REEF FISHING ACTIVITY IN THE KALEDUPA STAKEHOLDER AREA

Words with the subscript B, I and K indicate Bajau, Indonesian and Kaledupan Names.

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Introduction

Artisanal fisheries are highly important sources of food and income for a vast number of people in the tropics, and continue to have the one of the largest impacts on coral reefs. Yet small-scale fisheries remain understudied and catches, together with their impacts, are mostly un-quantified, let alone managed. The crux of the problem stems from the type of fisheries: multi-species, multi-gear, multi-landing site. To design suitable surveys requires an excellent knowledge of the fisheries, targeted surveys and an indication of changes of daily, monthly and seasonal effort for different fishing grounds, to avoid missing short-term variability. Thus sampling frequency is arbitrarily high, leading to expensive field work. As small-scale tropical fisheries are unlikely to receive sufficient government funding or commercial investment, adequate sampling is normally not feasible.

An alternative approach of using fisher's ecological knowledge as a source of information on fish ecology, on spatial/temporal trends in catch and effort, and relative catches, is beginning to become an accepted method of rapidly gathering information on data poor fisheries. Fisher's knowledge on families and most species of fish is exceptional, and they possess good ecological knowledge of schooling behaviour, spawning times, aggregation sites, territory, feeding and reproduction. This said, careful interviewing is required, where the interviewer must cross-check answers and have a good understanding of what the answers should be and the causes of variation. Furthermore, when using an interpreter he/she must understands the nature of the questions and be able to read the truthfulness of the interviewees response.

Once either catch or interview surveys are completed management options and their implementation for small-scale tropical fisheries suffer from the same cost restrictions as surveys, as well as lack of education, infrastructure, enforcement and economic alternatives to fishing. Part of the problem lies in the simple fact that most over exploited fisheries require fishers to reduce their catches in the short term, either through loss of fishing grounds to form No Fishing Zones (NFZ) or technical restrictions on gear and species size or by a reduction in the numbers of fishers.

This study aims to describe the techniques, temporal and spatial variations of the reef fisheries around Kaledupa, determine the relative importance of fishing to each of the communities and estimate the total catch. Furthermore, the status of the fishery is assessed, and scientifically suitable and potentially acceptable solutions presented.

Materials and Methods

Study Site

The Island of Kaledupa (fig. 1) makes up one of four main islands within the 1.39 million hectare Wakatobi Marine National park. Kaledupa has 78km of fringing reef, with 28-68% live coral cover, and 135km^2 of reef and flat (100-500m wide) above a 30m depth contour, beyond which depth rapidly increases to 150m and plateaus out at 300-400m.

Figure 1. Fishing grounds around the Kaledupan Stakeholder Area, Wakatobi Marine National Park, SE Sulawesi, Indonesia, With the exception of the Lagoon (maximum depth of 5m) at Kt6, Kt8, Kt11 and Kt13, the 3m contour indicates a steep reef wall or slope to 30-200m with average gradient of 1:1. Hoga, H1) Furake Bungeng Hoga; H2) Sampua pogo$_K$ Buli Hoga$_B$; H3) Sampua lanta Hoga$_K$ Buli Hoga$_B$; H4) Gili-Gili$_K$ Buli Hoga$_B$; H5) Pande Bangka$_K$ Buli Hoga$_B$; H6) Ngaromelai$_K$ Buli Hoga$_B$; H7) Umbu$_K$; H8) Toroh Jera$_B$ Hfatusaeau$_K$; H9) Wawonga$_K$; H10) Kompo$_K$ Guson Sumbanga$_B$; H11) One liu-liu$_K$; H12) Sampua Niga$_K$; H13) Ujunelauno$_K$; H14) Watu lanuno$_K$; H15) Silangan Hoga$_B$ Olo Hoga$_K$. Kaledupa East, Kt1) Bungeng Selo$_B$ Langgira$_K$; Kt2) Bungeng Langgira$_B$ Kafudo$_K$; Kt3) Toroh Bunko$_B$; Kt4) Bungeng Sampela$_B$ Sampualanta$_K$; Kt5) Bungeng Pagana$_B$ Sampuawatu$_K$; Kt6) Tekuu$_B$; Kt7) Bintana$_B$ Bakala$_K$; Kt8) Tambalagi$_B$ Wapaiti$_K$; Kt9); Bungeng Solo$_B$ Komoa$_K$: Kt10) Lebo$_K$; Kt11) Ballasuna$_B$ Wapaiti$_K$; Kt12) Luang Kee$_B$; Kt13) Susonan$_B$ Lindapa$_K$. Kaledupa West, Kb1) Toroh Taduna$_B$ Taduno$_K$; Kb2); Taduna$_B$ Sombano$_K$ Kb3); Sampua Koiya$_K$ Kb4) Sampua Manu$_K$ Batu Manu$_B$; Kb5); Watu manu$_K$ Kb6) Mantigola$_K$; Kb7) Latiha$_K$; Kb8) Tee Wali$_K$; Kb9) Tempara$_K$; Kb10) Henandoa$_K$; Kb11) Sampua Kaluku$_K$; Kb12) Tanu$_K$; Kb13) Peropa$_K$; Kb14) Tutu$_K$; Kb15) Watuwatianta$_K$; Kb16) Bahua$_K$; Kb17) Aoa hujawa$_K$ Pandan Jawa$_B$. Lintea, L1) Limbasimbanga$_K$ Langke-langke$_K$; L2) Selo Neselo$_K$ Batu Badi$_B$; L3) Moutanga$_K$; L4) Muliaa$_K$; L5) Shetooge$_K$; L6) Nselo-selo$_K$; L7) Poge Kabalo$_K$; L8) Kangkaru beka$_K$; L9) Darawa$_K$; L10) Onembiha$_K$; L11) P. Gili$_K$; L12) Tonua tolo$_K$; L13) Kokgmo$_K$; L14) Namosalla$_K$; L15) Toroh Lintea$_B$ Belo Belono$_K$; L16) Kaulaisa$_K$; L17) Ujunoumbu$_K$. Lower case letters indicate Bajau ($_B$) and Kaledupan ($_K$) names.

The seasons in the Wakatobi can be divided into four: the South-Easterlies, Northern Calm, Westerlies and Easterly Calm, with two short transition seasons of strong winds, the White Water and Northerlies. Typically the rainy season starts with the onset of the Northerlies and rain decreases in frequency throughout the Westerlies, where unpredictable storms are common. The constant South-Easterlies cause up welling of colder water in the Banda sea and the sea surface temperature drops from around 30°C to 26°C (Tomascik, et al., 1997). Tides are mixed prevailing semi-diurnal, with a maximum tidal range of 2.2m.

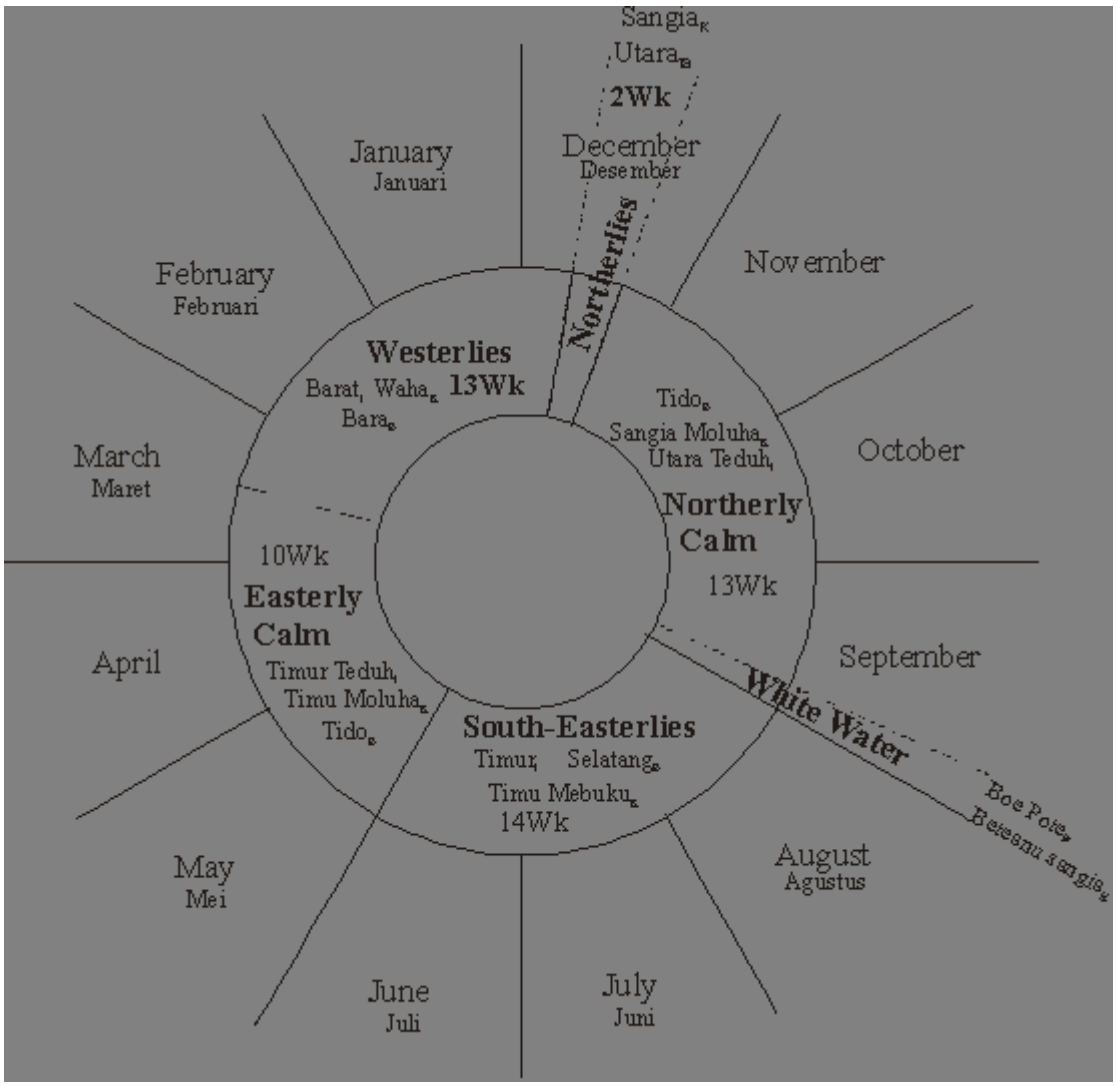


Figure 2. Seasons of Kaledupa, described in cardinal wind directions. Lengths of seasons (WK) are believed to be normally accurate to within 2 weeks.

In the last 3 years the Kaledupa population has increased by 11.7%, from 14,936 to 16,677, and is the second most populated island in the Wakatobi (pop. 76,000). The population consists of two ethnic groups; the land-based Kaledupans who are now predominantly farmers and involved in local infrastructure, and Bajau sea gypsies who have settled in the off shore villages of Mantigola, Sampela and La Hoa, and make up 13% of the population. Both groups rely heavily on fish as a source of protein, with some protein being supplied by chicken and goats.

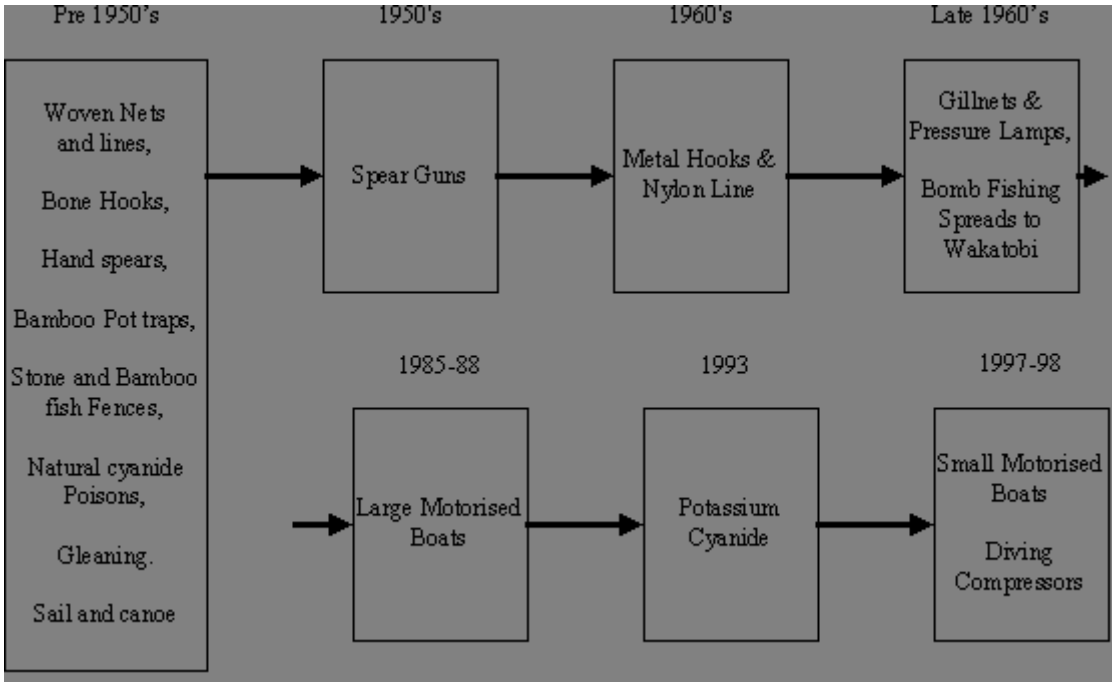


Figure 3. Change in fishing power around Kaledupa in the last 60 years.

Presently, the fishing techniques used around Kaledupa compose of 12 hand line, 12 net (mainly gillnets), 6 traps, a combination of speargun/freedive (sometimes with compressors) and a range of gleaning methods (on foot, by canoe, day or night and with or without spears). Since the 1950's there has been a rapid increase in fishing power, from subsistence low efficiency techniques to highly efficient commercial techniques and the opening up of new market for fish.

Most fish caught around Kaledupa are sold locally, at daily markets in Buranga, Langge and Ambeua, or shared between family and friends (particularly in Bajau villages). In the North Calm season, when catches are large and the price of fish drops, fish is often sold to Wanci or Tomea. Exports from Kaledupa traditionally include dried fish, shark, ray, octopus, and sea cucumber, which are exported to Bau Bau, Kendari and Makassar. Recently a live fish and lobster trade has started up (1993), in which live lobsters and fish, mostly caught at the atolls, are sold to middlemen on the atolls or to middlemen back in local villages. Middlemen then sell on to collector boats with holding tanks, for the export to Hong Kong and Singapore. With the spread of motorboats at the end of the 90's the offshore tuna fishery started which sold its excess catch (usually in the Westerlies, or when exceptionally large tuna are caught), to freezer ships that anchor off Mola, in Wanci. The most recent development has been the fresh octopus fishery, which has expanded rapidly since its start in 1995, and currently supplies fresh octopus to boats carrying ice from Wanci and Kendari, which are then exported to Hong Kong.

Catch Surveys

Catch surveys were run in the NE quarter of Kaledupa from June 2002 to May 2003 on random days once per week. The fishers were stopped at sea, their name(s), time they started fishing, boat, fishing gear, area and habitat were recorded and it was requested that the fishers return to the survey station at Sampela. If this was not possible, the catch to date was weighed to the nearest 0.1kg, identified to species level, the number of each species

counted, and the length of 20 randomly selected fish from each species measured to the nearest 0.5cm and estimated finish time taken. Once they returned to the survey station catch details were taken as above.

Fishers Census

A fisher's census was completed over the whole area of Kaledupa. People who said that fishing was an important source of income or depended on fishing for subsistence were classified as fishers and data regarding the number of days per month spent fishing was recorded, in addition to the primary and secondary techniques used.

Village Interviews

Following the fishers' census, the villages of Darawa, Mantigola, Peropa/Taou and Sampela were selected for more detailed examination of catch and fishing effort, due to the large fisher populations at these sites and representation of the full range of fishing techniques and patterns of those areas. The fishing activities of entire households were surveyed. For each technique and each season, fishers were asked to estimate their catch, where they fished, target species and number of days per month they spent fishing. Questions on catch and effort were repeated several times in different manners to establish a true estimate and cross-checked on previously collected information on catch and effort. In addition, the perceptions of fishers on the change in numbers, species and size of fish over the last 5 years were obtained.

Results

Fishing Techniques

A large number of fishing techniques were recorded by interviews (table 1, 2 & 3), though not all were observed during catch surveys. Predominant techniques were: hand lines on reef flat and slope (including lures or bait on the reef wall at night); trawled lures for tuna; Octopus fishing (using spears, speargun, bamboo stake or fake octopus lure); drive-in encircling gillnet; drive-in gillnet (parallel to the reef); set gillnet (parallel to reef); set gillnet (perpendicular to the reef); speargun (in combination with free dive gleaning); gleaning (on foot, with a canoe, and/ or a spear, day or night); refuge pot traps on the reef flat/crest; and fish fences. Few techniques were used by women fishers, who were mainly Bajau and only Kaledupans used pot traps or fish fences (tables 1, 2 & 3).

Fishing Patterns

Reef fishing and tuna fishing patterns were firstly determined by tides, as all access in and out of villages was restricted to days in the lunar cycle with mid to high tides in the morning. Market times 6am-11am also determined the most reef and tuna fishing. Three clear fishing periods were evedent: morning 5am-11am; afternoon 3pm-5pm; and evening 6pm-4am.

Gleaning is restricted to 3-6 days of extreme low tides per half lunar cycle, where night gleaning was predominant during the few months over the summer equinox and day gleaning was predominant on the couple of months over the winter equinox. Mixed day and night

gleaning occurred in the interim periods. The octopus fishery only occurred during low tides in the day.

Monthly tidal cycles determined the set and active net fishers, who required periods of large tidal flux and limited tidal flux respectively, irrespective of the time of the day, though evenings of moonlight were preferred. Night hand line fishing predominantly occurred during the first 3 days before a full moon, using baited lines and the first 3 days before a new moon, using lanterns and lures.

Seasons determined the timing of Atoll fishing where access to atolls and outer islands was mainly restricted to the calm seasons. However, fishers on the West coast of Kaledupa are sheltered from the South-Easterlies and fish Kaledupa Atoll during this season, giving fishers on the west coast the perception of one long calm season plus the Westerlies period. Tuna is restricted to the South-Easterlies and the Westerlies, as fishers are unable to catch tuna during the calm seasons.

Table 1. Types of hand line techniques used around Kaledupa. Data was collected from direct observations or interviews. Only hand line on reef flat is performed by women.

Technique	Bait/lure	Habitat	Ethnicity	Target Families
$Ngambur_B$ $Birinako_K$ (hand line)	Sardine	Lagoon Reef flat	Bajau & Kaledupan	Lethrinids, Siganids, Serranids & Labrids
$Nguglor_B$ $Hekaulu_K$ (hand line)	Sardine	Reef wall to 100m	Bajau & Kaledupan	Serranids, Lutjanids, Carangids & large Lethrinids.
$Ngaraggu_B$/ $Ngangaragu_B$/ $Ngarinta_B$ $Cigi\text{-}Cigi_K$ (hand jig)	Silk lure	Reef wall	Bajau	Serranids & Lethrinids
$Nyaka_B$ (live small fish with hook through tail)	Live small fish	Reef flat	Bajau	Lethrinids, Carangids, Lutjanids & Serranids.
$Nyampeh_B$ (hand line)	Bread	Reef flat	Bajau	Siganids & Acanthurids.
$Taba\text{-}taba_{BK}$ (night trawl full moon)	Silver lure	Reef flat	Kaledupan	Holocentrids, Priacanthids, & Lutjanids.
$Bena\text{-}Bena_B$ $Mbena\text{-}mbena_K$ (Ngarinta, Ngugllor or Nyaka at night with lamp)	Sardine or Silk lure	Reef wall	Bajau	Priacanthids, Carangids, Sphyraenids & Lutjanids.
Missi $Sangang_B$ (Ngambur or Ngugullor without lamp at night)	Sardine	Reef Flat or Reef wall	Bajau	Lethrinids &Lutjanids.
Missi boroh $kareo_B$ $Kalamba\text{-}lambae_K$ (Benthiclongline)	Tuna, 140m of 25cm long tracers, 4m apart	Oceanic Benthic	Kaledupan	Oceanic Sharks
$Binsa_{BK}$ (hand jig, just off bottom)	Feather lure	Off reef wall, 100m+	Kaledupan/ Bajau	Serranids & Scombrids
$Nyanyambalah_B$	Fake	Near	Bajau	Scombrids

Hekatunda$_K$ (trawled lures)	sardines and flying fish or feathers	shore and Pelagic	

Table 2. Types of net techniques used around Kaledupa. Data were collected from direct observations or interviews. No net techniques are used by women.

Technique	**Width (m); Length (m); Mesh size (In)**	**Net settings**	**Ethnicity**	**Target Species**
Ngambi$_B$ Lamba Tutup$_K$ (seine net with scare lines)	W 3; L 80-200; MS 2-3¾"; 800m scare lines	Surface to bottom: Reef slopes Reef flat	Bajau & Kaledupan	Acanthurids, Lutjanids, Serranids, Lethrinids, Scarids & Balistids
Lamba Tada$_K$ Kiloh$_B$ (fish trap built from coral with coral leaders)	Dead coral walls	Reef flat.	Kaledupan	Acanthurids, Lutjanids, Serranids, Lethrinids, Scarids & Balistids
Ngalabu$_B$ Banto$_K$ (drive-in encircling gillnet)	W 2; L 60-200; MS 1-1½"	Surface: Reef Flat	Bajau	Exocoetids, Hemiramphids, Clupeids, Siganids, Gerrids & Lethrinids.
Ngarua$_B$ Tonabu di Rambisi$_K$ (drive-in gillnet, parallel to reef)	W 1.5-3; L; 50-440; MS 1½ -2¼"	Surface to bottom: Reef Flat	Bajau & Kaledupan	Mullids, Hemiramphids, Lutjanids, Holocentrids, Siganids, Lethrinids, Labrids, Balistids & Scarids.
Ula$_B$ (drive-in gillnet, parallel to reef, at night)	W 1.5-3; L; 90-440; MS 2-2¼"	Surface to bottom: Reef Flat	Bajau	Mullids, Hemiramphids, Siganids, Holocentrids, Lethrinids & Labrids.
Ngampa$_B$ Nilabu$_K$, Nabu$_K$ or Tonabu$_K$ (set gillnet, parallel to reef)	W 1-2, L 50-440; MS 2-2½"	Surface: Reef Flat	Bajau & Kaledupan	Lethrinids, Siganids & Gerrids
Ngampa mate$_B$ Nabu$_K$ or Tonabu$_K$ (set gillnet, perpendicular to reef)	W 1-2;L 50-700; MS 1-1¾"	Surface: Reef Flat	Bajau	Clupeids & Hemiramphids
Bagang$_B$ Kurungkuru$_K$ (two-boat lift net, with lantern at night)	<1"	Reef Flat	Kaledupan	Exocoetids, Hemiramphids & Clupeids
Bando$_{BK}$ (hand lift net)	<1"	Reef Flat	Kaledupan	Clupeids
Jala$_B$ Buani$_K$ (hand cast net)	1"	Reef flat	Kaledupan	Clupeids
Ringgi Pai$_B$ Jari Nuhai$_K$ (ray net)	W 4; L 460; MS 20"	Reef slopes	Bajau	Rays
Ringgi Kareo$_B$ Jari Kodipo$_K$ (shark tangle net)	W 4; L 1000; MS 8"	Reef wall	Bajau	Reef Shark

Catch Surveys

In total 890 catch surveys were performed over 77 survey days, covering all fisheries from June 2002 to May 2003, in the NE of Kaledupa. The Bajo of Sampela represented 97% of the fishers surveyed. For clarity and ease of survey, the fisheries were partitioned into Reef Fish, Gleaning, Octopus, Pelagic and Atoll trips. These fisheries removed 316 species of fin fish, 36 holothurians, 28 gastropods, 17 bivalves, 6 crustaceans, 6 echinoderms, 3 cephalopods and 1 opisthobranch species.

Table 3. Other gear types used around Kaledupa. Data was collected from direct observations or interviews. Only octopus collection and gleaning is performed by women.

Technique	Habitat	Ethnicity	Target Families
$Mana_B$ $Pana_K$ (spear-gun)*[FD]	Reef crest Reef wall	Bajau	Scarids, Serranids, Siganids & Lethrinids.
$Nyarummeng_B$ Tohe $Mata\text{-}mata_K$ (free-dive)	Reef crest Reef wall	Bajau	Holothuriids, Palinurids, Tridacnids
$Ngutta_B$ Nohe $Simbuko_K$ (octopus collection)	Reef flat Reef crest	Bajau & Kaledupan	*Octopus cyanea*
$Ngaligga_B$ (gleaning, using a spear from canoes)	Reef flat Reef crest	Bajau & Kaledupan	Reef flat fish Holothuriids, octopus,
$Nuba_B$ Henga-$hengaro_K$ (day gleaning)	Reef flat Reef crest	Bajau & Kaledupan	Reef flat fish, Holothuriids, octopus, and other inverts.
Nyulu/ Nyulu $neti_B$ Surabi longa/ $bangka_K$ (night gleaning by foot/boat)	Reef flat Reef crest	Bajau & Kaledupan	Reef flat fish, Seacucumber, octopus, and other inverts.
$Bila_B$ $Sero_K$ (fish fence)	Reef flat	Kaledupan	Siganids, Atherinids, Mullids, Lethrinids, Ariids & Scarids
Polo $repe_K$ $Bubu_{Bl}$ (pot trap in mangrove baited with fish)	Mangrove	Kaledupan	Portunids, Calappidae & Palinurids
$Polo_K$ $Bubu_{Bl}$ (refuge pot trap in reef crest or flat)	Reef crest Reef flat	Kaledupan	Mullids, Scarrids, Lethrinids & Labrids
Polo hao_K $Bubu_{Bl}$ (pot trap in reef wall baited with starfish)	Reef wall	Kaledupan	Balistids, Serranids & Lutjanids.
Kulu-$Kulu_K$ $Bubu_{Bl}$ (pot trap in reef wall baited with algal turf)	Reef wall	Kaledupan	Siganids
Polo $ganda_K$ $Bubu_{Bl}$ (pot trap on buoy hanging above reef slope and baited with starfish)	Reef slope	Kaledupan	Balistids
$Saliko_B$ $Gasa_K$ (hand pot trap)	Reef flat	Kaledupan	Siganids, Scarids, Lethrinids & Labrids

$Tuba_B$ $Tofole_K$ (natural poison)*[FD]	Reef crest	Bajau Kaledupan	&	Serranids
	Reef wall			Palinurids
$Potas/Rasong_B$ $Bius_K$ (potassium cyanide)*[FD]	Reef crest	Bajau Kaledupan	&	Serranids
	Reef wall			Palinurids

CPUE & CPFD

CPUE excluding traps ranged from 0.58 kg fisher^{-1} h^{-1} for hand lines on the reef wall to 1.68 kg fisher^{-1} h^{-1} for tuna fishing with hand lines (table 4). However, catch per fisher per day (CPFD) was highest for fish fences at 13.77 kg fisher^{-1} trip^{-1} and lowest for hand line fishing on reef flats 2.47 kg fisher^{-1} trip^{-1} (table 4). Refuge pot fishers owned on average 13 traps, lifting half of them every 2 days.

Table 4. Fishing operations, catch per unit effort (CPUE) and catch per fisher day (CPFD) recorded during 77 survey days around the NE of Kaledupa Island between from June 2002 to May 2003.

	CPUE (SE) **kg fisher^{-1} h^{-1}; *kg fisher^{-1} trap^{-1}soak^{-1}**	**Length of trip (h)**	**CPFD (SE) (kg fisher^{-1} trip^{-1})**	**Number of fishers per operation**
Line (reef flat)	0.85 (0.07)	3:41	2.47 (0.12)	1.0
Line (reef Wall)	0.58 (0.04)	4:43	2.48 (0.17)	1.0
Line (tuna)	1.68 (0.20)	6:19	10.57 (1.30)	1.6
Refuge Pot traps	*0.79 (0.10)	48 h soak (3:52)	5.99 (1.23)	1.1
Fish Fence	*13.77 (1.32)	24hr soak	13.77 (1.32)	1.2
Drive-in encircling gillnet; 1-1½”	0.89 (0.15)	3:55	3.00 (056)	2.1
Drive-in gillnet, parallel to reef; 1½ -2½”	0.86 (0.12)	3:57	3.36 (0.40)	1.7
Set gillnet, parallel to reef 3-3½”	0.65 (0.09)	5:36	3.24 (0.41)	1.7
Set gillnet, perpendicular to reef; 1-1¾”	0.43 (0.13)	6:41	2.62 (0.76)	1.9

Octopus	0.91 kg fisher h^{-1}	Apx 4 h	3.63 kg $fisher^{-1}$ $trip^{-1}$	1.00
Night gleaning (boat)	1.43	3-4 h	5.01	1.09
Day Gleaning	1.25	2:37 h	3.27	1.00
Spear gun/ free dive	0.71 (0.14)	5:10	2.97 (0.31)	1.5

Catch Composition

Lethrinids (17-63%) dominated speargun, line fishing on the reef wall and flat, drive-in gillnets parallel to reef and set gillnets parallel to reef, where as Scaridae (32%) dominated refuge pot traps, Siganidae (34%) fish fences, Clupeidea (83%) drive-in encircling gillnets and Hemiramphidae (81%) set gillnets perpendicular to reef (table 5).

Village Interview

Interviews in the villages of Darawa, Mantigola, Peropa/Taou and Sampela (representing 59% of the fisher population from the census) were used to generate estimates of Effort, Catch and CPFD for all fishing gears (fig. 5, 6 & 7), where effort was recorded as days fishing. Perceptions of fishermen on changes of fish numbers, species and size are shown in figure 8. Generally although most fishermen said there had been a reduction in numbers fish they were unaware of a problem as they tended to change technique from line to net or net to fish fence, and as the numbers have decreased the price has risen. However, older generations or those who cannot afford to change technique believed there was a serious problem and that net fishers were to blame. Fishermen also noted that in the last year the number of fish fences around Kaledupa had doubled.

Table 5 Catch composition of fishing gears around Kaledupa Island during 77 survey days from June 2002 to May 2003. Fish families contributing less than 1% are summed as "other."

Family	**Catch composition (% of total numbers of fish) by gear**								
	Speargun	**Line (reef flat)**	**Line (reef wall)**	**Refuge pot traps**	**Fish Fence**	**Drive-in encircling gillnet; 1-1½"**	**Drive-in gillnet, parallel to reef; 1½ - 2½"**	**Set gillnet, parallel to reef 3-3½"**	**Set gillnet, perpendicular to reef; 1-1¾"**
Acanthuridae			1.9	6.1	1.4		2.0	6.8	
Ariidae					10.5				
Atherinidae					19.5				
Balistidae	2.5	1.4	2.3	3.7				1.2	
Belonidae			2.2		1.5				
Carangidae			6.1		3.3		1.2	1.0	
Chaetodontidae				4.7					
Clupeidea					3.5	82.7	7.9		8.2
Diodontidae	1.5			1.1					
Exocoetidae						13.2			
Gerreidae	2.2	2.6			2.3		2.4	14.8	
Haemulidae	1.2								
Hemiramphidae					3.5	4.0			81.0
Holocentridae	1.2		5.8					5.9	
Labridae	11.1	7.9		6.6	2.8		5.2	5.1	2.8
Leiognathidae								1.8	

Lethrinidae	31.4	63.2	23.7	5.7	5.9		29.3	16.8	
Lutjanidae	2.2	1.5	17.0					7.1	
Monocanthidae									
Mullidae	7.4	2.5	2.4	29.8	2.2		13.5	7.0	2.1
Nemipteridae	2.2	1.8		2.9	1.3		3.1	1.1	1.9
Priacanthidae			2.0						
Scaridae	8.0	1.3		32.0	3.3		9.9	6.1	
Serranidae	5.2	7.2	23.3						
Siganidae	20.3	3.8		3.9	33.7		10.0	16.1	
Terapontidae							1.0	3.7	
Sphyraenidae									
Other	3.6	6.7	13.3	3.6	5.3	0.2	8.9	5.5	2.8

Figure 4a. Estimated total catch per season for Sampela.

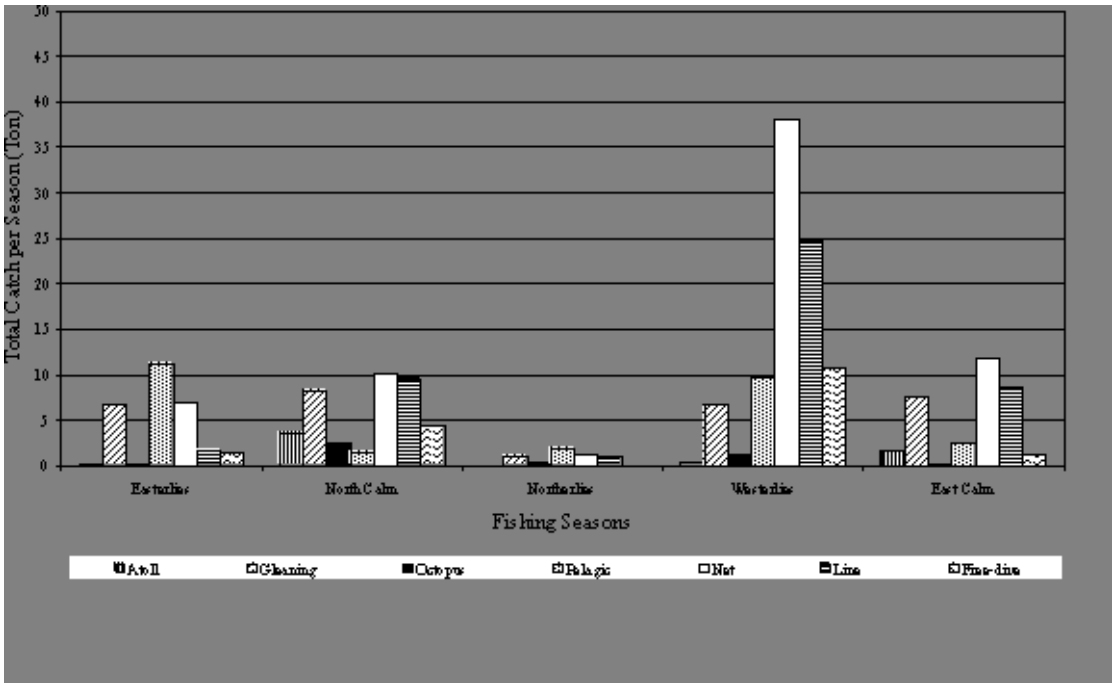


Figure 4b. Estimated monthly fishing effort for Sampela.

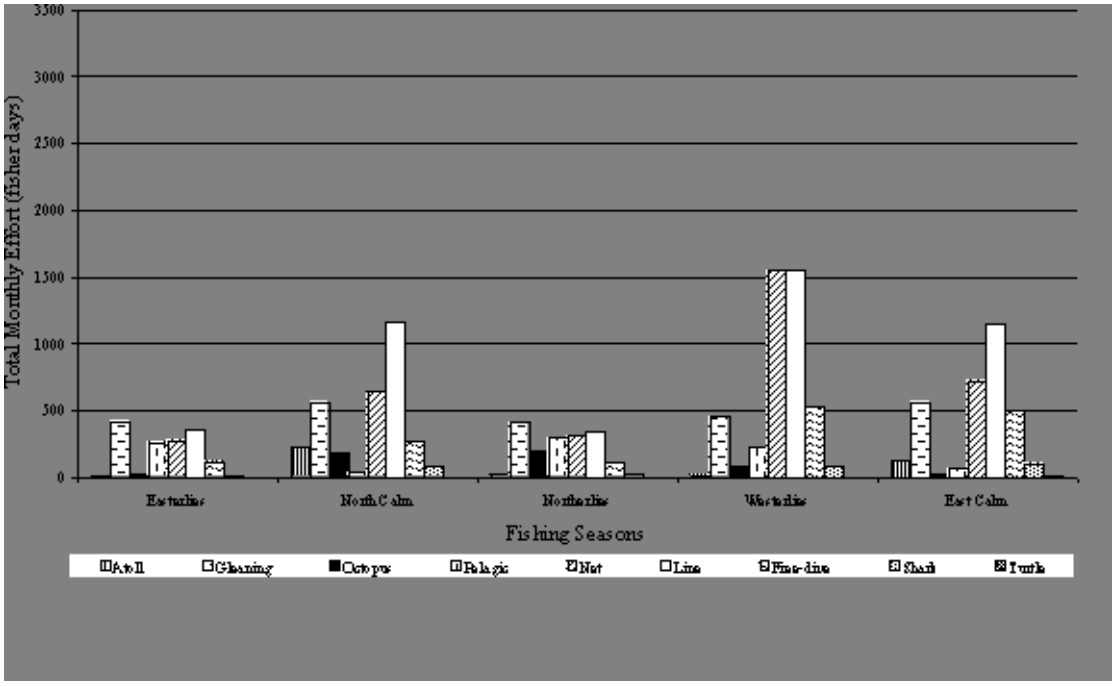


Figure 4c. Seasonal catch per fisher day (CPFD) for fishing techniques around Sampela.

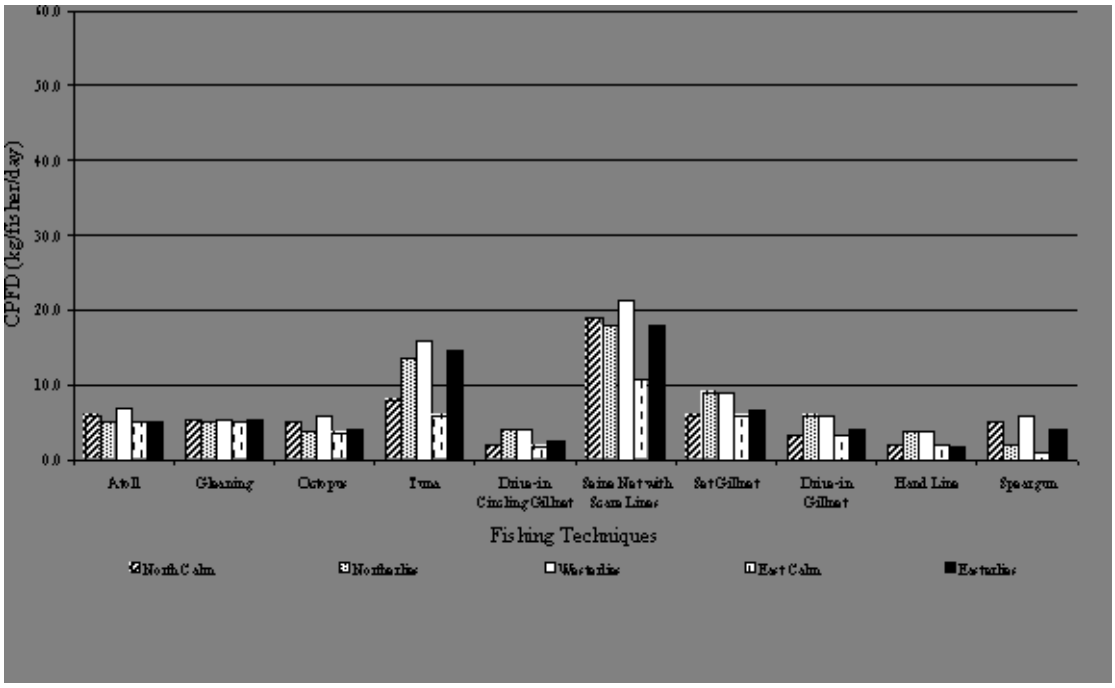


Figure 5a. Estimated total catch per season for Mantigola.

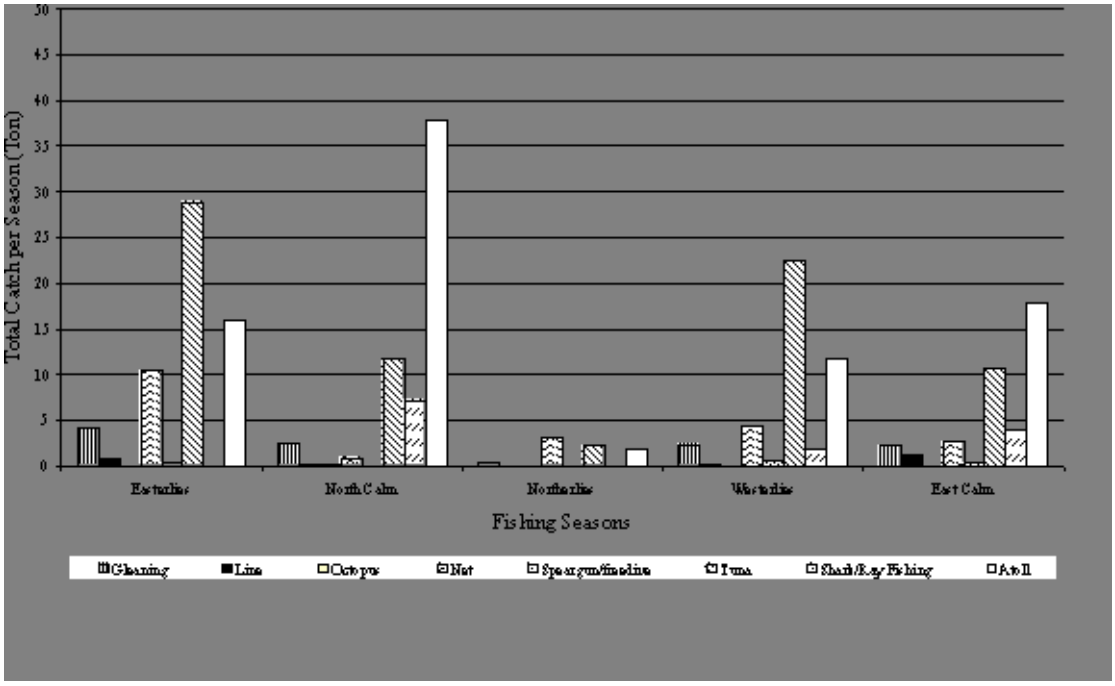


Figure 5b. Estimated monthly fishing effort for Mantigola.

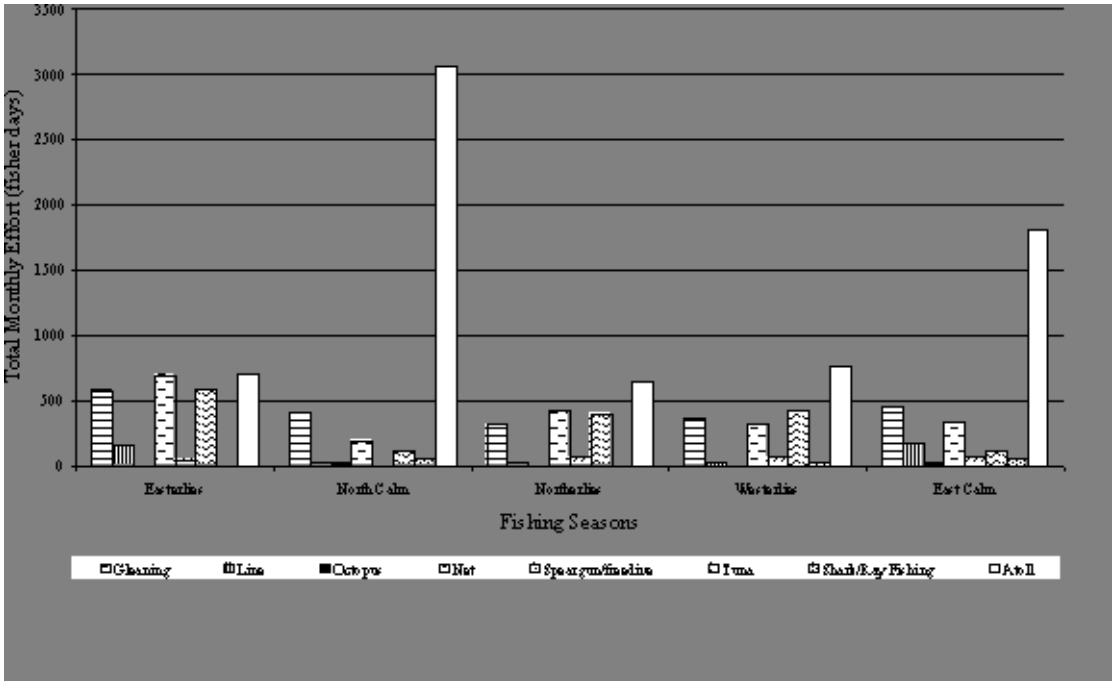


Figure 5c. Seasonal catch per fisher day (CPFD) for fishing techniques around Mantigola.

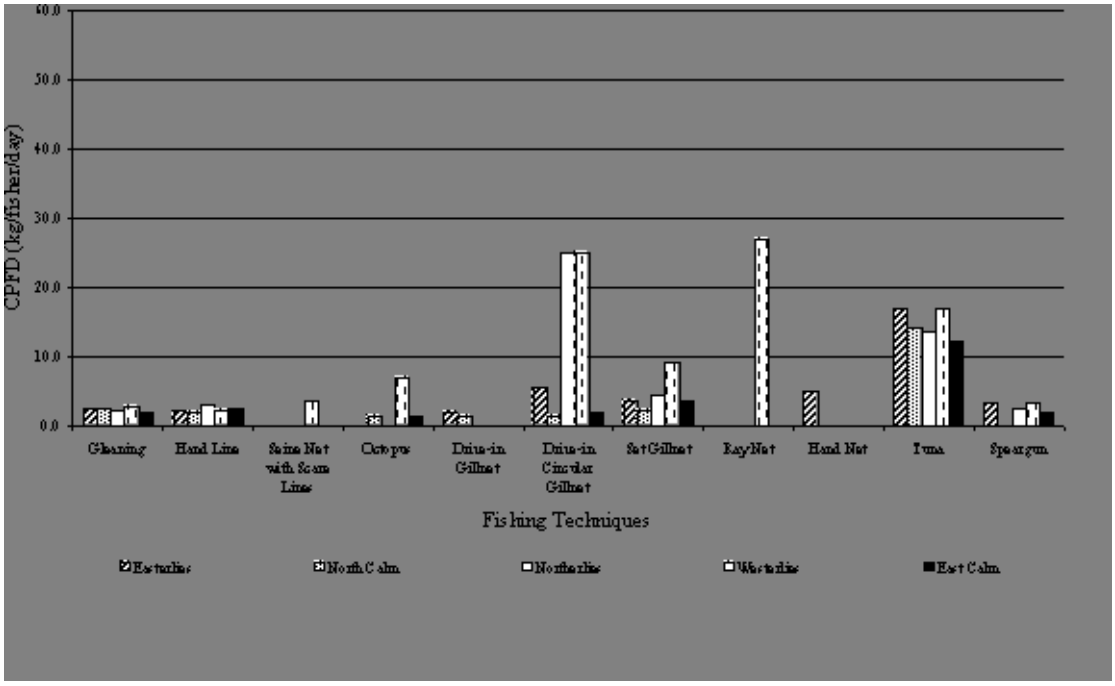


Figure 5d. Seasonal catch per fisher day (CPFD) for Mantigolans fishing Karang Kaledupa.

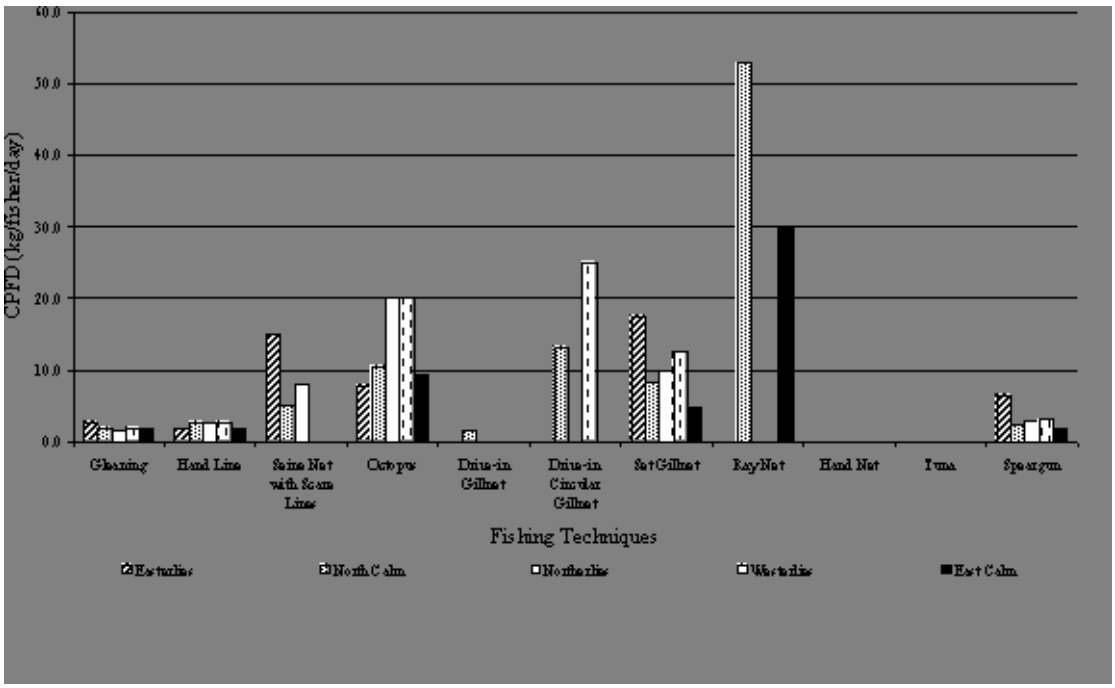


Figure 6a. Estimated total catch per season for Darawa.

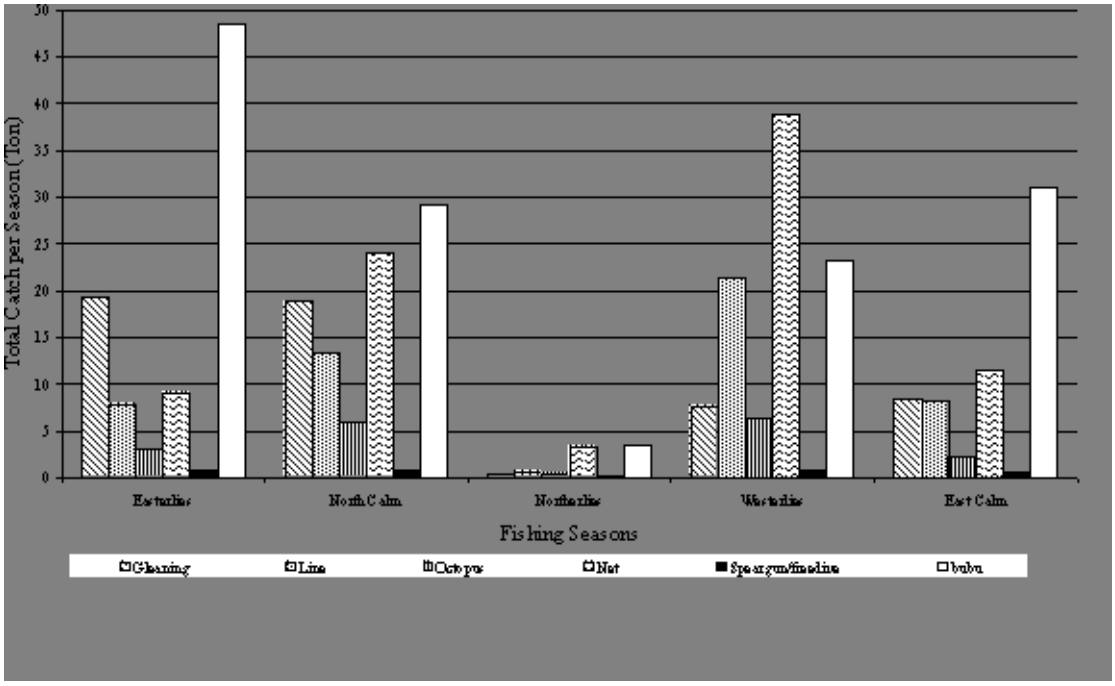


Figure 6b. Estimated monthly fishing effort for Darawa.

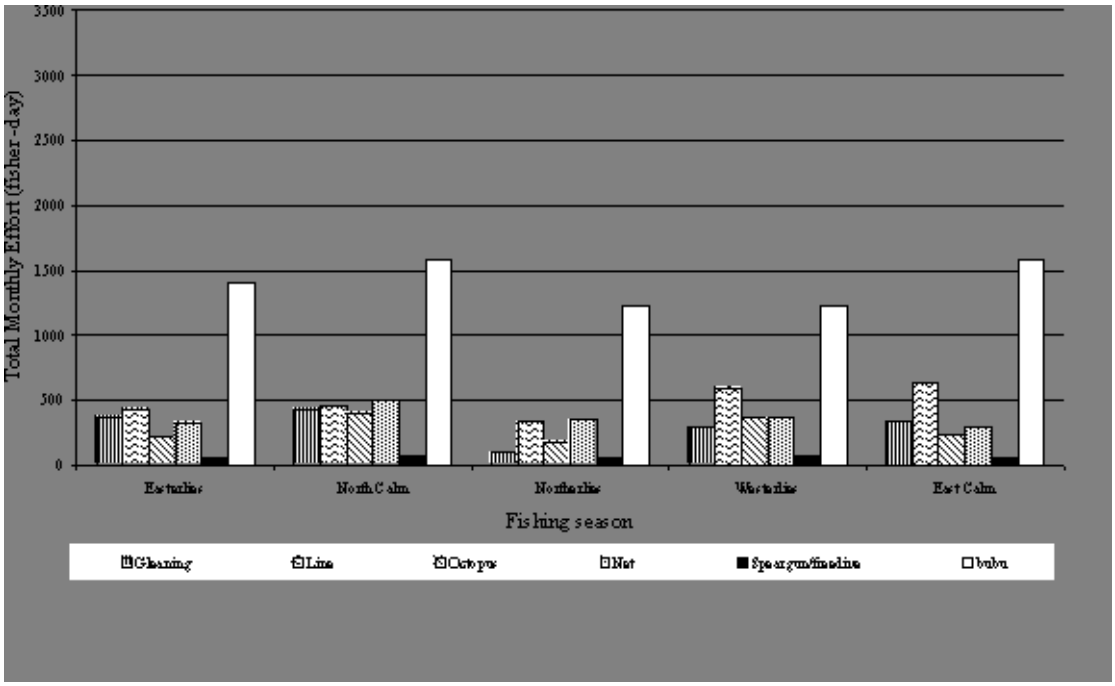


Figure 6c. Seasonal catch per fisher day (CPFD) for fishing techniques around Darawwa.

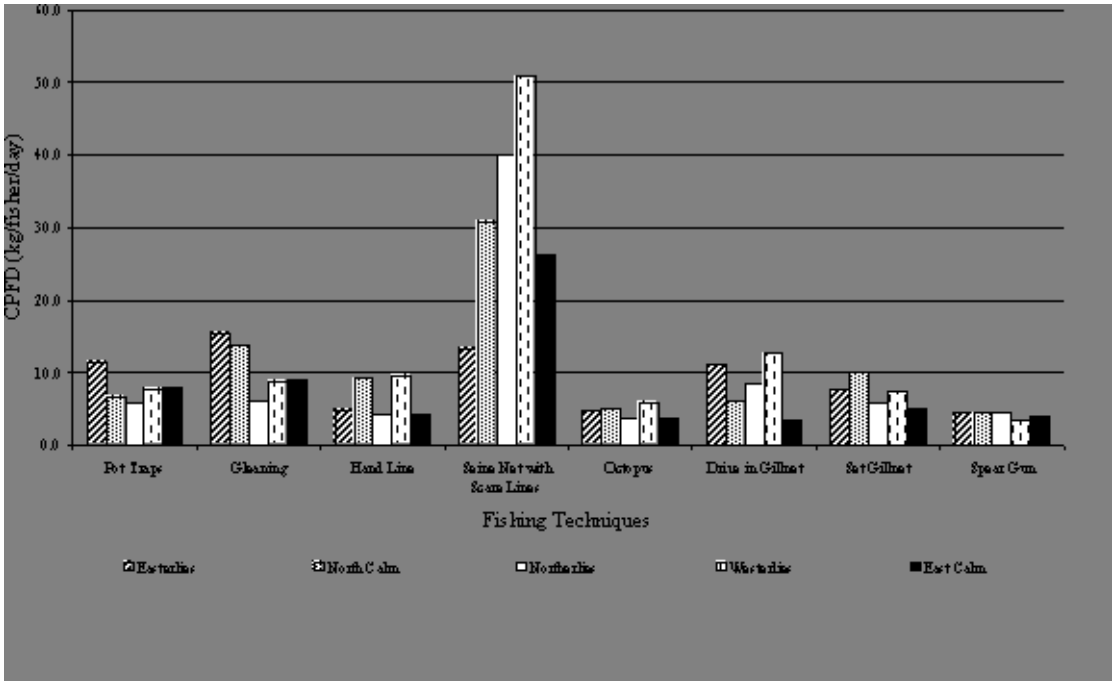


Figure 7a. Estimated total catch per season for Peropa/Taou.

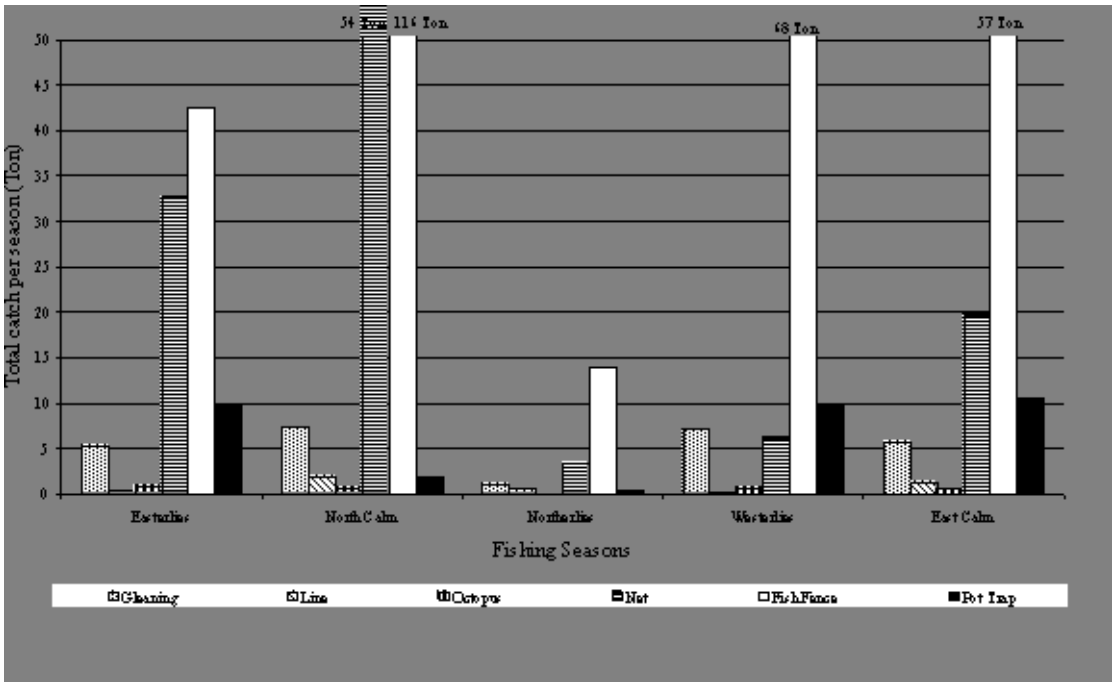


Figure 7b. Estimated monthly fishing effort for Peropa/Taou.

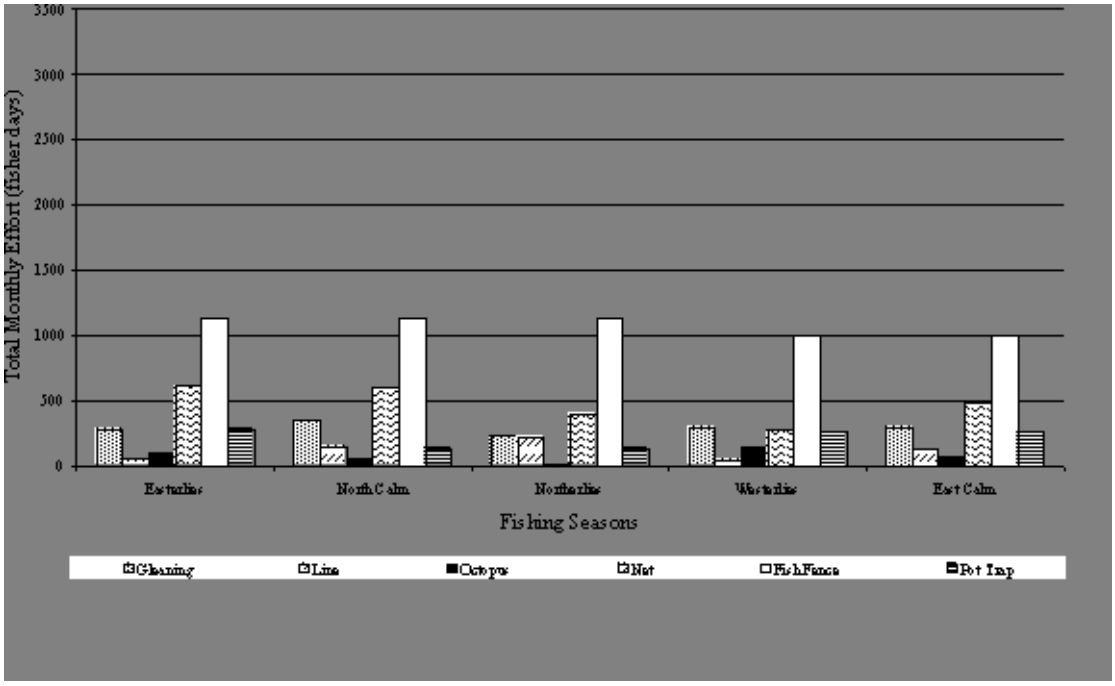


Figure 7c. Seasonal catch per fisher day (CPFD) for fishing techniques around Peropa/Taou.

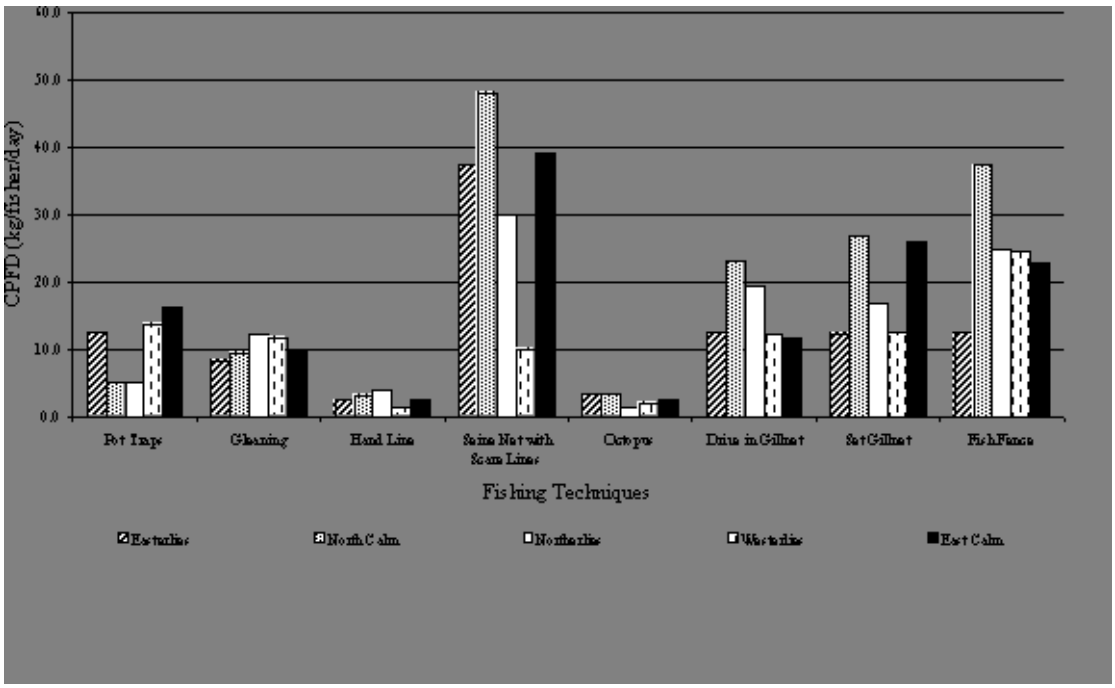


Figure 8a. Perception of 87 fishermen on the change of the size of species caught over the last 5 years.

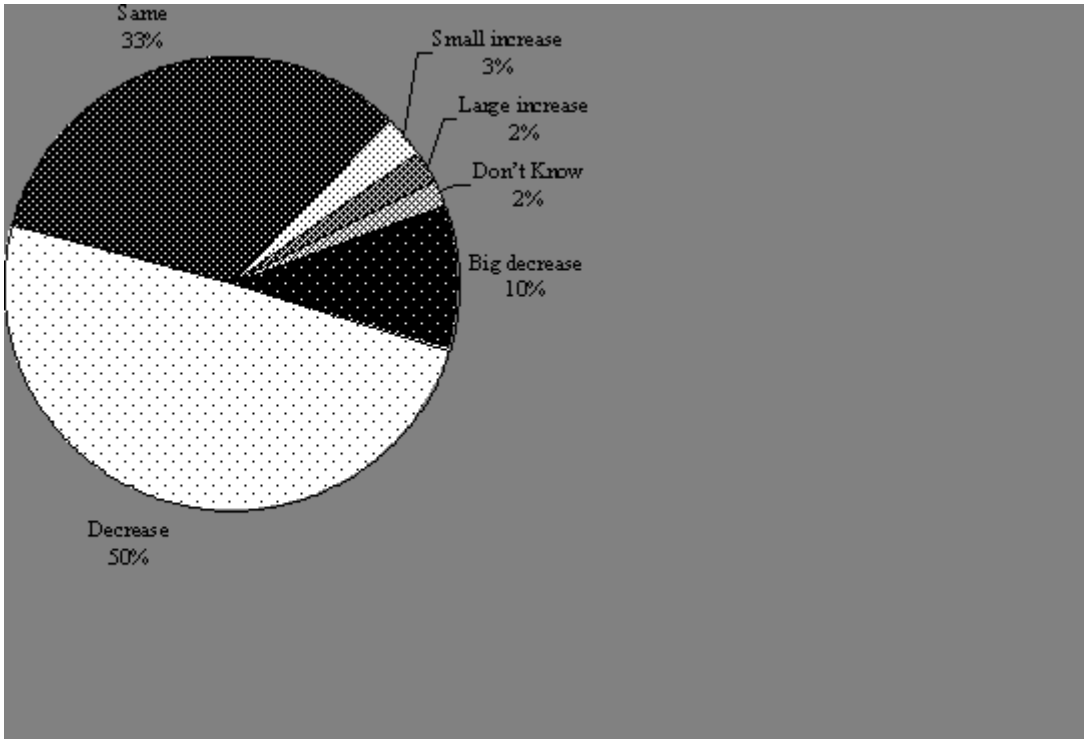


Figure 8b. Perception of 87 fishermen on the change of the number of species caught over the last5 years.

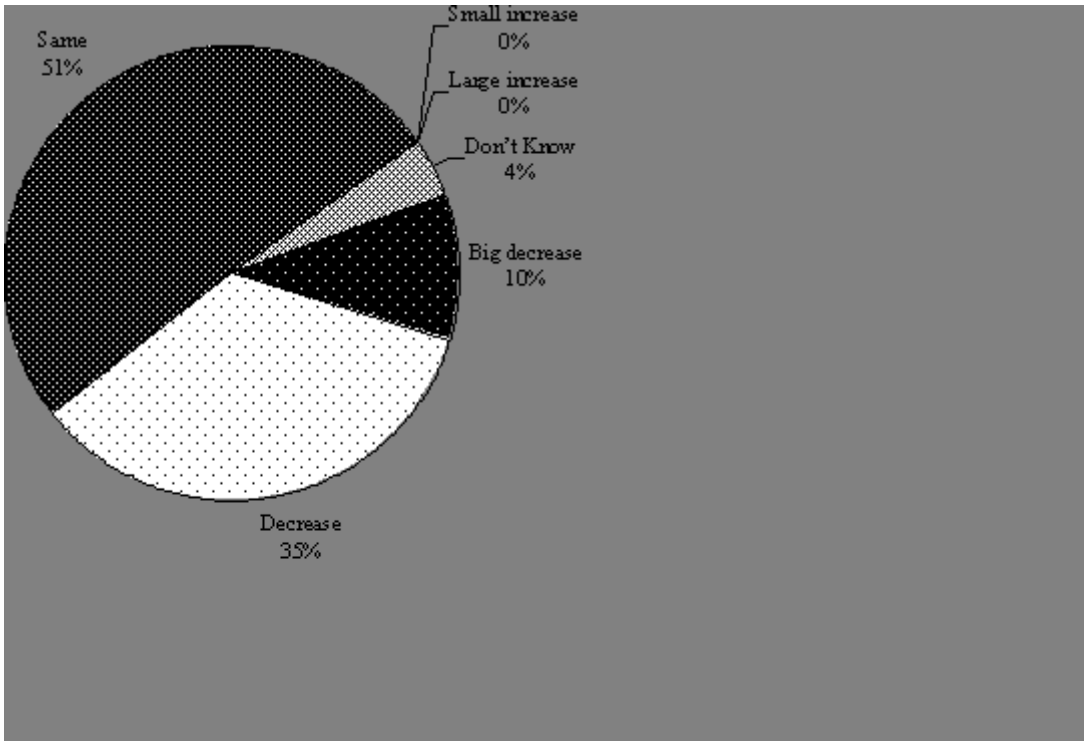


Figure 8c. Perception of 87 Fishermen on the Change of the Number of Fish Caught Over the last 5 Years

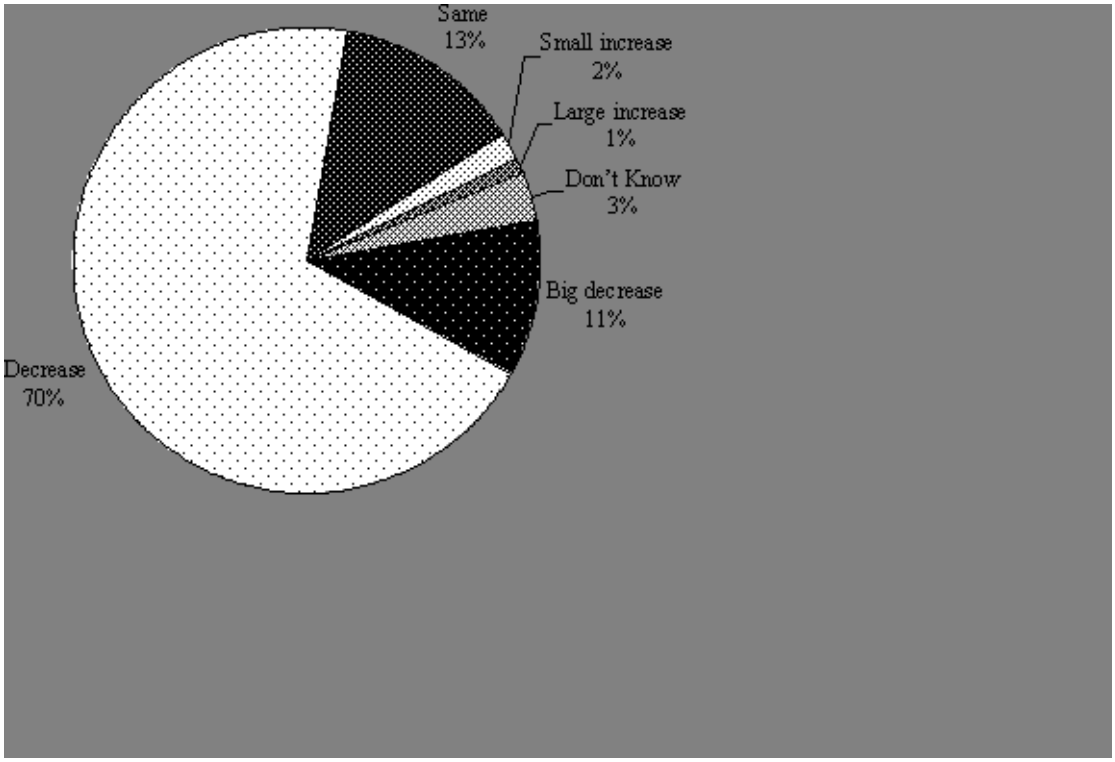


Table 6. Perception of 24 Bajau and 24 Kaledupan fishers to fisheries management options, asked the question "Do you agree or disagree on the rules for…"

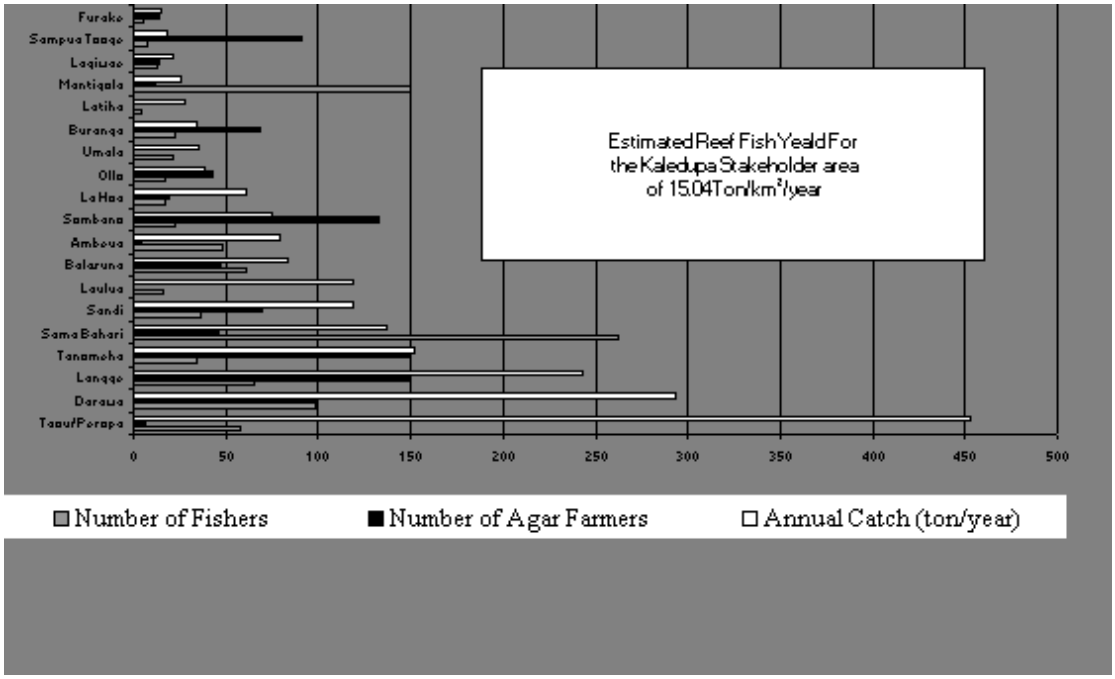
	Percentage response			
Kaledupans	**Yes**	**No**	**Unsure**	**No Comment**
The number of fishers in Kaledupa?	38	58	0	4
Outsiders fishing in Kaledupa?	96	4	0	0
Bomb fishing?	100	0	0	0
Cyanide fishing?	100	0	0	0
Net mesh size?	67	33	0	0
Net length?	54	38	0	4
Hook size?	54	38	0	8
Compressors?	83	8	0	4
Returning small fish/lobsters/Seacucumbers?	92	8	0	0
Giant clam collection ?	54	46	0	0
Turtle?	79	13	0	4
Shark?	58	29	0	4
Napoleon wrasse?	4	13	0	4
No fishing zone?	75	8	0	0
Extending the no fishing zone?	63	21	0	4
Creating another no fishing zone?	38	50	0	0
Zoning agar beds?	75	21	0	0
Allowing fishing in agar beds?	21	79	0	0
Bajau	**Yes**	**No**	**Unsure**	**No Comment**
The number of fishers in Kaledupa?	40	48	8	4
Outsiders fishing in Kaledupa?	96	4	0	0
Bomb fishing?	100	0	0	0
Cyanide fishing?	92	4	0	4
Net mesh size?	64	32	0	4
Net length?	36	60	0	4
Hook size?	12	88	0	0
Compressors?	92	8	0	0
Returning small fish/lobsters/Seacucumbers?	76	20	4	0
Giant clam collection?	4	60	36	0

Turtle?	36	48	12	4
Shark?	4	96	0	0
Napoleon wrasse?	28	68	4	0
No fishing zone?	92	8	0	0
Extending the no fishing zone?	64	36	0	0
Creating another no fishing zone?	36	64	0	0
Zoning agar beds?	92	4	0	4
Allowing fishing in agar beds?	84	12	4	0

Fisher's Census

The fisher's census identified 956 people, in 19 Kaledupan villages, 5.7% of the island's population, that were classified as fishers, with the Bajau representing 45% of the fishers of the total number of fishers. The census also identified 965 agar farmers, some of which also classified as fishers. Concentrating solely on reef fin fish, the interview and census data were combined to provide an estimate of the total catch and yield of reef fin fish for Kaledupa, 2031 ton/year and 15.04ton/km^2/year respectively. These figures include pelagic species caught on the reef flat or wall and reef fin fish caught during gleaning. Estimated catch for Kaledupa indicates that 11% of the reef fin fish are caught by the Bajau.

Figure 9. Estimated annual catch of reef fish, number of fishers and number of agar farmers within the Kaledupan stakeholder area.



Discussion

Kaledupa Island has multi-species and multi-gear fisheries, with varying degrees of subsistence artisanal and small-scale commercial fisheries, the intensities of which are defined by strong lunar and seasonal patterns. Interview generated CPFD for Sampela was found to correspond to NE Kaledupa CPFD from catch surveys, and thus illustrated that interviews can be important tools in the estimation of effort, catch and CPFD. This preliminary

study found that estimated reef fish yield for all Kaledupa (15 ton $km^{-2}y^{-1}$), NE Kaledupa CPUE (0.58 to 1.68 kg $fisher^{-1}$ h^{-1}), NE Kaledupa CPFD (2.47 to 13.77 kg $fisher^{-1}$ $trip^{-1}$) fulfilled the criteria for an unmanaged, overexploited fishery. The rapid increase in fishing power and general consensus that stocks have declined over the last 5 years, indicates that fishing may well have exceeded the maximum sustainable yield. Anecdotal evidence points to a reduction in the numbers of piscivores and commercially-fished species, and the loss of a number of species, indicates over-fishing and possible ecological change. In the last year 3 years the lobster and near shore tuna fisheries have collapsed around Kaledupa and many of the most valuable sea cucumber species have become commercially extinct. It is likely that further analysis, i.e. the percentage of fish caught below the size of maturation, will reveal additional indications of over fishing, and management implications for specific gears.

The protein source for almost all Kaledupans is fish. As the population of Kaledupa is likely to increase in the foreseeable future, the yield must increase to sustain growth without an alternative source of protein, which can only be achieved by management. Currently, without management, preliminary results of this study indicate over exploitation, which with the increase in demand for fish will cause the fisheries to collapse in the near future.

There are several combinations of factors which are likely to be reducing fishing yield around Kaledupa. As this study suggests fishing is beyond the Maximum Sustainable Yield (MSY), and any increase in effort will have a negative effect on yield. Due to the reliance on the sea for food and a last source of employment, fishing effort will only continue to increase with population growth. As fish stocks decline though reef fishing will no longer become an economically viable alternative for many fishers leading to greater unemployment particularly amongst the Bajau communities where land resources are not available to provide alternative income sources.

Agreed management action to reduce fishing effort in the short term is required. A well managed reef fishery can produce 2 - 3 times the current yields which would support the growing population. However, without reduction of effort to allow the fishery to recover and the MSY to be achieved, the spiral of decline will continue. The first step has to be restricting access to the fishery by allowing only fishers from the island of Kaledupa to participate. This could be achieved by registration of the boats, gear and fishers currently operating and then via a system of village appointed reef guardians and a strengthened ranger capacity to enforce the registration. Meetings of the Kaledupa Stakeholder Area have consistently supported this concept and there is great anger at the influx of external fishers using very efficient techniques (eg a 1km gill net used by a Wanci fisher) or destructive techniques (eg the contract bomb fishers operating from the village of Mola on Wanci). Once fishery registration is in position many more management options are available. For example types of fishing gear can be limited (eg mesh size) and in cases where the fishery impact is too great (eg fixed fences and pot traps) the fishing licences can be bought out to reduce fishing effort immediately.

The uncontrolled seasonal exploitation of fish aggregation sites also needs to be restricted, particularly with the projected increase in fishers and catch demand. Targeting these sites during aggregation times can not be efficiently controlled by technical measures which generally limit the lower sizes of fish caught, as fish fecundity increases almost exponentially with fish size. Exclusion of fishers may not be viable as such fishing practices are traditional, though it now seen as a major source of income, via the live fish trade. The solution to this may be to develop one no fishing zone on one aggregation site and develop community controlled aggregation sites similar to the one seen in Darawa on the other sites. The headman of Darawa leads the community to actively enforce a ban on bomb and cyanide fishing at L 15 (fig. 1), because they believe it destroys agar, and they also ban compressor use, because fishers using compressors tend to use cyanide. Furthermore, they keep commercial fishers (from outside the Kaledupan Stakeholder Area) away by charging them Rp5,000 each fisher per day. This system seams to work protecting the reef from long term damage and maintaining a potentially high yield, which may explain why the catch at Darawa is higher than elsewhere around Kaledupa. Such community organisation and continual support is dependent on the large number of agar farmers with agar beds in the most

productive area, behind the reef crest of the aggregation site. This system could be repeated at the aggregation sites at Kb 1 and the tip of H 1, with the addition of checks on the size of grouper caught, which the headman of Darawa was also concerned about.

Economic alternatives to fishing, although possible to develop with time (eg fish farming, lobster ranching, development of farmed chicken as an alternative protein source, intensification of agar cultivation etc) are not going to be able to provide the immediate solution required to prevent the Kaledupa reef fishery from collapsing. However, being able to develop some of these activities would additionally increase the protein sources and the employment opportunities on the reefs and need to be explored.

For any of these technical measures or effort restriction to be implemented awareness of the problems will need to be raised, which requires extension officers and education programs. Generally, CPFD's estimates from interviews for all gear types were in the ranges of those found in most reef fisheries associate with over exploited fisheries. However, the low CPFD's in combination with the high effort has generated large catches in Darawa and Peropa/Taou. Large catches and the increase in numbers of fish fences, is likely to mask obvious signs of over exploitation to Kaledupan fishing communities. Bajau fishing communities have expanded traditional tuna and atoll (particularly Mantigola) fisheries, which are also likely to hide signs of over exploitation to the Bajau communities. This is reflected by the view point of most fishers, that fish stocks have declined but due to price increases or new techniques, they do not perceive a real problem. This view is not accepted by local middlemen, who are more economically sensitive to fluctuation of catches, and many are receptive to the idea of management restrictions. Responses to interviews on the acceptability of management options (table 6), indicated that fishers are not adverse to change or restrictions, and that there is an understanding, or at least belief in the value of fisheries restrictions.

This study indicates that under the current level of fishing, the Kaledupan fisheries are over exploited and will be required to supply a higher yield in the near future, which can only be reached through effective management. The willingness amongst the local communities is there, as evidenced by the formation of village level reef conservation committees and the island level Kaledupa Stakeholder Area committee. In addition a research organisation (Operation Wallacea) is based within the Kaledupa Stakeholder Area and willing to provide technical assistance. The addition of the community facilitator and community education programmes of COREMAP Phase 2 and the capacity strengthening of the National Park rangers being undertaken by TNC/WWF, provides an ideal opportunity to use the Kaledupa reefs as a 'best practice' example of fishery management which could be used to inspire other communities to adopt similar approaches.