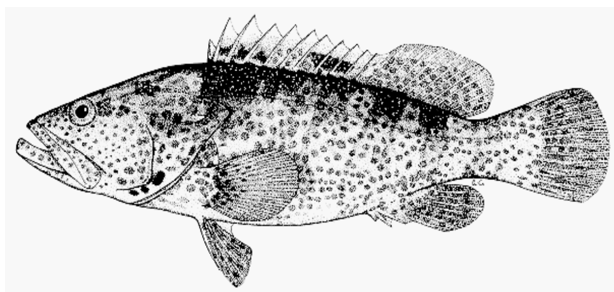
Harvest Characteristics of Gango, a Method to Capture Fingerling Groupers from Mangrove Areas in West Flores, Indonesia

A report from the TNC/YPAN Komodo marine conservation project



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The mission of The Nature Conservancy is to preserve plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.

To date the Conservancy and its members have been responsible for the protection of more than 10 million acres in the United States of America and Canada. It has helped like-minded partner organizations to preserve millions of acres in Latin America, the Caribbean, the Pacific and Asia. While some Conservancy-acquired areas are sold to other conservation groups, both public and private, the Conservancy owns more than 1,600 preserves- the largest private system of nature sanctuaries in the world.

Drawn by Indonesia's biological richness and its imminent danger, the Conservancy opened an office in Jakarta in 1991. The first target was to protect Lore Lindu National Park (Sulawesi). In 1995, the Conservancy started the Komodo project. The aim of this project is to help the authorities of Komodo National Park to protect the marine area around the Komodo Islands. The Conservancy has a long-term commitment to the protection of the marine biodiversity of Komodo National Park.

The Conservancy founded the Yayasan Pusaka Alam Nusantara, an Indonesia non-governmental organization. The Yayasan is dedicated to nature conservation in Indonesia, which makes it a key partner of the Conservancy.

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1 INTRODUCTION

1.1 The live reef fish trade

The Conservancy's Indonesia Coastal and Marine Program interest in fish culture developed through the threats posed to Indonesia's coral reefs by the Hong Kong-based live reef fish trade. The main target fish species of the live reef fish trade are groupers (*Epinephelus* spp., *Plectropomus* spp., mouse grouper *Cromileptes altivelis*) and Napoleon wrasse *Cheilinus undulatus*, but at least 30 other species are also regularly found as live food fish at the Hong Kong market (Johannes &. Reipen 1995; Lee & Sadovy 1998). Most of these fish end up in the aquariums of expensive restaurants, where they are sold to consumers with a taste for fresh fish. The live reef fish trade threatens Indonesia's coral reef biodiversity through three related mechanisms (Erdmann & Soede 1996; Pet & Pet-Soede 1999):

1. Destructive fishing practices, causing chemical damage to coral reefs through the use of cyanide solutions to stun and capture target fish species, and physical damage through diving fishermen who break away corals around the hiding places of stunned target fish.
2. High exploitation rates of wild populations of market-ready fish (adults and sub-adults), rendering it impossible for the wild stocks to recover. The most important target fish species are extremely vulnerable to overfishing, because these species tend to aggregate for spawning at certain sites during certain seasons. Once the commercial fishery locates a spawning aggregation site, the fishery can extract a significant portion of the adult stock with little effort.
3. High exploitation rates of wild populations of fingerlings of target fish. The fingerlings are used to supply the developing grow-out fish culture industry. Wild-caught fingerlings are kept in fish cages until they reach marketable size.

The volume of the live reef fish trade presently measures ca. 25,000 metric tonnes per annum, which corresponds to a value of ca. 1 billion US$. By supplying the market with well over 50% of this volume, Indonesia is the largest supplier of wild-caught live fish food fish. Being an export-oriented activity, the live reef fishery intensified because of the Indonesian monetary crisis. The present exploitation rate is much higher than can be sustained by Indonesia's coral reefs. The reefs of Western Indonesia are already depleted of the most valuable species, hence the life reef fish trade shifted its operation to Eastern Indonesia.

In an effort to combat the threats posed by the live reef fish trade, The Conservancy's Indonesia Coastal and Marine Program developed a strategy consisting of the following components:

I. Reforming marine policies, marine tenure and legal framework (including production of awareness and education materials)
II. Stimulating mariculture of high-quality food fish.

III. Identification, monitoring and management of spawning aggregation sites of the commercial fish species.

1.2 Developing fish culture to abate threats related to the live reef fish trade

Developing a fish culture enterprise in the Komodo area can help in two ways to abate threats posed by the live reef fish trade:

1. A profitable fish culture sector in the Komodo area can generate an alternative livelihood for fishermen who are presently using destructive fishing techniques, amongst others cyanide fishing.
2. Especially if *groupers* are cultured, fish culture can contribute to the transformation of the live reef fish trade from unsustainable, wild-caught based to sustainable, culture based.

Upon invitation of The Conservancy, AJ Aqua Intercon Pty. Ltd. carried out two surveys to assess the prospects for aquaculture in the Komodo area (Ogburn & Oburn 1996). The field work of the surveys took place in the period October 7-24 1996 and May 11-22 1997. The consultants concluded that the prospects for aquaculture development in the Komodo area are good. Some of the assets of the Komodo area from the perspective of mariculture are:

- Good water quality, because of the dry climate (no land run-off). Furthermore, because the Komodo area is a sea strait between two mayor islands (Sumbawa and Flores) there is a high flow-through of clean oceanic water. There is no history of 'red tide' algae blooms in the Komodo area –a considerable asset, as a ride tide bloom in April 1998 wiped out 90% of mariculture industry of Hong Kong, causing a loss of US$ 13 million to the Hong Kong economy.
- The Komodo area is not situated in a typhoon area
- The area has already been opened to the live reef fish trade, hence marketing of a live product should be relatively easy.
- The local communities are already familiar with fish cage technology
- There are numerous islands and shallow bays in the area, which offer suitable sites for mariculture activities (fish cages, hatchery enterprise).
- Commercial species that are suitable for mariculture are native in the area, therefore broodstock for mariculture can be acquired locally and there is no risk for unwanted introduction of foreign species into the area.
- Cheap 'trash fish' that is suitable for fishfeed is available throughout the year.

One of the bottlenecks to overcome is the availability of fingerlings that can be used by a fish grow-out enterprise. Presently, Taiwan is the only country that produces grouper fingerlings (mainly estuary grouper *Epinephelus coioides* and Malabar grouper *E. malabaricus*) (World Bank 1999). Though several research instutes in Indonesia successfully reproduced a variety of grouper species in captivity (Mous 1998; Balai Budidaya Laut Lampung 1998; Sugama et al. 1999), hatchery-reared grouper fingerlings are not yet widely available. Worldwide, capture from the wild remains the main source of grouper fingerlings for the grow-out industry.

1.3 Capture of grouper fingerlings from the wild –is it sustainable?

Gango is one of the many methods that are presently used in the Philippines to harvest grouper fingerlings (Ogburn & Johannes 1999). A *gango* is a loosely-knit structure of mangrove wood and stones (there is a variety of designs) that is put in the tidal area, near mangroves (Fig. 1). Fish tend to aggregate in and around the *gango*. After a period of 2-3 months, during low tide, the fishermen put an encircling net around the *gango*, and after the *gango* is fully enclosed, they disassemble the *gango* (Fig. 2). The fish that inhabited the *gango* stay behind and are easily caught. Thereafter, the fishermen rebuild the gango, and after 2-4 weeks the gango is harvested again. The *gango* method is described in detail in Ogburn & Johannes (1999).

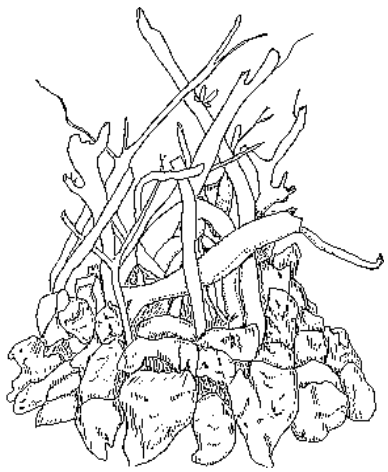

Figure 1*. Diagram of a gango (from Ogburn & Johannes 1999). An average gango covers a surface area of 5-10m^2, and is about 1.5 m high.*

Figure 2*. Harvesting of a gango. The encircling net is put around the gango, and the gango is disassembled.*

Little is known about the species and size composition of gango harvests. Ogburn & Johannes (1999) report that in the Philippines 90-100% of the harvest consists of estuary grouper, and 5-10% of Malabar grouper. However, these figures relate to the target fish (i.e. groupers) only. It is known that a large fraction of the harvest consists of a mixture of species. Part of this bycatch is used for either human consumption, or as fish feed, and part of the bycatch is discarded.

One of the main concerns about the gango method from an environmental and long-term socio-economical perspective is its sustainability, both in relation to target fish and to non-target fish. After all, the gango method might just present another fishing method, putting pressure on stocks that are already endangered by overfishing (Sadovy & Pet 1998). Presently, there are only anecdotal accounts from fishermen that have been using this method for a considerable time. These accounts suggest that the gango method can be applied without affecting the wild stocks (Ogburn & Johannes 1999). There are two theories that explain how fish can be harvested from the wild, without affecting the wild stocks:

1. *Gangos* provide shelter for juvenile fish, which would have died if the *gango* would not have been available.

2. *Gangos* catch juveniles, which suffer a high natural mortality (usually higher than 70% per year). Thus, the majority of the harvested juveniles would have died prematurely anyway.

The second theory does not in itself explain why capture of juveniles from the wild has a negligible effect on wild adult stock. After all, a small percentage of harvested juveniles would have survived to the 'wild' adult stock. However, if the number of would-be survivors is small, the second theory remains valid. This condition is fulfilled if the natural mortality of harvested juveniles is high, and the number of harvested fish is small compared to the wild stock of similar-sized fish. As the natural mortality rate is inversely correlated with size, this means in practice that fish for grow-out should be caught at the lowest possible size.

Putting the theories above to the test requires population dynamical studies of the fish community that is vulnerable to *gangos*. Hence, a description of the species and size composition of the *gango* harvest, and the seasonality therein, is indispensable.

In the framework of the Komodo mariculture project, a try-out of *gango* method in the Komodo area started in October 1997. The purpose of this try-out was to see whether the *gango* method would yield commercial grouper species in the Komodo area, and to do a preliminary environmental impact assessment by describing species and size composition of the harvest.

2 MATERIALS AND METHODS

2.1 Study area

The Komodo islands are located between the islands of Sumbawa and Flores in the Nusa Tenggara Timur province of Indonesia. Komodo National Park encompasses most of these islands. The Park was established in 1980 and has a management unit of 88 staff. The Park was declared a Man and Biosphere Reserve and a World Heritage Site in 1986. At the request of the Indonesian Department of Forestry, the Indonesian NGO Yayasan Pusaka Alam Nusantara (YPAN) and the International NGO Nature Conservancy (TNC) co-operate with Komodo National Park's authority to manage the Park.

Komodo National Park (KNP) includes three major islands (Komodo, Rinca and Padar) and numerous smaller islands, totaling 41.000 ha of land. The Park is famous as the habitat of the Komodo dragon *Varanus Komodoensis*, but it is also one of the richest areas for coral biodiversity in Indonesia, and it has one of the richest fish faunas in the world with an estimated 1000 species. The Park contains 132.000 ha of marine waters. The number and variety of islands, coupled with a range of physical conditions, such as wind exposure, current and wave action, result in a high diversity of coastal and marine habitats, including coral reefs, rocky shores, sea grass beds, sandy bays and mangroves. The Park belongs to the most diverse and richest marine environments in the world. There are presently some 2.300 inhabitants living within the Park, spread out over 3 settlements (Komodo, Rinca and Kerora). About 15.000 people live in villages directly surrounding the Park. Park inhabitants derive 90 % of their livelihood from a pelagic lift net fishery, which is targeting squid and small schooling pelagic fish.

The live reef fish trade entered the area in the late nineties, and presently groupers and Napoleon wrasse in and around the Park are under a heavy exploitation pressure, both by cyanide fishing and by hook-and-line fishing.

Gangos were constructed in four areas in West Flores, near the town Labuan Bajo (E 119°53' S 8°30'). The first *gango* area, Terang Bay (the estuary of Terang River), is situated ca. 20 km East of Labuan Bajo (Fig. 3 and 4). The surface area of Terang Bay is ca. 2000 ha. The bay is fringed with mangroves.

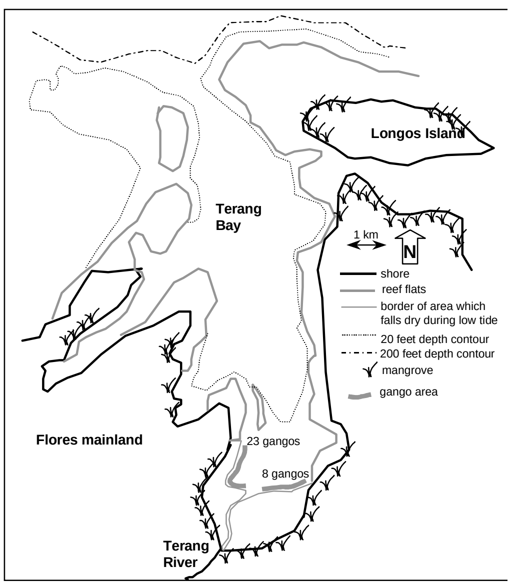

Figure 3. *Schematic map of Terang Bay, indicating the locations of the gangos.*

Figure 4. *Gangos in Terang Bay*

The other three *gango* areas, are located about 5 km South of Labuan Bajo (Fig. 5). Nangabido (Fig. 6) is an inlet (i.e., a creek of which the water flow is mainly determined by the tides), Nanganae (Fig. 7) is a river (freshwater, but during period of low rainfall, salt water may enter the river), and Menjaga (Fig. 8) is a small bay. All three areas are fringed by mangroves.

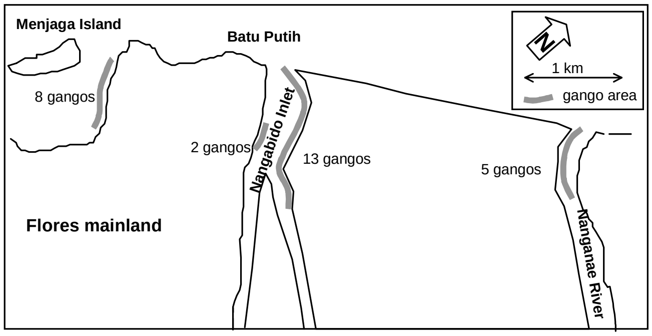

Figure 5. *Schematic map of Nangabido Inlet, Nanganae River and Menjaga Bay, with locations of the gangos*

Figure 6. *Nangabido Inlet.*

Figure 7. *Nanganae River.*

Figure 8. *Menjaga Bay*

2.2 *Gango* procedures

In total, 61 *gangos* were constructed: 31 in Terang Bay, 15 in Nangabido Inlet, 7 in Nanganae River and 8 in Manjaga Bay. In Nanganae, 2 gangos were washed away before they could be harvested after a period of heavy rainfall. The first gango was constructed on November 5, 1997, and the last harvest took place on February 15, 1999. In total, 180 harvests took place, most of them in Terang Bay and Nangabido Inlet (Figure 9). The interval period between rebuilding and harvesting varied between 4 and 211 days (Table 1). The total number of functional gangos (i.e., gangos that are aggregating fish) on each day is represented in Figure 10.

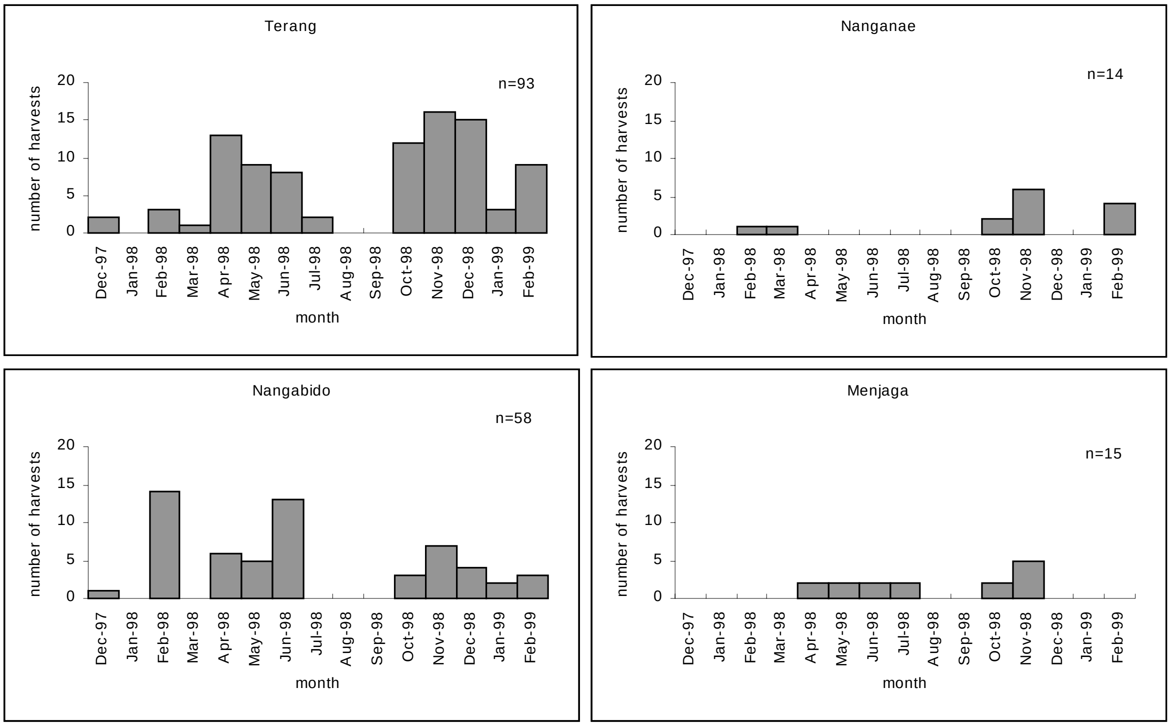

Figure 9. *Number of harvests realized per month in each of the sampling areas. The total number of harvests per area is indicated in the top right corner of each graph.*

Table 1. *The mean, minimum and maximum period between building and harvesting date (in days).*

Area	Mean	Min.	Max.
Terang Bay	90	4	211
Nangabido Inlet	78	10	198
Nanganae River	82	15	128
Menjaga Bay	100	11	220

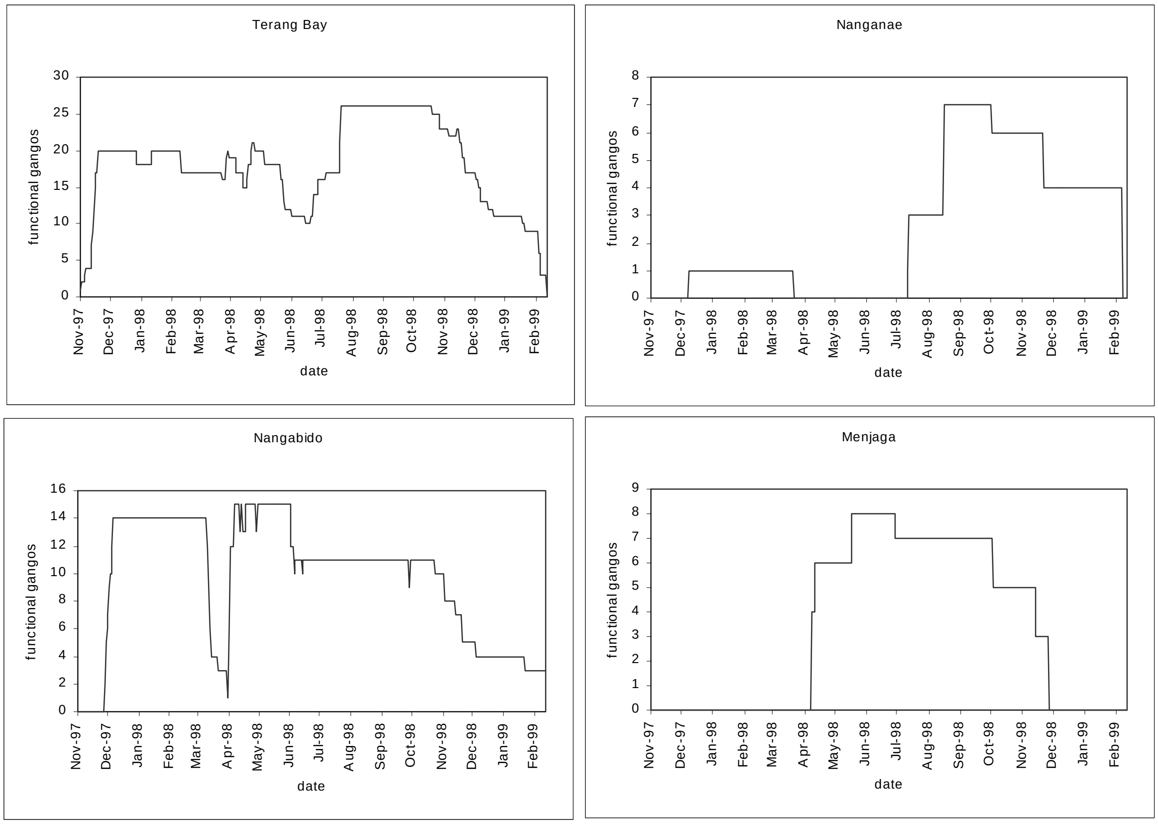

Figure 10. *Number of functional gangos (i.e., gangos that are aggregating fish) vs. date in each of the four study areas.*

2.3 Harvest sampling procedure

Already at the start of the fieldwork, it was clear that species diversity and number in the harvest was too high to determine the species of each fish within manpower constraints. Hence, based on the first harvests we established species groups that consisted of a taxonomic family or a higher taxonomic level. The most abundant commercial species were determined to the species level. Of each species group, a length-frequency distribution was established. Length measurements were made in total length (TL), to the nearest cm. If the number of individuals in a species group was too high to measure within manpower constraints, we measured a sub-sample of ca. 60 individuals. The sample was then raised according to the sub-sample factor. Invertebrates were only counted.

Before harvesting, the salinity at the bottom and the top of the watercolumn was measured using a refractosalinometer.

3 RESULTS

3.1 Species and numbers

The most abundant commercial species in the harvest were estuary grouper, mangrove jack *Lutjanus argentimaculatus*, and sea bass *Lates calcarifer* (Table 2, next page). Other commercial species that were occasionally encountered are Malabar grouper and mouse grouper *Cromileptes altivelis*. Some of the individuals in the *Epinephelus* spp group were identified to the species level (Table 3). Each of the identified species is found in the live reef fish trade, and therefore we considered them as target fish. However, the maximum size of some of these species (i.e., *E. bleekeri* and *E. polystigma*) is relatively low, and therefore they are presently not cultured. Target species comprised only a small fraction of the total harvest (Table 4). Overall, 1.4% of the fish harvest consists of target fish. Harvests from Terang Bay had the highest percantage of target fish (2.0%) and Menjaga Bay had the lowest percantage of target fish (0.01%).

Table 3. *Rank order (decreasing number in the total harvest) of occasionally identified groupers that were categorized in the 'Epinephelus spp'-group, and fish that were categorized in the 'miscellaneous fish'-group.*

Rank	Species
'Epinephelus spp.' – group	
1	whitespotted grouper *E. cearuleopunctatus*, Bleeker's grouper *E. bleekeri*
2	white-dotted grouper *E. polystigma*
3	giant grouper *E. lanceolatus*
'miscellaneous fish'-group	
1	scat *Scatophagus argus*, trevally *Carangidae*
2	bannerfish *Chaetodontidae Heniochus spp*., other butterflyfish *Chaetodontidae*, angelfish *Pomacanthidae*, batfish *Ephippidae*
3	parrotfish *Scaridae*, wrasse *Labridae*, emperors *Lethrinidae*
4	lionfish *Scorpaenidae Peterois spp* or *Dendrochirus spp.*, other scorpionfish *Scorpaenidae*, goatfish *Mullidae*
5	stonefish *Scorpaenidae Synanceia spp.*, eel *Muraenidae*, milkfish *Chanos chanos*, filefish *Monacanthidae*
6	sea horse *Syngnathidae*, stingray *Dasyatidae*

Note: also, one sea snake *Elapidae* was harvested

Table 4*. Mean numbers of target fish, non-target fish and invertebrates per harvest.*

	overall	Terang Bay	Nangabido Inlet	Nanganae River	Menjaga Bay
target fish	8.2	11	5.7	7.0	0.13
non-target fish	565	527	364	815	1342
invertebrates	367	589	148	167	20

***Table 2**. Overview of harvest numbers of each species or species group. AM = arithmetic mean, min = minimum number observed, max = maximum number observed, sum = total number harvested, %0 = percentage of absence from harvest ('zero observations'), GM = geomtric mean, GSD = geometric standard deviation. The AM is by definition higher than the GM, except where there was a substantial number of zero observations, because zero observations cannot be included in the calculation of the geometric mean. Hence, if the percentage of zero observations is high, the GM and also the GSD are less meaningful. The GSD is a muliplicative measure for the standard deviation, i.e., for estuary grouper in Terang Bay, 67% of the observations are in the interval between 5.3:2.1 and 5.3×2.1.*

	overall				Terang Bay				Nangabido Inlet				Nanganae River				Menjaga Bay			
species	AM	min	max	sum	AM	%0	GM	GSD	AM	%0	GM	GSD	AM	%0	GM	GSD	AM	%0	GM	GSD
identified fish																				
estuary grouper, *E. coioides*	4.5	0	27	814	6.6	3	5.3	2.1	3.1	19	2.8	2.1	1.4	29	1.5	1.9	0	100		
Malabar grouper, *E. malabaricus*	0.061	0	1	11	0.032	97	1.0	1.0	0.10	90	1.0	1.0	0.14	86	1.0	1.0	0	100		
Epinephelus spp. (1)	0.92	0	11	166	0.26	86	1.5	1.8	2.0	24	2.1	1.9	0.50	50	1.0	1.0	1.3	40	1.7	2
mouse grouper, *C. altivelis*	0.030	0	1	6	0.02	98	1.0	1.0	0.05	95	1.0	1.0	0	100			0.067	93	1	
sea bass, L.. calcarifer	0.61	0	15	109	1.2	62	2.0	2.4	0	100			0	100			0	100		
mangrove jack, *L. argentimaculatus*	2.9	0	30	528	3.3	28	2.8	2.5	2.5	33	2.5	2.4	5.5	14	4.4	2.6	0.067	93	1	
other snappers, *Lujanidae*	11	0	106	1990	16	3	11	2.8	6.8	10	4.9	2.5	4.7	43	6.7	2.0	1.5	40	2	2.1
sweetlips, *Heamulidae*	0.26	0	6	46	0.03	97	1.0	1.0	0.62	60	1.3	1.7	0.42	71	1.3	1.7	0.067	93	1	
rabbitfish, *Siganidae*	29	0	1440	5220	28	6	15	3.8	4.5	24	4.0	2.6	3.0	50	3.6	3.1	155	0	30	6.2
cardinal fish, *Apogonidae*	345	0	4408	62173	294	2	96	5.2	215	2	62	5.9	418	0	225	3.7	1103	0	553	3.9
pufferfish, *Tetraodontidae*	17	0	141	3095	17	9	12	2.9	17	14	9.5	3.3	33	0	12	5.5	4	33	4.3	2.4
flatfish, *Pleuro-nectiformes*	4.2	0	576	754	0.01	99	1.0		0.05	95	1.0	1.0	53	86	315	2.4	0.13	87	1	1
surgeonfish, *Acanthuridae*	6.2	0	60	1108	4.7	28	4.4	2.6	10	9	6.4	3.0	0.14	86	1.0	1.0	5.53	13	5.1	2.1
gobies, *Gobiidae*	50.9	0	280	9169	56	8	35	3.5	54	3	41	2.5	55	0	47	1.8	5.53	20	5.5	1.9
damselfish, *Pomacentridae*	2.4	0	59	433	1.6	58	2.6	2.3	3.1	31	2.9	2.4	6.0	57	6.2	3.9	1.13	60	2.2	2
invertebrates																				
shrimps, *Decapoda*	113	0	587	20384	144	2	110	2.2	93	2	58	3.0	103	0	78	2.3	10	0	7.9	2.4
crabs, *Decapoda*	37	0	438	6749	55	2	24	4.1	17	5	12	2.7	43	7	24	4.3	3.7	7	2.8	2.3
sea cucumbers, *Holothuria*	1	0	48	180	0.70	88	2.0	3.2	0.71	74	1.9	2.2	0	100			4.9	20	5.1	2
sea stars, *Asteroidea*	0.05	0	4	9	0.08	95	1.3	1.9	0	100			0	100			0.067	93	1	
sea urchins, *Echinoidea*	0.11	0	5	20	0.02	98	1.0	1.0	0.12	93	1.4	2.0	0	100			0.73	67	1.8	1.9
shells, (gastopods and bivalves)	215	0	5584	38660	389	8	174	4.8	37	9	17	3.8	21	14	22	1.8	0.47	87	3.2	1.9
miscellaneous fish (1)	97	0	640	17478	109	1	54	4.1	51	0	36	2.3	242	0	191	2.1	65	0	32	2.6

Notes:
(1) Some of the species that were identified and that were pooled in these species groups are listed in Table 3.

3.2 Size composition of the harvest

Descriptive statistics for size range of the fish in the harvest are presented in Table 5. The length-frequency distributions of are presented in Figs. 11-15. Of the target fish, estuary grouper was the only target fish of which a sizeable quantity of fingerlings was harvested. The size of two other most abundant target fish (mangrove jack and sea bass) were all past fingerling stage.

Table 5. *Mean, minimum and maximum total length (cm) per species category and study area over the total harvest.*

	Terang Bay			Nangabido Inlet			Nanganae River			Menjaga Bay		
species	mean	min	max	mean	min	max	mean	min	max	mean	min	max
estuary grouper	13.9	2	61	10.8	2	57	18.4	3	34	-	-	-
Malabar grouper	23	10	43	20.3	4	41	17.6	9	33	-	-	-
mouse grouper	6.5	6	7	6	2	9	-	-	-	12	-	-
other groupers	12.7	2	30	10.1	2	57	26.6	8	40	15.4	3	29
mangrove jack	22.3	12	46	23.1	5	43	17.6	9	33	21	-	-
sea bass	52.4	36	84	-	-	-	-	-	-	-	-	-
all other fish(1)				4.4	1	52	4.7	1	36	4.7	1	26

(1). This group consists of all fish, except the categories listed above.

Differences in length between areas were generally small, but significant for estuary grouper, ‘other groupers’, mangrove jack and ‘all other fish’ (the latter group consists of all fish, except target fish) (Wilcoxon’s rank sum test, $P<0.05$).

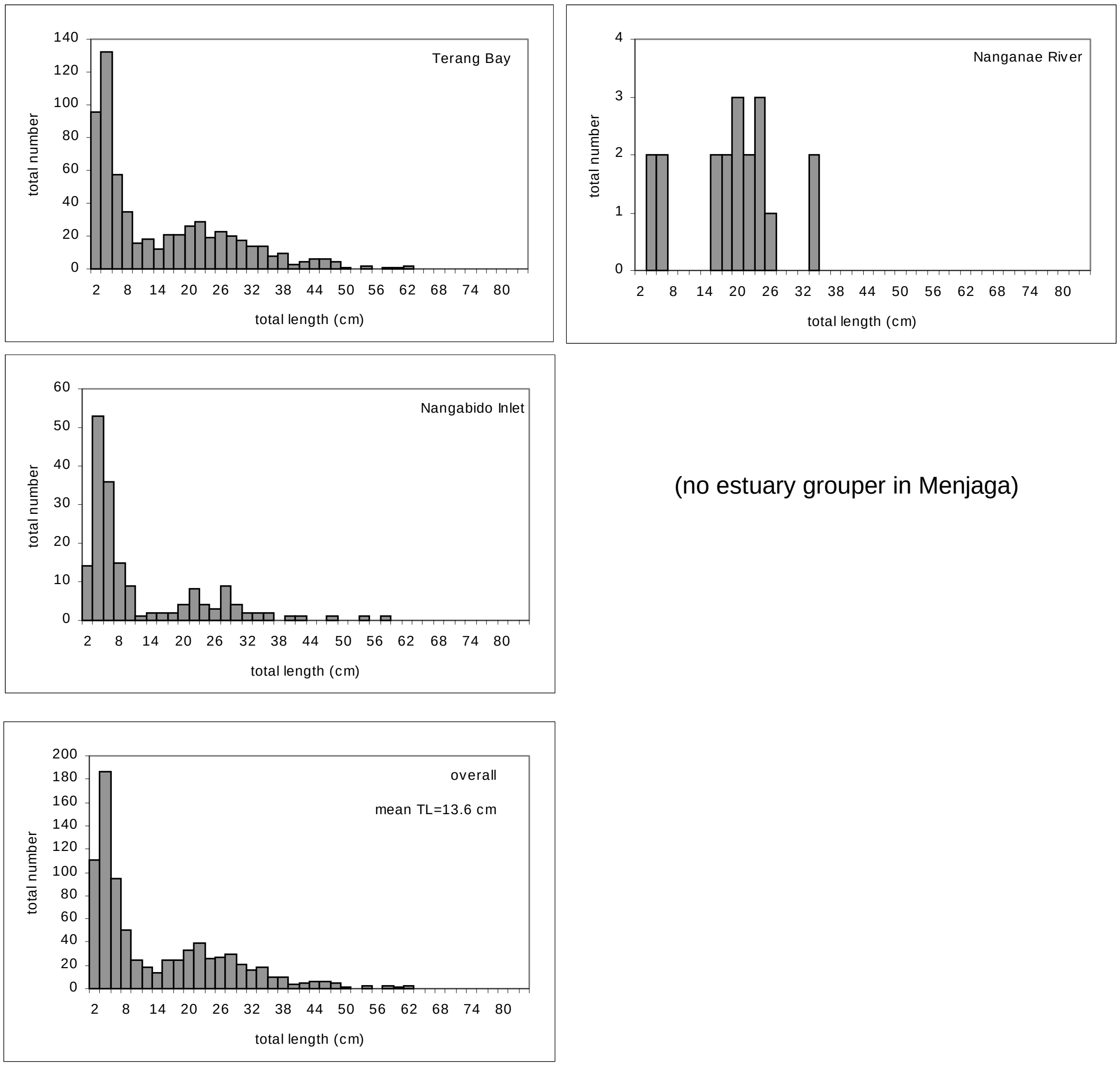

Figure 11. *Estuary grouper length-frequency distributions of the total harvest in each of the study areas.*

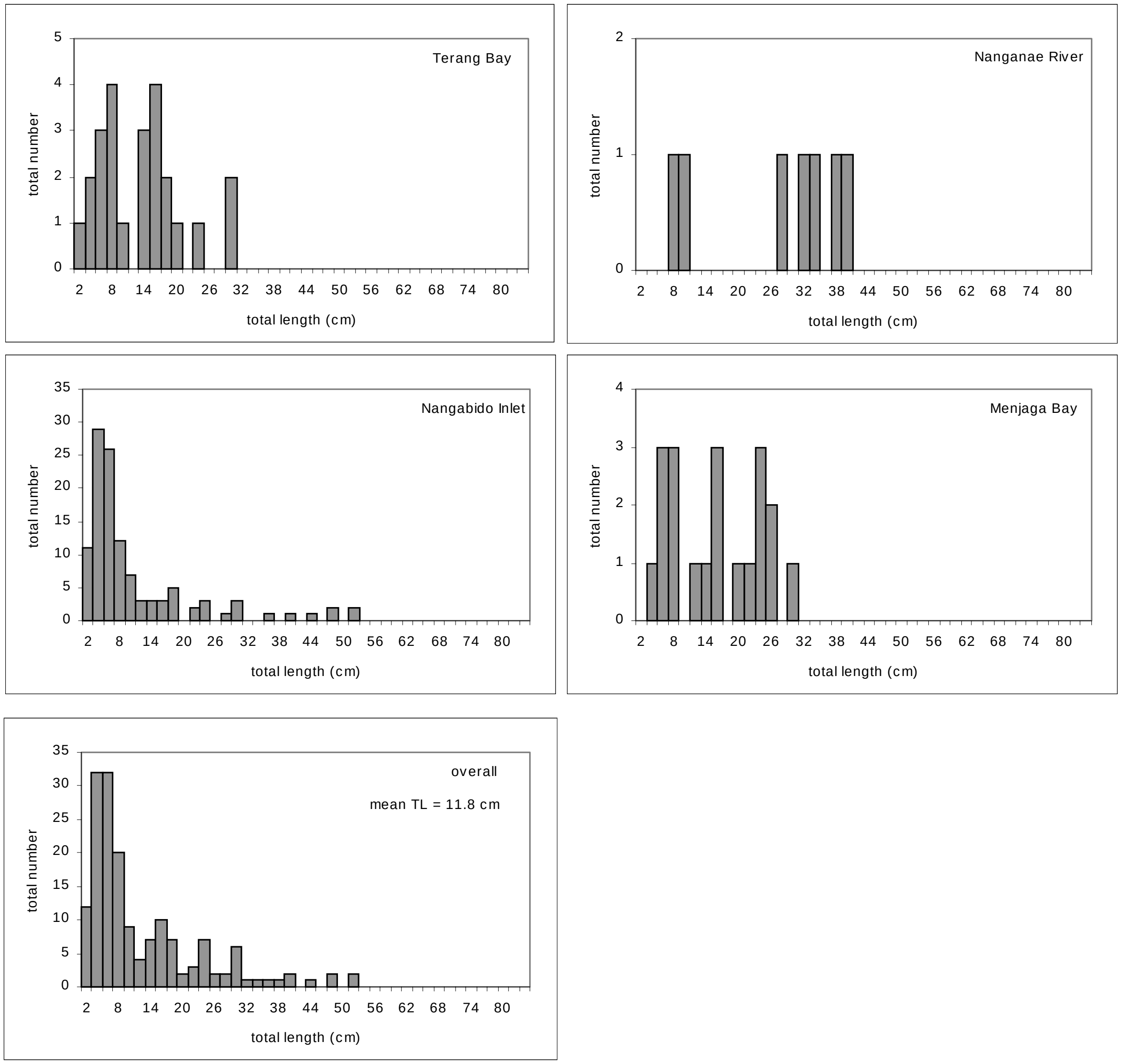

Figure 12. *'Other groupers' length-frequency distributions of the total harvest from each of the study areas.*

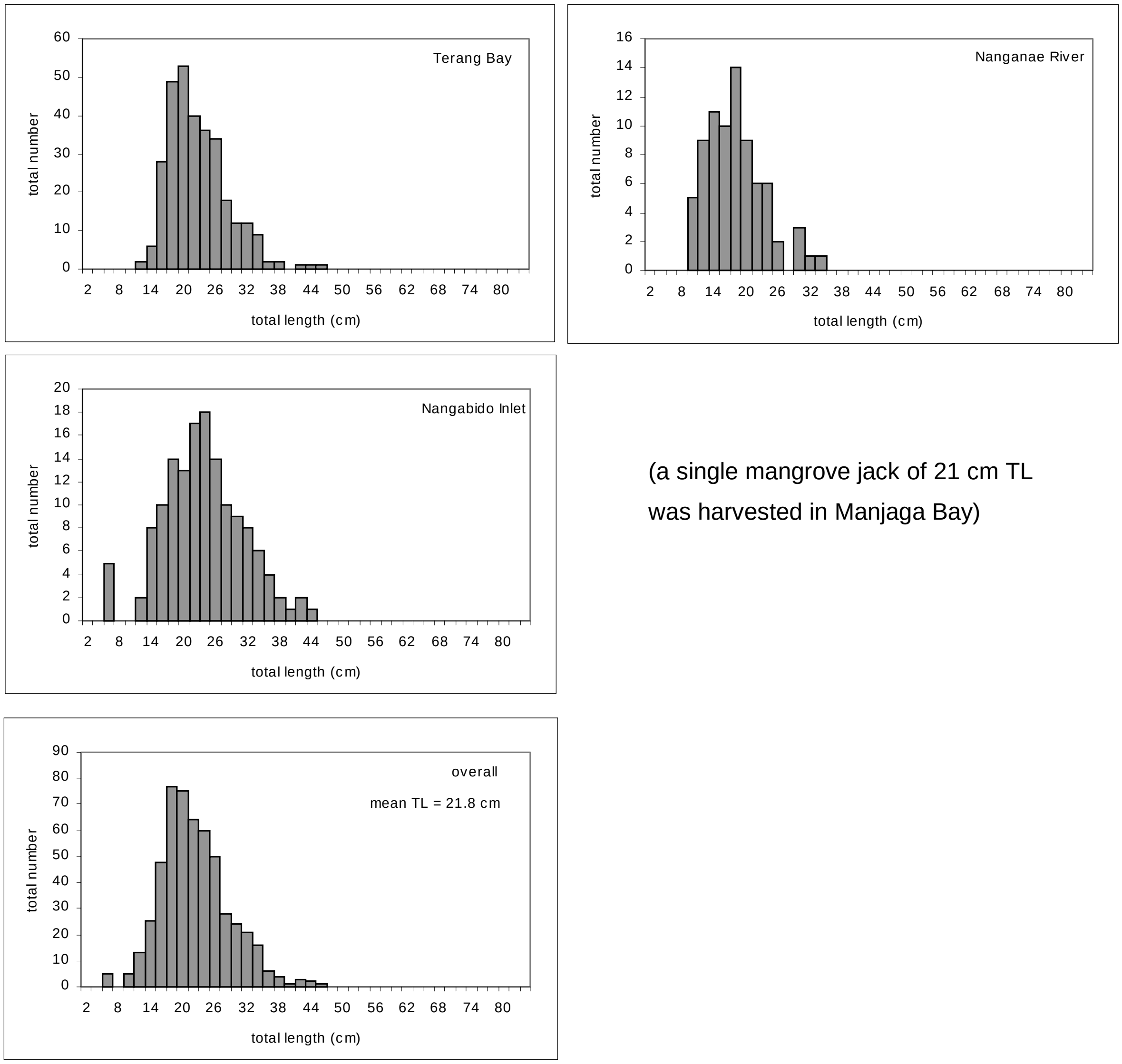

Figure 13. *Mangrove jack length-frequency distributions of the total harvest from each of the study areas.*

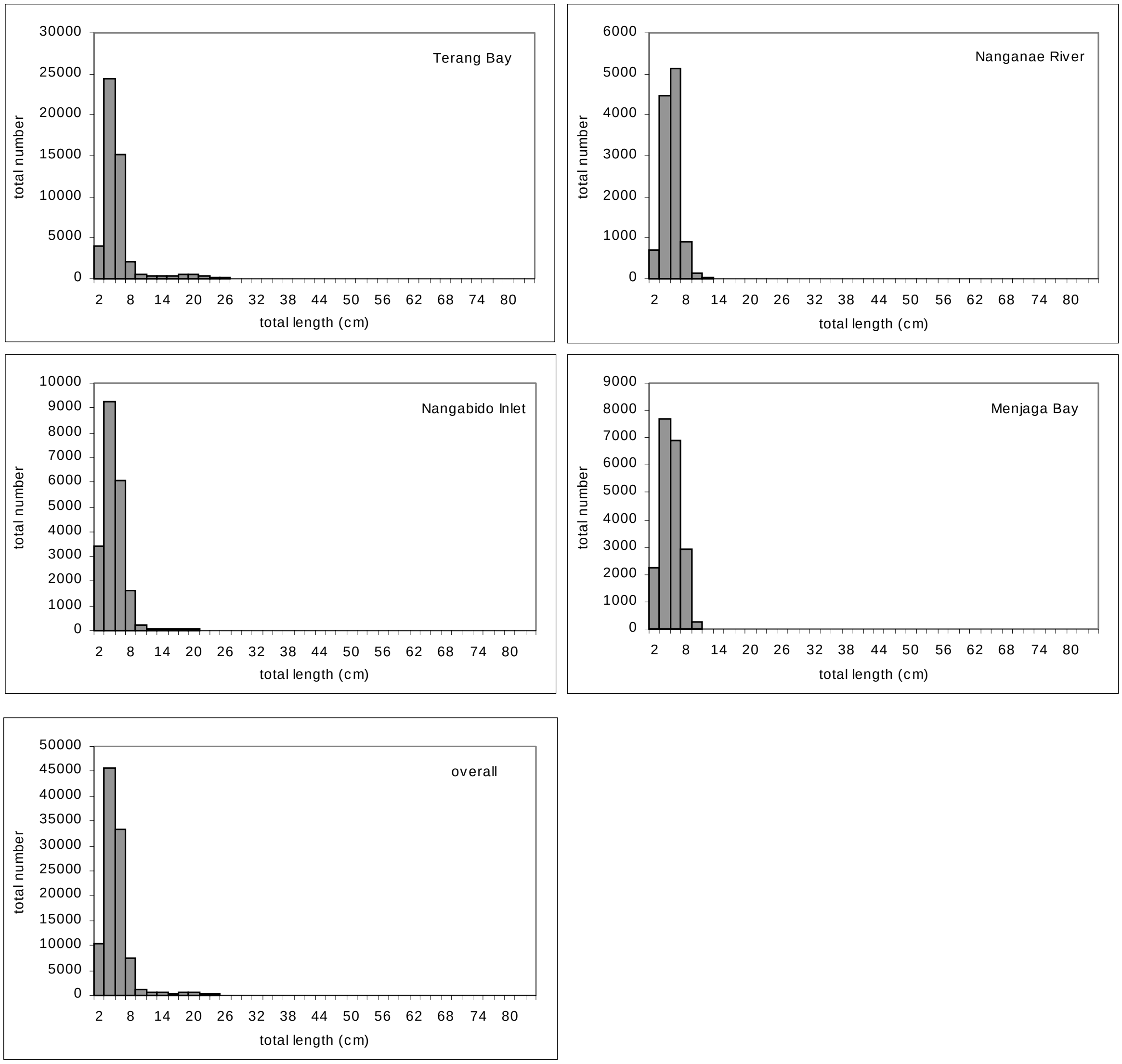

Figure 14. *'All other fish' (all fish except target fish) length-frequency distributions of the total harvest from each of the study areas.*

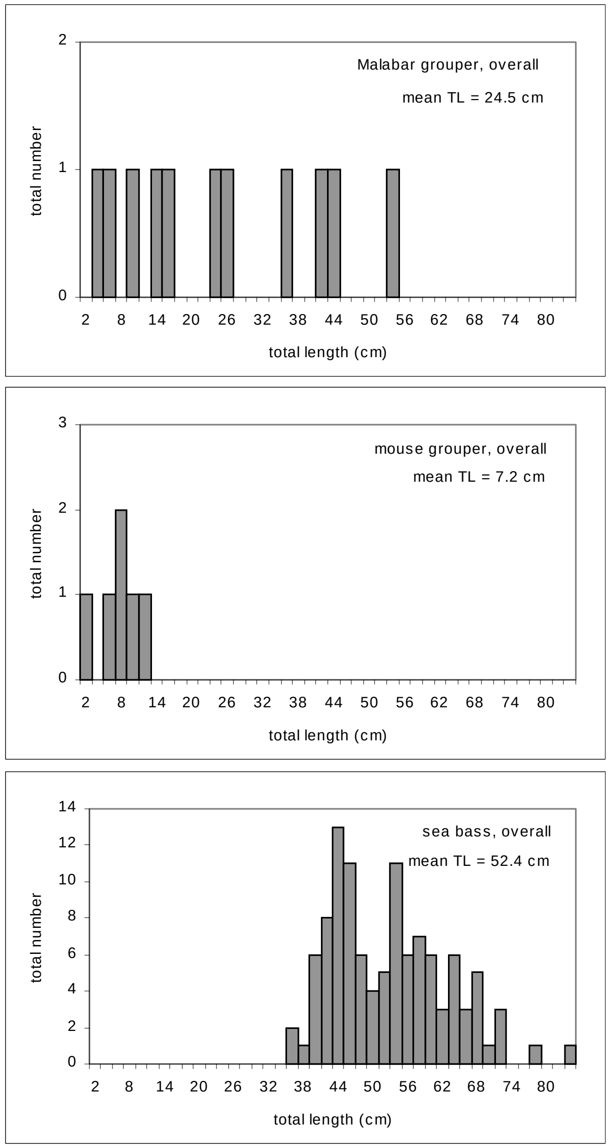

Figure 15. *Overall length-frequency distributions of the total harvest of Malabar grouper (upper panel), mouse grouper (middle panel) and sea bass (lower panel). Sea bass was only caught in Terang Bay.*

3.3 Seasonality in the harvest

Studying seasonality is mainly of interest to determine if there is a period during which grouper fingerlings are more abundant then in the rest of the year. In Terang Bay and Nangabido enough harvests were realized throughout the year to study the change in harvest numbers between seasons. However, *gangos* differ from most fishing methods in the sense that the harvest represents a process that took several weeks (namely, the interval period). In our study, the mean interval period (the period between building and harvesting) was ca. 90 days. Hence, the temporal resolution in which a pulse of immigrants to the *gangos* manifests itself is low. Furthermore, the harvest number of the most important grouper species in the catch is close to zero, which complicates the analysis (Mous, in prep.).

The overcome these challenges, an analysis was done on the smallest estuary grouper that were encountered during this study, the individuals of 3-4 cm TL. It is likely that the smallest individuals settled in the gango only shortly before capture, or else even smaller fish would have been found in the harvests with short interval periods. Variation in numbers within this size group was low (i.e., between zero and five individuals), but variation in presence in the harvest was sufficiently high. Therefore, we assessed the effect of season on the presence of small estuary grouper by constructing a generalized linear model with bionomial error distribution, logit link function, and season as explaining variable (McCullagh & Nelder 1989). We defined a season as a period of two months. We analyzed the other species groups (including estuary grouper >= 5 cm TL) in the same way, realizing that the temporal resolution is lower than the results suggest. Statistics from the models are summarized in Table 6. Model outputs (predicted values with 95% confidence limits of the mean) are represented in Figure 16.

Table 6. *Results from the generalized linear models (see text for further explanation).*

	Trials	Events	Total Deviance	Deviance Explained (%)	P
Terang Bay					
small estuary grouper	93	40	127.1	22	0.0005
large estuary grouper[(1)]	93	89	-	-	-
mangrove jack	93	76	110.2	4	0.56
sea bass	93	35	123.2	14	0.02
Nangabido Inlet					
small estuary grouper	58	23	77.9	29	0.0009
large estuary grouper	58	40	71.8	4	0.67
mangrove jack	58	39	73.4	21	0.01

(1) Because in only 4 of 93 harvests absence of large estuary grouper was observed, there was too little variation to perform the analysis.

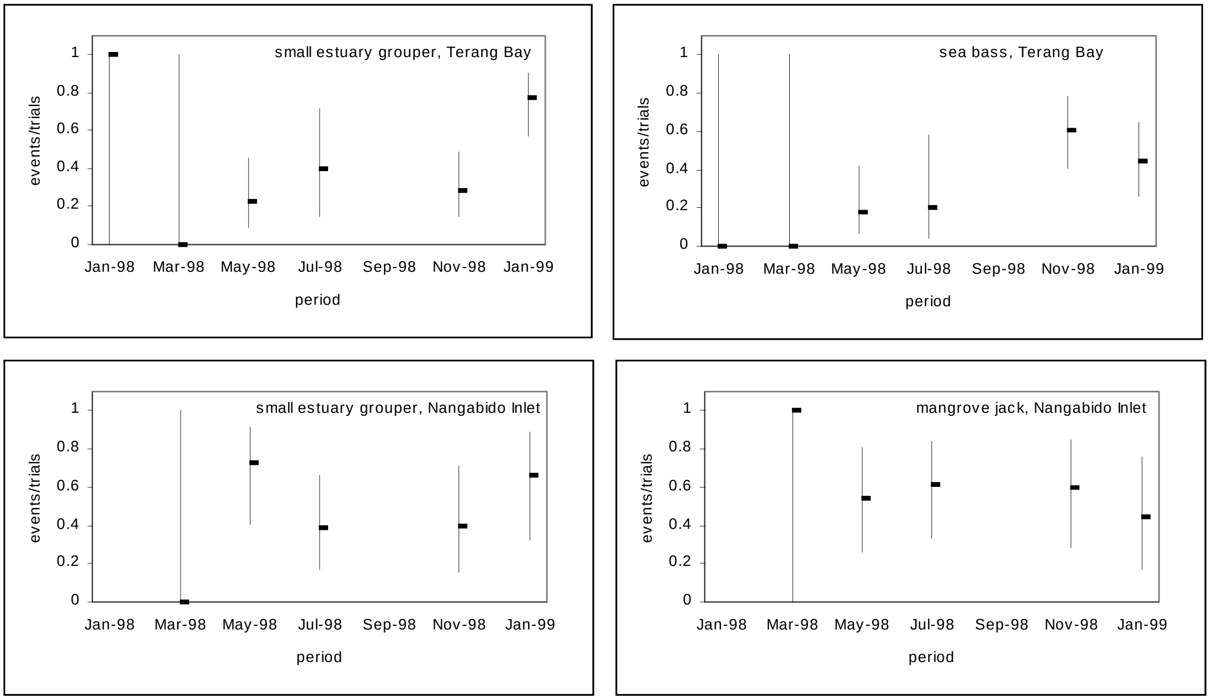

Figure 16. *Presence (with 95% confidence limits of the mean) of target fish in the harvests of Terang Bay and Nangabido Inlet. See text for further explanation.*

Both in Terang Bay and Nangabido Inlet, presence of small estuary grouper was significantly affected by season. In both areas, presence was relatively low in June-July and October-November 1998, and relatively high in December 1998 – January 1999. The two areas seemed to differ with respect to the period April-May 1998: presence was relatively high in Nangabido Inlet, and low in Terang Bay. There was no significant effect of season on the presence of large estuary grouper, and on the presence of mangrove jack from Terang Bay. For Nangabido Inlet, presence of mangrove jack was slightly, but significantly, lower in December 1998 – January 1999 than in the rest of the study period. Sea bass (only encountered in Terang Bay) showed a very strong seasonality. Sea bass was relatively often encountered during October-November 1998 and December 1998 – January 1999.

3.4 The relationship between interval period and harvest characteristics

The interval period was almost always strongly dependent on the harvesting date. Only during the periods April-May 1998 and November-December 1998 in Terang, harvests with both long and short interval periods occurred. Hence, the effect of interval period on harvest numbers and on harvest mean length of estuary grouper was assessed for observations from these periods only. As the mean interval period, the harvest number, and the mean total length did not differ much between these periods (mean interval period = 120 and 85, harvest number = 4.6 and 6.9, mean total length = 21 and 17 cm, for the first and the second period respectively), the observations were pooled. Both for harvest number and for mean total length (fig. 17A and B), the effect of interval period proved to be insignificant (Spearman non-parametric correlation, P=0.36 and P=0.69 for number and length respectively).

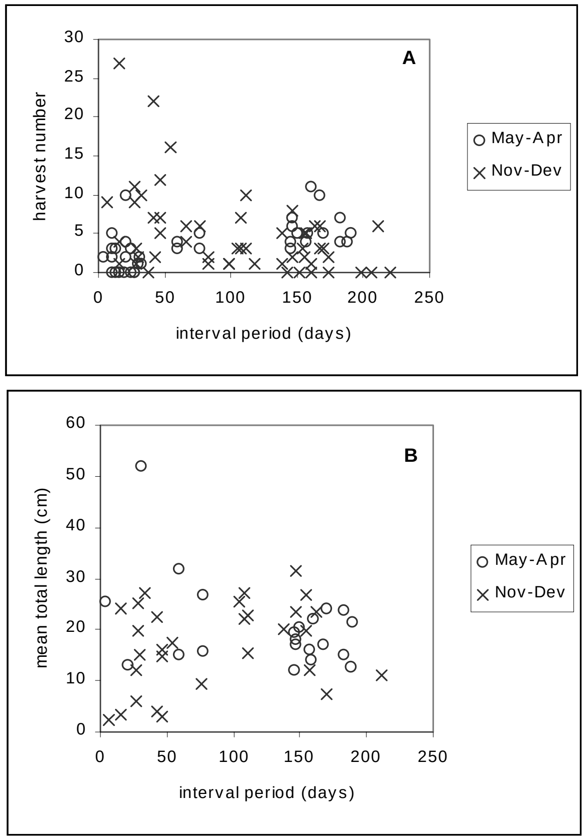

Figure 17*. Scatterplots of harvest number (graph A) and mean total length (graph B) vs. interval period. Data are from estuary grouper, period Apr.-May, Nov.-Dec. 1998, Terang Bay.*

3.5 Salinity

The salinity as measured at the surface and near the bottom usually differed little. The average difference was 1.9 ppm, the maximum difference was 22 ppm. In only 5% of the measurements, the difference was larger than 11 ppm. Hence, we present the mean calculated over bottom and surface salinity only. The difference in salinity regime between the areas was very distinctive (Fig. 18). Terang Bay showed the highest variation in salinity (ranging between 5 and 33 ppm). The salinity in Nangabido was generally between 21 and 31 ppm, except for 5 occasions when a salinity <= 5 ppm was measured. In Nanganae River, the salinity was 0 during all harvests, and in Menjaga Bay salinity was during all harvests close to the salinity of seawater (ranging between 29 and 35 ppm).

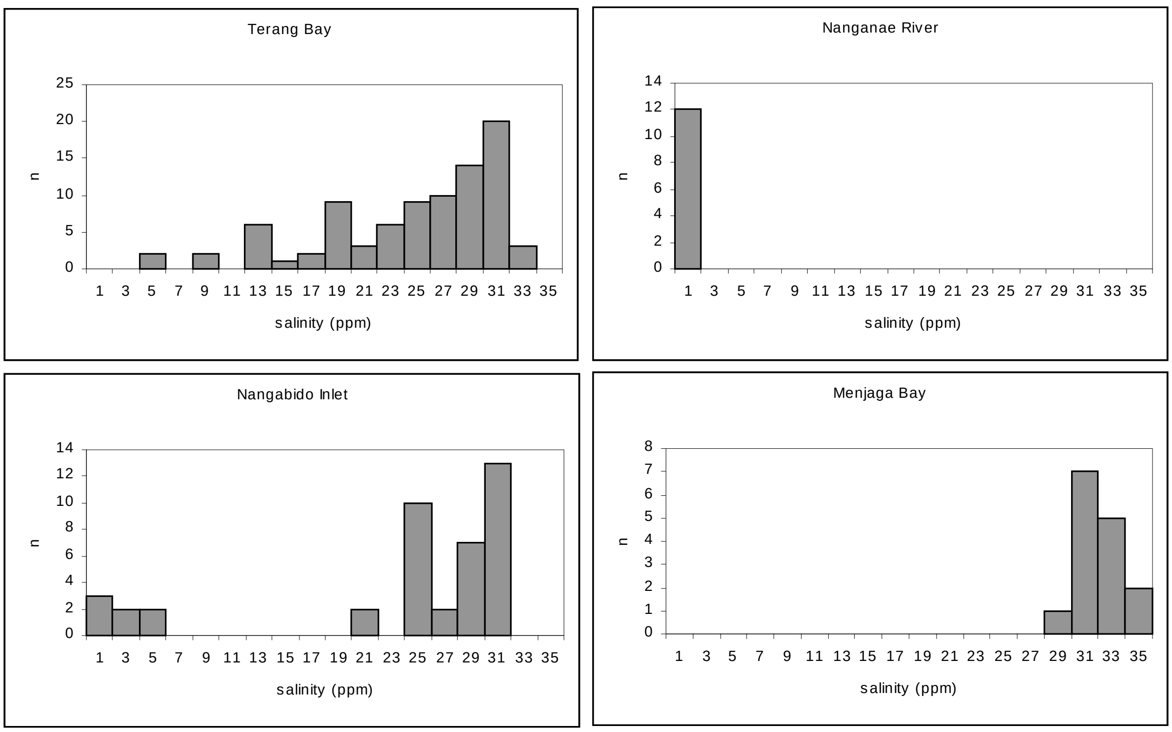

Figure 18*. Frequency distribution of salinity during the moment of harvesting in the four study areas.*

4 CONCLUSIONS

1. Of all grouper harvested (997 individuals), 82% in numbers consisted of estuary grouper, *Epinephelus coioides*. The remainder of the groupers consisted mainly of groupers that, though traded alive in Hong Kong, have little value for mariculture. Exceptions are: Malabar grouper *Epinephelus malabaricus* (11

individuals) mouse grouper *Cromileptes altivelis* (6 individuals) and giant grouper *E. lanceolatus* (at least 1 individual).

2. Other commercial species that were abundant in the harvest were mangrove jack *Lutjanus argentimaculatus* (528 individuals) and sea bass *Lates calcarifer* (109 individuals).
3. The gango method is not species-selective, nor size-selective. Only 1.4% of the fish harvest in numbers consisted of target fish. The remainder of the harvest was an assemblage of mangrove-dwelling species. *Gango* is not a specialized method for collecting fingerlings. The mean length in the harvest (13.4 cm TL) was above fingerling size, and 25% of all estuary grouper measured more than 22 cm TL. Fingerlings of neither mangrove jack, nor sea bass were caught. Probably, the gango harvests reflects a typical mangrove fish community, both in terms of species and size composition. In view of the wide size range in the harvest, it is likely that fish are harvested that would have had a good chance to survive in the wild. *Gango* is probably rather a capture than a farming technique. Hence, its application requires a strong management framework, because of the danger for overfishing.
4. The presence of 3-4 cm TL estuary grouper in gango harvests was notably high in the period December-January, but they were found in smaller numbers throughout the year.
5. The presence of sea bass in the harvests also showed high seasonality. This is probably related to its migratory behavior (Davis 1996).
6. There was no correlation between the interval period (the period between building and harvesting of a *gango*) and number or mean length of estuary grouper in the harvest. In the Philippines, gangos are harvested every 2-4 weeks. Probably, in Terang Bay and Nangabido Inlet, an interval period of maximal 14 days would result in the highest production of fingerlings per *gango*, per unit time.
7. There were clear differences in salinity during harvesting between the study areas. In order of decreasing salinity: Menjaga Bay, Nangabido Inlet, Terang Bay and Nanganae River (which always had a salinity of 0).

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