Kaledupa Fisheries Report
May 2009

Overview

The Wakatobi marine National Park ranks as one of the highest priorities for marine conservation in Indonesia because of the diversity of species, reef condition, and the opportunity to protect such a large network of Marine Protected Areas. Like many of Indonesia's marine environments, Wakatobi National Park's (the yellow box Figure 1) diverse coral habitats are threatened by overfishing and destructive fishing practices.

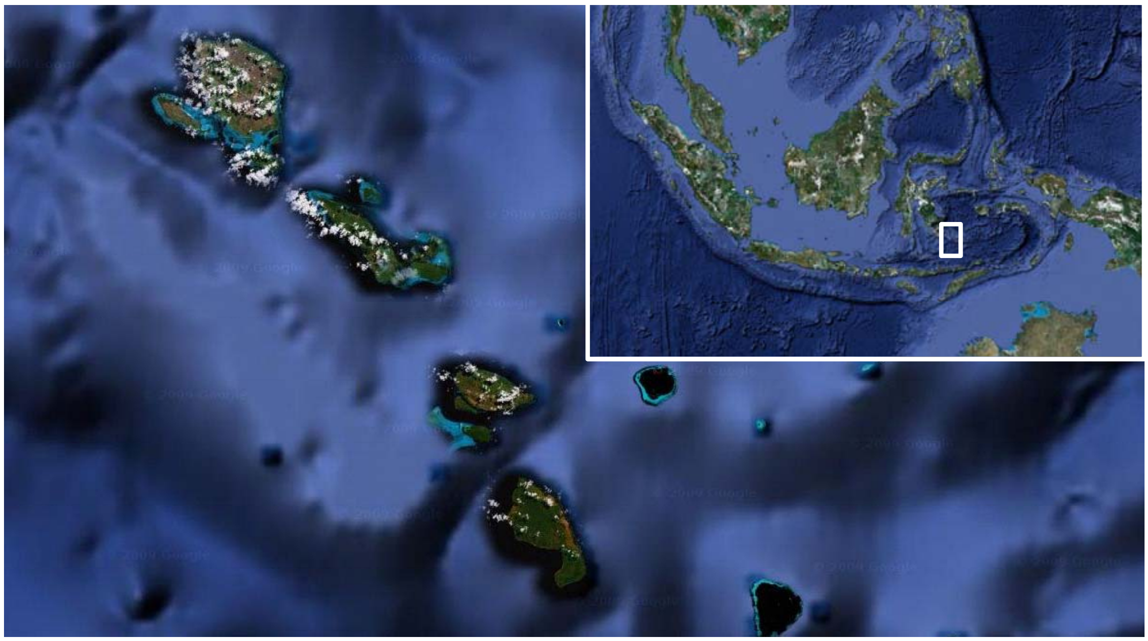


Figure 1: The main islands that form the Wakatobi archipelago: Wangiwangi Island, Kaledupa, Tomea, and Binongko.

One of the main problems on Indonesian coral reefs is over-fishing by local people using small scale or artisanal techniques. Until recently artisanal fishing has been regarded by the Indonesian government as too small scale to have any significant impact on reef fisheries. As a result there has been no legislation to restrict fisheries on coastal reefs and in many parts of the archipelago the reef fishery has been seriously impacted. An example of this is on the reefs around Kaledupa Island in the Wakatobi Marine National Park, SE Sulawesi in Indonesia. Scientists and university students as part of annual biodiversity and fisheries surveys funded through Operation Wallacea have studied these reefs and the fishery since 1996. The results from these surveys demonstrated a fishery that was in serious decline with average catch per unit effort at 10% of levels in other parts of the Pacific and evidence of some species being commercially extinct.

The Darwin Initiative funding was obtained to demonstrate how a reef fishery could be managed sustainably by using financial incentives. The advantage of using Kaledupa Island was the long-term presence of Operation Wallacea at the site to provide the monitoring data to assess the effectiveness of the scheme, the support (with powers devolved from central government) of the Wakatobi government in implementing the political changes needed, the existence of a strong fishers based NGO and a strong desire from the local fishers to manage their own fishery and stop the decline in their incomes.

The proposed scheme works by registering all the fishers and their boats on Kaledupa. This registration has proved popular with Kaledupan fishers since it prevents fishers from other islands utilizing their reefs. Once the scheme is fully implemented though the objective is to reduce overall fishing effort to ensure the fishery begins to recover by offering businesses for up to 30% of the fishers in exchange for surrendering their licences. The fishers coming out of the fishery would therefore only do so if the businesses created more income than continuing to fish the reefs, whilst those that remain in the fishery then have a licence with a value equal to that of the income created from the businesses for those 'selling' their licences. These remaining stakeholders would be allowed to trade the licences amongst those on Kaledupa or use them as collateral for raising funds. This scheme needs local byelaws introducing by the Wakatobi government and a Kaledupa Fishers Forum created to actively manage the reef fishery. A weekly fishery monitoring programme has been implemented to provide data by which the Forum can take the necessary decisions to maximise the sustainable yield from the reefs.

Summary of the Status of fisheries

From July 2007 until May 2008 Fisheries Monitors employed as part of the Darwin Initiative recorded 161,000, and 36,600 fish caught from June 2008 to April 2009 by fishermen in 9 villages on Kaledupa. Note that the difference in the number of fish recorded corresponds to the number of individual monitor days, which were three times as many during the 07/08 season as the 08/09 season. Catch Per Unit Effort (CPUE) was calculated for each fishing technique and this, along with analyses of species composition, percentage maturity, and percent change from previous years were used to assess the health of the reef fisheries around Kaledupa.

CPUE: Local fishermen's perceptions in Kaledupa are that catches and sizes are decreasing although there are few historical data with which we can compare current analysis. A six week survey in 2005 provides some comparisons with contemporary CPUE and the general picture from this year's data is one of gradual decline, although some villages are performing better than others. Darawa is consistently ranked highest in CPUE comparisons, particularly for gillnets, although for several techniques there are only a few samples so further analysis is required. Sombano is consistently ranked lowest or second lowest in CPUE comparisons for all villages and shows the most concerning change of all the data, with CPUE for gill net set parallel now just 10 % of what it was in 2005.

Catch composition analysis highlights the dependence of the fishery on four main families, Lethrinidae, Mullidae, Scaridae and Siganidae. Although there is geographical variability in the abundance of particular species caught by each technique, where there are sufficient samples to be confident in the data, 2 species from Siganidae, 2 species from Mullidae, 5 from Lethrinidae and a wide variety of Scaridae form a large proportion of many catches.

The dominance of certain species makes the results from **percentage maturity analyses** even more concerning because common species in the catches that mature at sizes greater than 20 cm are being caught before they have the opportunity to spawn. In fact, 82 % (for July 2007- May 2008) and 87% (June 2008- April 2009) of *all* species that mature at a size greater than 20 cm are caught before they are mature.. In general, the largest species such as groupers and trevallies, precisely those species that are highly sought after by divers, recreational anglers and fishermen, are caught many years before they spawn. For several of the larger species, not a single mature individual was recorded in catches from July 2007- May 2008 nor June 2008- April 2009. Suggestions of improvements to data collection, analysis, and some tentative management recommendations are also given.

Introduction

This is the 4th Kaledupa Fisheries Report produced by the Darwin Initiative with the intention of being used to compare fisheries data from the same season each year with data from consecutive years, as well as data from Kaledupa in relation to similar reef fisheries in South-East Asia and the Western Pacific. The report presents a template for future reporting by local Darwin Initiative Kaledupan staff, a responsibility which they will take in the future. This report expresses fisheries issues in a clear, uncomplicated style so that fisheries information can be understood by the general public and Kaledupans may appreciate and support management recommendations.

Due to problems with the database, previous reports were only based on data from July-September 2007. The 3rd Kaledupa Fisheries Report was based on 11 months of data (July 2007- May 2008), this report covers the following 11 months (June 2008 – April 2008) so at the time of writing this report there were 22 months of data to analyse (though April was not complete). Catch composition and percentage maturity are also calculated, making this a long report with many tables that contrast the 07/08 season with the 08/09 season. As a consequence, each of the main sections starts with a summary of all techniques averaged throughout the season before subsequent sections go into more detail.

Detailed tables of CPUE per quarter and catch composition per technique will prove invaluable benchmarks for future analyses and will help the KFF form targeted seasonal or geographical policies rather than only blanket recommendations for all of Kaledupa. Previous databases had “bugs” regarding dates, i.e.: the fisheries date column: on date column, from the tenth of every month the day and year always switches. For example, 12-5-2008 becomes 8-5-2012. This stems from the regional settings and format of the date column; Day/Month/Year vs Month/Day/Year. Furthermore dates entered as 5/01/09 were interpreted by the data base as 1 May 2009, and not 5 January 2009. This problem has been corrected, however the data deserves closer look and validating against paper copies if available.

Other notes:

The fisheries census for the remaining villages is being compiled into a separate document which outlines the demographic of Kaledupan's involved in finfish fisheries, seaweed aquaculture and invertebrate fisheries. Concepts of fisheries management and a description of data collection are included in the December 2007 report, available on the internet[1]. To save space these are not repeated again. Readers who are unfamiliar with Kaledupan fisheries will find an excellent overview in "An Assessment of the Fisheries of Kaledupa," from the Kaledupa Fisheries Pilot Project 2005, available on the Operation Wallacea website.

Data Collection and Analysis

This report is based on data collected between July 2007 and April 2009 using methods described in the December 2007 report, available on the internet[1]. Data analysis for finfish is separated into three areas:

Catch Per Unit Effort: Processed in an identical way to previous reports but now including a breakdown of CPUE per quarter for each fishing technique. Over time this should identify any seasonal patterns in CPUE.

Catch Composition: There are two aspects to this analysis. Firstly, catch data from each gear type and each village has been segregated to family level for those families that comprise more than 5 % of the catch. Secondly, using data from Fishbase (www.fishbase.org), each species has been allocated a feeding type from carnivore, detritivore, herbivore and omnivore and the percentage of each feeding type calculated for each technique in each village.

Percentage Maturity: Of the 161,000 fish counted by fisheries monitors between July 2007 and May 2008, 84,000 fish were measured, of the 36,600 fish recorded between June 2008 and April 2009 nearly 26,000 were measured . Each fish was compared to estimates of size of maturity from Fishbase and an answer of 'mature' or 'immature' was returned. These were aggregated and estimates of percentage maturity were calculated for each technique and selected families and species.

While the fisheries monitoring program is generating vast quantities of useful data, data for invertebrates from trading logbooks is still proving more difficult. In the absence of an assessment of fishing effort it has not been possible to calculate CPUE for invertebrates and it is hoped that this will be possible in the future. Any reference to line

[1] http://www.opwall.com/Library/index.shtml

fishing refers only to handline fishing. There are scattered samples from benthic longlines in the database but these are only sporadic.

Results

For simplicity, the results in each section presented below begin with a summary table for CPUE, catch composition and percentage maturity that looks at the effect of a fishing technique in Kaledupa averaged from June 2007 – May 2008. Later analyses dig deeper in search of detailed differences between time periods, villages and type of fish captured.

Catch Per Unit Effort

Summary – average for all techniques

Although there are data from 2005 which use the same methodology and theoretically provide a baseline comparison for contemporary data, one needs to handle differences carefully for two main reasons. Firstly, according to the December 2007 report, samples were taken from "very different sample sites" and, secondly, although the 2005 data was based on 135 fishing operations, when this is separated into different fishing techniques and villages it actually means most of the 2005 results below are based on only 3-8 samples. Nevertheless where available data from 2005 is contrasted to data from the 07/08 and 08/09 seasons.

Comparisons between villages for each fishing technique are made in the relevant sections below. This section focuses on comparisons between 2005, the 2007/2008 season and the present (2008/2009 season) (Table 1). For normal bubus there was a slight increase in CPUE in Darawa from 2005, to the 2007/2008 season, although the CPUE has dropped in the 2008/2009 season. Although the sample size for Lentea was very small in the 2008/2009 season the trend for normal bubu's is one of increasing CPUE. The 2008/2009 season resulted in higher CPUE for Lenta, however the sample size is again very small. The CPUE in Darwa for normal Bubus in lower than the previous years, similar to the CPUE from 2005. In Sombano there has been a slight decline between 2005 and the 07/08 season, and corresponding increase in the 08/09 season. The highest CPUE from large bubus in Darawa during the 07/08 season was 40 times greater than that of the smallest and two records back in August 2007 change the average CPUE from 0.6 to 2.6, it is therefore possible that those early records contain some degree of error. CPUE values from Darwa's Bubus in the 08/09 season range from 0.4 kg/day to 1kg/day, corresponding to the lower values from the 07/08 season. Overall the average CPUE has not changed appreciably from the 2007/2008 season to the 2008/2009 season.

The apparent large decline in CPUE of fish fences in Darawa and Sombano is a concern although the high variability in catch in 2005 and the different sample sites used in 07/08 means that no strong conclusion can be made as to whether this reflects reality. Average CPUE has continued to declined in the 08/09 season, at every site except Sombano where there was a 0.15 kg/day increase (from 4.57 to 4.72 Kg/day).

	Bubu normal (kg/day)	Bubu large (kg/day)	Fish fence (kg/day)	Speargun (kg/hr)	Line (kg/hr)
Balasuna 07/08			9.75 (5.60:4)		1.26 (0.25:12)
Balasuna 08/09			8 (6:2)		1.09 (0.07: 19)
Darawa 2005	0.55 (0.04:15)	0.63 (0.18:3)	32.92 (18.03:3)		1.4(0.63:3)
Darawa 07/08	0.78 (0.13:27)	2.63(1.39:9)	12.88 (5.92:4)		1.52 (0.35:6)
Darawa 08/09	0.54 (0.047: 58)	0.69 (0.07:8)	7.24 (1.14: 17)		1.22 (0.15: 18)
Langge 07/08	0.51 (0.03:35)		6.29 (0.70:20)		1.69 (0.16:21)
Langge 08/09	0.36 (0.017:26)		3.42 (0.07: 91)		1.85 (0.75:8)
Lentea 2005	0.26 (0.13:2)		4.83 (1.91:3)		
Lentea 07/08	0.45 (0.04:18)				1.5 (0.42:3)
Lentea 08/09	0.74 (0.33: 4)				1.49 (0.12: 13)
Lewuto 07/08			11.7 (1.186:88)		
Lewuto 08/09			9.99 (0.82:122)		
Mantigola 07/08				1.33 (0.27:21)	1.36 (0.26:8)
Mantigola 08/09				1.27 (0.27, 7)	2.34 (0.51: 12)
Peropa 07/08			18.33 (1.31:120)		
Peropa 08/09			6.44 (0.54: 121)		1.5 (1: _)
Sama Bahari 2005				1.32 (0.25:7)	1.38 (0.34:6)
Sama Bahari 07/08	0.33 (_:1)			2.53 (0.18:29)	2.75 (1.15:3)
Sama Bahari 08/09				2.18 (0.38:45)	1.49(0.14, 22)
Sombano 2005	0.36 (0.06:18)		13.47 (2.96:3)		
Sombano 07/08	0.28 (0.02:51)		4.57 (0.63:9)		1.17 (0.08:15)
Sombano 08/09	0.343 (0.024:68)	0.44 (0.06:27)	4.72 (0.25: 21)		1.48 (0.30: 5)
Average 2005	0.44 (0.04:35)	0.63 (0.18:3)	17.07 (6.74:9)	1.32 (0.25:7)	1.36 (0.20:17)
Average 07/08	0.47 (0.04:131)	2.63 (1.39:9)	14.23 (0.82:245)	2.04 (0.17:50)	1.48 (0.10:68)
Average 08/09	0.50 (0.104: 156)	0.49 (0.05:35)	6.81 (0.35: 37)	2.04 (0.31: 54)	1.49(0.10: 98)

Table 1: Mean CPUE with standard error and sample size in parentheses for bubus, net fish fence, speargun and line from July 2007 - May 2008, June 2008- April 2009 contrasted with existing data from sampling conducted in 2005.

Speargun CPUE in Sama Bahari appears to almost double over the two years although the December 2007 report points out that these data are from different sites. Even at the increased level of 2.53 kg/hr CPUE is still at the lower end of the range expected from scientific publications of 0.4-8.5 kg/hr (see the Kaledupa 2005 report). Speargun CPUE's appear similar for the 2008/2009 season to the2007/2008 season.

Line CPUE shows no change between 2005 and 2007/2008 in Darawa, indicating that large changes mentioned in the December 2007 report have been smoothed out with more samples. One can expect the same to occur with the apparent differences in Sama Bahari, as the 2007/2008 data is based on only 3 samples. CPUE values for line fishing from the 2008/2009 season are similar to the data from the 2007/2008 season, except in the case of Sama Bahari and the above mentioned sample that is based on only 3 samples and is markedly higher than the other values for line fishing.

	Gill net set parallel (kg/m/hr)	Gill net set perpendicular (kg/m/hr)	Gill net encircle (kg/m/hr)	Gill net act parallel (kg/day)	Seine net (kg/m/set)
Balasuna 2007/2008	0.006 (0.0003:53)	0.025 (0.021:3)		0.012 (0.003:5)	
Balasuna 2008/2009	0.006 (0.0003: 126)	0.006 (0.001:4)		0.013 (0.001:12)	
Darawa 2005			0.05 (0.01:8)		
Darawa 2007/2008		0.082 (0.033:4)	0.383 (_:1)	0.049 (0.012:14)	(_:1)
Darawa 2008/2009	0.009 (0.007:2)	0.072 (0.027:5)	0.0121(_:1)	0.031 (0.004:36)	
Langge 2007/2008	0.005 (0.0009:10)	0.014 (_:1)	0.026 (0.012:3)	0.013 (0.007:4)	(0.014:3)
Langge 2008/2009	0.006 (0.002:13)	0.018 (0.004:2)	0.009(_:1)	0.012 (0.002:3)	
Lentea 2005	0.028 (0.022:2)		0.03 (0.01:4)	0.01 (_:1)	(_:1)
Lentea 2007/2008	0.007 (0.001:9)	0.011 (0.001:8)	0.014 (_:1)	0.045 (0.012: 19)	(0.005:3)
Lentea 2008/2009	0.007 (0.000:39)	0.012 (0.001:21)		0.016 (0.003: 25)	
Mantigola 2007/2008	0.014 (0.0011:167)	0.020 (0.002:30)	0.014 (0.004:9)	0.025 (0.005: 42)	(0.043:6)
Mantigola 2008/2009	0.014 (0.001:182)	0.027 (0.001:140)	0.0328(0.0193:8)	0.034 (0.006: 125)	
Sama Bahari 2005	0.007 (_:1)	0.035 (0.004:7)	0.05 (0.01:9)	0.08 (0.05: 6)	
Sama Bahari 2007/2008	0.012 (0.0025:26)	0.019 (0.002:41)	0.033 (0.011:5)	0.017 (0.001: 57)	0.42 (_:1)
Sama Bahari 2008/2009	0.012 (0.001:39)	0.017 (0.001:83)	0.030(0.028:13)	0.0125 (0.0008: 73)	
Sombano 2005	0.037 (0.011:15)			0.01 (_:1)	
Sombano 2007/2008	0.0037 (0.001:12)	0.012 (_:1)			
Sombano 2008/2009	0.003 (0.000:15)	0.003 (0.000:15)			
Average 2005	0.034 (0.009:18)	0.035 (0.004:7)	0.04 (0.01:21)	0.07 (0.04:7)	N/A
Average 2007/2008	0.011 (0.0007:277)	0.021 (0.002:87)	0.043 (0.017:19)	0.026 (0.003:141)	(0.024:13)
Average 2008/2009	0.010 (0.000:418)	0.023 (0.001:256)	0.029 (0.005:23)	0.0251 (0.003, 274)	

Table 2: Mean CPUE with standard error and sample size (in parentheses) for net fishing from July 2007 - May 2008 contrasted with existing data from sampling conducted in 2005 and data from June 08 to April 2009.

Values from Gill nets set parallel to the reef (both active and static) show similar values for the 08/09 season as the 07/08 season (Table 2), although significantly lower than in 2005. The 2005 data from Sama Bahari and Lentea are from only a few samples and have high standard errors. Generally the data from 2005 have high standard errors and low sample sizes, however the data from Sombano are clearly shows a decline in CPUE by 10 times from 2005 to the present. Despite all of the data limitations outlined above this is one fishing technique that seems to be performing very poorly.

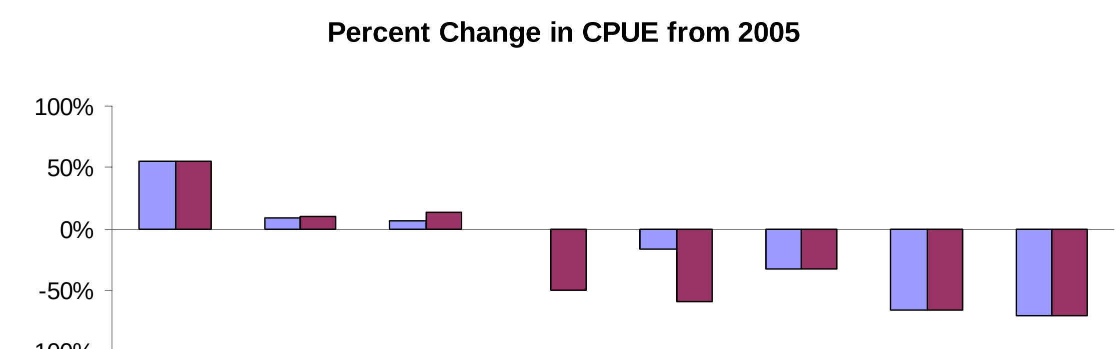
Data from 2005 is only available from Sama Bahari for gill net set perpendicular and this shows a significant decline in CPUE from the 05 sampling to the 07/08 and 08/09 seasons.

There are few samples for gill net encircling and more are required, particularly from Darawa to assess if the high catch in 2007/2008 is an error. Again in 2008/2009 there is only one set for gill net encircling from Darwa which is not sufficient to examine whether the large values from 07/08 are within a normal range. The general pattern of CPUE data from gill net encircling is a decline from 2005 to the 07/08 and 08/09 seasons, and a similar value from 07/08 to 08/09 with the exception of Mangitola where the 08/09 CPUE is twice that of the previous season.

Gill net active parallel to the reef shows a significant decline from 2005 to 07/08, however the overall CPUE value from 08/09 is similar to that from 07/08, which suggests that the data collection in 2005 may have been wholly different.

There is not enough seine net data to compare 2005 with the present day, as there were no seine nets recorded during the 08/09 season.

Of the eight fishing techniques (discounting large bubus because of the low sample numbers), where averages are available for 2005 and the present day, based on standard error estimations alone, one shows a significant increase (bubu large), three show a significant decrease (gill net set parallel, gill net set perpendicular and gillnet active parallel) and the others showing no significant change. These data are variable, but the general picture, especially for the net fisheries, is one of gradual decline. The percentage change of these fisheries is shown in Figure 2. Although this graph suggests a fairly even pattern of the CPUE for 4 fishing techniques increasing or remaining stable and 4 decreasing it actually hides an important detail. The 4 techniques that show declining CPUEs actually account for 85 % of the total catch made by all 8 techniques. Therefore even minor declines in CPUE for those techniques will translate into far fewer fish being landed by fishermen.



	Speargun	Line	Bubu normal	Gill net encircle	Fish fence	Gill net set perpendicu	Gill net set parallel	Gill net act parallel
07/08	55%	9%	7%	0%	-16%	-33%	-67%	-71%
08/09	55%	10%	14%	-50%	-60%	-33%	-67%	-71%

Figure 2: Percentage change of CPUE between 2005 and the present day. Only fishing techniques that had data for both time periods are included.

Bubu

CPUE values from Bubu traps (Table 3) from all villages have fairly constant CPUE throughout the year, although the sample size is small. Darawa records the highest average CPUE per year for all sites with Langge and Lentea significantly less but still larger than Sombano.

Bubu Normal		Jan-Mar	Apr-May	Jul-Sep	Oct-Dec
Darwa	2007			1.025 (0.275:8)	0.489 (0.049:10)
	2008	0.851 (0.415:5)	0.652 (0.186:12)	0.431 (0.030:18)	0.449 (0.041:13)
	2009	0.715 (0.110:22)			
Langee	2007			0.625 (0.024:4)	0.551 (0.027:20)
	2008	0.426 (0.052:8)	0.398 (0.023:14)	0.350 (0.045:9)	0.366 (0.008:8)
	2009	0.349 (0.034:4)			
Lentea	2007			0.365 (0.079:8)	0.466 (0.033:3)
	2008	0.428 (0.071:3)	0.54 (0.116:5)		0.9 (0.4:3)
	2009	0.25 (_:1)			
Sama Bahari	2007		(_:1)		
Sombano	2006				0.263 (_:1)
	2007			0.272 (0.047:10)	0.302 (0.052:14)
	2008	0.276 (0.022:22)	0.286 (0.041:13)	0.442 (0.103:15)	0.327 (0.033:24)
	2009	0.363 (0.055:21)	0.413 (0.073:9)		

Table 3: Mean CPUE (kg/trap/day) with standard error and sample size for normal bubu traps, split by quarter from July 2007 - May 2008.

As mentioned in the summary above, high CPUE for large bubus from the first sampling quarter shown in Table 4 could be human error. There is not enough data from later quarters to identify any significant changes in CPUE per quarter.

BubuLarge		Jan-Mar	Apr-May	Jul-Sep	Oct-Dec
Darwa	2007			6.680 (3.261:3)	0.721 (0.267:4)
	2008	0.333 (_:1)	0.6 (0.2:2)	0.6 (_:1)	0.7 (0.2:2)
	2009	0.777 (0.146:3)			
Sombano	2008	0.513 (0.088:6)	0.484 (0.087:4)	0.480 (0.087:8)	0.408 (0.118:12)
	2009	0.422 (0.106:4)			

Table 4: Mean CPUE (kg/trap/day) with standard error and sample size for normal bubu traps, split by quarter.

Fish Fences

CPUE data for Langge, Lewuto and Peropa is based on many samples throughout the year with a low standard error (Table 5). For Langge, CPUE for July-December 2007 is significantly higher than in 2008 and it will prove interesting in future years to see if this is a seasonal phenomenon. Averaged over the year, Peropa had significantly higher CPUE than the other villages.

Fish Fence		Jan-Mar	Apr-May	Jul-Sep	Oct-Dec
Balasuna	2007			0.298 (0.148:3)	
	2008	0.208 (_:1)			14 (_:1)
	2009	2 (_:1)			
Darwa	2007				1.5 (1:2)
	2008	5.916 (5.583:2)	17.75 (0.25:2)	6 (1.154:3)	9.5 (2.783:3)
	2009	6.954 (1.590:11)			
Langgee	2007			0.450 (0.155:4)	0.268 (0.037:8)
	2008	2.990 (0.405:9)	4.035 (0.442:14)	4.225 (0.577:20)	3.372 (0.179:38)
	2009	2.66 (0.271:25)			
Lewuto	2007			0.240 (0.048:27)	0.739 (0.082:32)
	2008	6.109 (0.915:18)	8.245 (0.885:46)	9.292 (1.924:41)	8.806 (0.794:16)
	2009	11.37 (1.189:48)			
Peropa	2007			0.712 (0.106:37)	0.846 (0.091:44)
	2008	5.308 (1.183:35)	11.17 (1.238:38)	7.559 (1.331:38)	6.427 (0.863:31)
	2009	4.538 (0.556:39)			
Sombano	2007			0.25 (_:1)	
	2008	4.285 (0.454:7)	5.071 (0.716:7)	4.75 (0.689:5)	4.278 (0.363:7)
	2009	4.916 (0.523:6)	5.25 (0.25:2)		

Table 5: Mean CPUE (kg/day) with standard error and sample size for net fish fences, split by quarter.

Speargun

Speargun CPUE (Table 6) for Sama Bahari is consistently high throughout the year compared to Mantigola. In general there are not enough data to draw significant conclusions regarding CPUE trends for spear gun fishing, simple trends may be the result of additional unrecorded factors. For example Speargun fishing in Sama Bahari is highest in the first two quarters of the month, which is the calm season, and may influence the catchability of the fish. More research on the efficacy of speargun fishing is needed.

Spear Gun		Jan-Mar	Apr-May	Jul-Sep	Oct-Dec
Darawa	2008	1.666 (_:1)		3.25 (1.25:2)	
Mantigola	2007			2.06 (0.94:5)	1.85 (0.364:4)
	2008	0.837 (0.211:5)	2.430 (1.603:10)		1.416 (0.083:2)
	2009	2.125 (0.375:2)			
Sama Bahari	2007				12 (0.358:12)
	2008	2.750 (0.229:10)	2.730 (0.521:15)	1.606 (0.151:10)	1.97 (0.688:21)
	2009	2.238 (0.728:6)			

Table 6: Mean CPUE (kg/hr) with standard error and sample size for speargun, split by quarter from.

Line

Based on a range of 0.59-5.1 kg/hr in scientific publications (see 2005 report), all of the sites in Table 7 are at the lower end of the range. From the currently available data, differences between sites and quarters are only marginal.

Line	Year	Jan-Mar	Apr-May	Jul-Sep	Oct-Dec
Balasuna	2007			1.888 (1.055:3)	0.949 (0.050:2)
	2008	1.176 (0.080:6)	1.226 (0.109:7)	1.196 (0.121:4)	0.958 (0.095:6)
	2009	1.049 (0.120:7)			
Darwa	2007			1.550 (0.949:2)	
	2008	1.270 (0.231:8)	1.095 (0.095:7)	0.888 (0.111:3)	0.770 (0.078:4)
	2009	1.515 (0.218:10)			
Langee	2007	0.75 (0.25:2)		2.4 (0.413:5)	1.538 (0.117:7)
	2008	2.071 (0.895:10)	1 (_:1)		2.700 (_:1)
	2009	1.729 (0.856:7)			
Lantea	2007			1.166 (_:1)	1 (_:1)
	2008	1.142 (0.142:2)	1.285 (_:1)	1.733 (0.286:4)	1.700 (0.152:3)
	2009	1.216 (0.097:5)			
Mantigola	2007			0.983 (0.270:5)	
	2008	2.666 (_:1)	1.336 (0.238:3)	3.164 (1.235:2)	2.5 (_:1)
	2009	2.144 (0.640:9)			
Sama Bahari	2007			7.5 (2.5:2)	1.708 (0.231:3)
	2008		1.375 (0.375:2)	1.319 (0.325:3)	1.158 (0.298:5)
	2009	1.694			
Sombano	2007			0.800 (_:1)	1.176 (0.156:5)
	2008	1.115 (0.160:5)	1.466 (0.133:2)	1.149 (_:1)	1.25 (_:1)
	2009	1.666 (0.509:3)			

Table 7: Mean CPUE (kg/hr) with standard error and sample size for line fishing, split by quarter from July 2007 - May 2008.

Gill Net – active encircling

Aside from the anomalous datum point recorded in the first month of surveys from Darawa, all sites and quarters where there are CPUE data are similar and there are too few data to draw firm conclusions from Table 8.

Gill Net Active Encircling		Jan-Mar	Apr-May	Jul-Sep	Oct-Dec
Darawa	2007			0.383 (_:1)	
	2008	0.070 (0.004:2)			
	2009	0.012 (1:1)			
Langee	2008	0.018 (_:1)	0.029 (0.020:2)		

Lentea	2007			0.014 (_:1)	
Mangitola	2007			0.011 (0.004:8)	0.036 (_:1)
	2008		0.028 (0.008:3)	0.025 (0.014:2)	0.041 (0.015:3)
Sama Bahari	2007			0.047 (0.027:2)	0.029 (_:1)
	2008	0.019 (0.005:2)	0.024 (0.017:2)	0.050 (0.016:5)	0.017 (0.003:5)
	2009	0.013 (_:1)			

Table 8: Mean CPUE (kg/m/hr) with standard error and sample size for gill net encircling, split by quarter from July 2007 - May 2008.

Gill Net – active parallel to the reef

Averaged data for the 11 month period indicates that CPUE at Darawa and Lentea is significantly higher than other sites (Table 9), particularly Balasuna, Langge and Sama Bahari. Caution is needed with these data because exceptionally high CPUE for Darawa and Lentea is recorded in the first quarter of sampling, where the majority of errors seem to have occurred. Further survey data over the next 6 months should identify whether the CPUE from Darawa and Lentea is genuinely higher.

Gill Net Active Parallel to Reef		Jan-Mar	Apr-May	Jul-Sep	Oct-Dec
Basaluna	2007				0.009 (_:1)
	2008	0.021 (4:4)	0.020 (2:2)	0.012 (4:4)	0.013 (4:4)
	2009	0.008 (0.001:2)			
Darwa	2007			0.116 (0.025:3)	0.037 (0.017:4)
	2008	0.028 (0.003:12)	0.041 (0.017:8)	0.034 (0.007:19)	0.021 (0.003:7)
	2009	0.030 (0.008:6)			
Langee	2007			0.029 (0.004:2)	
	2008	0.005 (_:1)	0.010 (0.000:2)		
	2009	0.014 (0.002:2)			
Lentea	2007			0.064 (0.016:12)	0.012 (0.002:5)
	2008	0.012 (0.001:9)	0.017 (0.006:3)	0.012 (0.002:5)	0.019 (0.006:12)
	2009	0.011 (0.002:5)			
Mantigola	2007			0.026 (0.005:34)	0.020 (_:1)

	2008	0.027 (0.005:15)	0.021 (0.003:29)	0.023 (0.002:27)	0.037 (0.014:41)
	2009	0.047 (0.016:35)	0.012 (0.000:3)		
Sama Bahari	2007		0.010 (_:1)	0.027 (0.002:10)	0.019 (0.002:11)
	2008	0.015 (0.002:15)	0.011 (0.000:40)	0.014 (0.002:18)	0.011 (0.000:23)
	2009	0.014 (0.002:14)	0.008 (_:1)		

Table 9: Mean CPUE (kg/m/hr) with standard error and sample size for gill net active parallel, split by quarter from July 2007 - May 2008.

Seine Net

One can cautiously identify from Table 10 that CPUE from Mantigola and Sama Bahari is significantly higher than at other sites. As for previously discussed fishing techniques, an exceptionally high CPUE is recorded for the first quarter which skews the data. Further sampling is required to see if this is a genuine seasonal effect or if it can be counted as human error when the fisheries monitoring system was starting. No seine nets were recorded From June 2008 to April 2009. thus this table is not updated.

Seine net	Jul-Sep 2007	Oct-Dec 2007	Jan-Mar 2008	Apr-May 2008	Av. Jul-May
Darawa				0.031 (_:1)	0.031 (_:1)
Langge	0.042 (0.014:3)				0.042 (0.014:3)
Lentea		0.017 (0.005:3)			0.017 (0.005:3)
Mantigola	0.154 (0.045:5)	0.022 (_:1)			0.132 (0.043:6)
Sama Bahari	0.42 (_:1)				0.42 (_:1)

Table 10: Mean CPUE (kg/m/hr) with standard error and sample size for seine net fishing, split by quarter from July 2007 - May 2008.

Gill Net – set parallel to the reef

The data set for gill net set parallel to the reef is relatively strong with continuous sampling for almost all sites throughout the year. CPUE from Mantigola is significantly higher than other sites although it does show a dip in the quarter Oct-Dec 2007 (Table 11). Sama Bahari, the site with the second highest CPUE, shows a similar dip and further sampling will help to identify if this is a seasonal effect. As for several fishing techniques, it is Sombano, Balasuna and Lentea that record the lowest CPUE for gill net set parallel to the reef.

Gill Net Set Parallel to Reef		Jan-Mar	Apr-May	Jul-Sep	Oct-Dec
Basaluna	2007			0.002 (0.000:5)	0.005 (0.000:14)
	2008	0.005 (0.000:30)	0.007 (0.000:14)	0.008 (0.001:23)	0.006 (0.000:17)
	2009	0.005 (0.000:20)	0.007 (0.002:3)		
Darwa	2009	0.009 (0.007:2)			
Langee	2007			0.004 (0.003:2)	0.005 (0.001:3)
	2008	0.005 (0.001:5)			
	2009	0.013 (0.009:3)			
Lentea	2007				0.006 (0.002:2)
	2008	0.006 (0.000:8)	0.007 (0.002:6)	0.007 (0.000:9)	0.009 (0.001:5)
	2009	0.006 (0.001:9)			
Mantigola	2007			0.010 (0.002:28)	0.008 (0.002:52)
	2008	0.016 (0.001:60)	0.021 (0.002:33)	0.010 (0.001:2)	0.021 (0.002:7)
Sama Bahari	2007			0.019 (0.002:7)	0.007 (0.001:5)
	2008	0.009 (0.001:10)	0.006 (0.002:4)	0.023 (_:1)	0.018 (0.005:4)
	2009	0.009 (0.002:5)	0.009 (0.002:3)		
Sombano	2007			0.002 (0.000:5)	0.007 (0.004:2)
	2008	0.003 (0.001:5)			0.004 (0.000:2)
	2009		0.002 (_:1)		

Table 11: Mean CPUE (kg/m/hr) with standard error and sample size for gill net set parallel to the reef fishing, split by quarter.

Gill Net – set perpendicular to the reef

There are many samples recorded for gill net set perpendicular to the reef from Mantigola and Sama Bahari but quarterly results are highly variable (Table 12) and there is no significant difference between those two sites averaged throughout the year. Although there are few data from Darawa, early indications are that CPUE is significantly higher there and this can be confirmed with further sampling over the next 6 months.

Gill Net Set Parallel to Reef		Jan-Mar	Apr-May	Jul-Sep	Oct-Dec
Basaluna	2007			0.003 (_:1)	
	2008	0.011 (_:1)			0.003 (_:1)
	2009	0.006 (_:1)			
Darwa	2007			0.173 (_:1)	0.083 (_:1)
	2008	0.035 (0.006:2)			
	2009	0.034 (_:1)			

Langee	2008				0.013 (_:1)
	2009	0.022 (_:1)			
Lentea	2007				0.006 (_:1)
	2008				0.006 (_:1)
	2009	0.015 (0.003:7)			
Mantigola	2007			0.002 (0.001:4)	0.024 (0.003:14)
	2008	0.024 (0.003:24)	0.033 (0.005:21)	0.021 (0.001:48)	0.050 (0.011:15)
	2009	0.030 (0.004:13)	0.005 (_:1)		
Sama Bahari	2007			0.016 (0.002:17)	0.028 (0.004:13)
	2008	0.017 (0.003:10)	0.014 (0.002:12)	0.015 (0.002:10)	0.015 (0.002:16)
	2009	0.018 (0.004:5)			
Sombano	2007				0.011 (_:1)

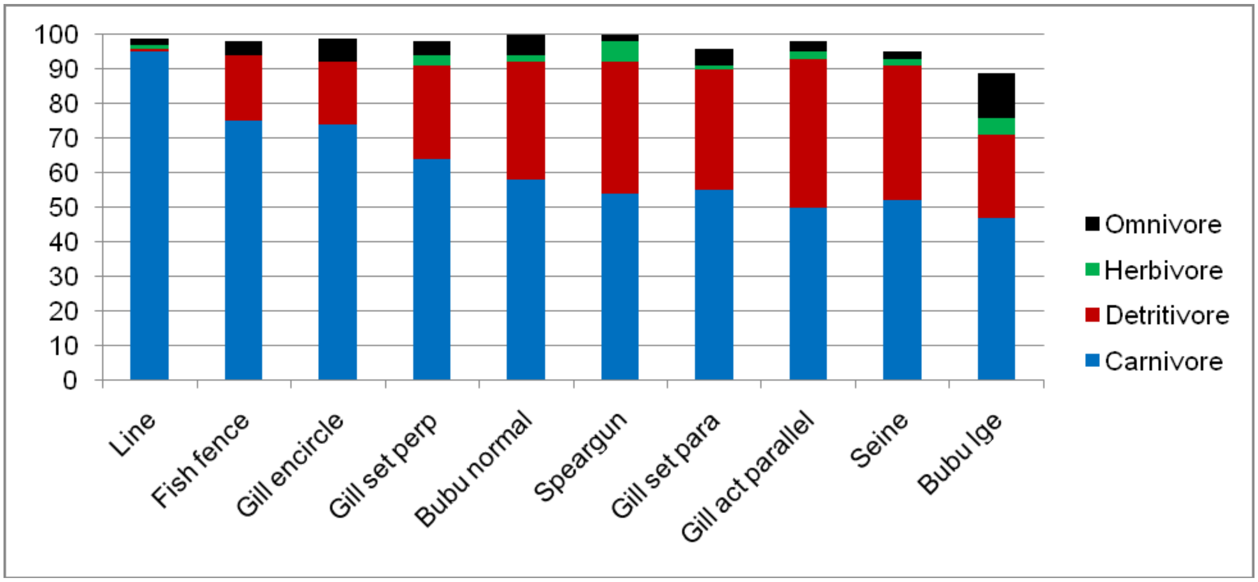
Table 12: Mean CPUE (g/m/hr) with standard error and sample size for gill net set perpendicular to the reef fishing, split by quarter from July 2007 - May 2008.

Catch composition

Summary - average for all techniques

The overall catch composition averaged for all sites and segregated into different techniques (Table 13) indicates that families can be roughly sorted into three categories:
1) Dominant for specific techniques. Almost half of the catch from fish fences is Clupeidea and 71 % of the catch of line fishermen is Lethrinidae.
2) Important family for several techniques. Of the eleven techniques in Table 13 Lethrinidae are a significant family for all of them, Mullidae significant for eight, Scaridae for nine and Siganidae for eight techniques. Together these four families account for the majority of the catch for nine techniques.
3) **Occasional.** This group includes those remaining families in Table 13 that typically comprise 5-10 % of the catch for one or more gears.
Carnivores comprise the majority of all catches (typically 50-75 %), detritivores approximately 20-40 % and herbivores and omnivores making up the remainder (2-8 %) (Figure 2). The exception to this is line fishing where 95 % of the catch are carnivores.

Figure 3: The percentage of feeding groups per fishing technique, 2007/2008 fishing season.



Family	Bubu Norm	Bub lge	Fish fence	Spr gun	Line	Gill set para.	Gill set perp.	Gill set encr.	Gill act para.	Sne net
Acanthuridae *surgeonfish*				6						
Carangidae Jacks										11
Clupeidea Herring			47					21		
Exocoetidae flying fish								7		
Hemiramphidae *garfish*								26		
Holocentridae *squirrelfish*						7	8			
Labridae Wrasse	6			8	8					
Lethrinidae bream/emperor	8	6	7	30	71	18	30	13	25	24
Lutjanidae Snapper						7	7			
Mugilidae Mullet										6
Mullidae Goatfish	34	29	6	7		7	7		11	
Nemipteridae threadfin bream										
Scaridae Parrotfish	31	42		13		5	7	7	11	18
Siganidae Rabbitfish		6	16	25		21	21	10	29	18

Other fish	15	17	24	11	21	35	20	16	24	23
Total sample	10576	712	71007	4609	4853	25181	15801	2704	15659	1583

Table 13: Percentage composition of all families that comprise more than 5 % of the total catch abundance, segregated by fishing technique. Total sample number is also included. Data based on the 2007/2008 fishing season.

Bubu normal and large

Mullidae and Scaridae were the most dominant families caught by normal bubus (Table 14) with other families such as Labridae forming an important contribution in specific villages. Dash-dot goatfish (*Parupeneus barberinus*) accounted for 58 % of the Mullidae and was the most abundant species in normal bubu catches; 1 in every 7 fish landed was a dash-dot goatfish. The percentage of carnivores was similar for all villages (~60%) except for Sama Bahari where catches of Balistidae (triggerfish) and Labridae increased the percentage of carnivores to 79 %. It is worth noting from Table 1 that the data from Sama Bahari is based on one sample and should be treated cautiously.

Catch Composition by family for villages with significant (>5% total) catch with normal bubu traps. Note that data from 2009 is based on the first quarter only.

	Darawa			Langgee			Lentea			Sama Bahari	Somba	
Family	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2007	2008
Acanthuridae	0.3%	0.0%	0.0%	1.3%	0.0%	0.0%	3.5%	3.7%	8.9%	0.0%	9.3%	4.2%
Balistidae	1.6%	2.0%	1.6%	1.3%	1.6%	0.0%	0.0%	0.0%	0.0%	21.2%	4.1%	4.0%
Chaetodontidae	0.1%	0.0%	0.5%	0.0%	0.4%	0.0%	1.5%	2.2%	0.0%	0.0%	1.1%	1.3%
Holocentridae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.5%	6.7%	3.6%	0.0%	0.4%	1.0%
Labridae	5.0%	6.7%	10.7%	1.4%	2.0%	0.0%	2.6%	9.0%	0.0%	17.8%	11.0%	11.2%
Lethrinidae	7.6%	13.4%	13.3%	2.3%	0.5%	0.0%	12.9%	20.9%	0.0%	0.0%	7.1%	5.6%
Lutjanidae	1.6%	2.1%	0.0%	0.0%	0.9%	0.0%	6.3%	11.9%	10.7%	0.0%	0.8%	1.4%
Mullidae	37.1%	31.3%	33.6%	60.7%	48.6%	40.8%	28.8%	20.1%	8.9%	40.4%	18.0%	29.0%
Nemipteridae	3.5%	0.3%	0.0%	4.0%	2.7%	1.7%	2.4%	0.0%	0.0%	0.0%	8.0%	6.2%
Scaridae	29.0%	27.7%	16.3%	19.9%	36.6%	36.5%	14.0%	6.7%	25.0%	11.6%	23.1%	23.6%
Siganidae	4.3%	2.8%	6.2%	1.4%	0.2%	1.3%	4.6%	0.0%	21.4%	0.0%	2.2%	0.9%
Not Classified	10.0%	13.7%	17.8%	7.8%	6.5%	19.7%	14.9%	18.7%	21.4%	8.9%	15.1%	11.5%
Total Catch (#'s)	7,109	4,055	1,736	3,798	5,250	939	3,844	3,954	906	17,815	2,624	100.0%
Feeding Group Composition of the Catch												
CARNIVORE	56%	53%	55%	71%	43%	38%	65%	69%	21%	79%	57%	58%
DETRITIVORE	24%	35%	29%	26%	43%	58%	22%	14%	39%	21%	31%	30%
HERBIVORE	2%	2%	1%	1%	0%	0%	4%	4%	7%	0%	2%	1%
OMNIVORE	9%	4%	8%	1%	14%	5%	4%	11%	18%	0%	7%	8%
Not Classified	8%	6%	6%	0%	0%	0%	3%	0%	14%	0%	1%	2%

Table 14: Percentage composition of all families that comprise more than 5 % of the total catch for bubu traps. The percentage of different feeding groups and total sample size is also included. Note that data from 2009 is based on the first quarter only.

Parrotfish form a large proportion of the catch composition for large bubus but aside from that similarity the catches are quite different. Mullidae comprise approximately 29 % of large bubu catches in Darawa while Snappers (Lutjanidae) do not even feature. It would be useful to collect large bubu data from other villages so see if this pattern is repeated and then to assess whether it is the entrance hole size that causes the difference.

Catch Composition by family for villages with significant (>5% total) catch with Large bubu traps. Note that data from 2009 is based on the first quarter only.

	Darawa			Sombano	
Family	2007	2008	2009	2008	2009
Acanthuridae	1.9%	0.6%	0.0%	31.8%	45.2%
Balistidae	0.6%	4.6%	0.0%	3.8%	7.0%
Chaetodontidae	0.6%	0.0%	0.0%	5.8%	7.0%
Holocentridae	0.0%	0.0%	0.0%	0.8%	0.9%
Labridae	3.5%	4.9%	20.8%	2.8%	1.7%
Lethrinidae	6.7%	7.2%	17.0%	1.1%	0.9%
Lutjanidae	3.2%	5.7%	0.0%	0.9%	1.7%
Mullidae	29.8%	29.3%	28.3%	4.4%	1.7%
Nemipteridae	1.9%	0.0%	0.0%	1.2%	5.2%
Scaridae	46.2%	24.4%	18.9%	13.9%	5.2%
Siganidae	5.4%	4.3%	0.0%	4.1%	2.6%
Not Classified	0.0%	19.0%	15.1%	29.6%	20.9%
Total Catch (#'s)	463	348	53	1,007	115

Feeding Group Composition of the Catch					
CARNIVORE	43%	51%	66%	27%	31%
DETRITIVORE	14%	45%	34%	54%	53%
HERBIVORE	7%	2%	0%	11%	14%
OMNIVORE	20%	2%	0%	4%	1%
Not Classified	17%	0%	0%	4%	1%

Fish fence

Of all the techniques, catch data from fish fences record the greatest degree of geographical variability (Table 15). Clupeidea are very significant in catches for Lewuto and Peropa but are not even recorded in fish fence samples from other villages. According to the database, only fish fences are used in Lewuto and Peropa, although according to personal communication with the author nets are occasionally used. Although the author has received reports of 50 fish being sold for Rph 2000, and villages being 'bored' of herring, the role of herring both economically and ecologically deserves further consideration. Only 4 samples are recorded from Balasuna, it is therefore not possible to be sure that the 23 % Gerreidae landed is typical, although the 8 % of this family taken by a larger sample at Langge suggested that fish fences do target Gerreidae. 50 % of catches from fish fences at Darawa were Mullidae, and the four species accounting for the majority of this were striped goatfish (*Upeneus vittatus)* 41 %, yellowstripe goatfish (*Mulloidichthys flavolineatus)* 23 %, dash-dot goatfish 18 % and asymmetrical goatfish (*Upeneus asymmetricus)* 12 %. At Sombano a large quantity of families accounted for only 2-3 % of the catch, so 38 % (the highest from all of the techniques) was categorized as ‘other fish’. Considering that Sombano appears to be amongst the most degraded sites, it will be interesting to see in the future if the pattern of catches being spread in small quantities amongst different families continues. For all villages Lethrinidae and Siganidae are important, with a few species dominating those families. Thumbprint emperors (*Lethrinus harak*) alone account for 35 % of all Lethrinidae catches, and smudgespot spinefoot (*Siganus canaliculatus*) comprises 72 % of all Siganidae caught by fish fences. Discounting the large quantities of herring, almost one in four fish caught by fish fences is a smudgespot spinefoot.

The proportion of different feeding habits is approximately similar for all sites except for Langge where the combination of Scaridae and Siganidae increases the contribution of detritivores to 40 %.

Catch Composition by family for villages with significant (>5% total) catch from fish fences traps. Note that data from 2009 is based on the first quarter only.

	Balasuna			Darawa			Langgee			Le
Family	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007
Acanthuridae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.4%	0.0%	0.0%	2.9%
Balistidae	3.9%	3.1%	0.0%	2.5%	4.7%	4.1%	11.5%	2.4%	5.8%	0.7%
Chaetodontidae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	1.3%	37.2%
Holocentridae	32.8%	0.0%	0.0%	0.3%	5.5%	0.0%	1.2%	13.4%	12.9%	1.1%
Labridae	10.6%	6.2%	0.0%	0.5%	1.1%	0.0%	2.9%	1.6%	2.3%	0.6%
Lethrinidae	2.2%	4.4%	0.0%	1.3%	1.6%	3.1%	0.9%	0.7%	0.6%	1.3%
Lutjanidae	20.6%	12.4%	94.1%	8.8%	10.0%	16.9%	22.9%	13.3%	14.7%	13.4%
Mullidae	0.6%	0.0%	5.9%	0.8%	3.2%	0.0%	0.1%	0.1%	0.8%	0.9%
Nemipteridae	0.0%	0.0%	0.0%	48.9%	49.9%	40.2%	3.3%	0.9%	18.8%	3.7%
Scaridae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
Siganidae	0.0%	17.3%	0.0%	14.6%	5.0%	2.0%	4.6%	2.8%	14.6%	1.3%
Not Classified	7.8%	44.4%	0.0%	17.9%	13.4%	27.3%	32.5%	34.0%	13.6%	27.4%
Total Catch (#'s)	180	225	17	1,661	793	652	1,873	4,489	618	7,576

Feeding Group Composition of the Catch

CARNIVORE	69%	20%	100%	54%	73%	40%	35%	50%	53%	64%
DETRITIVORE	23%	62%	0%	22%	22%	34%	45%	39%	32%	29%
HERBIVORE	1%	0%	0%	1%	0%	0%	0%	0%	0%	0%
OMNIVORE	7%	7%	0%	17%	4%	26%	18%	3%	13%	6%
Not Classified	0%	12%	0%	7%	1%	0%	2%	7%	2%	0%

Table 15: Percentage composition of all families that comprise more than 5 % of the total catch for net fish fences. The percentage of different feeding groups and total sample size is also included.

Speargun

Speargun fishermen from Sama Bahari clearly target Lethrinidae and Siganidae, with catches from Mantigola being more widely spread between those families and Acanthuridae, Labridae, Serranidae and Scaridae (Table 16). This is the only fishing technique where Serranids account for more than 5 % of the catch, but because catches from spearguns are relatively small compared to techniques like fish fences, this means that only 66 Serranids were caught in Mantigola compared to 156 by gill nets set parallel to the reef. One would expect that speargun fishing, like line fishing, would target larger, higher value piscivorous species, but detritivores still feature strongly in catches presumably because the larger parrot fishes (Scaridae) and Siganidae are worth targeting.

Spear Gun Catch Numbers

	Mantigola		Sama Bahari		
Family	2007	2008	2007	2008	2009
Acanthuridae	102	17	29	144	
Labridae	77		123	165	24
Lethrinidae	27	123	640	994	94
Mullidae	7	23	92	314	
Scaridae	51	87	92	315	27
Serranidae	13	30	2	14	
Siganidae	163	51	545	668	89
Not Classified	39	30	100	202	73
Grand Total	479	361	1623	2816	307

Feeding Group Composition of the Catch

Carnivore	25%	47%	53%	55%	38%
Detritivore	55%	31%	38%	38%	44%
Herbivore	18%	15%	6%	4%	0%
Omnivore	2%	3%	2%	0%	0%

Not Classified	0%	4%	1%	2%	18%

Table 16: Percentage composition of all families that comprise more than 5 % of the total catch for speargun fishing. The percentage of different feeding groups and total sample size is also included.

Line

As previously mentioned in the summary for this section, the striking characteristic from the catch composition data for line fishing is the predominance of carnivorous species. Catches from line fishing in every village are dominated by Lethrinids (Table 17) and spread fairly evenly between threadfin emperor (*Lethrinus genivittatus*), thumbprint emperor (*Lethrinus harak*), Orange striped emperor (*Lethrinus obsoletus*), Variegated emperor (*Lethrinus variegates*) and spangled emperor (*Lethrinus nebulosus*).

Line

	Balasuna			Darawa			Langgee			Lentea			Sama Bahari			
Family	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007
Balistidae	0.5%	1.3%	5.2%	0.6%		4.6%	0.5%	0.6%		5.2%	12.6%	4.4%	4.8%	0.4%	2.2%	0.4%
Carangidae	2.2%	3.4%	0.9%		1.4%			5.7%	4.5%	0.9%			0.6%	4.1%	4.8%	0.6%
Centropomidae	11.4%	6.5%					0.9%	3.7%	28.4%							
Clupeidea							8.1%	17.9%						30.1%		
Labridae		0.5%		8.1%	4.7%	15.4%	5.7%			9.0%	11.3%	17.8%			2.7%	5.1%
Lethrinidae	66.5%	39.6%	63.8%	88.7%	89.4%	61.5%	78.4%	50.3%	34.3%	82.3%	75.0%	68.9%	64.1%	50.9%	24.2%	78.8%
Lutjanidae	11.4%	24.2%	12.9%	0.3%	1.8%	7.7%	3.6%	15.1%	3.0%				30.5%	5.6%	45.7%	3.5%
Mullidae														4.5%		
Not Classified	8.1%	24.5%	17.2%	2.3%	2.7%	10.8%	2.7%	6.8%	29.9%	2.6%	1.1%	8.9%		4.5%	20.4%	11.6%
Total	185	384	116	345	716	65	742	352	67	423	364	45	167	269	186	491
Feeding Group Composition of the Catch																
Carnivore	96%	76%	95%	100%	98%	95%	99%	100%	93%	96%	98%	98%	100%	97%	89%	98%
Detritivore																
Herbivore																
Omnivore		2%			1%		1%			2%	2%	2%		1%	1%	2%
Not Classified	4%	22%	5%		1%	5%			7%	2%				2%	10%	

Table 17: Percentage composition of all families that comprise more than 5 % of the total catch for line fishing. The percentage of different feeding groups and total sample size is also included.

Gill net set parallel to the reef

Lethrinidae and Siganidae are the most caught families by gill nets for all villages (Table 18). Six species account for 71 % of Lethrinidae, spot cheeked emperor 17 % (*Lethrinus rubrioperculatus*), thumbprint emperor 14 % (*Lethrinus harak*), threadfin emperor 9 % (*Lethrinus genivittatus*), orange striped emperor 8 % (*Lethrinus obsoletus*), and long-fin emperor 8 % (*Lethrinus erythropterus*), and yellow-tailed emperor 7 % (*Lethrinus atkinsoni*). Two species account for 83 % of Siganidae, smudgepot spinefoot and black spinefoot (*Siganus fuscescens*) and are the most caught species by gill nets set parallel to the reef. Also noteworthy for this technique is the presence of Gerreidae in four of the six villages.

Generally carnivores comprise between 60% and 75 % of the feeding types with detritivores accounting for almost all the remainder. The exception is Balasuna where omnivorous grunters (Terapontidae) and a high concentration of detritivorous Siganidae reduce the proportion of carnivores.

Percentage composition of all families that comprise more than 5 % of the total catch for gill net set parllel to the reef, total sample size and the percent composition by feeding group of the catch.

Family	Balasuna			Langgee			Lentea			Mantigola			Sama Bahari			
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007
Acanthuridae	1.5%	0.8%	4.1%				7.3%	4.6%	4.8%	4.4%	1.4%	3.0%	1.0%		5.1%	
Caesionidae	1.8%	0.9%		2.1%						0.5%		0.3%	1.0%		7.5%	
Carangidae	2.2%	1.6%	2.1%	15.4%	6.8%	4.5%		1.9%		5.5%	4.3%	4.9%	0.4%		1.2%	2.9%
Clupeidea	0.2%	0.2%						2.6%		5.7%	6.3%	6.0%				
Gerreidae	6.0%	6.9%	7.9%	0.7%	25.9%	21.2%		5.5%	4.0%	2.3%	3.2%	2.7%	0.4%		0.3%	5.7%
Holocentridae	3.4%	0.7%	0.2%	0.7%				0.5%		7.0%	2.1%	4.6%	11.5%	19.9%	11.9%	0.5%
Labridae	3.3%	3.1%	3.7%	4.2%			2.1%	4.8%	5.2%	2.8%	2.4%	2.6%	0.6%	4.1%	0.9%	
Lethrinidae	9.7%	7.9%	10.3%	24.5%	25.9%	24.2%	15.6%	15.1%	18.0%	20.3%	20.5%	20.4%	28.0%	19.5%	21.7%	26.3%
Lutjanidae	3.6%	2.5%		4.2%	0.5%			3.4%	6.0%	3.6%	2.5%	3.1%	12.1%	8.6%	13.7%	3.8%
Mugilidae		0.5%	0.6%				4.0%	1.8%	1.2%	1.0%	3.2%	2.1%	1.0%		0.5%	
Mullidae	5.2%	5.2%	9.1%	17.5%	3.6%		7.3%	6.4%	13.6%	6.2%	12.7%	9.4%	6.4%	12.0%	7.1%	13.6%
Plotosidae		0.0%														
Scaridae	1.8%	3.5%	6.4%	1.4%			12.9%	3.3%	6.1%	9.2%	7.9%	8.5%	2.7%	8.1%	3.7%	
Siganidae	40.8%	44.7%	31.4%	21.7%	30.9%	40.9%	30.1%	22.0%	26.3%	23.5%	25.2%	24.3%	19.7%	12.2%	13.8%	12.9%
Terapontidae	3.2%	0.3%		0.7%			0.6%	1.0%		0.6%	1.0%	0.8%				
Not Classified	17.3%	21.2%	24.2%	7.0%	6.4%	9.1%	20.0%	27.0%	14.8%	7.4%	7.4%	7.4%	15.3%	15.6%	12.7%	34.4%
Grand Total	1039	2288	484	143	220	66	519	1325	521	4949	4662	9611	2609	467	6785	41

Feeding Group Composition of the Catch																
Carnivore	41%	34%	38%	71%	65%	58%	28%	50%	51%	55%	53%	54%	70%	76%	71%	63%
Detritivore	45%	53%	45%	26%	31%	41%	56%	33%	39%	40%	40%	40%	24%	22%	21%	13%
Herbivore	0%	0%		1%			1%	2%	1%	3%	0%	1%	0%	2%	1%	
Omnivore	10%	9%	11%	2%	4%		5%	6%	6%	1%	2%	1%	3%		5%	9%
Not Classified	3%	5%	7%			2%	10%	10%	4%	2%	4%	3%	2%		2%	15%

Table 18: Percentage composition of all families that comprise more than 5 % of the total catch for gill nets set parallel to the reef. The percentage of different feeding groups and total sample size is also included.

Gill net set perpendicular to the reef

Catch composition in the catch of gill nets set perpendicular to the reef varies considerably according to village. Siganidae, and specifically smudgespot spinefoot and black spinefoot, are an important family in every village but aside from this it is difficult to make generalizations. Scaridae feature in 5 villages with the catch being spread widely among different species. Lethrinidae and Mullidae form significant proportions of the catch in 4 villages with thumbprint (20 %), threadfin (15 %) and orange striped emperors (13 %) being the most significant for Lethrinidae, and 8 species of goatfish comprising between 5 and 15 % of the catch composition of Mullidae. Data in Table 19 originate from between only 1 and 4 samples for Balasuna, Darawa, Langge and Sombano, and this is probably the main reason for the high diversity in catch composition. The catch composition percentages of the sites where there are more data (Lentea, Mantigola and Sama Bahari) resemble each other more closely, with the abundance of Siganidae determining the degree of detritivorous feeding in each village.

The unusually high abundance of herbivores in the catch composition of Darawa is caused by 92 % of the Siganidae catch being spotted spinefoot (*Siganus punctatus*) a herbivorous species.

Percentage composition of all families that comprise more than 5 % of the total catch for gill net set perpendicular to the reef, total sample size and the percen
composition by feeding group of the catch.

	Balasuna			Darawa		Langgee	Lentea			Mantigola			Sama Bahari		
Family	2007	2008	2009	2007	2008	2008	2007	2008	2009	2007	2008	2009	2007	2008	2009
Acanthuridae	14.9%			7.2%	1.8%			2.1%	7.4%	0.5%	4.2%	0.4%	1.3%	2.1%	1.6%
Carangidae	3.0%							0.3%		7.2%	3.7%	4.7%	0.1%	2.1%	0.9%
Clupeidea	3.0%					80.1%				4.3%	8.5%			0.6%	11.2%
Gerreidae	24.2%				5.5%			5.4%		5.2%	3.0%	1.1%	0.8%	1.1%	
Holocentridae	1.9%				0.9%			0.6%		0.9%	1.9%		9.8%	16.3%	38.4%
Labridae		7.3%		4.6%	6.4%			3.3%	17.3%	1.8%	2.2%	2.2%	2.5%	0.8%	3.8%
Lethrinidae	6.7%		11.7%	0.8%	9.1%		32.1%	39.0%	13.6%	23.5%	22.0%	20.0%	40.5%	27.2%	7.1%
Lutjanidae					0.9%			5.0%			5.4%	5.7%	9.7%	9.5%	4.0%
Mugilidae	3.7%				9.1%			1.1%			1.5%	1.5%	0.7%	0.5%	2.5%
Mullidae	4.5%	8.5%		5.4%	38.2%		8.9%	14.7%	17.3%	6.6%	11.5%	14.5%	4.9%	6.1%	4.7%
Nemipteridae	9.3%	2.4%									0.8%		2.0%	1.3%	
Scaridae	3.7%	14.6%		30.9%	5.5%		19.6%	3.4%	12.3%	11.4%	5.7%	14.2%	3.3%	3.3%	1.3%
Siganidae	18.6%	43.9%	28.3%	49.7%	8.2%	15.2%	14.3%	13.6%	16.0%	32.2%	23.8%	22.2%	18.4%	14.7%	15.8%
Not Classified	6.7%	23.2%	60.0%	1.4%	14.5%	4.6%	25.0%	11.3%	16.0%	6.4%	5.9%	13.5%	6.2%	14.5%	8.7%
Grand Total	1,039	2,288	484	143	220	151	1	1,325	521	4,949	4,662	9,611	2,609	467	6,785
Feeding Group Compositon of the Catch															
Carnivore	52%	20%	23%	14%	47%	80%	41%	68%	54%	49%	59%	49%	71%	66%	71%
Detritivore	33%	49%	28%	16%	31%	15%	41%	21%	38%	48%	36%	42%	24%	21%	20%
Herbivore	15%	17%		44%	8%			2%	7%		2%	1%	1%	1%	
Omnivore		9%	48%	16%		5%	18%	5%		2%	1%	0%	3%	4%	5%
Not Classified		6%		10%	14%			5%		1%	2%	8%	1%	8%	4%

Table 19: Percentage composition of all families that comprise more than 5 % of the total catch for gill nets set perpendicular to the reef. The percentage of different feeding groups and total sample size is also included.

Gill net encircle

Generally, when there are fewer samples, catch composition is scattered among many families. Few samples from Darawa (1), Langge (3) and Lentea (1) seem to have the same effect of increasing diversity as gill nets set perpendicular to the reef (Table 20). It will be useful to have more sampling for Langge to identify the importance of Clupeidea throughout the year, and to see if the current level of recorded variability is a true reflection of geographical changes in catch composition. One suggestion is that the considerable variability from this technique comes from the difference in catch composition between the two sites where there are a good number of samples, Mantigola and Sama Bahari. The presence of Northern pilchard (*Amblygaster sirm*) and flying fish (*Cypselurus* sp.) accounted for 58 % of the catch in the Mantigola sample. Sama Bahari had a more typical distribution of families with smudgepot spinefoot being the most abundant individual species and Lethrinidae catch being made from nine different species. This was the only fishing gear were Hemiramphidae featured strongly in catch composition, and in both Mantigola and Sama Bahari barred (*Hemiramphus far*) and robust garfish (*Hemiramphus robustus*) were important.

The distribution of percentage feeding habit was essentially the same except for those villages that caught carnivorous Clupeidea.

Percentage composition of all families that comprise more than 5 % of the total catch for gill net set encircling, total sample size and the percent composition by feeding group of the catch.

	Darawa		Langgee	Lentea	Mantigola		Sama Bahari		
Family	2007	2008	2008	2007	2007	2008	2007	2008	2009
Carangidae				8%	2%	5%		1%	3%
Clupeidea			98%		38%	92%		6%	
Gerreidae				8%			2%		
Hemiramphidae		100%		47%	25%	1%	47%	23%	
Labridae	15%				3%		5%	1%	5%
Lethrinidae	23%			19%	0%	2%	20%	29%	63%
Mullidae	27%			19%	3%		1%	18%	22%
Scaridae	4%				2%		4%	5%	7%
Siganidae	30%				4%		13%	9%	
Not Classified			2%		23%		8%	6%	
Grand Total	92	127	133	79	830	482	890	1243	60
Feeding Group Compositon of the Catch									
Carnivore	66%	25%	100%	72%	95%	100%	78%	83%	93%
Detritivore	5%				2%		12%	9%	7%
Herbivore	17%				1%				
Omnivore	12%	75%		19%	1%		10%	8%	
Not Classified				9%	1%			0%	

Table 20: Percentage composition of all families that comprise more than 5 % of the total catch for gill nets active encircling. The percentage of different feeding groups and total sample size is also included.

Gill net active parallel

Smudgespot spinefoot and black spinefoot were again the most abundant species in the catches of this technique, accounting for 1 in 5 fish landed. Aside from Siganidae, Scaridae and Lethrinidae were the important families in all villages (Table 21). Whereas Siganidae were dominated by 2 species, there were 6 Scarids each accounting for 5 -18 % of the total and a further 23 species comprising the remainder. Two species (threadfin 20 % and thumbprint 34 % emperor) accounted for the majority of Lethrinidae. Acanthuridae and Carangidae were only significant in Balasuna and Langge respectively and further sampling is required to understand if this is usual. Of the 6 villages represented that use the technique gill net active parallel, 2 have catches composed predominantly of carnivores (Langge and Sama Bahari) and 4 predominantly of detritivores (Balasuna, Darawa, Lentea and Mantigola), with the difference often generated by the relative proportion of Lethrinids (carnivorous) and Siganids (detritivorous).

Percentage composition of all families that comprise significant catch for active gill nets set parallel to the reef, total sample size and the percent composition by feeding group of the catch.

	Balasuna			Darawa			Langgee			Lentea			Mantigola			
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	200
Acanthuridae	22%	2%		0%						6%	3%	9%	2%	6%	2%	3%
Carangidae	29%			3%	1%	7%	11%		11%	0%	1%		3%	5%	9%	1%
Gerreidae		10%		6%	6%		13%			4%	9%		0%	5%	3%	3%
Labridae		6%	23%	3%	1%	4%	2%			3%	7%		5%	3%	6%	4%
Lethrinidae		3%		14%	22%	13%	38%	23%	25%	10%	22%	21%	29%	17%	21%	30%
Mugilidae		1%		7%						1%	2%	2%	1%	6%	6%	1%
Mullidae		3%	17%	21%	25%	15%	7%		6%	4%	6%	12%	2%	13%	9%	13%
Scaridae		1%		12%	12%	7%	2%			5%	1%	23%	12%	7%	4%	11%
Siganidae	27%	38%	47%	24%	19%	20%	16%	27%	47%	52%	25%	23%	41%	27%	20%	30%
Not Classified	22%	38%	13%	11%	13%	35%	11%	50%	11%	15%	23%	11%	4%	12%	19%	4%
Grand Total		45	583	658	1,242	1,154	2,683	45	26	189	1,482	1,341	3,022	2,673	2,867	6,827
Feeding Group Composition of the Catch																
Carnivore	48.7%	50.7%	75.0%	45.5%	59.1%	51.7%	89.5%	57.7%	44.2%	34.0%	50.7%	39.8%	40.1%	52.8%	53.4%	60.6%
Detritivore	51.3%	17.3%		30.8%	32.1%	16.1%	5.3%	26.9%	48.4%	48.0%	28.3%	54.4%	56.0%	37.0%	36.4%	34.3%
Herbivore		2.5%		1.6%	0.7%		2.6%			4.1%	2.0%		3.1%	2.0%	2.1%	3.1%
Omnivore		14.5%	12.5%	4.0%	5.0%	1.3%	2.6%		7.4%	9.3%	9.5%	5.8%	0.7%	1.7%	1.3%	0.9%
Not Classified		15.1%	12.5%	18.1%	3.1%	30.9%		15.4%		4.6%	9.5%		0.0%	6.4%	6.8%	1.2%

Table 21: Percentage composition of all families that comprise more than 5 % of the total catch for gill nets active parallel. The percentage of different feeding groups and total sample size is also included.

Seine net

There is only 1 sample from Darawa and Sama Bahari, 3 from Langge and Lentea and 6 from Mantigola (Table 2), so it is difficult to make firm conclusions from such sparse data. Generally, Lethrinidae, Siganidae and Scaridae make up the largest proportion of catches (Table 22) with the 3 most abundant Lethrinid species being threadfin emperor (26 %), long-fin emperor (22 %) and thumbprint emperor (14 %). The 2 most abundant Siganids are smudgespot spinefoot (43 %) and silver spinefoot (*Siganus argenteus*). The most abundant Scarid is spinytooth parrot fish (39 %) with the remainder being comprised of 10 different species. Although Carangidae feature in a more dominant way than for other fishing techniques, the Langge sample is only 24 fish so further sampling is needed to see if this is typical.

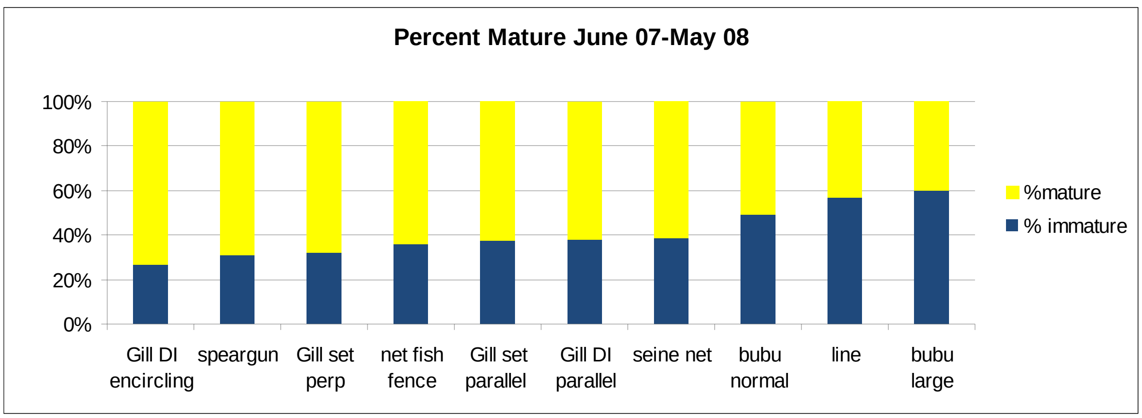
Seine net	Darawa	Langge	Lentea	Mantigola	Sama Bahari
Acanthuridae	9		7		10
Belonidae				7	
Carangidae		79		18	7
Hemiramphidae					10
Lethrinidae	17	13	10	28	30
Lutjanidae		8			
Mugilidae			30		5
Mullidae	12		6		
Scaridae	19		20	17	20
Siganidae	35		18	20	10
Other fish	8	0	9	10	8
Total sample	117	24	292	758	390
CARNIVORE	37	100	22	61	55
DETRITIVORE	58		40	36	41
HERBIVORE	5			3	
OMNIVORE			5		4

Table 22: Percentage composition of all families that comprise more than 5 % of the total catch for seine nets. The percentage of different feeding groups and total sample size is also included (table not updated, no new seine data since 2007).

Percentage Maturity

Summary – average for all techniques

The gear catching fewest immature fish (27 %) is gill net drive-in encircling (Figure 3). Highest catches of immature fish are surprisingly made by large bubus (60 %) and lines (57 %). Two points are worth considering with large bubus; firstly, the number of large bubu samples is small and catches are highly variable. Secondly, although the entrance to a large bubu permits larger fish, the author has observed first-hand that this does not prevent small fish being caught as well. The high levels of immature fish caught by line fishing are a concern, as this technique is not indiscriminately capturing all the reef fish in the vicinity, like a gill net or a fish fence, but is targeting larger, higher trophic level species such as Lethrinids. Caution is required with Figure 2 because it is a summary that masks much of the detail and is based on species abundance rather than catch weight or value. As an example of this, the reason that gill net drive encircling performs so well is because large numbers of mature Clupeidea are caught by this fishing technique.



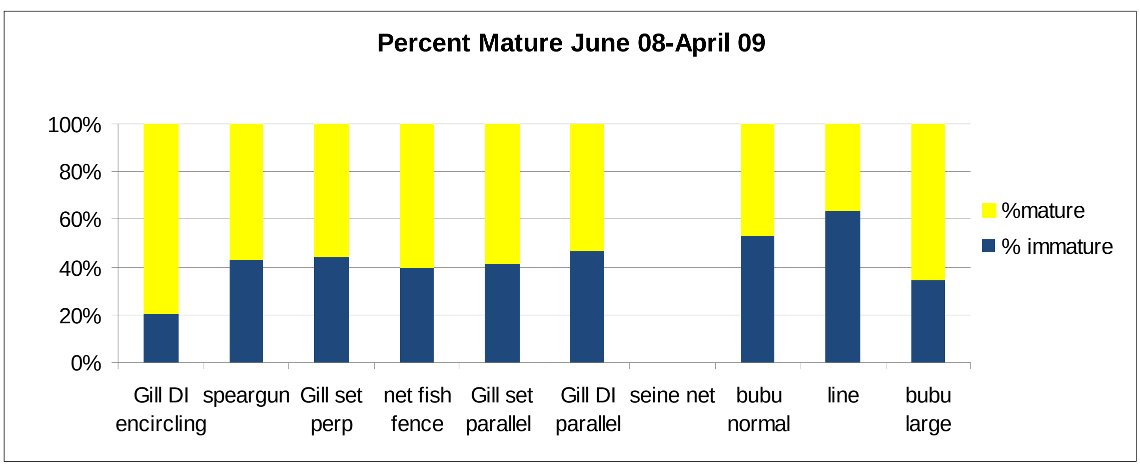


Figure 3: Percentage maturity of fish caught by fishing techniques averaged for all villages.

Species composition analysis described previously gives a breakdown of each family that comprised more than 5 % of the catch. For each of these families, the percentage of immature fish is shown in Table 23. What is immediately striking is that Lethrinidae are facing high fishing pressure, and not only from line fishing. Every fishing technique is catching Lethrinids, with between 44 % and 96 % of the catch being immature. Although vast quantities of Clupeidea (>33,000) were captured by fish fences, Table 23 shows that only 3 % of those caught were immature and 0 % of Clupeidea landed by gill net encircling were immature. A second family important for gill net encircling is Hemiramphidae, yet while these comprise 26 % of the catch all of them are immature.
Mullidae and Scaridae are the two most important families for bubu catches, yet at least 30 % of all Scaridae and 58 % of all Mullidae are immature when landed.

Family	Normal Bubu	Large Bubu	Net Fish fence	Spear-gun	Line	Gillnet set parallel to reef	Gillnet set perpendicular to reef	Gillnet encircling	Gillnet active parallel to reef
Acanthuridae	79% (43)	45% (178)	63% (83)	47% (79)	- (15)	40% (50)	66% (144)	- (21)	64% (84)
Carangidae			99% (385)	100% (3)	65% (46)	96% (55)	49% (102)	20% (24)	87% (22)
Clupeidea			4% (380)		25% (20)	- (34)	- (56)	13% (59)	(76)
Fistulariidae			75% (24)						
Hemiramphidae			- (110)			- (5)		4% (125)	(40)
Holocentridae	4% (24)	- (4)	31% (67)	100% (1)	100% (1)	14% (109)	37% (300)		29% (68)
Labridae	80% (173)	54% (28)	44% (149)	41% (99)	82% (61)	56% (119)	94% (36)	44% (10)	45% (207)
Lethrinidae	51% (177)	88% (16)	63% (1186)	70% (391)	78% (434)	72% (443)	77% (724)	43% (116)	78% (230)
Lutjanidae	22% (45)	14% (14)	16% (61)	5% (21)	43% (115)	32% (145)	33% (257)	20% (8)	55% (110)
Mugilidae			90% (20)			100% (39)	100% (30)		80% (13)
Mullidae	63% (860)	59% (71)	45% (618)	9% (140)	20% (5)	17% (201)	13% (272)	20% (122)	23% (532)
Nemipteridae	13% (100)	- (11)	8% (143)			- (46)	- (24)	3% (35)	(26)
Scaridae	48% (730)	34% (139)	40% (322)	30% (162)	6% (32)	22% (215)	42% (123)	38% (16)	42% (192)
Siganidae	50% (36)	9% (35)	35% (1476)	15% (208)	11% (9)	36% (550)	26% (507)	3% (39)	30% (792)

Table 23a: Percentage immaturity of families that account for at least 5 % of the catch of each fishing technique from the 08/09 season and total sample size (in parentheses).

Family	Bubu norm	Bubu Lge	Fish fence	Spr gun	Line	Gill set para.	Gill set perp.	Gill set encr.	Gill act para.	Sne Net
Acanthuridae				43						
Carangidae										65
Clupeidea			3					0		
Exocoetidae								0		
Hemiramphidae								100		
Holocentridae						15	14			
Labridae	78			19	57					
Lethrinidae	58	96	55	44	59	63	58	47	56	40
Lutjanidae							12			
Mugilidae						80				100
Mullidae	67	82	39	39		17	32		36	
Nemipteridae										
Scaridae	38	33		24		34	23	24	31	23

Siganidae	55	26	16		35	28	33	31	55

Table 23b: Percentage immaturity of families that account for at least 5 % of the catch of each fishing technique from the 07/08 season. Percentages above 50 % immature are indicated with red blocks and above 30 % with yellow.

The overall catch composition (Table 13) indicated that four families dominated catches for almost all villages; Lethrinidae, Mullidae, Scaridae and Siganidae. The results of percentage immaturity in Table 23 highlight that Lethrinidae and Mullidae are threatened by almost all techniques and Scaridae and Siganidae by selected techniques only.

Species analysis

Of the top 10 most caught species 2 are Siganids, 5 are Lethrinids and 2 are Mullids (Table 24). Although large quantities of bluestripe herring are caught by fish fences, these are all mature. The picture is mixed at a species level and largely depends on the size of maturity. 84 % of the smaller smudgespot spinefoot are already mature when caught, but only 43 % of black spinefoot are adults when landed. The same is true for Lethrinidae; only 28 % of thumbprint emperor and 0 % of orange striped and spot cheeked emperors are mature when landed. For Mullidae, 97 % of yellowstripe goatfish are mature when caught but for the larger dash dot goatfish only 6 % are mature. The crucial factor for all these species is whether they mature larger than 20 cm. If they do, then they are much more likely to be caught before they are adults. For the three Lethrinid species that are caught before they spawn,~ 90 % of the catch comes from 5 techniques ; gill net active parallel, gill net set parallel, gill net set perpendicular, lines and net fish fences. 90 % of black spinefoot are also caught by those same gill nets and net fish fences. Techniques targeting dash-dot goatfish were quite different with bubus and fish fences accounting for 70 % of the total catch of this species in brackets alongside fishing techniques are the percentage of that species caught by that technique.

Tables 23 and 24 represent only those families that comprise more than 5 % of the catch. While providing an important overview of the staple species that supply food and income to fishermen, this above analysis fails to drill down and capture those species threatened with commercial or even local extinction.

	Total caught		Mean size at capture	% immature

non	Scientific Name	Prior to 5/08	5/08-4/09	Techniques	Size mature	Prior to 5/08	5/08-4/09	Prior to 5/08	5/08-4/09
ipe g	*Herklotsich quadrimaculatus*	33,648	348	FF	7.3	11.1	10.2	0	4
gespot oot	*Siganus canaliculatus*	15,247	1,910	BB, BBL, FF, GA_PLL, CIR, SN, GN_PLL, GN_PPND, SPG, HL	14.8	17.1	17.4	16	14
spinefoot	*Siganus fuscescens*	8,383	1,641	BBl, FF (30), GA_PLL (23), GN_PLL(22), PN_PERP(17), CIR, SN, SPG(6)	17.8	17.2	16.9	57	57
pprint or	*Lethrinus harak*	6,286	1,417	BB (3), BBL, FF(29), GA_PPLL(24), CIR(1), SN (1), GN_PLL(13), GN_PERP(10), SPG (8), HL (10)	21.7	19.7	18.9	72	79
e striped or	*Lethrinus obsoletus*	4,313	635	BB, FF (10), GA_PLL (22), GN_PLL (20), CIR, SN, GN_PERP (17), SPG (8), HL	25.5	20	20.1	99	96
lot h	*Parupeneus barberinus*	4,081	715	BB(55), BBL (6), FF(10), GA_PLL (13), CIR, SN, GN_PLL(7), GN_PERP(5), SPG(4)	25.5	18.4	17.9	94	98
lfin or	*Lethrinus genivittatus*	3,429	443	BB, BBL, FF, GA_PLL, CIR, SN, GN_PLL, GN_PERP, SP, HL	11.7	15.1	15.7	9	6
wstripe h	*Mulloidichthys flavolineatus*	2,619	540	BB, FF, GA_PLL, GN_PLL, GN_PERP, SPG	13.9	18.7	18.1	3	12
ated or	*Lethrinus variegatus*	2,517	230	BB, FF, GA_PLL, CIR, SN, GN_PLL, GN_PERP, SPG, HL	9.6	14	15.2	4	0
heeked or	*Lethrinus rubrioperculatus*	2,188	718	BB(1), BBL, FF (11), GA_PLL (21), CIR(1), GN_PLL(38), GN_PERP(15), LN(12),	21.7	14.6	15.5	100	97

ique Key: Bubu Normal (BB), Large Bubu (BBL), Fish Fence (FF), Active Gill net set parallel to the reef (GA_PLL), Gill Net encirciled Active Gill net set perpendicular to the reef (GA_PERP), Gill net set perpendicular to the reef (GN_PERP), Gill net set parallel to the GN_PLL), Line (LN), Hand Line (HL), Seine (SN), Spear Gun (SPG)

Table 24: Percentage maturity of the 10 most caught species in the database from July 2007 – May 2008. The third column indicates the total caught with percentage immaturity being calculated only for those individuals that were measured. The numbers Ranking the difference between mean size of capture and size of maturation provides a simple method of seeing those species that are being

caught long before they have the opportunity to spawn (Table 25). These are the species that need targeted action plans in order to prevent local extinction.

Common name	Scientific Name	Total caught Prior to 5/08	5/08-4/09	Techniques	Village	Size mature (Ave. size caught prior to 5/08)	Average Size 5/08-4/09	% mature Prior to 5/08	5/08-4/09
Malabar grouper	*Epinephelus malabaricus*	36	15	line, speargun, gillnet set para	Lang., Lent., Mant.	85 (23)	17.3	0.0	0.0
Giant trevally	*Caranx ignobilis*	105	4	fish fence, line, seine, gillnet set para	Bala., Lang., Lew., Per.	71 (25)	66.5	2.0	50.0
Rainbow runner	*Elegatis bipunnulata*	20	1	trawled lures,,gill set para.	Mant.	67 (31)	24.0	0.0	0.0
Milk Shark	*Rhizoprionodon acutus*	106	0	gill set para.	Lent., Sama.	66 (35)	NA	0.0	NA
Barracuda	*Sphyraena barracuda*	125	59	fish fence, Gill encircle, Gill set para	Bala., Lang., Lew., Mant., Per., Sama.	66 (37)	34.6	1.0	1.7
Crocodilian longtom	*Tylosurus crocodilius*	163	33	fish fence, Gill act para, gill encircle, gill set para, gill set perp	Bala., Dar., Lang., Lent., Lew., Mant., Per., Sama., Som.,	57 (48)	46.8	15.0	21.2
Giant seapike	*Sphyraena jello*	68	34	fish fence, Gill act para, gill encircle, gill set para,	Bala., Lang., Lent., Lew., Per., Som.,	55 (35)	31.6	0.0	0.0
White-lipped catfish	*Paraplotosus albilabris*	148	16	fish fence, Gill set para	Bala., Lang., Lew., Per., Som.	52 (23)	22.6	0.0	0.0
Golden trevally, Silver trevally, Bigeye trevally	*Gnathanodon speciosus, Pseudocaranx dentex, Caranx sexfasciatus*	717	52 (Golden), 2(Silver), 252(Bigeye)	fish fence, gill set para, gill set perp, line, speargun	Bala., Dar., Lang., Lent., Lew., Mant., Per., Sama., Som.,	47-48 (20)	11.5(Golden), 22.5(Silver), 15.2 (Bigeye)	1.0	0(Golden), 0(Silver), 0(Bigeye)
Double spotted queenfish	*Scomberoides lysan*	159	8	fish fence, gill act para, gill set para, gill perp.	Bala., Dar., Mant., Per.	44 (26)	23.0	0.0	0.0
Flathead mullet	*Mugil cephalus*	991	201	fish fence, gill act para, gill encircle, gill set para, gill set perp,	Lang., Lent., Lew., Mant., Per., Sama., Som.,	41 (25)	21.4	0.0	0.0

Table 25: Percentage maturity of larger maturing species.

Throughout almost an entire year of sampling only 5 mature groupers of species that mature larger than 20 cm were recorded in the catches. The malabar grouper in table 26 is just one shocking example of catching fish long before they have had an opportunity to spawn. Not a single malabar grouper measured in the catch was mature and the mean size of capture was 23 cm, some 62 cm short of the size at maturation.

For the larger trevallies the situation is equally bleak. 95 giant trevallies were measured but only 2 were mature in 2007/2008 and 2 of 4 were mature in the 2008/2009 season. In the 2007/2008 season of 683 golden, silver and bigeye trevallies only 6 were mature, of 354 from the 2008/2009 season none were mature. Note that the number of fish caught is actually the number of fish that were subject to monitoring and that the differences in these numbers reflect the fact that in the 07/08 season nearly 3 times as many monitoring days were recorded.

This pattern recurs in Table 25 for many large, long-lived species that mature at sizes greater than 40 cm. It could be perceived that groupers and trevallies are ‘bonus’ species, ones that certainly are appreciated but that do not form the bulk of the catch. However, Table 25 also includes significant species that mature between 35 and 40 cm, and there are the smaller maturing orange striped emperor and dash-dot goat fish from Table 24 that mature at 25.5 cm that certainly are core species in the catch data. Having analysed all species maturity data, the startling statistic is that 82 % of fish caught that have a size of maturity greater than 20 cm were immature when landed. Almost all large species that do not mature until 20 cm are threatened with depletion by current fishing practices in Kaledupa.

Conclusions and Recommendations

The Darwin Initiative project on Kaledupa was started in response to a declining fishery and, although data from 2005 is limited, the general picture from a CPUE perspective is of gradual decline. Compared to CPUEs available for other reef areas (see citations in 2005 report) those from Kaledupa indicate the fishery is in a poor state of health. In terms of general performance of different villages, Darawa is consistently ranked highest in CPUE comparisons, particularly for gill nets, although for several techniques there are only a few samples so further analysis is required. Sombano is consistently ranked lowest or second lowest in CPUE comparisons for all villages and shows the most concerning change of all the data, with CPUE for gill net set parallel now just 10 % of 2005 levels. CPUE for gill nets fishing actively parallel, set parallel and set perpendicular have fallen most sharply since 2005 and this may be related to catching species before they are mature (see below). The CPUE of fish fences also shows a considerable decline from 2005 to 2007 and further decline to the 2008/2009 season. Although some techniques are stable, and some such as normal bubus even show an increase, the worst four fishing techniques for CPUE decline are also the ones that together account for 84 % of the fish caught. This is an extremely concerning statistic.

Catch composition analysis highlights the dependence of the fishery on four main families, Lethrinidae, Mullidae, Scaridae and Siganidae. Although there is geographical variability in the abundance of particular species caught by each technique, where there are sufficient samples to be confident in the data, the top ten species listed in Table 24 combined with a variety of parrotfish form a large proportion of many catches.

This makes the results from maturity analyses even more concerning because common species in the catches that mature at sizes greater than 20 cm are also being caught before they have the opportunity to spawn. This analysis alone does not account for the wider stock or life history characteristics. Hence, it is possible that there are larger mature individuals that are not being targeted by fishermen that will provide a steady stream of recruits for years to come. However, when data from recent years are compared with the practical experience of fishermen who report a decline in both the abundance and size of fish over several years the obvious conclusion is that recruitment overfishing is occurring. When percentage maturity data for the ten most caught species are compared with CPUE data there is a plausible relationship between the two. Gill nets and fish fences target those vital Lethrinids and black spinefoot before they spawn and it is those techniques that have shown a decline in CPUE since 2005. By consistently catching immature species there is the suggestion that gill nets fishing actively parallel, set parallel and perpendicular have caused a decline in CPUE. This pattern could well be occurring for fish fences too but the high variability in data from 2005 increase uncertainty. Further discussions with fishermen would be helpful to clarify if they have seen a decline in the catch of black spinefoot, thumbprint, spotcheeked and orange striped emperors.

In conclusion, the percentage maturity data give an instant indication that almost all larger species are being targeted in an unsustainable way. These include the high value species both to fishermen, recreational anglers and to divers.

Recommendations

The Kaledupan Fisheries Forum is still in the process of being formed and while not wanting to pre-empt the management decisions that they will take together about the future of the fishery, the author has included some general recommendations below, both from a project and a fisheries management perspective.

Project recommendations

The reef fisheries monitoring program is currently working extremely well. From observing several fisheries monitors they are working both diligently and precisely (even having arguments about the precise species from a particular genus!) and the data being generated is ideal for both temporal and spatial analysis. There are still a number of mistakes in the database ranging from typos to calculations of CPUE that are incorrect. Each record needs to be checked for accuracy soon after it has been entered, as mistakes from six months ago are so much harder to trace. Bugs and miscalculations in the database are currently being dealt with.

The lack of historical CPUE data is unfortunate because any analysis lacks the backdrop of how good the fishing really used to be. Over time, the shifting baselines of every new entrant to the fishery mean that long term dramatic declines in catch size and abundance are dulled. The best way to overcome these limitations is to compare CPUE and catch composition data from Kaledupa with those from similar reef habitats in the region. A wide literature review of relevant scientific publications as well as the inclusion of estimates from projects currently unpublished would be a great help in assessing the true state of the reef fisheries in Kaledupa.

Although catch composition at the level of feeding habit is a useful tool, it masks much of the detail in the data. As an example, both groupers and herring are recorded as carnivorous even though they are significantly different in size and in the prey they consume. Trophic levels have now been inputted for almost all species, so it is now possible to analyse the average trophic level per technique and village alongside other measures of species composition. This will be particularly useful in assessing if ‘fishing down the food webs’ effects are occurring.

Invertebrate data collected from traders are still infrequent and of a poor quality compared to fin fish. There is a specific need of accounting for the fishing effort that generated the catches recorded by the traders, as without this it is impossible to meaningfully monitor CPUE trends. One possible solution would be that one of the fishermen targeting invertebrates is tasked one day a week to account for the level of invertebrate fishing activity in that village. Furthermore, data on invertebrate size of maturity, life history and comparisons of CPUE with relatively un-fished areas elsewhere would enable a greater understanding of how sustainable the current level of invertebrate exploitation is in Kaledupa.

Fisheries management recommendations

Gear limitations: Competition for space to fish is intensifying with more fish fences, gill nets and bubus destined to be used as the island population grows and the abundance of fish decreases. If seaweed farming expands this will further heighten conflict over space. Capping fishing effort at current levels would at the very least limit the increase in catching power of each village and could be implemented soon with little social disturbance. The intention of the proposed licensing system is to do this at the level of individual fishers so as to limit new entrants to the fishery, but it needs to go one stage further and restrict the gear that fishermen use to current levels. This will prevent other fishermen 'taking up the slack' if 30 % of fishing effort is removed.

Further consideration is also required to ascertain if there are certain spawning grounds that should be protected at different times of the year. While there are options for minimum landing sizes at the species level this is only pertinent for the fishing techniques where the fish can be returned alive, or the result will be wasteful discarding. One of the difficulties that faces decision makers with gill nets is that they are catching different species from the same family some of which are generally mature like smudgespot spinefoot, threadfin emperor and yellowstripe goatfish and others which are generally immature such as black spinefoot, orange striped emperor and dash-dot goatfish. A further increase in mesh size may be an option but could also allow the smaller species of the family slip through the net even though they are mature.

Species management plans: Time and space are limited in this report so it has not been possible to look at the impact of every gear on each species. However it is possible to analyse important species and consider how particular management strategies may benefit them. As an example, one of the concerning facts from Table 25 was that from nearly 1000 blue-barred fish none were sexually mature. This species would benefit from specific management that is quite simple to execute. Assuming that all fish in bubus and fish fences are still alive at the time of capture, the 87 % of all blue-barred parrotfish that were caught by these techniques could have been returned alive with the introduction of a minimum landing size. Likewise, whilst the author was visiting various fishermen, a single berried lobster was entangled in a gill net and was worth the same as all the other fish combined that the fishermen caught that day (some 20 kg). Rather than make a short term opportunistic profit a species management plan for lobsters could see the introduction of a minimum landed size and a ban on landing berried lobsters. There will certainly be implementation difficulties; how would you stop a fisherman scrubbing the eggs from a berried lobster? But these are the difficulties that the KFF is designed to iron out. If fishermen in focus groups are asked which species they want to see return to a larger size or abundance, and if they themselves are the ones driving the species management plans, compliance is likely to be much higher.

Enforcement and Social cohesion: One of the fundamental problems with fisheries management is implementation and even more so in an environment where the catch (and therefore the evidence of infringements) is eaten daily. As the KFF is being formed the author advises that they look to initially implement policies that are palatable to all fisheries. One such example is a complete ban on fishers outside of Kaledupa fishing on the reefs. Although in principle this will happen with the introduction of the registration scheme, from conversations with fishermen in Kaledupa the regional government still seems to offer licenses to fish to whoever has the means to obtain them. Any benefits that accrue as a result of the hard work of Kaledupans to safeguard their resource may well be exploited by nomadic boats. It is this kind of issue that will bring all the fishermen together around a common ‘enemy’ and may help to galvanise the KFF. A further issue that needs serious consideration is the relationship between Kaledupan and Bajo fishermen. Even during short conversations about the relationship between them, a level of distrust and frustration has been expressed which could derail a process of joint decision making.

Alternative livelihoods: A proportion of reef fish is certainly exported off the island but further work is needed to assess how large this is. If the vast majority of reef fish are consumed by local people and fishing effort is reduced by 30 % there is potential for a protein shortage on Kaledupa while the stocks return to a higher level. This situation may be heightened by agar-agar farmers taking possession of large areas that were previously fishing grounds. It is essential that alternative livelihoods do not move the problem elsewhere. The author has witnessed firsthand people from one village going to another area and chopping down mangroves for firewood. Aside from the social discontent that this created for the area that was losing its mangroves the ecological effect for fish populations that use the nursery grounds could be serious. Clearly, seaweed farming is not actively destructive like chopping firewood but the ecological, as well as economic and social, implications of a boom in agar-agar farming need careful consideration before the industry is widely expanded.