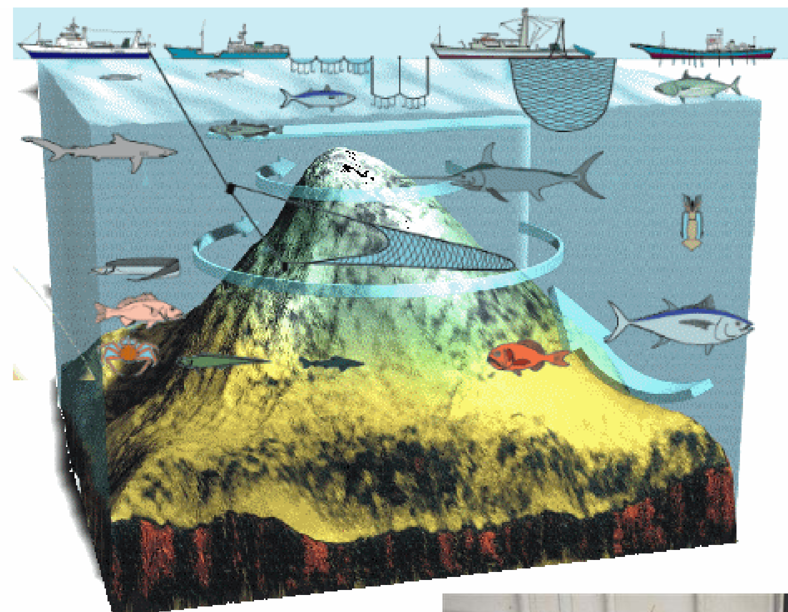
Effects of Pelagic Longline Fishing on Seamount Ecosystems Based on Interviews with Pacific Island Fishers



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SUMMARY

Seamounts aggregate pelagic species, including tunas, and support assemblages of pelagic species that differ from the open ocean. There is limited information on the ecological effects of pelagic fisheries on seamount ecosystems. We interviewed pelagic longline fishermen from Tonga, Fiji, Samoa, and the Cook Islands to obtain information on the frequency of fishing at seamounts, the locations and depth of seamounts regularly used for fishing grounds, factors considered when deciding whether or not to fish at seamounts, changes in methods when fishing at seamounts, distance from the seamount summit peak perceived to have an influence on pelagic fish abundance, perceived differences in catch at seamounts, and perceived differences in depredation (the removal of hooked fish and bait) by cetaceans and sharks. The 31 fishermen interviewed collectively identified close to 100 seamounts where they fish on a regular basis, with summit depths generally greater than 1000 m, and revealed that approximately 40% of their fishing effort occurs at seamounts. A third of interviewed fishermen always begin their first set of a trip at a seamount, and remain in the vicinity of the seamount if catch rates are acceptable. A third indicated that they fish at seamounts when targeting yellowfin tuna. When fishing at seamounts, some respondents indicated setting the gear along a depth contour in a horseshoe shape vs. fishing in a straight line when setting in the open ocean. When fishing at seamounts with a shallow summit, to reduce the risk of entanglement with the seabed, fishermen would reduce the number of hooks between floats, causing the gear to be deployed at a shallower depth. The fishermen estimated the range of influence of seamounts to be 20 km from the summit. Fishermen perceived the catch rates of yellowfin, skipjack, wahoo, mahi mahi and reef sharks to be higher, and albacore and blue shark catch rates to be lower at seamounts. Most fishermen perceived there to be no difference in depredation rates at seamounts relative to fishing in the open ocean. Bycatch of sensitive species (sea turtles, whales, seabirds) were perceived to be too rare an occurrence to observe a difference in interaction rates at seamounts.

1. Introduction: Effects of Pelagic Fishing on Seamount Ecosystems, Effect of Seamounts on Pelagic Species Abundance and Diversity

Seamount ecosystems have a high degree of endemism, support diverse benthic communities of organisms including sponges, corals, and long-lived, slow-growing specialist deep-sea demersal fish species, such as orange roughy, pelagic armorhead and alfonsino, and have relatively high pelagic species richness (Allain et al., 2006; Pitcher et al., 2007; Morato et al., 2010). Seamounts are also understood to aggregate pelagic species, including tunas, support assemblages of pelagic species that differ from the open ocean, and have high pelagic species richness relative to coastal and oceanic areas (Holland et al., 1999; Allain et al., 2006; Morato et al., 2008, 2009, 2010). Seamounts that rise up to one half of the water column impact the overlying ocean's currents and possibly isotherm distribution, by disrupting water flow, creating oceanographic perturbations, such as through advection and dispersion (Young et al., 2004; Allain et al., 2006). Depending on their physical characteristics and location, seamounts are an obstacle to flow, create local currents, and can increase upwelling and cause mixing around the seamount (Lueck and Mudge, 1997; White et al., 2007).

Seamounts that reach the Deep Scattering Layer (DSL)[1], especially those where the summit reaches the euphotic zone (intermediate and shallow seamounts, per the classification scheme of Pitcher et al. [2007]) have the potential to affect the pelagic ecosystem and pelagic fisheries. Upwelling around seamounts can bring nutrients from the deeper ocean to enhance primary productivity, supporting a variety of life (Rogers, 1994). Enhanced productivity at seamounts may also be the result of trapping the DSL and serving as a source of prey for top predators (Grubbs et al., 2002; Allain et al., 2006). It is hypothesized that pelagic fish aggregate at seamounts due to this enhanced primary productivity (Grubbs et al., 2002). In addition to enhanced prey availability, pelagic species may aggregate at seamounts for spawning and nursery habitat (Allain et al., 2006), or seamounts may serve as orientation features that assist tunas with navigation, where the seamounts are detected by tunas, and possibly other pelagic migratory species, through seamounts' effect on the earth's magnetic field (Walker et al., 1984; Holland et al., 1999; Morato et al., 2010). If this latter hypothesis is correct, the navigational importance of seamounts may explain observations of larger tuna aggregations at remote seamounts relative to seamounts located proximate to land masses (Fontenau, 1991; Holland et al., 1999) and possibly the observed differences in residence times of yellowfin and bigeye tunas at the Cross Seamount (Holland et al., 1999).

Bigeye and yellowfin abundance and depth distribution around seamounts, as well as around Fish Aggregating Devices and other floating objects, has been observed to differ from in open ocean ecosystems (Fontenau, 1991; Hampton and Gunn, 1998; Holland et al., 1990, 1999; Itano and Holland, 2000; Sibert et al., 2000; Schaefer and Fuller, 2002; Adam et al., 2003; Klimley et al., 2003; Campbell and Hobday, 2003; Musyl et al., 2003). The Cross Seamount near Hawaii, for example, is known to aggregate large schools of juvenile bigeye, and to a lesser degree, yellowfin tuna (Holland et al., 1999; Itano and Holland, 2000; Sibert et al., 2000; Adam et al., 2003). A proportion of tuna populations, and perhaps other large pelagic predators, found at seamounts are persistent (Hampton

[1] The Deep Scattering Layer, DSL, is a horizontal zone of living organisms, usually comprised of zooplankton and small swimming animals such as shrimp and fish, which typically migrates towards the sea surface at night and descends to deep water at daybreak (Pitcher et al., 2007). The layer scatters or reflects sound waves, causing echoes in depth sounders.

and Gunn, 1998; Holland et al., 1999; Itano and Holland, 2000; Sibert et al., 2000; Adam et al., 2003; Klimley et al., 2003; Campbell and Hobday, 2003). Tunas are understood to remain at an individual seamount from a few days to several months, and are not permanent residents at an individual seamount (Holland et al., 1999; Sibert et al., 2000; Adam et al., 2003). Based on a body of research at Cross Seamount, yellowfin generally do not repeat visitation to an individual seamount, while medium-sized bigeye (smaller than the spawning condition adults) generally repeat visits over a two to three-year period while they remain in the vicinity of the Hawaii archipelago (Adam et al., 2003). Adam et al. (2003) hypothesized that the larger size, spawning-aged adult bigeye tunas are not 'persistent' residents at the seamounts in the vicinity of Hawaii because the mature age classes migrate south to warmer waters where their spawning grounds are located (Nikaido et al., 1991).

In 1995, the eastern Australia longline fleet began to target swordfish along the inshore chain of Tasmantid seamounts off eastern Australia (Campbell and Hobday, 2003). Over the next six years there was a rapid and large depletion of swordfish off the central east coast of Australia (Campbell and Hobday, 2003). As effort on these seamounts and surrounding regions increased there was a significant decline in catch rates and fishing effort moved further offshore around the Lord Howe seamount chain, where high swordfish catch rates were again achieved initially. This pattern was repeated in subsequent years. From 1996 to 2001 the swordfish catch rate at grounds above seamounts dropped 75% from 15 to 5 swordfish per 1000 hooks (Campbell and Hobday, 2003). Catch rates in regions fished in previous years tended to show a relatively consistent pattern of decline over time, indicative of ongoing resource depletion, while relatively high catch rates were maintained on the periphery of the fishery as it continued to expand further offshore (Campbell, pers comm., 2009). For the initial two years after this fishery began, there were substantially higher swordfish catch rates at seamounts relative to grounds off seamounts. Swordfish catch rates subsequently declined at both seamount and non-seamount fishing grounds, and eventually reaching similar catch rates at both areas. This suggests that the observed decline in swordfish catch rates may be a regional basin-wide or seamount-field-wide phenomena, and not just related to small areas around individual seamounts (Campbell and Hobday, 2003).

There is limited information on physical characteristics of seamounts (e.g., minimum summit depth) that affect the composition and abundance of pelagic fish. For example, Morato et al. (2008) found that, in an area around the Azores, only seamounts with summits shallower than 400 m depth had a significant aggregation effect, and found that the area of influence of seamounts in this area was 20-30 km from the seamount peak. For Pacific seamounts, Morato et al. (2010) found higher pelagic species diversity occurred within 30–40 km of seamount summits relative to coastal and oceanic areas, though summit depths were not included in the analysis.

The adverse effects of marine capture fisheries on seamount ecosystems have received recent international attention. In particular, deep sea bottom trawl fisheries have been documented to degrade seamount habitat and alter seamount ecosystem functioning. However, the state of understanding of effects of pelagic fisheries on seamount ecosystems is relatively limited, as is the relationship between seamounts, pelagic species and pelagic fisheries (Allain et al., 2006; Pitcher et al., 2007). There have been few studies of the association between pelagic longlining and seamounts (Pitcher et al., 2007; Morato et al., 2008, 2009). Pelagic longine vessels are known to fish at 5-10% of all known Pacific seamounts (but this statistic includes seamounts with summits too deep to aggregate pelagic species [Morato et al., 2008]), with annual catches of as much as 24,000 tons of yellowfin, bigeye and albacore tunas coming from seamount ecosystems (Morato et al., 2009). There is evidence of an increased proportion of the Pacific bigeye and albacore catch coming from seamounts in recent years (Morato et al., 2009). Watson et al. (2007) estimated that globally, 10% of yellowfin, and 4% of bigeye, albacore and skipjack were caught near seamounts. There is a growing body of empirical evidence that pelagic fishing near seamounts results in higher catch rates of juvenile and undersized tunas and other unmarketable species of fish, and sensitive species groups (Fonteneau, 1991; Itano and Holland, 2000; Sibert et al., 2000; Adams et al., 2003; Klimley et al., 2005; Litvinov, 2007; Amorin et al., 2009; Parrish, 2009; Morato et al., 2008, 2010).

Despite their high fecundity and wide distribution, most tuna stocks are fully exploited, and some are overfished or even depleted. Of the 20 tuna stocks for which the status is known, at least five are 'overfished' (albacore in the North Atlantic, bigeye in the Atlantic, bluefin in the East and West Atlantic, and southern bluefin), meaning that they have biomass levels that are below maximum sustainable yield (MSY) or other biological threshold. In addition, the adult component of the western central Pacific may also be overfished (Langley et al., 2008). 'Overfishing' is occurring for at least an additional four stocks (bigeye in the East and western central Pacific, yellowfin in the Indian Ocean, and bluefin in the Pacific), meaning that the fishing mortality rate is higher than that which produces MSY or other biological threshold (Bayliff et al., 2005; IATTC, 2007a; Majkowski, 2007; WCPFC, 2007; Langley et al., 2008). Overfishing may also be occurring for yellowfin in the western central Pacific (Langley et al., 2007). There are skipjack stocks in the Pacific and Indian Oceans, and albacore in the South Atlantic and South Pacific, that are only moderately exploited (Bayliff et al., 2005; Majkowski, 2007; Hoyle et al., 2008; Langley and Hampton, 2008).

During declines in stock abundance, density of tunas at seamounts and other aggregating features may remain stable, and fishing efficiency may increase, causing tuna CPUE to remain stable or increase (i.e., the relationship between CPUE and abundance show hyperstability, and are not proportional, for schooling species) (Gulland, 1964; Hilborn and Walters, 1992; Pitcher 1995, Mackinson et al., 1997; Fonteneau et al., 1999; Gaertner and Dreyfus-Leon, 2004; Morato et al., 2009). As a result, increased fishing effort at seamounts could exacerbate the overexploitation of some tuna stocks.

Pelagic longline tuna fisheries have documented problematic bycatch of seabirds (Brothers et al. 1999, Gilman et al. 2005), sea turtles (Gilman et al., 2006b; FAO, 2010), sharks (Gilman et al. 2008), and possibly cetaceans (Forney 2004; Gilman et al., 2006a). Purse seine tuna fisheries have documented problematic bycatch of juvenile and undersized bigeye and yellowfin tunas and unmarketable species of fish for sets made on Fish Aggregating Devices (FADs) and other floating objects (Fonteneau et al., 2000; Romanov, 2002; Bromhead et al., 2003; Secretariat of the Pacific Community, 2006; An et al., 2009; WCPFC, 2007), sea turtles (Hall et al., 2000; Romanov, 2002; Molina et al., 2005; Molony, 2005; U.S. National Marine Fisheries Service, 2006; FAO, 2010), sharks (Hall 1998, Hall et al. 2000, Safina 2001, Romanov, 2002; Broomhead et al., 2003; Molony 2005; IATTC, 2009), and marine mammals (Hall, 1998; Romanov, 2002; Molony, 2005; U.S. National Marine Fisheries Service, 2006). There may be higher catch rates of these sensitive species groups at seamounts relative to coastal and open ocean areas (Morato et al., 2008, 2009, 2010), as well as higher catch rates of undersized and juvenile tunas and other non-target fish species (Fonteneau, 1991; Itano and Holland, 2000; Sibert et al., 2000; Adams et al., 2003). For example, a seamount aggregation affect has been demonstrated for several taxa of shark (Klimley et al., 2005; Litvinov, 2007; Morato et al., 2010), seabirds (Morato et al., 2008; Amorin et al., 2009) and marine mammals (Morato et al., 2008; Parrish, 2009). The sensitive species groups subject to bycatch are particularly vulnerable to overexploitation and slow to recover from large population declines due to their K-selected life-history strategy, characterized by long life spans, slow growth, delayed sexual maturity, low fecundity, and low natural mortality rates.

Pelagic and benthic components of seamount ecosystems may be functionally linked, such that pelagic fisheries' removal of seamount-associated pelagic species may indirectly affect seamount benthic communities. For instance, there is a trophic link between bentho-pelagic species and seamount benthos, where bentho-pelagic species, such as the alfonsino (*Beryx sp.*), have been found to feed both on pelagic and benthic prey species in New Caledonia (Lehodey, 1994; Parin et al., 1997). While the trophic link between large pelagic and the benthic component of seamounts likely exists, it is probably an indirect link, e.g., large pelagics preying on the predators of benthic prey, or preying on bentho-pelagic species (Allain, et al., 2006). Research to date has not documented pelagic species feeding directly on benthic organisms (Bulman et al., 2002; Grubbs et al., 2002). Furthermore, there is an ontogenetic link between pelagic and benthic seamount habitats: Most seamount benthic species have a pelagic stage, usually as juveniles (Allain et al., 2006). For instance, the armorhead (*Pseudopentaceros wheeleri*) demonstrates this ontogenetic link, as the armorhead is believed to have a pelagic stage from 1.5-2.5 years before recruiting to the seamount benthos (Boehlert and Sasaki, 1988). There also may be a mechanistic link between pelagic and benthic seamount habitats: a nutrient-rich benthic environment, necessary to support a diverse and productive benthic community, may likewise support a productive pelagic community, where the presence of the seamount traps food through trophic focusing (Allain et al., 2006).

2. Seamount Definition

For the purpose of this study, the definition of a seamount by Pitcher et al. (2007) has been used: "…any topographically distinct seafloor feature that is at > 100 m but which does not break the sea surface." This definition excludes large banks and shoals, and topographic features on continental shelves. Other literature have defined a seamount as an isolated underwater feature of limited extent across the summit, usually composed of hard substrate, and with an elevation higher than 1000 m above the seafloor (Menard, 1964; Allain et al., 2006). We adopt the seamount definition of Pitcher et al. (2007), which has a more biological, functional premise than geological, and is suited to discussing effects of seamounts on pelagic ecosystem functioning, and effects of pelagic fishing on seamount functioning. Some underwater features which do not meet these seamount definitions may have substantial effects on pelagic ecosystem functioning, pelagic species and fisheries, where, for example, the summit can be at the surface and visible. These include drowned reefs, drowned atolls, terraces, ridges, plateaus, banks or trenches.

There may be more than one million seamounts ≥ 100 m in elevation, while globally, there may be between 100,000 to 200,000 seamounts which reach ≥ 1000 m in elevation. Most of these are found in the Pacific, where around 30,000 seamounts ≥ 1000 m are believed to exist (Allain et al., 2006; Wessel, 2007). The Pacific tectonic plate is believed to contain close to half of seamounts that are > 2km in height (Wessel, 2001). While there are several sources of information on seamount distribution and characteristics (e.g., Smith and Sandwell, 1997; Smith and Jordan, 1988; Wessel, 2001; Kitchingman and Lai, 2004; Kitchingman et al. 2007), existing datasets consist largely of unverified satellite-derived data, and thus likely contain errors. Few seamounts have undergone in situ ship and submersible-based studies to document bathymetry, geology, oceanography, and biodiversity (Allain et al., 2006). By cross checking seamount positions in the Pacific Ocean with other available datasets, Allain et al (2008) compiled a validated dataset for seamounts in the Western and Central Pacific Ocean (WCPO). Adding new records from a number of sources, their final dataset contains records for 4,021 underwater features in the WCPO. By adding additional validated data from outside this defined area, Morato et al. (2009) compiled a list of 7,021 seamounts in an area bounded by 50°N-50°S and 105°E-95°W, for their study on tuna longline fishing around West and Central Pacific seamounts.

3. Tuna Fisheries of the Western and Central Pacific Ocean

Purse seine, pelagic longline and pole-and-line fisheries are the primary commercial fishing methods for catching tunas (Majkowski, 2007). Large longline vessels in the WCPO generally catch older age classes of bigeye and yellowfin tunas for the *sashimi* market and some longline fleets target albacore for canning. Purse seine vessels catch younger age classes of target skipjack and yellowfin and incidental bigeye tunas for canning (a small volume of Atlantic, Pacific and southern bluefin tuna is currently caught for tuna ranching [GFCM, 2005]) (Majkowski, 2007). Like purse seiners, pole-and-line vessels catch fish close to the surface, catching mostly skipjack and small/juvenile yellowfin, albacore and bluefin, primarily for canning (Majkowski, 2007). Tuna products are an important food source and global commodity. They are the third most important seafood commodity traded in value terms (FAO, 2007). The export value of 2006 internationally traded tuna products was US$6.9 billion, 8% of total global fish and fishery product exports (FAO, 2009). In 2006, skipjack and yellowfin tuna comprised the third and tenth largest contribution to global reported landings from marine capture fisheries by weight, respectively (FAO, 20090d). Japan, Taiwan, Indonesia, the Philippines, and Spain accounted for half of 2004 reported global landings (Majkowski et al., 2007). Catches from the Atlantic, Indian and Pacific Oceans produce about 10, 23 and 66 percent, respectively, of the total catch of the principal market species of tunas (Bayliff et al., 2005). The WCPFC area accounts for more 50% of reported world tuna landings (FAO, 2009).

The WCPO contains the most important tuna fishing grounds in the world, contributing about 50% (2.4 million tonnes in 2007) of reported global tuna landings (Lawson, 2008). Regional management of the highly migratory species, which includes tuna, billfish, and other pelagic species, comes under the Western and Central Pacific Fisheries Commission (WCPFC), based in the Federated States of Micronesia.

There were over 5,000 pelagic longline vessels operating in the Western and Central Pacific Fisheries Convention Statistical Area in 2007 (WCPFC, 2009). They caught a total of 267,000 mt of fish, comprising 29% bigeye, 26% albacore, 24% yellowfin, and 21% other species. There were 214 purse seiners, which caught just under 1.4 million mt of tuna, consisting of 84% skipjack, 13% yellowfin, and 2% bigeye. Over the past five years, the Pacific-Islands domestic albacore fisheries have grown from taking 32% of the total South Pacific albacore longline catch in 1998 to accounting for over 53% in 2005, while foreign distant water (large freezer vessels that undertake long trips over several months and operate over large areas) and foreign offshore (smaller vessels that are domestically based out of Pacific Island ports that target bigeye and yellowfin for the fresh sashimi market and have ice or chill capacity) fleets have been reduced in size in the WCPO (Williams and Reid, 2006). Table 1 summarizes the catch by longline and purse seine vessels operating in the WCPFC statistical area for 2007. Total offshore fisheries production, consisting mainly of tuna and other pelagic species, for the Pacific Island countries and territories combined, was estimated to be 1.15 million tons in 2007, worth more than USD1.5 billion to the economy of the region (Gillett, 2009).

Table 1. Number and catch of pelagic longline and purse seine vessels operating in the Western and Central Pacific Fisheries Convention Statistical Area and catch, 2007 (WCPFC, 2009).

Country or territory	Longline					Purse seine				
		Catch (mt)[1]					Catch (mt)[1]			
	Boats	ALB	BET	YFT	OTH	Boats	BET	YFT	SKJ	OTH
Australia	61	1,916	1,129	1,609	1,472	0	0	0	0	0
China	86	5,453	7,821	1,580	3,633	10	768	5,428	48,745	n/a
Taiwan	3,694	21,836	29,520	33,336	27,386	34	2,386	21,147	209,002	n/a
Cook Islands	35	2,099	188	251	220	0	0	0	0	0
FSM	26	0	1,395	548	0	4	196	1,448	11,853	n/a
Fiji	110	7,145	556	1,721	2,995	0	0	0	0	0
Fr. Polynesia	64	3,957	478	527	1,346	0	0	0	0	0
Indonesia	0	0	0	0	0	3	402	2,141	10,313	n/a
Japan	401	7,931	15,146	10,097	6,748	35	4,883	24,390	215,310	8,109
Kiribati	1	0	1	2	5	1	103	1,169	4,178	n/a
Korea	122	1,433	10,054	8,817	2,578	28	1,775	41,469	214,933	n/a
Marshall Is.	4	0	3	2	1	5	2,118	3,370	53,916	81
Nauru	0	0	0	0	0	0	0	0	0	0
N. Caledonia	23	1,324	53	393	352	0	0	0	0	0
New Zealand	44	359	213	25	407	10	431	1,509	28,622	n/a
Niue	13	55	10	34	24	0	0	0	0	0
Palau	0	0	0	0	0	0	0	0	0	0
PNG	22	1,564	104	1,319	238	41	4,464	40,216	174,957	417
Philippines	0	0	0	0	0	12	864	11,792	21,562	195
Samoa	60	3,113	3,113	305	236	0	0	0	0	0
Solomon Is.	0	0	0	0	0	5	817	6,326	10,164	n/a
Spain	15	0	0	0	4,217	3	3,040	4,019	12,688	n/a
Tonga	9	390	129	341	81	0	0	0	0	0
Tuvalu	0	0	0	0	0	0	0	0	0	0
Am. Samoa	29	5,337	198	616	436	0	0	0	0	0
USA	130	244	5,416	835	3,814	13	7,625	3,938	60,641	0
Vanuatu	55	6,404	1,574	594	329	10	391	7,030	59,589	0
Total	**5,004**	**70,560**	**77,101**	**62,952**	**56,518**	**214**	**30,263**	**175,392**	**1,136,473**	**8,802**

[1] ALB = albacore, BET = bigeye tuna, YFT = yellowfin tuna, SKJ = skipjack tuna

4. Methods

This study was conducted as part of the Oceanic Fisheries Management Project, funded by the Global Environment Facility, to achieve global environmental benefits through enhanced conservation and management of transboundary oceanic fishery resources in the Pacific Islands region and the protection of the biodiversity of the Western Tropical Pacific Warm Pool Large Marine Ecosystem. The project is executed by the Pacific Islands Forum Fisheries Agency in conjunction with the Secretariat of the Pacific Community and IUCN.

In order to obtain anecdotal information from the longline fishermen actively engaged in fishing in the region, interviews were conducted with longline fishermen from four Pacific Island countries: Tonga, Fiji, Samoa, and Cook Islands. These longline fleets were selected for inclusion in the study primarily based on logistical considerations by the investigators. The principal investigator travelled to these countries and conducted interviews, with the captains when available, or otherwise with the first mate. Where possible interviews took place on board the vessels when they were in port, where the fishermen had access to their GPS plotter and charts. While it would have been useful to interview fishermen in additional countries as well, the logistics and costs involved limited the extent of the survey to these four countries.

The survey form used to structure the interviews is included as Appendix 2. Information for each fishery was collected on:

(i) The proportion of effort on seamounts;
(ii) Incentives for targeting and not targeting seamounts;
(iii) Fishing gear and methods used at seamounts;
(iv) Relative depredation levels at seamounts;
(v) Ecosystem effects, including catch rates of target, incidental and discard species, of longline fishing at seamounts; and
(vi) Implications for the effects of pelagic longlining on seamount ecosystems.

5. Results

A total 31 longline fishermen from four countries, including 8 from Tonga, 9 from Fiji, 8 from Samoa, and 6 from the Cook Islands, were interviewed between September 2008 and February 2009. The respondents are listed in Appendix 2. The results of the survey are summarised in the subsequent subsections.

5.1. Locations of seamounts targeted by longline fishermen

The interviewed fishermen collectively indicated a total of nearly 100 seamount locations where they regularly fished within their country's respective Exclusive Economic Zones (EEZs). The approximate coordinates for these locations were taken from their GPS plotter, or from their navigational charts. Depths ranged from around 300m, though most were over 1000m deep, with some over 3000m. Figure 1 shows the approximate positions of these seamounts, as provided by the fishermen.

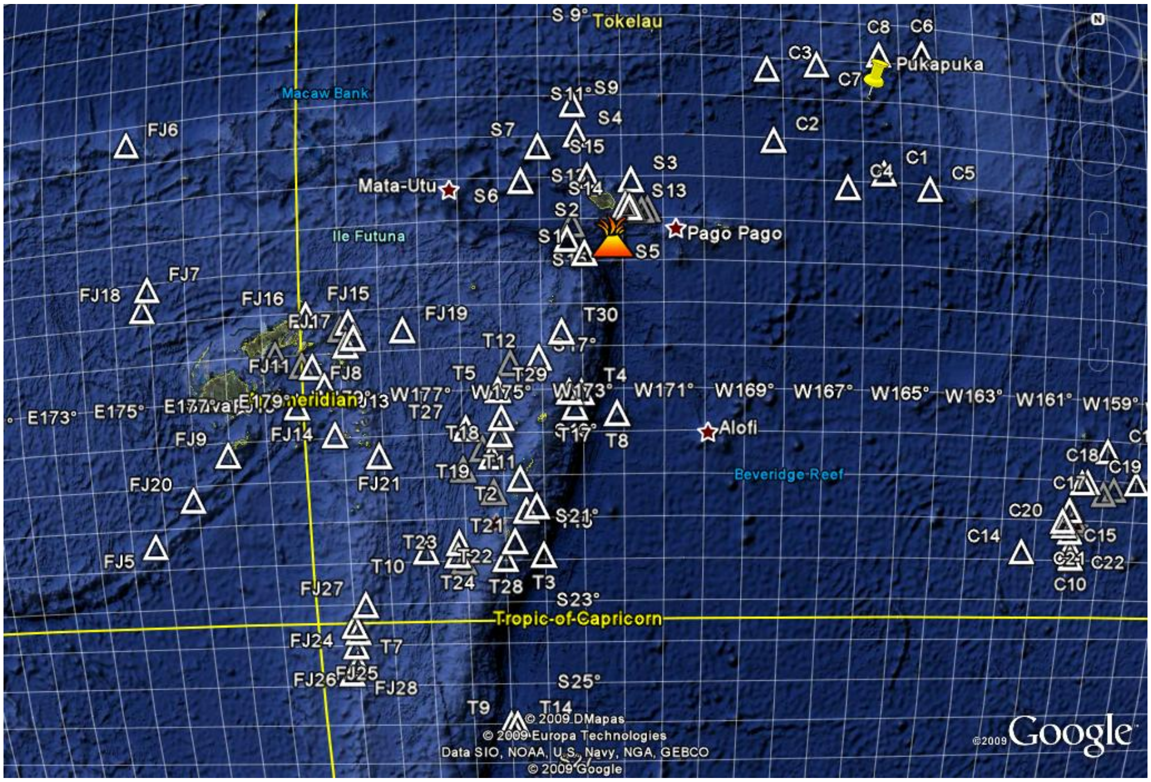

Figure 1. Approximate locations of seamounts targeted by fishermen in Cook Islands, Fiji, Samoa and Tonga.

5.2. Fishing effort around seamounts

Of 30 valid responses to this question, 80% indicated that they do target seamounts some of the time. Overall effort directed at seamounts from those interviewed indicated that approximately 39% of all sets are in the vicinity of seamounts (Fig. 2). The range was from 0% for boats that never target seamounts, to 86% for 1 boat in Tonga which regularly targets seamounts.

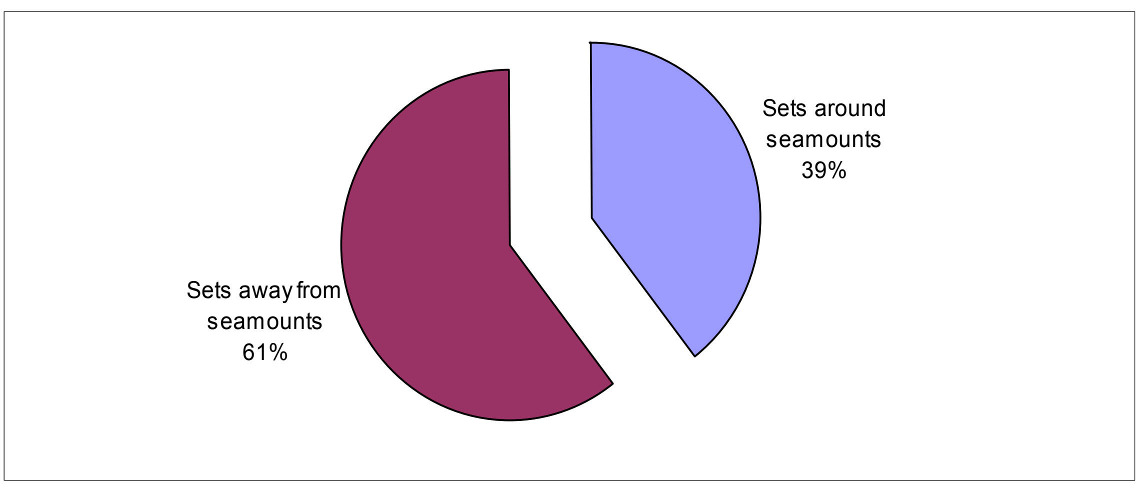

Figure 2. Percentage of effort around seamounts.

5.3. Why do fishermen choose to target seamounts?

Of 29 valid answers to this question, 10 fishermen responded that they always start at a seamount, and if fishing is not good there, they will then move away. The other major reason for fishing around a seamount was if the vessel was targeting yellowfin tuna, with 8 fishermen giving this reason. Other less common reasons given; were: moon phase (new moon to full moon); information from other boats that fishing was good around a particular seamount; the time of year; and if they were having no luck in the open ocean. One respondent indicated that they fished at seamounts because of the upwelling, and another for research purposes (Fig. 3).

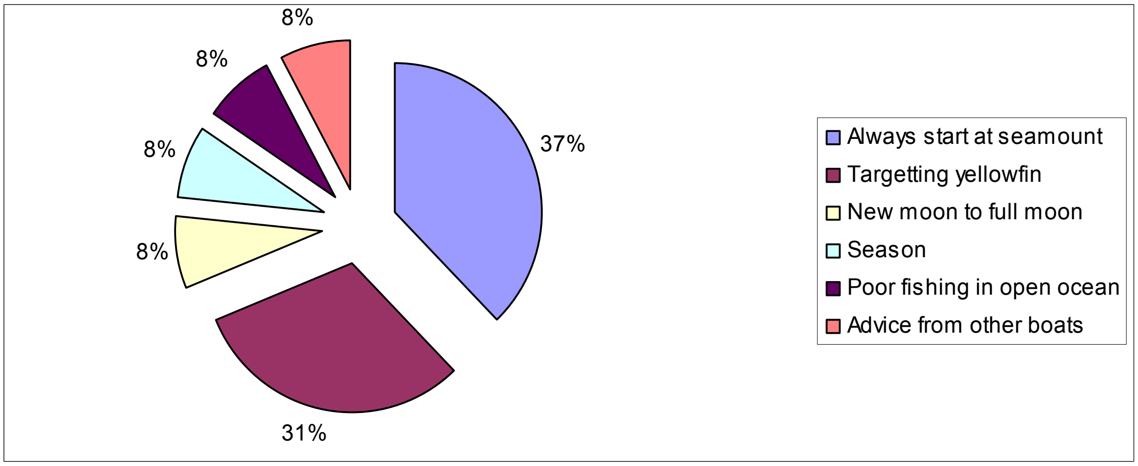

Figure 3. Why fishermen target seamounts.

5.4. Why do fishermen choose not to fish at seamounts?

Figure 4 shows why fishermen might avoid fishing on a seamount. Eight of 26 valid responses (31%) were based on a perception that there would be lower catches. The other major reason, given by 5 (19%) of respondents was that they were targeting albacore, and they believed catch rate of albacore was low around seamounts. One of these respondents also stated that bigeye catch was low around seamounts. Two respondents said they did not fish seamounts when the weather was bad, and another two indicated they preferred fishing the trenches to seamounts. Two others said they just fished randomly, with no particular reason to avoid a seamount. A number of other reasons for not fishing at seamounts were given by one respondent only, and these included:

- For 2 weeks after the full moon;
- There are sometimes more whales around seamounts;
- Following other boats that are doing well in the open ocean;
- After fishing a seamount for several trips, leave it alone to recover;
- Strong currents around seamounts;
- Too far from port (for one small Samoan alia); and
- Always start in the open ocean to see how the catch is.

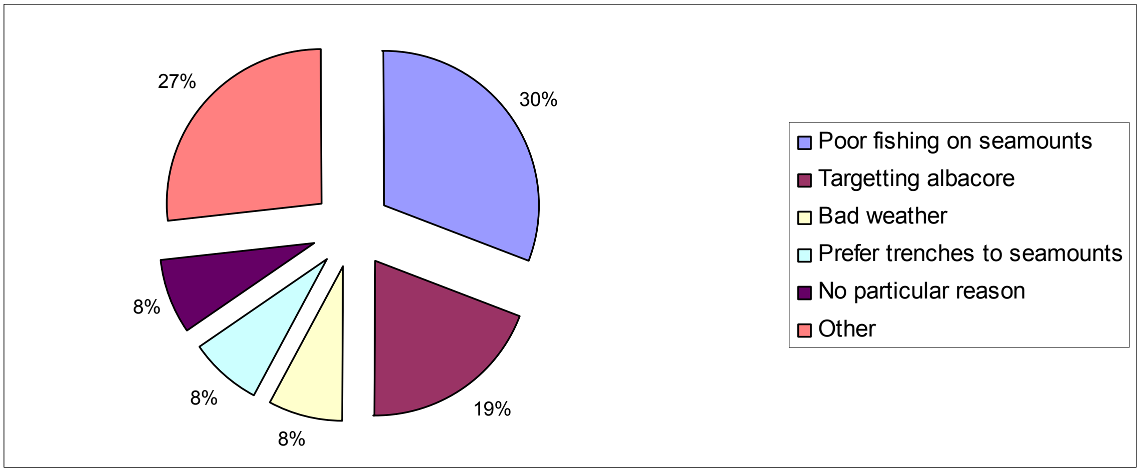

Figure 4. Why fishermen decide not to fish at seamounts.

5.5. Fishing methods at seamounts

The most common method for pelagic longlining in the Pacific Islands utilises monofilament line stored on a large hydraulically powered reel (drum). The survey showed that tuna longliners generally set between 1500 and 3000 hooks attached to 25 to 40 nautical miles (nm)[2] of line, on a daily basis. However, the smaller alia boats in the Samoan fleet utilise hand cranked longline reels setting around 5 nm of line and 300 hooks. Boats targeting swordfish generally set less hooks, ranging from 800 to 1300 over a similar distance. Branch lines are baited with small whole fish, such as sauri, though swordfish fishermen prefer to use squid.

For fishing around seamounts, approximately 50% of fishermen reported that they reduce the number of hooks they set between floats, which sets the line shallower, and reduces the risk of hook ups on shallower seamounts. Several fishermen also indicated that rather than set in a straight line, they would follow the contour, and set around the seamount, in a horseshoe formation. Others reported no change in the method used compared to the open ocean. Obviously the depth of the seamount would be a factor, with very deep seamounts providing no risk of hook ups, and therefore no need to reduce depth of set.

5.6. The range of seamount influence

The nature of the longline fishery made this a difficult question to answer for most fishermen. The average distance covered by the longlines was nearly 28 nm (52 km), so while one end of the line may have been dropped very close to a seamount, the other end could have been up to 40 nm away on the longer fishing lines. The distance that the line would drift between setting and hauling is also a complicating factor, making it difficult for fishermen to say with any degree of accuracy how far the influence of the seamount extended. Despite this, most fishermen still made an educated guess, resulting in an estimate for the average distance for seamount influence from the summit of 10.7 nm (20km), with a range from a high of 30nm (56km) to a low of 3nm (5.5 km). This is consistent with the results of an SPC analysis of longline observer data from the region, which found the influence of seamounts on pelagic species diversity (more species caught) to extend to 30-40 km from seamount summits (Morato et al, 2009).

[2] One nautical mile is equivalent to 1852 metres.

5.7. Catch rates near seamounts

Initially it was thought that it would be possible to get specific catch rates from the fishermen, in number of fish or kg. per 100 hooks. However, this proved a little ambitious, with fishermen reluctant to spend the time to analyse their historical catch records and relate these to specific geographical locations. Thus it was only possible to get a general indication of whether fishermen perceived that their catch rates were higher or lower for specific species near seamounts. Not all respondents had an answer for all species. Results from those fishermen that responded indicated that yellowfin, wahoo, mahi mahi, reef associated sharks, skipjack, bigeye, and swordfish were perceived as having higher catch rates around seamount. Table 2 summarizes the responses in regard to the more common species caught at seamounts.

Table 2. Relative catch of pelagic species around seamounts

	Relative catch rate around seamounts		
Species	**Higher**	**Lower**	**Same**
Yellowfin	14	1	0
Wahoo	13	2	0
Mahi mahi	13	0	0
Grey, brown, reef sharks	11	0	0
Skipjack	10	0	1
Bigeye	9	1	0
Swordfish	6	4	0
Marlin (all species)	3	5	2
Albacore	2	9	0
Blue sharks	1	10	0

In the related research conducted by SPC, blue sharks were found to have higher catch rates near seamounts (Morato et al, 2009). This inconsistency may be a result of fishermen not paying particular attention to species identification of shark by catch landed. The SPC research also found that striped marlin had a higher catch rate near seamounts. Unfortunately in the present study, fishermen did not discriminate between the 3 marlin species, so a comparison is not possible. SPC research also found no association of mahi mahi with seamounts, while wahoo was reported as having higher catch rates in oceanic sets. These last 2 inconsistencies with the fisher survey results are difficult to explain.

5.8. Size of fish caught near seamounts

Responses to this question were not particularly informative, with the possible exception of yellowfin, for which the answers were reasonably consistent. Fourteen respondents reported that yellowfin caught around seamounts are smaller, though 1 said they were bigger. Most of these respondents indicated that yellowfin around seamounts were generally in the 8kg to 30 kg range, whereas those from the open ocean were generally 35kg to 50kg. However, 2 of these respondents reported that deeper seamounts also have larger yellowfin than the shallower seamounts.

Bigeye tuna were also reported to be smaller around seamounts by a number of respondents, though this result was less certain. A total of 6 respondents reported this species was smaller, but 3 others said it was bigger.

Results for other species were even less conclusive, with only 2 respondents reporting smaller skipjack near seamounts, and 2 others saying swordfish were smaller. Another said marlin and mai mai were larger, and another said wahoo were also larger. Of the other respondents, 3 said in general fish were larger around seamounts, 3 said they were the same size as elsewhere, and the rest had no opinion.

5.9. Depredation

In relation to the question on depredation, there were 21 valid responses (Fig. 5). Of these, 14, or 67% indicated there was no difference between seamounts and open ocean, 5 respondents (24%) indicated it was worse near seamounts, and 2 (10%) indicated it was less of a problem around seamounts. Some fishermen indicated that the whale depredation problem is more seasonal, rather than related to proximity to seamounts. In Fiji the worst times are around March-April, and September-October. Few fishermen were able to reliably identify whales by species, though several thought the main culprits were short finned pilot whales.

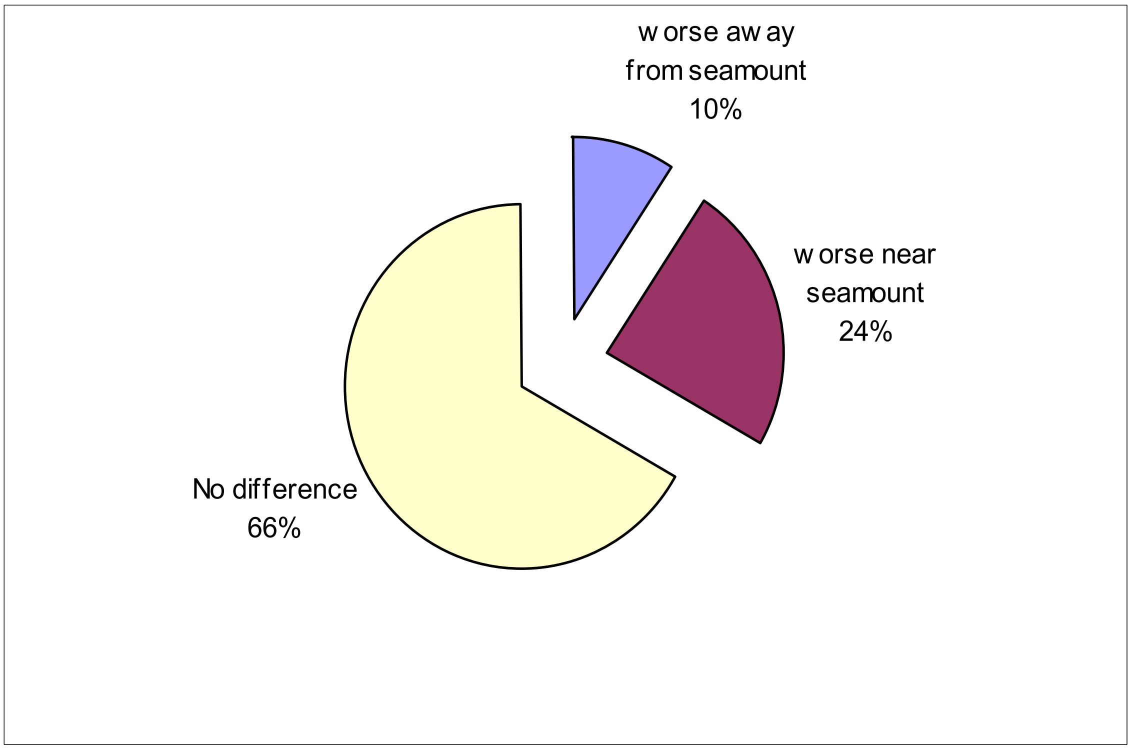

Figure 5. Fishermen's perception on depredation around seamounts.

5.10. Interaction with whales, turtles and seabirds

For the fisheries in the areas surveyed, incidental bycatch of whales, turtles and seabirds is reported to be minimal.

- **Whales:** Two respondents commented that in their entire history of longline fishing, each had experienced one whale tangled in the long line. In both cases, the line was broken and taken by the whale. It was not clear what sort of whale was involved. Other than this, 3 respondents said they see more whales in the open ocean than around seamounts, while the others had no opinion one way or the other.
- **Turtles:** Nine fishermen reported that they do occasionally see sea turtles, but these were not necessarily associated with seamounts. Four fishermen reported having

caught the “occasional turtle”, with one saying he had caught 2 in 8 years, and another saying he had caught 2 in 7 years. These were said to have been released alive, and none of these catches was associated with a seamount. However, one fisherman indicated that when fishing for swordfish, sometimes around seamounts, he can hook up to 2 turtles per trip. It should also be noted that most fishermen are aware of the possible implications of a high interaction rate with turtles on the fisheries, and may therefore not be telling the entire truth. The swordfish longline fishery in Hawaii was closed down for several years because of unacceptably high mortality of leatherback turtles (Gilman et al., 2006b).

- **Seabirds:** Eight respondents reported seeing more seabirds near seamounts than in the open ocean. However, only one respondent said that seabirds occasionally try and take the bait, and this was in the proximity of seamounts. Another respondent stated that seabirds are much more common south of 22 degrees latitude, and reported seeing giant albatross in these areas.

5.11. Fish bycatch

For finfish bycatch, caught only around seamounts, nothing significant from a conservation or management perspective was reported. Five fishermen reported having caught different snapper species, 2 had caught grouper and pomfrets, and 1 each had reported catches of barracuda, and oilfish. The reef fish had all been caught in the vicinity of fairly shallow seamounts.

The other interesting bycatch incidents reported, though not associated with seamounts, were one boat catching approximately 20 to 30 porcupine fish per set for one trip in Samoa, and another where hundreds of juvenile sunfish of approximately 2kg each were caught, also in Samoa.

6. Management Implications

This research based on the perceptions and anecdotal information from fishermen, has identified very little impact specifically associated with longline fishing on seamounts. The possible exceptions are:

- The incidental hooking and tangling of turtles by longliners, especially when targeting swordfish. A greater effort at mitigation of turtle bycatch around seamounts is probably justified.
- Hyperstability of catches, due to aggregations around certain seamounts, eg in 1993 at Capricorn seamount; catch rates of 13.1 marketable fish/100 hooks were achieved, compared to 2.6 fish/100 hooks in the open ocean (Anon, 1995). This possibility needs to be accounted for when analysing catch rates for making management decisions
- Some shark species were reported to have higher catch rates around seamounts, and most probably only the fins are retained while the finned carcasses are discarded. A greater degree of monitoring is justified to ensure that the shark carcass is also retained when a shark is finned.

7. Legal Avenues to Protect Seamounts

7.1. Within EEZs

An analysis of existing legislation by the IUCN Oceania legal section has concluded that existing legislation in each of the Pacific Island Forum countries (PIFCs) currently provides a means to protect seamounts from the effects of fishing within their EEZs. This is because, for each PIFC, existing legislation provides a basis to make regulations and/or make fishing the subject of a license from which conditions may be attached that could prohibit fishing from a specified area.

Whether the existing legislation is actually used to protect seamounts is not a legal question, rather it is a question of policy for each PIFC. Only one example was found during this study of an FFA Member Country with a measure in place that restricts pelagic longline fishing at or near underwater features, the definition of which would include seamounts. This was for the Federated States of Micronesia (FSM)[3].

A basis for the introduction of stand alone legislation (such as a *Seamount Fishing Prohibition Zone Act*) prohibiting fishing around seamounts may arise where the regulation and/or license making powers of the existing fisheries legislation is identified as being insufficient to manage compensation and/or political issues. However, care should be taken in drawing the conclusion that stand alone legislation (or even regulations) is needed to protect seamounts within an EEZ. Stand alone legislation (or regulations) will certainly lift the regulatory profile of the issue. However, appropriately drafted conditions on a license, if managed sensibly, can have the same effect without the political complications or time required to introduce new legislation.

The most practical issue facing a PIFC that wishes to prohibit fishing around a seamount in its EEZ is how it will meaningfully communicate and enforce the prohibition. The desired level of regulation will never be achieved if appropriate resources are not first invested in communication, education and drafting conditions. These conditions need to be clear and capable of being enforced if there is a breach. Application of the 'precautionary principle' will provide an extremely useful mechanism to drive regulatory change.

7.2. In areas beyond national jurisdiction (high seas)

The Pacific Ocean encompasses approximately 170 million sq.km. The high seas, areas beyond national jurisdiction, comprise at least 50% of this area. By definition, PIFCs are not able to regulate fishing activities in these areas. However, through the Western and Central Pacific Fisheries Commission, of which they are all members, they can regulate fisheries for highly migratory species, through Conservation and Management Measures (CMMs). However, for this to happen, the WCPFC has to agree on the relevant CMM. To date, the WCPFC has not adopted conservation or management measures, voluntary or binding, related to pelagic fishing, including longlining, on seamounts (personal communications, Andrew Wright, WCPFC)

8. Suggestion for management measures to focus on mitigation of impacts of purse seine fishing on juvenile bigeye and yellowfin tuna

This survey suggests that there is a higher catch rate of juvenile yellowfin around seamounts, which could be of concern if there was intensive longline effort directed at

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[3] The Code of FSM states that: A permit shall be denied:

(a) Where the Authority determines that the permit would authorize foreign fishing or domestic-based fishing on, over, or within one nautical mile of the edge of a coral reef that is wholly submerged at mean high tide within the exclusive economic zone; or;

(b) Where the Authority determines that the permit would authorize fishing on, over, or within one nautical mile of the edge of a coral reef that is wholly submerged at mean high tide within the exclusive economic zone, and that subsection (a) of this section does not apply to the permit application;

seamounts. However, when compared to the catch of juvenile yellowfin, as well as bigeye, by purse seiners, especially when fishing around floating objects, this impact becomes proportionally much less significant.

The last meeting of the Scientific Committee of the WCPFC reaffirmed that bigeye tuna is suffering from overfishing, and that a minimum 30% reduction in catch is required to remedy the situation. It was also stated that that greater overall yields could be obtained by reducing the mortality of small fish (Harley et al, 2009). One of the respondents in this seamount survey reported that he knew of purse seiners that discard small tuna, up to 200 or more metric tons in one set, consisting of skipjack, yellowfin, and bigeye, as the price was too low for small fish. Apart from the obvious biological implications of fishing stocks before they have reached sexual maturity, practices such as this also have significant economic impact on fisheries in the WCPO. A comparison between the value of bigeye tuna caught by longline and purse seine fisheries provides some thought provoking figures.

In 2007, the longline fleet caught 1.85 million bigeye tuna, with an average weight of 42kg each. These fish are worth an estimated USD350 each, at an average price of USD8.50/kg for fresh fish (Gillett, pers. comm., 2009). This equates to USD655 million. The purse seine fleet caught 2.5 times as many, though much smaller, fish, averaging less than 7kg. These fish were worth approximately USD1.00 per kg, for canning, a total value of USD4.6 million.

Information supplied by SPC on growth and mortality rates of bigeye (S. Hoyle, pers comm.) was used to estimate that these fish, if left for a little over 2 years, would increase in weight approximately 600%. These larger fish are worth 8.5 times more per kg., meaning each fish could be worth 50 times more in the longline fishery than in the purse seine fishery. After allowing for natural mortality, approximately 1.85 million of these small bigeye would still be alive, available to the longline fishery, if they had not been caught in the purse seine fishery. This could potentially double the present catch of the longline fleet, worth an additional USD650 million per year.

Though this is a “quick and dirty” analysis, it does provide some justification for further study on the loss of revenue to the Pacific due to the catch of juvenile bigeye tuna by purse seiners. A similar analysis could be done to determine the theoretical loss from purse seiners taking juvenile yellowfin, which would also be considerable.

It is the conclusion of the authors of the present study that further research is needed on the impacts of pelagic fisheries on juvenile bigeye and yellowfin tuna. A focal area of such research should be on purse seine fishing, particularly associated with sets around floating objects, with a view to minimizing catch of juveniles.

9. Note on the limitations of social surveys

Collecting anecdotal information in surveys such as this has its limitations. These include accuracy of respondents recall, inclusion of socially or politically desirable responses, or simply a cultural bias against perceived management intrusion within the fishing society. Given the political nature of some aspects of fishing activities at seamounts, some of the information received from interviewing fishers needs to be balanced against their awareness that responses may result in restrictive conditions being imposed. This is particularly so if their activities are perceived to be adversely affecting some species of concern, such as turtles, whales, and sharks. They may also be concerned that information on “secret fishing hot spots” may be made available to other fishermen. However, despite these limitations, information from interviews can provide very useful insights into the longline industry practices and perspectives on fishing at seamounts, which can help direct more scientifically based research in the future.

10. References

Adam, M. S., Sibert, J. R., Itano, D., Holland, K. N. 2003. Dynamics of bigeye (*Thunnus obesus*) and yellowfin (*T. albacares*) tuna in Hawaii's pelagic fisheries: analysis of tagging data with a bulk transfer model incorporating size-specific attrition. Fishery Bulletin. 101: 215-228.

Allain, V., Kirby, D., Kerandel, J. 2006. *Seamount Research Planning Workshop Final Report. Report of the Seamount Research Planning Workshop Held at the Secretariat of the Pacific Community, Noumea, New Caledonia, 20-21 March 2006*. Secretariat of the Pacific Community, Noumea, New Caledonia.

Allain, V., Kerandel, J., Andrefouet, S., Magron, F., Clark, M., Kirby, D., Muller-Karger, F. 2008. Enhanced seamount location database for the Western and Central Pacific Ocean: Screening and crosschecking of 20 existing datasets. *Deep-Sea Research I* 55(8): 1035-1047.

Amorim, P., Figueiredo, M., Machete, M., Morato, T., Martins, A., Santos, R. 2009. Spatial variability of seabird distribution associated with environmental factors: A case study of marine Important Bird Areas in the Azores. *ICES J Mar Sci* 66:29–40.

An, H., Kwon, Y., Kim, D., Moon, D., Hwang, S. 2009. *Effects of set type on catch of small-sized tuna by the Korean tuna purse seine fishery in the WCPO*. Western and Central Pacific Fisheries Commission Scientific Committee Fifth Regular Session, 10-21 August 2009, Port Vila, Vanuatu. Information Paper Number WCPFC-SC5-2009/FT-WP-02. Western and Central Pacific Fisheries Commission, Palikir, Pohnpei, Federated States of Micronesia.

Bayliff, W.H., Moreno, J.I., Majkowski, J. (eds). 2005. Second Meeting of the Technical Advisory Committee of the FAO Project "Management of Tuna Fishing Capacity: Conservation and Socio-economics". Madrid, Spain, 15-18 March 2004. FAO Fisheries Proceedings No. 2. Rome, FAO, 336 pp.

Boehlert, G. W. & Sasaki, T. 1988. Pelagic biogeography of the armorhead, *Pseudopentaceros wheeleri*, and recruitment to isolated seamounts in the North Pacific Ocean. *Fishery Bulletin* 86(3): 453-466.

Bromhead D, Foster J, Attard R, Findlay J, Kalish J. 2003. A review of the impacts of fish aggregating devices (FADs) on tuna fisheries. Final Report to the Fisheries Resources Research Fund. Bureau of Rural Sciences, Canberra, ACT, Australia.

Brothers, N., Cooper, J., Lokkeborg, S. 1999. *The incidental catch of seabirds by longline fisheries: Worldwide review and technical guidelines for mitigation.* FAO Fisheries Circular No. 937. Rome: Food and Agriculture Organization of the United Nations.

Bulman, C. M., Butler, A. J., Condie, S., Ridgway, K., Koslow, J. A., He, X., Williams, A., Bravington, M., Stevens, J. D., Young, J. W. 2002. A trophodynamic model for the Tasmanian Seamounts Marine Reserve: links between pelagic and deepwater ecosystems. *CSIRO Marine Research and Fisheries Research and Environment*, pp. 1-37.

Campbell, R., personal communication, CSIRO Australia, 14 July 2009.

Campbell, R., Hobday, A.J. 2003. Swordfish - Environment - Seamount - Fishery interactions off eastern Australia. Report to the Australian Fisheries Management Authority. CSIRO Marine Research, Hobart, Australia, 97 pp.

FAO. 2007. *The State of World Fisheries and Aquaculture 2006*. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2009. *The State of World Fisheries and Aquaculture 2008*. ISBN 978-92-5-106029-2. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2010. *Guidelines to Reduce Sea turtle Mortality in Fishing Operations. FAO Technical Guidelines for Responsible Fisheries*. Prepared by Gilman, E., Bianchi, G. ISBN 978-92-106226-5. Food and Agriculture Organization of the United Nations, Rome.

Fonteneau, A. 1991. Sea mounts and tuna in the tropical eastern Atlantic. *Aquatic Living Resources* 4(1): 13-25.

Fonteneau, A. 1991. Seamounts and tuna in the tropical Atlantic. *Aquatic Living Resources* 4: 13-25.
Fonteneau, A., Gaertner, D., and Nordstrom, V. 1999. An overview of problems in the catch per unit of effort and abundance relationship for the tropical purse seine fisheries. Collective Volume of Scientific Papers, ICCAT, 49(3): 258e278.
Fonteneau A, Pallares P, Pianet R. 2000. A worldwide review of purse seine fisheries on FADs. In: Le Gall JY, Cayré P, Taquet M (eds) Pêche thonière et dispositifs de concentration de poissons. Actes Colloques-IFREMER 28:15–35.
Forney, K.A. 2004. *Estimates of Cetacean Mortality and Injury in Two U.S. Pacific Longline Fisheries, 1994-2002*. Southwest Fisheries Science Center Administrative Report LJ-04-07, La Jolla, CA, USA. 17 pp.
Gaertner, D., Dreyfus-Leon, M. 2004. Analysis of non-linear relationships between catch per unit effort and abundance in a tuna purse-seine fishery simulated with artificial neural networks. *ICES Journal of Marine Science* 61(5): 812-820.
GFCM. 2005. Guidelines on Sustainable Bluefin Tuna Farming Practices. Scientific Advisory Committee Eighth Session, Tirana, Albania, 25-28 October 2005. General Fisheries Commission for the Mediterranean.
Gillett, R.D. 2009. Fisheries in the Economies of the Pacific Island Countries and Territories. Asian Development Bank, Manila, Philippines. 521 pp.
Gillett, R.D. Personal communication, Suva, Fiji, October 2009.
Gilman, E., Brothers, N., Kobayashi, D. 2005. Principles and approaches to abate seabird bycatch in longline fisheries. *Fish and Fisheries* 6(1): 35-49.
Gilman, E., Brothers, N., McPherson, G., Dalzell, P. 2006a. Review of cetacean interactions with longline gear. *Journal of Cetacean Research and Management* 8(2): 215-223.
Gilman, E, Zollett, E, Beverly, S, Nakano, H., Shiode, D., Davis, K., Dalzell, P., Kinan, I. 2006b. Reducing sea turtle bycatch in pelagic longline gear. *Fish and Fisheries* 7(1): 2-23.
Gilman, E., Clarke, S., Brothers, N., Alfaro-Shigueto, J., Mandelman, J., Mangel, J., Peterson, S., Piovano, S., Thomson, N., Dalzell, P., Donoso, M., Goren, M., Werner, T. 2008. Shark interactions in pelagic longline fisheries. *Marine Policy* 32: 1-18.
Grubbs, R. D., Holland, K. N., Itano, D. 2002. Comparative trophic ecology of yellowfin and bigeye tuna associated with natural and man-made aggregation sites in Hawaiian waters. 15th Meeting of the Standing Committee on Tuna and Billfish, SCTB15, Honolulu, Hawai'i, 22-27 July 2002. YFT-6, 1-21.
Gulland, J.A. (1964) Catch per unit effort as a measure of abundance. *Rapports et Procès-verbaux des Réunions Conseil International pour l'Exploitation de la Mer* **155:**8–14.
Hall MA, Alverson DL, Metuzals KI. 2000. By-catch: problems and solutions. Marine Pollution Bulletin 41(1-6):204-219.
Hall, M. 1998. An ecological view of the tuna-dolphin problem: impacts and trade-offs. Reviews in Fish Biology and Fisheries 8: 1–34.
Hampton, J., Gunn, J. 1998. Exploitation and movements of yellowfin tuna (*Thunnus albabcares*) and bigeye tuna (*T. obesus*) tagged in the north-western Coral Sea. *Mar. Freshwater Res.* 49: 475-89.
Harley, S, Hoyle, S, Langley, A., Hampton, J., Kleiber, P. 2009. Stock assessment of bigeye tuna in the western and central pacific ocean. WCPFC-SC5-2009/SA-WP-4 Report to the 5th meeting of Scientific Committee of the WCPFC.
Hilborn R., Walters C. 1992. Quantitative fisheries stock assessment(Chapman & Hall, New York) Choice, Dynamics and Uncertainty 570 pp.
Holland, K. N., Brill, R.W., Chang, R.K.C. 1990. Horizontal and vertical movements of yellowfin and bigeye tuna associated with fish aggregating devices. *Fish. Bull.* 88: 493-507.
Holland, K. N., Kleiber, P., Kajiura, S. M. 1999. Different residence times of yellowfin tuna, *Thunnus albacares*, and bigeye tuna, *T. obesus*, found in mixed aggregations over a seamount. Fishery Bulletin. **97**, 392-395.
Hoyle, S., Langley, A., Hampton, J. 2008. Stock assessment of albacore tuna in the South

Pacific Ocean. Western and Central Pacific Fisheries Commission, Scientific committee, Fourth Regular Session, WCPFC-SC4-2008/SA-WP-8, Port Moresby, Papua New Guinea, 11−22 August 2008.
Hoyle, S. Personal communication, SPC, Noumea, New Caledonia, October 2009.
IATTC. 2007a. *Stock Assessment Report 8*. Inter-American Tropical Tuna Commission, La Jolla, California, USA.
IATTC (2009). The Fishery for Tunas and Billfishes in the Eastern Pacific Ocean in 2008. 80th Meeting of the Inter-American tropical Tuna Commission (IATTC), La Jolla California, USA, 8-12 JUNE 2009. Document IATTC-80-05. p94–6.
Itano, D., Holland, K. N. 2000. Movement and vulnerability of bigeye (*Thunnus obesus*) and yellowfin (*Thunnus albacares*) in relation to FADs and natural aggregation points. Aquatic Living Resources. 13: 213-223.
Kitchingman, A., Lai, S. 2004. Inferences on potential seamount locations from mid-resolution bathymetric data. Fisheries Centre Research Reports. 12(5): 7-12.
Kitchingman, A., Lai, S., Morato, T., Pauly, D. 2007. How many seamounts are there and where are they located? P. 26-40 IN Pitcher, T., Hart, P., Morato, T., Clarck, M., Santos, R. (Eds.). 2007. Seamounts: Ecology, Fisheries and Conservation. Blackwell Science.
Klimley, A. P., Jorgensen, S. J., Muhlia-Melo, A., & Beavers, S. C. 2003. The occurrence of Yellowfin tuna (*Thunnus albacares*) at Espiritu Santo seamount in the Gulf of California. Fishery Bulletin. 101: 684-692.
Klimley, A., Richard, J., Jorgensen, S. 2005. The home of blue water fish. *Am Sci* 93: 42–49.
Langley, A., Hampton, J. 2008. Stock assessment of skipjack tuna in the Western and Central Pacific Ocean. Western and Central Pacific Fisheries Commission, Scientific committee, 4th Regular Session, WCPFC-SC4-2008/SA-WP-4, Port Moresby, Papua New Guinea, 11−22 August 2008.
Langley, A., Hampton, J., Kleiber, P., Hoyle, S. 2007. Stock assessment of yellowfin tuna in the Western and Central Pacific Ocean, including an analysis of management options. WCPFC SC3 SA WP-1, Honolulu, Hawaii, 13-24 August 2007.
Langley, A., Hampton, J., Kleiber, P., Hoyle, S. 2008. Stock assessment of bigeye tuna in the Western and Central Pacific Ocean, including an analysis of management options. WCPFC-SC4-2008/SA-WP-1 Rev.1, Port Moresby, Papua New Guinea, 11−22 August 2008.
Lawson T.A. (ed), 2008. Western and Central Pacific Fisheries commission Tuna fishery yearbook 2007. Oceanic Fisheries Programme Secretariat of the Pacific Community Noumea, New Caledonia.
Lehodey, P. 1994. Les monts sous-marins de Nouvelle-Caledonie et leurs resources halieutiques. 1-401.
Litvinov, F. 2007. Seamounts: Ecology, Fisheries and Conservation, eds Pitcher TJ, et al. (Blackwell Science, Oxford, UK), pp 202–206.
Lueck, R.G., Mudge, T.D. 1997. Topographically induced mixing around a shallow seamount. *Science* 276: 1831-3.
Mackinson, S., U.R. Sumaila, T.J. Pitcher. 1997. Bioeconomics and catchability: fish and fishers behaviour during stock collapse. *Fisheries Research* 31: 11-17.
Majkowski, J. 2007. Global Fishery Resources of Tuna and Tuna-like Species. FAO Fisheries Technical Paper 483. Food and Agriculture Organization of the United Nations, Rome.
Menard, H.W. 1964. *Marine Geology of the Pacific*. McGraw-Hill, New York.
Molina, A., Ariz, J., Palleres, P., Molina, R., Deniz, S. 2005. Project on new FAD Designs to Avoid Entanglement of By-Catch Species, Mainly Sea Turtles and Acoustic Selectivity in the Spanish Purse Seine Fishery in the Indian Ocean. 1st Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 8-19 August 2005, Noumea, New Caledonia. Fishing Technology Working Paper 2, Scientific Committee, Western and Central Pacific Fisheries Commission, Palikir, Federated States of Micronesia.

Molony, B. 2005. Estimates of the Mortality of Non-Target Species with an Initial Focus on Seabirds, Turtles and Sharks. WCPFC-SC1 EB WP-1. 1st Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, WCPFC-SC1, Noumea, New Caledonia, 8-19 August 2005.

Morato, T., Allain, V., Hoyle, S., Nicol, S. 2009. Tuna Longline Fishing around West and Central Pacific Seamounts. Information Paper. Scientific Committee, Fifth Regular Session, 10-21 August 2009, Port Vila, Vanuatu. WCPFC-SC5-2009/EB-IP-04. Western and Central Pacific Fisheries Commission, Palikir, Pohnpei.

Morato T, Varkey DA, Damaso C, Machete M, Santos M, Prieto R, Santos RS, Pitcher TJ. 2008. Evidence of a seamount effect on aggregating visitors. Marine Ecology-Progress Series 357: 23-32.

Morato, T., Hoyle, S., Allain, V., Nicol, S. 2010. Seamounts are hotspots of pelagic biodiversity in the open ocean. PNAS Early Edition www.pnas.org/cgi/doi/10.1073/pnas.0910290107.

Musyl, M. K., Brill, R. W., Boggs, C. H., Curran, D. S., Kazama, T. K., & Seki, M. P. 2003. Vertical movements of bigeye tuna (*Thunnus obesus*) associated with islands, buoys, and seamounts near the main Hawaiian Islands from archival tagging data. Fisheries Oceanography. **12**(3), 152-169.

Nikaido, H., N. Miyabe and S. Ueyanagi. 1991. Spawning time and frequency of bigeye tuna, *Thunnus obesus*. Bull., Nat. Res. Inst. Far Seas Fish., 28: 47-73.

Parin, N. V., Mironov, A. N., & Nesis, K. N. 1997. Biology of the Nazca and Sala y Gomez submarine ridges, an outpost of the Indo-West Pacific Fauna in the Eastern Pacific Ocean: Composition and Distribution of the Fauna, its communities and history. Advances in Marine Biology. **32**, 147-221.

Parrish FA (2009) Do monk seals exert top-down pressure in subphotic ecosystems? Mar Mamm Sci 25:91–106.

Pitcher, T.J. 1995. The impact of pelagic fish behaviour on fisheries. *Scientia Marina* 59: 295-306.

Pitcher, T., Hart, P., Morato, T., Clarck, M., Santos, R. (Eds.). 2007. Seamounts: Ecology, Fisheries and Conservation. Blackwell Science.

RDA, 2005.

Rogers, A.D. 1994. The biology of seamounts. *Advances in Marine Biology* 30: 305-350.

Romanov, E. 2002. Bycatch in the tuna purse-seine fisheries of the western Indian Ocean. Fish. Bull. 100(1): 90-105.

Safina, C. 2001. Tuna Conservation. Pp 413-459 In: B. A. Block and D. Stevens, eds. Tuna Ecological Physiology and Evolution. Academic Press.

Schaefer, K.M., Fuller, D.W. 2002. Movement, bbehavior, and habitat selection of bigeye tuna (*Thunnus obesus*) in the eastern equatorial Pacific, ascertained through archival tags. *Fish. Bull*. 100(4): 765-788.

Secretariat of the Pacific Community. 2006. *Preliminary Review of the Western and Central Pacific Ocean Purse Seine Fishery. Prepared for the Internal Meeting of Pacific Island Parties to the South Pacific Regional U.S. Multilateral Treaty, March 6-8, Honolulu, Hawaii.* Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia. 18 pp.

Sibert, J., Holland, K., Itano, D. 2000. Exchange rates of yellowfin and bigeye tunas and fishery interaction between Cross seamount and nears-shore FADs in Hawaii. *Aquatic Living Resources* 13: 225-232.

Smith, D.K., Jordan, T.H. 1988. Seamount statistics in the Pacific Ocean. Journal of Geophysical Research. 93(B4), 2899-2918.

Smith, W.H.F., Sandwell, D.T. 1997. Global sea floor topography from satellite altimetry and ship depth soundings. Science. 277(5334): 1956-1962.

U.S. National Marine Fisheries Service. 2006. Endangered Species Act Section 7 Consultation. Biological Assessment. Western and Central Pacific Purse Seine Fishery. Pacific Islands Regional Office, Honolulu, HI, USA. U.S. National Marine Fisheries Service.

Walker, M. M., Kirschvink, J. L, Chang, R. K. C., Dizon, A. E. 1984. A candidate magnetic sense organ in the yellowfin tuna *Thunnus albacares*. *Science* (Wash. D.C.) 224:751–753.

Watson, R. A. Kitchingman and W.W. Cheung. 2007. Catches from world seamount fisheries (Chapter 18). Pp: 400-412 in Pitcher, T.J., Morato, T., Hart, P.J.B., Clark, M., Haggan, N. and Santos, R. (eds) Seamounts: Ecology, Fisheries and Conservation. Fish and Aquatic Resources Series, Blackwell, Oxford, UK.

WCPFC (2007). Briefing Document: Agenda Item 5.3. Bycatch Mitigation- Small tuna on floating objects. Western and Central Pacific Fisheries Commission Informal Small Group WP-6. Scientific Committee Third Regular Session. Honolulu, United States of America 13-24 August 2007.

WCPFC. 2009. *Tuna Fishery Yearbook 2007*. Revised February, 2009. Western and Central Pacific Fisheries Commission, Palikir, Federated States of Micronesia.

Wessel, P. 2001. Global distribution of seamounts inferred from gridded Geostat/ERS-1 altimetry. Journal of Geophysical Research 106: 19431-19441.

Wessel, P. 2007. Seamount characteristics. Pp. 3-25 IN Pitcher, Pitcher, T., Hart, P., Morato, T., Clarck, M., Santos, R. (Eds.). 2007. Seamounts: Ecology, Fisheries and Conservation. Blackwell Science.

White, M., Bashmachnikov, I., Aristegui, J., Martins, A. 2007. Physical processes and seamount productivity. Pp. 65-84 IN Pitcher, T., Hart, P., Morato, T., Clarck, M., Santos, R. (Eds.). 2007. Seamounts: Ecology, Fisheries and Conservation. Blackwell Science.

Williams, P., C. Reid. 2006. Overview of Tuna Fisheries in the Western and Central Pacific Ocean, Including Economic Conditions – 2005. Prepared for the Western and Central Pacific Fisheries Commission Scientific Committee Second Regular Session, 7-18 August 2006, Manila, Philippines. Secretariat of the Pacific Community and Pacific Islands Forum Fisheries Agency, Noumea, New Caledonia, and Honiara, Solomon Islands. 42 pp.

Young, J. W., Hobday, A. J., Ryan, T., Griffiths, B., & Kloser, R. 2004. Spatial variations in micronekton distribution off eastern Australia from nets and acoustics. Pelagic Fisheries Research Programme PI Meeting, Nov.29 - Dec.1, 2004, University of Hawaii, Honolulu, Hawaii.

Appendix 1

List of Fishermen Participating in Interviews

Country	Fishing Vessel	Interviewee
Samoa	Coureur	Viliamu Chu Shing
Samoa	Yellowfin	Russell Finnety
Samoa	Lady Thailand	Samoa Tuifalefa
Samoa	Jay kay	Shay Nicholas
Samoa	Taumaia	Mr Manan Makalaw and Mr Sooty
Samoa	Tifa Aimoana	Tevita Hala
Samoa	Violamanu	Bob Bedford
Samoa	Kingfisher	Alfred Schwalger
Cook Islands	Island of Pukapuka	Kalo Uhrle
Cook Islands	Te Ravakai	Rodney Sparks
Cook Islands	Lady Mary	Tevita Vakasavi
Cook Islands	Ana	Panipasa Gede
Cook Islands	Gold Country	Bill Williams
Cook Islands	Viking Spirit	Dave Pooley
Tonga	Various (Neiufi, Southwind, Rosalind, Marine Princess, Capricorn)	Samiuela Paongo
Tonga	Paragon	Sekonaia Kalapa and Chin Choe
Tonga	Pacific Sunrise	Eti Palu
Tonga	Takuao (1997-2000, Ekiaki in 1994	Siua Finau
Tonga	5-6m sports fishing boat, trolling	Roger Miller
Tonga	Various (Kariel, Kylie, Akina)	Bill Holden
Tonga	Kariel	Simione Lave
Tonga	Various (Capricorn, Sea Star 1, Sea Star 2)	Vailele Taukieoku
Tonga	Provided background information	Soatame Taunaholo
Fiji	Great Ocean	Mr Luke
Fiji	Lady Ama	Nathan Lucas
Fiji	La Bella	Sikeli Tavola
Fiji	San Antone	Aisea Liwaiono
Fiji	Solander 2	Sam Mcgoon
Fiji	Winful 2	Mr Gimgwangseob and Mr. Ma
Fiji	Winful 6	Mr Lee and Mr. Ma
Fiji	Poseidon	Mr Saimone
Fiji	For Ika	John Dansey

Appendix 2

Survey Form
Pelagic Longline Fishing on Seamounts
Gear, Methods, Effort and Ecosystem Effects

INTRODUCTION

Study Purposes: We aim to determine (i) the proportion of pelagic longline effort targeting seamounts; (ii) incentives for targeting/not targeting seamounts; (iii) gear and methods used to fish at seamounts; (iv) amount of depredation that occurs at seamounts; (v) catch rates of target, incidental and discard species when at seamounts; and (vi) implications related to the effects of pelagic longlining on seamount functioning.

Who is Doing the Study: Eric Gilman and Kelvin Passfield are the principal researchers and work for the International Union for the Conservation of Nature (IUCN) (eric.gilman@iucn.org, kelvin.passfield@iucn.org). IUCN is an international membership organization with offices around the world, including the Regional Office for Oceania located in Fiji (http://www.iucn.org/oceania), and an office in Hawaii. The headquarters is in Switzerland. Members include 83 States, 110 government agencies, and about 800 non-governmental organizations. Website: http://www.iucn.org.

This study is part of the Oceanic Fisheries Management Project, funded by the Global Environment Facility. The Project aims to achieve global environmental benefits by enhanced conservation and management of transboundary oceanic fishery resources in the Pacific Islands region and the protection of the biodiversity of the Western Tropical Pacific Warm Pool Large Marine Ecosystem. It is executed by the Pacific Islands Forum Fisheries Agency in con-junction with the Secretariat of the Pacific Community and IUCN. Website: http://www.ffa.int/gef/.

Use of Information and Anonymity: Information collected from longline fishermen will be summarized in an IUCN technical report and other products of the Oceanic Fisheries Management Project. You can opt to keep your identity anonymous. If you provide permission to identify you as a survey respondent, we would include your name in acknowledgements. Results from this study will be summarized so that individual responses and respondents are not identified, e.g., "Most (75%) of respondents replied that they (do or do not catch a larger proportion of subadult tunas at seamounts than at other areas. All respondents indicated that they (do or do not) experience much higher depredation by cetaceans at seamounts."

DATE:
NAME OF FISHERMAN:
NATIONALITY:
F/V:
VESSEL FLAG STATE:
SEAPORT:
TARGET SPECIES:
POSITION ON VESSEL:
NUMBER OF YEARS LONGLINE FISHING:
YEARS LONGLINING FROM THIS SEAPORT:
FISHING GROUNDS:
NO, OF HOOKS SET PER TRIP (AVERAGE)
TOTAL DISTANCE COVERED BY LONGLINE

What do we mean by "seamount": We use the term loosely in this survey, to refer to any underwater feature, including a drowned reef, drowned atoll, bank or mountain, where the summit can be very deep or just below the surface.

1. What is the maximum distance that you normally travel from port to go fishing?

2. Do you ever fish at seamounts?

If NO, why not? (e.g., none at fishing grounds, too far from port, relatively low target species CPUE). End of survey.

If yes, how many trips do you make per year?
On average, how many days does each trip take (from port to port)?
How many sets do you make on an average trip
How many of these sets would be around seamounts?

3. Do other vessels fish at these seamounts.
If yes, how many other vessels do you think use these seamounts regularly
If no, why not (are they not known by other fishermen, are they too far from port, etc)?

4. For seamounts that you fish at that are not known by other fishermen, how did you learn about the seamount's location?

5. How many seamounts do you think are within the EEZ.

6. How many seamounts do you think are within fishing distance of the port?

7. How many seamounts do you fish on regularly?

8. Could you provide the following details of the seamounts on which you fish?

Name of Seamount.	Lat	Long	Shallowest depth	substrate if known (rocky, sand, muddy etc (how do you know?)

9. When do you choose to fish at seamounts? For instance, do you only fish at seamounts seasonally, or when particular oceanographic/atmospheric conditions exist (currents, wind direction or strength, SST)?

10. Why do you decide not to fish at seamounts (e.g., distance, wrong season, wrong oceanographic or weather conditions, too crowded with other vessels, gear conflicts, government restrictions, catch of non-target species is too high, not practical for some reason)?

11. Do you change your fishing method or gear in any way when fishing at a seamount? Please be as specific as possible – draw an illustration if helpful. E.g., do you change the length of your float lines or branchlines, or the depth at which you fish? Do you change the distance between hooks? Do you change the type of bait? Do you set gear upcurrent from the seamount and let it drift over the seamount? Do you change the timing of setting, soak or hauling?

12. Do you use satellite maps (SST, currents, etc.) or other tools differently when at seamounts versus at other grounds?

13. How far away from the seamount can you fish and still see a noticeable effect of the seamount on your catch?

14. Is depredation (removal of your hooked fish and bait) higher, lower, or the same at seamounts vs. at other fishing grounds? Please complete the following table for depredation (% of total bait or fish removed per set.

Depredation by	Near seamount		Greater than 10 NM from seamount	
	Bait taken	Fish taken	Bait taken	Fish taken
Sharks				
Whales				
Dolphins				
Others (specify)				

If depredation is higher at seamounts, do you do anything to try to avoid/reduce depredation?

15. For which fish species, if any (e.g., sharks, marlins, wahoo, tunas), is the catch rate or size of individuals different at seamounts from when not fishing at seamounts? Please complete the following table, in catch per set.

Species caught	**Near seamount**		**Greater than 10 NM from seamount**	
	No/set	**Av wt. Kg. per fish**	**No/set**	**Av wt kg per fish**
Albacore				
Big Eye				
Yellowfin				
Skipjack				
Wahoo				
Dolphin fish				
Marlin				
Swordfish				
Other billfish				
Sharks				
Others (specify)				

16. Is your accidental catch rate or interaction with turtles, birds or whales different when at seamounts? Please complete the following table

Interaction with	Trips affected per year	
	Near seamount	Greater than 10 NM from seamount
Turtles		
Whales		
Birds		
Others (specify)		

17. Do you catch some bycatch species only at seamounts that you don't catch at other grounds? If yes, what are these species?

18. If you catch more non-target (retained or discarded) species at seamounts, do you do anything to try to reduce catching any of these non-target species?
If yes, what?

19. Do see any problems resulting from pelagic fishing at seamounts? Any kind of problem – ecological (e.g., deplete target species, catch rate of turtles high) social (gear conflicts), etc.

20. Should we keep your information anonymous or can we include your name in our report?
THANK YOU