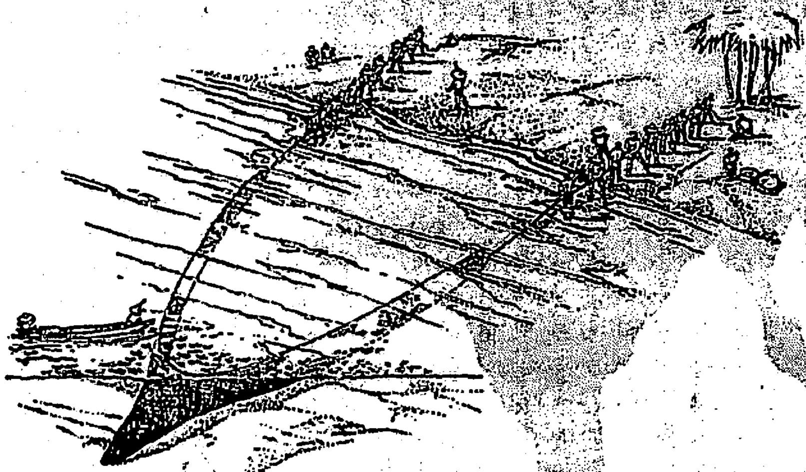

Resource and Ecological Assessment of Lagonoy Gulf, Philippines

(Volume 2: Technical Monograph)

Edited by

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Capture Fisheries Technology and Dynamics of Fishing Operations of the Lagonoy Gulf Fisheries

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Abstract

The multigear fisheries in Lagonoy Gulf exploits a highly diverse, multispecies complex. About 7,500 fishers reside in the 15 coastal municipalities bordering the gulf and employ roughly 34 distinct types of fishing methods/gear. A total of 10,709 units of various types of fishing gear was enumerated in the 164 coastal barangays. This sum consisted predominantly of handlines and gillnets which collectively account for about 75% of the total number of gear units in the area. The fishing grounds visited by the more common gears employed in the gulf are presented. Some overlaps in the fishing grounds of ring nets with the handlines and gillnets were observed mostly in the coastal areas (less than 15 km from the shore). Gillnets and handlines also exhibited the same fishing spots mostly in areas with floating fish shelters. Dynamite fishing was recorded in the coastal areas of Albay.

Introduction

Lagonoy Gulf, located in the Bicol Region on the Pacific coast of the Philippines, is a relatively large body of water spanning an area of about 3,000 km^2 (Fig. 1). One feature of the gulf is its deep bathymetry which plays an important role in the hydrographic properties of the area (Villanoy and Encisa, this vol.). About 90. % of the area has a depth greater than 10 fathoms. The coastline is bounded by 15 municipalities, namely: Tiwi, Malinao, Tabaco, Malilipot, Bacacay and Rapu-rapu (in Albay province); Bato, Virac and San Andres (in Catanduanes province); and Caramoan, Presentacion, Lagonoy, San Jose, Tigaon and Sangay (in Camarines Sur province). Currently, about 7,500 fishers reside in these coastal municipalities in of 164 coastal barangays (Table 1). They employ a multiplicity of fishing gears (34 types) to exploit the multispecies fisheries resources of the gulf (Table 2). Total annual landings from fishing operations in the gulf are estimated to be about 33,380 t or 11 t. km^{-2} yr^{-1} during the course of investigations covering the period January - December 1994 (see Soliman et al., this vol.).

This study, which is part of a multidisciplinary effort to assess the status of the Lagonoy Gulf fisheries, is intended principally to characterize catch and effort of the fisheries in the gulf. Towards this end, it specifically covers capture methods/technology and use distribution as well as the dynamics of fishing operations.

The capture fisheries of the Philippines are traditionally subdivided into commercial and municipal sectors on the basis of vessel gross tonnage. As defined in the Philippine Fisheries Decree of 1975 (i.e.. P.D. 704), commercial fisheries include fishing operations that use vessels of over 3 gross tons (GT) while municipal fisheries involve the use of vessels of 3 GT or less, including operations that do not involve the use of water craft. Such delineation recognizes the duality in character of Philippine fisheries. With only some exceptions (e.g., small trawlers and ring nets which should be more appropriately classified as commercial, given considerations of capital inputs, ownership and, sometimes, gross tonnage), this sectoral delineation describes the duality in character of the Lagonoy Gulf fisheries and is retained for purposes of the discussion below.

Materials and Methods

Data used for this study were collected in the Lagonoy Gulf area from January to December 1994. They stem directly from three data generation activities conducted in the area, namely: (1) inventory of fishing gears, (2) monitoring of commercial and municipal fisheries landings, and (3) monitoring of fishing operations. These data generation activities were executed as part of the Capture Fisheries Resource Assessment component of the Lagonoy Gulf Resource and Ecological Assessment Project funded by the Philippine Department of Agriculture under its Fisheries Sector Program.

The fishing gear inventory was conducted from July to November 1994. All the 164 coastal barangays (i.e., villages) within the 15 municipalities bordering Lagonoy Gulf were covered during the course of the inventory. For each coastal barangay, complete enumeration of the number of units by type of fishing gear was done with the assistance of local barangay officials. This involved listing down the names of all fishers in the barangay and the fishing gears/s they own (or co-own and the name of the co-owner to prevent double counting). Additional information pertaining to seasonality of use (e.g., months the gear is used, number of trips per year), among others, was also obtained. Estimates of the number of units by type of gear (by municipality and for the entire bay) were obtained by summing up the figures for each barangay. The seasonality of use (i.e., number of trips per year) by gear type was obtained by averaging all responses. During the course of the gear inventory, verification (via direct observation and interviews with selected fishers) was conducted on information obtained during the earlier phases of the monitoring of fishing operations and landings. The information included gear type on target species, typical design and specifications, and operational details.

The monitoring of fishing operations out in the field was conducted from February to December 1994. Members of the research team joined and observed (on a monthly basis) actual fishing operations of the more common gear types at sea (see Soliman et al., this vol.). Fishers-cooperators in the 17 landing sites used for municipal and commercial fisheries monitoring provided access for this purpose. Such activity provided primary information on gear design and specification, target species, difference between catch and landing, and consistency of operational details by gear type. Moreover, confirmatory checks (albeit qualitative) on magnitude as well as species and length composition of the catches were made. In addition, notes on gear design and specifications as well as area and time of operations were included whenever possible. The grids for spatial encoding of results of fishing operations are shown in Fig. 2. The data were analyzed using a Geographic Information System (GIS).

Results and Discussion

Capture Methods/Technology

A multiplicity of fishing gear is used by fishers operating in Lagonoy Gulf to exploit its multispecies resource. A total of 34 distinct types of fishing gear was observed in the area during the course of the fishing gear inventory (Table 2). The table includes 8 types of handlines/longlines, 7 types of gillnets, 5 types of liftnets, 5 types of seines and 8 types of other gear (dominated by fish trap, fish corral and spear gun). Two types of gear are not included in the table, namely: blast fishing and cyanide fishing. Both (which are known to occur off the islands in Albay and in Camarines Sur) are illegal and difficult to monitor during the course of the assessments made.

A total of 10,709 units of various types of fishing gear was enumerated in the 164 coastal barangays bordering Lagonoy Gulf. This sum consisted predominantly of relatively simple, inexpensive fishing gears such as handlines (5,476 units), gillnets (1,965 units), longline (427 units), fish traps (513 units), crab liftnets (341 units) and spear guns (560 units) which collectively account for 87% of the total number of gear units in the area. The typical design, specifications and operational setup of the more common fishing gears used in Lagonoy Gulf are summarized in Appendix 1. The design and operational details were compared with those described by Umali (1950). Highlights of findings for each gear are given below.

<u>Handlines and longlines</u>

Handlines used in Lagonoy Gulf are either single-(*kawil*) or multiple-hook (*ug-ug*) types. The lines used are made either of nylon or monofilament polyamide material. The number of hooks used can be as high as 300 per fishing operation. Fishing is usually done between 5 a.m. and 5 p.m. involving 1-3 fishers using a nonmotorized or motorized banca powered by a 10-16 hp gasoline engine. Target fishes are either large pelagics or demersals in hard bottom or coralline areas. There are 5,746 units of handlines which account for 51% of the total gear units in the area. Tuna handlines account for 102 units of handlines. Target species of this gear type are the scombrids, principally yellow fin tuna.

Bottom-set longlines (*kitang*) used in the gulf are multiple-hook, line gears set near the sea bottom. Baskets are to longlines as panels are to gillnets. Each longline basket consists of a mainline, floatline and 3-8 branchlines. Between 3 and 10 baskets are joined together to form a longline unit. Longlines are set in water depths of 10-40 m. About 20-750 hooks are used in a longline operation, with fishing time of about 3-4 hours. Setting and hauling operations are done manually and involve two fishers using a *banca* usually powered by 16 hp gasoline engines. Target fishes are large carangids and groupers. A total of 427 units operates in the gulf.

Gillnets

Gillnets are curtain-like pieces of netting which effect capture by gilling or entangling fishes. Collectively, there are 7 types of gillnets consisting of 1,965 units (or 18% of the total gear units in the area) operating in Lagonoy Gulf. One or more panels of curtain-like netting make up a gillnet unit. The design and specifications for a standard panel are given in Appendix 1 to describe the various gillnet types. Gillnets are named according to mode of operation (e.g., drift gillnet, bottom set gillnet) or target species (e.g., crab gillnet). Netting materials for gillnets usually consist of nylon or polyamide monofilaments, with rigging ropes consisting of polyethylene materials of various sizes. Most gillnets use rubber sandal (*tsinelas*) materials cut in strips of 1-3 cm depth by 5-15 cm length for their floats. Some use tubular plastics as floating material. Lead sinkers of 7.6-15.2 g/piece are common and the number varies according to the sinking force required. Mesh sizes vary between 2 and 30 cm depending on the target species: Boats used for gillnet operations involve 5-m long bancas with outriggers powered by 10-16 hp gasoline engines. Fishing or soak time for gillnets vary between 2 and 6 hours per trip a day.

The drift gillnet (*palutang*) and bottom set gillnet (*pankeng patundag*) are used during daylight hours involving 1-2 fishers per fishing unit. The drift gillnets are set near surface waters in depths of 10-40 m and used to target small pelagics species. The bottom set gillnet is usually set 4-20 m deep. They are used to target shrimps, croakers, mullets and small demersals. Of the gillnet types, only the bottom-set gillnet (*lampurna*) involves "active" fishing practices. This involves the use of a scare device (*timbog/tupak*) to pound the water surface to drive the fishes toward the net that is set in a semi-circular pattern.

Crab gillnet (*pankeng pangasag*) are set at the bottom during nighttime given the nocturnal habits of portunid crabs. This type of gear, handled by a single fisher, is set in shallow, soft-bottom waters of 4-15 m deep.

Ring net

The ring net (*kalansisi*) is the only gear type classified under the commercial fisheries in the gulf. It is a rectangular piece of netting, with a pursing mechanism at the bottom, very similar in operations with the purse seine. Ring net is operated by forming a circle around a school of fish and then closing its bottom by means of a purse rope and a tom weight. Each ring net unit involves the use of two boats more than 3 gross tons each. Fish are aggregated with the use of *payaos* or light attraction. Target fishes are small pelagics such as skipjack tuna, round scads and mackerels. Operations involve 10-20 fishers per ring net unit and fishing operations are done during daytime or nighttime. A total of 19 ringnet units operate in Lagonoy Gulf.

Other Gears

The beach seine (*sinsuro*) is a trawl-like gear set nearshore in shallow waters and dragged towards the shore. Fishing operations are usually during the early morning. Mesh size in the bunt area is 1-2 cm. The operation usually involves 20-40 persons and targets small demersals. A total 136 units operate in the area.

Fish corrals (*baklad/bunuan*) are semi-permanent gears used for guiding and trapping fish. Made of netting materials supported by bamboo frames, the gear consists of a guiding barrier (or leader), a series of (2-3) playground areas, and a bunt or catching area. The gear is set in sheltered waters and is oriented and shaped as to direct the voluntary movement of fishes into the bunt area. The bunt net (with 1-2 cm mesh size) is usually set in the evening for harvesting using scoop nets the following morning. Operations usually involve 2-3 fishers using a non-motorized boat (*banca*) for transportation to and from the shore. Fish corrals usually target small pelagics but catch a substantial portion of small demersal fishes and some shrimps.

The crab liftnet (*bintol sa kasag*) is a tray-like trap made of synthetic nettings set against bamboo frames. A pullrope is attached to each trap for setting and handling, and the baits used are placed at the center of each trap. About 20 units are set by a single fisher during each trip in shallow depths near mangrove areas. Traps are set early in the morning and retrieved before noon. Target species is the mud crab, and operations usually involve the use of a nonmotorized *banca*.

Fish traps (*bubo sa sira*) are baited, basket-like bamboo contraptions set in nearshore waters of 5-30 m depth. The nonreturn valve of each trap allows easy entry but difficult exit of fish. A pullrope is attached to each trap for setting and hauling operations. About 7-15 traps are used in a fishing operation with 2-3 hours soaking time. Operations involve a single fisher using either a motorized (10-16 hp) or nonmotorized *banca*. Four to six haulings are common in an overnight operation. Target fishes are snappers, groupers and large siganids.

The spear gun (*pana*) consists of improvised spear gun, spears, goggles and swimming fins. The spear gun has a wooden handle and frame fitted with steel nozzle and rubber band. The spears used are either single- or multi-tipped, with the latter intended for smaller fishes. Operations are conducted in waters up to 20 m deep, usually in hard bottom or coralline areas. Target fishes are groupers, carangids and large siganids. The use of compressors with plastic line tubings to prolong the stay of divers underwater is increasingly becoming a feature of spear gun operations.

The bagnet (*basnig*) is a conical or cubical bag operated with the aid of light during the dark phase of the moon, and the capture is effected by a lifting motion. A total of 28 units operate in the gulf. Of this, 8 are classified as baby . The target species of the bagnets are round scads, mackerels, herrings, sardines and anchovies, while siganid fry and anchovies are of the baby bagnets. Operations involve 5-10 fishers and use a 12-16 hp motorized *banca*.

The pullnet (*bitana*) is a rectangular piece of netting pulled by two persons within wading depth to enclose, gill and/or entangle fishes. Designed like a gillnet, a pullnet is used to target anchovies. Operations do not involve a boat. Forty-nine pull net units operate within the gulf.

Dynamics of Fishing Operation

The east coast of Albay and about half of the Caramoan Peninsula are relatively sheltered from strong winds of the southwest monsoon (June to October), while during the northeast monsoon (November to March), these areas become more exposed to strong winds. Generally, fishing is relatively good in the gulf during summer months (April to May) or transition between the two monsoon seasons.

Table 3 shows the seasonality of use and the average number of trips of the 34 gear types in the gulf. Almost all types of handlines, gillnets and barrier/traps and the beach seine are used throughout the year. On the average, from 45 to 284 trips are made per year, with the beach seine having the highest frequency of use. The ring net is used from March to October with an average trip per year of 147.

The fishing grounds of the more common fishing gears are shown in Appendix 2. The thematic (GIS) maps were generated from the fish landing monitoring from January to December 1994 from 17 sites. Simple handlines are employed throughout the gulf. Higher trip frequencies are observed in the coastal areas and in the deeper portions of the gulf with established floating fish shelter (*payao*). The multiple and tuna handlines are employed in deeper areas. Higher frequencies of observation were also recorded in the areas with fish shelters.

Fishing grounds visited by gillnets are mostly coastal areas with depth less than 100 m. However, drift gillnets are also employed in the deeper portions of the gulf where floating fish shelters are located. Dynamite fishing was also observed in some areas in the gulf. Higher frequencies of use were noted in reef areas off Batan Island in Albay. Ring nets, which are classified as commercial, operate more frequently in coastal areas (less than 15 km from the shore) off the coast of Albay and Camarines Sur.

The operational ranges of different gear types indicate some overlaps in fishing grounds of gears employed in the area. For example, fishing spots of ring nets overlap with gillnets and handlines mostly in coastal areas. while these two types are used in areas where there are fish shelters. Moreover, dynamite fishing is prevalent in coral reef areas. This information may be useful for the overall management of the fisheries resources in Lagonoy Gulf.

Acknowledgments

We thank our research aides, Ed Bola, Rolando Buenaflor, Florante Bustamante, Anastacio Cante, Jr., Jose Gonzales, Jr. and Jovel Tasarra who helped us in the collection of data during the gear inventory. Thanks also to Jun Jumao-as, Malou Beldua, Francisco Diaz and Guillermo Divison who helped in the retrieval of the gear inventory forms; and to Zoraida Alojado for generating the thematic maps using GIS.

Reference

Umali, A.F. 1950. Guide to the classification of fishing gear in the Philippines. Res. Rep. 17. 165 p. Fisheries and Wildlife Service, US Department of the Interior, Washington, D.C.

Table 1. Number of fishers in the 164 coastal barangays/villages in Lagonoy Gulf, 1994.

Province	Municipality	No. of coastal barangays	No. of fishers
Albay	1. Rapu-Rapu	18	994
	2. Bacacay	26	931
	3. Malilipot	7	229
	4. Tabaco	14	516
	5. Malinao	4	144
	6. Tiwi	12	380
Camarines Sur	7. Sangay	7	421
	8. Tigaon	2	97
	9. Lagonoy	7	432
	10. San Jose	7	197
	11. Presentacion	11	457
	12. Caramoan	6	400
Catanduanes	13. San Andres	20	1,558
	14. Virac	17	325
	15. Bato	6	391
	Total	164	7,472

Table 2. Number of units by type of fishing gears in the coastal municipalities bordering Lagonoy Gulf

Fishing gear		Albay							Catanduanes				Camarines Sur							Grand	Percentage	
English name	Local name	1	2	3	4	5	6	Total	7	8	9	Total	10	11	12	13	14	15	Total	total	(%)	
Handlines																						51.13
1 Artificial bait	*Pangcamuus*			3	7	9	11	30												30	0.28	
2 Hook and line/simple handline/	*Kawil/banwit*																					
handline/pole and line	*pahulaul/ligawnan*	262	39	154	112	251	353	1,171	167	518	629	1,314	360	549	205	642	102	653	2,511	4,996	46.65	
3 Multiple handline	*Ug-ug*			2		25	18	45		25	28	53			133		15	16	164	262	2.45	
4 Octopus jig	*Tora-tora/pancogita*				5	10	12	27												27	0.25	
5 Squid jig	*Pampusit*					2		2												2	0.02	
6 Troll line	*Kasikas/balakwit*	1				2		3		30	24	54								57	0.53	
7 Tuna handline	*Pambangkulis*	48		46		8		102												102	0.95	
Longlines																						3.99
8 Bottom-set longline	*Kitang*	4	10	60	8	90	70	242	3	8	39	50	1		69	44		21	135	427	3.99	
Gillnets																						18.35
9 Bottom-set gillnet	*Pankeng patundag*	42	29	84	41	246	252	694	71	74	233	378	65	82	159	23	4	63	396	1,468	13.71	
10 Crab gillnet	*Pankeng pangkasag*					9	10	19										24	24	43	0.40	
11 Bottom-set gillnet with scareline	*Lampurnu*			2				2												2	0.02	
12 Drift gillnet (monofilament)	*Bugkat/palutang*	23		39	5	59	28	154		4	23	27	18	8	7			9	42	223	2.08	
13 Drift gillnet (PE)	*Largarete/palutang*			3		33		36		2	132	134	15	18	6				39	209	1.95	
14 Encircling gillnet	*Taksal*	19						19												19	0.18	
15 Gillnet with compressor	*Panke-compresor*										1	1								1	0.01	
Liftnets																						5.23
16 Baby bagnet	*Basnig pangkuyog*			8				8												8	0.07	
17 Bagnet	*Basnig*			7			7	14										6	6	20	0.19	
18 Crab liftnet	*Bintol sa kasag*					35		35	1		17	18				28	60		88	141	1.32	
19 Lobster liftnet	*Bintol pambanugan*						341	341											0	341	3.18	
20 Pushnet	*Sakag*		2			1		3								1			1	4	0.04	
21 Skimming net	*Sapyaw*			2		40		42							1	1		2	4	46	0.43	
Seines																						3.63
22 Beach seine	*Sinsuro*	3	22	29	11	8		73	13	2		15		3	5	28	1	11	48	136	1.27	
23 Milkfish fry seine*	*Bangusan*			2				2								17	32		49	51	0.48	
24 Pull net/baby beach seine	*Bitana/sagudsod*					32	5	37						6	2	4			12	49	0.46	
25 Ring net	*Kalansisi/palakaya*	3	2	2		2		9					2					8	10	19	0.18	
26 Seine net	*Sarap/pukot*		3	32	18	52		105					3	4	1			21	29	134	1.25	
Hand instruments																						7.31
27 Spear	*Tabula*					8		8												8	0.07	
28 Scoopnet	*Tikpaw/silo*			1		1		2		2	12	14						4	4	20	0.19	
29 Spear gun	*Pana*	8		49	86	53	45	312	6	46	48	100	12	66	13	10	2	45	148	560	5.23	
30 Spear gun with compressor	*Pana-compresor*						118	118			45	45	27	5					32	195	1.82	
Barrier and traps																						10.34
31 Crab pot (mud and blue crab)	*Bubo sa kasag/lumit*		152			189	130	471								60			60	531	4.96	
32 Fish corral	*Baclad/bunuan*				10	21	11	42	1		5	6				15			15	63	0.59	
33 Fish pot	*Bubo sa sira*			2	7	165	43	217			121	121		3	9	163			175	513	4.79	
Bikolano indigenous																						0.02
34 Beach seine with scareline	*Kunay*															2			2	2	0.02	
	TOTAL	413	259	527	310	1,351	1,454	4,385	262	711	1,357	2,330	503	744	610	1,038	216	883	3,994	10,709	100.00	100.00

1) Tiwi 2) Malinao 3) Tabaco 4) Malilipot 5) Bacacay 6) Rapu-rapu 7) Bato 8) Virac 9) San Andres 10) Caramoan 11) Presentacion 12) Lagonoy 13) San Jose 14) Tigaon 15) Sangay

Table 3. Seasonality of fishing gears in Lagonoy Gulf.

(■ = shaded month in the original chart)

Fishing gear		Month												Average no. of trips yr^{-1}
English name	Local name	J	F	M	A	M	J	J	A	S	O	N	D	
Handlines														
1 Artificial bait	*Pangcanuus*		■	■	■	■	■	■	■					75.00
2 Hook and line/simple handline/ handline/pole and line	*Kawil/banwit pahulad/ligawnan*	■	■	■	■	■	■	■	■	■	■	■	■	122.19
3 Multiple handline	*Ug-ug*	■	■	■	■	■	■	■	■	■	■	■	■	64.38
4 Octopus jig	*Tora-tora/pangcogita*		■	■	■	■	■	■	■					75.00
5 Squid jig	*Pampusit*		■	■	■	■	■	■	■					270.00
6 Troll line	*Kasikas/balakwit*	■	■	■	■	■	■	■	■	■	■	■	■	159.91
7 Tuna handline	*Pambangkulis*	■	■	■	■	■	■	■	■	■	■	■	■	155.02
Longlines														
8 Bottom-set longline	*Kitang*				■	■	■	■	■	■	■			91.41
Gillnets														
9 Bottom-set gillnet	*Pankeng patundag*	■	■	■	■	■	■	■	■	■	■	■	■	202.21
10 Crab gillnet	*Pankeng pangkasag*	■	■	■	■	■	■	■	■	■	■	■	■	78.60
11 Bottom-set gillnet with scareline	*Lampurna*				■	■	■	■	■					50.00
12 Drift gillnet (monofilament)	*Bugkat/palutang*	■	■	■	■	■	■	■	■	■	■	■	■	118.81
13 Drift gillnet (PE)	*Largarete/palutang*		■	■	■	■	■	■	■	■	■	■		111.89
14 Encircling gillnet (drift)	*Taksal*					■	■	■	■	■				72.89
15 Gillnet with compressor	*Panke-compresor*	■	■	■	■	■	■	■	■	■	■	■	■	36.00
Liftnets														
16 Baby bagnet	*Basnig pangkuyog*		■	■	■	■								90.00
17 Bagnet	*Basnig*	■	■	■	■	■	■	■	■	■	■			151.10
18 Crab liftnet	*Bintol sa kasag*	■	■	■	■	■	■	■	■	■	■	■	■	79.21
19 Lobster liftnet	*Bintol pambanagan*		■	■	■	■	■	■	■	■	■			131.04
20 Pushnet	*Sakag*		■	■	■	■	■	■	■	■				200.00
21 Skimming net	*Sapyaw*						■	■	■	■				43.50
Seines														
22 Beach seine	*Sinsuro*	■	■	■	■	■	■	■	■	■	■	■	■	283.24
23 Milkfish fry seine*	*Bangusan*		■	■	■	■	■	■	■	■	■			131.63
24 Pullnet/baby beach seine	*Bitana/sagudsod*		■	■	■	■	■	■						50.94
25 Ring net	*Kalansisi/palakaya*			■	■	■	■	■	■	■	■			147.37
26 Seine net	*Sarap/pukot*				■	■	■	■	■	■	■	■	■	56.96
Hand instruments														
7 Spear	*Tabula*			■	■	■	■							58.38
28 Scoopnet	*Tikpaw/silo*			■	■	■	■							106.80
29 Spear gun	*Pana*			■	■	■	■	■						131.70
30 Spear gun with compressor	*Pana-compresor*		■	■	■	■	■	■						276.69
Barrier and traps														
31 Crab pot (mud and blue crab)	*Bubo sa kasag/hanit*	■	■	■	■	■	■	■	■	■	■	■	■	128.47
32 Fish corral	*Baclad/sagkad/bunuan*	■	■	■	■	■	■	■	■	■	■	■	■	237.90
33 Fish pot	*Bubo sa sira*	■	■	■	■	■	■	■	■	■	■	■	■	111.87
Bikolano indigenous														
34 Beach seine with scareline	*Kunay*		■	■	■	■	■	■						45.00

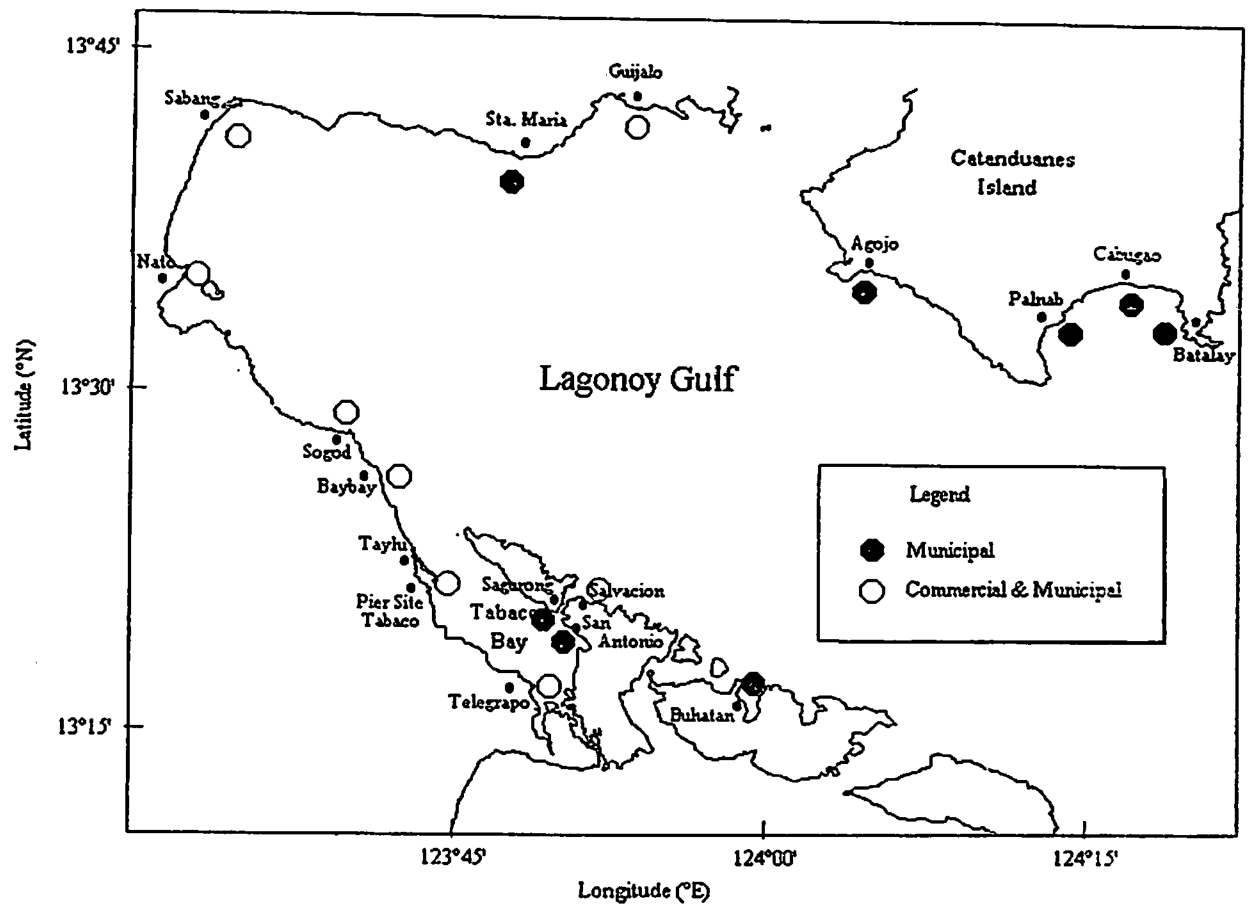


Fig. 1. Fish landing areas monitored for municipal and commerical fisheries assessment.

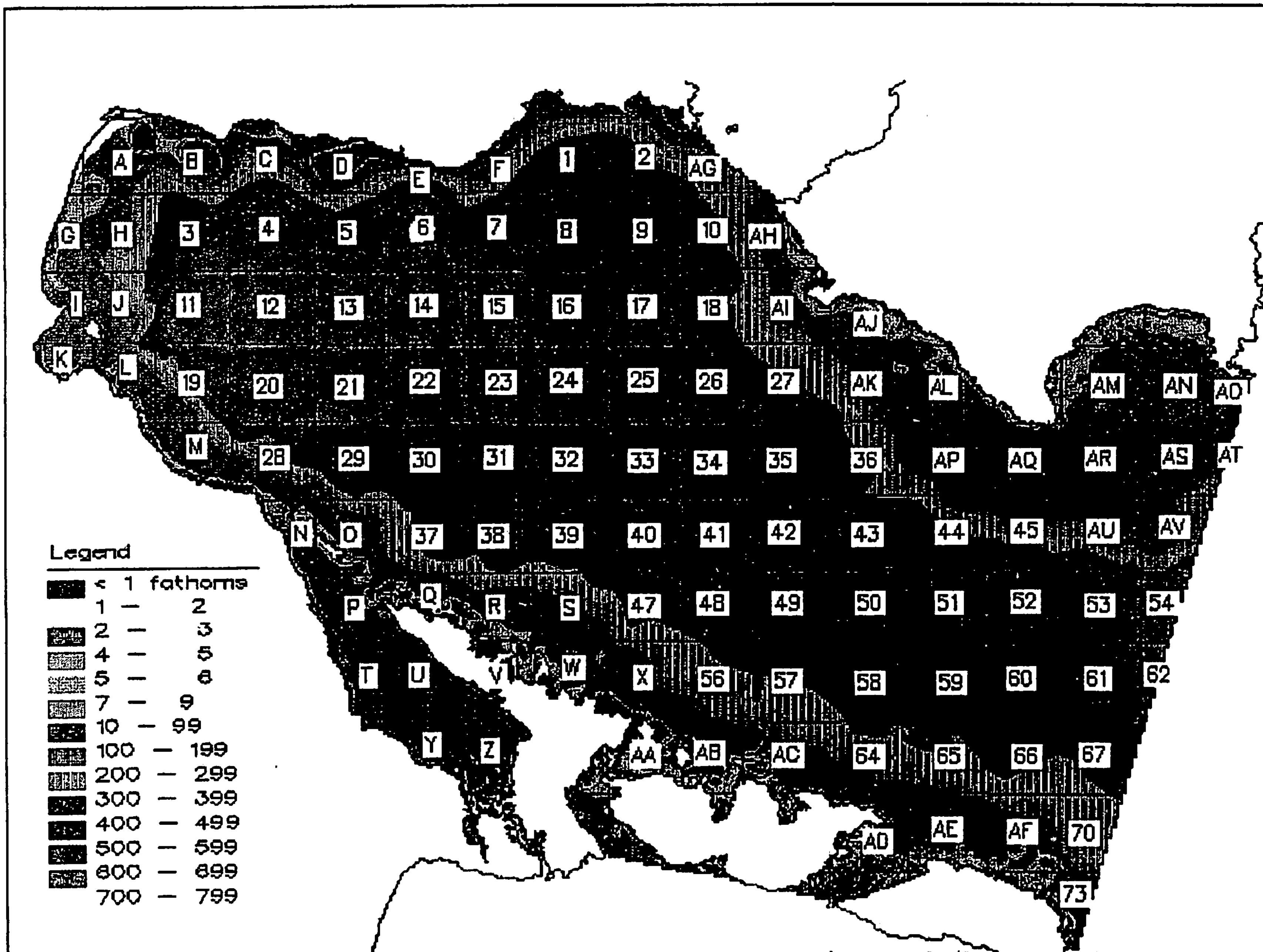


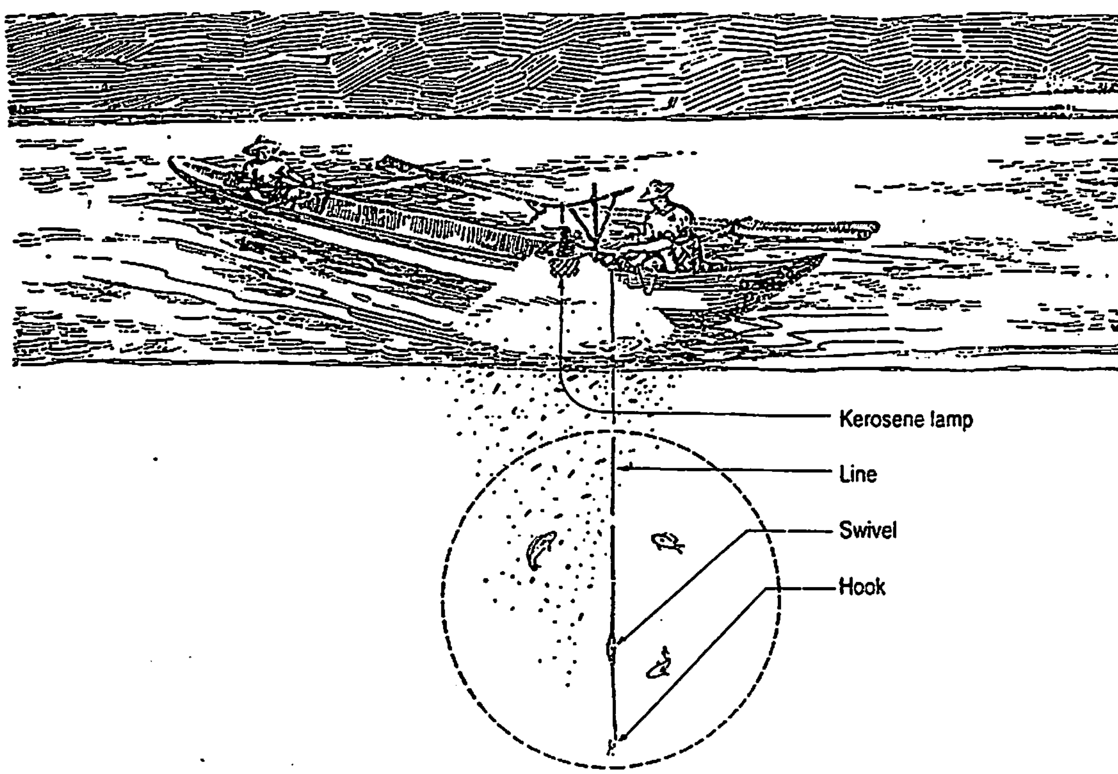
Fig.2. Map grids for spatial encoding of results of fishing operation monitoring.

Appendix 1

Design and Operational Setup of Fishing Gears Commonly Used in Lagonoy Gulf

1. Simple handline
2. Multiple handline
3. Tuna handline
4. Bottom-set longline
5. Bottom-set gillnet
6. Drift gillnet
7. Encircling gillnet
8. Pullnet
9. Beach seine
10. Bagnet
11. Spear gun
12. Fish trap/pot
13. Crab liftnet
14. Fish corral
15. Ring net

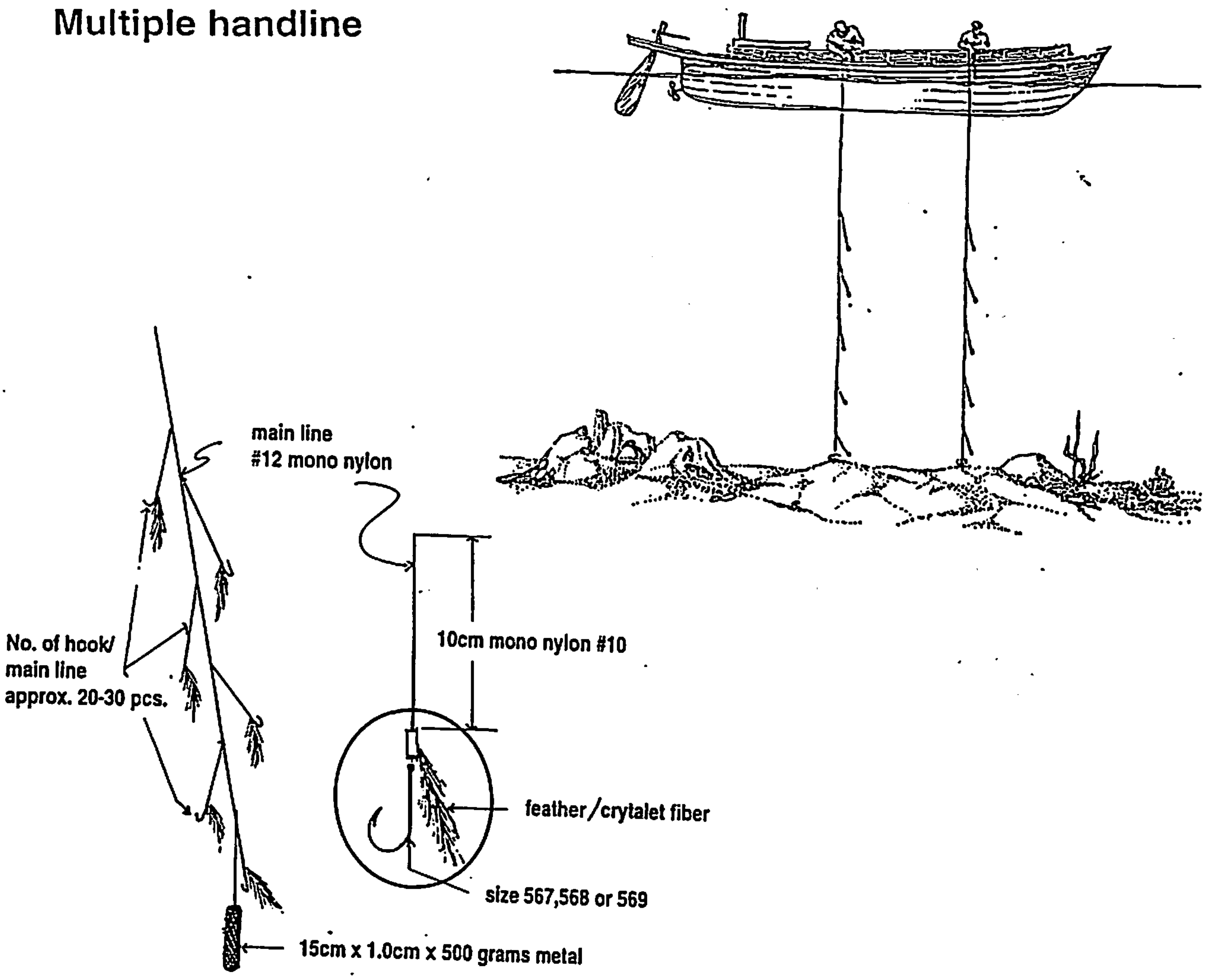
Simple handline



PART	MATERIAL	STD./UNIT
LINE	Mono-nylon (PA)	#12=total l =25m
SINKER	Lead (fabricated)	15cm x 1.0cm (500 grams wt.)
BAIT	Natural	
HOOK		#1567,568 or 569

Simple handline **Set-up design** (Umali, 1950)	**Target Species** Carangids, mackerels, dolphin fish, reef fishes	**Banca** Non-motorized

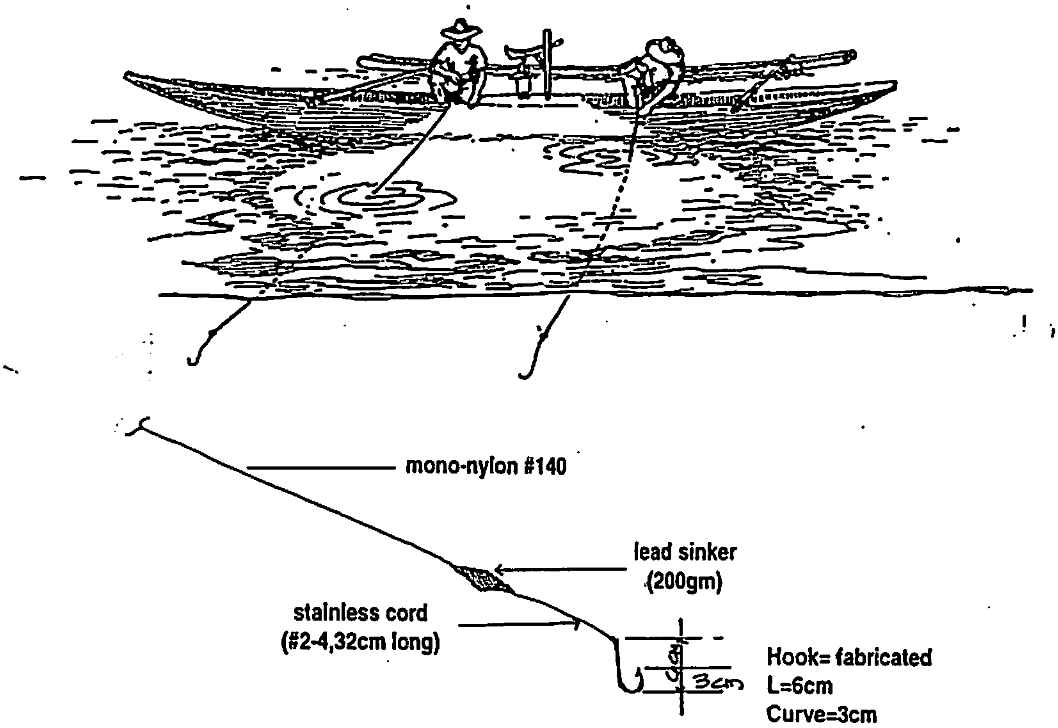
Multiple handline



PART	MATERIAL	STD./UNIT
LINE	Mono-nylon	#12=total L=25m
	Stainless cord	#10- L=10cm
SINKER	Lead (fabricated)	15cm x 1.0cm (500 grams wt.)
BAIT	Artificial (feather or crystalet)	
HOOK		#1567,568 or 569 (20-30 pcs)

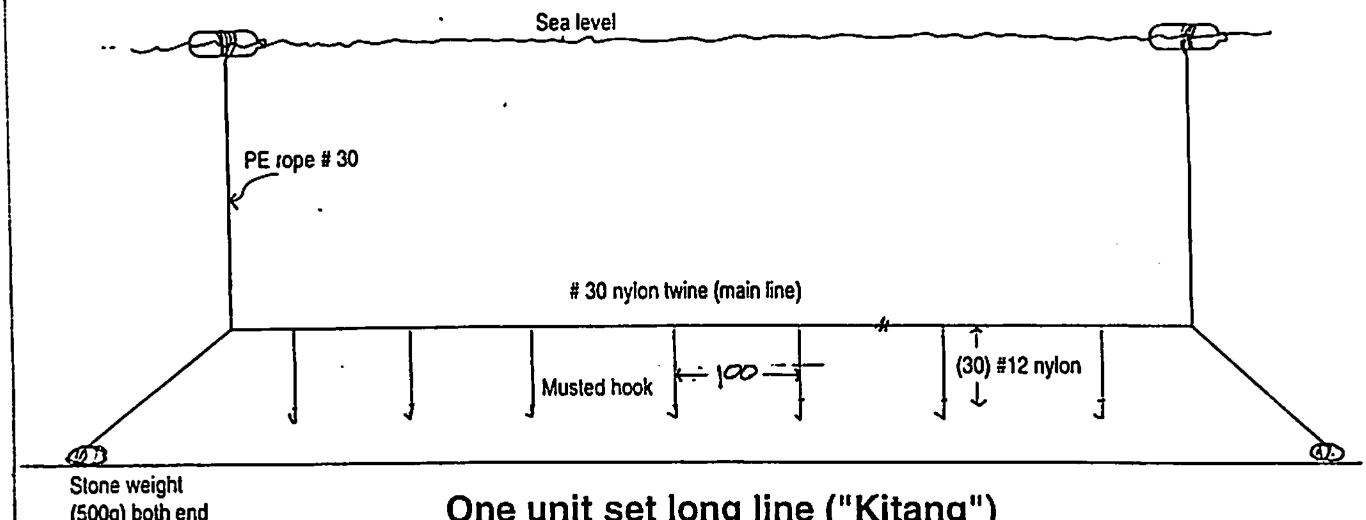
Multiple handline (V6-V6)	Target Species Carangids,mackerels	Banca Non-motorized

Tuna Handline (for yellowfin tuna)



PART	MATERIAL	STD./UNIT
LINE	Mono-nylon	#140 Lt.=300m
	Stainless cord	#2-4 Lt.=9cm
SINKER	Lead	200 grams
BAIT	Live fish/squid	
HOOK	Fabricated (stainless)	6cm-lenght
		3cm-lenght

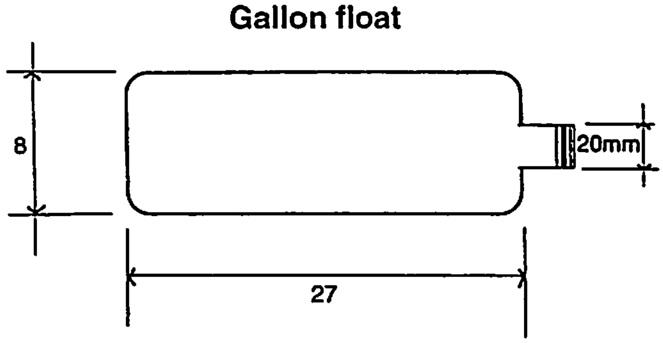
Tuna Handline "Tambangkulis"	**Target Species** Yellowfin tuna	**Banca** Motorized 16 hp gasoline



One unit set long line ("Kitang")

Length of 4 units - 1,752m

Gallon float



Description:

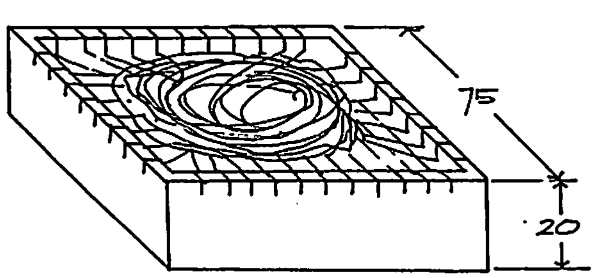
Name: Set long line (Kitang) 4 units

Overall length: 75m (4 units)

No. of hooks per unit -437

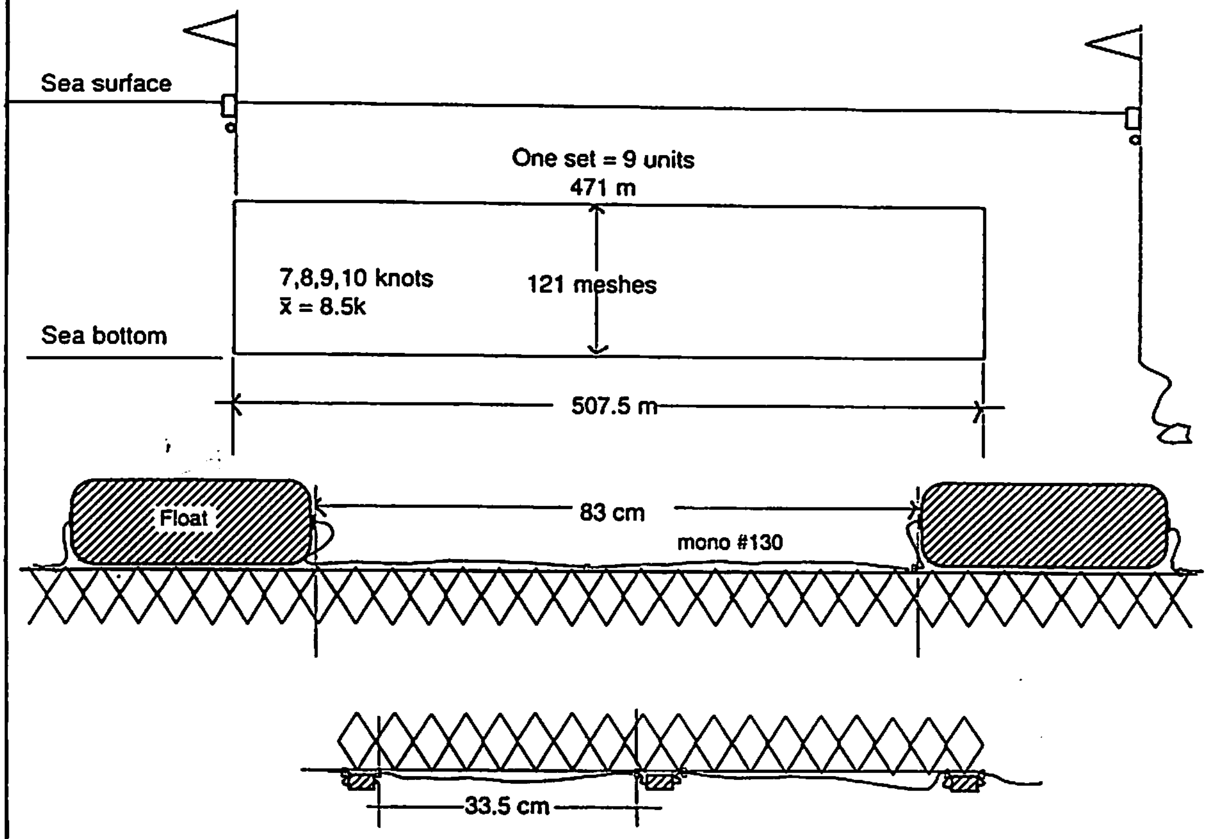
Hook interval - 1 meter

Musted hook no.- 571



Set long line box with hooks arrange on four (4) sides of the wooden box.

Bottom Set Long Line "Kitang"	**Target Species** Groupers, carangids	**Banca** Motorized 16hp gasoline

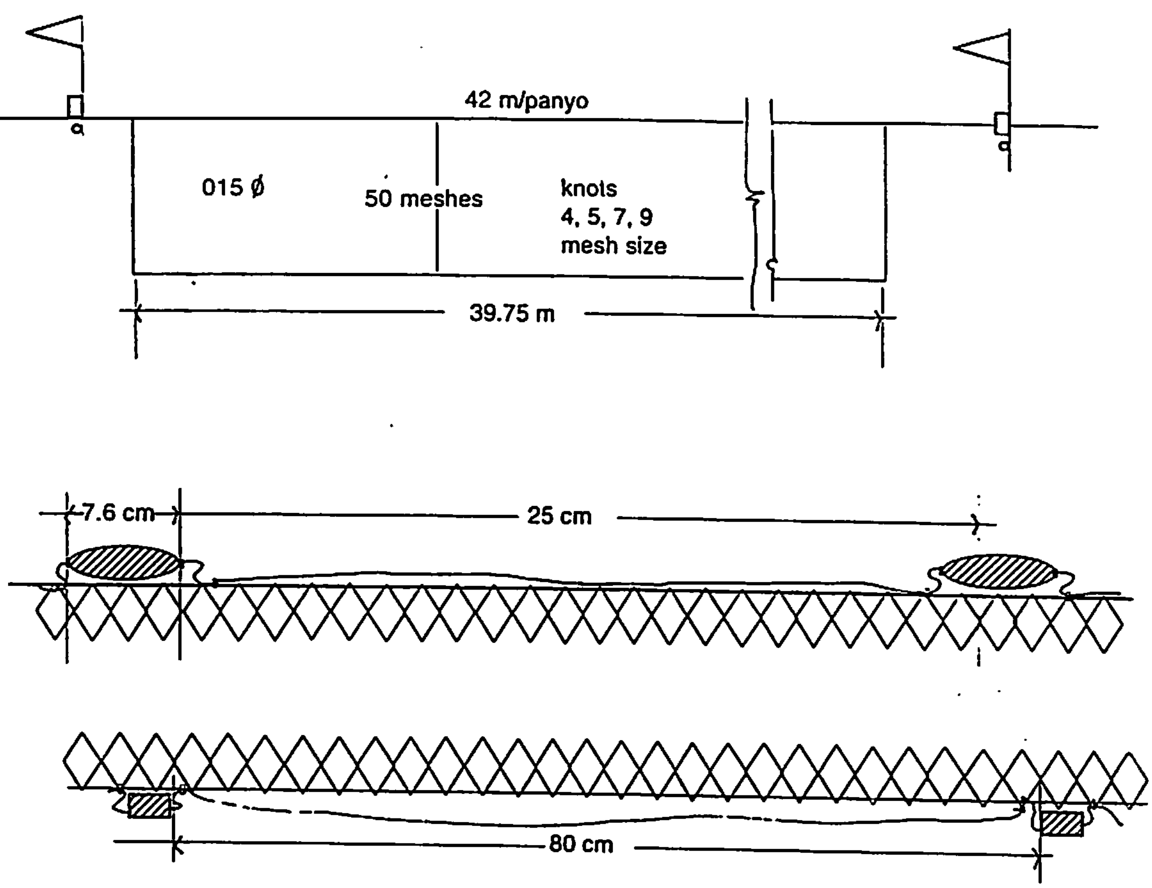


PART	MATERIAL	STANDARD/UNIT	REMARKS
Net	Nylon mono	020 - 025 diameter (7-8-9-10k) knots mesh size 100m stretched length 150 meshes down, IPC	Shrinkage 53% top 57% bottom 9pcs/set
Buoy line	Nylon-mono	#130,507.5m	
Hang line	Nylon-mono	#130, 471m	
Sinker line	Nylon-mono	#130, 507.5m	
Hang line	Nylon-mono	#130, 507.5m	
Float	Tubular plastic (Japan)	7.00 cm long, 611 pcs	
Sinker	Lead	4 X 0.5 cm, 1,515 pcs	

Bottom Set Gillnet
"Palubog/Palundag"

Target Species
Siganids,Mullets & Goat-fishes, asstd. pelagics

Banca
Motorized: 10-16hp gasoline
non-motorized

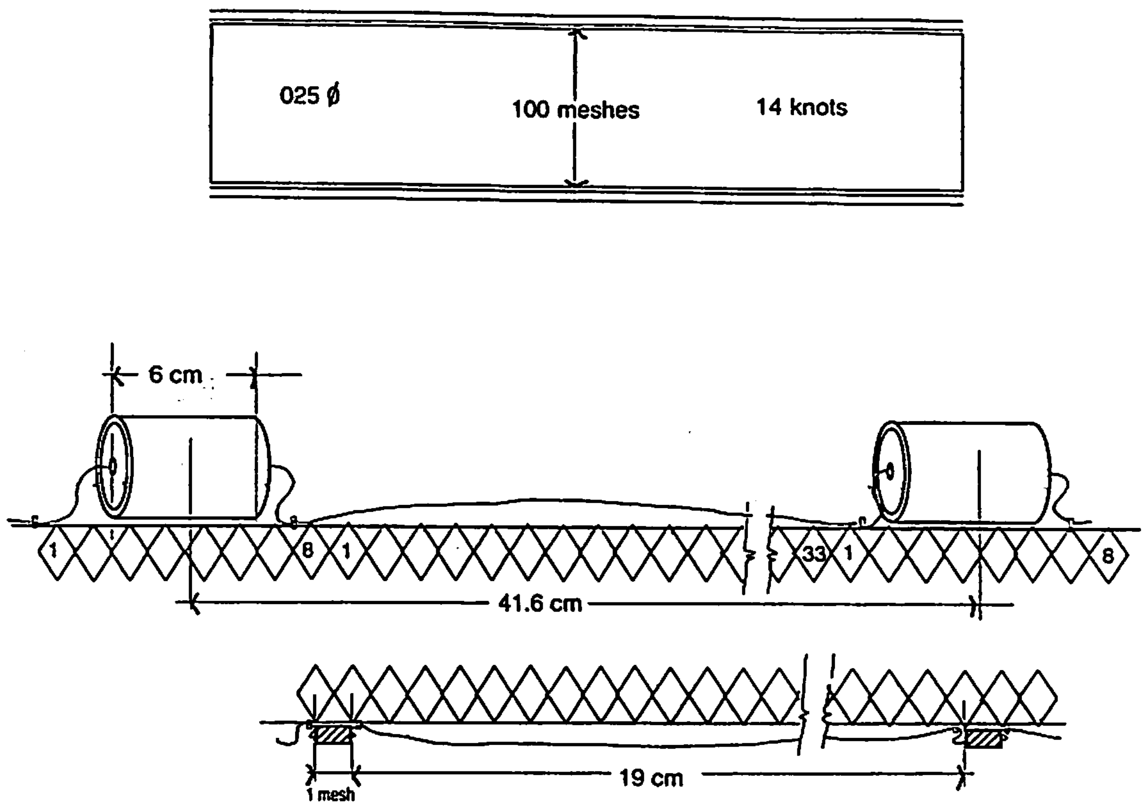


PART	MATERIAL	STANDARD/UNIT	REMARKS
Net	Nylon mono	100 m stretched length # 040 & 045 twine diameter	
Buoy line	PE	4,5,7,9 knots (110m T.L.)	Connecting ratio:
Hang line	PE	# 12, 46 m	4k - 5k = 1:1
Sinker line	PE	# 12, 40 m	5k - 7k = 1:3
Hang line	PE	# 12, 40 m	
Float	Plastic	85-90 pcs	
Sinker	Lead	1 X 3 or 4	700 grams

Drift Gillnet
"Palataw/ Palutang"

Target Species
Garfishes/ halfbeaks
other pelagics

Banca
Motorized
16hp gasoline

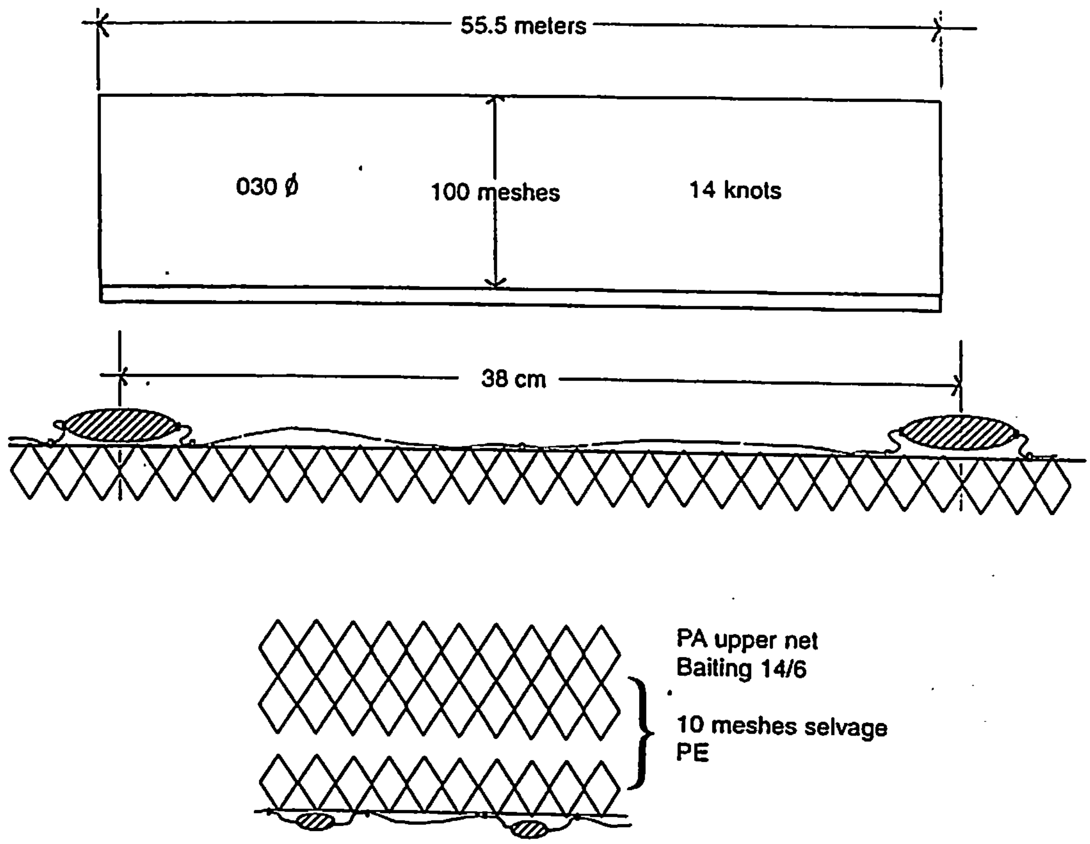


PART	MATERIAL	STANDARD/UNIT	REMARKS
Net	Nylon mono	025 twine diameter 14 knots mesh size 100 M stretched depth 100 meshes down, IPC	Shrinkage 42% top 46.5% bottom
Buoy line	PE	#6 42 m, IPC	
Hang line	PE	#7 42 m, IPC	
Sinker line	PE	#6 47 m, IPC	
Hang line	PE	#7 42 m, IPC	
Float	rubber	6 cm X 1.5 cm dia., 100 pcs	
Sinker	Lead	4 cm	7kilos

Encircling Gillnet
"Taksal/pangulong/
palutang"

Target Species
Clupeids/small pelagics

Banca
Motorized
16hp gasoline



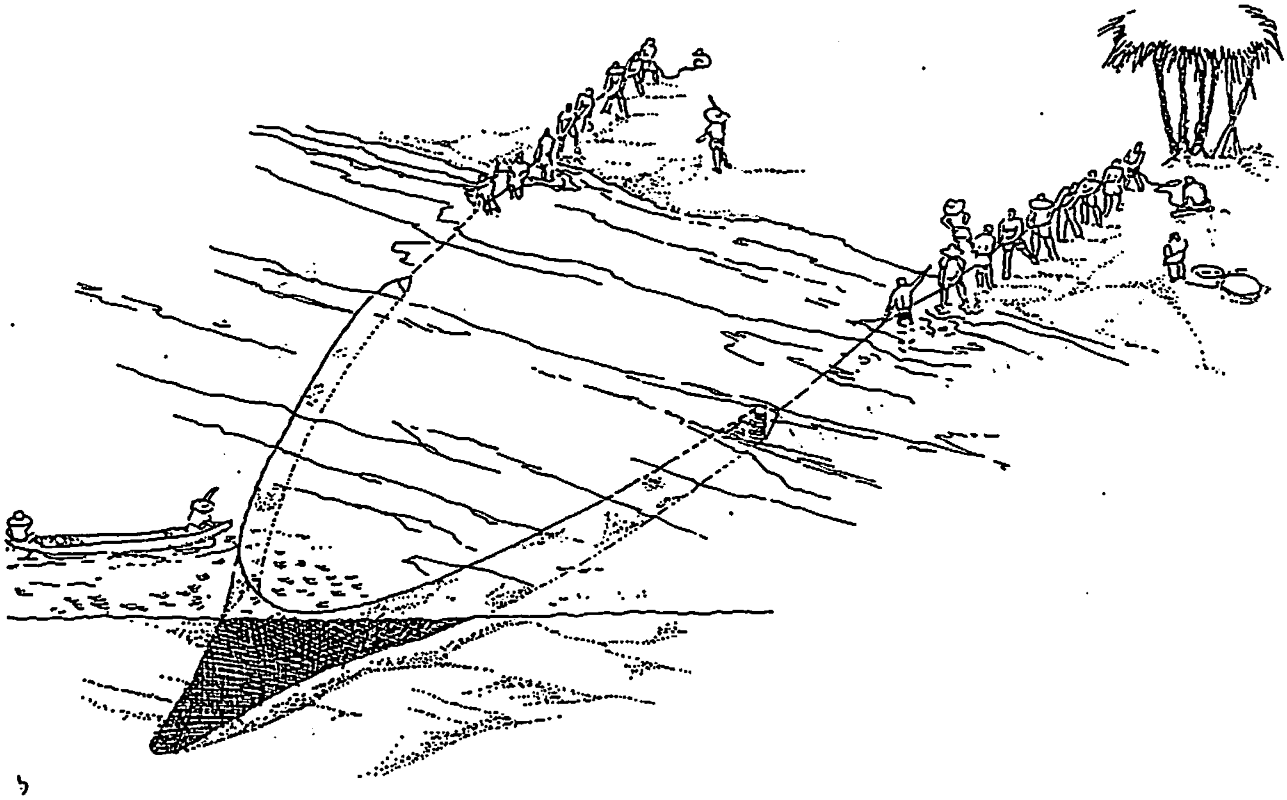
NET PA mono

Mesh size: 14 ϕ (23 cm) HR
100 meshes depth
100 m. stretched length
55.5 m actual length
030 twin diameter
6 panno

Selvage net PE

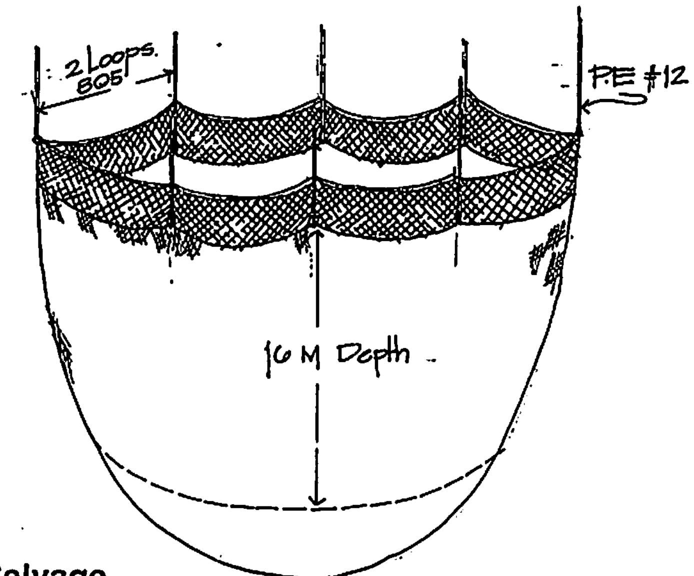
Float rubber (tsinelas)	150 pcs sizes	
Sinker (concrete fabricates)		3.5-4kg
Float line PE	# 7 56m	
Sinker line PE	# 5 56m	
Hang line PE	# 7 56 top	
Hang line PE	# 8 56 bottom	

Pull net "Bitana"	**Target species** Anchovies/ demersals	Operated without banca (at wadding depths)

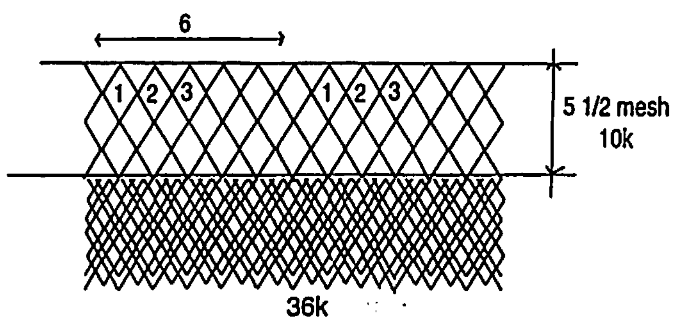


Part	Material	
Netting Material		
a) wing	CC net (Polarex a & 10 k) knotless	Float line = PE #12
b) bunt	Fine mesh (Hapa net) length = 12m	Net line = PE # 12
Total net length	= 250m	Sinker line = PE # 12
Height	= 3m	
Rope length	= 300m	
Sinker	= Homemade concrete (10x5cm) oblong	
Float	= Rubber/44cm long plastic	
Staple Lt.	= 20cm	
# mesh/staple	= 12	
Flt. material	= 44cm	
Sinker Int.	= 16cm	

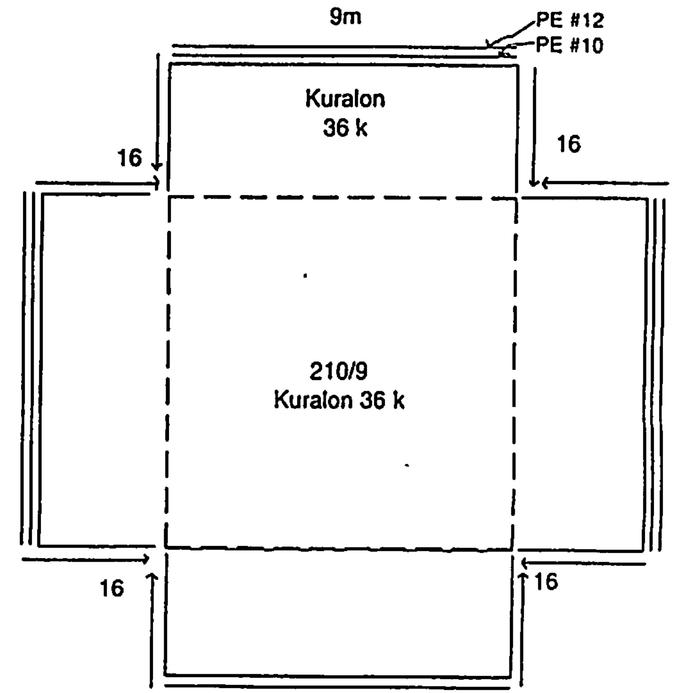
Operational Set-up/ design (Umali 1950)	Beach siene " Sinsuro"	Target Species Demersals	Banca Non-motorized



Selvage



Joining Ratio = 1:3, Hr = 60.6%

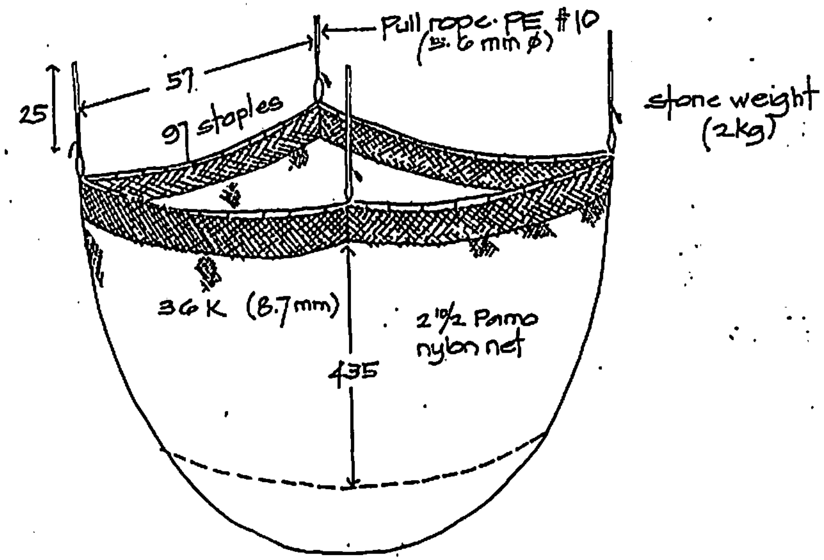


Structural Plan of Bag Net

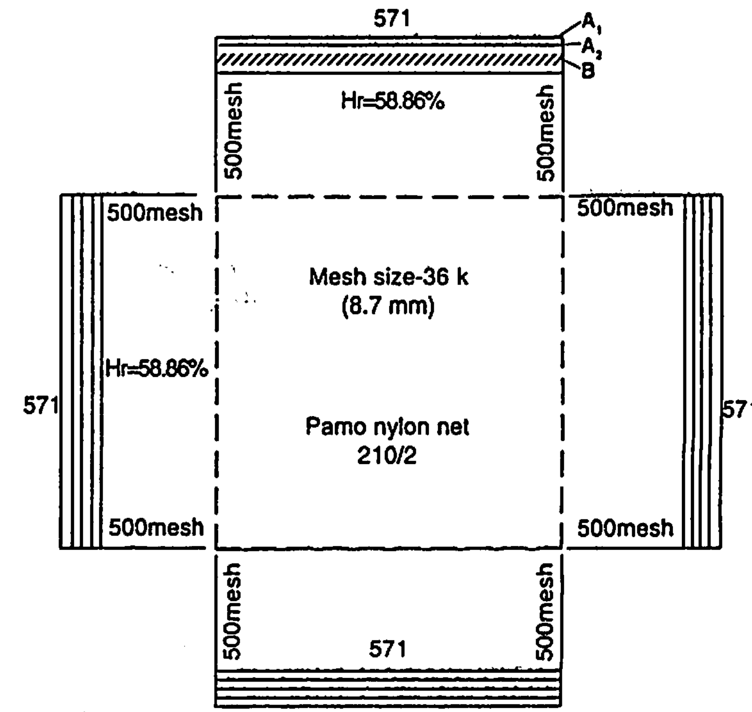
Hanging line.............................. PE #12
Reeving line..............................PE #10
Pull ropes.................................. PE #14
No. of between loops.............170

Note: All units in cm.

Bag net "Basnig"	**Target Species** Anchovies, round scads, mackerels, herrings,sardines	**Banca** Motorized, gasoline 12-16hp

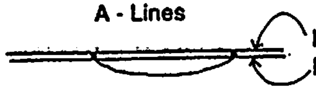


Bag net for siganid fry and anchovies



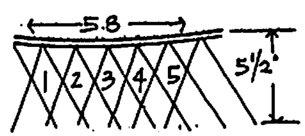
Structural Plan
of a bag net for siganid and anchovies

A - Lines



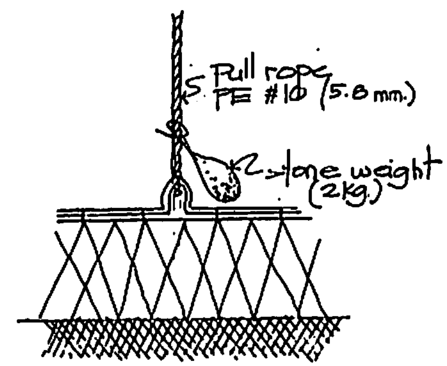
Hanging line- PE #8-4.8 mm dia.
Reeving line- nylon #200

B - Selvage



5 1/2 mesh (16k - 20mm mesh)
multifilament nylon 210/3
Hr=58.86%

C - Joining Ratio: 1:2



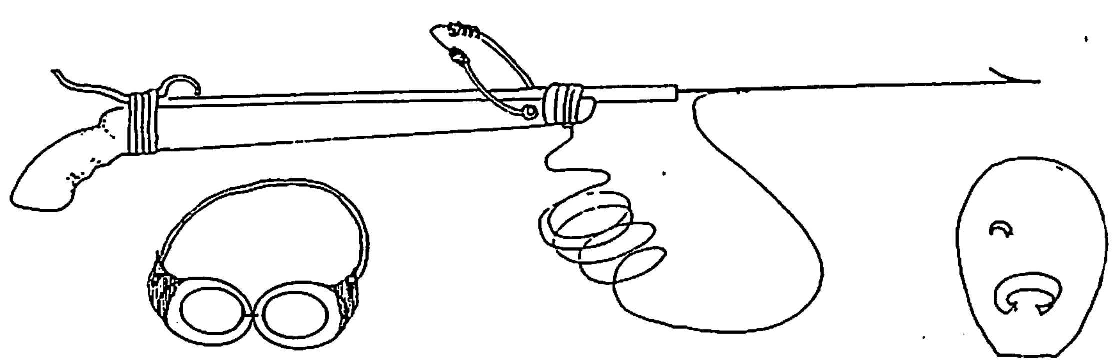
D - Ropes

1) Staple length ....5.8 cm
2) No. of mesh/staple ...5 mesh
   (1 fixed + 4 free mesh)
3) No. of staple (one side)....97 staples

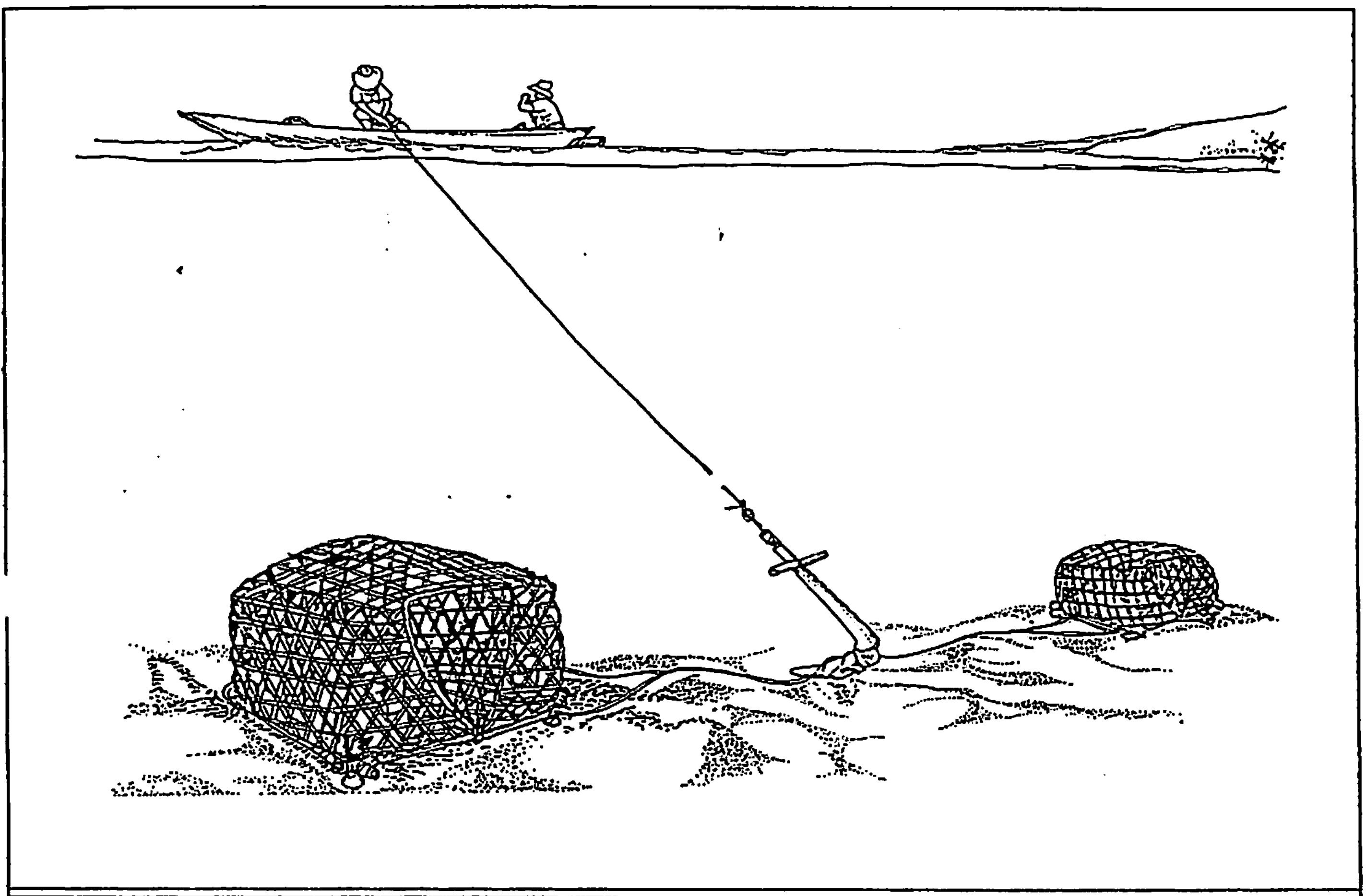
E - Construction Specification:

A_1- Hanging line...PE #8
A_2- Reeving line....nylon #200
B - Selvage 16k
  1) 5 1/2 mesh depth
  2) mesh size ...16k
  3) pamo nylon net (210/3)

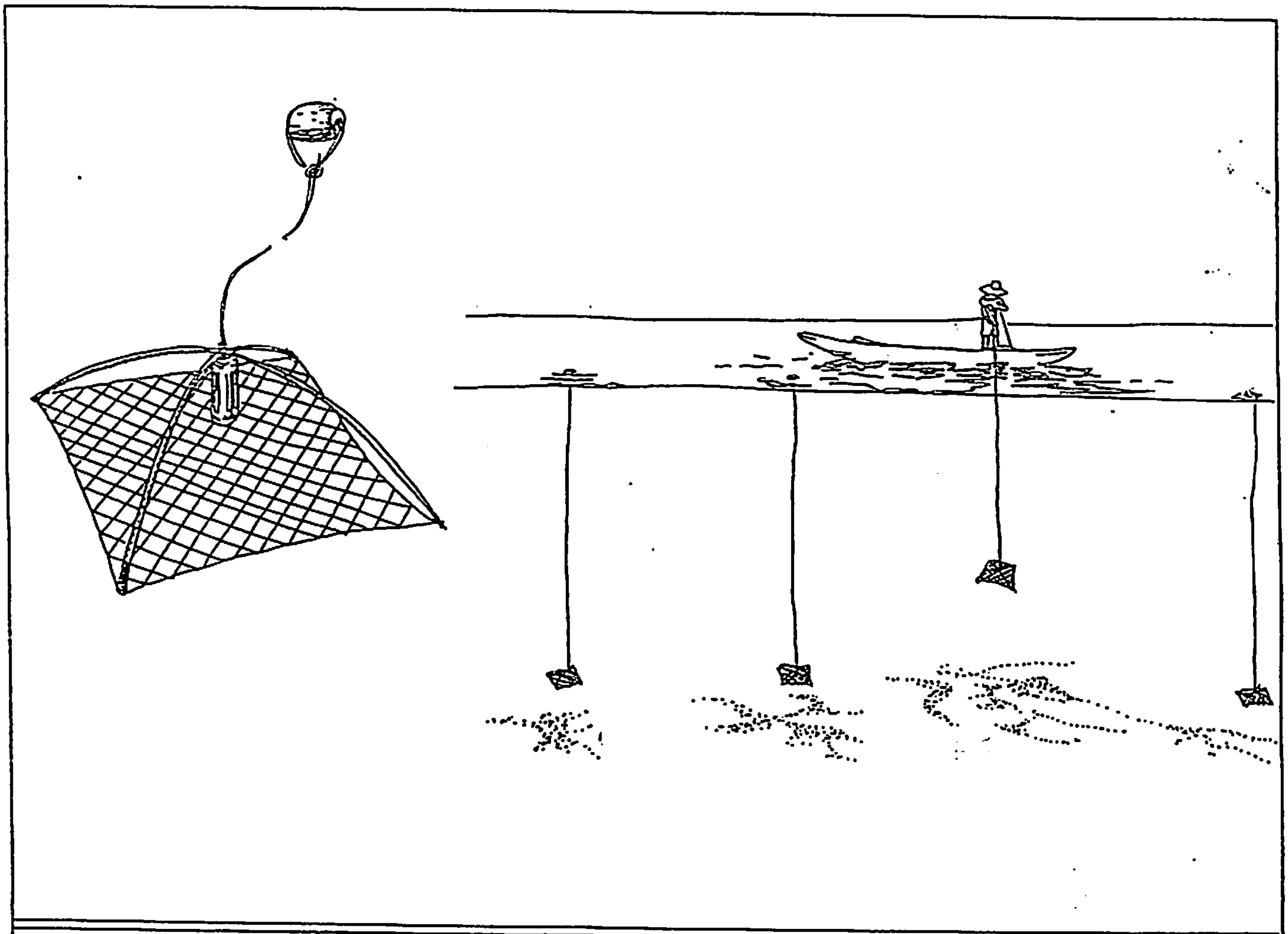
Note: All units in cm.



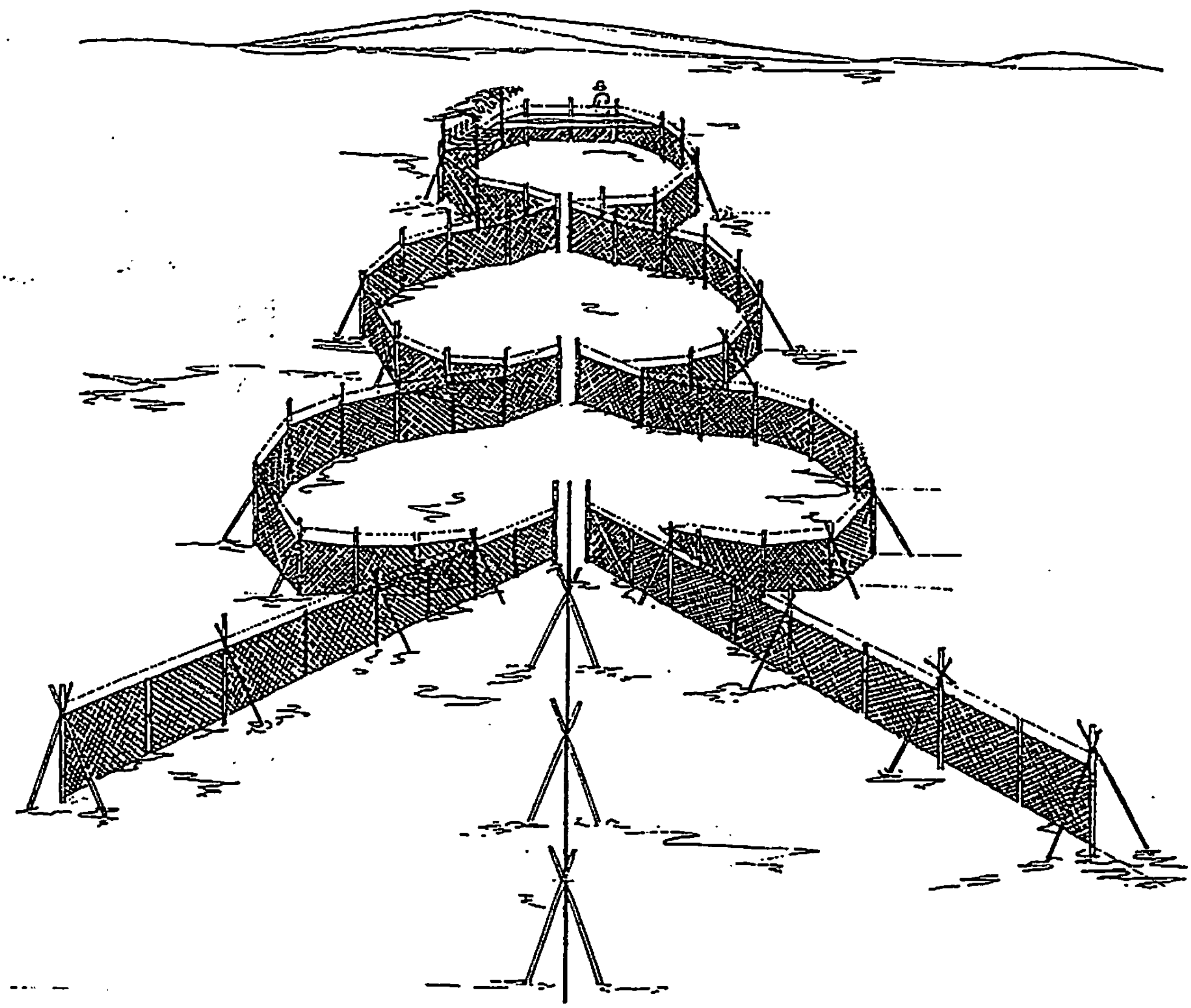
Operational Set-up/ design	**Spear gun** "Pana"	**Target Species** Groupers, carangids, siganids	**Banca** Motorized with compressor/ or free diving



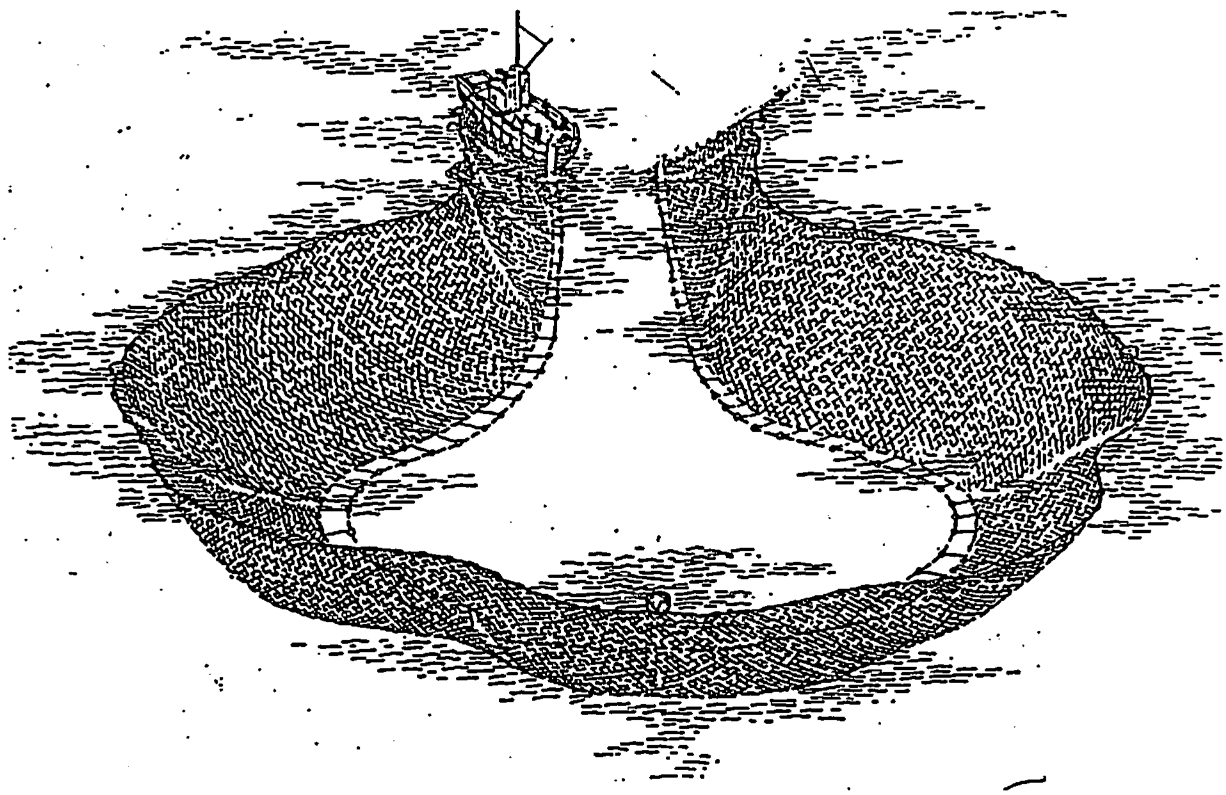
Operational Set-up/ design (Umali 1950)	Fish trap "Bubo"	Target Species Snappers, siganids/ groupers	Banca Non-motorized, motorized, 16 hp



Operational Set-up/ design (Umali 1950)	Crab liftnet "Bintol"	Target Species Crabs	Banca Non-motorized



Operational Set-up/ design (Umali 1950)	Fish corral "Baklad/sagkad/bunuan"	Target Species Siganids,lethrinids,theraponids, snappers, other pelgics	Banca Non-motorized



Part

I- Primary Wing

Netting material	- PE, 3 ply 4k
Float	- Plastic (NGR #12)
Float internal	- 80cm
Sinker	- lead #6
Sinker internal	- 50cm
Staple lenght	- 25cm
# mesh/staple	- 6
# staple/meter	- 4
Lenght (wing)	- 25cm
Height (wing)	- 25m

II- Secondary Wing

Netting material	- Pamo nylon fishnet 9 ply 8 k } (CR=(connecting ratio) 2:1
Selvage	- PE 5 ply 8 k } (CR=(connecting ratio) 2:1
Sinker internal	- 50cm
Height (wing)	- 28m
"Other aspects"	- same as primary wing

III- Bunt (center portion of gear)

Netting material	- Pamo nylon net (PE?) 10 ply 17 k
Staple lenght	- 20cm
Selvage	- 8 k/ PE 9 ply
Sinker interval	- 19cm
Float interval	- 20cm
Height (wing)	- 40m

IV- Others

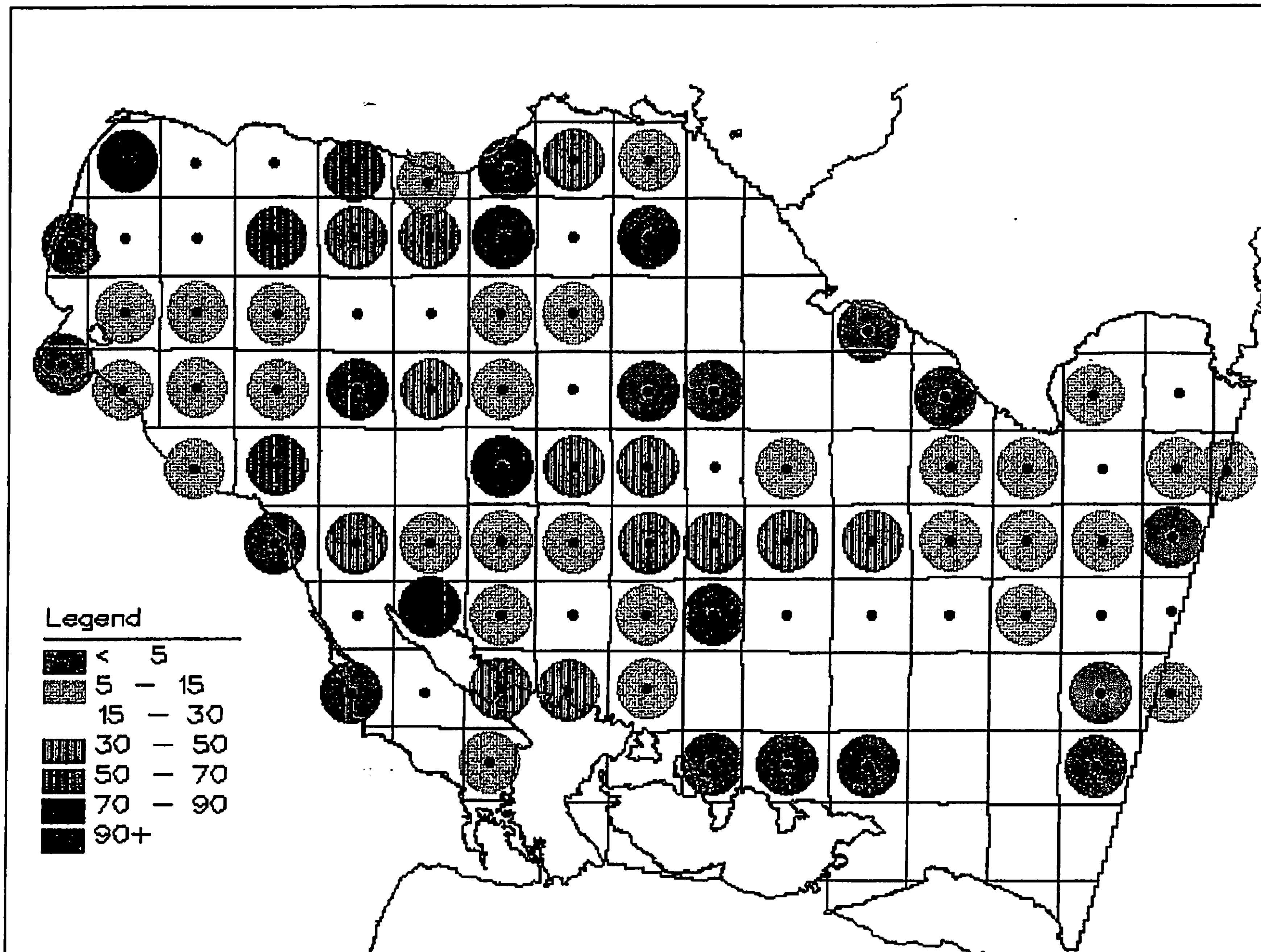
Rope	- PE # 20 (double)
Ring size	- 1/8" stainless steel
Ring circ.	- 16cm
Ring interval	- 5m
Tom weight	- 100 kg

Operational Set/design	Ringnet "Klansisi/palakaya"	Target Species Skipjack tuna, pelagics	Banca Motorized 300 +3 gross tonnage

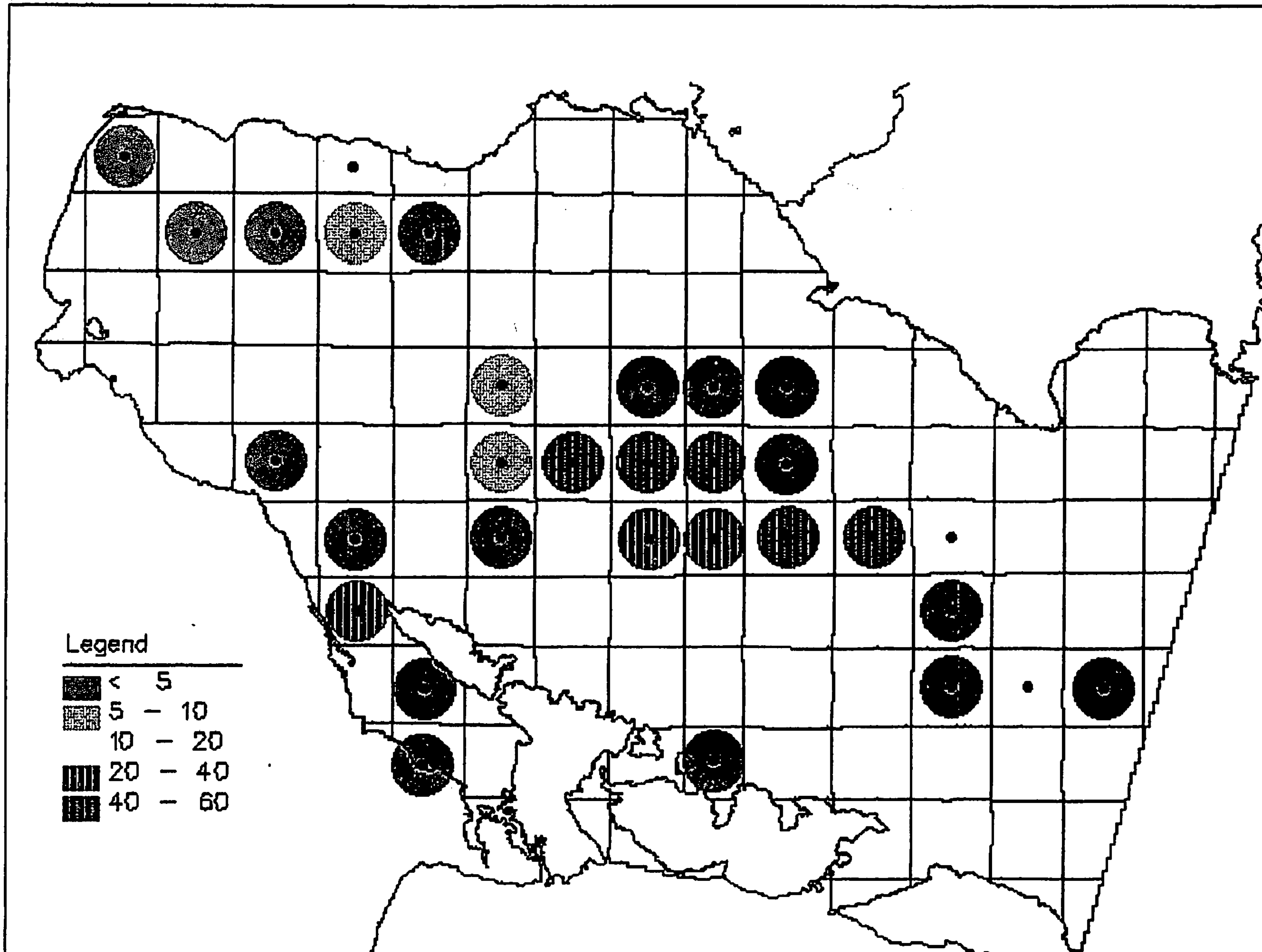
Appendix 2

Fishing Grounds of the Commonly Used Fishing Gears in Lagonoy Gulf

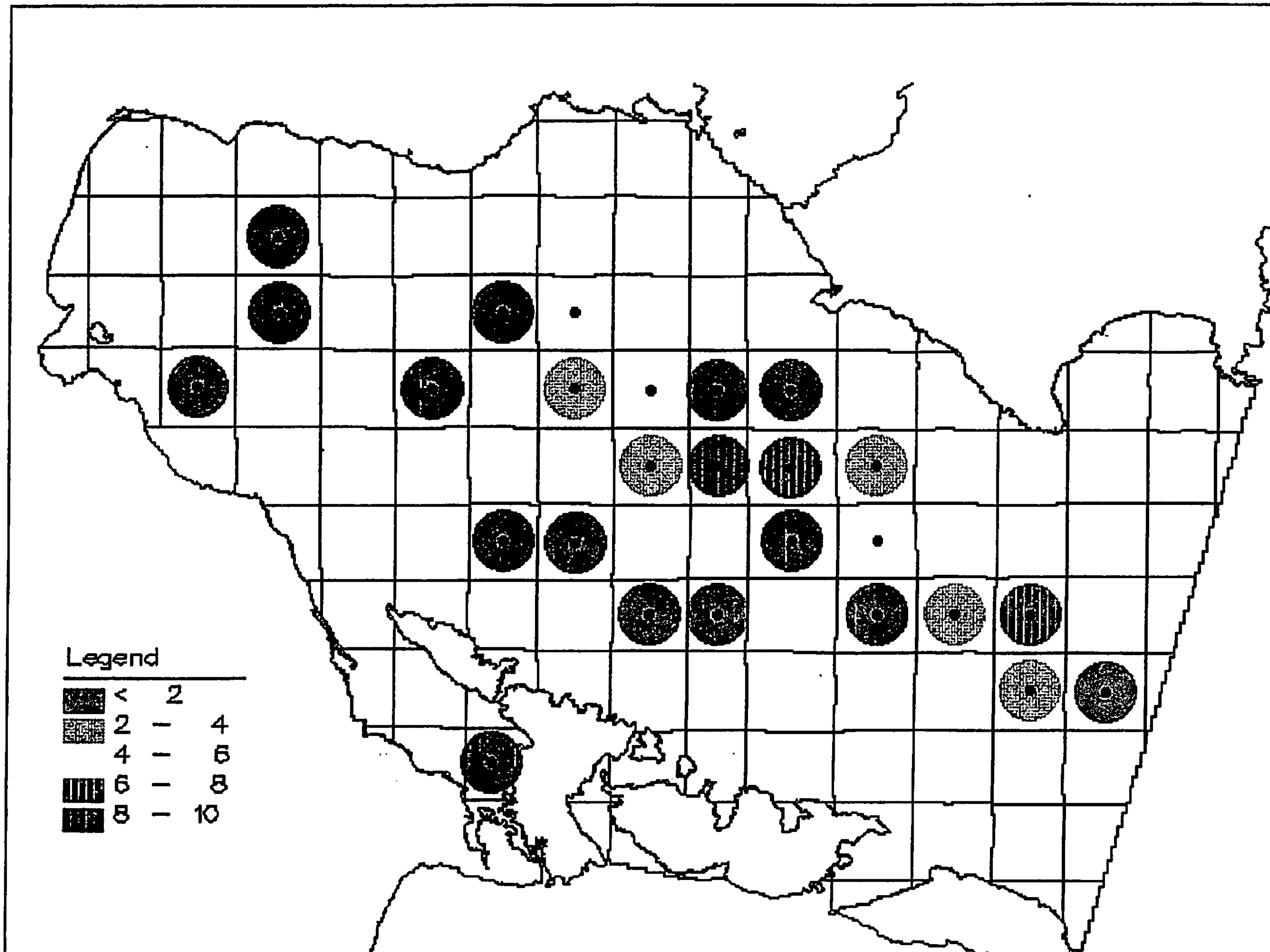
1. Simple handline
2. Multiple handline
3. Tuna handline
4. Bottom-set longline
5. Longline
6. Bottom-set gillnet
7. Drift gillnet (monofilament)
8. Drift gillnet (PE)
9. Beach seine
10. Fish corral
11. Spear gun
12. Ring net
13. Dynamite



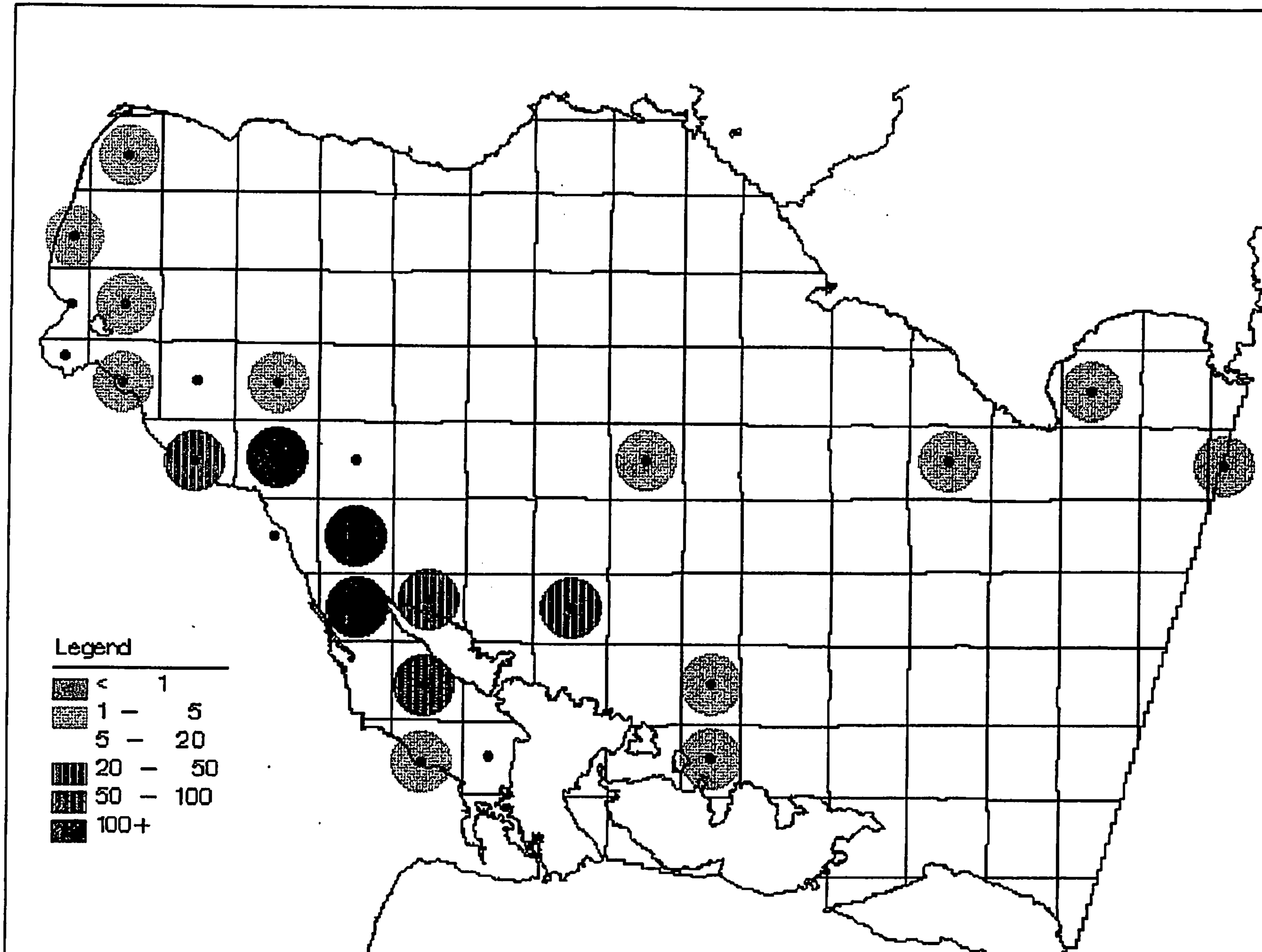
Appendix 2.1. Digitized map showing the fishing grounds visited by simple handlines.



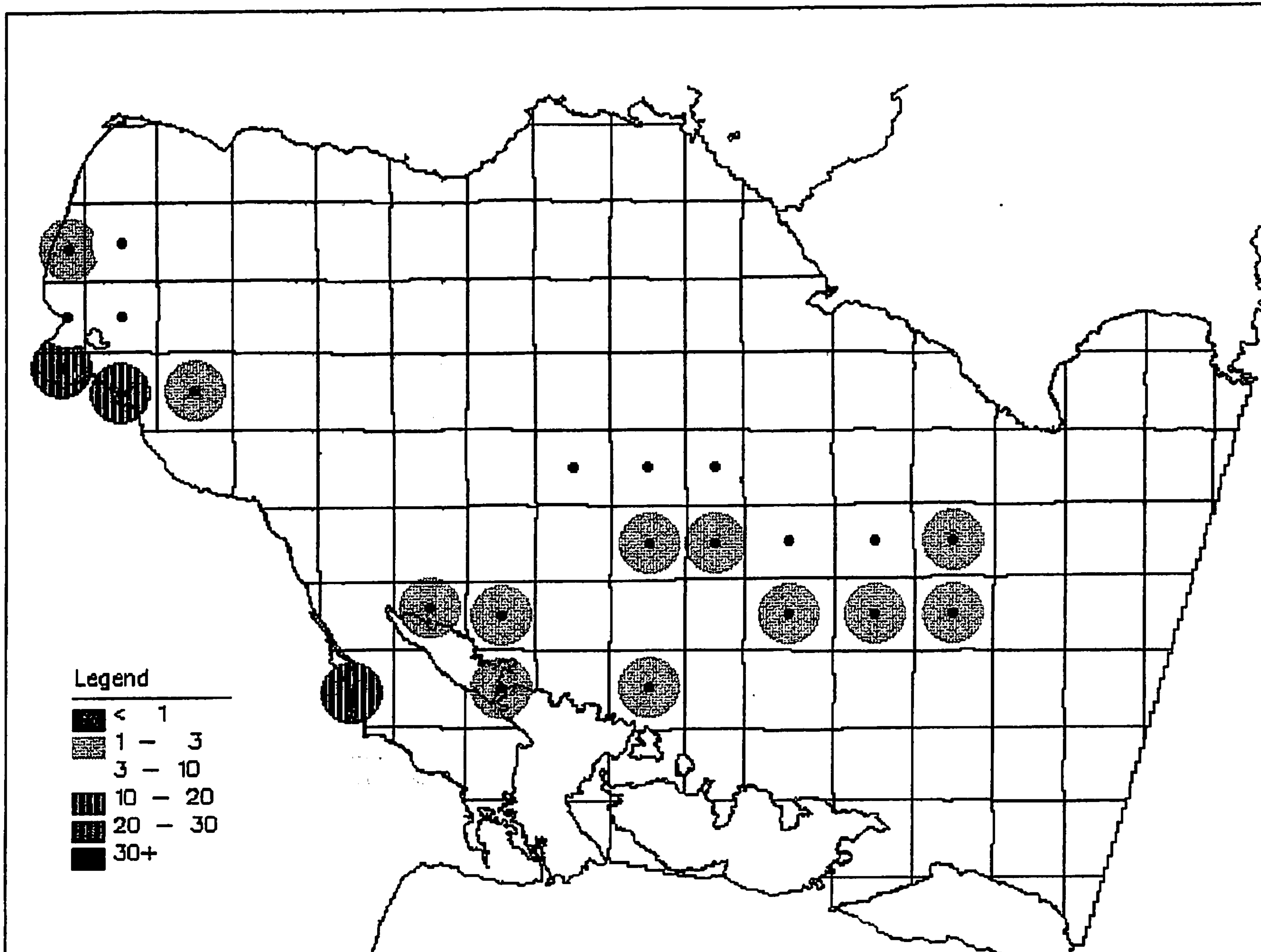
Appendix 2.2. Digitized map showing the fishing grounds visited by multiple handline.



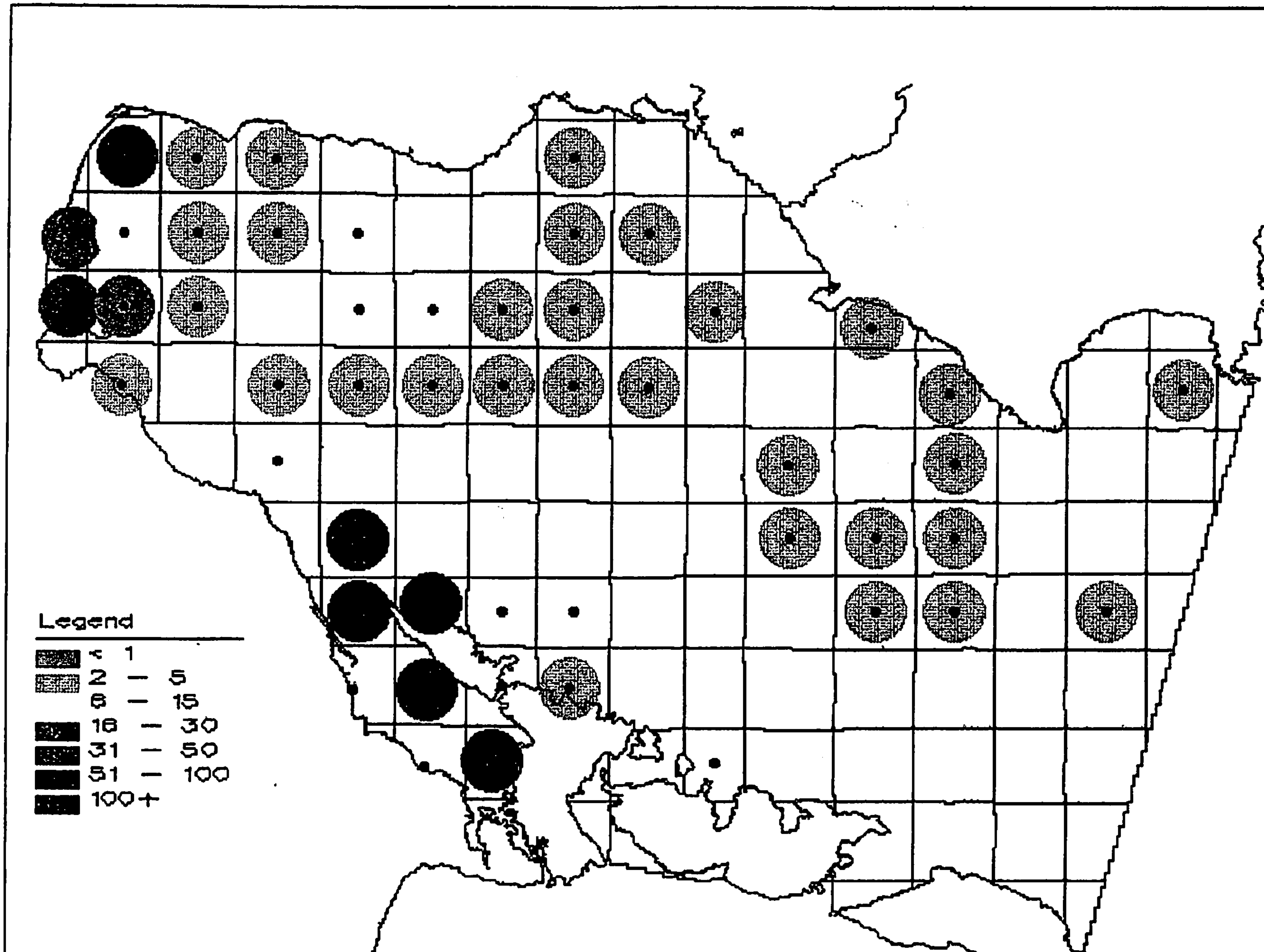
Appendix 2.3. Digitized map showing the fishing grounds visited by tuna handline.



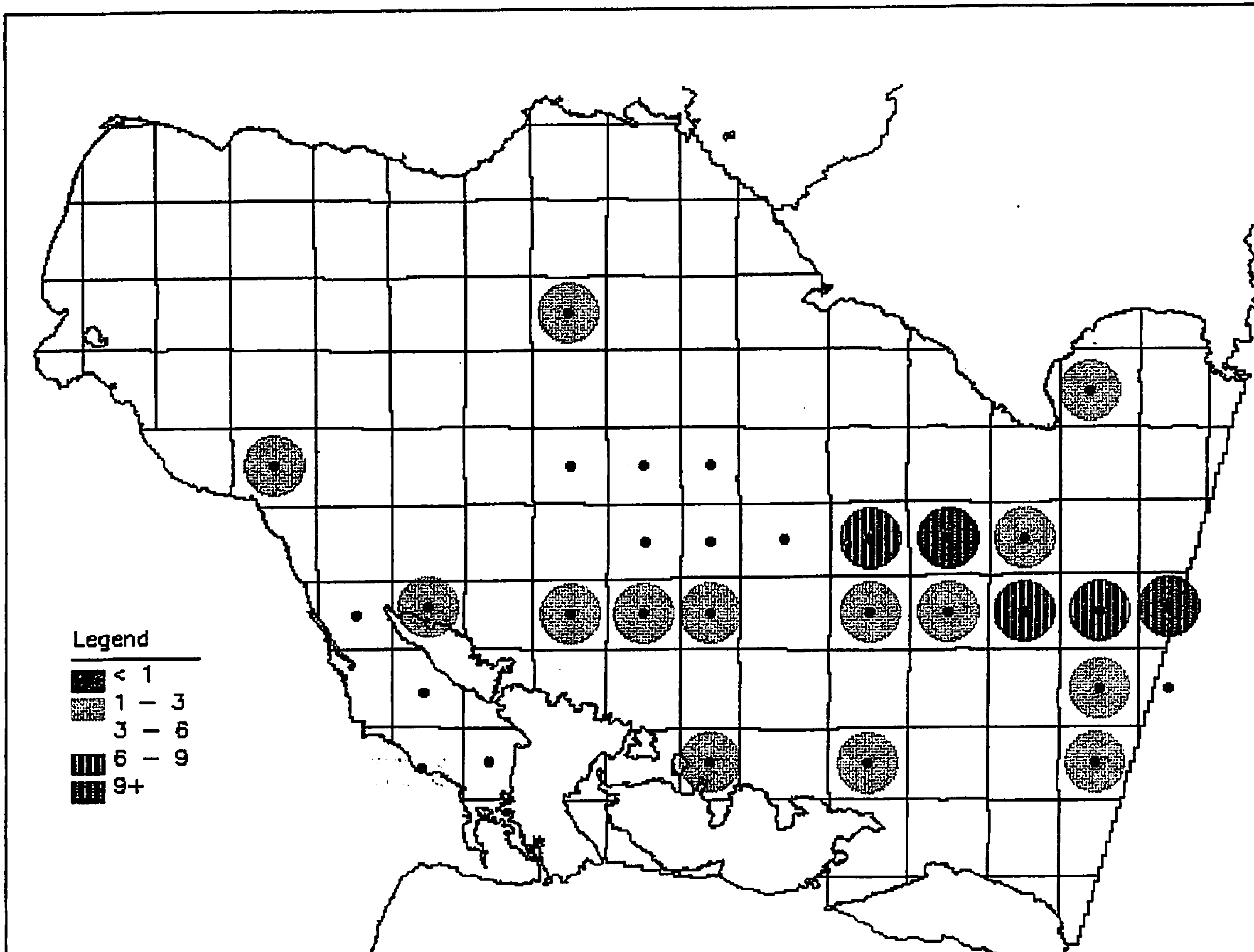
Appendix 2.4. Digitized map showing the fishing grounds visited by bottom-set longline.



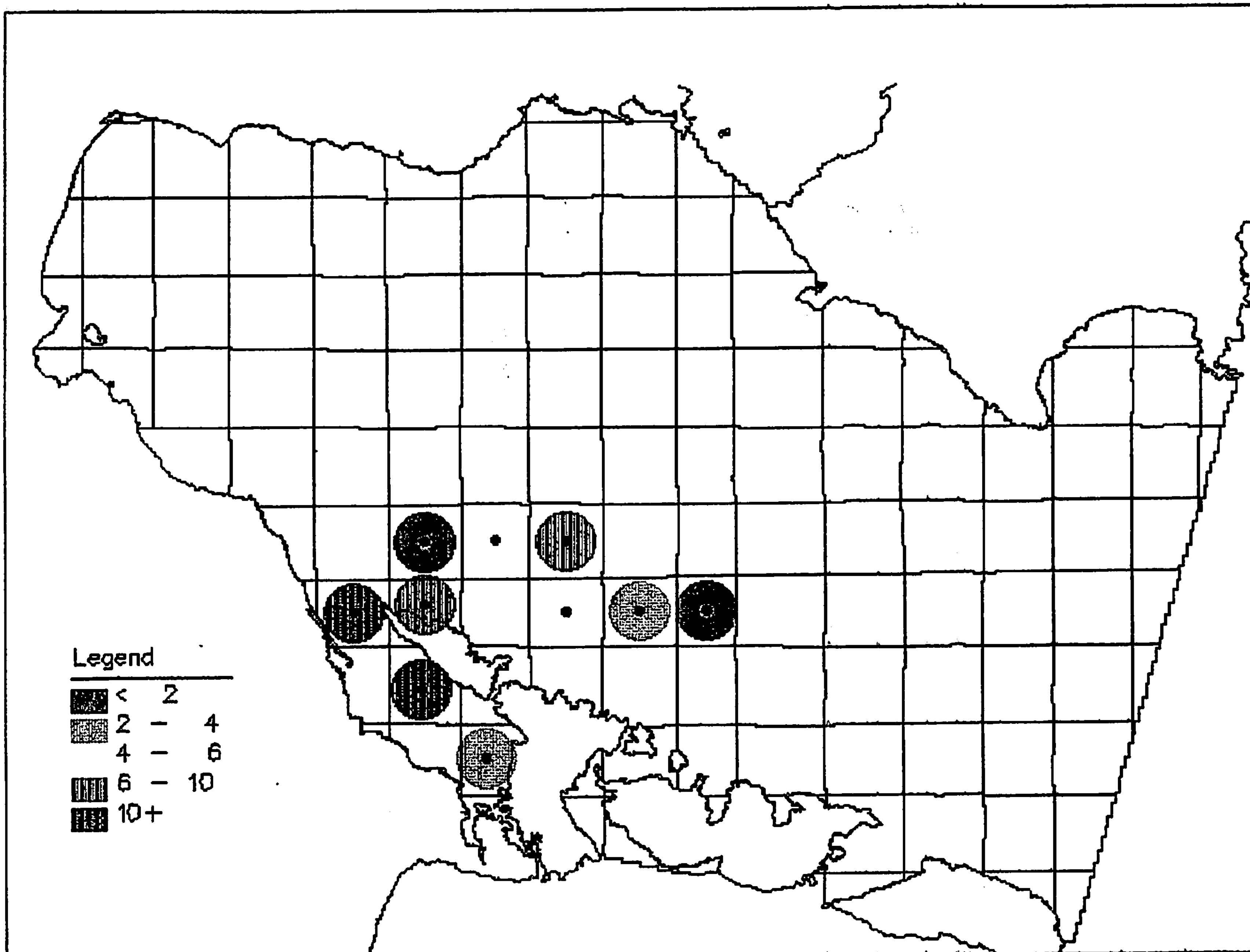
Appendix 2.5. Digitized map showing the fishing grounds visited by longline.



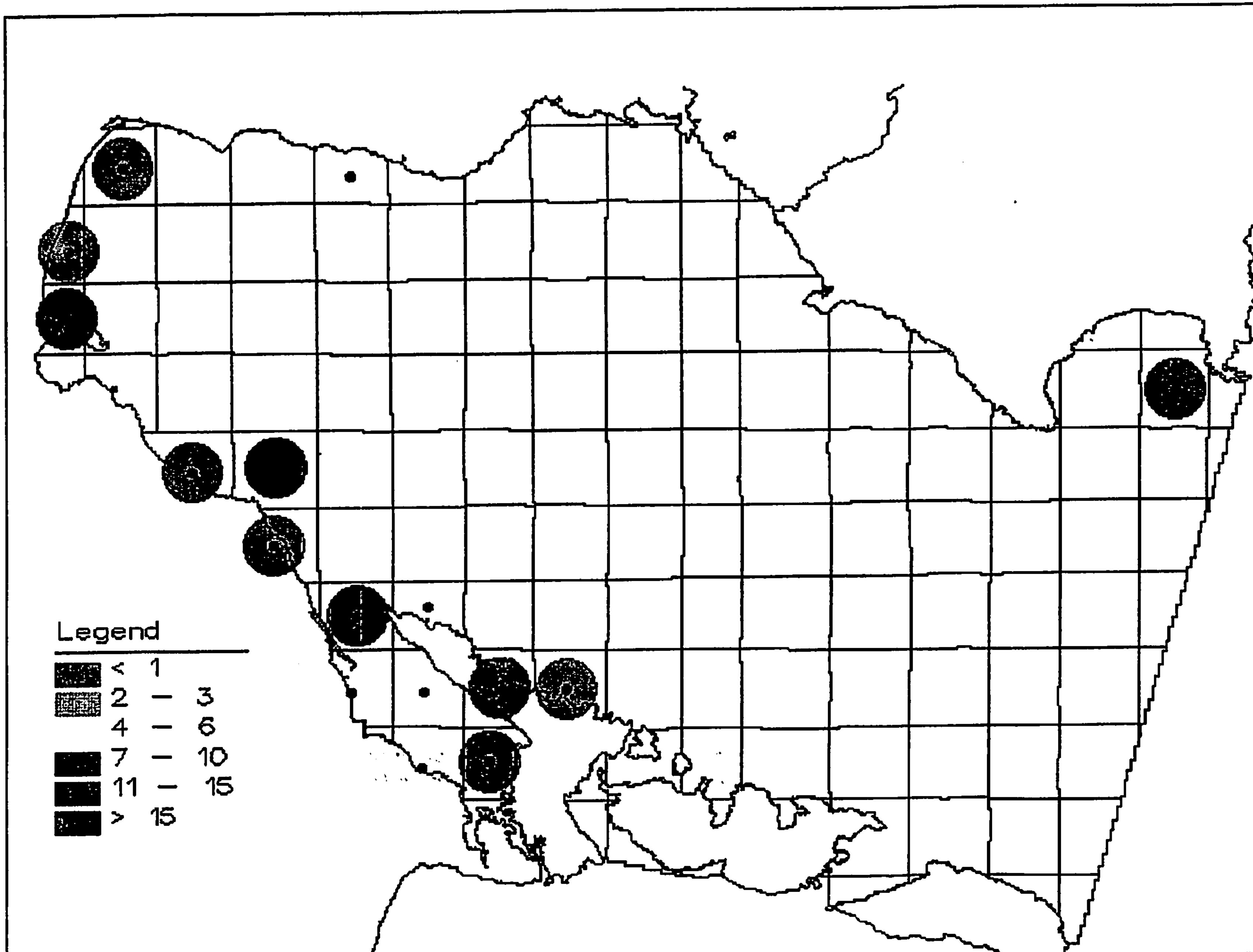
Appendix 2.6. Digitized map showing the fishing grounds visited by bottom-set gillnet.



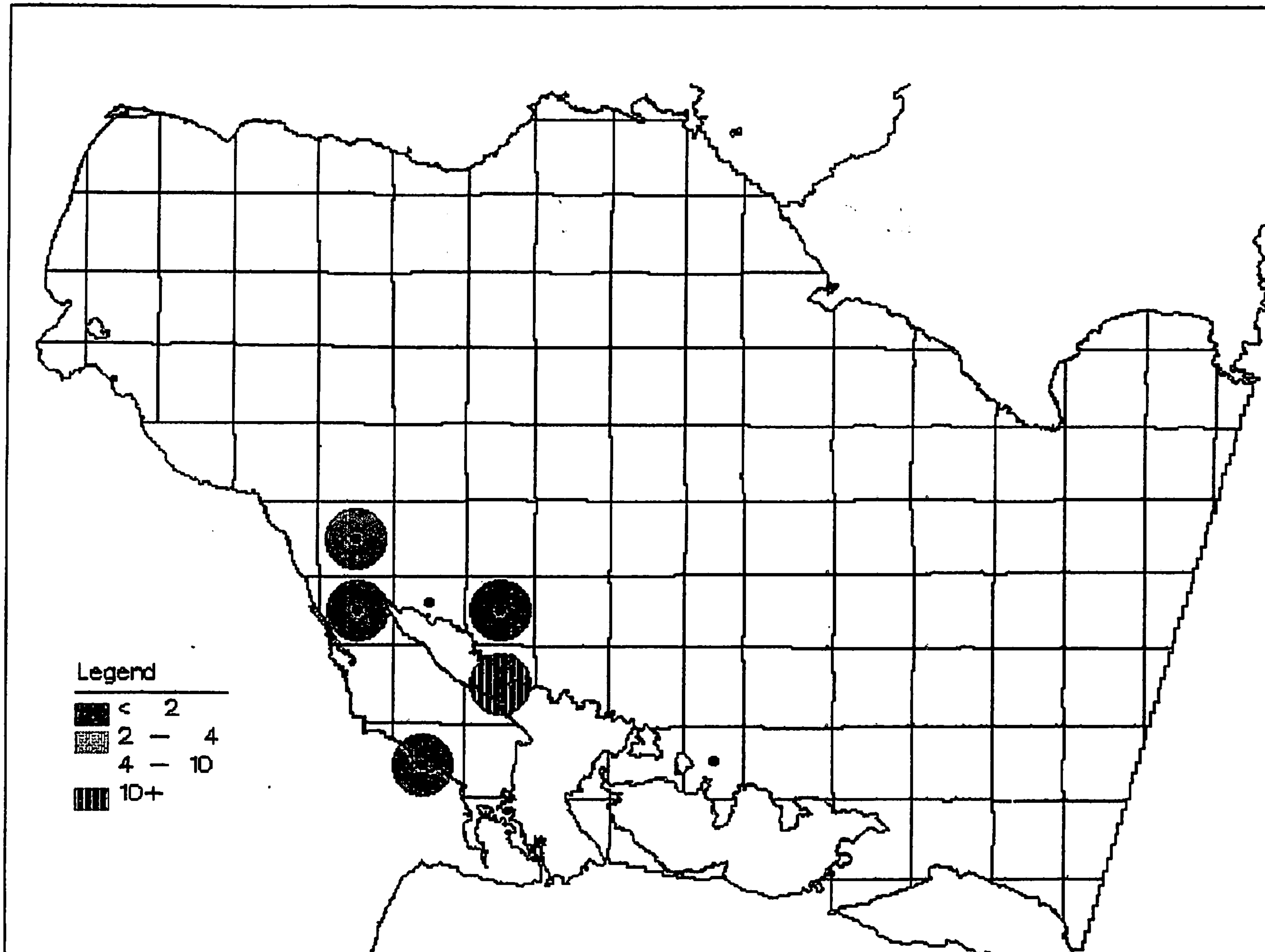
Appendix 2.7. Digitized map showing the fishing grounds visited by drift gillnet (monofilament).



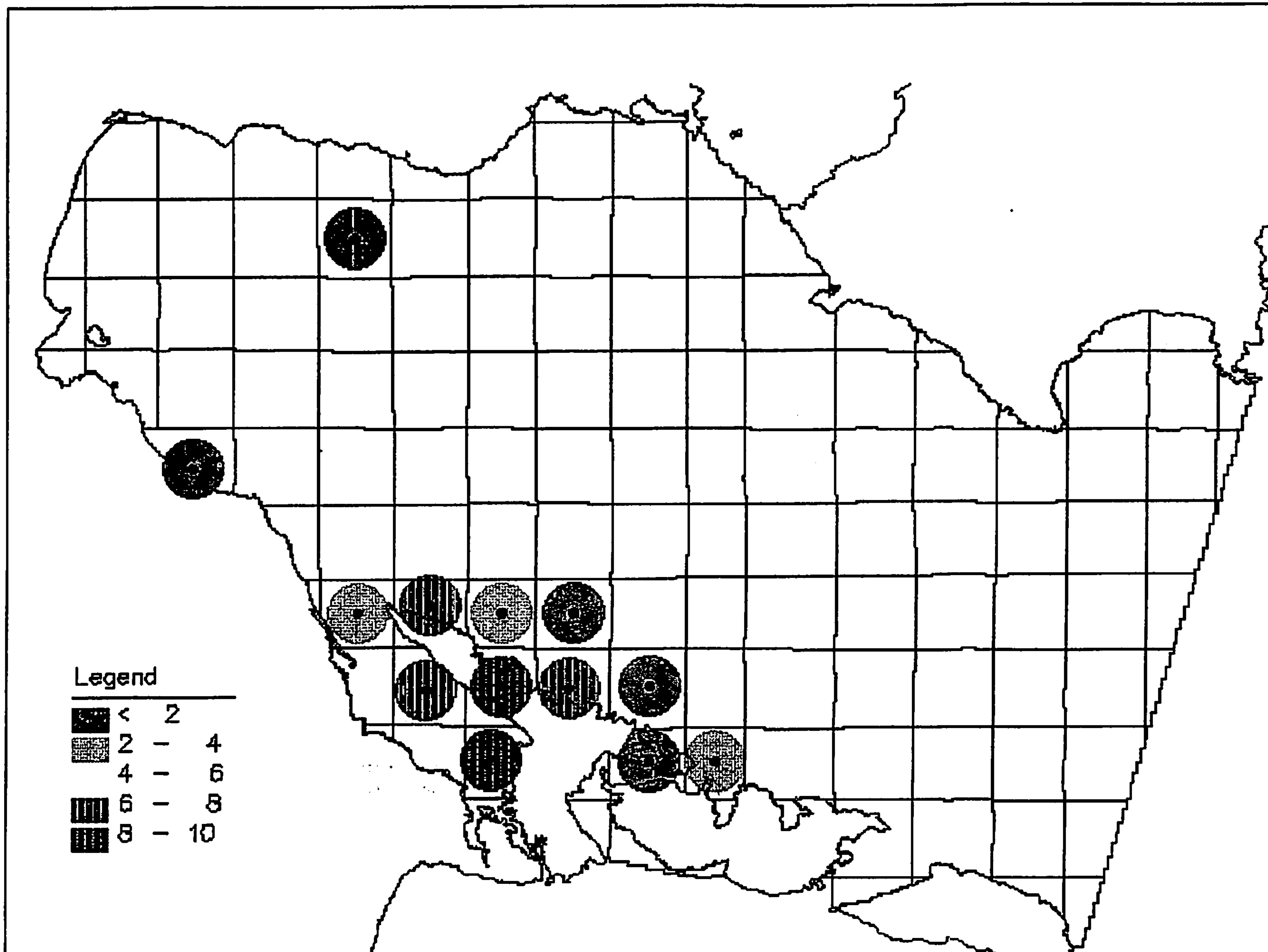
Appendix 2.8. Digitized map showing the fishing grounds visited by drift gillnet (PE).



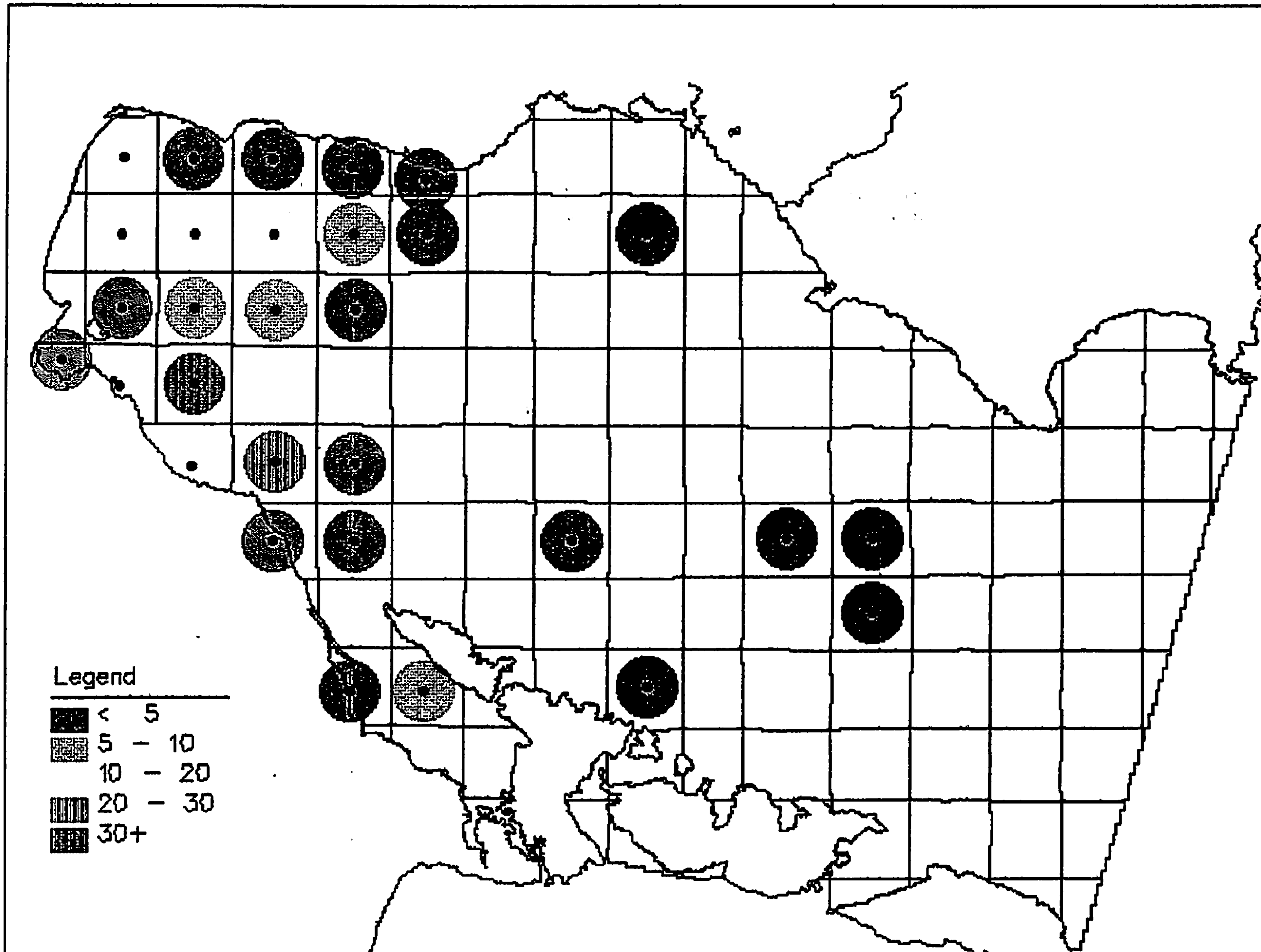
Appendix 2.9. Digitized map showing the fishing grounds visited by beach seine.



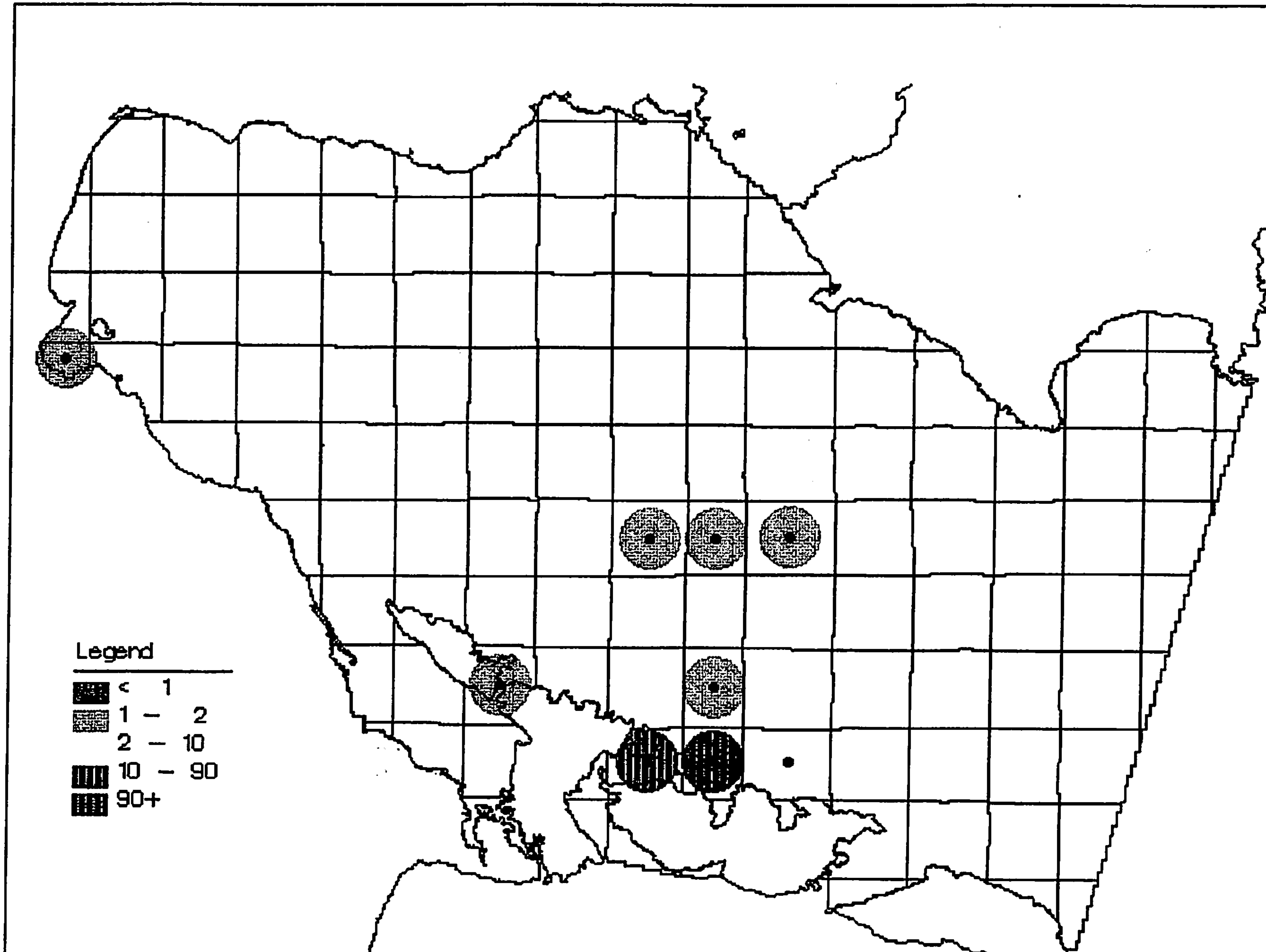
Appendix 2.10. Digitized map showing the fishing grounds visited by fish coral.



Appendix 2.11. Digitized map showing the fishing grounds visited by spear gun.



Appendix 2.12. Digitized map showing the fishing grounds visited by ringnet.



Appendix 2.13. Digitized map showing the fishing grounds visited by dynamite.

A Checklist of Fishes and Invertebrates Caught and Observed in Lagonoy Gulf

by

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A Checklist of Fishes and Invertebrates Caught and Observed in Lagonoy Gulf

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Abstract

This fish species checklist is the first of its kind in Lagonoy Gulf. Activities such as: 1) the monitoring of catch and landings of commercial and municipal fishing gears from January to December 1994, and 2) the reef fish visual census that was conducted in conjunction with coral reefs survey were the sources of information. The inclusion of 480 fish species belonging to 199 genera and 79 families, and 21 species of invertebrates is indicative of the high diversity of the exploited fisheries in the gulf. However, only about 25 of the 480 species are dominant or of economic importance.

Introduction

Lagonoy Gulf is semi-enclosed and has an approximate area of 3,071 km^2. It is located between 123°31'37"E to 124°20'36"E and 13°44'30"N to 13°10'33"N (Fig. 1). The northern part of the gulf is bounded by portions of Caramoan Peninsula and Catanduanes Island while its southern side is bounded by the group of islands east of Albay. The gulf maintains continuity with the Pacific Ocean through its northwestern (Maqueda Channel) and southeastern channels.

Around 34 types of fishing gears (Garces et al., this vol.) are used in Lagonoy Gulf thus, accounting for the high diversity of the gulf's exploited fisheries. The fish stock ranges from small demersals and large pelagics. Several invertrebrates are also included.

This paper is an attempt to provide a list of the fishes and invertebrates in Lagonoy Gulf. The species listed during the capture fisheries component's fish landing and catch surveys conducted from January to December 1994, and those that were observed during the reef fish visual census conducted by Nañola and Cabansag (this vol.) were the sources of information.

This study is part of the wider range of investigations of the fisheries in the gulf under the "Lagonoy Gulf Resource and Ecological Assessment Project" conducted by the International Center for Living Aquatic Resources Management (ICLARM)-Bicol University College of Fisheries (BUCF) consortium with funding from the Fisheries Sector Program (FSP).

Materials and Methods

The fish and invertebrate samples used for this study were collected and observed in Lagonoy Gulf from January to December 1994. Specimens were identified, either in the laboratory or in situ, through activities such as: 1) fish landing monitoring; 2) catch surveys; and 3) reef fish visual census.

Fish landing monitoring were conducted thrice-weekly, when possible, in each of the 17 fish landing sites (Fig. 1) distributed throughout the gulf. The location of these landing sites allows for an even and appropriate coverage of the landings of almost all the fishing gears used in Lagonoy Gulf. Catch surveys (test-fishing) were conducted monthly on 12 types of fishing gear (Table 1). These surveys are periodically done to ascertain total catch, operational details and changes in fishing operations.

The reef fish visual surveys were conducted by Nañola and Cabansag (this vol.) in January, April and July using a modified technique described by English et al. (1994). The literatures used in the species identification are given in the reference section (e.g. Carcasson 1977; Fischer and Whitehead 1974; Lewis et al. 1983; Munro 1967; Randal et al. 1990; Rau and Rau 1980; Schroeder 1980; and Shirai 1986).

Results and Discussion

Appendix 1 shows the list of fishes and invertebrates caught by the various fishing gears used in Lagonoy Gulf from January to December 1994, and those observed during the fish visual census conducted in January, April and July 1994. The list includes 11 species of cartilaginous fish (Class Chondrichthyes) belonging to 10 genera and 6 families. Bony fishes (Class Osteichthyes) contribute 469 species distributed among 189 genera and 73 families. Of these, 234 species were recorded during the fish landing and catch surveys conducted by the capture fisheries component of the Lagonoy Gulf REA (Appendix 2).

There are 21 species of invertebrates in addition to the 480 fish species. However, it is worth noting that only about 25 species may be considered dominant or of economic importance (Soliman et al., this vol.). Among the common and most prized species in the gulf are tunas, sailfishes and siganid fry. All the other species may be economically less important but they are part of the dietary budget of the population around the gulf (i.e., considering the population's eating habits).

This listing is the first of its kind in Lagonoy Gulf. The inclusion of 501 fish and invertebrate species is indicative of the high diversity of the exploited stock in the gulf.

Acknowledgement

We would like to thank Mr. Plutomeo Nieves and Mr. Marcial Jane, both from the Bicol University College of Fisheries, and Eduardo Bola, Rolando Buenaflor, Florante Bustamante, Anastacio Cante Jr., Jose Gonzales Jr. and Jovel Tasarra, all Research Aides of the Capture Fisheries Assessment Component of the Lagonoy Gulf REA Project, for their invaluable assistance during the conduct of this study.

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Table 1. Fishing gears monitored for catch rates in Lagonoy Gulf.

Gear type	Site								Total
	San Jose	Tiwi	Malinao	Tabaco	Bacacay	San Miguel Is.	Rapu-rapu Is.	Catanduanes	
Pulled nets									
1 Ring net	*	*		*					3
2 Beach seine	*	*	*	*				*	5
3 Pull net							*		1
Lift nets									
4 Bagnet				*	*				2
5 Drive-in net							*		1
Entangling nets									
6 Bottom set gillnet						*	*		2
7 Drift gillnet	*		*	*	*	*	*	*	7
8 Largarete				*	*				2
9 Crab gill net					*				1
Hand lines									
10 Simple hand line	*	*	*		*		*		5
11 Mutiple hand line					*		*		2
12 Troll line		*	*						2
Longlines									
13 Bottom-set longline		*	*					*	3
Barrier and trap									
14 Fish corral						*	*	*	3
Hand instrument									
15 Spear gun						*			1
Bicol indigenous									
16 Lampurnas						*	*		2

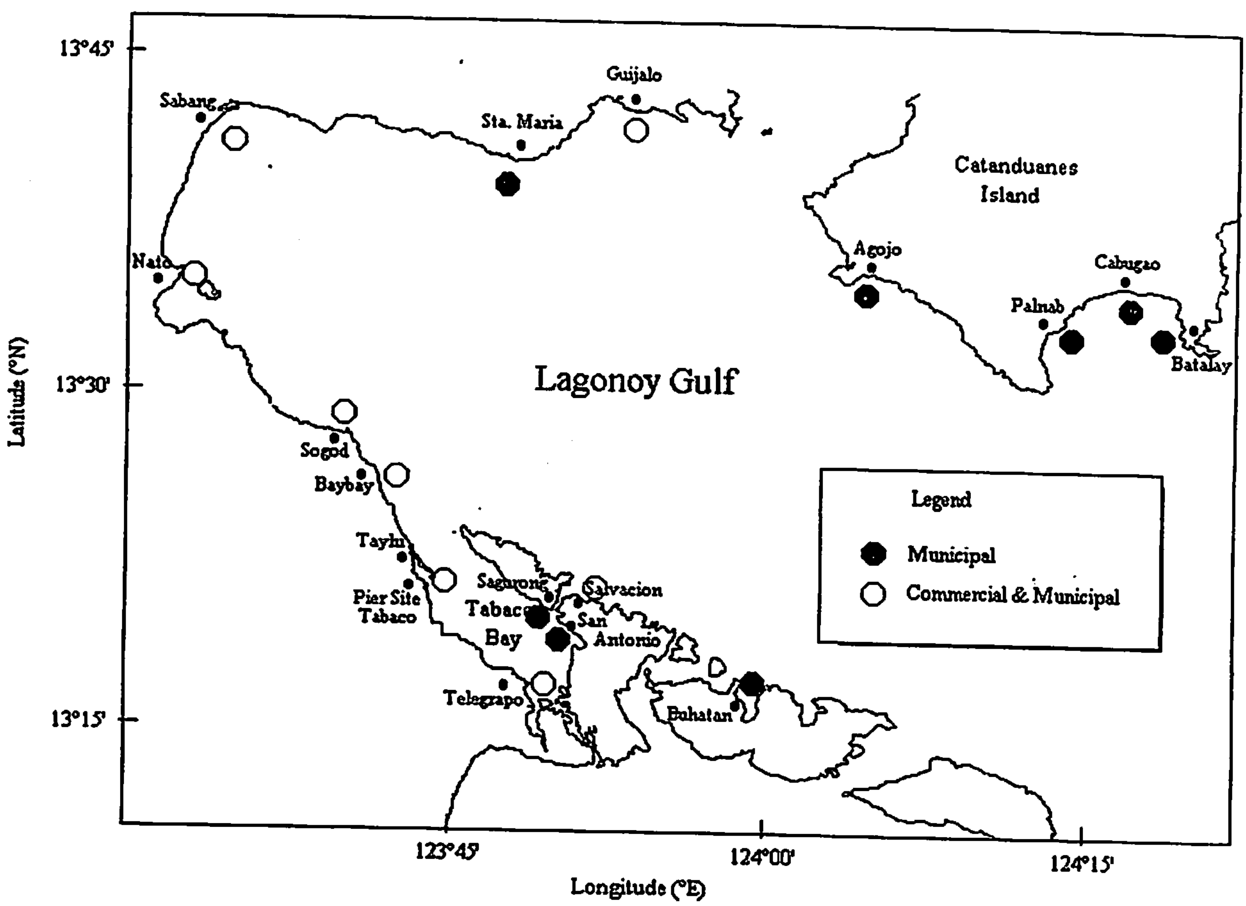

Fig. 1. Fish landing areas monitored for municipal and commerical fisheries assessment.

Appendix 1. Fishes and invertebrates observed in Lagonoy Gulf from January to December 1994.

CLASS	FAMILY	GENUS	SCIENTIFIC NAME
1 CHONDRICHTHYES			
	1 CARCHARHINIDAE		
		1	1 Apristurus herklotsi
		2	2 Atelomycterus marmoratus
		3	3 Carcharhinus melanopterus
	2 SQUALIDAE		
		4	4 Squalus acanthias
	3 DASYATIDAE		
		5	5 Dasyatis kuhli
			6 Dasyatis sephen
		6	7 Himantura uarnak
		7	8 Taeniura lymma
	4 MOBULIDAE		
		8	9 Mobula japonica
	5 ORECTOLOBIDAE		
		9	10 Chiloscyllium griseum
	6 RHINCODONTIDAE		
		10	11 Rhincodon typus
2 OSTEICHTHYES			
	7 ACANTHURIDAE		
		11	12 Acanthurus dussumiere
			13 Acanthurus gahhm*
			14 Acanthurus grammoptilus*
			15 Acanthurus japonicus*
			16 Acanthurus lineatus*
			17 Acanthurus nigrofuscus*
			18 Acanthurus pyroferus*
		12	19 Ctenochaetus binotatus*
			20 Ctenochaetus marginatus*
			21 Ctenochaetus striatus*
			22 Ctenochaetus strigosus*
		13	23 Naso annulatus
			24 Naso lituratus*
			25 Naso unicornis*
		14	26 Zebrasoma flavescens*
			27 Zebrasoma scopas*
			28 Zebrasoma veliferum*
	8 APOGONIDAE		
		15	29 Apogon compressus*
			30 Apogon lineatus
			31 Apogon spp.*
		16	32 Apogonichthys poecilopterus
			33 Apogonichthys quadrifasciatus
		17	34 Cheliodipterus lineatus*
			35 Cheliodipterus macrodon*
			36 Cheliodipterus quinquelineatus*
	9 ATHERINIDAE		
		18	37 Hypoatherina woodwardi
	10 AULOSTOMIDAE		
		19	38 Aulostomus chinensis*
	11 BALISTIDAE		
		20	39 Balistapus undulatus*
		21	40 Melichthys vidua*
		22	41 Monacanthus scopas
		23	42 Rhinecanthus aculeatus*
		24	43 Sufflamen bursa*
			44 Sufflamen chrysoptera*
	12 BELONIDAE		
		25	45 Tylosurus crocodilus
			46 Tylosurus strongylorus
	13 BLENNIIDAE		
		26	47 Atrosalarias fuscus*
		27	48 Cirripectes polyzona*
		28	49 Meiacanthus grammistes*
		29	50 Plagiotremus laudandus*
			51 Plagiotremus rhinorhynchus*
		30	52 Salarias fasciatus*
	14 CARANGIDAE		
		31	53 Alectis ciliaris
			54 Alectis indicus
		32	55 Alepes djeddaba
			56 Alepes kalla
		33	57 Atule mate
		34	58 Carangoides ferdau
			59 Carangoides fulvogutatus
			60 Carangoides malabaricus
			61 Carangoides oblongus
			62 Carangoides plagiotaenia
			63 Carangoides spp.
		35	64 Caranx armatus
			65 Caranx ignobilis
			66 Caranx melampygus
			67 Caranx sexfaciatus

* Fishes observed during the fish visual surveys.

CLASS	FAMILY	GENUS	SCIENTIFIC NAME
			68 Caranx stellatus
			69 Caranx tile
		36	70 Decapterus kurroides
			71 Decapterus macrosoma
			72 Decapterus maruadsi
		37	73 Elagatis bipinnulatus
		38	74 Gnathanodon speciosus
		39	75 Megalaspis cordyla
		40	76 Scomberoides lysan
			77 Scomberoides tol
		41	78 Selar boops
			79 Selar crumenophthalmus
		42	80 Selaroides leptolepis
		43	81 Seriolina nigrofasciata
		44	82 Trachinotus baillonii
			83 Trachinotus blochii
		45	84 Ulua mandibularis
			85 Ulua mentalis
		46	86 Uraspis uraspis
	15 CENTRISCIDAE		
		47	87 Aeoliscus strigatus
	16 CENTROPOMIDAE		
		48	88 Lates calcarifer
		49	89 Psammoperca waigiensis
	17 CHAETODONTIDAE		
		50	90 Chaetodon argentatus*
			91 Chaetodon auriga*
			92 Chaetodon baronessa*
			93 Chaetodon citrinellus*
			94 Chaetodon kleinii*
			95 Chaetodon lineolatus*
			96 Chaetodon lunula*
			97 Chaetodon melannotus*
			98 Chaetodon octofasciatus*
			99 Chaetodon oxycephalus*
			100 Chaetodon plebeius*
			101 Chaetodon punctatofasciatus*
			102 Chaetodon reticulatus*
			103 Chaetodon trifascialis*
			104 Chaetodon trifasciatus*
			105 Chaetodon ulientensis*
			106 Chaetodon unimaculatus*
			107 Chaetodon vagabundus*
			108 Chaetodon xanthurus*

CLASS	FAMILY	GENUS	SCIENTIFIC NAME
		51	109 Chelmon rostratus*
		52	110 Coradion chrysozonus*
		53	111 Forcipiger longirostris*
		54	112 Heniochus acuminatus*
			113 Heniochus chrysostomus*
			114 Heniochus varius*
		55	115 Parachaetodon ocellatus*
	18 CHANIDAE		
		56	116 Chanos chanos
	19 CHIROCENTRIDAE		
		57	117 Chirocentrus dorab
	20 CIRRHITIDAE		
		58	118 Cirrhitichthys falco*
		59	119 Paracirrhites arcatus*
			120 Paracirrhites forsteri*
	21 CLUPEIDAE		
		60	121 Anodontostoma chacunda
		61	122 Dussumieria acuta
		62	123 Escualosa thoracata
		63	124 Herklotsichthys punctatus
		64	125 Hilsa kelee
		65	126 Nematalosa nasus
		66	127 Pellona dithchela
		67	128 Sardinella clupeoides
			129 Sardinella fimbriata
			130 Sardinella gibbosa
			131 Sardinella leiogaster
			132 Sardinella longiceps
			133 Sardinella melanura
			134 Sardinella perforata
			135 Sardinella sirm
		68	136 Spratelloides delicatulus
			137 Spratelloides gracilis
	22 CORYPHAENIDAE		
		69	138 Coryphaena hipporus
	23 CYNOGLOSIDAE		
		70	139 Cynoglossus puncticeps
	24 DIODONTIDAE		
		71	140 Diodon liturarus*
	25 DREPANIDAE		
		72	141 Drepane punctata
	26 ECHENEIDIDAE		
		73	142 Echeneis naucrates

CLASS	FAMILY	GENUS	SCIENTIFIC NAME
	27 ENGRAULIDAE		
		74	143 *Stolephorus commersonii*
			144 *Stolephorus heterolobus*
			145 *Stolephorus indicus*
			146 *Stolephorus zollingeri*
	28 EXOCOETIDAE		
		75	147 *Cheilopogon atrisignis*
			148 *Cypselurus oligolepis*
		76	149 *Cypselurus poecilopterus*
	29 FISTULARIDAE		
		77	150 *Fistularia commersonii*
			151 *Fistularia petimba*
	30 FORMIONIDAE		
		78	152 *Formio niger*
	31 GERRIDAE		
		79	153 *Gerres abreviatus*
			154 *Gerres filamentosus*
			155 *Gerres oyena*
		80	156 *Pentaprion longimanus*
	32 GOBIIDAE		
		81	157 *Amblyeleotris steinitzi**
		82	158 *Yongeichthys criniger**
	33 GRAMMISTIDAE		
		83	159 *Diploprion bifasciatus**
		84	160 *Grammistes sexlineatus**
	34 HAEMULIDAE		
		85	161 *Plectorhynchus chaetodontoides*
			162 *Plectorhynchus diagrammus**
			163 *Plectorhynchus goldmanni*
			164 *Plectorhynchus pictus*
			165 *Plectorhynchus polytaenia*
	35 HEMIRAMPHIDAE		
		86	166 *Hemirhamphus far*
			167 *Hemirhamphus georgii*
	36 HOLOCENTRIDAE		
		87	168 *Adioryx* spp.
		88	169 *Myripristis murdjan**
			170 *Myripristis* spp.
		89	171 *Neoniphon sammara**
		90	172 *Sargocentron caudimaculatum**
	37 ISTIOPHORIDAE		
		91	173 *Istiophorus orientalis*
		92	174 *Makaira mitsukurii*

CLASS	FAMILY	GENUS	SCIENTIFIC NAME
	38 LABRIDAE		
		93	175 *Anampses caeruleopunctatus**
			176 *Anampses meleagrides**
			177 *Anampses neoguinaicus**
			178 *Anampses twistii**
		94	179 *Bodianus axillaris**
			180 *Bodianus mesothorax**
		95	181 *Cheilinus bimaculatus**
			182 *Cheilinus chlorourus**
			183 *Cheilinus diagrammus**
			184 *Cheilinus fasciatus*
			185 *Cheilinus trilobatus*
			186 *Cheilinus undulatus*
			187 *Cheilinus unifasciatus**
		96	188 *Cheilio inermis*
		97	189 *Choerodon anchorago*
			190 *Choerodon schoenleinii*
		98	191 *Cirrhilabrus cyanopleura**
		99	192 *Coris gaimard**
			193 *Coris variegata**
		100	194 *Diproctacanthus xanthurus**
		101	195 *Epibulus insidiator**
		102	196 *Gomphosus varius**
		103	197 *Halichoeres biocellatus**
			198 *Halichoeres hortulanus*
			199 *Halichoeres margaritaceous**
			200 *Halichoeres marginatus**
			201 *Halichoeres melanochir**
			202 *Halichoeres melanurus**
			203 *Halichoeres nebulosa**
			204 *Halichoeres prosopeion**
			205 *Halichoeres scapularis**
		104	206 *Hemigymnus fasciatus**
			207 *Hemigymnus melapterus**
		105	208 *Hologymnosus doliatus**
		106	209 *Labrichthys unilineatus**
		107	210 *Labroides dimidiatus**
		108	211 *Labropsis manabei**
		109	212 *Macropharyngodon meleagris**
			213 *Macropharyngodon negrosensis**
		110	214 *Pseudocheilinus evanidus**
			215 *Pseudocheilinus hexataenia**
			216 *Pseudocheilinus octotaenia**
		111	217 *Stethojulis bandanensis**

CLASS
FAMILY
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SCIENTIFIC NAME

218 *Stethojulis strigiventer**
219 *Stethojulis trilineata**
112 220 *Thalassoma amblycephala*
221 *Thalassoma hardwicke**
222 *Thalassoma. janseni**
223 *Thalassoma lunare*
224 *Thalassoma lutescens**

39 LACTARIIDAE
113 225 *Lactarius lactarius*

40 LEIOGNATHIDAE
114 226 *Gazza minuta*
115 227 *Leiognathus bindus*
228 *Leiognathus brevirostris*
229 *Leiognathus daura*
230 *Leiognathus elongatus*
231 *Leiognathus equulus*
232 *Leiognathus fasciatus*
233 *Leiognathus leuciscus*
234 *Leiognathus rivulatus*
235 *Leiognathus smithursti*
236 *Leiognathus splendens*
116 237 *Secutor insidiator*
238 *Secutor ruconius*

41 LETHRINIDAE
117 239 *Lethrinus harak*
240 *Lethrinus lentjan*
241 *Lethrinus miniatus*
242 *Lethrinus nebulosus*
243 *Lethrinus ornatus*
244 *Lethrinus reticulatus*
245 *Lethrinus xanthochilus*

42 LUTJANIDAE
118 246 *Aphareus rutilans*
119 247 *Caesio caerulaureus*
248 *Caesio chrysozonus*
249 *Caesio cuning*
250 *Caesio erythrogaster*
251 *Caesio lunaris*
252 *Caesio trilineata**
120 253 *Lutjanus argentimaculatus*
254 *Lutjanus biguttatus*
255 *Lutjanus bohar*
256 *Lutjanus caeruleovittatus*
257 *Lutjanus carponotatus*

CLASS
FAMILY
GENUS
SCIENTIFIC NAME

258 *Lutjanus decussatus*
259 *Lutjanus erythropterus*
260 *Lutjanus fulviflamma*
261 *Lutjanus fulvus*
262 *Lutjanus gibbus*
263 *Lutjanus kasmira*
264 *Lutjanus lutjanus*
265 *Lutjanus malabaricus*
266 *Lutjanus rivulatus*
267 *Lutjanus russelli*
268 *Lutjanus sebae*
269 *Lutjanus spilurus*
270 *Lutjanus* spp.
121 271 *Macolor macularis**
272 *Macolor niger**
122 273 *Pterocaesio pisang*
274 *Pterocaesio tile*

43 MEGALOPIDAE
123 275 *Megalops cyprinoides*

44 MENIDAE
124 276 *Mene maculata*

45 MICRODESMIDAE
125 277 *Nemateleotris magnifica**
126 278 *Ptereleotris evides**

46 MONACANTHIDAE
127 279 *Amanses scopas**
128 280 *Oxymonacanthus longirostris**
129 281 *Paraluteres prionurus**
130 282 *Pervagor aspricuadus**

47 MUGILIDAE
131 283 *Mugil cephalus*
132 284 *Liza vaigiensis*

48 MULLIDAE
133 285 *Parupeneus barberinoides**
286 *Parupeneus barberinus*
287 *Parupeneus flavolineatus*
288 *Parupeneus indicus*
289 *Parupeneus janseni*
290 *Parupeneus luteus*
291 *Parupeneus macronemus*
292 *Parupeneus pleurospilos*
293 *Parupeneus trifasciatus**
134 294 *Upeneus moluccensis*
295 *Upeneus sulphureus*

CLASS	FAMILY	GENUS	SCIENTIFIC NAME
			296 *Upeneus taeniopterus*
			297 *Upeneus tragula*
			298 *Upeneus vittatus*
	49 MURAENESOCIDAE		
		135	299 *Muraenesox cinereus*
		136	300 *Synbranchus bengalensis**
	50 NEMIPTERIDAE		
		137	301 *Gymnocranius griseus*
		138	302 *Nemipterus marginatus*
			303 *Nemipterus metopias*
			304 *Nemipterus bathybius*
		139	305 *Pentapodus macrurus**
		140	306 *Scolopsis bilineatus*
			307 *Scolopsis cancellatus*
			308 *Scolopsis ciliatus*
			309 *Scolopsis ghanam*
			310 *Scolopsis lineatus**
			311 *Scolopsis temporalis**
	51 OSTRACIIDAE		
		141	312 *Ostracion cubicus**
			313 *Ostracion meleagris**
			314 *Ostracion nasus*
			315 *Ostracion solorensis**
	52 PLATACIDAE		
		142	316 *Platax orbicularis*
			317 *Platax pinnatus*
	53 PEMPHIRIDAE		
		143	318 *Pempheris oualensis**
	54 PINGUIPEDIDAE		
		144	319 *Parapercis clathrata**
			320 *Parapercis cylindrica**
	55 PLATYCEPHALIDAE		
		145	321 *Platycephalus indicus*
	56 PLOTOSIDAE		
		146	322 *Plotosus anguillaris*
			323 *Plotosus lineatus**
	57 POLYNEMIDAE		
		147	324 *Polynemus microstoma**
	58 POMACANTHIDAE		
		148	325 *Centropyge bicolor**
			326 *Centropyge bispinosus**
			327 *Centropyge colini**
			328 *Centropyge shepardi**
			329 *Centropyge tibicen**

CLASS	FAMILY	GENUS	SCIENTIFIC NAME
			330 *Centropyge vroliki**
		149	331 *Chaetodontoplus mesoleucus**
		150	332 *Pygoplites diacanthus**
	59 POMACENTRIDAE		
		151	333 *Abudefduf trifasciatus*
		152	334 *Amblyglyphidodon aureus**
			335 *Amblyglyphidodon curacao**
			336 *Amblyglyphidodon leucogaster**
		153	337 *Amphiprion clarkii**
			338 *Amphiprion frenatus**
			339 *Amphiprion melanopus**
			340 *Amphiprion ocellaris**
		154	341 *Chromis analis**
			342 *Chromis atripes**
			343 *Chromis caerulea**
			344 *Chromis margaritifera**
			345 *Chromis retrofasciata**
			346 *Chromis ternatensis**
			347 *Chromis vanderbilti**
			348 *Chromis viridis**
			349 *Chromis weberi**
			350 *Chromis xanthura**
		155	351 *Chrysiptera cyanea**
			352 *Chrysiptera oxycephala**
			353 *Chrysiptera reticulata**
			354 *Chrysiptera rex**
			355 *Chrysiptera rollandi**
			356 *Chrysiptera talboti**
		156	357 *Dascyllus reticulatus**
			358 *Dascyllus trimaculatus**
		157	359 *Neoglyphidodon melas**
			360 *Neoglyphidodon nigroris**
			361 *Neoglyphidodon* spp.*
		158	362 *Plectoglyphidodon dickii**
			363 *Plectoglyphidodon lacrymatus**
		159	364 *Pomacentrus alexanderae**
			365 *Pomacentrus amboinensis**
			366 *Pomacentrus bankanensis**
			367 *Pomacentrus brachialis**
			368 *Pomacentrus chrysurus**
			369 *Pomacentrus coelestis**
			370 *Pomacentrus emarginatus**
			371 *Pomacentrus lepidogenys**
			372 *Pomacentrus moluccensis**

CLASS
FAMILY
GENUS
SCIENTIFIC NAME

373 *Pomacentrus nagasakiensis**
374 *Pomacentrus philippinus**
375 *Pomacentrus siamsiang**
376 *Pomacentrus stigma**
377 *Pomacentrus taeniometopon**
378 *Pomacentrus vaiuli**
379 *Pomacentrus richardsoni**
380 *Pomacentrus* spp.*
160 381 *Stegastes nigricans**

60 POMADASYDAE
161 382 *Pomadasys hasta*
383 *Pomadasys maculatus*

61 PRIACANTHIDAE
162 384 *Priacanthus cruentatus*
385 *Priacanthus hamrur*
386 *Priacanthus macracanthus*
387 *Priacanthus tayenus*

62 PSETTODIDAE
163 388 *Psettodes erumei*

63 PSEUDOCHROMIDAE
164 389 *Ogilbyina queenslandiae**
165 390 *Pseudochromis porphyreus**
391 *Pseudochromis* spp.*

64 SCOMBRIDAE
166 392 *Auxis thazard*
167 393 *Euthynnus affinis*
168 394 *Katsuwonus pelamis*
169 395 *Rastrelliger brachysoma*
396 *Rastrelliger chrysozonus*
397 *Rastrelliger kanagurta*
170 398 *Scomberomorus commerson*
171 399 *Thunnus albacarres*

65 SCARIDAE
172 400 *Calotomus japonicus**
173 401 *Hipposcarus longiceps**
174 402 *Scarus bowersi**
403 *Scarus forsteni**
404 *Scarus frenatus**
405 *Scarus ghobban**
406 *Scarus globiceps**
407 *Scarus harid**
408 *Scarus nicrorhinus**
409 *Scarus niger**
410 *Scarus rivulatus**

CLASS
FAMILY
GENUS
SCIENTIFIC NAME

411 *Scarus schlegeli**
412 *Scarus sordidus**
413 *Scarus* spp.*

66 SCORPAENIDAE
175 414 *Dendrochirus zebra**
176 415 *Pterois antennata**
416 *Pterois volitans**

67 SERRANIDAE
177 417 *Anyperodon leucogrammicus**
178 418 *Cephalopholis argus*
419 *Cephalopholis aurantius*
420 *Cephalopholis boenak*
421 *Cephalopholis leopardus*
422 *Cephalopholis miniatus*
423 *Cephalopholis sexmaculatus*
424 *Cephalopholis urodelus*
425 *Cephalopholis urodeta**
179 426 *Cromileptes altivelis*
180 427 *Epinephelus australis*
428 *Epinephelus caeruleopunctatus*
429 *Epinephelus corallicola*
430 *Epinephelus fairo*
431 *Epinephelus fasciatus*
432 *Epinephelus fuscoguttatus*
433 *Epinephelus megachir*
434 *Epinephelus merra*
435 *Epinephelus microdon*
436 *Epinephelus sexfaciatus*
437 *Epinephelus summana*
438 *Epinephelus tauvina*
181 439 *Plectropomus maculatus*
440 *Plectropomus oligacanthus*
441 *Plectropomus truncatus*
182 442 *Variola louti*

68 SIGANIDAE
183 443 *Siganus argenteus*
444 *Siganus canaliculatus*
445 *Siganus corallinus**
446 *Siganus fuscescens**
447 *Siganus guttatus*
448 *Siganus javus*
449 *Siganus lineatus*
450 *Siganus spinus*
451 *Siganus vermiculatus*

CLASS	FAMILY	GENUS	SCIENTIFIC NAME
			452 *Siganus virgatus*
			453 *Siganus vulpinus**
	69 SILLAGINIDAE		
		184	454 *Sillago maculata*
			455 *Sillago sihama*
	70 SOLEIDAE		
		185	456 *Solea humilis*
		186	457 *Synaptura marginata*
	71 SPARIDAE		
		187	458 *Argyrops spinifer*
	72 SPHYRAENIDAE		
		188	459 *Sphyraena barracuda*
			460 *Sphyraena jello*
			461 *Sphyraena obtusata*
	73 SYNGNATHIDAE		
		189	462 *Doryrhamphus dactyliophorus**
		190	463 *Hemitaurichthys polylepis**
	74 SYNODONTIDAE		
		191	464 *Saurida gracilis**
			465 *Saurida micropectoralis*
			466 *Saurida tumbil*
		192	467 *Synodus binotatus**
			468 *Synodus variegatus**
	75 TETRAODONTIDAE		
		193	469 *Arothron nigropunctatus**
		194	470 *Cantherhines pardalis**
		195	471 *Canthigaster amboinensis*
			472 *Canthigaster benetti**
			473 *Canthigaster solandri**
			474 *Canthigaster valentini**

CLASS	FAMILY	GENUS	SCIENTIFIC NAME
	76 THERAPONIDAE		
		196	475 *Therapon jarbua*
			476 *Therapon quadrilineatus*
			477 *Therapon theraps*
		199	480 *Zanclus cornutus*
1 INVERTEBRATES			
			1 *Actinopyga echinetes*
			2 *Actinopyga miliaris*
			3 *Anadara maculata*
			4 *Anadara antiquata*
			5 *Bohadsohia marmorata*
			6 *Loligo* spp.
			7 *Metapenaeus* spp.
			8 *Octopus* spp.
			9 *Paphia amabilis*
			10 *Penaeus monodon*
			11 *Penaeus* spp.
			12 *Polymesoda coaxans*
			13 *Portunus pelagicus*
			14 *Scylla serrata*
			15 *Seppia* spp.
			16 *Sepioteuthis lessoniana*
			17 *Thalamita* spp.
			18 *Thelenata ananas*
			19 *Tridacna squamosa*
			20 *Tripnuestes gratilla*
			21 *Vasum turbinelllus*

Appendix 2. Checklist of fishes and invertebrates caught by the various fishing gears used in Lagonoy Gulf from January to December 1994.

FAMILY / SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES: ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAG.IS.	BATAN/RAPU-RAPU
1 ACANTHURIDAE						
1 *Acanthurus dussumiere*	Dussumiere's surgeon fish					Salingkupaw
2 *Naso annulatus*						
2 APOGONIDAE						
3 *Apogon lineatus*						
4 *Apogonichthys poecilopterus*	Cardinal fish	Parangan	Parangan	Parangan	Parangan	Parangan
5 *Apogonichthys quadrifasciatus*	Rifle Cardinal fish	Parangan	Parangan	Parangan	Parangan	Parangan
3 ATHERINIDAE						
6 *Hypoatherina woodwardi*	Narrow-striped silverside	Guno	Guno	Guno	Guno	Guno
4 BALISTIDAE						
7 *Monacanthus scopas*	Broom filefish			Sulay bagyo		Sulay bagyo
5 BELONIDAE						
8 *Tylosurus crocodilus*	Common gar	Dual	Duwal	Dual	Dual	Dual
9 *Tylosurus strongylurus*						
6 CARANGIDAE						
10 *Alectis ciliaris*	Pennant fish	Mamsa	Lawihan	Malagimango		
11 *Alectis indicus*	Asiatic threadfish	Bangkungan	Bangkungan	Bangkungan	Bangkungan	
12 *Alepes djeddaba*	Even-bellied crevalle	Liaw-liaw	Salaysalay	Salaysalay	Salaysalay	Salaysalay
13 *Alepes kalla*	Deep-bellied crevalle				Salaysalay	Salaysalay
14 *Atule mate*	Yellow-tailed scad	Salay-salay	Salay-salay	Salay-salay	Salay-salay	Salay-salay
15 *Carangoides ferdau*						
16 *Carangoides fulvogutatus*	Gold-spotted trevally	Kalpi	Kalpi-on	Kalpi-on	Tagiptipon	Tagiptipon
17 *Carangoides malabaricus*	Malabar cavalla		Talakitok	Barurog		
18 *Carangoides oblongus*						
19 *Carangoides* spp.						
20 *Caranx armatus*	Long-finned cavalla	Talakitok	Talakitok	Talakitok	Talakitok	Talakitok
21 *Caranx ignobilis*	Lowly trevally					
22 *Caranx melampygus*	Blue-finned trevally	Mamsa	Tagiptipon	Taruk-ogan		Tarakugan
23 *Caranx sexfaciatus*	Great trevally	Tagiptipon	Tagiptipon	Tagiptipon	Tagiptipon	Tagiptipon
24 *Caranx stellatus*	Spotted cavalla					
25 *Caranx tile*						
26 *Decapterus kurroides*	Round scad	Sibubog	Sibubog	Sibubog	Sibubog	Sibubog
27 Decaptrerus *macrosoma*	Blue mackerel scad	Sibubog	Sibubog	Sibubog	Sibubog	Sibubog
28 *Decapterus maruadsi*	Round scad	Sibubog	Sibubog	Sibubog	Sibubog	Sibubog
29 *Elagatis bipinnulatus*	Rainbow runner					

FAMIL / SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES: ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAO.IS.	BATAN/RAPU-RAPU
30 *Gnathanodon speciosus*	Toothless cavalla		Kalpi-on	Talakitok	Talakitok	
31 *Megalaspis cordyla*	Hard tail/finny scad	Pak-an	Pak-an	Pak-an	Pak-an	Pak-an
32 *Scomberoides lysan*	Whitefish/skinnyfish	Lapis	Lapis	Lapis	Lapis	Lapis
33 *Scomberoides tol*	Slender leatherskin	Lapis	Lapis	Lapis	Lapis	Lapis
34 *Selar boops*	Ox-eyed scad	Atuloy	Atuloy	Atuloy	Atuloy	Atuloy
35 *Selar crumenophthalmus*	Big-eyed scad	Matang baka	Matang baka	Matang baka	Matang baka	Matang baka
36 *Selaroides leptolepis*	Yellow-striped crevalle					
37 *Seriolina nigrofasciata*	Black-banded trevally	Bagaong sa Lawod	Bagaong sa Lawod	Bagaong sa Lawod	Bagaong sa Lawod	Bagaong sa Lawod
38 *Trachinotus baillonii*	Small-mouthed pampano	Pampano				
39 *Trachinotus blochii*	Snub-nosed pampano	Pampano	Pampano	Pampano	Pampano	Pampano
40 *Ulua mandibularis*	Cala-cale trevally		Pampano			
41 *Ulua mentalis*	Cala-cale trevally		Mamsa			
42 *Uraspis uraspis*	Five-banded brown jack	Tagiptipon	Molgan			
7 CARCHARHINIDAE						
43 *Apristurus herklotsi*						
44 *Atelomycterus marmoratus*						
45 *Carcharhinus melanopterus*						
8 CENTRISCIDAE						
46 *Aeoliscus strigatus*	Shrimpfish					
9 CENTROPOMIDAE						
47 *Lates calcarifer*	Silver sea bass	Bolgan	Sapan	Bolgan	Bolgan	Bolgan
48 *Psammoperca waigiensis*						
10 CHANIDAE						
49 *Chanos chanos*	Milkfish	Bangus/awa	Bangus/awa	Banglus	Bangus/awa	Bangus/awa
11 CHIROCENTRIDAE						
50 *Chirocentrus dorab*	Dorab wolf-herring	Barera	Barera	Barera	Barera	Barera
12 CLUPEIDAE						
51 *Anodontostoma chacunda*	Chacunda gizzard-shad		Kabasi			
52 *Dussumieria acuta*	Rainbbow sardine		Alabaybay			
53 *Escualosa thoracata*			Bolinaw			
54 *Herklotsichthys punctatus*	Spotted herring					
55 *Hilsa kelee*	Kelee shad					
56 *Nematalosa nasus*	Long-finned gizzard shad	Suogan				
57 *Pellona dithchela*	Indian pellona					
58 *Sardinella clupeoides*	Sharp-nosed pilchard	Turay	Turay	Turay	Turay	Turay

FAMILY / SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAG.IS.	BATAN/RAPU-RAPU
59 *Sardinella fimbriata*		Tamban	Tamban	Tamban	Tamban	Tamban
60 *Sardinella gibbosa*	Gold-striped sardinella		Tamban			
61 *Sardinella leiogaster*	Smoothbelly sardinella		Lupnos			
62 *Sardinella longiceps*	Indian-oil sardinella		Tamban			
63 *Sardinella melanura*	Black-tipped sardinella		Tamban			
64 *Sardinella perforata*	Deep-bodied herring					
65 *Sardinella sirm*	Spotted sardinella					
66 *Spratelloides delicatulus*	Blue-backed sprat					
67 *Spratelloides gracilis*						
13 CORYPHAENIDAE						
68 *Coryphaena hipporus*	Common dolphin fish	Lamadang/dorado	Dorado/lapanak	Lamadang	Lamadang	Lamadang
14 CYNOGLOSIDAE						
69 *Cynoglossus puncticeps*	Speckled tongue sole	Palad	Palad	Palad	Palad	Palad
15 DASYATIDAE						
70 *Dasyatis kuhli*	Blue-spotted stingray	Pagi	Pagi	Pagi	Pagi	Pagi
71 *Dasyatis sephen*	Fan-tailed ray					
72 *Himantura uarnak*	Long-tailed ray	Pagi	Pagi	Pagi	Pagi	Pagi
73 *Taeniura lymma*						
16 DREPANIDAE						
74 *Drepane punctata*	Spotted sickle fish	Bayang	Bayang	Bayang	Bayang	Bayang
17 ECHENEIDIDAE						
75 *Echeneis naucrates*	Indian remora	Kini	Kini	Kini	Kini	Kini
18 ENGRAULIDAE						
76 *Stolephorus commersonii*	Commerson's anchovy	Bolinao	Bolinao	Bolinao	Bolinao	Bolinao
77 *Stolephorus heterolobus*	Short-headed anchovy	Bolinao	Bolinao	Bolinao	Bolinao	Bolinao
78 *Stolephorus indicus*	Indian anchovy	Lipatang	Alipatang	Lipatang	Lipatang	Lipatang
79 *Stolephorus zollingeri*	Long-jawed anchovy	Bolinao	Bolinao	Bolinao	Bolinao	Bolinao
19 EXOCOETIDAE						
80 *Cypselurus oligolepis*						
81 *Cypselurus poecilopterus*	Spotted flying fish	Iliw	Iliw	Iliw	Iliw	Iliw
82 *Cheilopogon atrisignis*	Greater spotted flyingfish	Iliw	Iliw	Iliw	Iliw	Iliw
20 FISTULARIDAE						
83 *Fistularia commersonii*	Cornetfish	Sikwan	Torotot	Torotot	Torotot	Sikwan
84 *Fistularia petimba*	Red cornetfish	Sikwan	Torotot	Torotot	Torotot	Sikwan

FAMILY / SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES: ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAG.IS.	BATAN/RAPU-RAPU
21 FORMIONIDAE						
85 *Formio niger*	Black pomfret	Pampano	Pampano	Pampano	Pampano	Pampano
22 GERRIDAE						
86 *Gerres abreviatus*						
87 *Gerres filamentosus*	Whipfin mojarra	Sakalan	Kapas	Latab	Sakalan	Sakalan
88 *Gerres oyena*						
89 *Pentaprion longimanus*	Taiwan silverbiddy	Surosalming	Burlis	Surosalming	Surosalming	Surosalming
23 HAEMULIDAE						
90 *Plectorhynchus chaetodontoides*	Harlequin sweetlip					
91 *Plectorhynchus goldmanni*	Diagonal-banded sweetlip	Alatan	Alatan	Alatan	Alatan	
92 *Plectoryhnchus pictus*	Painted sweetlip	Alatan	Alatan	Alatan	Alatan	
93 *Plectoryhnchus polytaenia*	Ribboned sweetlip	Olibalay	Olibalay	Gurayan	Olibalay	Olibalay
24 HEMIRAMPHIDAE						
94 *Hemirhamphus far*	Black-barred garfish	Bugiw	Bugiw	Bugiw	Bugiw	Bugiw
95 *Hemirhamphus georgii*	Non-spotted halfbeak	Bugiw	Bugiw	Bugiw	Bugiw	Bugiw
25 HOLOCENTRIDAE						
96 *Adioryx* spp.		Suga	Suga	Suga	Suga	Suga
97 *Myripristis* spp.		Suga	Suga	Suga	Suga	Suga
26 ISTIOPHORIDAE						
98 *Istiophorus orientalis*	Sailfish/Marlin	Malasugi	Malasugi	Malasugi	Malasugi	Malasugi
99 *Makaira mitsukurii*	Spearfish	Malasugi	Malasugi	Malasugi	Malasugi	Malasugi
27 LABRIDAE						
100 *Cheilinus fasciatus*	Scarlet-breasted wrasse	Angol	Angol	Angol	Angol	Angol
101 *Cheilinus trilobatus*	Triple-tailed Maori wrasse	Hipus	Hipus	Hipus	Hipus	Hipus
102 *Cheilinus undulatus*	Napoleon humphead					
103 *Cheilio inermis*	Cigar wrasee	Talad	Lambungayaw	Talad	Talad	Talad
104 *Choerodon anchorago*						
105 *Choerodon schoenleinii*	Black-spotted tuskfish	Maming	Maming			
106 *Halichoeres hortulanus*	Checkerboard wrasse	Maringyan	Maringyan	Maringyan	Maringyan	Maringyan
107 *Thalassoma amblycephala*						
108 *Thalassoma lunare*	Moon wrasse	Labayan	Angol	Angol	Angol	Angol
28 LACTARIIDAE						
109 *Lactarius lactarius*	False trevally					
29 LEIOGNATHIDAE						
110 *Gazza minuta*	Toothed ponyfish	Sapsap	Sapsap	Tambong	Sapsap	Sapsap

FAMILY / SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES: ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAG.IS.	BATAN/RAPU-RAPU
111 *Leiognathus bindus*	Orange-finned ponyfish					
112 *Leiognathus brevirostris*						
113 *Leiognathus daura*	Gold-striped ponyfish	Barurog	Barurog	Barurog	Barurog	
114 *Leiognathus elongatus*	Slender ponyfish	Sapsap	Sapsap	Sapsap	Sapsap	Sapsap
115 *Leiognathus equulus*	Common slipmouth	Dalupani	Dalupani	Lupani	Dalupani	Dalupani
116 *Leiognathus fasciatus*	Banded ponyfish					
117 *Leiognathus leuciscus*	Whipfin ponyfish					
118 *Leignathus rivulatus*	Off-shore ponyfish					
119 *Leiognathus smithursti*						
120 *Leiognathus splendens*	Splendid ponyfish					
121 *Secutor insidiator*	Slender-barred ponyfish	Sakmo	Sakmo	Sakmo	Sakmo	Sakmo
122 *Secutor ruconius*	Deep pugnose ponyfish					
30 LETHRINIDAE						
123 *Lethrinus harak*	Black-spotted emperor	Saligan	Saligan	Saligan	Saligan	Saligan
124 *Lethrinus lentjan*	Red-spotted emperor	Bokawon	Bokawon	Bokawon	Bukhawon	Bukawon
125 *Lethrinus miniatus*	Long-nosed emperor	Dugso	Dugso	Dugso	Dugso	Dugso
126 *Lethrinus nebulosus*						
127 *Lethrinus ornatus*	Yellow-striped emperor	Manlagaas	Manlagaas	Manlagaas	Manlagaas	Manlagaas
128 *Lethrinus reticulatus*						
129 *Lethrinus xanthochilus*	Yellow-lipped emperor		Kamasuhon	Camasuhon		
31 LUTJANIDAE						
130 *Aphareus rutilans*	Flame snapper	Sapi		Sapi		
131 *Caesio caerulaureus*						
132 *Caesio chrysozonus*	Golden-banded fusilier	Aspe	Solid	Solid	Solid	Solid
133 *Caesio cuning*	Red-bellied fusilier	Solid	Solid	Solid	Solid	Solid
134 *Caesio erythrogaster*	Yellow- tailed fusilier	Dalagang bukid	Solid	Anduhaw	Solid	Anduhaw
135 *Caesio lunaris*	Rising moon fusilier	Solid	Solid	Solid	Solid	Solid
136 *Lutjanus argentimaculatus*	Silver snapper					
137 *Lutjanus biguttatus*						
138 *Lutjanus bohar*						
139 *Lutjanus caeruleovittatus*	Nine-striped snapper		Agbaon			
140 *Lutjanus carponotatus*						
141 *Lutjanus decussatus*	Checkered snapper					
142 *Lutjanus erythropterus*						
143 *Lutjanus fulviflamma*	Black-spotted snapper	Madarag	Ayungan	Taldukan	Arungan	Arungan

FAMILY / SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES: ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAG IS.	BATAN/RAPU-RAPU
144 *Lutjanus fulvus*	Flame-colored snapper	Maya-maya	Maya-maya	Maya-maya	Maya-maya	Maya-maya
145 *Lutjanus gibbus*	Humpback snapper	Maya-maya	Maya-maya	Maya-maya	Maya-maya	Maya-maya
146 *Lutjanus kasmira*	Blue-lined snapper					
147 *Lutjanus lutjanus*						
148 *Lutjanus malabaricus*	Malabar red snapper	Maya-maya	Maya-maya	Maya-maya	Maya-maya	Maya-maya
149 *Lutjanus rivulatus*						
150 *Lutjanus russelli*						
151 *Lutjanus sebae*	Emperor snapper					
152 *Lutjanus spilurus*	Blue-striped snapper					
153 *Lutjanus* spp.						
154 *Pterocaesio pisang*	Slender fusilier	Tonong	Tonong	Tonong	Tonong	Tonong
155 *Pterocaesio tile*	Bar-tailed fusilier		Dalagang-bukid	Roskita		Solid
32 MEGALOPIDAE						
156 *Megalops cyprinoides*	Indo-Pacific Tarpon	Bulan-Bulan	Bulan-Bulan	Bulan-Bulan	Bulan-Bulan	Bulan-Bulan
33 MENIDAE						
157 *Mene maculata*	Spotted moonfish	Kutao				Kutao
34 MOBULIDAE						
158 *Mobula japonica*	Devil ray	Pasa-pasa	Pasa-pasa	Pasa-pasa	Pasa-pasa	Pasa-pasa
35 MUGILIDAE						
159 *Mugil cephalus*						
160 *Liza vaigiensis*	Diamond-scaled mullet	Balanak	Balanak	Balanak	Balanak	Balanak
36 MULLIDAE						
161 *Parupeneus barberinus*	Dash and dot goatfish	Agingoy	Manitis	Gurayan	Arikiik	Agingoy
162 *Parupeneus flavolineatus*	Yellow-striped goat fish	Arikiik	Tiaw	Tiaw	Arikiik	Tiaw
163 *Parupeneus indicus*	Yellow-spotted goatfish	Timbungan	Timbungan	Timbungan	Timbungan	Timbungan
164 *Parupeneus janseni*	Rosy goatfish	Agingoy	Agingayon	Agingoy	Agingoy	Agingoy
165 *Parupeneus luteus*	Golden-spotted goatfish	Timbungan	Timbungan	Timbungan	Timbungan	Timbungan
166 *Parupeneus macronemus*	Long-barbelled goatfish	Timbungan	Timbungan	Timbungan	Timbungan	Timbungan
167 *Parupeneus pleurospilos*						
168 *Upeneus moluccensis*	Gold-banded goatfish	Tiaw	Tiaw	Tiaw	Arikiik	Tiaw
169 *Upeneus sulphureus*	Yellow goatfish	Tiaw	Tiaw	Tiaw	Tiaw	Tiaw
170 *Upeneus taeniopterus*		Tiaw	Tiaw	Tiaw	Tiaw	Tiaw
171 *Upeneus tragula*	Bar-tailed goatfish	Tiaw	Gurayan	Tiaw	Tiaw	
172 *Upeneus vittatus*	Yellow-banded goatfish	Tiaw	Tiaw	Tiaw	Arikiik	

FAMILY / SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES: ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAG.IS.	BATAN/RAPU-RAPU
37 MURAENESOCIDAE						
173 *Muraenesox cinereus*	Sharp-toothed eel	Obod	Obod	Obod	Obod	Obod
38 NEMIPTERIDAE						
174 *Gymnocranius griseus*	Naked-headed large-eyed bream	Bulao	Bulao	Bulao	Bulao	Bulao
175 *Nemipterus bathybius*	Bottom threadfin bream	Tagisi	Tagisi	Tagisi	Tagisi	Tagisi
176 *Nemipterus marginatus*	Pale-finned threadfin bream	Kanasi	Kanasi	Kanasi	Kanasi	Kanasi
177 *Nemipterus metoplas*	Slender threadfin bream	Kanasi	Kanasi	Kanasi	Kanasi	Kanasi
178 *Scolopsis bilineatus*	Two-lined monocle bream	Tonong	Tonong	Tonong	Tonong	Tonong
179 *Scolopsis cancellatus*	Latticed monocle bream	Tonong	Tonong	Tonong	Tonong	Tonong
180 *Scolopsis ciliatus*	Saw-jawed monocle breram	Tunong	Punong	Punong	Punong	Punong
181 *Scolopsis ghanam*	Peppered monocle bream	Tonong	Tonong	Tonong	Tonong	Tonong
ORECTOOBIDAE						
182 *Chiloscyllium griseum*						
39 OSTRACIIDAE						
183 *Ostracion nasus*	Small-nosed boxfish		Baka-baka			
40 PLATACIDAE						
184 *Platax orbicularis*	Long-finned batfish	Bayang	Bayang	Bayang	Bayang	Bayang
185 *Platax pinnatus*	Orange-ringed batfish	Bayang	Bayang	Bayang	Bayang	Bayang
41 PLATYCEPHALIDAE						
186 *Platycephalus indicus*	Bar-tailed flathead	Itang	Itang	Itang	Itang	Itang
42 PLOTOSIDAE						
187 *Plotosus anguillaris*	Striped catfish	Iito	Iito	Iito	Iito	Iito
43 POMACENTRIDAE						
188 *Abudefduf trifasciatus*						
44 POMADASYDAE						
189 *Pomadasys hasta*	Common javelinfish	Agoot	Agoot	Agoot	Agoot	Agoot
190 *Pomadasys maculatus*	Blotched grunt	Agoot	Agoot	Agoot	Agoot	Agoot
45 PRIACANTHIDAE						
191 *Priacanthus cruentatus*	Glass big-eye	Kuwaw	Kuwaw	Kuwaw	Kuwaw	Kuwaw
192 *Priacanthus hamrur*						
193 *Priacanthus macracanthus*	Red big-eye	Kuwaw	Kuwaw	Kuwaw	Kuwaw	Kuwaw
194 *Priacanthus tayenus*	Purple-spotted big-eye	Kuwaw	Kuwaw	Kuwaw	Kuwaw	Kuwaw
46 PSETTODIDAE						
195 *Psettodes erumei*	Indian halibut	Palad	Palad	Palad	Palad	Palad

FAMILY / SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES: ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAG.IS.	BATAN/RAPU-RAPU
47 RHINCODONTIDAE						
196 *Rhincodon typus*						
48 SCOMBRIDAE						
197 *Auxis thazard*	Frigate mackerel	Turingan				
198 *Euthynnus affinis*	Eastern little tuna		Burawon	Burawon		
199 *Katsuwonus pelamis*	Skipjack tuna	Pundahan	Pundahan	Pundahan	Pundahan	Rayado
200 *Rastrelliger brachysoma*	Short-bodied mackerel	Burao	Burao	Burao	Burao	Burao
201 *Rastrelliger chrysozonus*	Striped mackerel	Burao	Burao	Burao	Burao	Burao
202 *Rastrelliger kanagurta*	Long jaw mackerel	Burao	Burao	Burao	Burao	Burao
203 *Scomberomorus commerson*	Spanish mackerel	Tangigi	Tangigi	Tangigi	Tangigi	Tangigi
204 *Thunnus albacares*	Yellowfin tuna	Bangkulis	Bangkulis	Bangkulis	Bangkulis	Bangkulis
49 SERRANIDAE						
205 *Cephalopholis argus*	Peacock rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
206 *Cephalopolis aurantius*	Orange rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
207 *Cephalopolis boenak*	Blue-lined coral cod	Baraka	Baraka	Baraka	Baraka	Baraka
208 *Cephalopolis leopardus*						
209 *Cephalopolis miniatus*	Coral rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
210 *Cephalopolis sexmaculatus*	Sixgirdle grouper	Baraka	Baraka	Baraka	Baraka	Baraka
211 *Cephalopolis urodelus*						
212 *Cromileptes altivelus*	Humpback sea bass	Bulgan	Bulgan	Bulgan	Bulgan	Bulgan
213 *Epinephelus australis*	White-spot rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
214 *Ephinephelus caeruleopunctatus*	Ocellated rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
215 *Ephinephelus corallicola*	Coral rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
216 *Ephinephelus fairo*	Trout cod	Baraka	Baraka	Baraka	Baraka	Baraka
217 *Ephinephelus fasciatus*	Black-tipped rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
218 *Ephinephelus fuscoguttatus*	Flower cod	Baraka	Baraka	Baraka	Baraka	Baraka
219 *Epheniphelus megachir*	Long-finned rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
220 *Ephinephelus merra*	Honeycomb rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
221 *Ephinephelus microdon*						
222 *Epheniphellus sexfaciatus*	Six-banded rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
223 *Ephinephelus summana*	Speckled-finned rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
224 *Ephinephelus tauvina*	Estuary rock cod	Baraka	Baraka	Baraka	Baraka	Baraka
225 *Plectropomus maculatus*	Leopard cod	Baraka	Baraka	Baraka	Baraka	Baraka
226 *Plectropomus oligacanthus*	Vermicular leopard cod	Baraka	Baraka	Baraka	Baraka	Baraka
227 *Plectropomus truncatus*	Square-tailed grouper	Baraka	Baraka	Baraka	Baraka	Baraka

FAMILY/ SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES: ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAG IS.	BATAN/RAPU-RAPU
228 *Variola louti*						
50 SIGANIDAE						
229 *Siganus argenteus*	Silver spinefoot	Bataway	Cataway	Bataway	Bataway	Kitong
230 *Siganus canaliculatus*	White-spotted spine foot	Bataway	Bataway	Bataway	Bataway	Bataway
231 *Siganus guttatus*	Golden spinefoot	Mublad	Sandig	Sandig	Mublad	Mublad
232 *Siganus javus*	Streaky spinefoot	Mublad	Mublad	Mublad	Mublad	Mublad
233 *Siganus lineatus*	Goldline spinefoot	Bataway	Cataway	Bataway	Bataway	Kitong
234 *Siganus spinus*	Marbled spinefoot	Bataway	Kataway	Kataway	Bataway	Kitong
235 *Siganus vermiculatus*	Reticulated rabitfish	Mublad	Mublad	Mublad	Mublad	Mublad
236 *Siganus virgatus*	Bar-headed rabbitfish	Mublad	Mublad	Mublad	Mublad	Mublad
51 SILLAGINIDAE						
237 *Sillago maculata*	Banded whiting	Osu-us	Osu-us	Osu-us	Osu-us	Osu-us
238 *Sillago sihama*	Northern whiting	Osu-us	Osu-us	Osu-us	Osu-us	Osu-us
52 SOLEIDAE						
239 *Solea humilis*	Ovate sole	Palad	Palad	Palad	Palad	Palad
240 *Synaptura marginata*						
53 SPARIDAE						
241 *Argyrops spinifer*	Long-spined bream	Murinay	Murinay	Murinay	Murinay	Murinay
54 SPHYRAENIDAE						
242 *Sphyraena barracuda*	Great bar	Manabang	Manabang	Manabang	Manabang	Manabang
243 *Sphyraena jello*	Sea pike baracuda	Manabang	Manabang	Manabang	Manabang	Manabang
244 *Sphyraena obtusata*	Torcillo	Puti/titso	Titso		Titso	
55 SQUALIDAE						
245 *Squalus acanthias*						
56 SYNODONTIDAE						
246 *Saurida micropectoralis*	Short-finned lizardfish	Tiki	Tiki	Butong-panday	Tiki	Tiki
247 *Saurida tumbil*	Common sauri	Tiki	Tiki	Butong-panday	Tiki	Tiki
57 TETRAODONTIDAE						
248 *Canthigaster amboinensis*						
58 THERAPONIDAE						
249 *Therapon jarbua*	Striped therapon	Bagaong	Bagaong	Bagaong	Bagaong	Bagaong
250 *Therapon quadrilineatus*	Four-lined croaker	Bagaong	Bagaong	Kanigit	Bagaong	Bagaong
251 *Therapon theraps*	Large-scaled theraponid	Bagaong	Bagaong	Bagaong	Bagaong	Bagaong
59 TRICHIURIDAE						
252 *Trichiurus haumela*	Hairtail	Langkoy	Espada	Espada	Langkoy	Langkoy

FAMILY / SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAMES: ALBAY	CATANDUANES	CAMARINES SUR	SN MIGUEL/CAG.IS.	BATAN/RAPU-RAPU
60 XIPHIIDAE						
253 *Xiphias gladius*	Swordfish	Bigo	Bigok	Big-ho	Bigok	Bigok
61 ZANCLIDAE						
254 *Zanclus cornutus*	Moorish idol	Kalibangbang	Kalibangbang	Kalibangbang	Kalibangbang	Kalibangbang
INVERTEBRATES						
1 *Actinopyga echinetes*	Sea cucumber	Balat				
2 *Actinopyga miliaris*	Sea cucumber	Balat				
3 *Anadara antiquata*	Cockle	Cod-cod	Cod-cod	Cod-cod	Cod-cod	Cod-cod
4 *Anadara maculata*	Cockle	Cod-cod	Cod-cod	Cod-cod	Cod-cod	Cod-cod
5 *Bohadsodia marmorata*						
6 *Loligo* spp.	Squid	Pusit	Pusit	Pusit	Pusit	Pusit
7 *Metapenaeus* spp.	Shrimp	Buyod	Hipon	Buyod		
8 *Octopus* spp.	Octopus	Cogita	Cogita	Cogita	Cogita	Cogita
9 *Paphia amabilis*						
10 *Penaeus monodon*	Tiger prawn	Sugpo/buyod	Sugpo	Sugpo/osbon		
11 *Penaeus* spp.	Shrimp	Buyod	Hipon	Buyod	Buyod	Buyod
12 *Polymesoda coaxan*	Mud clam	Tuwoy	Tuwoy	Tuwoy	Tuwoy	Tuwoy
13 *Portunus pelagicus*	Blue crab	Kasag	Kasag	Kasag	Kasag	Kasag
14 *Scylla serrata*	Mud crab	Ha-nit	Alimango	Ha-nit	Ha-nit	Ha-nit
15 *Sepioteuthis lessoniana*	Broad-finned squid	Canuus	Canuus	Canuus	Canuus	Canuus
16 *Seppia* spp.	Cuttlefish	Canuus	Canuus	Canuus	Canuus	Canuus
17 *Thalamita* spp.	Swimming crab	Bungkang	Bungkang	Bungkang	Bungkang	
18 *Thelenata ananas*						
19 *Tridacna squamosa*	Scaly tridacna	Manglot	Manglot	Manglot	Manglot	Manglot
20 *Tripnuestes gratilla*	Sea urchin	Ogob-ogob				
21 *Vasum turbinellus*	Vase shell	Alan-alan	Alan-alan	Alan-alan	Alan-alan	Alan-alan

3

Catch and Effort in the Lagonoy Gulf Fisheries

by

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Soliman, V.S., P. Nieves, L.R. Garces and Q.P. Sia III. 1995. Catch and effort in the Lagonoy Gulf fisheries, p. 000-000. *In* G. Silvestre, C. Luna, V. Soliman and L. Garces (eds.) Resource and ecological assessment of Lagonoy Gulf, Philippines. ICLARM Tech. Rep. 000, 000 p.

Abstract

The multigear fisheries in Lagonoy Gulf exploits a highly diverse, multispecies complex. A total of 454 fish species belonging to 194 genera and 78 families were observed. The gulf's projected annual fish production, based on the January to December 1994 data collection, was 27,970.70 tons. Nearly 7,500 fishers residing in the 164 coastal barangays of the 15 municipalities bordering the gulf contributed to this production. These fishers employ around 30 gear types, of which handlines had the major contribution (i.e., 60.08% of the annual production). This was followed by gillnets (14.9%), seines (10.49%), hand instruments (7.54%), lift nets (2.91%) barriers and traps (2.84%), longlines (1.21%), and beach seine with scareline (0.02%).

Scombrids and carangids constitute, in terms of aggregate weight, around 67% of the landed catch in the gulf. In generally, the fisheries of Lagonoy Gulf subsists on both big and small pelagics that are caught by relatively cheap, small, simple and artisanal fishing gear.

This comprehensive assessment was the first ever conducted in Lagonoy Gulf. Comparisons with previous assessments yielded inconclusive due to dissimilarities in the methodologies used, and aerial extent of the study area. In the light of such trend, it is reasonable to state that the extent and quality of available catch and effort data are insufficient to infer the status of Lagonoy Gulf fisheries.

Introduction

Lagonoy Gulf is a large semi-enclosed and ellipse-shaped body of water that is located between 123°31'37"E to 124°20'36"E and 13°44'30"N to 13°10'33"N. It is bounded on the north by Caramoan Peninsula in Camarines Sur, northeast by Nagumbuaya Point in Catanduanes, and on the south by Batan and Rapu-rapu Islands, north of Albay Gulf (Fig.1). More than half of the gulf's entire water area of 3,071 km^2 is 800-14,000 m deep. Enclosed within its 221.08 km coastline are 9 bays (ie., Tabaco, Gaba, Kalanaga and Pili of Albay; Atulayan, Guijalo, Cabugo, Palag of Camarines Sur; and Cabugao of Catanduanes). These bays serve as key areas for fishing in the gulf.

The fisheries of the gulf encompass the exploitation of 475 fish and invertebrate species by nearly 7,500 fishers using around 30 kinds of mostly artisanal gear. The need for an assessment of data from such fisheries and their subsequent utility should be evident for 2 basic reasons: (1) such do not exist for Lagonoy Gulf, and this study is the first although there were a few studies off Albay coast, which is only part of the gulf; and (2) fishery exploitation trends in its bordering municipalities suggest the need for sound management basis. Relevant to first reason, it should be mentioned that this first assessment is also to be understood as a simple assessment (i.e., only catch and effort data were mainly analyzed) compared to the more comprehensive analyses on growth, mortality and recruitment patterns (see Beverton and Holt, 1957; Gulland, 1969, 1983; FAO, 1980; Pauly, 1984).

This paper presents the production of the gulf's fishery resources based on the catch and effort data that were collected by the Capture Fisheries Assessment Component of the Resource and Ecological Assessment of Lagonoy Gulf Project implemented by the International Center for Living Aquatic Resources Management (ICLARM) and the Bicol University College of Fisheries (BUCF) with funding from the Fisheries Sector Program of the Department of Agriculture (DA-FSP).

Materials and Methods

Seventeen selected fish landing sites were surveyed from January to December 1994 for landings and catches of municipal and commercial fishing gear. These sites allow for an even and appropriate coverage of fishing operations in Lagonoy Gulf since they are major fish landing areas (Fig. 1).

Fish landing surveys were conducted by recording the gear type, total weight of catch, catch composition, weight per species, fishing area, fishing time, gear specifications and boat type of landed catch. The surveys were conducted in the 17 sites, 3 days a week per site whenever possible. All data were obtained by direct catch measurement and by interviewing fishers at the sites during fish landing activities. Each landed catch datum may represent catch from one gear or from an aggregate of several gear types.

Data sets similar to that of fish landing surveys were obtained during catch surveys, only that the latter involved data collection on-board fishing vessels or on shore immediately after a fisher's trip. Members of the research team directly obtained data from the fishers before the latter's catch was sold or even sorted. Such survey activities provided better assessment of catch from a fishery, although the data were relatively more tedious to collect than those in fish landing surveys. Catch surveys were conducted monthly for 16 gear types in selected sampling areas. The gear monitored for catch survey were chosen on the basis of: frequency of use by fishers, catch rate relative to total fish production, and potential impact on resources and habitats. Additional biological data (e.g., morphometric measurements, weight, and sexual maturity) were also obtained during catch surveys.

The data gathered during the fish landing and catch surveys were entered into LAGONOYBase (Alojado and Garcia, in Vol. 3). Catch rates of each gear type for each survey activity where computed by using the simple average formula. Furthermore, the catch rates of gear types studied both in the fish landing and catch survey were computed using the formula:

$$CR = \frac{(n_{cs}*CS)+(n_{fl}*FL)}{n_{cs}+n_{fl}}$$

where:

n_{cs}	=	number of observations during catch surveys
n_{fl}	=	number of observations during fish landing survey
CS	=	catch rate for catch survey
FL	=	catch rate for fish landing survey

Total fish production in the gulf was computed by multiplying the derived catch rates with other measures of fishing effort (i.e., gear count and annual trip frequencies obtained during the gear inventory). This operation was done on each gear type such that the total gulf-wide fish production was obtained by summing-up the estimated annual catch of each gear.

Results and Discussion

The catch rates of about 30 gear types used in Lagonoy Gulf were determined through the year-long fish landing and catch surveys. Ring net, which was the only form of commercial fishing in the gulf, exhibited the highest catch rate (397.38 kg/trip) while crab pot had the lowest catch rate of 3.23 kg/trip. Of all the other gear, only bag net and tuna handline exhibited catch rates higher than 100 kg/trip (Table 1). The seasonal oscillations in the catch rates of 6 major contributor gear types are presented in Fig. 2. The summer months (March to May), and July to September were the observed peaks for majority of these 6 gear types whose contributions were estimated at 78.5% of the gulf's total annual production. The catch composition of these gear types is presented in Appendix 1.

It is worth noting, however, that fishing gear with high catch rates did not necessarily contribute much to total production. Some other measures of fishing effort such as gear count and annual trip frequency, which were obtained during the gear inventory activities, somehow influenced each gear type's contribution to the gulf's total production. Basically, Lagonoy Gulf has

has a handline-gillnet fisheries. Gear types belonging to the handline and gillnet groups contributed 74.98% of the gulfs 27,970.70 t estimated annual production. Of all the gear types, simple handline had the highest contribution (46.54%) while gillnet with compressor had the lowest contribution of 0.0027% (see also Table 1).

In terms of species composition, the aggregate weight of big pelagics (i.e., *Katsuwonus pelamis* and *Thunnus albacarres*) contributed around 45% recorded landings in Lagonoy Gulf. Table 2 shows the preponderance of both the big and small pelagics in the gulfs recorded landings, which means that the subsistence of Lagonoy Gulfs fisheries rely on the pelagics.

The projected annual fish production in Lagonoy Gulf based on the results of the 1994 Lagonoy Gulf REA was way above the yearly estimates from 1980-1987 and 1990-1992 (Table 3). Lagonoy Gulfs production values from 1980 to 1987 were extracted from regional fish productions estimated by the Bureau of Fisheries and Aquatic Resources (BFAR). From 1980 to 1981, the landing statistics of the gulf were obtained from few sampling stations scattered in areas that covered only the provinces of Catanduanes and Camarines Sur. Then from 1982 to 1987, the coverage of Lagonoy Gulf as a statistical area exetended up to portions of Albay Province and even up to San Bernardino Strait, which covered parts of Northern Samar.

There was, again, a shift of aerial scope for the 1990 to 1992 Lagonoy Gulf production estimates (BAS undated). This time, production estimates in the gulf were taken within the boundaries set by the DA-FSP Program. However, the 1990-1992 production estimates reported by the Bureau of Agricultural Statistics (BAS) included only the production of municipal fisheries. Hence, the three-year total annual production estimates in the gulf, for purposes of this study, were derived by adding the BAS values to the commercial fisheries production values extrapolated from the 1980-1987 BFAR estimates. These derived total production values, when compared to the 1994 Lagonoy Gulf REA estimate, were almost 300% lower. Such discrepancy in prodcution estimates could mainly be attributed to the differences in the sampling methods used. Generally, it would be inconclusive to compare the 1994 production estimate with all the other previous estimates. Appropriate trends in the gulfs fish production cannot be easily discerned from such comparisons wherein the methodologies used and aerial coverage were dissimilar.

The results of this assessment have to be understood in the light of data limitations that first assessments are generally burdened with. It is reasonable to state that, in general, the extent and quality of available catch and effort data are insufficient to infer on the status of Lagonoy Gulf fisheries.

Acknowledgement

We would like to thank Mr. Marcial Jane, from Bicol University College of Fisheries, and Ronnel Dioneda, Leo Pura, Eduardo Bola, Rolando Buenaflor, Florante Bustamante, Anastacio Cante Jr., Jose Gonzales Jr., and Jovel Tasarra, all staff members of the Capture Fisheries Component of the Lagonoy Gulf REA Project for their invaluable assistance during the conduct of this study.

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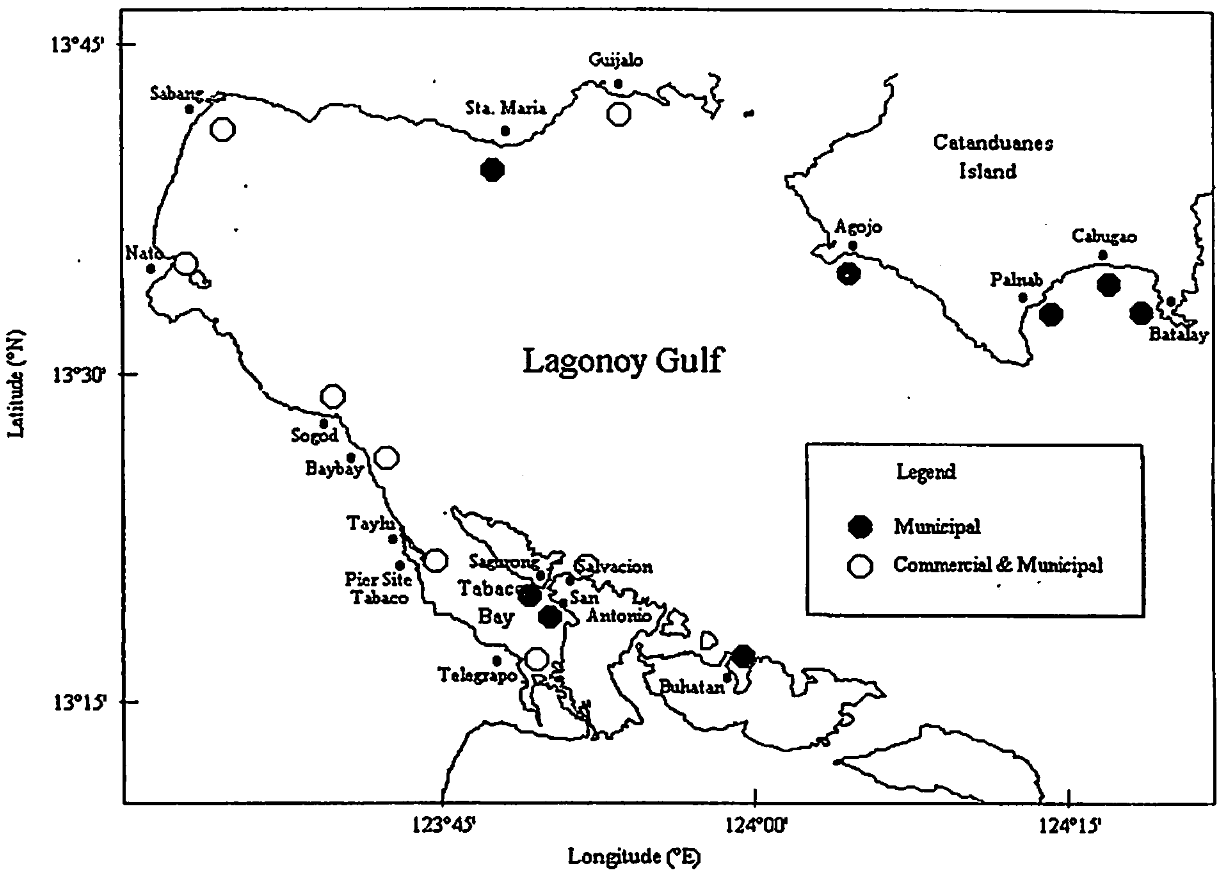

Fig. 1. Fish landing areas monitored for municipal and commerical fisheries assessment.

Table 1. Estimated annual catch by fishing gear type in Lagonoy Gulf (1994).

Fishing gear		Annual trip	No. of gear units	Catch rate	Estimated	Percentage	Percentage
English name	Local name	frequency		(kg/trip)	annual catch (kg)	(%)	(%)
Handlines							60.08
1 Artificial bait	Pangcanuus	75.00	30	6.74	15,165.00	0.0542	
2 Hook and line/simple handline/ handline/pole and line	Kawil/banwit pahulad/ligawnan	122.19	4996	21.33	13,018,440.86	46.5431	
3 Multiple handline	Ug-ug	64.38	262	28.71	484,275.49	1.7314	
4 Octopus jig	Tora-tora/pangcogita	75.00	27	26.70	54,067.50	0.1933	
5 Squid jig	Pampusit	270.00	2	22.79	12,306.60	0.0440	
6 Troll line	Kasikas/balakwit	159.91	57	60.38	550,361.80	1.9676	
7 Tuna handline	Pambangkulis	155.02	102	168.84	2,669,704.83	9.5446	
Longlines							1.21
8 Bottom-set longline	Kitang	91.41	427	8.69	339,346.05	1.2132	
Gill nets							14.90
9 Bottom-set gillnet	Pankeng patundag	202.21	1468	7.26	2,156,283.13	7.7091	
10 Bottom-set gillnet w/ scareline	Lampuma	50.00	2	85.67	8,566.67	0.0306	
11 Drift gillnet (Monofilament)	Bugkat/Palutang	118.81	223	30.08	797,054.98	2.8496	
12 Drift gillnet (PE)	Largarete/Palutang	111.89	209	51.49	1,204,148.67	4.3050	
13 Gill net w/ compressor	Panke-compresor	36.00	1	20.80	748.80	0.0027	
Lift nets							2.91
14 Baby bagnet	Basnig pangkuyog	90.00	8	24.78	17,841.60	0.0638	
15 Bagnet	Basnig	151.10	20	191.29	578,075.63	2.0667	
16 Crab lift net	Bintol sa kasag	79.21	141	8.94	99,847.37	0.3570	
17 Push net	Sakag	200.00	4	3.39	2,712.00	0.0097	
18 Skimming net	Sapyaw	43.50	46	58.12	116,292.96	0.4158	
Seines							10.49
19 Beach seine	Sinsuro	283.24	136	35.51	1,367,817.05	4.8902	
20 Milkfish fry seine*	Bangusan	131.63	51	67420*			
21 Pull net/baby beach seine	Bitana/Sagudsod	50.94	49	56.61	141,306.95	0.5052	
22 Ring net	Kalansisi/Palakaya	147.37	19	397.38	1,112,669.97	3.9780	
23 Seine net	Sarap/pukot	56.96	134	41.00	312,938.24	1.1188	

Fishing gear		Annual trip frequency	No. of gear units	Catch rate (kg/trip)	Estimated annual catch (kg)	Percentage (%)	Percentage (%)
English name	Local name						
Hand instruments							7.54
24 Spear gun	Pana	131.70	560	7.67	565,734.57	2.0226	
25 Spear gun w/ compressor	Pana-compresor	276.69	195	28.62	1,544,179.22	5.5207	
Barrier and traps							2.84
26 Crab pot (mud and blue crab)	Bubo sa kasag/hanit	128.47	531	3.23	220,342.75	0.7878	
27 Fish corral	Baklad/Sagkad/Bunuan	237.90	63	12.54	187,971.10	0.6720	
28 Fish pot	Bubo sa sira	111.87	513	6.72	385,656.16	1.3788	
Bikolano indigenous							0.02
29 Beach seine w/ scareline	Kunay	45.00	2	76.00	6,840.00	0.0245	
TOTAL			10278.00		27,970,695.96	100.0000	100.00

*catch unit is in number of fry pieces.

Table 2. Species composition of the recorded landing in Lagonoy Gulf from January to December 1994.

Species	Percent
Katsuwonus pelamis	32.25
Thunnus albacarres	10.01
Auxis thazard	5.52
Selar boops	3.34
Decapterus moruadsi	3.28
Decapterus macrosoma	3.23
Stolephorus commersonii	3.17
Coryphaena hipporus	3.02
Tylosurus giganteus	2.35
Rastrelliger kanagurta	2.19
Other species	31.64

Table 3. Marine fishery production of Lagonoy Gulf, Bicol Region

Year	Commercial	Change (%)	Municipal	Change (%)	Comc-Munpl	Total Prodct'n	Change (%)
1980	560.00	0.00	11614.00	0.00	4.82	12174.00	0.00
1981	252.00	-55.00	24095.00	107.47	1.05	24292.00	99.54
1982	367.00	45.63	16471.00	-31.64	2.23	16883.63	-30.50
1983	182.00	-50.41	10324.00	-37.32	1.76	10455.59	-38.07
1984	1230.00	575.82	21208.00	105.42	5.80	23013.82	120.11
1986	296.00	-75.93	14384.00	-32.18	2.06	14604.07	-36.54
1987	283.00	-4.39	14123.00	-1.81	2.00	14406.00	-1.36
1990	647.53	118.76	8460.00	-41.18	7.65	9226.29	-36.82
1991	670.21	3.50	9163.00	8.31	7.31	9836.72	6.62
1992	692.90	3.38	7041.00	-23.16	9.84	7737.28	-21.34
Mean	481.17	62.37	13688.30	5.39	4.45	14262.94	6.85

Sources: BFAR Statistics (1980-87) and BAS Statistics (1990-1992 municipal fishery production);
commercial fisheries data for 1990-1992 are extrapolated.

Appendix 1. Catch composition of major gear types used in Lagonoy Gulf from January to December 1994.

Fishing gear : Ring net
Annual catch : 1,112.67 t

Species/Group	Relative Abundance (%)
Katsuwonus pelamis	70.46
Auxis thazard	10.03
Decapterus macrosoma	7.43
Decapterus maruadsi	3.03
Rastrelliger kanagurta	1.91
Selar boops	1.44
Atule mate	1.32
Rastrelliger chrysozonus	0.69
Megalaspis cordyla	0.55
Thunnus albacarres	0.47
Others	2.67

Fishing gear : Beach seine
Annual catch : 1,367,817.05 kg

Species/Group	Relative Abundance (%)
Stolephorus commersonii	33.56
Stolephorus heterolobus	20.48
Stolephorus indicus	10.94
Thunnus albacarres	6.99
Selaroides leptolepis	2.19
Decapterus moruadsi	1.99
Clupea peruva	1.88
Seppia spp.	1.69
Scomberomorus commerson	1.44
Upeneus moluccensis	1.02
Others	16.22

Fishing gear : Bagnet
Annual catch : 578.08 t

Species/Group	Relative Abundance (%)
Stolephorus commersonii	74.66
Stolephorus heterolobus	11.36
Stolephorus zolengeri	5.31
Rastrelliger chrysozonus	2.21
Decapterus maruadsi	1.47
Decapterus macrosoma	0.81
Rastrelliger brachysoma	0.74
Atule mate	0.74
Scomberoides lysan	0.61
Sphyraena barracuda	0.57
Others	1.52

Fishing gear : Bottom-set gillnet
Annual catch : 2156.28 t

Species/Group	Relative Abundance (%)
Scomberomorus commerson	24.22
Selar boops	13.69
Siganus canaliculatus	9.67
Katsuwonus pelamis	6.65
Lethrinus lentjan	3.07
Portonus pelagicus	2.69
Rastrelliger kanagurta	2.69
Auxis thazard	2.67
Atule mate	2.61
Sardinella albella	1.83
Others	30.21

Fishing gear : Drift gillnet (monofilament)
Annual catch : 797.06 t

Species/Group	Relative Abundance (%)
Cyselorus oligolepis	55.02
Cyselorus poecilopterus	15.71
Tylosurus giganteus	15.07
Sardinella albella	6.25
Megalaspis cordyla	0.78
Mugil cephalus	0.67
Hemiramphus far	0.65
Rastrelliger kanagurta	0.59
Sphyraena jello	0.48
Siganus virgatus	0.47
Others	4.31

Fishing gear : Simple handline
Annual catch : 13018.44 t

Species/Group	Relative Abundance (%)
Thunnus albacarrres	28.44
Coryphaena hipporus	18.68
Katsuwonus pelamis	9.85
Thunnus alalunga	5.31
Istiophorus platypterus	4.74
Lethrinus lentjan	3.51
Tetrapturus audax	2.66
Selar boops	2.43
Rastrelliger brachysoma	2.42
Xiphias gladius	1.75
Others	20.21

Fishing gear : Drift gillnet (PE)
Annual catch : 1204.15 t

Species/Group	Relative Abundance (%)
Sardinella albella	20.05
Rastrelliger kanagurta	17.59
Decapterus maruadsi	16.41
Selar boops	13.53
Auxis thazard	11.97
Atule mate	7.71
Sphyraena jello	6.46
Sardinella longiceps	1.94
Caranx stellatus	0.64
Sardinella fimbriata	0.41
Others	3.29

Fishing gear : Spear Gun
Annual catch : 565.73 T

Species/Group	Relative Abundance (%)
Siganus canaliculatus	20.21
Siganus javus	10.65
Lethrinus lentjan	9.73
Cheilinus fasciatus	7.82
Siganus spp.	5.19
Parupeneus barberinus	4.24
Caesio tile	3.89
Naso lituratus	2.59
Parupeneus lutues	2.47
Groupers	5.93
Others	27.03

Fishing gear : Spear gun w/ compressor
Annual catch : 565.73 t

Species/Group	Relative Abundance (%)
Naso lituratus	13.26
Cheilinus fasciatus	10.98
Siganus canaliculatus	6.76
Caesio tile	6.16
Caesio cunning	5.72
Parupeneus indicus	4.42
Siganus javus	3.52
Siganus guttatus	2.36
Lethrinus lentjan	2.27
Groupers	20.79
Others	23.76

Fishing gear : Tuna handline
Annual catch : 2669.71 t

Species/Group	Relative Abundance (%)
Thunnus albacarres	94.32
Coryphaena hipporus	2.99
Katsuwonus pelamis	1.36
Xiphias gladius	0.62
Auxis thazard	0.31
Sphyraena barracuda	0.18
Thunnus abesus	0.08
Others	0.13

4

Population Parameters and Exploitation Ratios of Selected Fishes Caught in Lagonoy Gulf, Philippines

by

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Population Parameters and Exploitation Ratios of Selected Fishes Caught in Lagonoy Gulf, Philippines

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Sia III, Q.P., L.R. Garces and G.T. Silvestre. 1995. Population parameters and exploitation ratios of selected fishes caught in Lagonoy Gulf, Philippines, p. 000-000. *In* G. Silvestre, C. Luna, V. Soliman and L. Garces (eds.) Resource and ecological assessment of Lagonoy Gulf, Philippines. ICLARM Tech. Rep. 000, 000 p.

Abstract

Growth parameters (L_∞ and K) of the von Bertallanfy growth equation and mortality coeficients (M, F and Z of the negative exponential decay model) for selected fish species caught by beach seine, ring net and fish corral in Lagonoy Gulf from January 1994 to December 1994 were obtained using ELEFAN I of direct fit of L/F data, and mortalities routines of FiSAT (FAO-ICLARM Stock Assessment Tools). Using these derived parameters, the exploitation ratios (E=F/Z) and recruitment patterns of the selected fish species were also computed. Almost all species showed high growth rates (K=0.90-1.1) and mortality coefficients (Z=2.20-6.57). These high values indicate high turnover rates for the bulk of the exploited biomass in the gulf. The recruitment patterns derived for most of the studied species were unimodal (i.e., one recruitment pulse annually). There was also a big range of values obtained for exploitation ratios (E=0.10-0.65) with 4 out of the 7 selected species having E values higher than 0.50. Values of E higher than 0.50 indicate heavy fishing pressure.

Introduction

Lagonoy Gulf, in southeastern Philippines, is one of the country's traditional fishing grounds. The gulf's exact location is between 123°31'37"E to 124°20'36"E and 13°44'30"N to 13°10'33"N. Its boundaries extend up to the Caramoan Peninsula and Catanduanes Island in the north and the Batan, San Miguel and Cagraray group of islands in the south. The gulf covers an area of 3,071 km^2 and has a coastline of about 225 km (Fig. 1).

The annual fish production in the gulf as estimated by the Bureau of Fisheries and Aquatic Resources (BFAR) and Bureau of Agricultural Statistics (BAS) from 1980 to 1992 ranged from 7,737.28 tons to 24,292 tons. However, the production estimate of the Resource and Ecological Assessment (REA) Study in 1994 was estimated at 27,900.00 tons. The reasons for these discrepancies in the values of production estimate are further discussed in Soliman et. al this vol. Around 7,500 fishers rely on the gulf for a living. The fishery products harvested by these fishers are brought to adjacent municipalities and urban centers including Virac, Tabaco, Legaspi, Sorsogon, Naga, Iriga, Daet and even Metro Manila.

This study, which is the first ever conducted in Lagonoy Gulf, is an attempt to assess the exploited stock in the gulf using the conventional length-based methods appropriate for tropical fisheries. The population parameters (growth, mortality, and recruitment patterns) and exploitation ratios of selected fish species comprising a bulk of the exploited biomass in the gulf are presented.

Materials and Methods

The length frequency data generated during the course of catch survey (i.e., monthly observations of fishing operations by gear) in Lagonoy Gulf from January 1994 to December 1994 were used. Of the data obtained from the 12 gears monitored for catch survey, only the length frequency data of the selected species caught by beach seine, ring net and fish corral were used. Details of the gears' specifications are presented in Garces et al. this vol. These 3 gears were chosen because they were observed to exhibit trawl-like selectivity. The gears were made as substitute for trawl since trawling is not practiced in the gulf. Warfel and Manacop (1950) identified portions of Lagonoy Gulf as unsuitable for trawling operations.

Fish samples were obtained from the catch per day-trip of each fishing gear. Table 1 presents the number of day-trips taken by each gear type at the study's duration. Whenever possible, the samples were sorted up to the species level and those species with high occurence were sampled for length distribution (Appendix 1). The fork length (i.e., the measurement from the tip of the snout to the shortest median caudal ray) for species with forked, emarginate and lunate caudal fins or the total length (i.e., the measurement from the snout to the end of the caudal fin) for species with pointed, rounded and truncate caudal fins were taken for each fish sample.

Several criteria were set for the inclusion of species length distributions in this paper's analysis. Included were: 1.) high abundance or high economic importance of the species, 2.) species' representation of a large fraction of population size distribution, and 3.) credible modal size progression exhibited by the species. These collected size distribution data undergo a series of preliminary screening processes before their inclusion in the analysis.

The acquired length distribution data were run through ELEFAN I, mortalities, and recruitment patterns routines incorporated in FiSAT. ELEFAN I was used in estimating the parameters L_∞ and K of the von Bertallanfy growth formula while mortalities routine was used to estimate total mortality (Z) via the catch curve method, natural mortality (M) using a built-in empirical equation, and fishing mortality (F) by getting the difference between Z and M. The exploitation ratios (E=F/Z) of species were also derived using the mortalities routine. In obtaining the seasonal oscillations of each species, the recruitment patterns routine was used. These oscillations are derived by using the growth parameters L_∞ and K obtained through ELEFAN I and then by back-projecting the length distribution data into a one year time axis. The peaks observed in such patterns reflect recruitment pulses and the seasonality of recruitment. The typical outputs of the three FiSAT routines used are presented in Figures 2-4.

Results and Discussion

Only 7 species caught by 3 types of fishing gear (roughly 7% of Lagonoy Gulfs annual fish production) were included in the analysis (Table 1). Beach seine, ring net and fish corral were chosen in lieu of trawl since only these 3 gear types among the various fishing gear used in Lagonoy Gulf were observed to exhibit near trawl-like selectivity . It is worth noting, however, that these 3 gear types may not share common selection properties. A case in point would be the observed slight disparity in the growth parameters and mortalities values obtained from a single species (*Decapterus maruadsi*) caught separately by ring net and beach seine. Should ring net and beach seine have commom selection properties, the disparity could be attributed to the difference in fishing grounds of ring net and beach seine (Figs. 5 & 6).

Majority, if not all, of the species investigated exhibited relatively fast growth rates. This can be shown in the 0.55-1.10 range of K values derived via ELEFAN I. The fish corral-caught *Siganus canaliculatus* had the lowest K value (0.55) while *Stolephorus commersonii* (beach seine) and *Decapterus macrosoma* (ring net) had the highest K value (1.10). These estimates are within the range of values reported from Philippine fishing grounds (see Corpuz et al. 1986, Ingles and Pauly 1984, Silvestre 1986), as well as in the Southeast Asian region (see Chullasorn and Martosubroto 1986, Dwiponggo et al. 1986). The recruitment patterns derived for 4 of the 7 species were unimodal (i.e., one recruitment pulse per year). Only *S. indicus*, *Atule mate* and *S. canaliculatus* were observed to have bimodal recruitment.

The 7 species studied showed high Z values (more than 2.20). These high Z estimates suggest very low annual survival rates while natural mortality estimates ranged from 1.38 (*S. canaliculatus*) to 2.51 (*S. indicus*). Fishing mortality, on the other hand, varied from 0.23 (*Rastrelliger kanagurta*) and 4.13 (*D. maruadsi*). Four out of the 7 species had higher fishing mortality than natural mortality. These 4 species were the ones that exhibited higher exploitation rates (E=0.55-0.65). The remaining 3 species had E values that ranged from 0.10 to 0.41. Cinco and Silvestre (in press) cited that E values between about 0.30 and 0.50 are optimal in maximizing biological yield (see also Gulland 1971, Beddington and Cooke 1983, and Pauly 1984), which implies that high fishing pressure is prevailing in the gulf. The overall results of the tests indicate biological overfishing of the resources in Lagonoy Gulf.

Acknowledgement

We would like to thank Mr. Plutomeo Nieves and Marcial Jane, both from Bicol University College of Fisheries, and Ronnel Dioneda, Leo Pura, Eduardo Bola, Rolando Buenaflor, Florante Bustamante, Anastacio Cante Jr., Jose Gonzales Jr. and Jovel Tasarra, all staff members of the Capture Fisheries Component of the Lagonoy Gulf REA Project for their invaluable assistance during the conduct of this study.

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Table 1. Length distribution sampling conducted in Lagonoy Gulf.

Fish corral	Date	Beach seine	Date	Ring net	Date
	2/10/94		1/15/94		4/17/94
	3/17/94		2/14/94		4/18/94
	4/27/94		2/6/94		5/22/94
	5/17/94		3/14/94		6/14/94
	6/26/94		3/18/94		6/22/94
	7/22/94		4/24/94		6/5/94
	8/12/94		5/15/94		6/5/94
	10/27/94		6/15/94		7/12/94
	11/27/94		7/1/94		7/17/94
			7/25/94		7/26/94
			8/9/94		8/14/94
			9/9/94		8/27/94
			10/10/94		8/29/94
			10/17/94		9/11/94
			11/14/94		9/15/94
			11/7/94		10/29/94
					11/27/94

Table 2. Population parameters of selected fish species in Lagonoy Gulf.

Fishing gear	Species	n	L_∞	K	Z	M	F	E	NRP
Beach seine	*Decapterus maruadsi*	304	17.45	1.05	6.31	2.18	4.13	0.65	1
	Stolephorus commersonii	25242	12.48	1.10	6.57	2.47	4.10	0.62	1
	Stolephorus indicus	1744	11.47	1.09	3.58	2.51	1.07	0.30	2
Ring net	*Atule mate*	2680	16.40	1.00	4.75	2.15	2.60	0.55	2
	Decapterus macrosoma	6283	18.25	1.10	5.65	2.22	3.43	0.61	1
	Decapterus maruadsi	16815	21.00	0.90	4.84	1.87	2.97	0.61	1
	Rastrelliger kanagurta	7610	17.80	0.91	2.20	1.97	0.23	0.10	1
Fish corral	*Siganus canaliculatus*	342	19.74	0.55	2.32	1.38	0.94	0.41	2

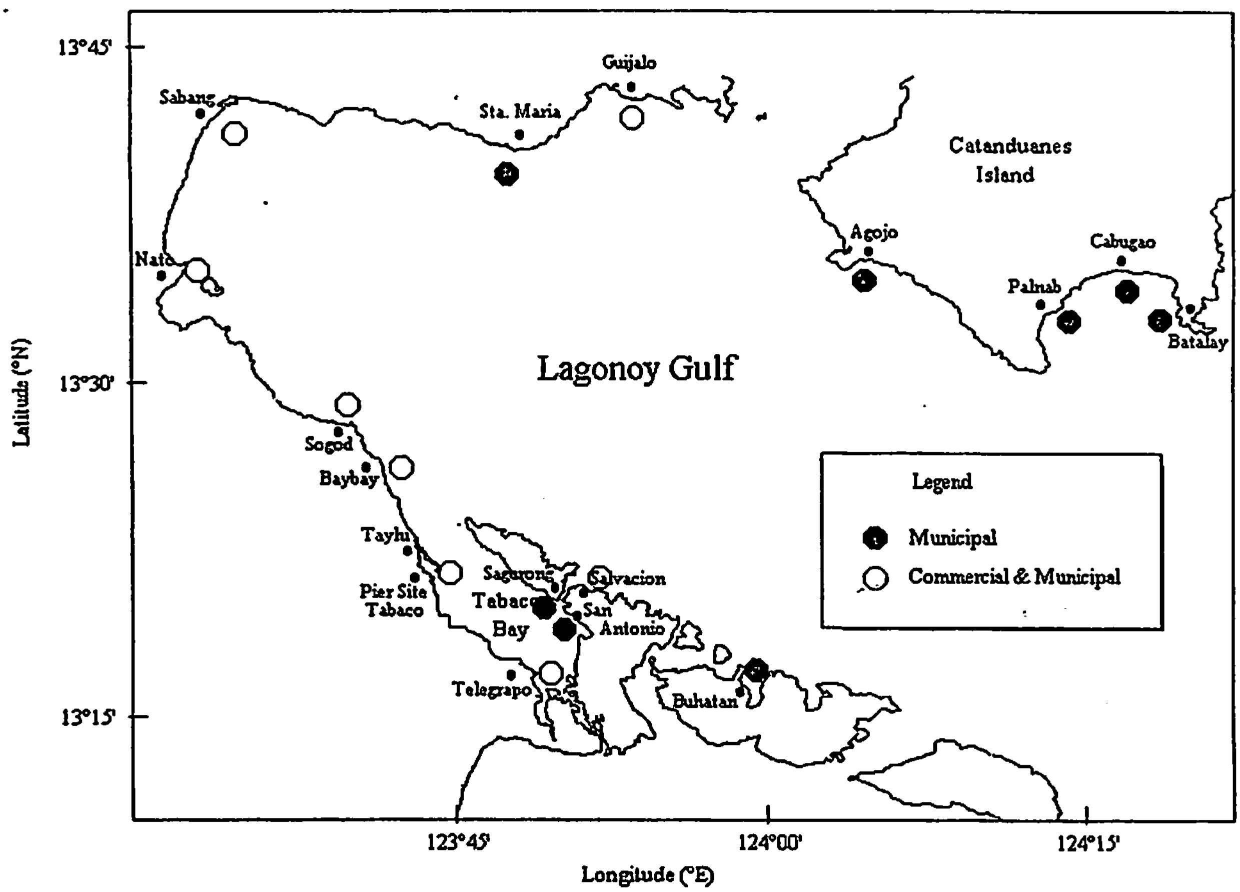
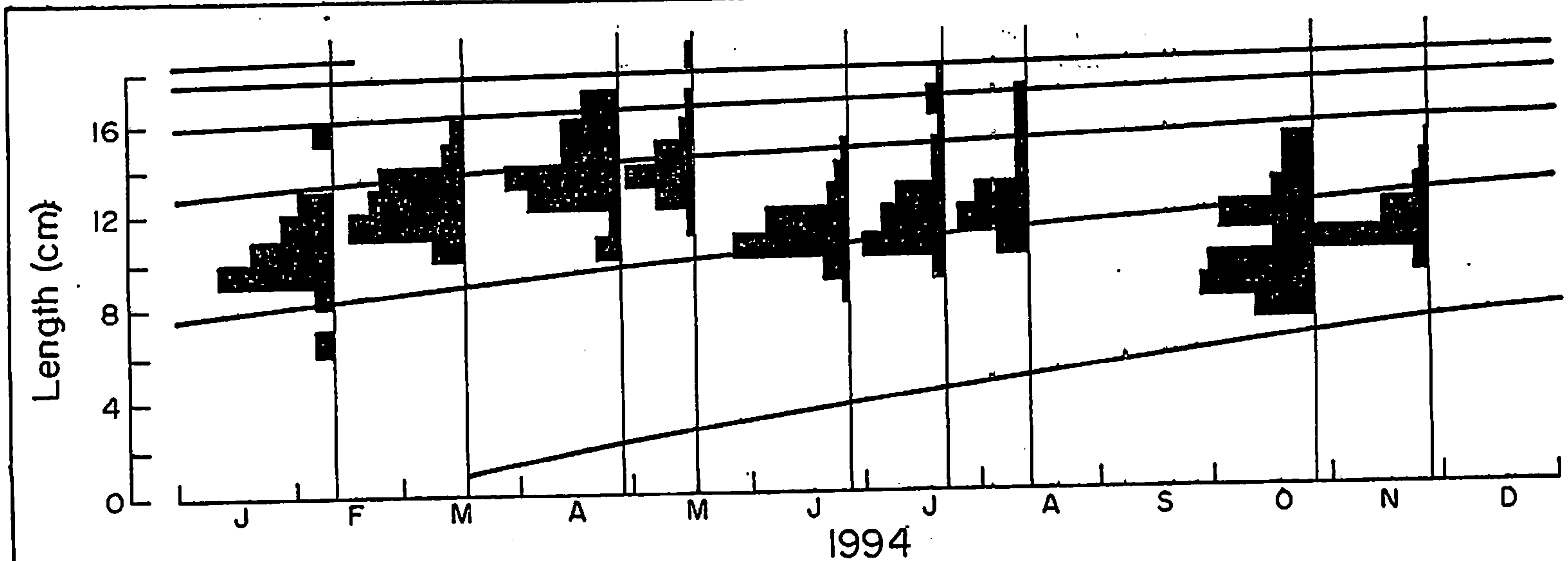
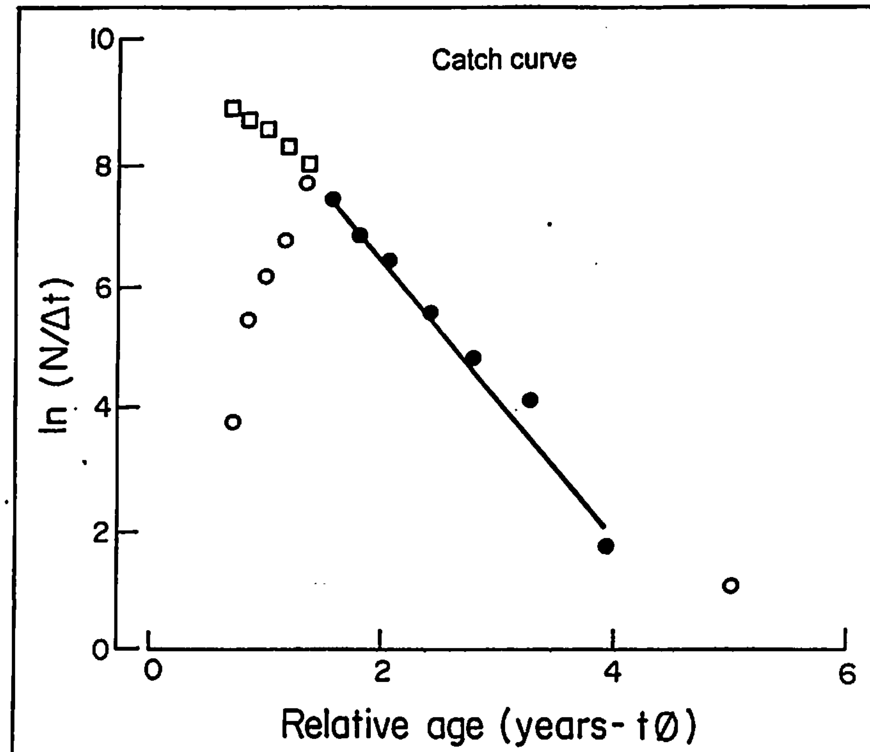


Fig. 1. Fish landing areas monitored for municipal and commerical fisheries assessment.



Species name	*Siganus canaliculatus* (fish corral (LG))	
L	=	19.74
K	=	0.550
C	=	0.000
WP	=	0.000
SS	=	7
SL	=	11.00
Rn	=	0.260

Fig. 2. Growth parameters of fish corral-caught *Siganus canaliculatus* in Lagonoy Gulf.



Filename: Temp Wt.mode (1b)

Growth parameters

L_∞ : 19.74 cm K : 0.55

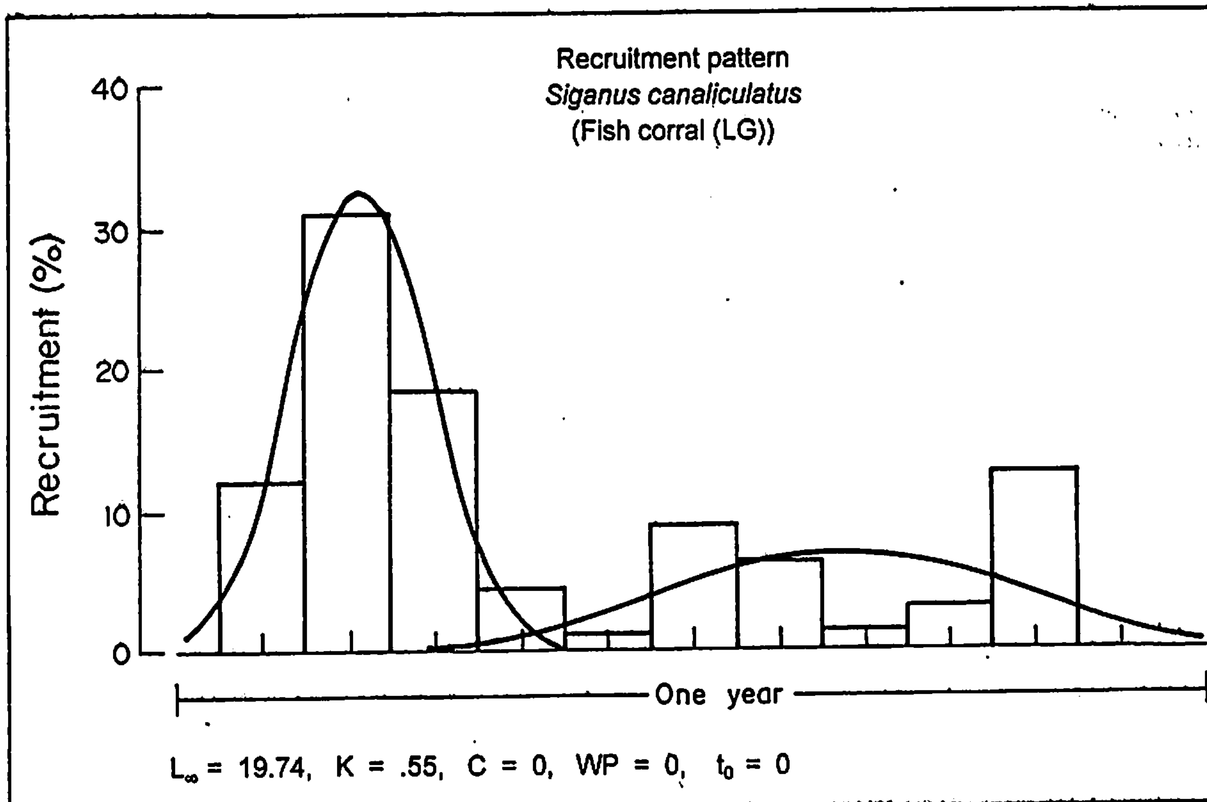
C : 0.00 WP : 0.00

Cutoff length (L')	=	11.000
Mean length (from L')	=	12.828
Z from catch curve	=	2.32
Z entered	=	2.32
Natural mortality (M, for T=29°C)	=	1.38
M value used	=	1.38
Fishing mortality (F=Z-M) (Z & M as entered)	=	0.94
Exploit rate (E=F/Z)	=	0.41

Species name:
Siganus canaliculatus
Other file identifiers:
Fish corral (LG)

Range of length observations:
6-19 cm
Class size:
1 cm

Fig. 3. Mortality coefficients of fish corral-caught *S. canaliculatus* in Lagonoy Gulf.



File: Temp
Wt. mode (1b)

Relative time	Percentage of recruitment
1	12.31
2	31.26
3	18.34
4	4.48
5	0.97
6	8.99
7	6.36
8	1.34
9	2.90
10	12.63
11	0.42
12	0.00

Group parameters:

Mean (1)	1.68	Mean (2)	7.31
S.D. (1)	0.79	S.D. (2)	2.03
N(%) (1)	64.30	N(%) (2)	35.70

Species name
Siganus canaliculatus
Other file identifiers
Fish corral (LG)

Fig. 4. Recruitment patterns of fish corral-caught *S. canaliculatus* in Lagonoy Gulf.

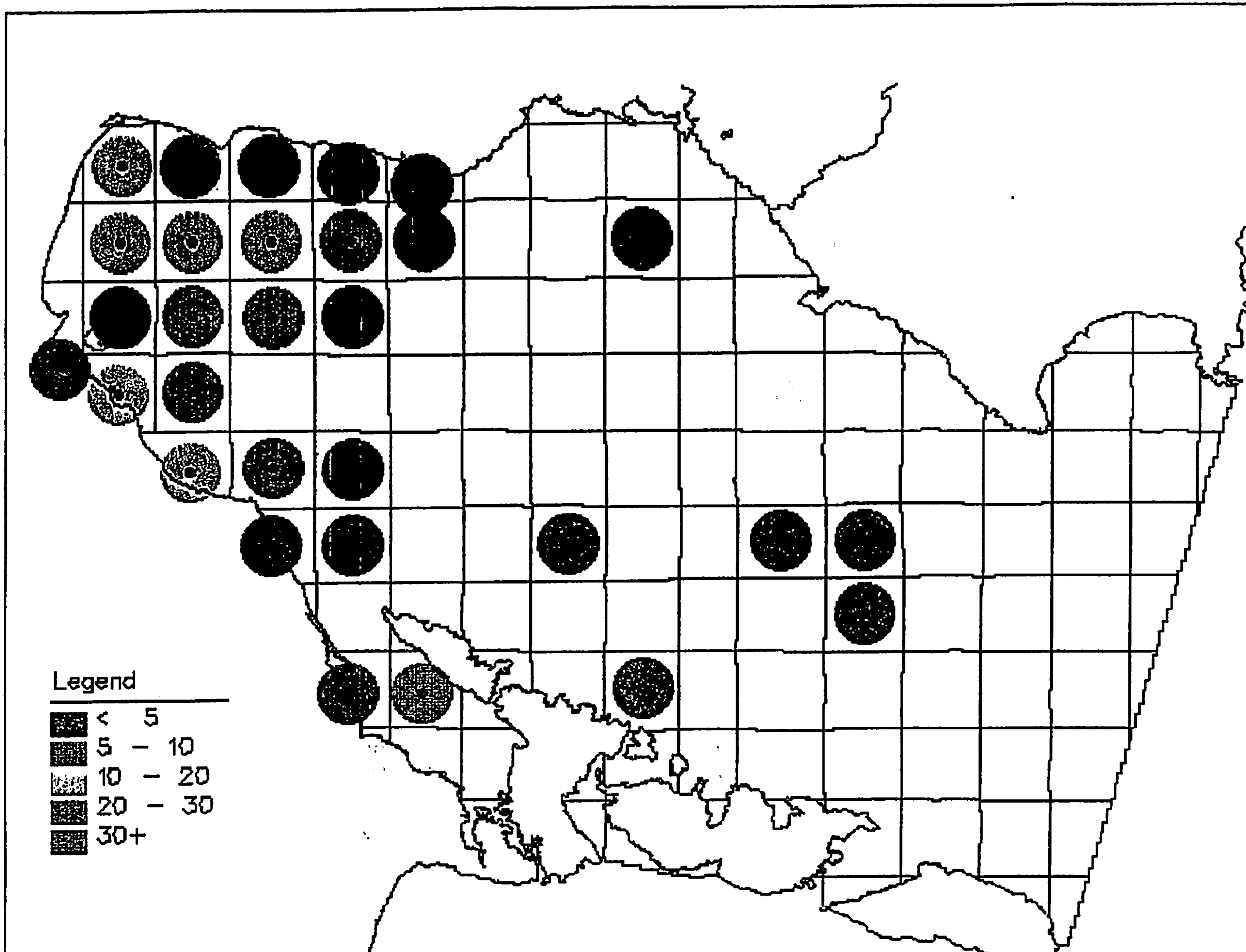


Fig. 5. Intensity and operational range of ring net in Lagonoy Gulf.

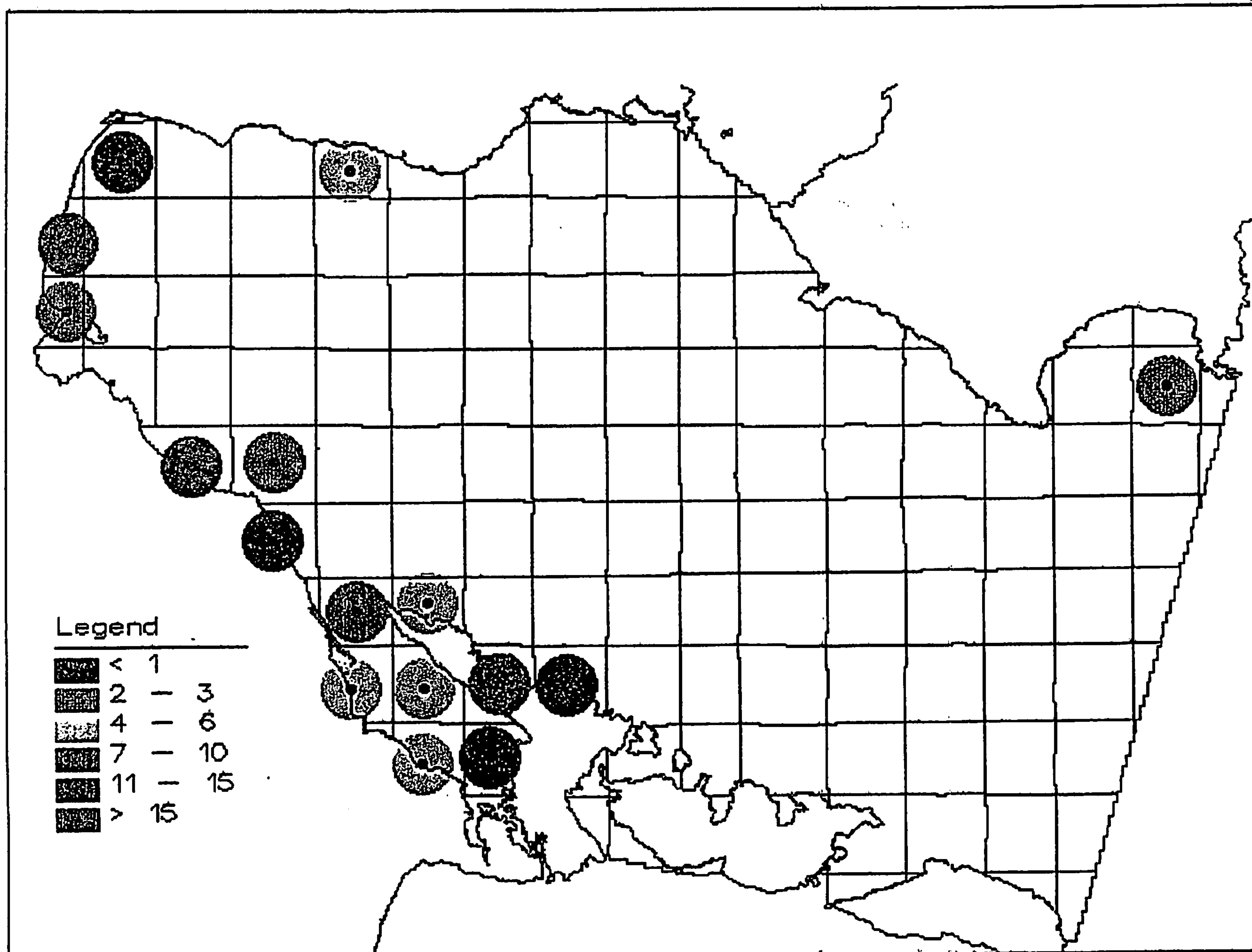


Fig. 6. Intensity and operational range of beach seine in Lagonoy Gulf.

Appendix 1. Length distribution of selected fish species caught in Lagonoy Gulf.

Decapterus maruadsi Beach seine (LG)

ML\DATE	4/15/94	5/15/94	7/1/94	10/10/94	11/7/94
11.5		11	2	4	
12.5		33	8	61	2
13.5	4	24	19	66	28
14.5		2	6		32
15.5			1		
16.5			1		
Sum	4	70	37	131	62

n = 304.00

Stolephorus commersonii Beach seine (LG)

ML\DATE	1/15/94	2/10/94	6/15/94	7/25/94	8/9/94	9/9/94
3.25		80				
3.75		240				
4.25		639				
4.75		351				
5.25	23	719				
5.75	0	240				
6.25	23	493				93
6.75	23	523	202			1759
7.25	0	365	3034		1477	370
7.75	0	63	202		7015	555
8.25	0		2832	38	2215	
8.75	0		809	0	738	
9.25	0			0		
9.75	23			75		
10.25	0					
10.75	23					
Sum	115	3713	7079	113	11445	2777

n = 25,242.00

Stolephorus indicus Beach seine (LG)

ML\DATE	3/16/94	4/24/94	10/17/94	11/14/94
3.75			24	
4.25	15		506	
4.75	30		193	
5.25	35		24	
5.75	5		0	
6.25	10	31	0	
6.75	18	0	121	
7.25	52	41	24	
7.75	74	205	96	
8.25	28	72	0	29
8.75	12	41	0	
9.25	6	0	0	
9.75	18	0	24	
10.25		10		
Sum	303	400	1012	29

n = 1,744.00

Atule mate Ring net (LG)

ML\DATE	5/22/94	6/15/94	7/15/94	8/22/94	9/13/94	10/2/94
7.5					62	
8.5	61	66	45	113	554	
9.5	0	132		113	246	44
10.5	30			225	493	200
11.5	30			0	112	44
12.5				9	0	22
13.5				0	51	
14.5				28		
Sum	121	198	45	488	1518	310

n = 2,680.00

Decapterus macrosoma Ring net (LG)

ML\DATE	4/17/94	6/14/94	7/12/94	8/27/94
9.5	73		92	220
10.5	73		229	55
11.5	110	173	824	386
12.5		866	595	441
13.5		1125	366	110
14.5		87	366	
15.5			46	
16.5			46	
Sum	256	2251	2564	1212

n = 6,283.00

Decapterus maruadsi Ring net (LG)

ML\DATE	5/22/94	6/10/94	7/18/94	8/22/94	9/13/94	10/2/94
6.5	54					
7.5	27			451		24
8.5	457		31	226		24
9.5	81	295	63	677		166
10.5	54	1253	221	3611	53	285
11.5	0	884	441	2595	348	213
12.5	108	62	826	226	444	
13.5	27	221	583	0	465	
14.5		381	360	0	127	
15.5				10	190	
16.5				0	42	
17.5				20		
18.5				30		
19.5				109		
20.5				50		
Sum	808	3096	2525	8005	1669	712

n = 16,815.00

Rastrelliger kanagurta Ring net (LG)

ML\DATE	4/18/94	5/22/94	6/5/94	7/17/94	8/14/94	9/11/94	11/27/94
8.5	40				101		
9.5	819			58	303		
10.5	1358			144	303		
11.5	779	162		29			
12.5		325		0			63
13.5			65	288		110	379
14.5			195	86		220	948
15.5			325	29		110	316
16.5						55	
Sum	2996	487	585	634	707	495	1706

n = 7,610.00

Siganus canaliculatus Fish corral (LG)

ML\DATE	2/10/94	3/17/94	4/27/94	5/17/94	6/26/94	7/22/94	8/12/94	10/27/94	11/27/94
6.5	1								
7.5	0							6	
8.5	1				1			12	
9.5	7				4	2		11	5
10.5	5	3	2		18	14	3	4	39
11.5	3	12	1	1	13	11	7	10	17
12.5	2	10	8	5	3	8	5	4	5
13.5	0	9	10	9	2	2	1	3	2
14.5	0	2	5	5	1	2	1	3	1
15.5	1	1	5	2		1	1		
16.5			3	1		3	1		
17.5				0		1			
18.5				1					
Sum	20	37	34	24	42	44	19	53	69

n = 342.00

A Preliminary Trophic Model of the Coastal Fisheries Resources of Lagonoy Gulf

by

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A Preliminary Trophic Model of the Coastal Fisheries Resources of Lagonoy Gulf

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Abstract

A steady-state trophic model of the coastal fisheries resources of Lagonoy Gulf was derived via ECOPATH II using parameters obtained from various studies conducted in the area in 1994 and available literature with study areas having similar characteristics with the gulf. The model consists of 11 groups (including detritus) and exploitation ratios (E) derived from the model varied between 0.006 and 0.900. The weighted mean E value for exploited groups (large predators, intermediate predators, small pelagics, demersal zoobenthos feeders, large crustaceans and small crustaceans) in Lagonoy Gulf is about 0.25. E values for large and intermediate predators, is about 0.74 and 0.90, respectively. This indicate that these groups are highly exploited resources in the area. Selected summary statistics relevant to system efficiency are given together with recommendations for possible improvement of the preliminary model.

Introduction

Lagonoy Gulf, located in the Bicol Region on the Pacific coast of the Philippines, is a relatively large body of water spanning an area of about 3,000 km^{-2} (Fig. 1). The circulation of waters in Lagonoy Gulf is strongly linked to the Asian Monsoons and as a consequence the surface layer flow also reverses seasonally. One feature of the gulf is its deep bathymetry which plays an important role to the hydrographic properties of the area (Villanoy and Encisa, this vol.). About 90.5% of the area has a depth greater than 10 fathoms.

The coastline is bounded by 15 municipalities, namely: Tiwi, Malinao, Tabaco, Malilipot, Bacacay, and Rapu-rapu (in Albay province); Bato, Virac and San Andres (in Catanduanes province); and Caramoan, Presentatcion, Lagonoy, San Jose, Tigaon and Sangay (in Camarines Sur province). Currently, a total of about 7,500 fishers reside in these coastal municipalities with a total of 164 coastal barangays. They employ a multiplicity of fishing gears (34 types or 10,700 gear units) to exploit the multispecies fishery resources of the gulf (Garces et al., this vol.). Gear types consisted predominantly of handlines and gillnets which collectively account for about 75% of the total number of gear units in the gulf. A total of 480 fish species belonging to 199 genera and 79 families and 21 species of invertebrates are included in the list of exploited resources of the gulf (Dioneda et al., this vol.) However, only about 25 species are dominant or of high economic importance. Total annual landings from fishing operations in the gulf was estimated to be about 27,900 t (or about 9.3 t km^{-2} $year^{-1}$) during the course of investigations covering the period January to December 1994 (see Soliman et al. this vol.). Species belonging to the family Scombridae and Carangidae contribute to almost 70% of the total landed catch.

Results from the one-year monitoring of surface waters from 15 sampling stations in the gulf indicated that the annual average temeperature ranges from 29.3 to 30.2 oC, a salinity from 26.1 to 33.3 ppt, and a dissolved oxygen of 7.02 to 8.24 mg l^{-1} (see Valmonte-Santos et al., this vol.). Primary productivity was estimated using the light and dark bottle technique, chlorophyll *a* and nutrient (NO3), average productivity values were 2,200.00 gC m^{-2} $year^{-1}$ (net production), 64.48 gC m^{-2} $year^{-1}$, and 228.42 gC m^{-2} $year^{-1}$, respectively (see Brizuela et al., this vol.). The estimated zooplankton biomass ranged from 43.59 to 530.22 gC m^{-2} $year^{-1}$ (Garces et al. this vol.).

This paper aims to provide a preliminary steady-state trophic model of the coastal fisheries resources of Lagonoy Gulf. The model was derived via ECOPATH II using parameters obtained from various studies conducted in the area in 1994 under the Resource and Ecological Assessment (REA) of Lagonoy Gulf and available literature with study areas having similar characteristics with the gulf.

Materials and Methods

The ECOPATH Model

The ECOPATH II System combines an approach by Polovina (1984a) for estimation of biomass and food consumption of the various elements (species or groups of species) of an aquatic ecosystem with an approach by Ulanowicz (1986) for analysis of flows between the elements of ecosystems. The core routine of ECOPATH II is derived from the ECOPATH program of Polovina and Ow (1983) and Polovina (1984b, 1985).

The ecosystems that are analyzed with ECOPATH must be in steady-state, which means that the flows in and out of each components (boxes) must be balanced over the time period studied. This may be a tricky requirement but it can be met for most ecosystems by either averaging over total period or by taking "snapshots" of the system, i.e., by looking at short time intervals (Christensen and Pauly 1992a,b).

Basically, the approach is to model an ecosystem using a set of simultaneous linear equations (one for each group *i* in the system, i.e.,

Production by (*i*) - all predation on (*i*) - non predation losses of (*i*) - export of (*i*) = 0, for all (*i*).

Another way of expressing the basic equation is through the production of any (consumer) group (*i*), which is equal to pi = PBi*Bi where PB*i* is the production/biomass ratio (i.e., total mortality of (*i*)) and B*i* its biomass. This leads to:

$$PBi = Ci + (Bj * QBj * DCji) - (1-EEi)\ PBi * Bi$$

where:

C*i* is the catches of i
B*j* is the biomass of predator j
QB*j* is the predator j's food consumption
DC*ji* is the fraction of prey *i* in the diet of predator *j*, and
EE*i* is the Ecotrophic Efficiency, the fraction of the production of i that is consumed within the system being described.

ECOPATH II also allows, for any *i*, the estimation of one of the parameters, provided that estimates of the other parameters are available. Thus, for example, for any *i*, Ecotrophic Efficiency can be estimated if its biomass (B) and PB are known along with B, QB and DC of all its predators. In addition, ECOPATH II can be used as an approach for balancing ecosystem models, since it includes: (1) routines for balancing the flow in a steady-state ecosystem from estimation of a missing parameter for all groups in the system; (2) routines for estimating network flow indices; and (3) miscellaneous routines for deriving additional indices such as food selection and omnivory indices (Christensen and Pauly 1992c).

Data Sources and Parameter Estimation

Due to limited diet composition studies, the trophic groupings given by Pauly and Christensen (1993) for a similar tropical ecosystem was utilized. Table 1 gives the summary of input parameters to ECOPATH II used in the study. Table 2 shows the 11 trophic groups used to construct the model.

Production to biomass ratios (P/B=Z) or instantaneous total mortality for groups 8 and 9 were obtained from length-based assessments (via ELEFAN) using the data from the REA (see Sia et al. this vol.). Other entries in Table 1 were taken from the results of the REA studies and in the literature, as follows: (1) phytoplankton biomass from Brizuela et al. (this vol.) using the chlorophyll *a* values; (2) zooplankton biomass from Garces et al. (this vol.); (3) Q/B ratios from Silvestre et al. (1993), and Pauly and Christensen (1993); (4) catches from capture fisheries resources assessment studies

(Soliman et al., this vol.); (5) ecotrophic efficiency (EE) assumed to be 0.95 for groups 2 to 10 (see Polovina 1984a). Table 3 gives the estimates of catch and P/B for selected trophic groups while Table 4 gives a summary of the food composition ratios used in the input to ECOPATH II.

Results and Discussion

The steady-state trophic model for the fisheries resources in Lagonoy Gulf was derived using ECOPATH II which consist of 11 groups. A summary of the selected output statistics is given in Table 5. This is a preliminary model based mainly on input parameters from the model of a deep shelf in South China Sea described by Pauly and Christensen (1993) and the data from the 1994 REA for Lagonoy Gulf.

The biomass estimated from the model are relatively high. This may be due to the fact that the most important groups, i.e., large and intermediate predators, small pelagics, are highly migratory groups. Migration has not been taken into account in this model as unassimilated food kept at 20% for all groups. Fish biomass estimates were obtained only for reef fishes using the fish visual census technique (see Nañola and Cabansag, this vol.). Thus, ECOPATH II was used to estimate the biomasses using the data in Table 1 to calibrate the validity of the generated estimates.

The phytoplankton biomass used in the model was calculated from 64.48 gC m^{-2} $year^{-1}$ which was obtained from the chlorophyll *a* study (see Brizuela et al. this vol.). Zooplankton biomass was obtained from Garces et al. (this vol.). The potential fish production that could be supported by the primary and secondary sources of productivity was estimated at 20.7 to 250 mt km^{-2} $year^{-1}$. The estimated fish production from catch surveys is about 27,900 t or 9.3 t km^{-2} $year^{-1}$ (Soliman et al., this vol.), while the estimated total catches from the model is about 27.498 t km^{-2} $year^{-1}$. The fish production from the fish surveys is within the range of the catches estimated by ECOPATH II.

Exploitation ratios derived from the model varied between 0.006 and 0.900 with a weighted mean E value of exploited fish groups of about 0.25. The exploited groups include large and intermediate predators, demersal zoobenthos feeders, and small pelagics with E values of 0.740, 0.049, 0.067, 0.017, 0.003, and 0.006, respectively. These indicate that large predators mostly the Scombrids and Carangids are heavily exploited resources of the gulf. This observation is consistent with the results of the catch and effort study (see Soliman et al., this vol.).

The model as a whole is balanced given some incompatibility or absence of input parameters (e.g., exports). However, more effort should be put in obtaining reliable biomass estimates for important groups such as large predators and small pelagics. Recent reports obtained from similar systems will also be helpful in comparing this preliminary model. The model could also be refined using the data to be obtained from the REA monitoring and other stock assessment activities in Lagonoy Gulf.

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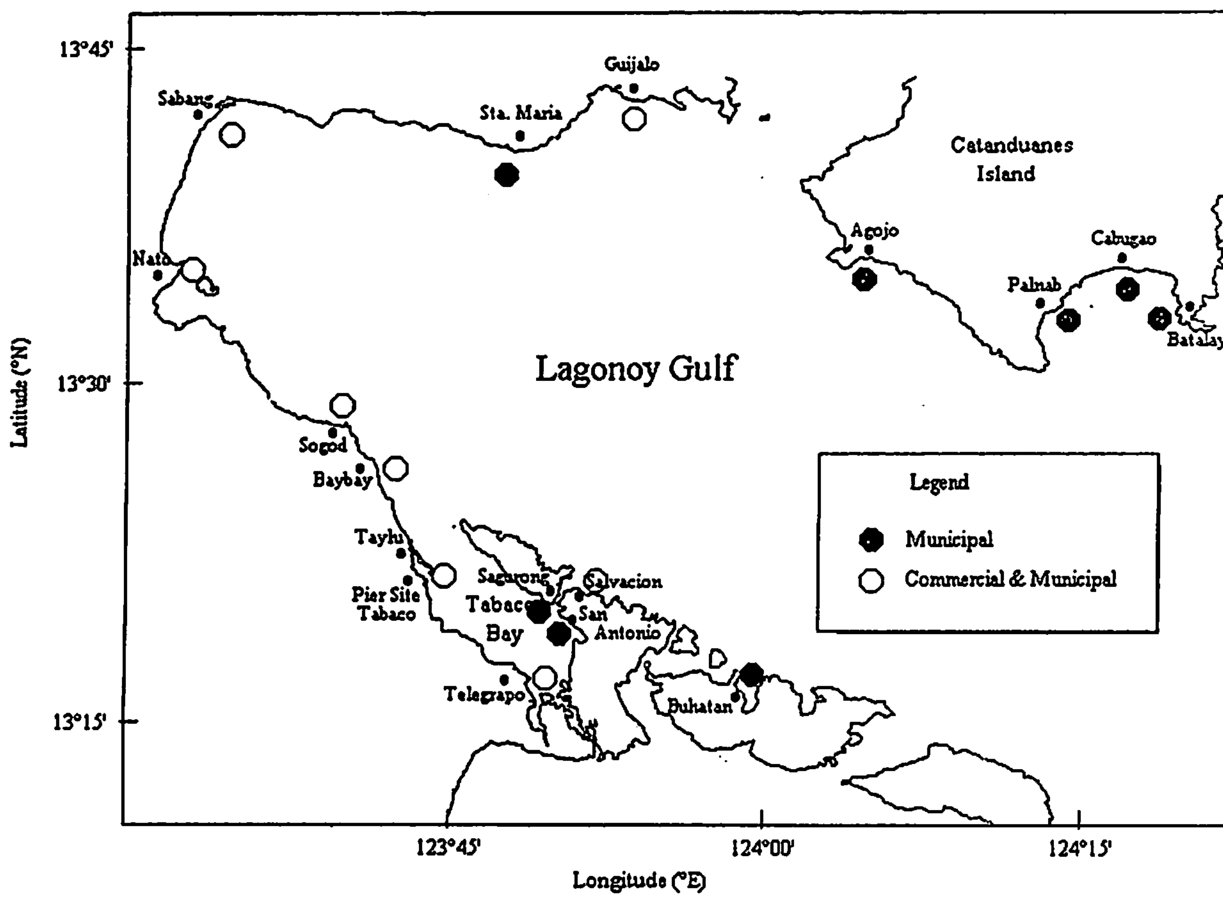

Fig. 1. Fish landing areas monitored for municipal and commerical fisheries assessment.

Table 1. Summary of input parameters.

GROUP NO.	GROUP NAME	PP [1]	EXPORT [2]	CATCH	BIOMASS	PB	QB
1	Phytoplankton	1.00	0.000	0.000	6150.000	71.000	-
2	Zooplankton	0.00	0.009	0.009	524.000	67.000	280.000
3	Crustaceans	0.00	0.206	0.206	-	4.000	22.000
4	Other inverts.	0.00	0.484	0.484	-	3.000	15.000
5	Reef fishes	0.00	0.266	0.266	11.500	3.200	31.000
6	Heterotrophic benthos	0.00	0.150	0.150	-	3.100	16.640
7	Demersal zooplankton feeders	0.00	1.260	1.260	-	6.060	8.200
8	Small pelagics	0.00	7.500	7.500	-	1.340	17.900
9	Intermediate predators	0.00	2.060	2.060	-	1.420	11.800
10	Large zoobenthos feeders	0.00	0.062	0.062	-	1.300	8.200
11	Large predator	0.00	15.500	15.500	-	2.000	8.400
12	Detritus	0.00	0.000	-	0.000	-	-

1) 0 - consumer; 1 - producer; 0.5 - if mixed producer/consumer.
2) Exports refer to "loses" to other systems and include harvests.

GROUP NO.	GROUP NAME	EE	GE	Non-assimilated food
1	Phytoplankton	-	-	0
2	Zooplankton	-	-	20
3	Crustaceans	0.950	-	20
4	Other inverts.	0.950	-	20
5	Reef fishes	-	-	20
6	Heterotrophic benthos	0.950	-	20
7	Demersal zooplankton feeders	0.950	-	20
8	Small pelagics	0.950	-	20
9	Intermediate predators	0.950	-	20
10	Large zoobenthos feeders	0.950	-	20
11	Large predator	0.950	-	20
12	Detritus	-	-	0

Table 2. Checklist of families/groups (adapted from Pauly and Christensen 1993; Silvestre et al. 1993).

Group No.	Group Name
11	Large Predators Carcharinidae, Scombridae (excluding *Rastrelliger*)
10	Large zoobenthic feeders Dasyatidae, Ephipidae, Rhynchobatidae
9	Intermediate predators Ariidae, Carangidae (excluding *Decapterus, Selar Alepes, Selaroides, Megalaspis*), Centropomidae, Chirocentridae, Lutjanidae, Muraenesocidae, Muraenidae, Plotosidae, Psettodidae, Sciaenidae, Serranidae, Sphyraenidae, Synodontidae, Trichiuridae
8	Small pelagics Carangidae (e.g., *Decapterus, Selar, Alepes, Selaroides*), Clupeidae, Engraulidae, Hemiramphidae, Loliginidae, Scombridae (e.g., *Rastrelliger*), Caesionidae,Exocoetidae
7	Small demersal predators Apogonidae, Cynoglossidae, Haemulidae, Leiognathidae, Mullidae, Mugillidae, Nemipteridae, Platycephalidae, Polynemidae, Priacanthidae, Siganidae, Sillaganidae, Theraponidae, Tetraodontidae, Dussumieriidae, Gerridae
6	Heterotrophic benthos (squids & cuttlefish) Octopodidae, Sepiidae, *Loligo*
5	Reef fishes Acanthuridae, Balistidae, Labrudae, Pomacentridae
4	Other inveretbrates Palinuridae, (excluding Penaeidae, Portunidae,Scyllaridae)
3	Crustaceans Penaeidae, Portunidae, Scyllaridae
2	Zooplankton Copepods
1	Primary producers Phytoplankton

Table 3. Estimates of P/B ratios and catch of selected trophic groups. Values were obtained from the capture fisheries assessment from January to December 1994.

Group/Family	Representative Genera/Species	Relative abundance (%)	Estimated Catch	Group Catch	% of Group Catch	Z (P/B)
Large Predators (11)				15.5111	56.26	
Carcharinidae	*Carcharinus* spp.	0.01	0.0030		0.02	
Coryphaenidae		3.02	0.8909		5.74	
Scombridae	*Auxis thazard*	5.52	1.6284		10.50	
	Euthynnus affinis	0.19	0.0561		0.36	
	Katsuwinus pelamis	32.25	9.5138		61.34	
	Scomberomorus commerson	1.58	0.4661		3.00	
	Thunnus albacarres	10.01	2.9530		19.04	
Large zoobenthic feeders (10)				0.0620	0.22	
Dasyatidae	*Dasyatis* spp.	0.21	0.0620		100.00	
Intermediate Predators (9)				2.0603	7.47	1.42
Carangidae	*Caranx* spp.	3.15	0.9293		45.10	2.26
Chirocentridae		0.01	0.0030		0.14	
Formionidae		0.01	0.0030		0.14	
Lutjanidae		0.57	0.1682		8.16	
Lethrinidae		2.19	0.6461		31.36	1.29
Megalopidae		0.01	0.0030		0.14	
Muarenosocidae		0.02	0.0059		0.29	
Plotosidae	*Plotosus* spp.	0.02	0.0059		0.29	
Psettodidae		0.01	0.0030		0.14	
Serranidae	*Epinephalus* spp.	0.14	0.0413		2.00	
Synodontidae	*Saurida tumbil*	0.01	0.0030		0.14	
Sphyraenidae		0.83	0.2449		11.88	
Trichiuridae	*Trichiurus haumela*	0.01	0.0041		0.20	
Small pelagics (8)				7.5520	27.39	1.34
Scombridae	*Rastrelliger brachysoma*	0.55	0.1623		2.15	
	Rastrelliger chrysozonus	0.44	0.1298		1.72	
	Rastrelliger kanagurta	2.19	0.6461		8.55	1.97
Engarulidae	*Stolephorus* spp.	4.52	1.3334		17.66	2.47
Exocoetidae		1.39	0.4101		5.43	
Caesiodidae	*Caesio spp.*	0.31	0.0915		1.21	
Clupeidae		2.10	0.6195		8.20	
Carangidae	*Selar boops*	3.34	0.9853		13.05	
	Selar crumenopthalmus	0.16	0.0472		0.63	
	Decapterus kurroides	0.04	0.0118		0.16	
	Decapterus moruadsi	3.28	0.9676		12.81	3.58
	Decapterus macrosoma	3.23	0.9529		12.62	2.22
	Deacpterus macarellus	0.20	0.0590		0.78	
	Magalaspis cordyla	0.35	0.1033		1.37	
	Selaroides leptolepis	0.25	0.0738		0.98	
Belonidae		2.35	0.6933		9.18	
Hemiramphidae	*Hemiramphus* spp.	0.90	0.2655		3.52	

Table 3. (continuation)

Group/Family	Representative Genera/Species	Relative abundance (%)	Estimated Catch	Group Catch	% of Group Catch	Z (P/B)
Demersal zoobenthos feeders (7)				1.2685	4.60	
Apogonidae	*Apogon* spp.	0.03	0.0089		0.70	
Gerridae	*Gerres* spp.	0.13	0.0384		3.02	
Haemulidae		0.16	0.0472		3.72	
Holocentridae		0.09	0.0266		2.09	
Leiognathidae	*Leiognathus* spp.	0.15	0.0443		3.49	
Mullidae	*Upeneus* spp.	0.83	0.2449		19.30	
Mugilidae	*Mugil* spp.	0.11	0.0325		2.56	
Nemipteridae		0.64	0.1888		14.88	
Priacanthidae		0.11	0.0325		2.56	
Siganidae		1.94	0.5723		45.12	
Sillaginidae	*Sillago* spp.	0.01	0.0030		0.23	
Sparidae		0.01	0.0030		0.23	
Soleidae		0.02	0.0059		0.47	
Theraponidae	*Therapon* spp.	0.07	0.0207		1.63	
Heterotrophic benthos (6)				0.1505	0.55	
Octopodidae	*Octopus* spp.	0.44	0.1298		86.27	
Loligo	*Loligo* spp.	0.07	0.0207		13.73	
Reef fishes (5)				0.2655	0.96	
Acanthuridae		0.23	0.0679		25.56	
Balistidae		0.09	0.0266		10.00	
Labridae		0.58	0.1711		64.44	
Other invertebrates (4)				0.4838	1.75	
Invertebrates		1.64	0.4838		100.00	
Crustaceans (3)				0.2065	0.75	
Portunidae		0.64	0.1888		91.43	
Scyllaridae		0.05	0.0148		7.14	
Crab		0.01	0.0030		1.43	
Zooplankton (2)				0.0089	0.03	
Sergestid shrimp		0.03	0.0089		100.00	
Phytoplankton (1)						
	TOTAL	93.4540	27.5689	27.5689		

Table 4. Summary of food consumption ratios of various trophic groups.

Species: Zooplankton	
Phytoplankton	0.700
Zooplanton (O' order cycle)	0.050
Detritus	0.250
	1.000
Species: Crustaceans	
Phytoplankton	0.100
Zooplankton	0.200
Crustaceans (O' order cycle)	0.050
Other invertebrates	0.050
Detritus	0.600
	1.000
Species: Other invertebrates	
Phytoplankton	0.200
Zooplankton	0.300
Crustaceans (O' order cycle)	0.050
Other invertebrates	0.050
Detritus	0.400
	1.000
Species: Reef fishes	
Phytoplankton	0.300
Zooplankton	0.500
Crustaceans	0.050
Other invertebrates	0.050
Reef fishes (O' order cycle)	0.050
Detritus	0.050
	1.000
Species: Heterotrophic benthos	
Phytoplankton	0.100
Zooplankton	0.250
Crustaceans	0.100
Other invertebrates	0.100
Reef fishes	0.050
Heterotrophic benthos (O' order cycle)	0.050
Small pelagics	0.100
Detritus	0.250
	1.000
Species: Demersal zooplankton feeders	
Phytoplankton	0.010
Zooplankton	0.300
Crustaceans	0.300
Other invertebrates	0.020
Heterotrophic benthos	0.020
Demersal zooplankton feeders (O' order cycle)	0.020
Intermediate predators	0.030
Detritus	0.250
	1.000

Table 4. (continuation)

Species: Demersal zooplankton feeders	
Phytoplankton	0.010
Zooplankton	0.300
Crustaceans	0.300
Other invertebrates	0.020
Heterotrophic benthos	0.020
Demersal zooplankton feeders (O' order cycle)	0.020
Intermediate predators	0.030
Detritus	0.300
	1.000
Species: Small pelagics	
Phytoplankton	0.350
Zooplankton	0.500
Crustaceans	0.050
Other invertebrates	0.050
Detritus	0.050
	1.000
Species: Intermediate predator	
Zooplankton	0.350
Crustaceans	0.100
Other invertebrates	0.050
Reef fishes	0.050
Heterotrophic benthos	0.100
Demersal zooplankton feeders	0.200
Small pelagics	0.050
Intermediate predator (O' order cycle	0.050
Detritus	0.050
	1.000
Species: Large zoobenthos feeders	
Zooplankton	0.300
Crustaceans	0.150
Other invertebrates	0.150
Detritus	0.400
	1.000
Species: Large predators	
Zooplankton	0.100
Reef fishes	0.050
Heterotrophic benthos	0.050
Small pelagics	0.550
Intermediate predator	1.200
Large predator	0.050
	1.000

Table 5. Summary of selected output statistics obtained via ECOPATH II for the Lagonoy Gulf coastal fisheries ecosystem. Estimates in brackets are input parameters.

Group No.	Group name	Biomass	E (=F/Z)	EE[a]	GE[b]	Flow to detritus	Trophic level	Omnivory Index
1	Phytoplankton	(6150.000)	-	0.238	-	332667.438	1.000	0.0000
2	Zooplankton	(524.000)	-	0.272	0.239	54903.988	2.053	0.526
3	Crustaceans	106.641	-	0.950	0.182	490.549	2.351	0.2958
4	Other invertebrates	125.651	-	0.950	0.200	395.799	2.456	0.3216
5	Reef fishes	(11.500)	0.006	1.545	0.103	51.259	2.754	0.3361
6	Heterotrophic benthos	19.955	0.003	0.950	0.186	69.503	2.893	0.4851
7	Demersal zooplankton feeders	12.919	0.817	0.950	0.739	25.101	2.899	0.4359
8	Small pelagics	83.927	0.067	0.950	0.075	306.081	2.667	0.3068
9	Intermediate predator	30.082	0.049	0.950	0.120	73.131	3.438	0.2770
10	Large zoobenthos feeders	0.053	0.90	0.900	0.159	0.094	2.737	0.3813
11	Large predator	10.473	0.74	0.950	0.238	18.642	3.834	0.2000
12	Detritus	-	-	0.100	-	0.000	1.000	0.1420

[a] ecotrophic efficiency (proportion of fishing plus predatory mortality to total mortality.

[b] gross efficiency = production/food consumption.

Table 6. Summary statistics for the preliminary steady-state trophic model of the coastal fisheries resources in Lagonoy Gulf.

Sum of all consumption	=	153691.0
Sum of all exports	=	349961.9
Sum of all respiratory flows	=	86688.1
Sum of all flows into detritus	=	389001.6
	=	
Total system throughput	=	979342.7
Sum of all production	=	472914.7
	=	
The fishery has a "mean trophic level	=	4.39
It's gross efficiency (catch/prim. prod.) is	=	0.000063
Calculated total net primary production	=	436650.0
Total primary production/total respiration	=	5.0370
Net system production	=	349961.844
Total primary production/total biomass	=	61.7156
Total biomass/total throughput	=	0.007
Total biomass (excluding detritus)	=	7075.201
Total catches	=	27.498
Connectance index	=	0.488
System omnivory index	=	0.279

6

Hydrographic Properties of Waters in Lagonoy Gulf

by

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and

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Hydrographic Properties of Waters in Lagonoy Gulf

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Villanoy, C. and E. Encisa. 1995. Hydrographic properties of waters in Lagonoy Gulf, p. 000-000. *In* G. Silvestre, C. Luna, V. Soliman and L. Garces (eds.) Resource and ecological assessment of Lagonoy Gulf, Philippines. ICLARM Tech. Rep. 000, 000 p.

Abstract

Conductivity-Temperature-Depth (CTD) surveys were conducted in Lagonoy Gulf during January, April and July 1994 to determine spatial and temporal variations of the density structure. Seasonal variations of the atmospheric driving mechanisms associated with the Asian monsoons strongly influence the property distributions at the upper 150 m. Water at the level of the permanent thermocline (>150 m) is predominantly supplied from outside the Gulf in the east and is possibly drained through the Maqueda Channel to the north. The water properties at these depths do not show significant monsoon-related variability except as a consequence of upper layer convergence and divergence produced by the interaction of the flow with the presence of the coast.

Introduction

Lagonoy Gulf is a relatively large gulf in the southeastern part of Luzon Island, extending almost 80 km in length and roughly 30 km in width (Fig. 1). One unique feature of the gulf is its very deep bathymetry which plays an important role in determining hydrographic properties and the fact that the water properties are essentially oceanic in character due to the wide connections to the open ocean. As a result, the tidal component of the circulation is expected to be less dominant compared to areas with shallower depths. The gulf is roughly rectangular in shape and the presence of Catanduanes Island results in two different connections of unequal widths which open into the open ocean at different directions. This has some implications on the degree to which processes outside the gulf influence the waters in the interior.

As in most coastal waters in the Philippines, the primary driving force for the circulation at seasonal time scales are the Asian monsoon system. The monsoon system is characterized by the seasonal reversal of winds associated with the oscillation of the pressure field between the Asian and Australian Continents (Wyrtki 1961). In the Philippines, the monsoons prevail from the southwest during June to October with wind speeds of about 3 m s^{-1} and from the northeast from November to February with wind speed magnitudes reaching 5 m s^{-1} (Fig. 2). As a consequence, the wet season in the eastern part of the country occurs during the northeast monsoon in contrast to the western part which coincides with the southwest monsoon season. The transition between the monsoons is generally characterized by weak easterly winds. The monthly mean rainfall estimates obtained from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) station in Virac, Catanduanes show high precipitation during the months of October to December (350-437mm/month) and low precipitation during the months of February to April (90-118mm/month). The monthly mean air temperatures also show a distinct seasonality with maximum values reaching 28°C during May and June and minimum temperatures of about 21°C occurring during February.

The primary objective of this paper is to describe the seasonal variations of the density structure of the Lagonoy Gulf waters and to infer the flow patterns which would produce such density structure.

Methodology

Conductivity-Temperature-Depth (CTD) surveys were conducted in January, April and July 1994 to coincide with the northeast monsoon, summer transition and southwest monsoon seasons, respectively. The positions of the CTD stations during the three surveys are shown in Fig. 3. During the January survey, only the western part of the Gulf was surveyed because of instrument problems. Tabaco Bay was also included during the second survey with 14 stations established. The CTD profiles were measured using an Applied Microsystems STD-12 profiler with a programmed sampling interval of 0.5 m and extended up to a maximum of 400 m. The location of each station was determined using a hand-held Magellan NAV1000 Global Positioning System (GPS).

Results

The water properties in Lagonoy Gulf are essentially oceanic in character (e.g. small salinity gradients), apparently due to the deep bathymetry and wide connections with the open ocean allowing significant water exchange. The general features of the hydrographic properties can be described using a scatterplot of the temperature and salinity combinations on a temperature-salinity (TS) diagram for each of the seasonal surveys. The TS plots for January, April, July and a separate diagram for the Tabaco Bay stations are shown in Fig. 4. The solid lines in Fig. 4 represent lines of constant density. In all the surveys, temperature always decreases with depth and is characteristic of tropical waters. The seasonal variation of temperature reflects the variation of surface heat flux with coldest temperatures found during January and warmest during April. The shallow depths in Tabaco Bay result in generally warm temperatures (>25°C) throughout the water column while in Lagonoy Gulf, the coldest temperature measured was around 10°C at about 400 m depth which was the deepest limit of the CTD casts.

The TS curves in Lagonoy Gulf also exhibit a subsurface salinity maximum which is found at around 150 m and represents the upper boundary of the permanent thermocline as the properties below this depth do not show significant seasonal variability. The formation region of this salinity maximum is found just below 30°N in the North Pacific where surface salinity in excess of 35 psu is found throughout the year (Tomczak and Godfrey 1994). This water mass is carried by the major ocean currents in the Pacific and the existence of the upper salinity maximum in the Lagonoy Gulf profiles suggests that the exchange between the gulf and the open ocean is significant and that topographic or terrestrial factors do not affect the water characteristics significantly particularly below the surface boundary layer.

The base of the permanent thermocline, referred to as the intermediate water, is characterized by the lower salinity minimum. However, this feature was not resolved in the CTD surveys because the core layer of the salinity minimum is found at depths greater than the maximum depth of the CTD casts. In the upper 150 m, seasonal variations are evident which can be attributed to atmospheric heating and precipitation. As mentioned earlier, water temperatures were generally warmer during April while lower surface salinities were observed during January which coincide with the rainy season for this part of the country.

For convenience in presenting the density structure of the waters in Lagonoy Gulf, horizontal distributions of temperature, salinity and densities at depths of 2, 80, 150 and 250 m for January, April and July will be presented separately. The presentation of the results beyond 2 m however, will be limited only to the April and July data as the January data did not extend throughout the whole gulf. However, general flow patterns during the northeast monsoon will be extrapolated from the numerical circulation model developed for Lagonoy Gulf as described in Villanoy and Encisa (this vol.). The contour plots of the horizontal property distributions are shown in Figs. 5-8. The selected depths were chosen to represent property fields at the surface (5 m), below the mixed layer (80 m), the salinity maximum (150 m) and the permanent thermocline (250 m). However, it should be noted that the different layers are not separated by distinct boundaries. Rather, a gradual transition of characteristics is evidenced by the density profiles which show an almost linearly increasing density with depth, at least for the top 400m.

The horizontal distribution of temperature at 2 m (Fig. 5a) is generally decreasing towards the mouth of Lagonoy Gulf during January and April but the highest temperatures were observed in the western part of the gulf during April. This is probably due to heat flux thru the surface and freshwater runoff from the large rivers in this part of the gulf which can establish near surface stratification thereby suppressing vertical mixing of the warm surface waters with the cooler subsurface waters resulting in warmer surface temperatures compared to the July temperatures. This is supported by the horizontal salinity distribution at 2 m (Fig. 5b) which shows lower salinities at the western part of the gulf. On the other hand, the water property distributions at 2 m for July is generally uniform throughout the gulf.

At 80 m, local atmospheric effects on the water density are diminished and the property distributions partially reflect the flow patterns. Isotherm patterns for April (Fig. 6a), for instance, are oriented along the axis of the gulf with the warmest temperatures found off Catanduanes Island and minimum temperatures found at the southwestern boundary of the gulf. On the other hand, the isotherms for the July data are oriented perpendicular to the length of the bay with colder water found at the western part and warmer waters at the mouth. The salinity field (Fig. 6b) shows a slightly similar pattern except for the reversal of the gradients. During April, the higher salinities are found near the mouth while in July, high salinities are found in the western part of the gulf. The distribution of the density (Fig. 6c) follows the salinity distribution closely. Due to the coastline configuration of the gulf, any horizontal flow at any depth will result in either a convergence or divergence of the flow simply because the inner part of the gulf is closed. As a result, some vertical motion may occur and any changes in the properties in the horizontal motion may be an indication of the contribution of waters from a different depth. For example, the July data (Fig. 6a) show a positive thermal gradient towards the mouth of the gulf. Since temperature is decreasing monotonically with depth, it is likely that the colder temperatures at the western part of the gulf may be entrained from below to supply the divergence region resulting from horizontal flow seawards. This is consistent with the salinity field where the higher salinities are found in the western part. Note that as mentioned earlier the subsurface salinity maximum is found at around 150 m. Thus, at 80 m, the salinity will still be increasing with depth and any upward motion at the western part may result in the entrainment of slightly saltier water at 80 m. This is not as evident for the April data but some flow patterns can still be discerned. At depths where frictional effects are small (e.g., outside the surface and bottom frictional boundary layers), horizontal currents are usually associated with sloping isopycnals across the current which is due to the rotational effects of the earth. In the northern hemisphere, the isopycnals slope downwards to the right of the direction of the current and consequently, the temperature and salinity vary in the horizontal motion across the current. Applying these principles to the April case, it can be inferred that the flow at 80 m is predominantly towards the northeast with the likelihood of some of the flow entering Maqueda Channel from the south. This is supported by the temperature, salinity and density horizontal distributions shown in Fig. 6.

The fact that the lower salinity maximum is found at depths of around 150 m can be also used to infer general horizontal flow patterns at this depth based on the argument that the salinity of the salinity maximum will be eroded by mixing with less saline waters from above and below. The horizontal salinity field at 150 m shown in Fig. 7b shows decreasing salinities from the mouth towards the interior of the gulf. This is consistent with the above argument as the source for the lower salinity maximum is from outside the gulf hence the highest salinities are expected to be found closer to the source. As the water moves towards the inner portions of the gulf, it is continually mixed with the fresher waters from above and below resulting in a continual decrease in salinity. From the contour plots of Fig. 7b, flow at 150 m is towards the interior. The high salinities near Maqueda Channel can also be interpreted as water flowing from south of Catanduanes Island proceeding directly northwards into Maqueda Channel in view of the similar salinities or relatively small difference in "age". During July, however, the flow appears to be southeastwards in the southern part of the gulf and northwestwards in the northern part. Density gradients at this depth (Fig. 7c) are very weak which indicate that there is a general reduction in current magnitudes compared to the flow at 80 m.

Compared to the property distributions at the different depth levels presented, the distributions at 250 m (Fig. 8) show the least variability. The temperature range is only <2°C compared to > 3°C at 150 m and salinity varies only by <0.3 psu and density by 0.4 kg m^{-3}. The relative uniformity of the water properties in the deeper parts of the gulf suggests that the currents are weak and that seasonal variability may be small. However, if the flow in the upper layers are to be considered, to satisfy the principle of conservation of volume (continuity equation), it is essential that the net transport in the upper layers must be balanced by an opposite flow in the lower layers.

The horizontal distributions of temperature, salinity and density for Tabaco Bay at 1 m are shown in Fig. 9. The eastern part of the bay is characterized by lower temperatures, higher salinities and higher densities compared to the western part. The lower salinities are presumably due to the river discharge from the rivers surrounding the bay which influences the density field, particularly in the surface layers. Similarly, the mean circulation pattern in Tabaco Bay can be inferred from the property distributions and this can be seen very clearly in the temperature field. Since the mean winds are from the east, it is expected that the eastern and northeastern boundaries of Tabaco Bay will experience surface divergence because the surface layer is being driven towards the mouth. As a consequence, the isotherms will be elevated in these areas as shown in Fig. 9a where the colder waters are found adjacent to the eastern and northeastern boundaries of the bay.

Discussion

Despite the wide connections with the western Pacific, the hydrographic characteristics of Lagonoy Gulf are strongly influenced by seasonal variations of atmospheric forcing associated with the Asian monsoon system. This is very evident in the surface layer where thermohaline effects due to surface heating and freshwater discharge from land-based sources are strong. This can also be shown more clearly by looking at the mixed layer depths (Fig. 10) which is defined as the depth at which the temperature is about 0.5°C less than the surface value (Sprintall and Tomczak 1992). Mixed layer depths are shallower at the northwestern part of the gulf and this can be explained by the fact that the eastern part is more exposed to wave and wind mixing resulting in a deeper mixed layer and that freshwater discharge from the rivers in the western part produces a near surface stratification. This stratification promotes water column stability and inhibits mixing between the warm surface waters and colder subsurface waters.

It is not possible at this point to determine the degree to which processes outside the gulf interact with the local circulation because of the lack of information on the variability of the density structure outside the mouth. The dominant oceanographic feature east of Lagonoy Gulf is a northward flowing current which forms the root of the Kuroshio current and also transports the North Pacific subtropical water whose signature is the subsurface salinity maximum (Ffield and Gordon 1992). The presence of this salinity maximum in the Lagonoy Gulf salinity profiles strongly suggests that part of this current enters the gulf, at least at the 150 m level for the most part of the year and is probably drained out of the gulf through the Maqueda Channel to the north.

The seasonal reversal of the flow patterns above 150 m indicates that the monsoons are an important direct driving mechanism for the circulation of the layers above the permanent thermocline. However, it is also indirectly forcing the circulation at the level of the permanent thermocline as a consequence of the divergence and convergence of the upper layer circulation brought about by the irregular coastline shape.

Conclusion

The circulation of the waters in Lagonoy Gulf inferred from the variations in the density field has been shown to be influenced by several factors. The surface properties, for instance, are directly influenced by the local atmospheric conditions such as surface heating and freshwater runoff from land-based sources. Underneath the mixed layer and above the permanent thermocline (<150 m), the seasonal variation of prevailing winds associated with the Asian monsoon system results in the seasonal reversal of the flow and the divergence and convergence within this layer brought about by the shape of the gulf influences the circulation in the lower layers as a consequence of mass balance. At the level of the permanent thermocline (>150 m), atmospheric influences are reduced and monsoon-related variations are not as evident. Instead, oceanographic processes outside the gulf appear to be more important in determining the density structure. The weaker gradients at the deeper layers is an indication of reduced current magnitudes.

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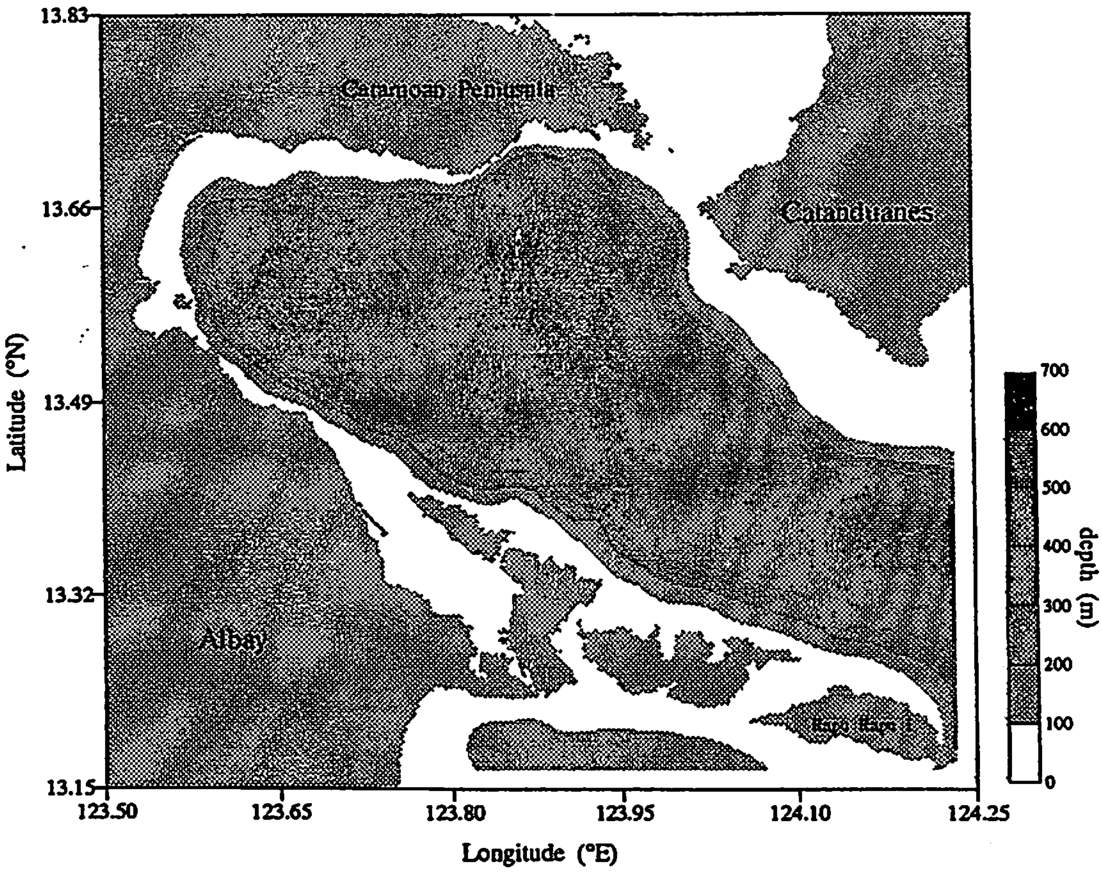

Fig. 1. Bathymetric map of Lagonoy Gulf.

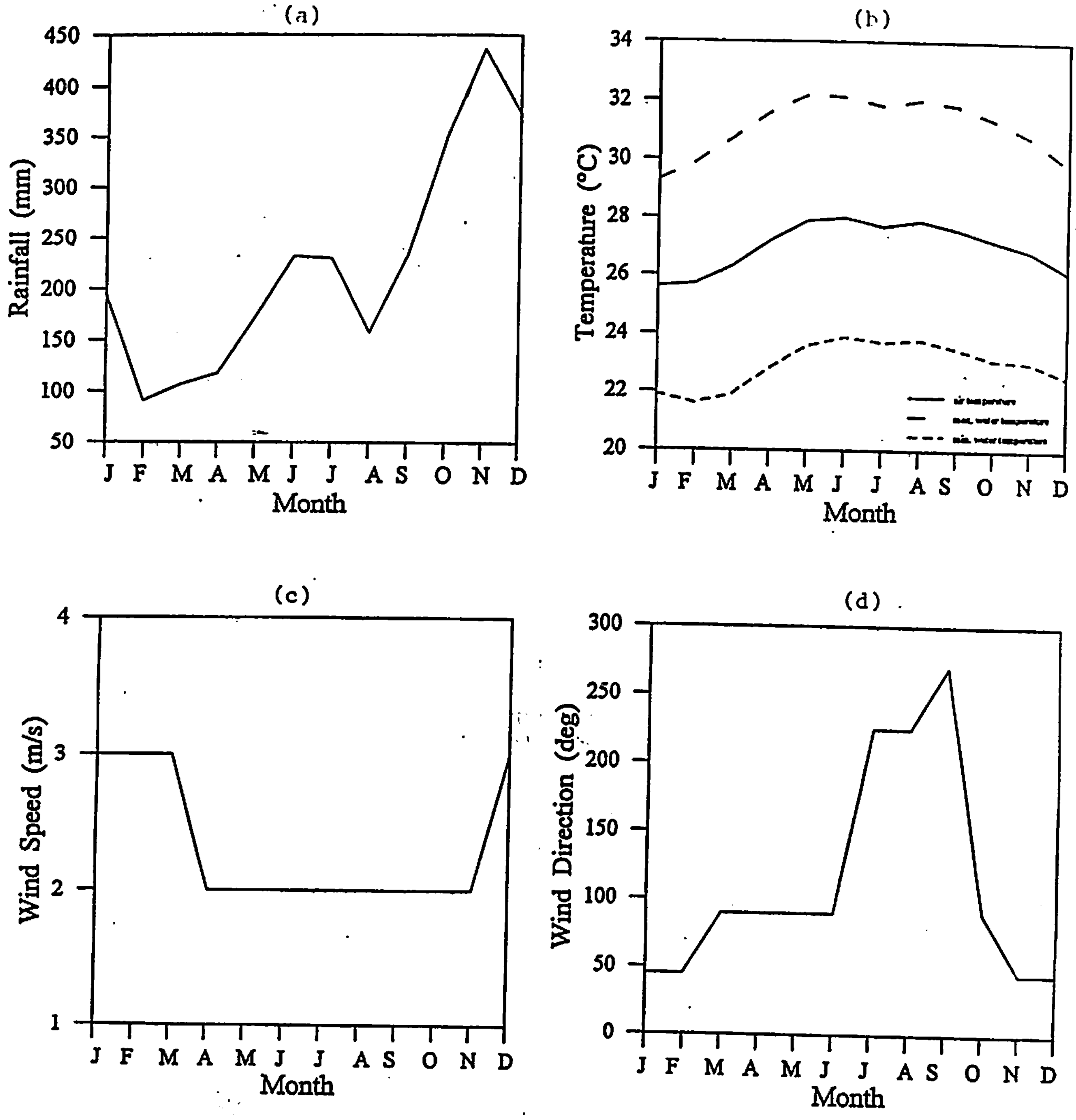

Fig. 2. Monthly mean wind velocity (a), air temperature (b), and rainfall (c) in Virac Catanduanes (from PAGASA).

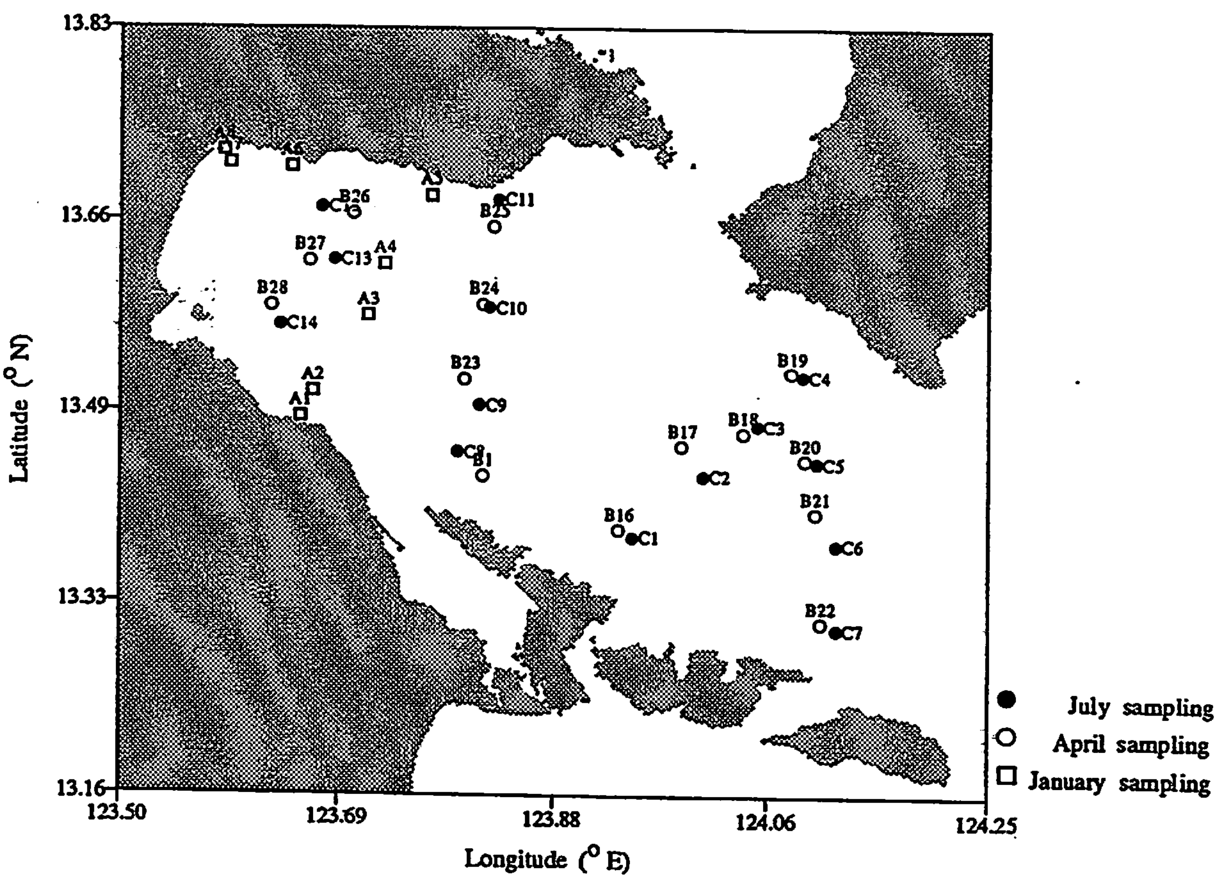

Fig. 3a. CTD Station positions in Lagonoy Gulf.

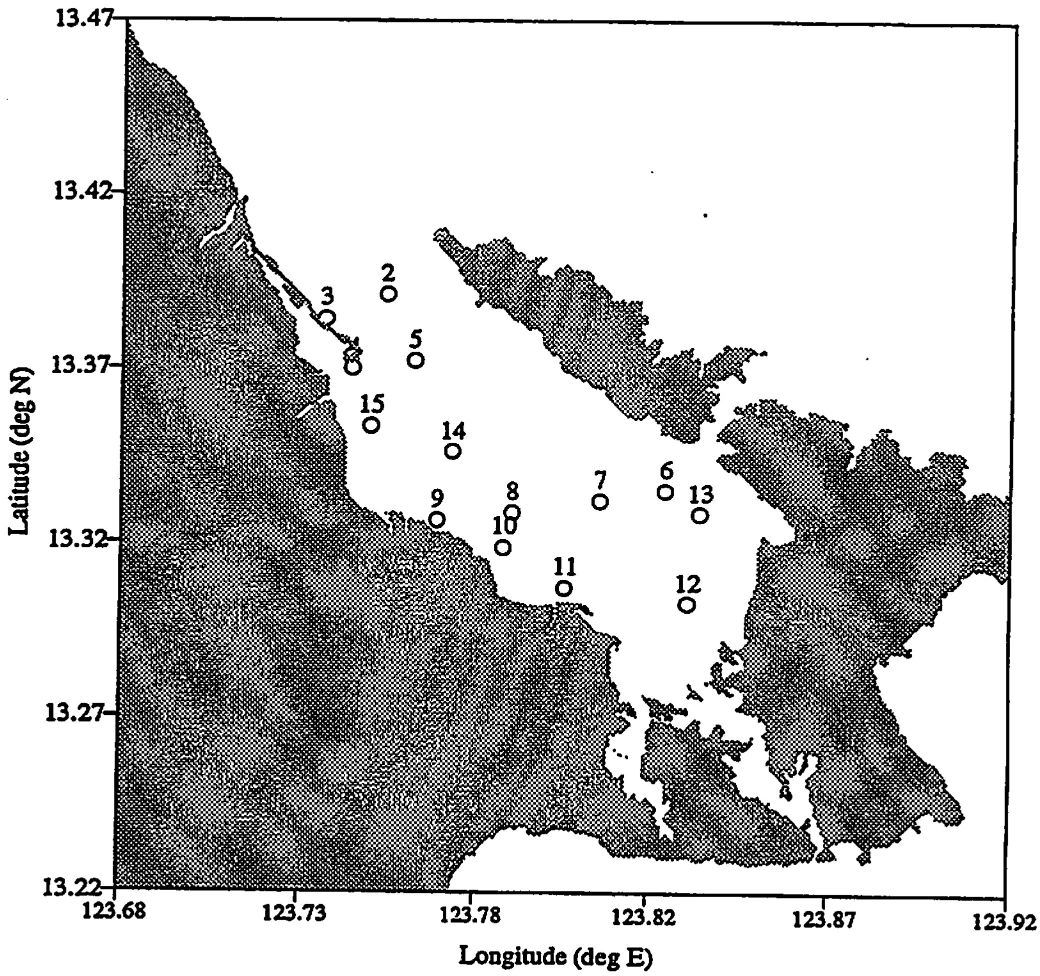

Fig. 3b. CTD Station positions in Tabaco Bay.

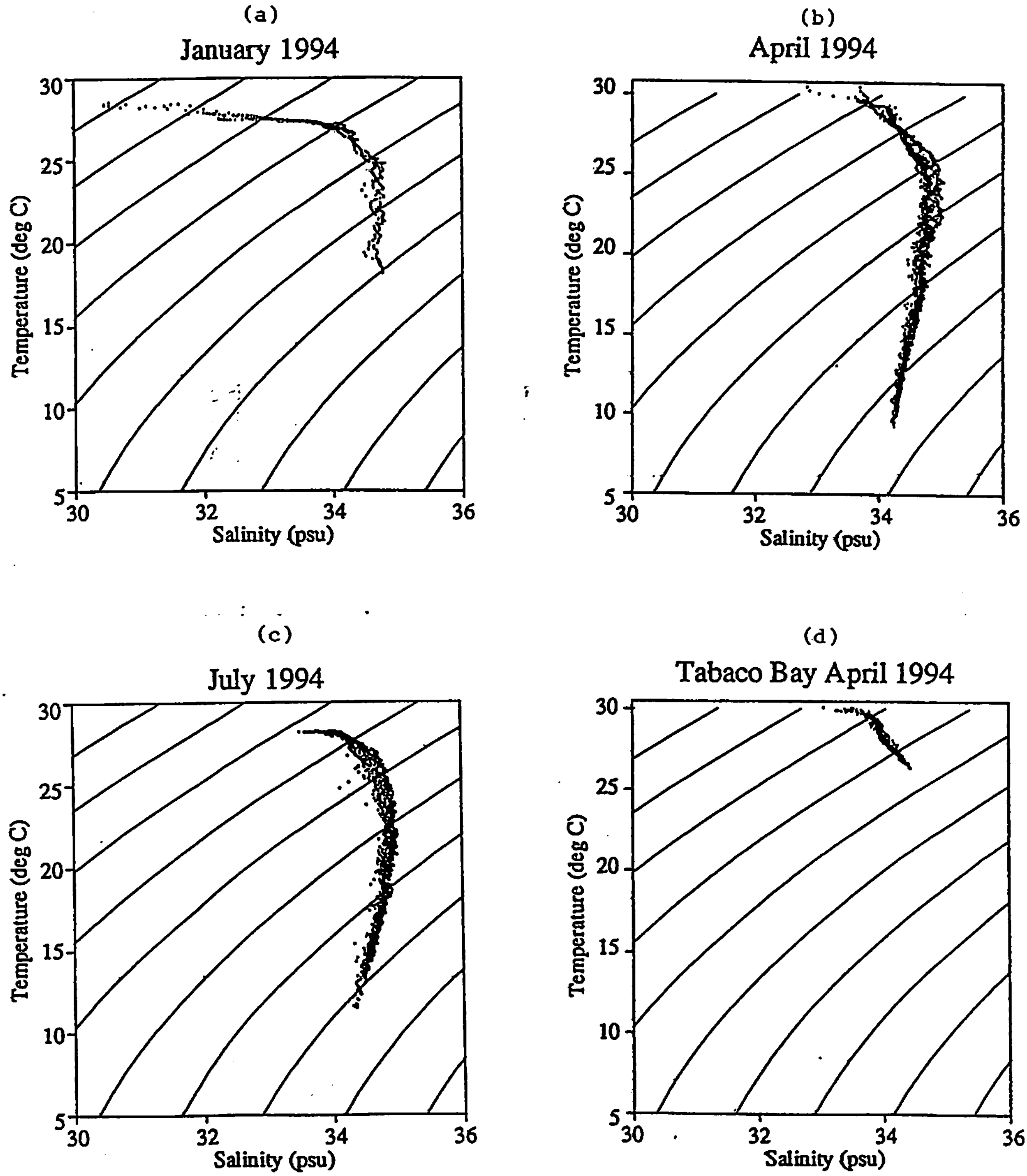

Fig. 4. TS diagrams for January (a), April (b) and July (c) for Lagonoy Gulf CTD data and April (d) for Tabaco Bay.

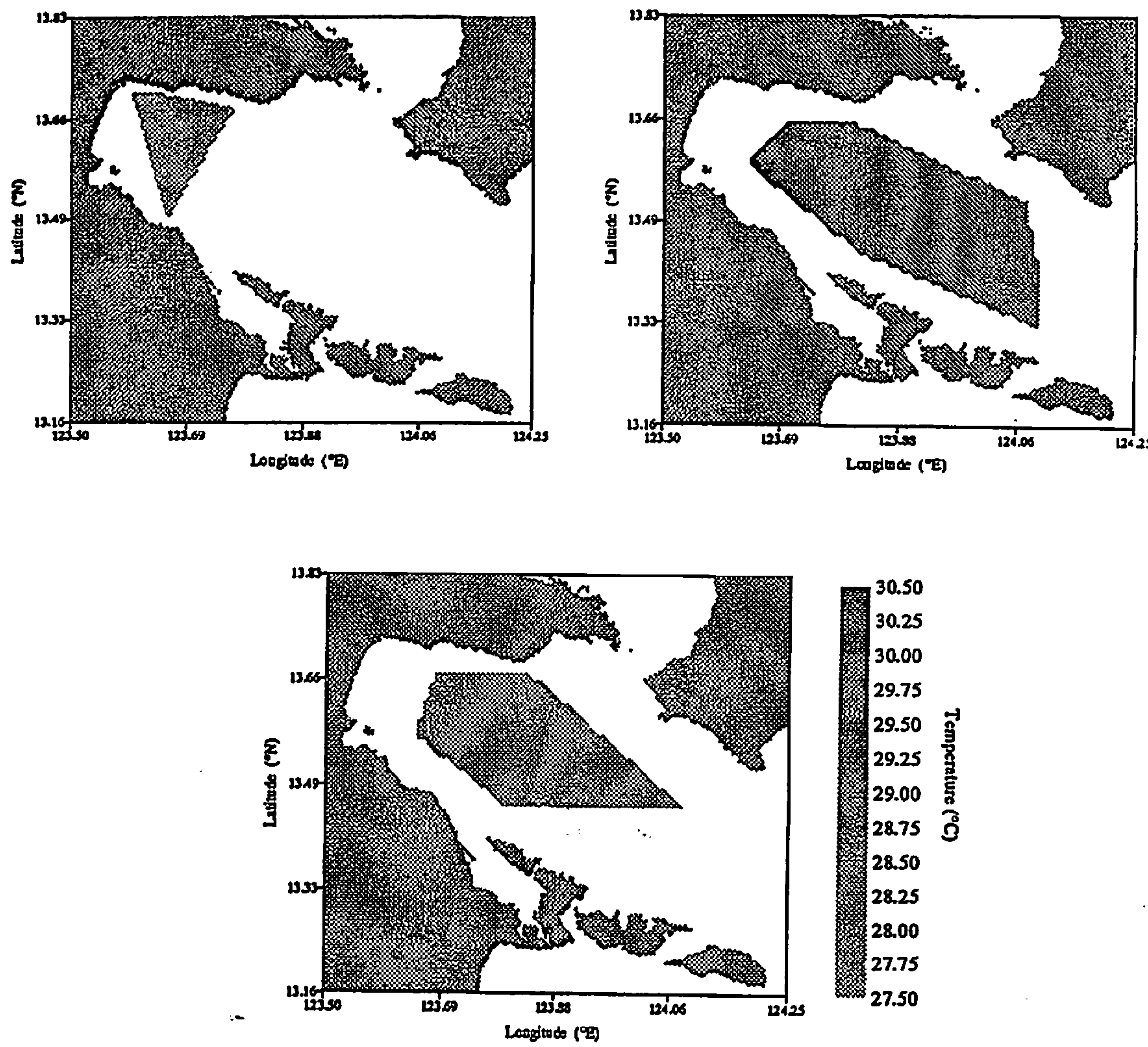

Fig. 5a. Horizontal distributions of temperature at 2m depth.

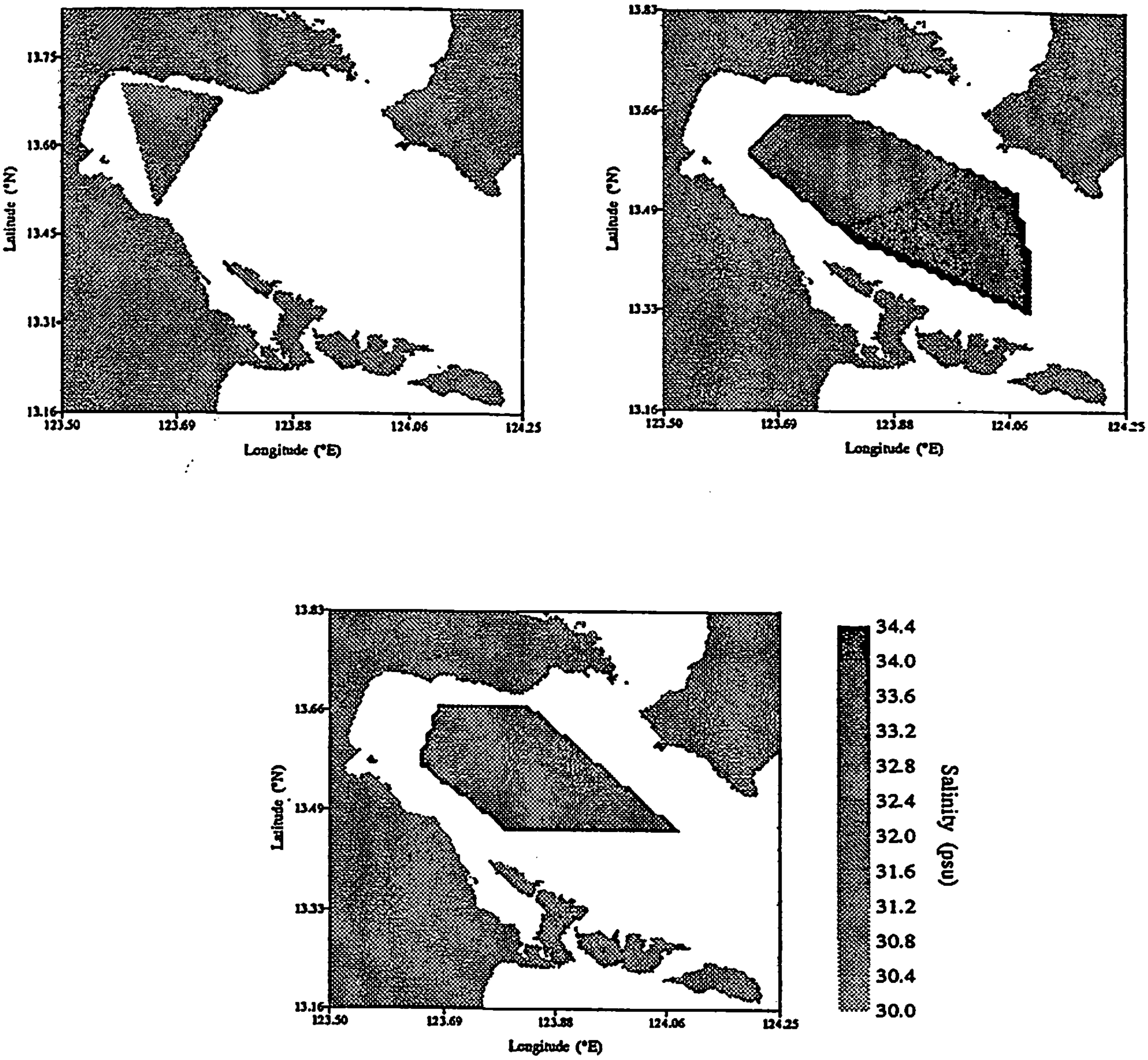

Fig. 5b. Horizonatal distributions of salinity at 2m depth.

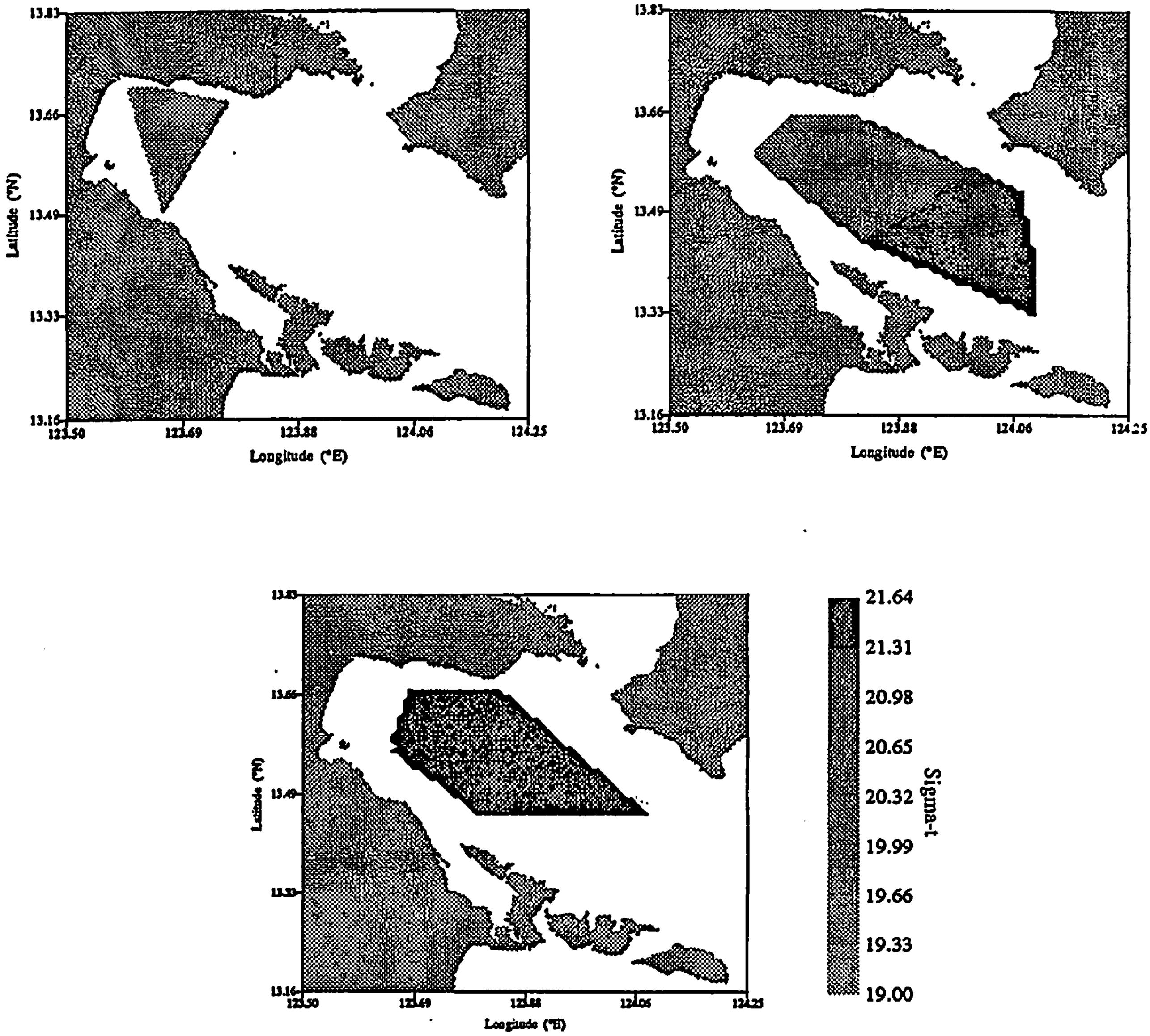

Fig. 5c. Horizontal distributions of density at 2m depth.

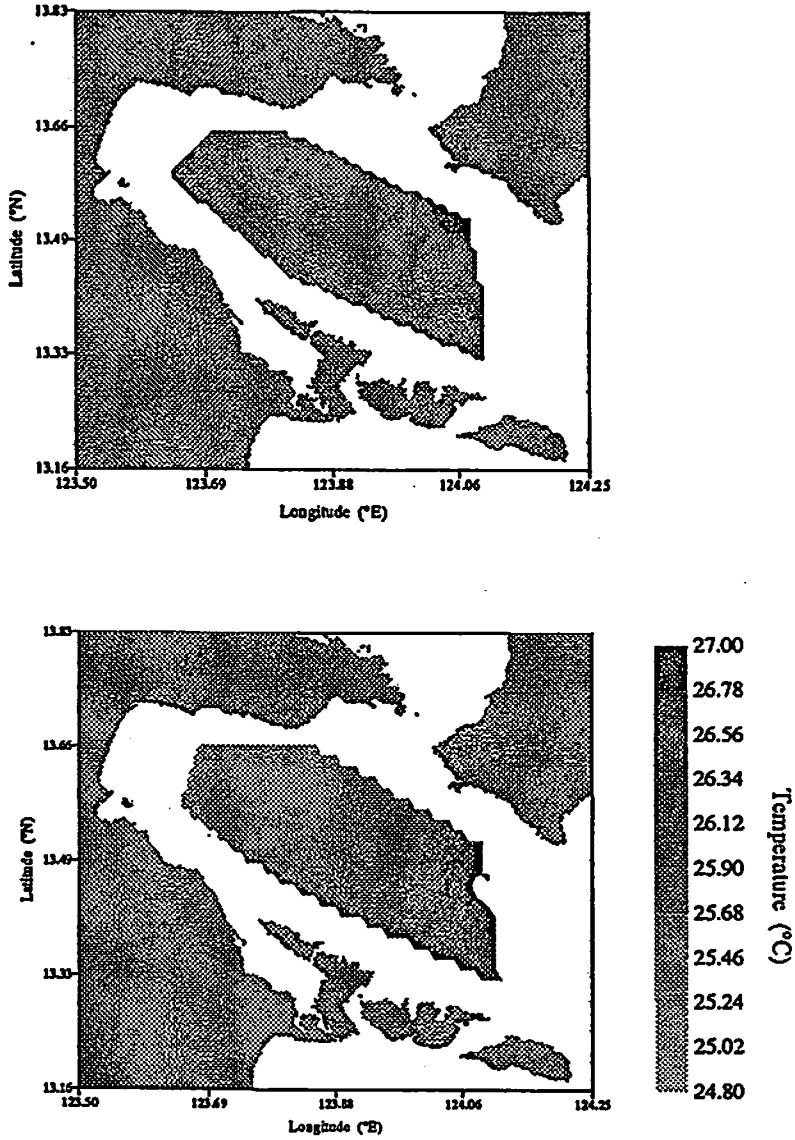

Fig. 6a. Horizontal distributions of temperature at at 80m depth.

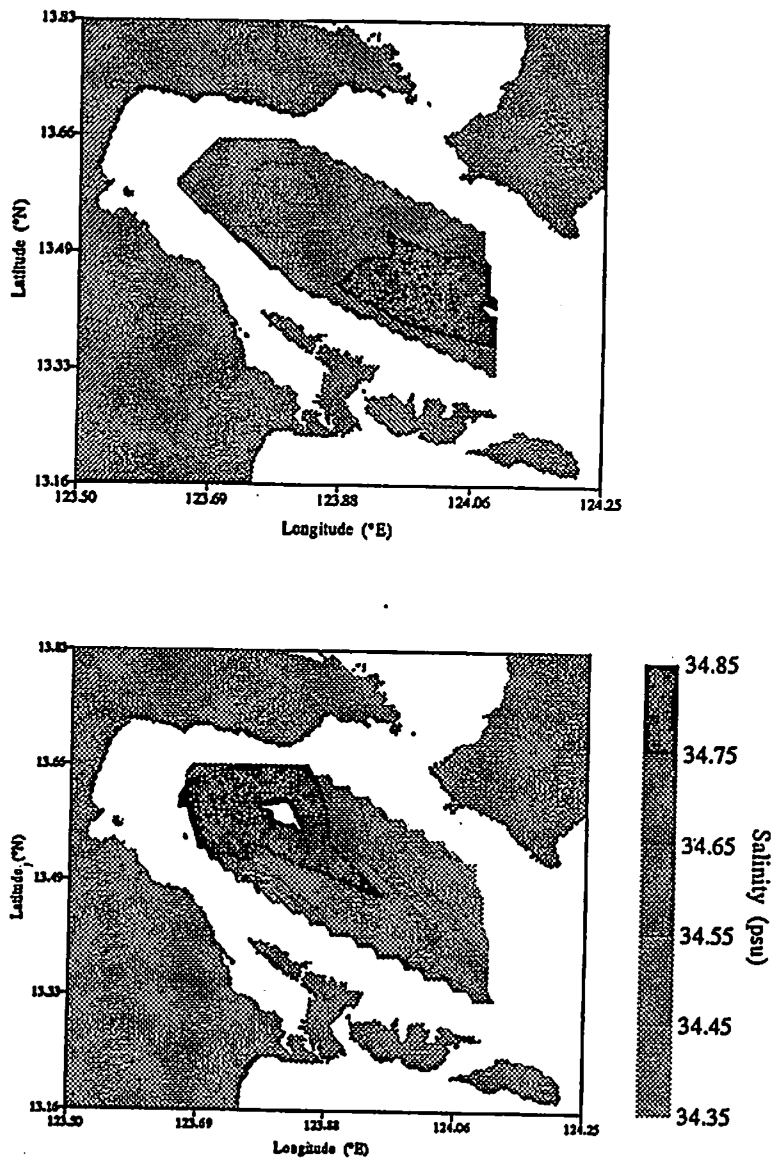

Fig. 6b. Horizontal distributions of salinity at 80m depth.

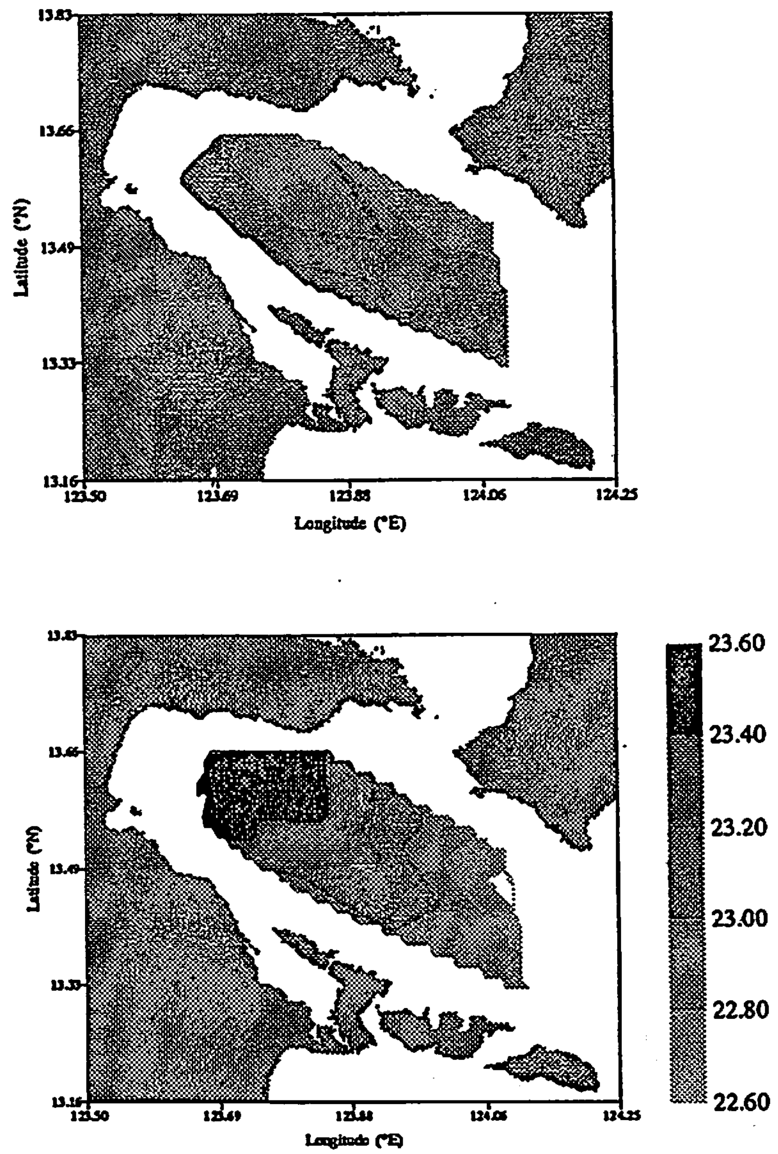

Fig. 6c. Horizontal distributions of density at 80m depth.

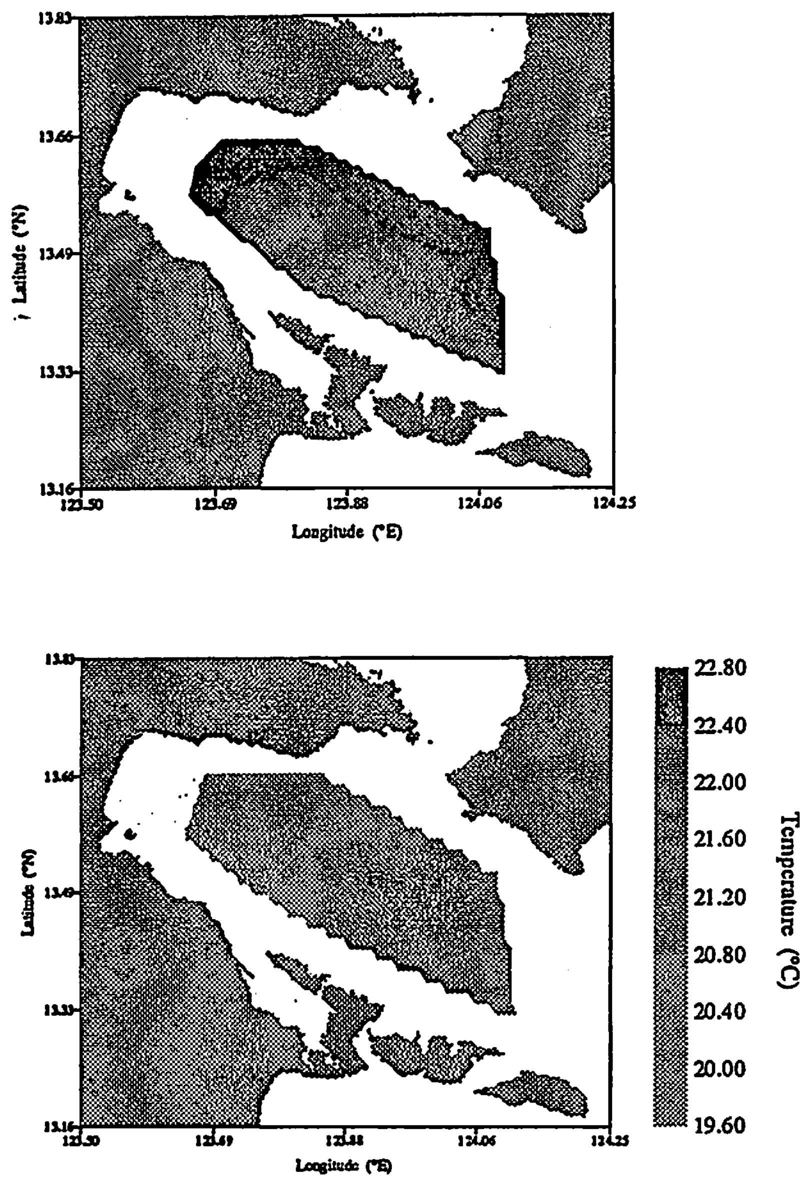

Fig. 7a. Horizontal distributions of temperature at 150m depth.

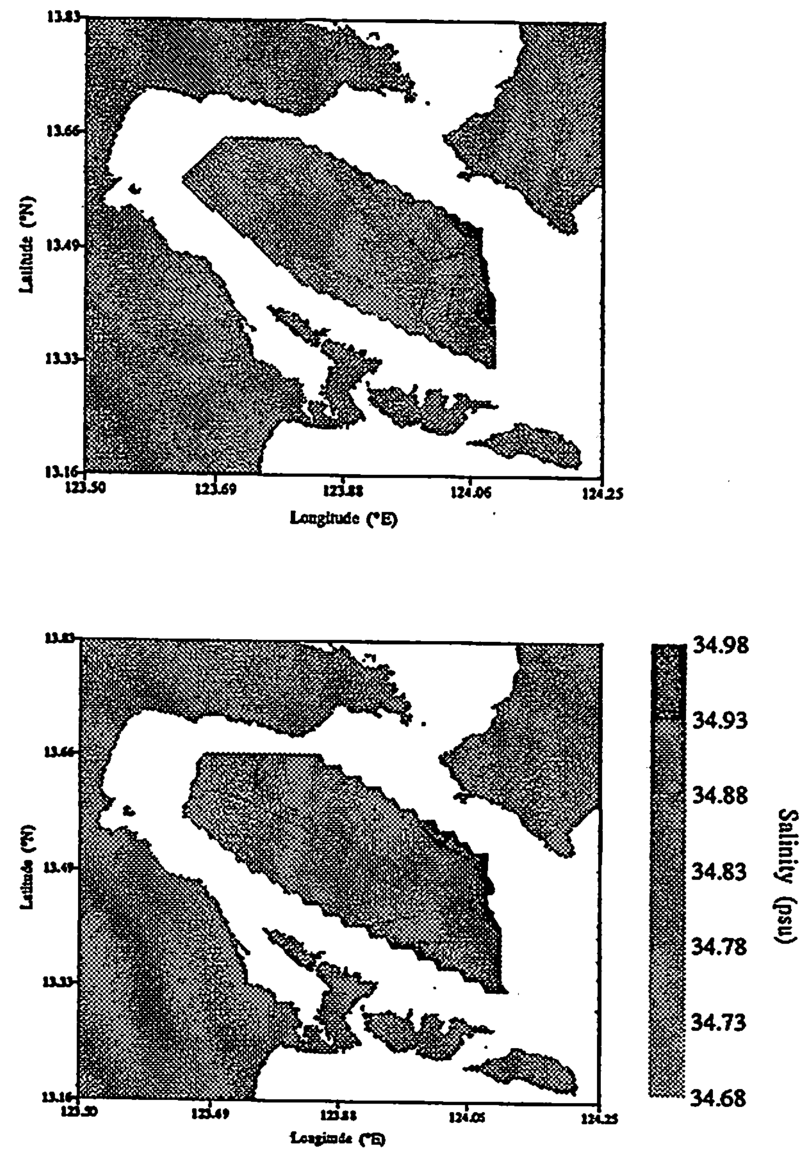

Fig. 7b. Horizontal distributions of salinity at 150m depth.

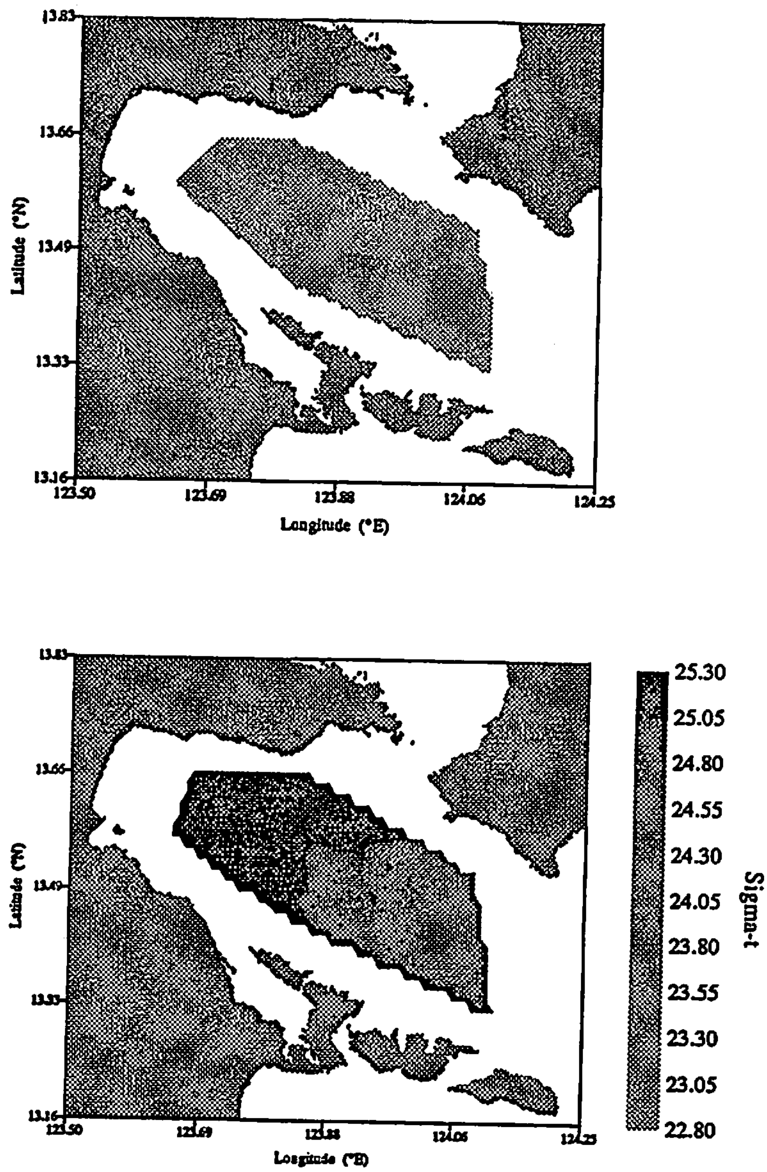

Fig. 7c. Horizontal distributions of density at 150m depth.

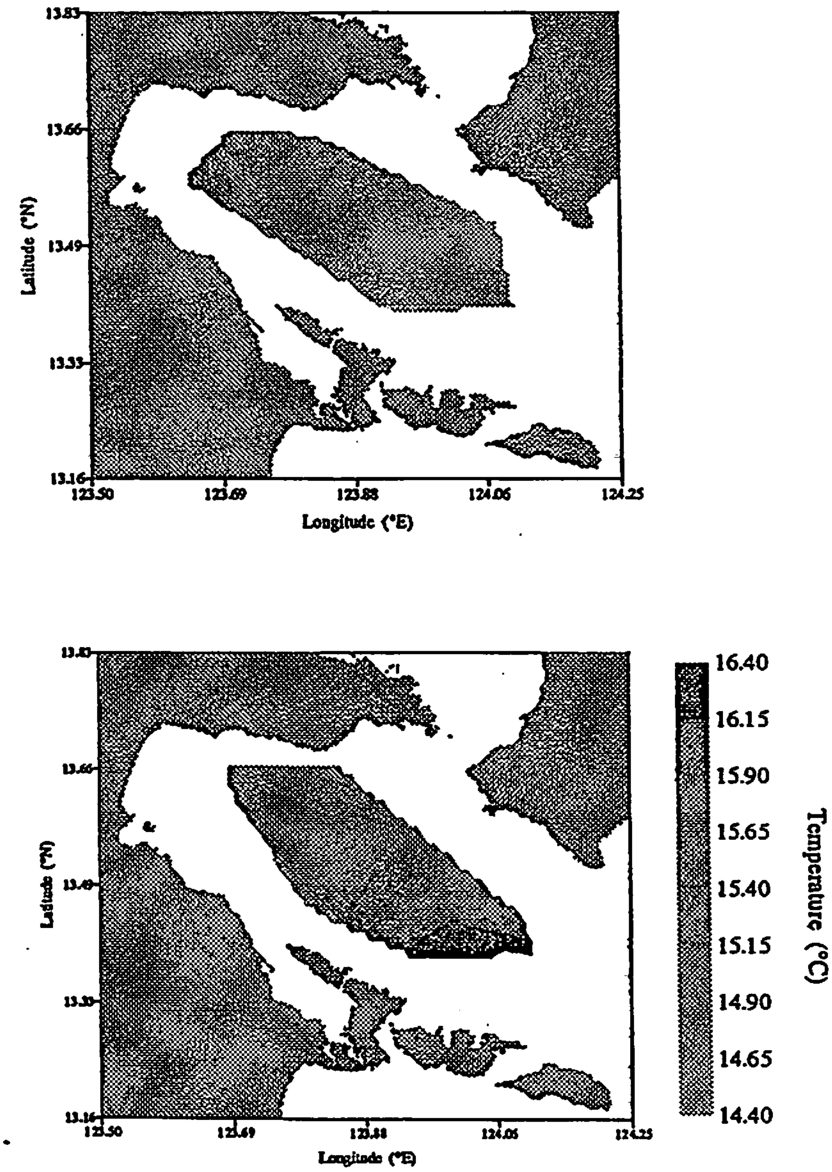

Fig. 8a. Horizontal distributions of temperature at 250m depth.

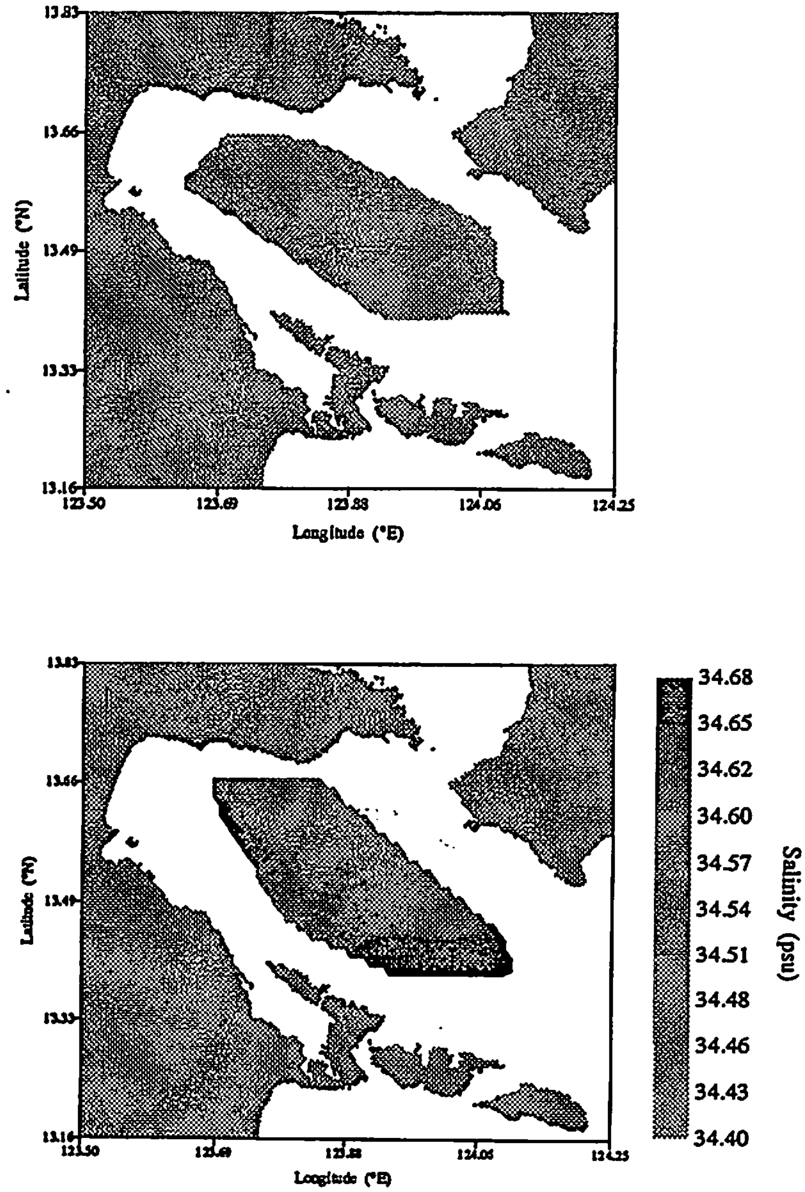

Fig. 8b. Horizontal distributions of salinity at 250m depth.

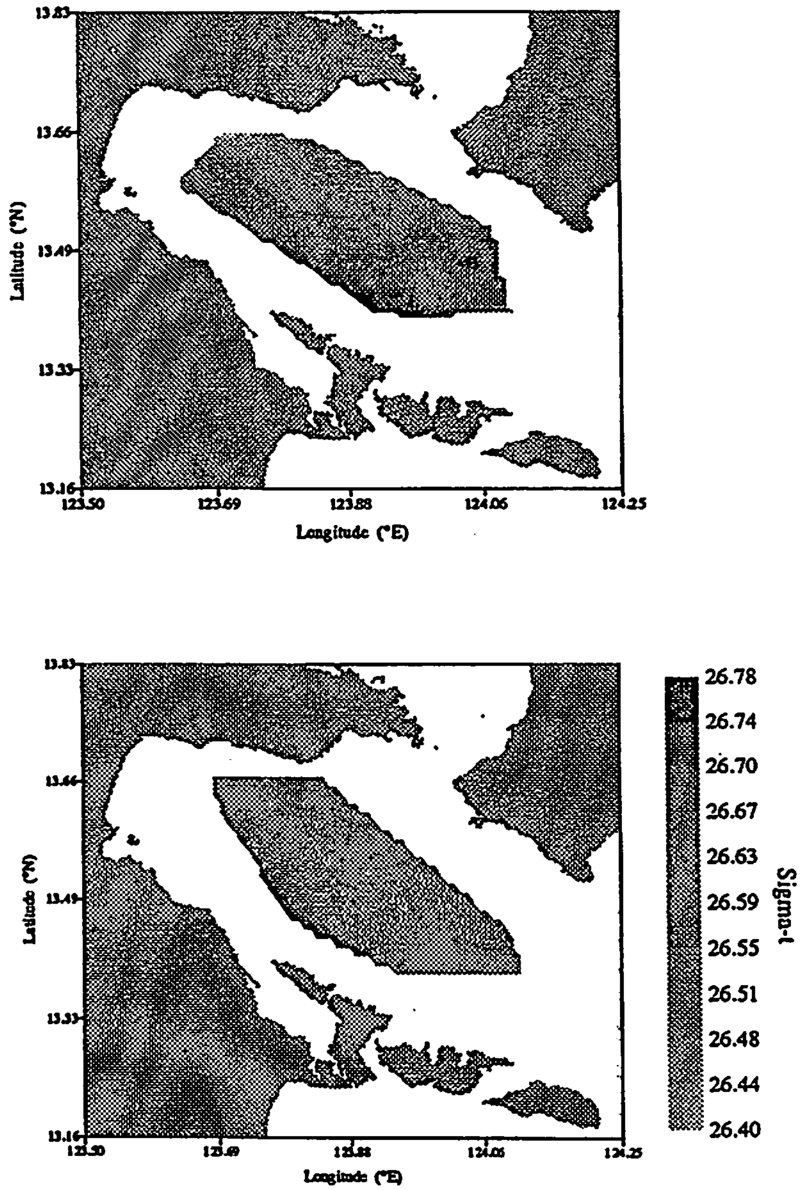

Fig. 8c. Horizontal distributions of density at 250m depth.

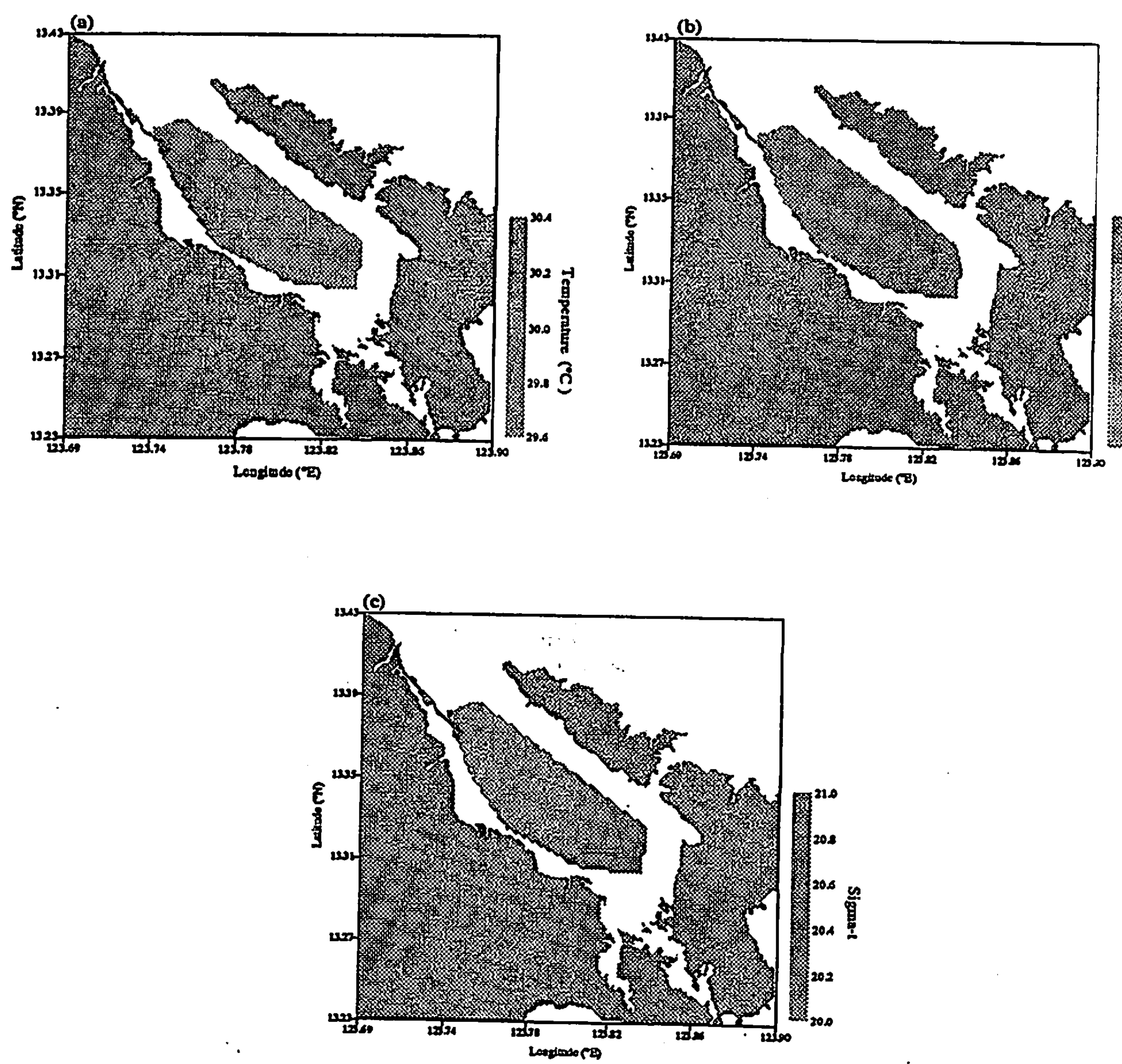

Fig. 9. Surface distributions of temperature (a), salinity (b) and density (c) in Tabaco Bay during April, 1994.

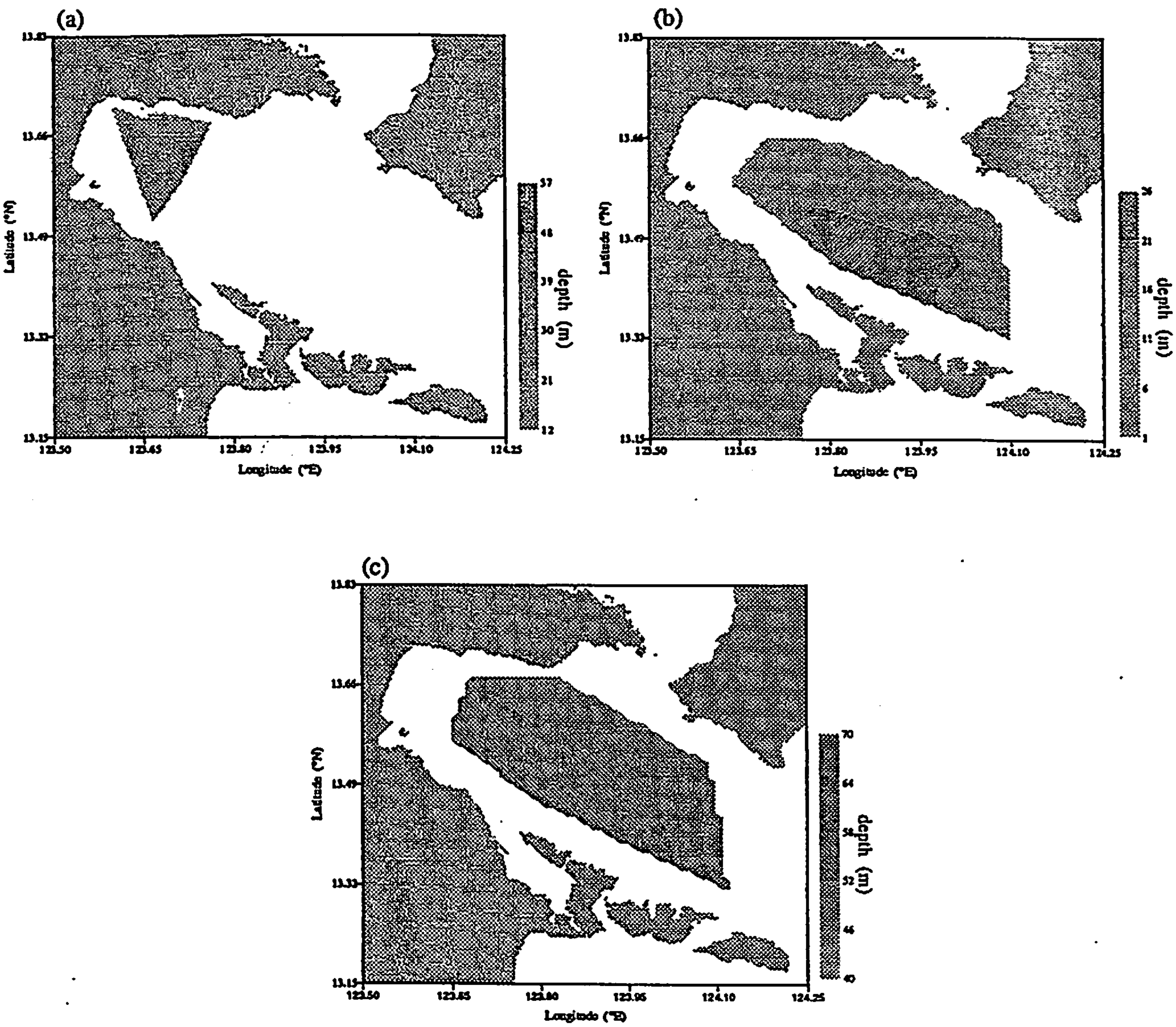

Fig. 10. Mixed layer depths for January, April and July, 1994.

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A Numerical Circulation and Dispersal Model of Lagonoy Gulf

by

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Abstract

A two-layer stratified-flow circulation model of Lagonoy Gulf was developed to simulate seasonal circulation patterns. The results are consistent with circulation patterns inferred from hydrographic data and show a monsoon dominated upper layer and an opposing flow in the lower layer as a consequence of the surface layer divergence and convergence. The main feature of the upper layer circulation is the strong flow between the Maqueda Channel and the mouth of the Gulf between Catanduanes and Rapu-rapu Islands which inhibits water exchange between the waters in the interior west of this flow and the open ocean. As a consequence, dispersal patterns derived from a Langrangian transport model show strong advection out of the gulf of particles released at point sources close to this flow within five days while particles released in the western part of the gulf remains in the western part even after simulation runs of up to 30 days. The tidal component of the circulation does not significantly influence the dispersal patterns of particles released within the gulf.

Introduction

The circulation of the waters in Lagonoy Gulf, as inferred from hydrographic data, is described in a separate paper by Villanoy and Encisa (this vol.) In thc upper 150 m, the circulation is strongly linked to the Asian monsoons and as a consequence, the surface layer flow also reverses seasonally. Within the permanent thermocline, monsoonal effects are reduced and the distribution of the salinity at the subsurface salinity maximum suggests that the flow is directed towards the interior of the gulf through the gulf mouth between Catanduanes Island and Rapu-rapu Island and is drained northward through the Maqueda Channel. Underneath this layer, the flow pattern is generally opposite to that of the upper layers as a result of the convergence and divergence at the upper layers due to the flow constraints imposed by the coastline shape.

The primary objective of this study is to develop a model of the circulation of the waters in Lagonoy Gulf in order to quantify the flow patterns derived from property distributions described in Villanoy and Encisa (in press). The velocity fields derived from the model will also be used to derive potential dispersal patterns of larvae, nutrients and pollutants released in Lagonoy Gulf as well as to estimate the residence times.

Methods

The Circulation Model

The numerical model used in this study is a two-dimensional stratified flow model and is described by Koutitas (1988). The ocean is assumed to be made up of two homogeneous layers of different densities and the average velocities for each layer are calculated by solving the vertically-integrated form of the equations of motion for each layer. The governing equations used in the model are as follows;

$$\frac{\partial \eta_o}{\partial t} + \frac{\partial}{\partial x}(U_o h_o) + \frac{\partial}{\partial y}(V_o h_o) = 0 \qquad (1)$$

$$\frac{\partial (\eta - \eta_o)}{\partial t} + \frac{\partial}{\partial x}(Uh) + \frac{\partial}{\partial y}(Vh) = 0 \qquad (2)$$

$$\frac{\partial U}{\partial t} + U \frac{\partial U}{\partial x} + V \frac{\partial U}{\partial y} = -g \frac{\partial \eta}{\partial x} + \frac{\tau_{o} - \tau_{o}}{\lambda \rho_o h} + fV \qquad (3)$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}=-g\frac{\partial \eta}{\partial y}+\frac{\tau_{sy}-\tau_{iy}}{\lambda\rho_o h}-fU \qquad (4)$$

$$\frac{\partial U_o}{\partial t}+U_o\frac{\partial U_o}{\partial x}+V_o\frac{\partial U_o}{\partial y}=-\lambda g\frac{\partial \eta}{\partial x}-(1-\lambda)g\frac{\partial \eta_o}{\partial x}+\frac{\tau_{ix}-\tau_{bx}}{\rho_o h_o}+fV_o \qquad (5)$$

$$\frac{\partial V_o}{\partial t}+U_o\frac{\partial V_o}{\partial x}+V_o\frac{\partial V_o}{\partial y}=-\lambda g\frac{\partial \eta}{\partial y}-(1-\lambda)g\frac{\partial \eta_o}{\partial y}+\frac{\tau_{iy}-\tau_{by}}{\rho_o h_o}-fU_o \qquad (6)$$

where

U, V are the vertically-averaged components of velocity for the upper layer with initial thickness in no-flow conditions of h,
U_o, V_o are the vertically-averaged components of velocity for the lower layer with initial thickness in no-flow conditions of h_o,
η and η_o are the sea surface elevation and interface displacement, respectively,
f is the coriolis parameter (),
g is the gravitational acceleration (=9.8 m s^{-1}),
λ is the ratio of the densities of the two layers (=0.98) and
ρ_o is the reference density (=1.025 kg m^{-3}).

The surface (τ_{sx}, τ_{sy}), interfacial (τ_{ix}. τ_{iy}) and bottom stress (τ_{bx}, τ_{by}) terms are parameterized by;

$$\frac{\tau_{sx}}{\rho_o}=k_w W_x\sqrt{\left(W_x^2+W_y^2\right)} \qquad (7)$$

$$\frac{\tau_{sy}}{\rho_o}=k_w W_y\sqrt{\left(W_x^2+W_y^2\right)} \qquad (8)$$

$$\frac{\tau_{ix}}{\rho_o} = (U - U_o) k_1 \sqrt{\left[(U - U_o)^2 + (V - V_0)^2\right]} \tag{9}$$

$$\frac{\tau_{iy}}{\rho_o} = (V - V_o) k_1 \sqrt{\left[(U - U_o)^2 + (V - V_0)^2\right]} \tag{10}$$

$$\frac{\tau_{bx}}{\rho_o} = k_b U_o \sqrt{\left(U_o^2 + V_o^2\right)} \tag{11}$$

$$\frac{\tau_{by}}{\rho_o} = k_b V_o \sqrt{\left(U_o^2 + V_0^2\right)} \tag{12}$$

where k_w, k_i and k_b are the wind, interfacial and bottom drag coefficients, respectively and W_x and W_y are the components of the prescribed wind velocity.

The equations are solved on a 40x34 grid with a grid length of 1,800 m (Fig. 1) using an explicit finite difference scheme on a staggered grid. The model includes two open boundaries; across Maqueda Channel and along the mouth of the Gulf between Catanduanes and Rapu-rapu Island. The bathymetry used in the model was obtained from navigational charts and is also shown in Fig. 1. A minimum depth of 15 m was imposed on the model bathymetry.

The tidal forcing was also introduced into the model by prescribing the tidal elevations at the eastern open boundary and the wind-driven component is forced by prescribing the wind speeds in equations (7) and (8). The velocity, sea surface elevation and interface displacements at the open boundaries are specified using the Orlanksi radiation condition (Chapman 1985). Several experiments were also conducted in order to determine the sensitivity of the model to the friction coefficients.

The wind-forced model was integrated with time and calculations were stopped when the velocity, sea surface and interface displacement fields approached steady state ($\partial / \partial t \approx 0$). The time series for kinetic energy, average sea surface elevation and interface displacements are shown in Fig. 2.

The Dispersal Model

Dispersal of particles in the velocity fields calculated from the circulation model was simulated using a Langrangian transport model (Koutitas 1988). Unlike Eulerian techniques which calculate the concentration of substances at fixed points in space, Langrangian methods involved tracking the paths of individual particles as they are carried by the moving fluid. The dispersal of substances in a fluid medium can be assumed to be influenced by three processes namely, advection, turbulent diffusion and decay. The advective component is accomplished by the local fluid velocity which is derived from the circulation model. Diffusion is simulated by assuming a random Brownian motion of the particles which has been established to produce realistic diffusion patterns (Koutitas 1988). The predicted path of a particle can be calculated using the equation;

$$X_i^{n+1} = X_i^n + \left(U_a + U_d\right) * \Delta t \tag{13}$$

$$Y_i^{n+1} = Y_i^n + \left(V_a + V_d\right) * \Delta t \tag{14}$$

where X_i^{n+1} and Y_i^{n+1} are the coordinates of particle i at time $t=n+1$, U_a and V_a are the advective velocities derived from the circulation model, U_d and V_d are the velocity of the particles executing a random walk and Δt is the model time step. The turbulent velocities, U_d and V_d, are selected using a random number from a uniformly distributed sample within the range from $-U_r$ to $+U_r$ where;

$$U_r = \sqrt{\left(\frac{6D}{\Delta t}\right)} \tag{15}$$

and D is the diffusion coefficient.

Results

A total of four experiments were conducted to determine the seasonal and tidal circulation patterns in Lagonoy Gulf. Table 1 lists the different experiments and friction parameters used.

Wind-driven Circulation

The vertically-averaged velocities are shown in Fig. 3. During the northeast wind-forced case (Fig. 3a), the flow through the Maqueda Channel is directed towards the interior of the Gulf after which it turns southeastwards to exit north of Rapu-rapu Island. A slight westward flow off the southern coast of Catanduanes Island can also be seen which almost immediately turns southward to merge with the outflow further to the south. In the interior, west of 123°45'E, the currents are weak and no significant exchange between the main flow from Maqueda to the mouth and the western part of the gulf occurs. During the southwest monsoon (Fig. 3b), the flow pattern is reversed. The net transport through the mouth of the gulf is westward and the flow through the Maqueda Channel is towards the north. The current magnitudes in the western part of the gulf remains weak. The easterly-forced upper-layer circulation (Fig. 3c) is similar to that of the southwest-forced case wherein the main flow enters the mouth of the gulf and exits through the Maqueda Channel. The current magnitudes, however, are significantly weaker presumably due to the weaker easterly winds.

Associated with the wind-driven currents, sea level slopes are produced due to the piling of the water against coastal boundaries. The sea surface elevation plots for the three wind-forced simulations are shown in Fig. 4. Highest sea surface elevations are found at the southwest portion of the gulf during the northeast monsoon and at the northeast part during the southwest monsoon. Easterly wind forcing piles up the water against the western part of the bay resulting in a sea surface slope directed towards the west. Convergence of the surface layer at the coastal boundaries also results in the depression of the interface between the layers and the considerably larger slopes of the interface are opposite to that of the sea surface (Fig. 5).

The lower layer circulation is linked to the upper layer circulation as a consequence of the principle of continuity of volume. The upper layer circulation is influenced mainly by the monsoonal forcing and any net flow into or out of the gulf in the upper layer must be balanced by a return flow in regions where monsoonal forcing effects are weaker such as in the layers underneath the wind-dominated upper layer. In Lagonoy Gulf, the return flow in the lower layers are directly opposite to that of the upper layer (Fig. 6). The strong currents at Maqueda Channel are probably due to the concentration of the flow due to the narrow width and shallow depth of this passage. Apart from the strong currents at the passages into the open sea, the magnitude of the currents in the lower layer are generally very weak.

Tidal Circulation

The tides in Lagonoy Gulf are typically of the semidiurnal type with a mean tidal range of about 1.2 m (NAMRIA 1994). The predicted tides for 1 January 1994 at 5 different tidal stations within and around Lagonoy Gulf are shown in Table 2. The arrival times of the tides can provide general information on the direction of the tide progression. The tides arrive earliest at Virac, Catanduanes presumably because it is relatively exposed to the western Pacific. Legaspi City and Tabaco are situated in the inner parts of Albay Gulf and Lagonoy Gulf, respectively, thus the tides arrive at a later time because of their greater distance from the open ocean. Hitoma, which is located within Maqueda Channel is also slightly delayed compared to Virac and this is probably due to the fact that Hitoma and Virac are at the opposite sides of the island and the delay represents the time it takes for the tides to travel around the island, either on the eastern side or through Maqueda Channel. Because of this delay, during ebb tides the sea level south of Maqueda Channel will be slightly lower compared to the area north of the channel. This results in a pressure gradient which forces water in Maqueda Channel to flow southward and vice-versa for the flood tides (Fig. 7). The flow across the mouth of the Gulf between Catanduanes and Rapu-rapu Islands is also not unidirectional but is characterized by westward flow through Catanduanes and eastward flow north of Rapu-rapu Island. The net flow across the gulf mouth is therefore balanced by the change in sea level and the flow through Maqueda Channel. However, the magnitude of the tidal residual currents are small compared to the wind-driven component suggesting the dominance of the wind-driven circulation in the upper layer circulation.

Dispersal Simulations

A total of 24 dispersal simulations were conducted corresponding to eight point sources for three different prevailing wind conditions. The dispersal model was run for each of the experiments until all particles were advected out of the model domain or up to 30 days whichever came first. The locations of the eight point sources are shown in Table 3. The primary assumption in the dispersal experiments is that the oscillating tidal circulation is superimposed on the steady wind-driven component. Comparison between pure wind-driven dispersal and wind-driven plus tidal current dispersal showed no significant difference. This reinforces the suggestion that the tides in Lagonoy Gulf play a minor role in the circulation primarily because of the very deep bathymetry.

The salient feature of the upper-layer circulation determined from the circulation model is the strong flow between the Maqueda Channel and the mouth of the gulf. As a result, particles released along the vicinity of the axis of this flow is almost completely advected out of the model domain after a period of about 5 days (Figs. 8a-d), regardless of the prevailing wind conditions. On the other hand, particles released at points west of the main current remain in the gulf even after 30 days of simulation. For instance, the dispersal patterns of particles released off Tiwi (Fig. 8f), the northwestern tip of San Miguel Island (Fig. 8g) and off the north coast of Batan Island (Fig. 8e) spread along the southern boundary of the gulf during the northeast monsoon and flow towards the western part of the gulf during the southwest monsoon and easterly winds. In the innermost part of the bay (e.g. just off Lagonoy River), the dispersal of particles is very limited (Fig. 8h), remaining within the vicinity and spreading radially over a very short distance during the whole 30-day simulation.

Discussion

The model-derived circulation patterns of Lagonoy Gulf are in general agreement with the flow patterns inferred from property distributions presented in Villanoy and Encisa (in press). The upper layer circulation is primarily influenced by the monsoons and exhibits a seasonal reversal of the flow. The similarity between water properties at the mouth of the Gulf and at the vicinity of Maqueda Channel is consistent with the occurrence of a strong flow between these two areas. On the other hand, the lower layer circulation is dominated by compensatory flow brought about by the convergence and divergence of the surface layer and as a consequence, the flow is generally opposite to that of the surface layer. The model does not allow entrainment or exchange between the two layers thus the divergence/convergence of the surface layer will be reflected as vertical excursions of the interface between the two layers. The weak vertically-averaged current magnitudes of the lower layer also support the weak density gradients at the deeper layers.

It is likely that underneath the wind-dominated layer, processes outside the gulf may partly influence flow patterns within the gulf. However, because of the lack of information on conditions outside the gulf, the possible effects of these processes were not included in the model. This is perhaps one of the limitations of the model in that remote forcing (from the western Pacific), which is probably contributing a significant amount of energy into the circulation in Lagonoy Gulf was not taken into account.

The dispersal patterns of particles released from different point sources also indicate that the residence times vary within the gulf. The presence of two openings into the open ocean and the strong connectivity between these two imply that within the vicinity of this flow, the water exchange is rapid whereas in the interior of the bay west of this flow, residence time is longer. It is apparent that in the presence of a strong-current across the gulf, horizontal exchange between the interior of the gulf and the open ocean is limited by the strong horizontal shear associated with the flow and exchange is accomplished by the entrainment of water between the interior and the strong Maqueda-gulf mouth flow. This is illustrated clearly in the dispersal patterns wherein particles released at point sources west of the main axis of the flow remain in the interior for up to 30 days while those released near the current axis is advected out of the gulf in about 5 days.

This presents some difficulties in determining residence times because some areas in the gulf are flushed more quickly than the other areas and the dispersal patterns presented here should provide some indications of the time scales involved, at least for the upper layer. In the lower layer, residence times several orders of magnitude larger than the upper layer is likely as a consequence of the weaker magnitudes of the lower layer velocities.

Although peak tidal current magnitudes are sometimes larger than the wind-driven components, the residual tidal current magnitudes are small (Fig. 9) and for a large area like Lagonoy Gulf where tidal excursion lengths are small compared to the spatial scale of the gulf, it is the residual tidal currents which will be more relevant in the dispersal of suspended or dissolved materials for periods greater than the tidal period.

Conclusion

The circulation patterns derived from the numerical circulation model are consistent with circulation patterns inferred from hydrographic data which suggest a monsoon dominated upper layer and an opposing flow in the lower layer as a consequence of the surface layer divergence and convergence. The main feature of the upper layer circulation is the strong flow between the Maqueda Channel and the mouth of the Gulf between Catanduanes and Rapu-rapu Islands which inhibits water exchange between the waters in the interior west of this flow and the open ocean. As a consequence, dispersal patterns derived from a Langrangian transport model show strong advection out of the gulf of particles released at point sources close to this flow within five days while particles released in the western part of the gulf remains in the western part even after simulation runs of up to 30 days. The tidal component of the circulation does not significantly influence the dispersal patterns of particles released within the gulf.

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Table 1. Numerical experiments and friction parameters used.

Expt No.	Forcing	d_w	d_i	d_b
1	NE wind (7 ms-1)	5e-5	.005	.05
2	SW wind (7 m s-1)	5e-5	.005	.05
3	E wind (5 m s-1)	5e-5	.005	.05
4	Semi-diurnal Tides	-	.005	.05

Table 2. Predicted tides for January 1, 1994

Station	Time	Height
Legaspi City	0131	-0.30
	0757	1.41
	1342	0.19
	1942	1.46
Virac, Catanduanes	0129	-0.30
	0749	1.37
	1335	0.12
	1934	1.44
Tabaco, Albay	0158	-0.30
	0825	1.34
	1409	0.19
	2010	1.39
Hitoma, Catanduanes	0150	-0.30
	0815	1.47
	1401	0.19
	2000	1.52
Batan Island, Albay	0134	-0.27
	0801	1.44
	1345	0.22
	1945	1.49

Table 3. Coordinates of the point sources used in the simulations

Expt No.	Latitude	Longitude
1	13°28'48"N	123°55'48"E
2	13°15'00"N	124°09'00"E
3	13°36'00"N	124°02'24"E
4	13°33'00"N	124°07'48"E
5	13°18'00"N	123°58'48"E
6	13°27'36"N	123°43'12"E
7	13°25'12"N	123°45'36"E
8	13°42'00"N	123°34'48"E

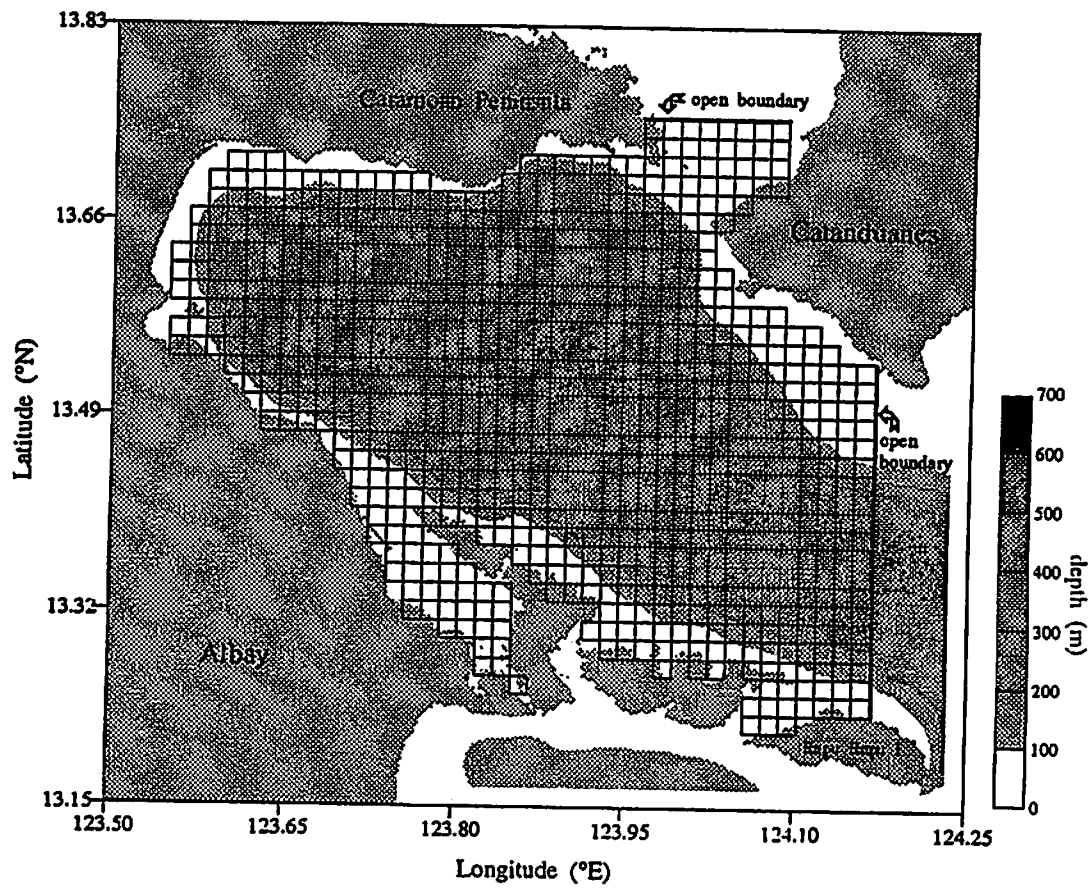

Fig. 1. Map showing the bathymetry and model grid of Lagonoy Gulf.

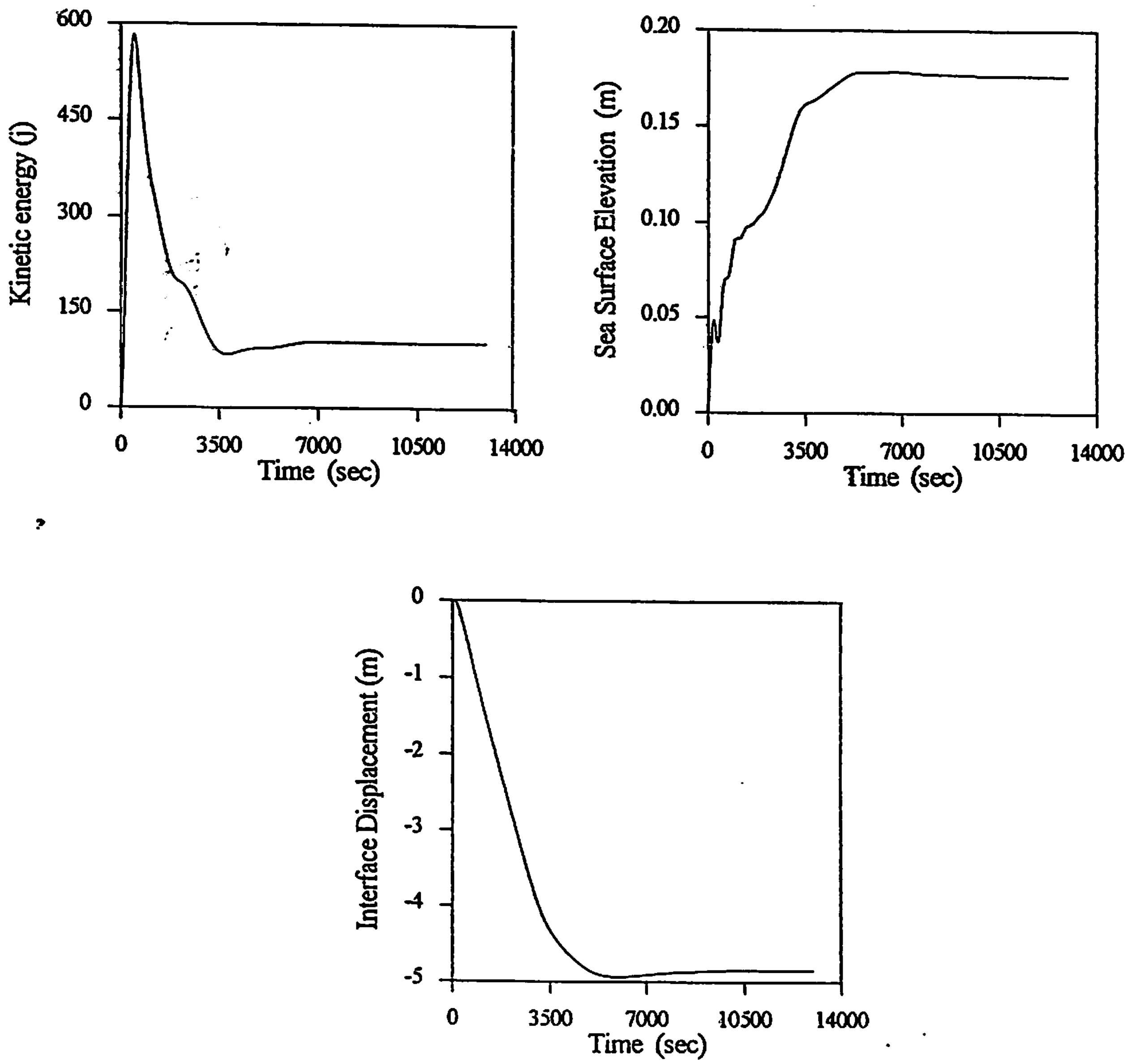

Fig. 2. Time series of kinetic energy, average sea surface elevation and average interface displacement for the wind-forced simulation runs.

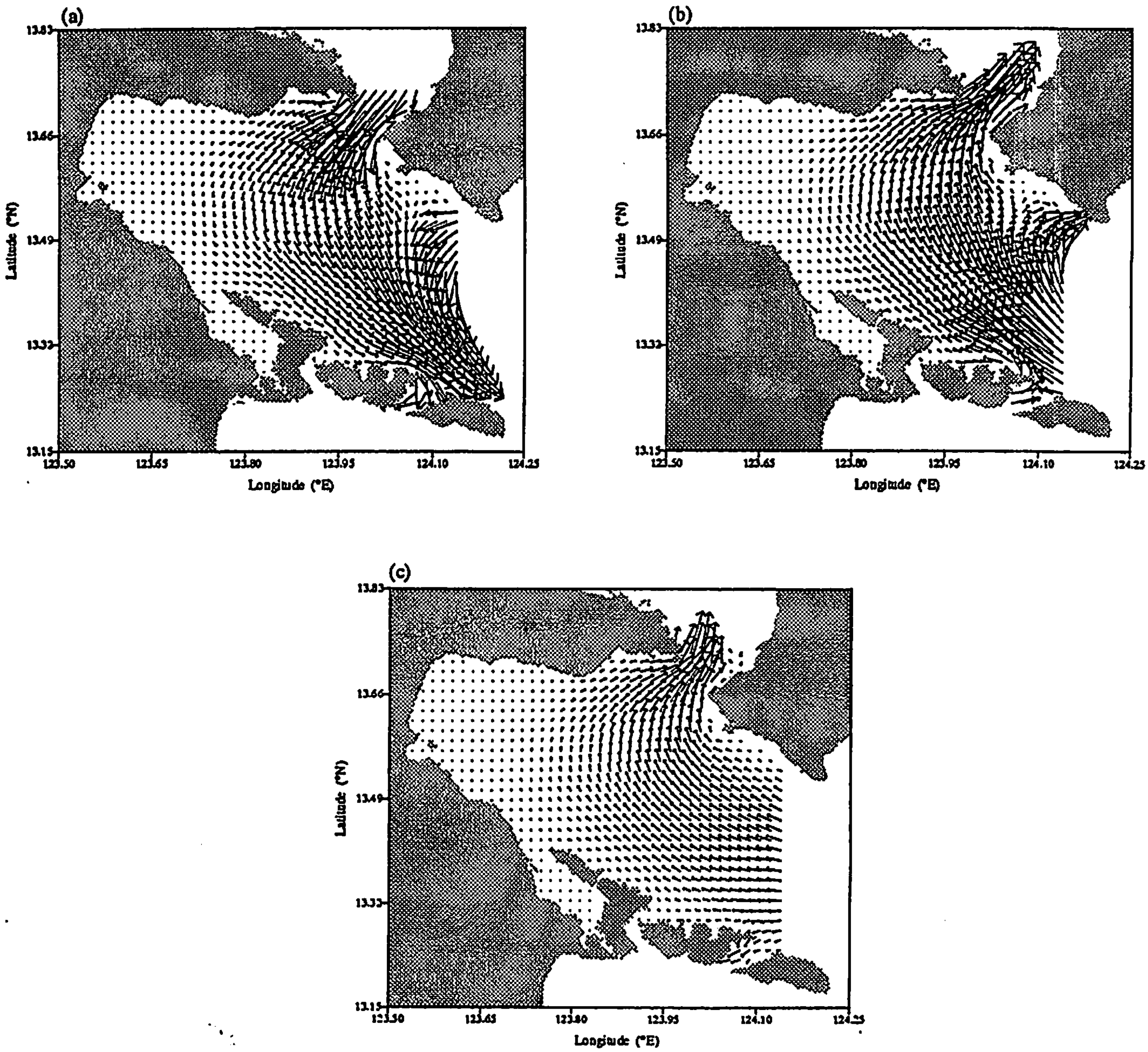

Fig. 3. Upper layer vertically-averaged velocity field for the northeast (a), southwest (b) and easterly (c) wind-forced simulation runs.

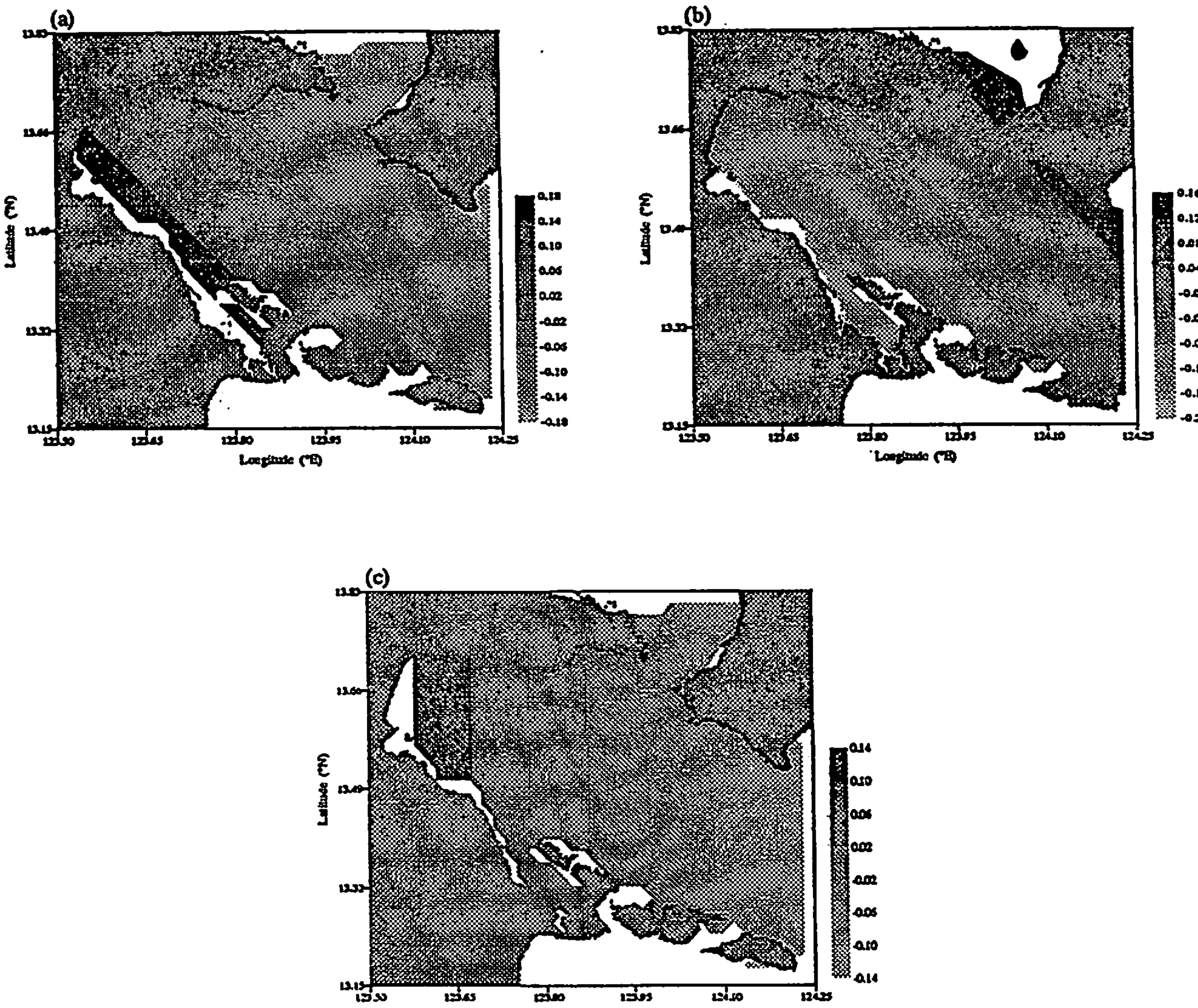

Fig. 4. Sea surface elevation for the northeast (a), southwest (b) and easterly (c) wind-forced simulation runs.

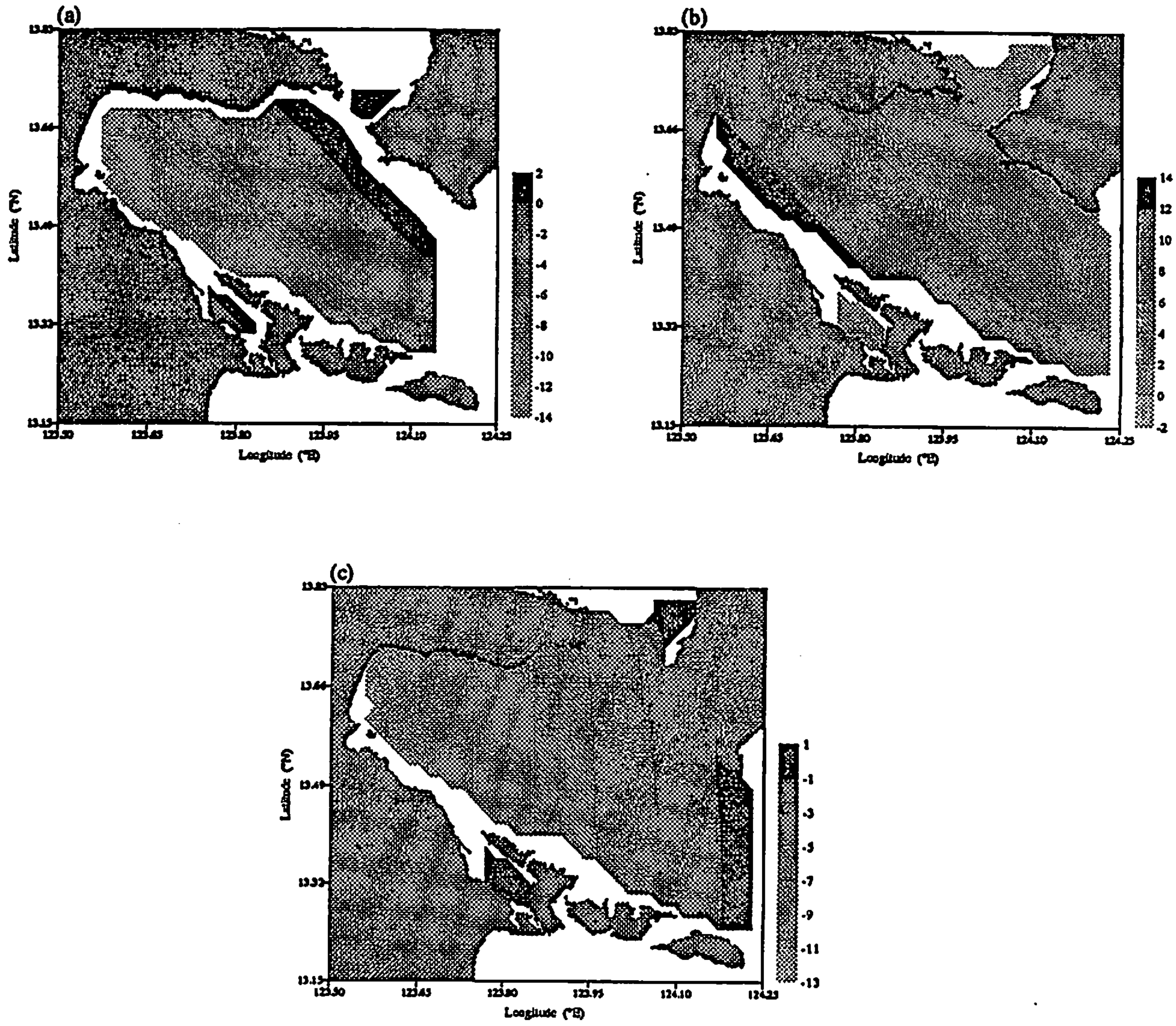

Fig. 5. Interface displacement for the northeast (a), southwest (b) and easterly (c) wind-forced simulation runs.

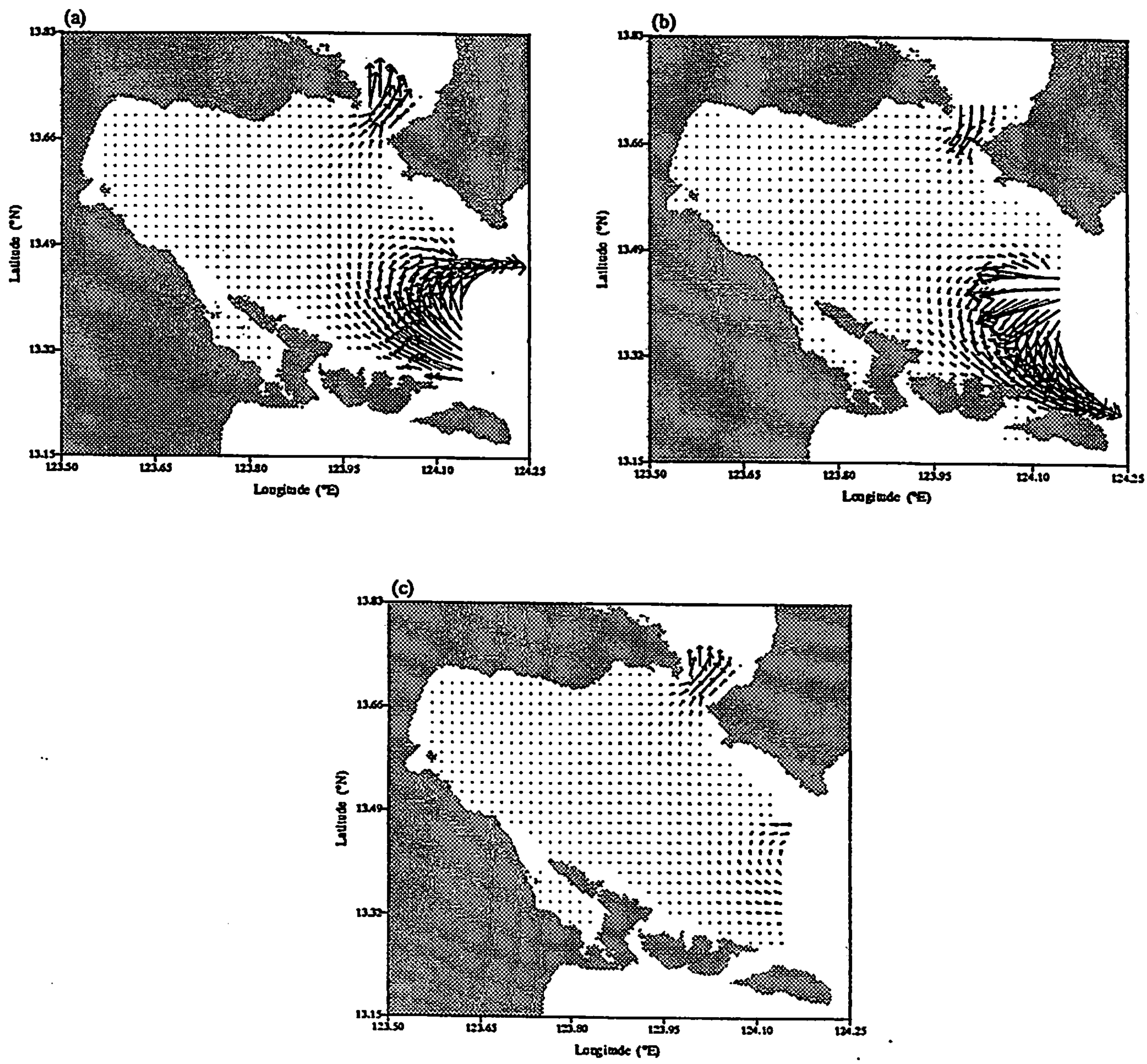

Fig. 6. Lower-layer vertically-averaged velocity fields for the northeast (a), southwest (b) and easterly (c) wind-forced simulation runs (max. arrow =0.7 ms^{-1}).

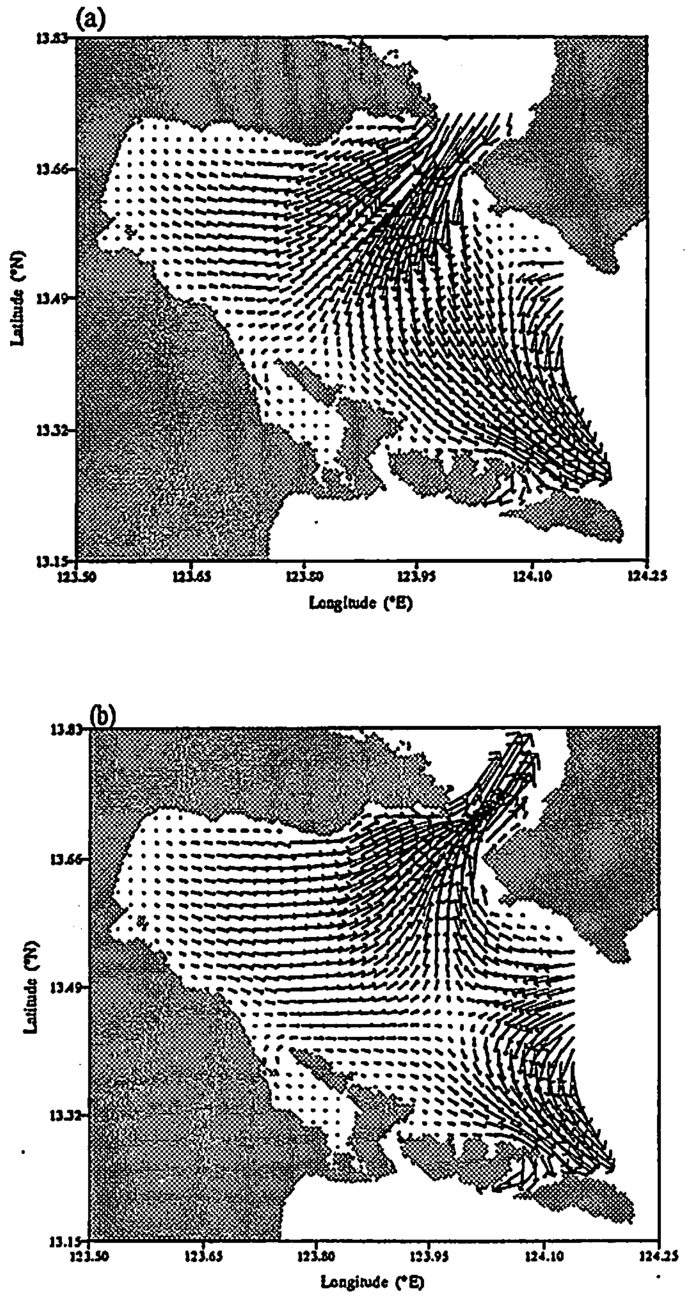

Fig. 7. Upper-layer tide-forced velocity fields for ebb (max. arrow = 2.2 ms^{-1}) (a) and flood (max. arrow = 1.2 ms^{-1}) (b) tides.

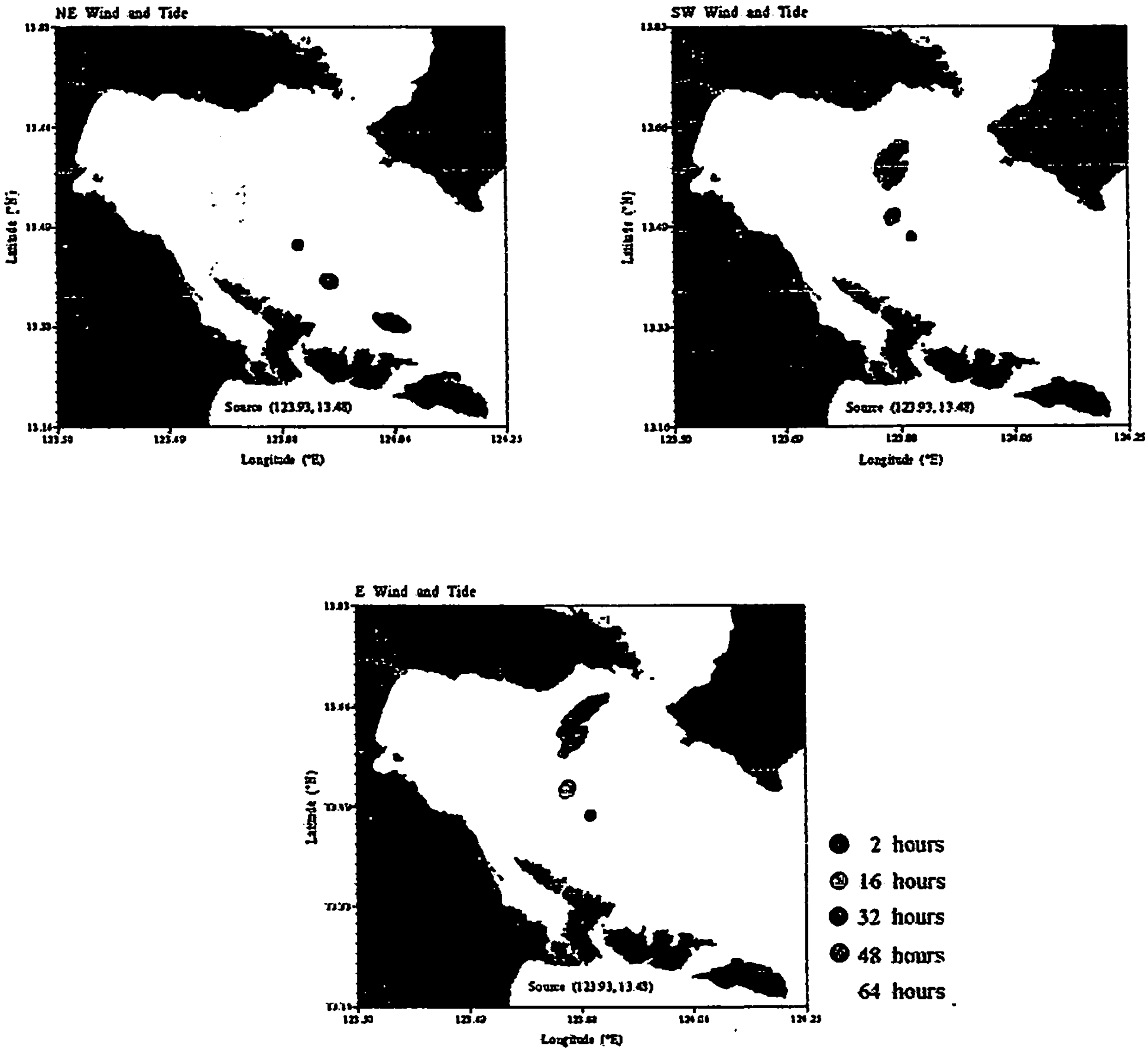

Fig. 8a. Dispersal patterns of particles released during different wind conditions from the different point sources. Letters correspond to the experiments, in sequence.

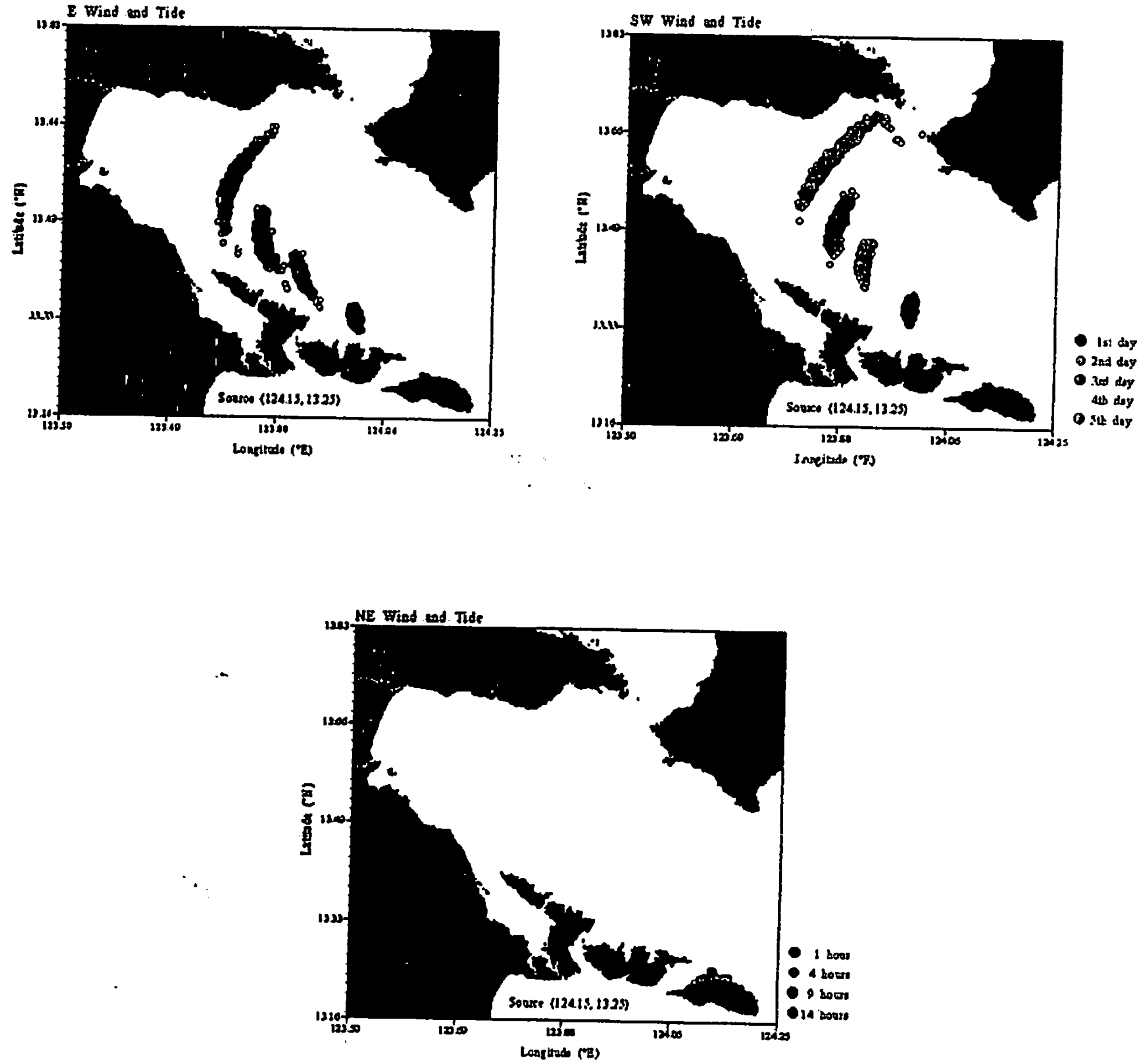

Fig. 8b. Dispersal patterns of particles released during different wind conditions from the different point sources.

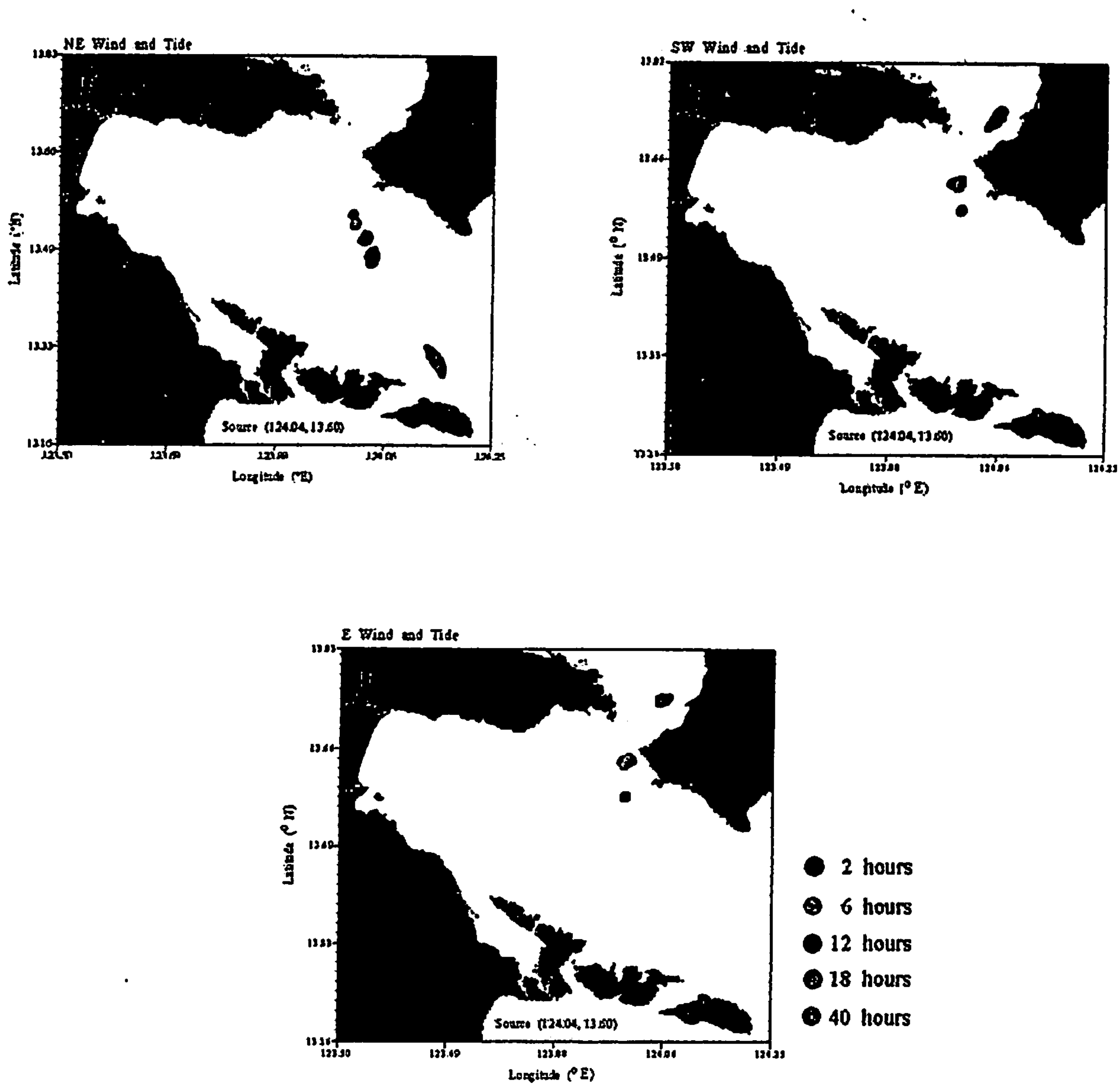

Fig. 8c. Dispersal patterns of particles released during the different wind conditions from the different point sources.

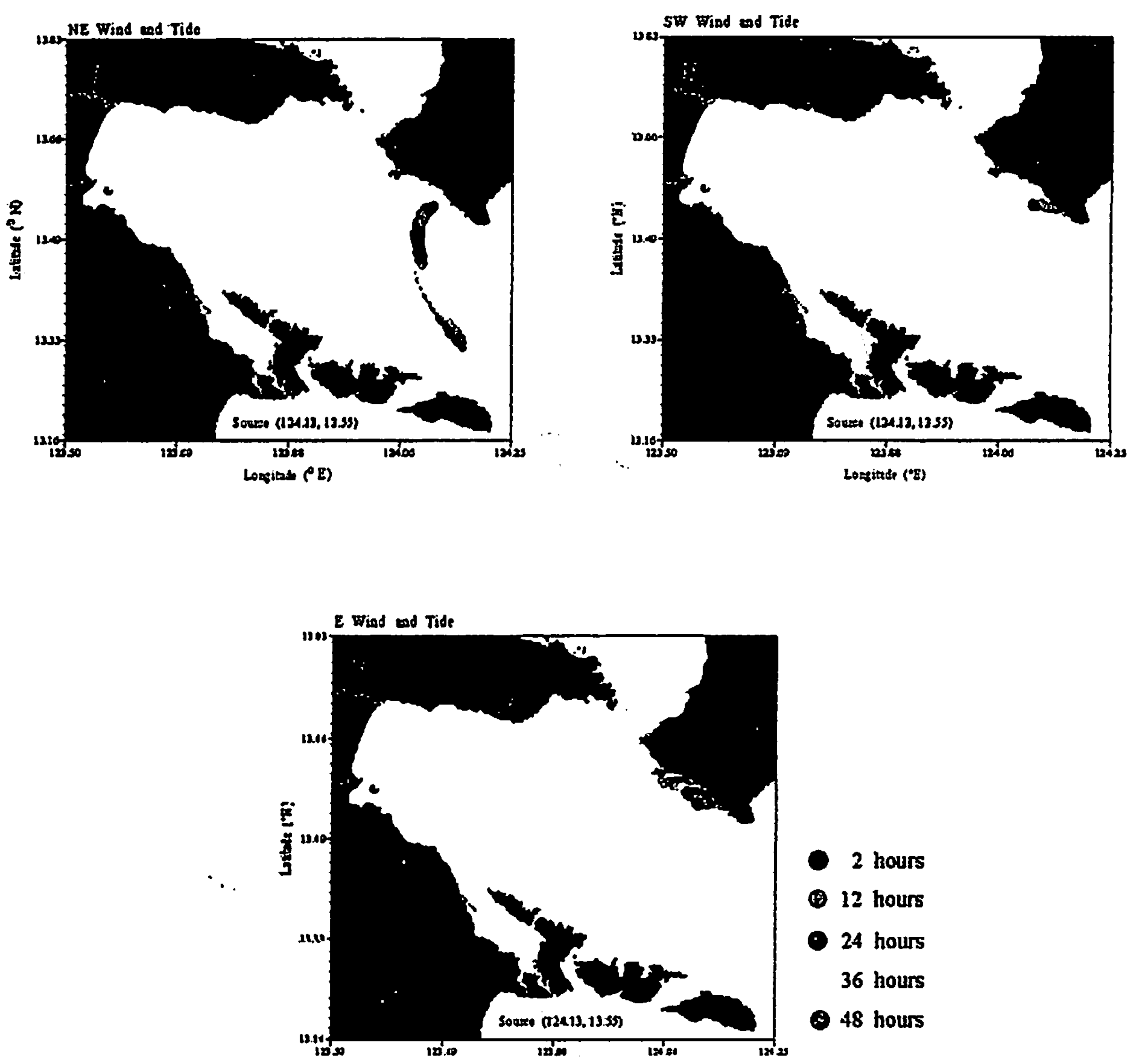

Fig. 8d. Dispersal patterns of particles released during different wind conditions from the different point sources.

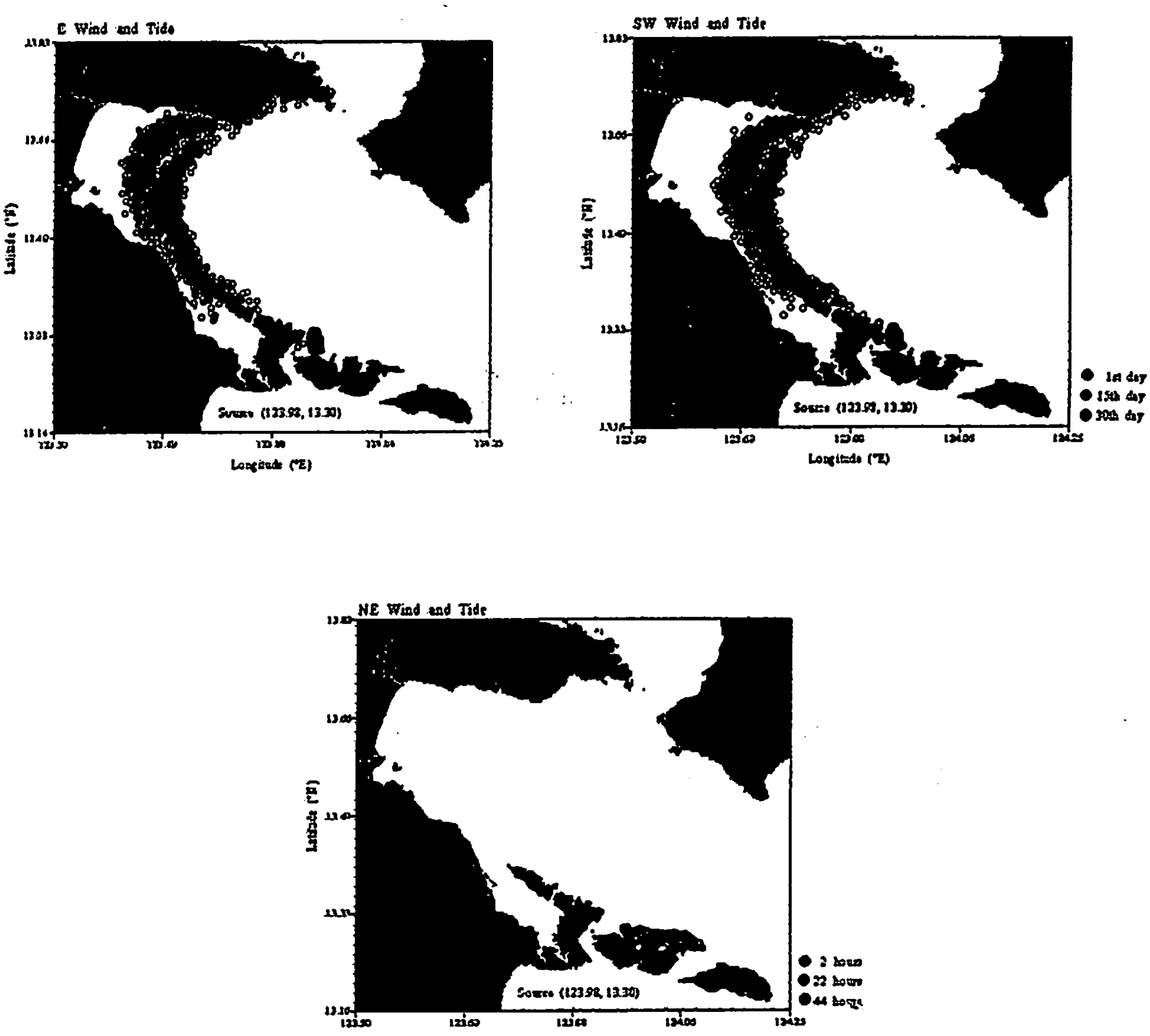

Fig. 8e. Dispersal patterns of particles released during different wind conditions from the different point sources.

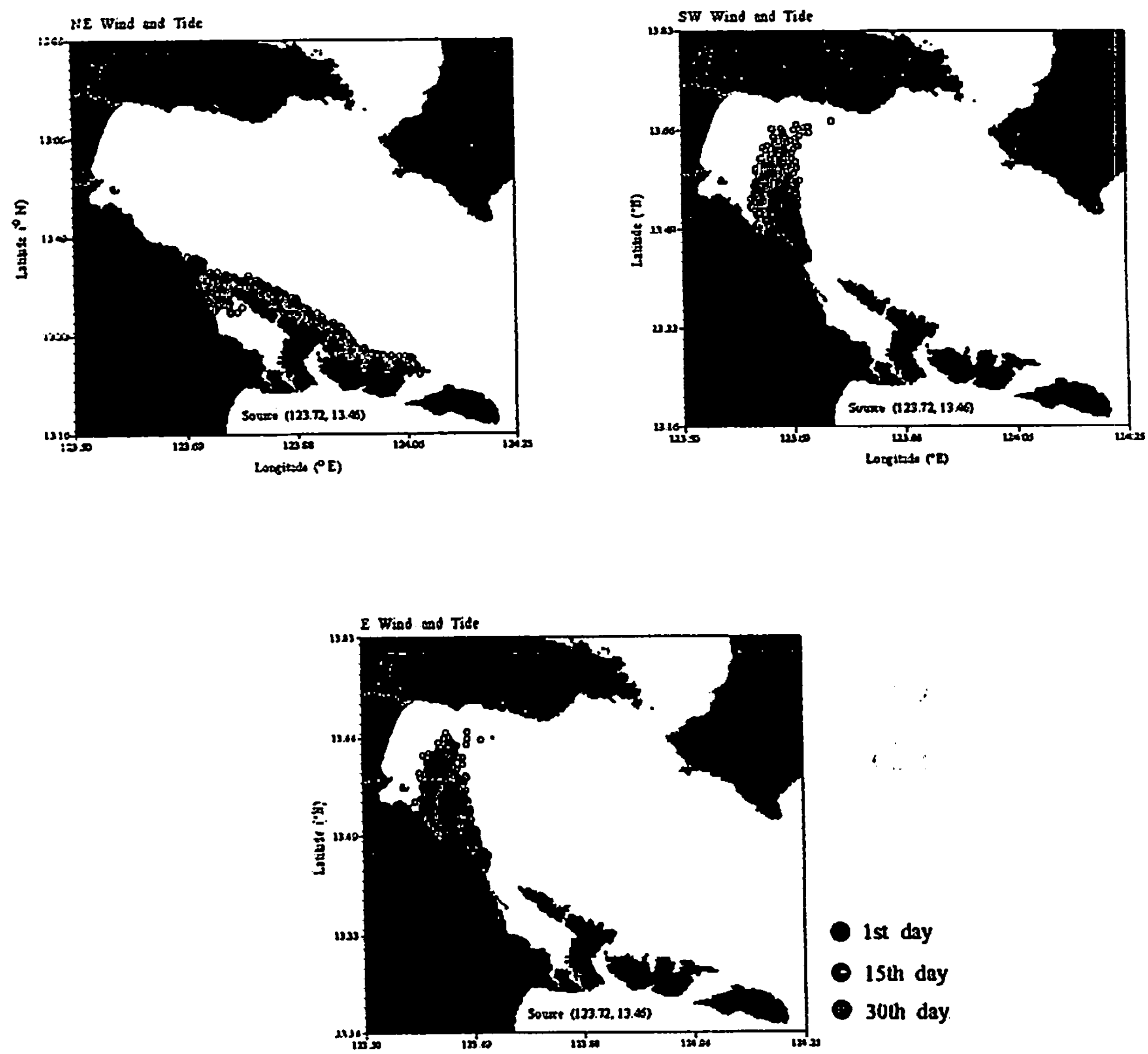

Fig. 8f. Dispersal patterns of particles released during different wind conditions from the different point sources.

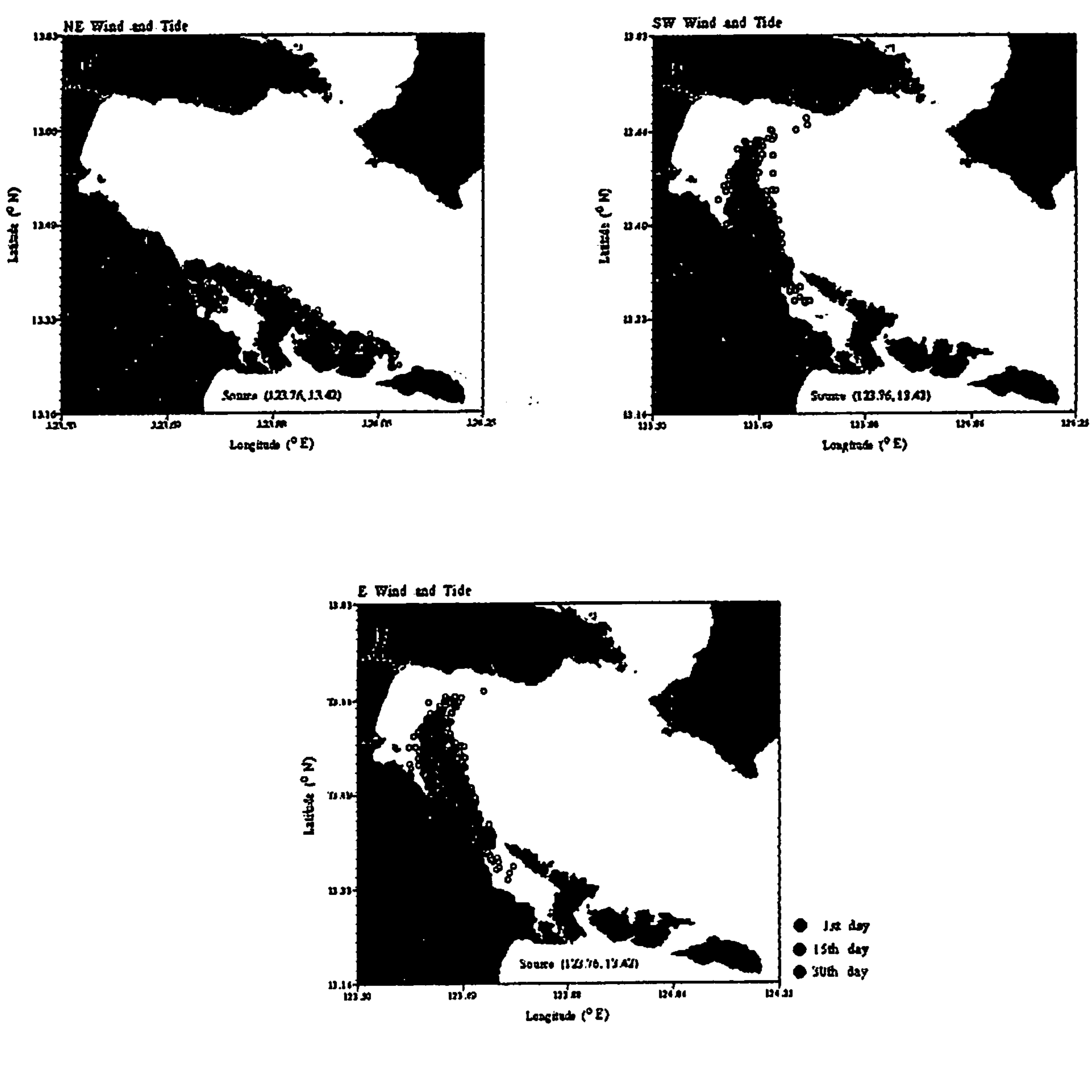

Fig. 8g. Dispersal patterns of particles released during different wind conditions from the different point sources.

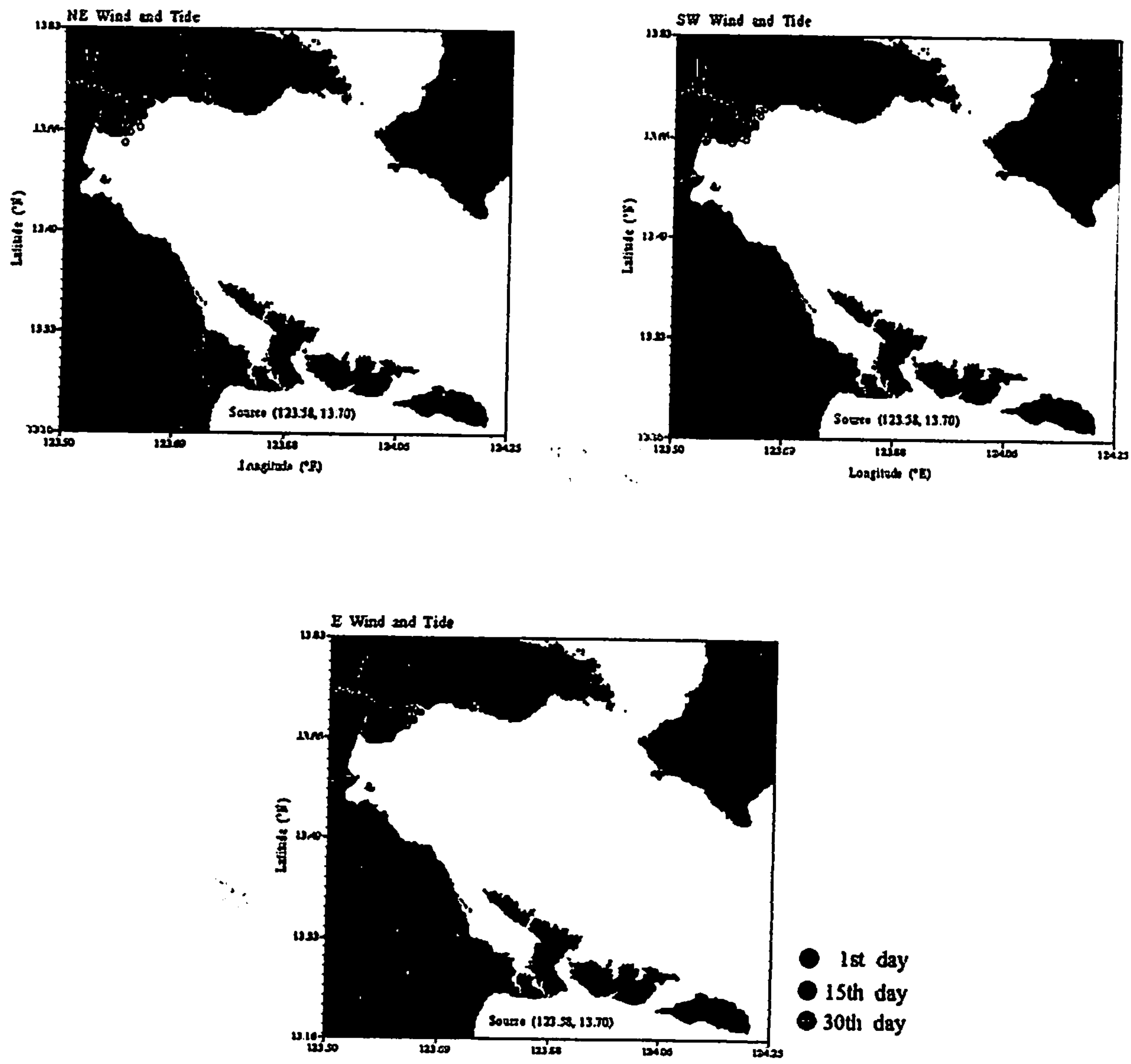

Fig. 8h. Dispersal patterns of particles released during different wind conditions from different point sources.

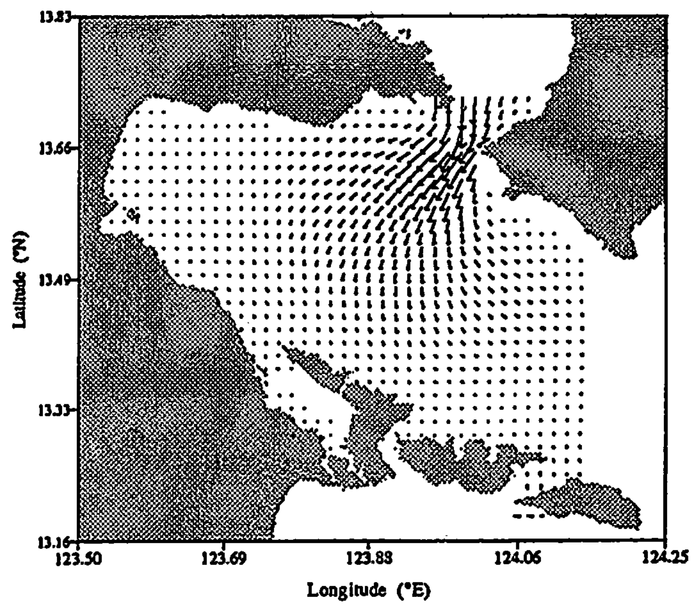

Fig. 9. Tidal velocity field averaged over one tidal cycle (residual tidal currents).

Assessment of Water Quality in Lagonoy Gulf
Part I. General Water Quality

by

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Abstract

General water quality studies were conducted in Lagonoy Gulf from January to December 1994. Variations in water quality parameters (transparency, suspended solids, temperature, salinity, dissolved oxygen and pH) coincided with the changes in monsoon periods. Ebb and flood periods also influenced these variables. General water quality parameters monitored in the gulf were within the allowable limits set by the Environmental Management Bureau (EMB) of the Department of Environment and Natural Resources (DENR 1990) for Class SC waters.

Introduction

Lagonoy Gulf (approximately 80 km long and 30 km wide) is known for its fisheries resources. Thus, maintenance of good water quality is necessary to ensure continued productivity and long-term sustainability of resources. At present, Lagonoy Gulf falls under Class SC marine waters. Aside from commercial and sustenance fishing (fishery class II), other uses of the waters include recreational water class II (boating, etc.) and fish and wildlife sanctuaries in marshy and mangrove areas (EMB 1990).

To date, information on water quality of the gulf is scanty. Investigations were limited to those done for the Tiwi Geothermal Power Plant (Balagot 1990; Bermas et al. 1991 and PGI 1993). Hence, this study was conducted to obtain information on the water quality characteristics of Lagonoy Gulf on a spatial and temporal scale. This will serve as basis in the formulation of management tools for proper utilization of the gulf.

The objectives of the study are the following:

1. to monitor the following parameters: temperature, transparency, salinity, pH, suspended solids and dissolved oxygen (DO);
2. to compare values obtained with existing water quality criteria (EMB criteria for Class SC marine water); and
3. to identify possible sources of pollution or other factors which may cause water quality parameters to exceed allowable levels.

Materials and Methods

1. Station description and sampling frequency

Fifteen sites were selected as sampling stations for the study (Fig. 1.1). These stations were chosen to represent the various habitats in the gulf:

a. coral reef/seagrass/seaweed areas - Rawis Point (Sta. 1) and Casolgan Pass (Sta. 13), San Miguel Island, Albay; Agoho (Sta. 6), San Andres, Catanduanes; Acal Point (Sta. 9), Rapu-rapu Island, Albay; and Gaba Bay (Sta. 10), Batan Island, Albay;
b. estuary/mangrove area - Bariw Point (Sta. 14), Malinao, Albay; Sogod River (Sta. 2), Tiwi, Albay; Lagonoy River (Sta. 4), San Jose, Camarines Sur; Bato River (Sta. 7), Bato, Catanduanes; and Cagraray Island (Sta. 12), Bacacay, Albay; and
c. deep area - midgulf stations: Grid 13 (Sta. 3), Grid 33 (Sta. 11), Grid 50 (Sta. 8), Maqueda Channel (Sta. 5) and Tabaco Bay (Sta. 15).

The coordinates and brief description of each station are given in Table 1.1. A hand-held Magellan Nav 1000 Global Positioning System (GPS) was used in determining coordinates. Ideally, sampling for all the stations must be within the same tidal phase to eliminate variability due to tides. However, because of the large distance among stations and unfavorable climatological conditions at times, data gathering during each sampling was done within a period of seven days.

Sample collection and data gathering were conducted once a month for 12 months (January-December 1994). Duplicate samples and measurements were maintained throughout the study for physico-chemical and biological parameters. The influence of tides on the water quality parameters was determined by collecting samples during ebb and flood periods at Sogod River, Lagonoy River and Tabaco Bay. This was conducted in April (summer) and September (southwest monsoon).

2. *General water quality*

Water samples were collected using a Kemmerer water sampler (1.2 L). They were taken from 3 depths: 0.5 - 2 m for surface, 50 m for mid-depth and 80 -250 m for the lower depth. A Furuno echosounder was used in estimating water depths for stations which depths exceeded 10 m. Depth information from a nautical chart (NAMRIA 4715) was used for stations which depths were beyond the range of the echosounder. *In situ* measurements were done on the following parameters: (1) water temperature using thermometer (alcohol thermometer 0 - 100°C); (2) transparency using Secchi disk (20 cm diameter); (3) salinity using Atago refractometer (0 - 100 ppt); (4) pH using Merck 0-14 pH paper and pHScan 2; and (5) dissolved oxygen (DO) using Modified Winkler method. Samples for suspended solid content were filtered from 1 liter of water using a preweighed 47 mm glass fiber filter paper (GC 50). These were kept cold until analysis by gravimetric method (APHA 1985).

3. *Spatial distribution*

Lagonoy Gulf was divided into 121 grids with 5-6 km distance in each grid (Fig. 1.2). Sampling was done in May (summer) and August (southwest monsoon). Surface samples were collected and determined for general water quality.

4. *Statistical analysis*

Statistical analysis was done to test the relationships and significance of the parameters measured. In characterizing the association between parameters (response and environment), there is a need for statistical procedure that can handle several variables. In correlation analysis, any one or a combination of associations can be examined thus providing a measure of the degree of association between the variables or the goodness of fit of a prescribed relationship to the data at hand (Gomez and Gomez 1984). Significance of the values obtained was compared using the Duncan Multiple Range Test (DMRT). This test provides information on significant difference of sites studied using different variables.

Results and Discussion

The study started with a reconnaissance survey in November 1993, the start of northeast monsoon. This period had a maximum wind speed of 5 m s^{-1} and lasted until February. Southwest monsoon in the gulf was from June to October. The wind speed was 3 m s^{-1}. The transition between the northeast and southwest monsoons, from March to May (summer), was characterized by weak easterly winds (Villanoy and Encisa this vol.).

Seasonal variation

Depth

Based on depth measurements (Table 1.2), the estuary and mangrove areas were relatively the shallowest (1.5-7.0 m), followed by coral reef/seagrass/seaweeds areas (1.25-13.0 m). The depth of the deep sites ranged from 85 m to 1,009.5 m.

Transparency

Photosynthetic organisms such as algae depend on light for their metabolic activities. The ability of light to penetrate the water column measured as transparency for Lagonoy Gulf is given in Table 1.3 and Fig. 1.3. Deep areas gave the highest transparency reading (average of 17.2 m) while coral reef/seagrass/seaweeds and estuary/mangrove areas gave shallower depths of light penetration (average of 5.1 m and 2.8 m, respectively). However, since the latter areas are shallower, light has penetrated to the bottom for these sites.

Results of correlation analysis showed that there is significant positive relationship between transparency reading and depth in all areas (r=0.97 for coral reef/seagrass/seaweeds area; r=0.93 in estuary/mangrove and r=0.57 in deep stations, all at 1% level of significance, Table 1.9). This implies light penetration to the bottom for shallow areas (corals and estuary) while deep stations allowed deeper transparency.

Based on the Duncan Multiple Range Test (DMRT), the three areas are significantly different from each other in terms of transparency (Table 1.10). The factors which can influence light penetration in these areas include silt, suspended materials and plankton (phytoplankton and zooplankton) concentrations. The presence of zooplankton may have affected transparency in coral reef/seagrass/seaweeds area as shown by the inverse relationship between these two variables (r=-0.59, at 1% level of significance, Table 1.9, Fig. 1.4). This indicates that higher plankton biomass reduced light penetration in these areas.

Variations in suspended material content in Lagonoy Gulf are shown in Fig. 1.5. Suspended solids were high from March to June and lowest in November for all the stations monitored. This observation is similar with results from San Miguel Bay (Bicol Region) (Mendoza et al. 1993). Coral reef/seagrass/seaweeds areas had the highest amount of suspended solids in March (65.40 mg l-1, Table 1.4). Suspended solid loads on a monthly basis have complied with the limits set by EMB, i.e., loading must not exceed 30 mg l^{-1} increase per monitoring period.

Temperature

Water temperature in Lagonoy Gulf was monitored for one year and its variability is presented in Fig. 1.6. Temperatures were low (28 - 29°C) during the northeast monsoon (November - February) in all the areas. There was an increase in temperature during summer (April - June) and then a decrease with the onset of southwest monsoon (July - October). Range of water temperature recorded in the gulf is similar to that in San Miguel Bay (24.5 - 33.7°C, Mendoza et al. 1993). The limit set by EMB for Class SC waters on temperature should not exceed 3°C increase per monitoring period and waters in the gulf complied with this requirement.

DMRT results showed that temperature behavior was not significantly different in the three areas (Table 1.10). However, for the deep areas, a thermocline was present below 50 m depth as confirmed by Villanoy and Encisa (this vol.).

Salinity

Salinity is a measure of the mass of dissolved salts in a given mass of solution (APHA 1989). Table 1.6 presents the results of salinity measurements in Lagonoy Gulf. Lowest salinity values were determined in the estuary/mangrove area (0-35 ppt, mean = 29.16 ppt) followed by coral reef/seagrass/seaweeds (27-36 ppt, mean = 32.05 ppt) and deep area surface samples (30-36 ppt, mean of 35.26 ppt). Mid-depth waters had salinity measurements of 27-35 ppt with a mean of 32.47 ppt while bottom waters ranged from 30-36 ppt with a mean of 33.62 ppt. Results from DMRT showed that the estuary/mangrove areas are significantly different from the two other areas (Table 1.10). Less saline waters in the estuary/mangrove areas are due to the freshwater input from the rivers. At the deep areas, salinity increased with depth from 32.5 ppt in surface to 33.6 ppt at the bottom.

Fig. 1.7 presents the variation in salinity values in Lagonoy Gulf for a period of one year. At the onset of summer, there was an increase in salinity in all the areas and a decrease during rainy period (June - August). Similar results were seen in San Miguel Bay (Mendoza et al. 1993) and in the oceanographic studies for Lagonoy Gulf by Villañoy and Encisa (this vol.). High evaporation rate during summer leads to increased salinity and the onset of southwest monsoon brings in rain which causes the lower salinity values.

Results of correlation analysis in the estuary/mangrove areas showed that water temperature has a direct influence on salinity, r=0.29 at 5% level of significance (Table 1.9). At high temperature, there is tendency for more evaporation especially in shallower areas which results in higher salinity values.

Dissolved oxygen

Dissolved oxygen (DO) concentration in the gulf ranged from 6 to 11.45 mg l-1 in coral reef/seagrass/seaweeds areas and 5.87 - 11.94 mg l-1 in estuary/mangrove areas (Table 1.7, Fig. 1.8). For the deep areas, the range of DO was 6.11 - 12.28 mg l-1 in surface waters, 4.11 - 10.62 mg l-1 in mid-depth and 4.2 - 9.5 mg l-1 in bottom waters. DMRT results show that only the DO concentration in the bottom waters is significantly different from the rest of the samples (Table 1.10). The lower DO concentrations found at lower depths may be attributed to respiration processes which consumed the gas. This implies that the demand for oxygen at these depths exceeded its supply from primary producers and atmospheric oxygen. The shifting of monsoon winds which results in increased water turbulence may have also affected oxygen dissolution in the water column. In addition, temperature may also affect the dissolution of oxygen in the gulf. During northeast monsoon when temperature was lowest, DO levels were slightly high. Similar observations were found in San Miguel Bay (Mendoza et al. 1993). Overall, surface DO concentrations in Lagonoy Gulf were greater than 5 mg l-1 which complies with the criteria for Class SC waters.

Results of correlation analysis in the estuary/mangrove areas showed that DO increased with transparency (r=0.26, significant at 10% level, Table 1.9, Fig. 1.9). This indicates that as more light becomes available for photosynthetic activities of the phytoplankton, there will be more oxygen produced. On the other hand, the inverse relationship of suspended solids with DO in the surface waters of the deep areas (r =-0.30, 5% level of significance, Table 1.9) imply that suspended solids could hinder light penetration hence less photosynthetic activities and correspondingly lower DO concentrations are produced.

pH

pH, or the negative log of the hydrogen ion concentration, is a measure of the acid-base strength of the water (Sherman and Sherman 1989). The variability of pH in Lagonoy Gulf for a period of one year is presented in Fig. 1.10. The start of the southwest monsoon (June) exhibited an increase in pH values in the gulf. This was unlike in San Miguel Bay where higher pH was recorded during easterlies from May to June (Mendoza et al. 1993). No significant difference in pH trend was seen in the three areas (Table 1.9). pH in the gulf varied from 7.0 to 8.5 in coral reef/seagrass/seaweeds area and from 6.0 to 8.75 in the estuary/mangrove areas. Waters in the deep areas had a pH range of 6.5 - 8.9. The pH of Lagonoy Gulf waters is within limits (pH 6 - 8) set by EMB.

Tidal variation

In addition to waves and currents, tides are one of the most striking features in coastal areas because they could also affect movement of biological and chemical components in seawater. Tidal pattern in the Philippines is classified as mixed tide with prevailing semidiurnal tides (Soegiarto 1981). This was seen in Lagonoy Gulf for most months of the year. The tidal height in the gulf ranged from -0.60 to 1.60 m (NAMRIA 1994).

In order to determine the influence of tides on the water quality parameters of Lagonoy Gulf, three stations were monitored during summer (April) and southwest monsoon (September). These are Tabaco Bay to represent the deep area (control station), Sogod River to evaluate effects of Tiwi Geothermal Plant on Lagonoy Gulf and Lagonoy River since it is the major tributary of the gulf (Fig. 1.1).

Tabaco Bay

Water moves from Tabaco Bay to Lagonoy Gulf during ebb and the reverse occurs during flood. Table 1.11 presents the results of the 24-hour monitoring of general water quality in the bay during summer and southwest monsoon. A correlation matrix for the different parameters is presented in Table 1.12. Water temperature has a highly significant inverse relationship with salinity during flood and ebb periods in both summer and southwest monsoon (r=-0.50 and r=-0.40, 1% level of significance, respectively). The negative relationship between suspended solids and DO (r=-0.35, 5% level of significance, Table 1.12, Fig. 1.11) indicates that increased suspended load may have carried more organic matter which utilized the oxygen for its breakdown.

Lagonoy River

A major tributary of the gulf is Lagonoy River. Table 1.13 gives the results of the 24-hour monitoring of general water quality in relation to tidal variations in the river. The correlation matrix to relate the parameters is shown in Table 1.14. Similar to Tabaco Bay, cooler temperatures were associated with more saline waters during flood periods (r=-0.38, 10% level of significance). This refers to Lagonoy Gulf waters entering Lagonoy River. The significant decrease in transparency as suspended solid increased (r=-0.97, 1% level of significance, Fig. 1.12) during southwest monsoon may be attributed to the rains which carried suspended particles into Tabaco Bay.

The relationship between tide height and salinity for Lagonoy River is shown in Fig. 1.13. During flood, salinities were higher and the reverse happened during ebb. This refers to gulf waters which has a higher salinity entering the river during flood and less saline water coming out of the river during ebb (r=0.99, 5% level). A similar trend was determined for pH (r=0.91, 10% level of significance, Fig. 1.14). The lower pH during ebb may be due to the influence of land-derived organic materials (humic acid, fulvic acid) which are acidic in nature. The amount of particulate matter had an inverse relationship with transparency in Lagonoy River (r=-0.79, 1% level of significance, Table 1.14).

Sogod River

Table 1.15 presents the results of the 24-hour monitoring of the general water quality in relation to tidal variation in Sogod River, while Table 1.16 gives the results of correlation. Water temperature was monitored for 24 hours and, interestingly, temperature increased during ebb period (Fig. 1.15), which may be due to the influence of thermal discharges from the Tiwi Geothermal Plant. This was observed not only during summer but also during southwest monsoon (rainy period) (Fig. 1.16). The decrease in transparency during summer may be due to the presence of plankton in the waters (r=-0.99, 1% level of significance) (Fig. 1.17). Just like in the two other rivers monitored, tidal heights affected the amount of suspended materials in Sogod River which in turn influenced transparency (r=0.93 and r=-0.54, 10% level of significance, respectively, Fig. 1.18) during southwest monsoon.

Table 1.17 gives the results of correlation analysis across seasons and tidal heights. The amount of suspended solids in Sogod River could be affected by terrestrial runoff during ebb (r=0.82, 5% level of significance) which in turn influenced transparency (r=-0.43, 5% level of significance).

Spatial Distribution

This study was also conducted to describe the horizontal distribution of general water quality in Lagonoy Gulf. Twenty-six out of 46 coastal areas and 17 out of 75 deep stations were selected to measure spatial distribution in the gulf. This number of stations represented 35% of the total number of grids defined for the gulf. Geographical location and short description of each are presented in Table 1.18 while the bathymetry of deep and coastal areas in Lagonoy Gulf is shown in Fig. 1.19.

Table 1.19 gives the results of general water quality measured during the two sampling periods in all the grids. Transparency or the ability of light to penetrate the water column varied from 1.5 to 30 m in the coastal sites and 15 - 56 m for deep stations during summer (Fig. 1.20). Readings fluctuated from 1.5 to 26 m in the coastal sites and 10 - 31 m for deep stations during southwest monsoon (Fig. 1.21). Transparency readings may be affected by the presence of suspended materials or other biotic organisms in the water column that entered through river runoff or leaching from the land especially during rainy days. In coastal areas, anthropogenic activities may influence transparency more than biotic organisms.

Suspended materials quantified during summer were found to be higher than during southwest monsoon for both coastal and deep areas (Figs. 1.22 - 1.23). On the average, suspended matter content for coastal and deep stations in summer were 44.43 mg l^{-1} and 43.25 mg l^{-1}, respectively while during southwest monsoon, values were 24.50 mg l^{-1} and 28.32 mg l^{-1}, respectively.

Temperatures varied from 30 to 33°C for coastal areas and 31 - 32°C for deep areas in summer (Fig. 1.24) whereas southwest monsoon gave 28 - 32°C for coastal sites and 29 - 31°C in deep areas (Fig. 1.25).

In Lagonoy Gulf, dissolved oxygen content was lower during summer when temperature was higher (Fig. 1.26) than during southwest monsoon (Fig. 1.27). This may be explained by solubility of oxygen which decreased with increased temperatures.

Salinity fluctuated from 27 to 37 ppt in summer and 25-37 ppt during the southwest monsoon in coastal stations (Figs. 1.28 - 1.29). Dilution effect of the rains lowered the salinity during southwest monsoon. Salinity values in deep stations varied from 26 to 35 ppt during summer and 28 - 35 ppt during southwest monsoon (Figs. 1.28 - 1.29).

Summary and Conclusion

Lagonoy Gulf waters did not exceed the permissible level for water quality (i.e., suspended solids, temperature, DO, salinity and pH) parameters of Class SC waters. Seasonal variation and tidal effects were found to be pronounced in the gulf. Southwest monsoon brought about lower water temperature and salinity due to the effects of rains. During ebb period, there was increase in water temperature in Sogod River which may be due to thermal discharges from the Tiwi Geothermal Plant. In general, suspended matter load increased during ebb period. These materials may have come from the coastal barangays and other domestic activities which contributed to the loadings. Coastal areas had lower transparency estimates than deeper sites. Discharges from domestic and other land activities (e.g., erosion) may be responsible for the shallow transparency in the former.

Acknowledgement

We would like to acknowledge the assistance of Zaida Alojado for the maps, Cesar Luna, Marcos Jose Vega, Len Garces, Quintin Sia III, Skorzeny de Jesus, Antonio Borre, Antonino Mendoza, Ma. Karina Luth Discaya, Rodrigo Zamudio, Leo Pura, Anastacio Cante, Jose Gonzales Jr., Quillon Sarte, Francisco Diaz and Guillermo Divison who helped us in the conduct of the study.

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Table 1.1. Description of Lagonoy Gulf stations monitored for water quality, 1993 - 94.

Station	Location	Area	Remarks
1 Rawis Point	13°24.81'N 123°45.75'E	San Miguel Island, Tabaco, Albay	- coral reef site
2 Sogod River	13°29.05'N 123°39.28'E	Tiwi, Albay	- estuary - freshwater input - passageway of effluents from Tiwi Geothermal Power Plant
3 Grid 13	13°36.69'N 123°41.07'E	Midgulf	- deep area
4 Lagonoy River	13°43.60'N 123°35.75'E	San Jose, Camarines Sur	- estuary - presence of mangroves - freshwater input - riverbanks with fishing village - fish landing site
5 Maqueda Channel	13°39.22'N 123°58.86'E	Area between Caramoan Peninsula and Catanduanes	- deep area - exchange point of waters between Lagonoy Gulf and Maqueda Channel
6 Agoho Point	13°35.86'N 124°03.75'E	San Andres, Catanduanes	- presence of mangrove - sanctuary area
7 Bato River	13°35.58'N 124°17.0'E	Bato, Catanduanes	- estuary - freshwater input - presence of NAPOCOR diesel power plant - human settlements along riverbank
8 Grid 50	13°23.02'N 124°04.07'E	Midgulf	- deep area
9 Acal Point	13°13.53'N 124°06.82'E	Rapu-rapu Island, Rapu-rapu, Albay	- coral reef site
10 Gaba Bay	13°16.73'N 123°59.01'E	Batan Island, Rapu-rapu, Albay	- presence of mangrove - fish landing site
11 Grid 33	13°29.0'N 123°55.70'E	Midgulf	- deep area
12 Cagraray	13°19.91'N 123°54.43'E	Cagraray Island, Bacacay, Albay	- mangrove area - site between San Miguel and Batan Islands
13 Casolgan Pass	13°22.58'N 123°51.44'E	Area between San Miguel and Cagraray Islands	- seagrass/seaweed area
14 Bariw Point	13°22.38'N 123°43.69'E	Tabaco, Albay	- estuary - freshwater input - presence of effluents from ALENDECO
15 Tabaco Bay	13°20.09'N 123°46.50'E	Tabaco, Albay	- deep area

Table 1.2 Depth (m) estimates at different areas in Lagonoy Gulf, Dec 93 - Dec 94.

STATION	SAMPLING PERIOD													AVERAGE
	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
I. CORAL REEF/SEAGRASS/SEAWEED AREA														
1 Rawis Point	-	7.00	5.00	12.00	13.00	7.00	13.00	8.00	12.00	12.00	-	-	-	9.89
6 Agoho Point	11.00	9.00	11.00	5.00	5.00	4.00	6.00	10.00	5.00	3.50	3.50	11.00	4.00	6.77
9 Acal Point	-	-	4.00	8.00	5.00	6.00	5.00	5.00	5.00	6.00	-	-	-	5.50
10 Gaba Bay	-	-	3.00	3.00	4.00	2.00	3.00	2.00	2.00	4.00	1.25	2.00	2.00	2.57
13 Casolgan Pass	-	-	7.00	3.00	2.00	2.00	3.00	1.50	3.00	3.00	2.50	3.00	1.50	2.86
Average	11.00	8.00	6.00	6.20	5.80	4.20	6.00	5.30	5.40	5.70	2.42	5.33	2.50	5.52
II. ESTUARY/MANGROVE AREA														
2 Sogod River	6.50	4.00	6.00	3.50	5.00	5.00	4.00	7.00	3.00	2.00	3.50	5.00	7.00	4.73
4 Lagonoy River	2.00	4.00	3.00	2.00	3.00	4.00	2.00	5.00	3.00	3.50	1.50	1.00	3.00	2.85
7 Dato River	-	1.80	2.50	3.00	5.00	4.60	5.00	4.00	3.00	5.00	3.00	1.50	2.00	3.37
12 Cagraray Island	-	-	-	1.20	2.00	1.50	3.00	2.00	1.50	1.50	-	-	-	1.81
14 Bariw Point	-	-	0.75	1.00	1.00	1.50	1.50	1.00	2.00	1.00	1.50	4.00	1.50	1.52
Average	4.25	3.27	2.45	2.14	3.20	3.32	3.10	3.80	2.50	2.60	2.38	2.88	3.38	2.86
III. DEEP AREA														
3 Grid 13	-	914.00	914.00	914.00	914.00	914.00	914.00	914.00	914.00	914.00	914.00	**	914.00	29.43
5 Maqueda Channel	-	-	850.39	850.39	850.39	850.39	850.39	850.39	850.39	850.39	850.39	**	850.39	29.33
8 Grid 50	-	-	1,009.49	1,009.49	1,009.49	1,009.49	1,009.49	1,009.49	1,009.49	1,009.49	-	-	-	1,009.49
11 Grid 33	-	-	950.60	950.60	950.60	950.60	950.60	950.60	950.60	950.60	-	-	-	950.60
15 Tabaco Bay	-	-	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00
Average	-	914.00	761.90	761.90	761.90	761.90	761.90	761.90	761.90	761.90	30.00	29.00	29.00	420.77

Note: - means no data.

*depth estimates based on nautical chart (Source: NAMRIA 4715)

** inclement weather did not permit sampling

Table 1.3. Transparency (m) estimates at different areas in Lagonoy Gulf, December 93 - December 94.

Classification	Sampling Period													Average
	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Coral reef/seagrass/seaweed area														
1 Rawis Point	-	4.00	5.00	9.00	10.00	7.00	12.00	7.00	12.00	9.00	-	-	-	8.33
6 Agoho Point	8.00	8.50	11.00	5.00	5.00	4.00	6.00	8.00	5.00	3.50	3.50	11.00	4.00	6.35
9 Acal Point	-	-	4.00	8.00	5.00	6.00	5.00	5.00	5.00	6.00	-	-	-	5.50
10 Gaba Bay	-	-	3.00	3.00	4.00	2.00	3.00	2.00	2.00	4.00	1.25	2.00	2.00	2.57
13 Casolgan Pass	-	-	7.00	3.00	2.00	2.00	3.00	1.50	3.00	3.00	2.50	3.00	1.50	2.86
Average	8.00	6.25	6.00	5.60	5.20	4.20	5.80	4.70	5.40	5.10	2.42	5.33	2.50	5.12
II. Estuary/mangrove area														
2 Sogod River	3.00	3.00	6.00	3.00	5.00	5.00	4.00	7.00	3.00	2.00	3.50	5.00	7.00	4.35
4 Lagonoy River	1.00	-	3.00	2.00	3.00	4.00	2.00	3.00	3.00	3.50	1.50	1.00	3.00	2.73
7 Bato River	-	1.50	2.50	2.00	5.00	4.00	5.00	3.00	3.00	3.50	3.00	1.50	2.00	3.00
12 Cagraray Island	-	-	-	1.20	2.00	1.50	3.00	2.00	1.50	1.50	-	-	-	1.81
14 Bariw Point	-	-	0.75	1.00	1.00	1.50	1.50	-	2.00	1.00	1.50	4.00	1.50	1.43
Average	2.00	2.25	3.06	1.84	3.20	3.20	3.10	3.75	2.50	2.30	2.38	2.88	3.38	2.76
III. Deep area														
3 Grid 13	-	-	19.00	17.00	13.00	32.00	22.00	19.00	18.00	12.00	27.00	*	15.00	19.40
5 Maqueda Channel	-	6.50	20.00	18.00	21.00	49.00	22.00	12.00	21.00	20.00	16.50	*	29.00	21.36
8 Grid 50	-	-	22.00	20.00	20.00	26.00	18.00	17.00	22.00	23.00	-	-	-	21.00
11 Grid 33	-	-	17.00	22.00	20.00	19.00	22.00	15.00	31.00	24.00	-	-	-	21.25
15 Tabaco Bay	-	-	14.50	16.00	5.00	15.00	11.00	7.00	10.00	8.50	13.00	12.00	9.00	11.00
Average		6.50	18.50	18.60	15.80	28.20	19.00	14.00	20.40	17.50	18.83	12.00	17.67	17.25

Note: - means no data.

*inclement weather did not permit sampling.

Table 1.4. Suspended solid concentrations (mg^{-1}) at different areas in Lagonoy Gulf for February - December 1994.

Classification	Sampling Depth (m)	Sampling Period Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
I. Coral reef/seagrass/seaweed area													
1 Rawis Point	2.00	31.40	68.90	27.35	39.55	39.80	32.35	27.55	29.55	-	-	-	37.06
6 Agoho Point	2.00	37.55	61.80	34.05	46.40	40.65	27.50	25.30	40.95	28.30	18.30	44.25	36.82
9 Acal Point	2.00	31.85	61.60	33.35	41.55	39.35	12.55	39.00	41.85	-	-	-	37.64
10 Gaba Bay	2.00	30.25	66.95	33.05	34.30	39.05	21.25	31.10	35.90	33.25	16.90	33.00	34.09
13 Casolgan Pass	2.00	30.90	67.75	33.00	45.95	41.80	26.40	23.25	41.30	28.70	12.75	33.60	35.04
Average	2.00	32.39	65.40	32.16	41.55	40.13	24.01	29.24	37.91	30.08	15.98	36.95	35.07
II. Estuary/mangrove area													
2 Sogod River	2.00	32.75	68.40	30.90	40.35	43.05	26.95	32.60	33.50	28.75	17.95	40.40	35.96
4 Lagonoy River	2.00	34.10	66.60	33.30	43.55	35.10	30.20	18.65	30.80	30.80	8.20	27.35	32.60
7 Bato River	2.00	34.70	64.55	17.75	31.15	39.00	1.60	21.20	30.75	33.80	12.10	35.55	29.29
12 Cagraray Island	2.00	-	60.65	30.00	41.25	42.55	29.10	27.45	40.65	-	-	-	33.96
14 Bariw Point	0.75	31.25	39.15	26.00	37.45	40.95	24.90	27.50	44.80	38.60	7.95	40.45	32.64
Average	1.75	33.20	59.87	27.59	38.75	40.13	22.55	25.48	36.10	32.99	11.55	35.94	33.10
III. Deep area													
Surface													
3 Grid 13	2.00	27.45	40.00	29.40	37.50	41.35	27.80	20.25	31.80	30.40	*	33.55	31.95
5 Maqueda Channel	2.00	33.70	62.75	34.00	34.80	38.45	26.60	30.20	37.65	28.60	*	35.30	36.21
8 Grid 50	2.00	20.95	64.05	32.30	43.35	38.80	21.15	19.65	21.85	-	-	-	32.76
11 Grid 33	2.00	26.80	65.40	32.00	51.15	23.55	26.80	28.35	41.35	-	-	-	36.93
15 Tabaco Bay	2.00	30.75	42.80	31.00	58.50	33.35	21.20	33.95	35.70	36.15	13.45	34.90	33.80
Average	2.00	27.93	55.00	31.74	45.06	35.10	24.71	26.48	33.67	31.72	13.45	34.58	32.68
Middle													
3 Grid 13	50.00	32.85	42.00	28.45	39.00	37.30	21.95	28.70	30.70	22.30	*	38.80	32.21
5 Maqueda Channel	50.00	31.50	63.20	29.20	42.15	40.15	24.25	20.55	38.50	32.95	*	36.70	35.92
8 Grid 50	50.00	18.95	61.45	38.10	38.15	41.90	20.35	24.30	26.30	-	-	-	33.69
11 Grid 33	50.00	21.05	64.35	31.00	43.00	40.60	23.60	29.65	34.05	-	-	-	35.91
15 Tabaco Bay	50.00	33.60	41.45	34.00	40.25	34.25	21.45	27.65	35.00	25.15	14.35	36.55	31.25
Average	50.00	27.59	54.49	32.15	40.51	38.84	22.32	26.17	32.91	26.80	14.35	37.35	32.13
Bottom													
3 Grid 13	250.00	25.80	40.15	30.50	34.70	32.30	27.75	20.05	33.40	29.35	*	39.05	31.31
5 Maqueda Channel	250.00	28.50	65.60	34.50	36.80	40.50	26.25	20.35	38.30	30.35	*	37.05	35.82
8 Grid 50	250.00	13.15	60.95	35.35	44.50	41.45	21.85	22.15	38.30	-	-	-	34.71
11 Grid 33	250.00	18.10	64.25	34.00	49.55	31.80	21.75	25.00	35.65	-	-	-	35.01
15 Tabaco Bay	84.00	25.75	44.55	35.00	67.20	36.15	26.40	40.80	34.45	31.90	14.00	32.05	35.30
Average	216.80	22.26	55.10	33.87	46.55	36.44	24.80	25.67	36.02	30.53	14.00	36.05	32.84

Note: - means no data.

*inclement weather did not permit sampling

Table 1.5. Temperature (°C) measurement at different areas in Lagonoy Gulf, December 93 - December 94.

Station	Sampling Depth (m)	Sampling Period													Average
		Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
I. Coral reef/seagrass/seaweed area															
1 Rawis Point	2.00	-	28.20	28.00	28.50	29.00	31.50	31.00	29.00	30.00	29.00	-	-	-	29.36
6 Agoho Point	2.00	28.00	28.20	30.00	28.00	29.50	32.00	32.00	30.00	30.00	29.50	30.50	28.00	29.50	29.63
9 Acal Point	2.00	-	-	28.00	27.50	29.00	32.50	31.00	29.00	30.00	29.00	-	-	-	29.50
10 Gaba Bay	2.00	-	-	28.00	29.00	29.75	32.00	31.00	29.00	30.00	29.00	30.00	29.00	28.00	29.52
13 Casolgan Pass	2.00	-	-	28.00	30.00	29.75	33.00	31.00	29.75	31.00	29.50	31.00	28.50	28.50	30.00
Average	2.00	28.00	28.20	28.40	28.60	29.40	32.20	31.20	29.35	30.20	29.20	30.50	28.50	28.67	29.60
II. Estuary/mangrove area															
2 Sogod River	2.00	29.00	28.50	28.00	29.00	30.00	31.75	31.00	29.00	31.00	30.00	30.00	29.00	29.50	29.67
4 Lagonoy River	2.00	27.00	28.00	28.50	29.00	31.00	31.50	32.00	29.00	29.00	29.00	31.00	27.50	29.50	29.38
7 Bato River	2.00	-	28.00	29.00	27.00	29.00	31.00	33.00	29.00	30.00	30.00	29.50	27.00	29.00	29.29
12 Cagraray Island	2.00	-	-	-	28.00	30.00	32.50	31.00	30.00	30.00	30.00	-	-	-	30.21
14 Bariw Point	0.75	-	-	27.00	29.00	29.00	32.00	31.00	28.00	31.00	29.00	29.00	29.00	30.00	29.45
Average	1.75	28.00	28.17	28.13	28.40	29.80	31.75	31.60	29.00	30.20	29.60	29.88	28.13	29.50	29.60
III. Deep area															
Surface															
3 Grid 13	2.00	-	-	29.50	29.50	29.75	32.00	31.00	29.00	29.00	29.00	30.00	*	29.00	29.43
5 Maqueda Channel	2.00	-	29.00	28.50	28.00	29.00	32.00	31.00	29.00	30.00	30.00	30.00	*	29.00	29.33
8 Grid 50	2.00	-	-	28.00	28.00	28.00	32.50	30.00	29.50	30.00	30.00	-	-	-	29.50
11 Grid 33	2.00	-	-	28.00	29.00	29.00	32.00	31.00	29.00	30.00	29.00	-	-	-	29.63
15 Tabaco Bay	2.00	-	-	28.50	30.00	28.00	32.00	30.00	29.00	31.00	29.00	30.00	29.00	29.00	29.59
Average	2.00		29.00	28.50	28.90	28.75	32.10	30.60	29.10	30.00	29.40	30.00	29.00	29.00	29.49
Middle															
3 Grid 13	50.00	-	-	28.00	29.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	*	27.00	27.56
5 Maqueda Channel	50.00	-	-	28.00	28.00	30.00	29.00	28.00	28.00	28.00	27.00	28.00	*	28.00	28.11
8 Grid 50	50.00	-	-	28.00	28.00	27.75	29.00	29.00	28.00	28.00	29.00	-	-	-	28.34
11 Grid 33	50.00	-	-	28.00	29.00	28.00	29.75	28.00	27.00	28.00	29.00	-	-	-	28.34
15 Tabaco Bay	50.00	-	-	27.50	28.50	28.00	30.00	28.00	27.00	28.00	28.50	29.00	29.00	28.00	28.32
Average	50.00	-	-	27.90	28.50	28.35	29.15	28.20	27.60	28.00	28.30	28.33	29.00	27.67	28.13
Bottom															
3 Grid 13	250.00	-	-	27.00	28.00	26.00	26.00	25.00	26.00	25.00	27.00	25.00	*	25.00	25.56
5 Maqueda Channel	250.00	-	-	25.00	26.00	28.00	26.00	25.00	26.00	25.00	25.00	27.00	*	25.00	25.45
8 Grid 50	250.00	-	-	28.00	26.00	27.00	26.00	26.00	27.50	26.00	25.00	-	-	-	26.44
11 Grid 33	250.00	-	-	28.00	25.00	28.00	25.00	25.00	24.00	25.00	26.00	-	-	-	25.75
15 Tabaco Bay	84.00	-	-	27.00	28.00	27.00	29.00	25.00	26.00	26.00	27.50	28.00	29.00	27.00	27.23
Average	216.80	-	-	27.00	26.60	27.20	26.40	25.20	25.90	25.40	26.10	26.67	29.00	25.67	26.08

Note: - means no data.

*inclement weather did not permit sampling.

Table 1.6. Salinity (ppt) measurements at different areas in Lagonoy Gulf, January - December 94.

Classification	Sampling Depth (m)	Sampling Period												Average
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
I. Coral reef/seagrass/seaweed area														
1 Rawis Point	2.00	32.00	-	35.00	30.00	31.50	31.00	31.00	29.00	33.00	-	-	-	31.56
6 Agoho Point	2.00	34.00	-	35.00	32.00	30.00	31.00	32.00	27.00	30.00	33.00	35.00	33.00	32.00
9 Acal Point	2.00	-	-	33.00	34.00	37.00	32.00	28.00	31.00	34.00	-	-	-	28.63
10 Gaba Bay	2.00	-	-	30.00	34.00	34.00	35.00	26.00	30.00	33.00	32.00	32.00	32.00	31.80
13 Casolgan Pass	2.00	-	-	30.00	33.00	34.00	30.00	32.00	32.00	30.00	32.00	32.00	32.00	31.70
Average	2.00	33.00		32.60	32.60	33.30	31.80	29.80	29.80	32.00	32.33	33.00	32.33	32.05
II. Estuary/mangrove area														
2 Sogod River	2.00	30.00	-	-	32.50	31.75	31.00	32.00	30.00	30.00	33.00	30.00	32.00	31.23
4 Lagonoy River	2.00	32.00	-	35.00	32.00	30.00	31.00	32.00	30.00	33.00	35.00	2.00	2.00	26.73
7 Bato River	2.00	-	-	25.00	29.00	28.00	32.00	0.00	25.00	33.00	32.00	24.00	33.00	26.10
12 Cagraray Island	2.00	-	-	33.00	33.00	33.00	31.00	30.00	33.00	32.00	-	-	-	32.14
14 Bariw Point	0.75	-	-	30.00	26.00	36.00	32.00	30.00	25.00	32.00	33.00	32.00	32.00	30.80
Average	1.75	31.00		30.75	30.50	31.75	31.40	24.80	28.60	32.00	33.25	22.00	24.75	29.16
III. Deep area														
Surface														
3 Grid 13	2.00	-	-	30.00	33.00	32.00	31.00	30.00	30.00	35.00	35.00	*	32.00	32.00
5 Maqueda Channel	2.00	30.00	-	35.00	30.00	33.00	31.00	31.00	30.00	35.00	35.00	*	30.00	32.00
8 Grid 50	2.00	-	-	35.00	35.00	34.00	30.00	30.00	34.00	35.00	-	-	-	33.29
11 Grid 33	2.00	-	-	35.00	32.00	30.00	30.50	35.00	30.00	31.00	-	-	-	31.93
15 Tabaco Bay	2.00	-	-	30.00	31.00	35.00	34.00	36.00	30.00	33.00	31.00	32.00	30.00	32.20
Average	2.00	30.00		33.00	32.20	32.80	31.30	32.40	30.80	33.80	33.67	32.00	30.67	35.26
Middle														
3 Grid 13	50.00	-	-	30.00	34.00	34.00	33.00	28.00	32.00	35.00	35.00	*	32.00	32.00
5 Maqueda Channel	50.00	-	-	35.00	32.00	33.00	34.00	31.00	27.00	32.00	33.00	*	31.00	32.00
8 Grid 50	50.00	-	-	35.00	35.00	32.00	31.00	30.00	30.00	33.00	-	-	-	32.29
11 Grid 33	50.00	-	-	35.00	31.00	30.00	35.00	30.00	32.00	34.00	-	-	-	32.43
15 Tabaco Bay	50.00	-	-	30.00	34.00	38.00	34.00	38.00	30.00	33.00	33.00	32.00	30.00	33.20
Average	50.00	-	-	33.00	33.20	33.40	33.40	31.40	30.20	33.40	33.67	32.00	31.00	32.47
Bottom														
3 Grid 13	250.00	-	-	32.00	33.00	34.00	35.00	30.00	32.00	35.00	35.00	*	33.00	33.22
5 Maqueda Channel	250.00	-	-	38.00	35.00	35.00	36.00	32.50	35.00	33.00	35.00	*	34.00	34.19
8 Grid 50	250.00	-	-	35.00	35.00	35.00	32.00	34.50	35.00	33.00	-	-	-	34.21
11 Grid 33	250.00	-	-	30.00	34.00	30.00	35.00	30.00	35.00	35.00	-	-	-	32.71
15 Tabaco Bay	84.00	-	-	30.00	35.00	38.00	35.00	-	30.00	35.00	33.00	34.00	33.00	33.67
Average	216.80	-	-	31.75	34.40	34.40	34.60	31.75	33.40	34.20	34.33	34.00	33.33	33.62

Note; - means no data.

*inclement weather did not permit sampling.

Table 1.7. Dissolved oxygen content (mg/l) at different areas in Lagonoy Gulf, January - December 94.

Station	Sampling Depth (m)	Sampling Period												Average
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
I. Coral reef/seagrass/seaweed area														
1 Rawis Point	2.00	-	6.69	7.47	7.24	6.75	6.71	7.20	7.44	6.66	-	-	-	7.02
6 Agoho Point	2.00	5.99	8.09	7.83	9.40	9.10	7.24	9.52	11.26	6.46	8.96	6.75	8.22	8.24
9 Acal Point	2.00	-	6.89	7.57	10.11	8.66	6.83	9.79	8.81	6.31	-	-	-	8.12
10 Gaba Bay	2.00	-	-	9.06	8.80	7.54	7.15	11.45	7.24	7.10	6.51	8.13	6.90	7.99
13 Casolgan Pass	2.00	-	6.74	8.64	8.96	9.64	6.85	7.34	7.20	6.85	6.41	7.10	8.13	7.62
Average	2.00	5.99	7.10	8.11	8.90	8.34	6.96	9.06	8.39	6.68	7.29	7.33	7.75	7.80
II. Estuary/mangrove area														
2 Sogod River	2.00	6.20	8.46	7.26	10.36	6.46	5.87	10.52	8.47	7.54	6.56	7.00	7.78	7.71
4 Lagonoy River	2.00	6.29	8.00	7.26	8.57	8.87	6.85	11.94	7.70	6.68	6.86	7.29	8.03	7.86
7 Bato River	2.00	-	7.73	7.17	8.66	6.74	8.76	11.52	7.69	6.34	6.85	6.79	8.32	7.21
12 Cagraray Island	2.00	-	-	5.36	9.54	8.76	6.17	7.83	6.71	7.10	-	-	-	7.35
14 Bariw Point	0.75	-	5.46	7.74	9.03	8.32	6.75	7.44	7.24	6.68	6.90	7.73	9.35	7.51
Average	1.75	6.25	7.41	6.96	9.23	7.83	6.88	9.85	7.56	6.87	6.79	7.20	8.37	7.53
III. Deep area														
Surface														
3 Grid 13	2.00	-	8.36	7.89	8.20	6.95	6.75	9.94	7.78	6.75	7.05	*	8.42	7.10
5 Maqueda Channel	2.00	-	8.23	6.99	7.91	8.57	6.90	10.77	8.22	6.85	6.85	*	6.85	7.10
8 Grid 50	2.00	-	6.80	7.86	8.97	7.93	7.02	12.28	7.78	6.85	-	-	-	8.19
11 Grid 33	2.00	-	6.89	7.66	8.86	6.85	7.24	9.50	7.78	6.85	-	-	-	7.70
15 Tabaco Bay	2.00	-	6.11	6.89	8.77	6.95	7.24	10.82	7.15	7.15	6.64	6.85	8.49	7.55
Average	2.00		7.28	7.46	8.54	7.45	7.03	10.66	7.74	6.89	6.85	6.85	7.92	7.53
Middle														
3 Grid 13	50.00	-	9.70	7.49	7.89	6.95	6.02	9.84	7.83	6.96	6.81	*	8.96	7.13
5 Maqueda Channel	50.00	-	8.44	7.49	8.03	6.31	6.93	9.89	9.79	6.68	6.95	*	7.15	7.06
8 Grid 50	50.00	-	6.89	7.61	8.26	7.64	7.41	10.62	7.44	6.88	-	-	-	7.84
11 Grid 33	50.00	-	7.24	7.66	8.80	8.81	7.44	8.71	7.44	6.90	-	-	-	7.88
15 Tabaco Bay	50.00	-	5.46	5.60	8.30	7.15	7.41	5.34	4.11	6.71	5.78	5.53	6.71	6.19
Average	50.00	-	7.55	7.17	8.26	7.37	7.04	8.88	7.32	6.83	6.51	5.53	7.61	7.22
Bottom														
3 Grid 13	250.00	-	6.44	7.80	6.86	6.56	5.97	9.59	7.44	6.36	6.46	*	7.24	6.43
5 Maqueda Channel	250.00	-	8.06	7.09	7.27	6.17	6.27	9.45	7.93	6.05	6.36	*	6.80	6.50
8 Grid 50	250.00	-	6.63	6.87	8.81	6.66	6.73	9.50	7.29	6.36	-	-	-	7.36
11 Grid 33	250.00	-	6.00	6.73	9.29	5.87	5.92	7.78	6.85	6.02	-	-	-	6.81
15 Tabaco Bay	84.00	-	4.87	4.30	4.20	5.58	4.99	7.07	5.58	3.87	3.77	4.80	4.89	4.90
Average	216.80	-	6.40	6.56	7.29	6.17	5.98	8.68	7.02	5.73	5.53	4.80	6.31	6.40

Note: - means no data.

* inclement weather did not permit sampling.

Table 1.8. pH measurements at different areas in Lagonoy Gulf, January - December 94.

Classification	Sampling Depth (m)	Sampling Period												Average
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
I. Coral reef/seagrass/seaweed area														
1 Rawis Point	2.00	7.00	7.19	7.00	7.00	8.00	8.10	8.30	7.00	8.20	-	-	-	7.53
6 Agoho Point	2.00	7.00	7.00	7.50	8.00	7.70	7.90	8.20	7.00	8.20	8.00	7.00	7.00	7.54
9 Acal Point	2.00	-	7.81	7.00	7.00	8.00	8.10	8.30	7.50	8.00	-	-	-	7.71
10 Gaba Bay	2.00	-	7.00	7.00	7.00	8.00	8.10	8.70	8.20	8.00	8.00	7.50	7.00	7.68
13 Casolgan Pass	2.00	-	8.49	7.00	7.00	8.00	8.00	8.30	7.00	8.00	8.00	7.50	7.00	7.66
Average	2.00	7.00	7.50	7.10	7.20	7.94	8.04	8.36	7.34	8.08	8.00	7.33	7.00	7.57
II. Estuary/mangrove area														
2 Sogod River	2.00	7.00	6.67	7.50	7.00	7.50	7.00	7.90	7.00	8.10	7.90	7.00	7.00	7.30
4 Lagonoy River	2.00	7.00	7.90	7.50	7.50	7.80	7.00	8.10	7.00	7.90	7.90	6.50	7.00	7.43
7 Bato River	2.00	7.00	7.95	6.00	7.50	7.90	8.10	8.30	7.50	8.00	7.90	7.00	7.00	7.51
12 Cagraray Island	2.00	-	-	7.00	8.75	8.00	8.30	8.20	8.00	8.00	-	-	-	8.04
14 Bariw Point	0.75	-	6.50	7.00	6.00	8.00	7.80	8.30	7.50	7.90	8.00	7.00	7.00	7.36
Average	1.75	7.00	7.26	7.00	7.35	7.84	7.64	8.16	7.40	7.98	7.93	6.88	7.00	7.45
III. Deep area														
Surface														
3 Grid 13	2.00	-	7.86	7.00	7.00	7.00	7.50	8.70	7.50	8.20	8.00	*	7.00	7.58
5 Maqueda Channel	2.00	7.00	7.00	7.00	7.00	7.80	7.80	8.00	7.00	7.80	8.10	*	7.50	8.20
8 Grid 50	2.00	-	7.70	7.00	8.00	8.00	8.00	8.00	7.50	8.10	-	-	-	7.79
11 Grid 33	2.00	-	7.65	7.00	7.00	7.10	8.00	8.70	7.00	8.50	-	-	-	7.62
15 Tabaco Bay	2.00	-	7.00	7.00	6.50	8.00	7.90	8.90	7.00	8.00	8.00	7.00	7.00	7.48
Average	2.00	7.00	7.44	7.00	7.10	7.58	7.84	8.46	7.20	8.12	8.03	7.00	7.17	7.50
Middle														
3 Grid 13	50.00	-	7.00	7.00	8.00	7.20	7.50	8.60	7.00	8.00	7.90	*	7.00	7.52
5 Maqueda Channel	50.00	-	7.00	7.00	7.00	7.50	7.90	8.00	7.00	8.00	8.00	*	7.50	7.49
8 Grid 50	50.00	-	7.09	7.00	8.00	8.00	8.00	8.00	7.50	8.50	-	-	-	7.76
11 Grid 33	50.00	-	7.44	7.00	7.00	7.50	8.00	8.70	7.50	8.20	-	-	-	7.67
15 Tabaco Bay	50.00	-	7.00	7.00	6.50	8.00	7.90	8.60	7.00	8.20	8.00	7.00	7.00	7.47
Average	50.00	-	7.11	7.00	7.30	7.64	7.86	8.38	7.20	8.18	7.97	7.00	7.17	7.53
Bottom														
3 Grid 13	250.00	-	7.57	7.50	7.00	7.00	7.00	8.20	7.00	8.20	8.50	*	7.00	7.50
5 Maqueda Channel	250.00	-	7.00	7.00	7.00	7.80	8.00	7.90	7.00	8.00	8.20	*	7.50	7.54
8 Grid 50	250.00	-	7.47	7.00	8.00	7.90	8.10	8.00	7.00	8.00	-	-	-	7.68
11 Grid 33	250.00	-	7.30	7.00	7.00	7.50	7.70	8.50	7.50	7.70	-	-	-	7.53
15 Tabaco Bay	84.00	-	7.00	7.00	6.50	8.00	8.10	8.60	7.00	8.00	8.00	7.00	7.00	7.47
Average	216.80	-	7.27	7.10	7.10	7.64	7.78	8.24	7.10	7.98	8.23	7.00	7.17	7.51

Note: - means no data.

*inclement weather did not permit sampling.

Table 1.9. Correlation matrix of the different variables from three areas of Lagonoy Gulf, 1994.

Parameters	Depth (m)	Trans-parency (m)	Suspended Solids (mg l $^{-1}$)	Water Temp (°C)	DO (mg l $^{-1}$)	pH	Salinity (ppt)	Zoo Bio (mg m $^{-3}$)	Chlor *A* (mg m $^{-3}$)
I. Coral reef/seagrass/seaweed area									
Depth (m)	1.00	0.97***						-0.56***	
Transparency (m)		1.00						-0.59***	
Suspended solids (mg l $^{-1}$)			1.00						
Water temperature (°C)				1.00		0.35***			
DO (mg l $^{-1}$)					1.00		-0.31**		
pH						1.00			
Salinity (ppt)							1.00		
Biomass (mg m $^{-3}$)								1.00	
Chlorophyll (mg m $^{-3}$)									1.00
II. Estuary/mangrove area									
Depth (m)	1.00	0.93***			0.30**			-0.46***	
Transparency (m)		1.00			0.26*			-0.43***	
Suspended solids (mg l $^{-1}$)			1.00		-0.28*		0.48***	-0.26*	
Water temperature (°C)				1.00		0.43***	0.29**		
DO (mg l $^{-1}$)					1.00				
pH						1.00			
Salinity (ppt)							1.00	-0.33**	
Biomass (mg m $^{-3}$)								1.00	
Chlorophyll (mg m $^{-3}$)									1.00
III. Deep area									
Surface									
Depth (m)	1.00	0.57***							
Transparency (m)		1.00		0.42***					
Suspended solids (mg l $^{-1}$)			1.00		-0.30**			-0.38***	
Water temperature (°C)				1.00					
DO (mg l $^{-1}$)					1.00				
pH						1.00	0.36**		
Salinity (ppt)							1.00		
Biomass (mg m $^{-3}$)								1.00	
Chlorophyll (mg m $^{-3}$)									1.00
Middle									
Depth (m)	1.00								
Transparency (m)		1.00							
Suspended solids (mg l $^{-1}$)			1.00			-0.26*	0.33**		
Water temperature (°C)				1.00					
DO (mg l $^{-1}$)					1.00		-0.36**		
pH						1.00			
Salinity (ppt)							1.00		
Biomass (mg m $^{-3}$)								1.00	
Chlorophyll (mg m $^{-3}$)									1.00
Bottom									
Depth (m)	1.00								
Transparency (m)		1.00							
Suspended solids (mg l $^{-1}$)			1.00						
Water temperature (°C)				1.00					
DO (mg l $^{-1}$)					1.00				
pH						1.00			
Salinity (ppt)							1.00		
Biomass (mg m $^{-3}$)								1.00	
Chlorophyll (mg m $^{-3}$)									1.00

Note: * - significant at 10%.
** - significant at 5%.
*** - significant at 1%.

Table 1.10. Duncan Multiple Range Test (DMRT) of the variables monitored in three areas of Lagonoy Gulf, 1994.

Parameter	Areas				
	Coral reef/seagrass/ Seaweed area	Estuary/mangrove area	Deep area		
			Surface	Middle	Bottom
Transparency (m)	5.02[b]	2.80[c]	18.50[a]		
Suspended solids (mg l^{-1})	35.98[a]	33.47[a]	33.60[a]	33.65[a]	34.41[a]
Water temperature (°C)	29.62[a]	29.55[a]	29.62[a]	28.23[b]	26.28[c]
Salinity (ppt)	31.92[a]	29.17[b]	32.24[a]	32.55[a]	33.65[a]
Dissolved oxygen (mg l^{-1})	7.83[a]	7.67[a]	7.80[a]	7.45[a]	6.58[b]
pH	7.62[a]	7.48[a]	7.57[a]	7.57[a]	7.54[a]
Biomass (mg m^{-3})	188.72[b]	375.63[a]	7.43[c]		

Means followed by the same letter are not significantly different from each other.

Table 1.11. General water quality parameters monitored for 24 hours in Tabaco Bay, summer (May) and southwest monsoon (August), 1994.

Time	Suspended solids (mg l^{-1})			Temperature (°C)			Salinity (ppt)			Dissolved oxygen* (mg l^{-1})			pH		
	2	50	84	2	50	84	2	50	84	2	50	84	2	50	84
Summer															
0100	23.80	23.00	35.90	29.00	28.00	27.00	33.00	33.00	33.00	8.17	8.57	4.06	7.00	7.00	6.50
0200	22.70	20.20	40.15	29.00	28.00	27.00	30.00	33.00	34.00	-			6.50	7.00	7.00
0300	21.85	20.50	20.05	29.00	28.00	28.00	30.00	35.00	34.00	8.07	7.39	3.77	7.00	7.50	7.50
0400	35.00	18.20	27.25	29.00	28.00	27.00	30.00	32.00	34.00	-			7.00	7.00	7.00
0500	35.70	32.50	40.65	29.00	27.00	28.00	31.00	34.00	35.00	9.84	7.30	4.09	7.00	7.00	7.00
0600	28.10	37.15	39.15	28.00	28.00	27.00	35.00	34.00	33.00	-			7.00	6.50	7.00
0700	30.00	28.80	31.60	29.00	28.00	28.00	31.00	34.00	34.00	8.13	8.37	4.36	7.00	7.00	7.00
0800	31.90	32.35	34.90	29.00	29.00	28.50	30.00	35.00	31.00	-			7.00	7.00	7.00
0900	30.90	39.40	30.25	30.00	29.00	29.00	25.00	28.00	30.00	8.71	7.23	3.87	7.00	7.00	6.50
1000	25.50	31.65	30.00	30.00	29.50	29.00	32.00	30.00	32.00	-			7.00	7.00	7.00
1100	40.25	28.05	30.20	30.00	29.00	29.00	35.00	30.00	30.00	8.13	6.51	3.37	7.00	7.00	7.00
1200	35.45	32.70	35.05	30.00	30.00	29.00	30.00	30.00	30.00	-			7.00	7.00	7.00
1300	28.15	35.60	29.55	31.00	29.00	29.50	30.00	30.00	30.00	7.97	6.66	3.91	7.00	7.00	7.00
1400	32.85	24.85	42.30	30.00	28.50	28.50	30.00	34.00	35.00	-			7.00	7.50	7.50
1500	30.05	29.10	57.60	30.00	27.00	28.50	30.00	33.00	34.00	7.49	5.09	3.33	7.00	7.00	7.00
1600	29.50	35.80	60.45	29.00	28.00	28.00	29.00	30.00	30.00	-			7.00	7.00	7.00
1700	30.20	33.80	34.40	29.00	28.00	27.50	30.00	34.00	34.00	7.93	5.43	5.24	7.00	7.00	7.50
1800	-			-			-			-			-		
1900	27.75	30.10	39.75	29.00	29.00	28.00	33.00	35.00	35.00	9.01	8.13	4.27	7.00	7.00	7.50
2000	26.45	32.35	59.50	29.00	28.00	28.00	31.00	35.00	35.00	-			7.00	7.00	7.00
2100	33.40	26.30	37.95	29.00	27.00	27.00	26.00	32.00	32.00	10.43	10.29	5.53	6.50	7.00	7.50
2200	28.20	31.95	36.25	29.00	28.00	28.00	33.00	33.00	32.00	-			6.50	7.00	7.00
2300	26.15	30.45	41.75	29.00	28.00	27.00	33.00	33.00	33.00	7.93	7.34	3.91	7.00	7.00	7.00
2400	21.90	27.50	29.55	29.00	28.00	27.00	34.00	32.00	34.00	-			7.00	7.00	6.50
Southwest monsoon															
0100	38.50	32.70	33.15	29.00	28.00	27.50	34.00	35.00	35.00	-			8.20	8.00	8.00
0200	30.20	31.15	51.9[illegible]	29.00	28.00	27.00	34.00	35.00	35.00	6.76	4.84	3.77	8.20	8.00	8.00
0300	34.55	40.80	31.95	29.00	28.00	27.50	35.00	35.00	35.00	-			8.00	8.00	8.00
0400	26.70	28.75	32.45	29.00	28.00	27.00	35.00	32.00	31.00	6.80	5.39	3.81	7.90	8.00	8.00
0500	34.90	30.25	28.00	29.00	28.00	27.00	34.00	35.00	35.00	-			8.00	8.20	7.90
0600	35.70	35.00	34.45	29.00	28.50	27.50	33.00	33.00	35.00	7.14	6.43	3.87	8.00	8.20	8.00
0700	-			-			-			-			-		
0800	39.20	39.30	41.40	29.00	28.50	27.50	30.00	32.00	35.00	6.86	5.71	3.23	8.10	8.00	7.90
0900	-			29.00	28.50	28.00	30.00	33.00	33.00	-			8.10	8.20	8.10
1000	-			29.50	28.50	27.50	34.00	35.00	35.00	7.00	6.41	3.67	8.00	8.20	8.00
1100	-			30.00	28.50	27.50	33.00	35.00	35.00	-			8.10	8.20	8.20
1200	-			30.00	29.00	28.00	32.00	34.00	35.00	7.63	6.86	4.06	8.10	8.10	8.00
1300	-			-			-			-			-		
1400	24.25	26.05	45.25	31.00	28.00	26.00	30.00	32.00	32.00	7.14	5.18	3.91	8.00	8.00	7.90
1500	19.05	32.15	37.00	31.00	28.00	27.00	31.00	30.00	32.00	-			8.20	8.00	8.00
1600	18.25	31.70	30.10	30.50	29.00	27.00	30.00	30.00	31.00	7.44	6.46	3.87	8.00	7.90	7.90
1700	27.30	27.45	21.25	30.50	28.00	28.00	30.00	32.00	30.00	-			8.00	7.70	8.00
1800	-			-			-			-			-		
1900	22.25	23.55	25.45	30.00	28.00	27.00	33.00	35.00	35.00	-			8.20	8.20	8.20
2000	32.35	23.90	24.75	30.00	28.00	28.00	35.00	35.00	35.00	-			8.20	8.00	8.00
2100	32.90	35.90	36.00	29.50	28.00	27.00	34.00	35.00	35.00	-			8.10	8.00	8.00
2200	28.40	35.85	40.70	29.00	28.00	28.00	35.00	35.00	35.00	7.10	5.93	3.63	8.20	8.00	8.00
2300	30.50	29.95	34.05	29.50	28.00	27.00	34.00	35.00	35.00	-			8.20	8.00	8.00
2400	33.15	48.05	140.10	29.00	28.00	27.00	35.00	35.00	35.00	6.94	5.71	3.67	8.20	8.00	8.00

Note: - = no data.

*sampling was done every other hour

Table 1.12. Correlation matrix of the parameters measured in Tabaco Bay to evaluate tidal variation during summer (April) and southwest monsoon (September), 1994.

Parameter	Tidal height (m)	Transparency (m)	Suspended Solids (mg l^{-1})	Water Temp (°C)	Salinity (ppt)	DO (mg l^{-1})	pH	Chloro *a* (mg m^{-3})	Zoo Bio (mg m^{-3})
Summer									
Tidal height (m)	1.00				0.50 *				
Transparency (m)		1.00							
Suspended solids (mg l^{-1})			1.00			-0.35 **			
Water temperature (°C)				1.00	-0.50 ***	0.34 **			
Salinity (ppt)					1.00	-0.36 **			
Dissolved oxygen (mg l^{-1})						1.00			
pH							1.00		
Chlorophyll a (mg m^{-3})								1.00	
Biomass (mg m^{-3})									1.00
Southwest monsoon									
Tidal height (m)	1.00		-0.62 *				0.53 *		
Transparency (m)		1.00							
Suspended solids (mg l^{-1})			1.00	-0.31 *		-0.39 *			
Water temperature (°C)				1.00	-0.40 ***	0.85 ***	0.33 ***		
Salinity (ppt)					1.00	-0.30 *			
Dissolved oxygen (mg l^{-1})						1.00	0.49 ***		
pH							1.00		
Chlorophyll *a* (mg m^{-3})								1.00	
Biomass (mg m^{-3})									1.00

Note: *** - significant at 1% level.

** - significant at 5% level.

* - significant at 10% level.

Table 1.13. General water quality parameters monitored for 24 hours in Lagonoy River, summer (April) and southwest monsoon (August), 1994.

Time	Suspended solids (mg^{-1})	Temperature (°C)	Salinity (ppt)	DO* (mg l^{-1})	pH
Summer					
0100	29.60	27.00	35.00	8.61	7.00
0200	28.80	28.00	34.00		7.00
0300	27.10	28.00	33.00	5.76	7.00
0400	33.45	28.00	34.00		7.00
0500	34.25	28.00	34.00	8.34	7.00
0600	31.85	29.00	33.00		7.00
0700	34.75	29.00	32.00	6.36	7.00
0800	34.45	29.50	32.00		7.20
0900	31.65	29.00	28.00	7.50	7.00
1000	35.80	29.00	31.00		7.50
1100	35.30	29.00	30.00	8.89	7.00
1200	32.30	30.00	31.00		7.00
1300	23.65	30.00	30.00	7.24	7.00
1400	31.60	29.00	30.00		7.50
1500	32.45	30.00	31.00	8.27	7.50
1600	32.45	29.75	31.00		7.50
1700	30.80	29.75	31.50	8.51	7.50
1800	29.40	29.00	31.00		7.50
1900	30.50	28.00	28.00	10.50	7.30
2000	31.20	28.00	29.00		7.20
2100	29.35	28.00	30.00	8.20	7.00
2200	30.10	27.50	31.00		7.00
2300	34.90	27.50	31.50	9.30	7.00
2400	30.70	27.00	34.00		7.00
Southwest monsoon					
0100	22.78	28.50	30.00	6.80	7.70
0200	14.05	28.50	33.00		7.70
0300	13.45	28.50	35.00	6.76	7.90
0400	21.70	29.00	35.00		7.90
0500	17.60	28.00	35.00	6.80	8.00
0600	17.00	29.00	33.00		7.90
0700	14.90	29.00	33.00	6.66	7.50
0800	16.30	30.00	30.00		7.90
0900	27.60	30.00	30.00	6.77	7.90
1000	27.95	30.00	27.00		8.00
1100	29.60	30.00	27.00	6.27	8.00
1200	27.90	30.00	28.00		8.00
1300	28.75	29.00	32.00	7.24	7.90
1400	26.55	29.00	32.00	-	8.00
1500	-	-	-	-	-
1600	-	-	-	-	-
1700	26.10	29.00	35.00	7.14	7.90
1800	28.75	29.00	32.00		8.00
1900	32.10	29.00	30.00	6.86	7.90
2000	30.65	29.00	30.00		7.90
2100	30.30	29.00	30.00	6.80	7.90
2200	27.10	29.00	25.00		7.90
2300	26.55	29.00	25.00	6.31	7.80
2400	24.25	29.00	25.00		7.70

Note: - = no data.

*sampling was done every other hour.

Table 1.14. Correlation matrix of the parameters measured in Lagonoy River to evaluate tidal variation during summer (April) and southwest monsoon (September), 1994.

Parameter	Tidal height (m)	Transparency (m)	Suspended solids (mg l^{-1})	Water Temp (°C)	Salinity (ppt)	DO (mg l^{-1})	pH	Chloro *a* (mg m^{-3})	Zoo Bio (mg m^{-3})
Summer									
Tidal height (m)	1.00								
Transparency (m)		1.00				-0.81 **			
Suspended solids (mg l^{-1})			1.00						
Water temperature (°C)				1.00	-0.38 *		0.47 **		0.80 *
Salinity (ppt)					1.00			-0.89 **	
Dissolved oxygen (mg l^{-1})						1.00		-0.91 **	
pH							1.00		0.76 *
Chlorophyll *a* (mg m^{-3})								1.00	
Biomass (mg m^{-3})									1.00
Southwest monsoon									
Tidal height (m)	1.00				0.99 **		0.91 *		
Transparency (m)		1.00	-0.97 ***		0.69 **			-0.94 *	
Suspended solids (mg l^{-1})			1.00	0.36 *	-0.50 **		0.42 **		
Water temperature (°C)				1.00	-0.39 *		0.36 *		
Salinity (ppt)					1.00	0.74 ***		-0.76 **	-0.79 **
Dissolved oxygen (mg l^{-1})						1.00			
pH							1.00		
Chlorophyll *a* (mg m^{-3})								1.00	0.68 *
Biomass (mg m^{-3})									1.00

Note: *** - significant at 1% level.

** - significant at 5% level.

* - significant at 10% level.

Table 1.15. General water quality parameters monitored for 24 hours in Sogod River, summer (April) and southwest monsoon (September), 1994.

Time	Suspended solids (mg l^{-1})	Temperature (°C)	Salinity (ppt)	DO* (mg l^{-1})	pH
Summer					
0100	30.55	29.00	30.00	-	7.00
0200	29.15	29.00	31.00	8.51	7.00
0300	26.05	29.00	29.50	-	7.00
0400	28.65	29.00	34.00	8.66	7.00
0500	25.20	28.00	30.00	-	7.00
0600	30.20	28.50	34.00	8.76	7.00
0700	23.80	29.00	33.00	-	7.00
0800	28.90	29.00	33.00	8.23	7.20
0900	29.05	29.00	34.00	-	7.00
1000	27.80	29.00	35.00	8.81	7.50
1100	31.35	29.00	35.00	-	7.00
1200	30.35	30.00	33.00	8.51	7.00
1300	31.20	29.00	35.00	-	7.00
1400	28.20	31.00	31.00	10.33	7.50
1500	29.70	31.00	35.00	-	7.50
1600	28.50	30.00	32.00	9.26	7.50
1700	27.35	30.00	33.00	-	7.50
1800	31.65	29.00	34.00	8.61	7.50
1900	31.95	29.00	34.00	-	7.30
2000	28.20	29.00	34.00	9.01	7.20
2100	28.35	29.00	34.00	-	7.00
2200	32.05	29.00	35.00	8.81	7.00
2300	28.85	29.00	35.00	-	7.00
2400	29.45	29.00	34.50	8.81	7.00
Southwest monsoon					
0100	18.05	28.00	30.00	6.56	7.70
0200	28.35	28.50	32.00	-	7.70
0300	26.45	28.00	28.00	6.55	7.90
0400	29.90	28.50	30.00	-	7.90
0500	26.05	29.00	32.00	6.41	8.00
0600	23.10	29.00	34.00	-	7.90
0700	30.20	29.00	33.00	6.11	7.50
0800	21.90	29.50	32.00	-	7.90
0900	23.35	29.50	28.00	-	7.90
1000	29.25	30.00	31.00	-	8.00
1100	33.90	30.00	30.00	7.54	8.00
1200	32.25	30.10	31.00	-	8.00
1300	27.05	31.00	28.00	7.48	7.90
1400	35.50	31.00	31.00	-	8.00
1500	38.05	30.00	31.00	8.66	-
1600	24.85	30.00	31.00	-	-
1700	27.50	30.00	31.00	8.81	7.90
1800	21.70	30.50	30.00	-	8.00
1900	31.30	30.00	31.00	7.00	7.90
2000	32.00	30.00	32.00	-	7.90
2100	-	-	-	-	7.90
2200	-	-	-	-	7.90
2300	10.45	29.00	35.00	6.90	7.80
2400	23.00	28.00	32.00	-	7.70

Note: - = no data.

*sampling was done every other hour.

Table 1.16. Correlation matrix of the parameters measured in Sogod River to evaluate tidal variation during summer (April) and southwest monsoon (September), 1994.

Parameter	Tidal height (m)	Transparency (m)	Suspended solids (mg l^{-1})	Water Temp (°C)	Salinity (ppt)	DO (mg l^{-1})	pH	Chloro *a* (mg m^{-3})	Biomass (mg m^{-3})
Summer									
Tidal height (m)	1.00								
Transparency (m)		1.00			-0.61 **	0.87 **			-0.99 ***
Suspended solids (mg l^{-1})			1.00		0.46 **				
Water temperature (°C)				1.00		0.76 ***			
Salinity (ppt)					1.00				
Dissolved oxygen (mg l^{-1})						1.00			
pH							1.00		
Chlorophyll *a* (mg m^{-3})								1.00	
Biomass (mg m^{-3})									1.00
Southwest monsoon									
Tidal height (m)	1.00		0.93 *						
Transparency (m)		1.00	-0.54 *	-0.74 ***	0.53 *	-0.86 *			
Suspended solids (mg l^{-1})			1.00	0.42 *					
Water temperature °C)				1.00		0.63 *			
Salinity (ppt)					1.00				
Dissolved oxygen (mg l^{-1})						1.00			
pH							1.00		
Chlorophyll *a* (mg m^{-3})								1.00	
Biomass (mg m^{-3})									1.00

Note: *** - significant at 1% level.

** - significant at 5% level.

* - significant at 10% level.

Table 1.17. Correlation matrix of the variables measured for tidal variation during two periods in Sogod River, 1994.

Parameter	Tidal height (m)	Transparency (m)	Suspended solids (mg l^{-1})	Water Temp (°C)	Salinity (ppt)	DO (mg l^{-1})	pH	Chloro *a* (mg m^{-3})	Biomass (mg m^{-3})
Tidal height (m)	1.00		0.82 **						
Transparency (m)		1.00	-0.43 **	-0.45 **	0.37 *				-0.71 *
Suspended solids (mg l^{-1})			1.00	0.28 *		0.37 *			
Water temperature (°C)				1.00		0.38 *			
Salinity (ppt)					1.00		-0.37 **		
Dissolved oxygen (mg l^{-1})						1.00	-0.61 ***		
pH							1.00		
Chlorophyll *a* (mg m^{-3})								1.00	
Biomass (mg m^{-3})									1.00

Note: *** - significant at 1% level.

** - significant at 5% level.

* - significant at 10% level.

Table 1.18. Location of stations selected for grid sampling in summer (May) and southwest monsoon (August) 1994.

Station/grid	Latitude	Longitude	Remarks
I. Coastal areas			
T (Bariw)	13°22.38"N	123°43.69' E	WQ station
P (Rawis)	13°24.81' N	123°45.75' E	WQ station
M (Sogod)	13°29.°5' N	123°39.28' E	WQ station
Grid L	13°34.00' N	123°35.40' E	coastal area
Grid I	13°35.22' N	123°32.98' E	coastal area
Grid G	13°38.45' N	123°33.46' E	coastal area
A (Lagonoy)	13°43.60' N	123°35.75' E	WQ station
Grid C	13°41.09' N	123°41.09' E	coastal area
Grid D	13°41.01' N	123°45.01' E	coastal area
Grid F	13°41.01' N	123°50.22' E	coastal area
Grid AH	13°39.47' N	124°01.79' E	coastal area
AI (Agoho)	13°35.86' N	124°03.75' E	WQ station
Grid AP	13°29.98' N	124°08.05' E	coastal area
Grid AR	13°29.98' N	124°12.99' E	coastal area
Grid AM	13°33.53' N	124°14.56' E	coastal area
AN (Bato)	13°35.58' N	124°17.00' E	WQ station
Grid AO	13°32.71' N	124°18.72' E	coastal area
Grid AT	13°29.99' N	124°19.01' E	coastal area
Grid AF	13°13.21' N	124°11.16' E	coastal area
AE (Acal Pt)	13°13.53' N	124°06.82' E	WQ station
Grid AC	13°17.01' N	124°01.96' E	coastal area
AB (Gaba)	13°16.73' N	123°59.01' E	WQ station
X (Cagraray)	13°19.91' N	123°54.43' E	WQ station
Grid W	13°20.99' N	123°52.19' E	coastal area
Grid R	13°24.03' N	123°49.96' E	coastal area
V (Casolgan)	13°22.58' N	123°51.44' E	WQ station
II. Deep areas			
U (Tabaco)	13°20.09' N	123°46.50' E	WQ station
Grid 29	13°30.11' N	123°45.01' E	deep area
Grid 13	13°36.69' N	123°45.07' E	WQ station
Grid 11	13°36.00' N	123°38.00' E	deep area
Grid 2	13°41.01' N	123°56.00' E	deep area
AG (Maqueda)	13°39.22' N	123°58.86' E	WQ station
Grid 17	13°35.00' N	123°56.00' E	deep area
Grid 15	13°35.01' N	123°49.99' E	deep area
Grid 31	13°29.03' N	123°49.93' E	deep area
Grid 33	13°29.00' N	123°55.70' E	WQ station
Grid 35	13°30.59' N	124°02.36' E	deep area
Grid 48	13°22.97' N	123°58.96' E	deep area
Grid 50	13°23.02' N	124°04.07' E	WQ station
Grid 52	13°24.00' N	124°11.00' E	deep area
Grid 54	13°24.00' N	124°17.00' E	deep area
Grid 66	13°18.04' N	124°12.75' E	deep area
Grid 64	13°18.67' N	124°05.26' E	deep area

Table 1.19. General water quality variables measured during grid sampling in Lagonoy Gulf, summer (SM; May) and southwest monsoon (SW; August) 1994.

Station	Transparency (m)		Suspended solids (mg l^{-1})		Temperature (°C)		Dissolved oxygen (mg l^{-1})		Salinity (ppt)		pH	
	SM	SW	SM	SW	SM	SW	SM	SW	SM	SW	SM	SW
I. Coastal areas												
Grid T	1.50	2.00	37.45	27.50	32.00	31.00	8.32	7.24	36.00	25.00	8.00	7.50
Grid P	7.00	12.00	39.55	27.55	31.50	30.00	6.75	7.44	30.00	29.00	8.00	7.00
Grid M	5.00	3.00	40.35	32.60	31.75	31.00	6.46	8.47	32.00	30.00	7.50	7.00
Grid L	11.00	22.00	48.75	22.05	32.00	30.00	8.34	9.51	31.00	32.00	7.90	7.00
Grid I	11.00	20.00	39.65	29.40	32.00	29.00	7.80	9.63	28.00	30.00	8.00	7.00
Grid G	5.00	20.00	46.75	26.15	32.00	28.00	8.52	9.63	27.00	30.00	8.00	7.00
Grid A	4.00	3.00	43.55	18.65	31.50	29.00	8.87	7.70	30.00	30.00	7.80	7.00
Grid C	21.00	17.00	47.45	17.26	31.00	29.00	8.16	10.26	33.00	28.00	8.00	7.00
Grid D	22.00	19.00	37.30	17.95	31.00	28.00	8.24	10.08	35.00	27.00	8.00	7.00
Grid F	18.00	16.00	62.55	19.65	31.00	29.00	9.06	10.44	34.00	35.00	8.00	7.00
Grid AH	27.00	22.00	46.40	-	30.00	29.00	11.16	7.98	30.00	31.00	7.80	8.20
Grid AI	4.00	5.00	46.40	25.30	32.00	30.00	9.10	11.26	30.00	27.00	7.70	7.00
Grid AP	22.00	22.00	43.85	16.35	32.00	29.00	8.34	9.78	35.00	33.00	7.80	7.00
Grid AR	15.00	25.00	51.30	14.25	31.00	29.00	8.40	10.98	32.00	33.00	8.00	7.00
Grid AM	18.00	18.00	35.95	25.10	31.00	30.00	11.10	9.00	31.00	30.00	8.00	7.00
Grid AN	4.00	3.00	31.15	21.20	31.00	30.00	6.74	7.59	28.00	25.00	7.90	7.50
Grid AO	29.00	26.00	43.10	18.80	31.00	29.00	8.58	9.60	35.00	34.00	8.00	7.00
Grid AT	30.00	21.00	49.95	27.15	31.00	32.00	8.22	9.60	28.00	37.00	8.00	7.00
Grid AF	12.00	16.00	46.55	37.30	32.00	30.00	10.98	10.08	29.00	32.00	8.00	7.50
Grid AE	6.00	5.00	41.55	39.00	32.50	30.00	8.66	8.81	37.00	31.00	8.00	7.50
Grid AC	11.00	18.00	44.75	39.10	32.00	29.00	8.76	9.54	33.00	31.00	8.00	7.50
Grid AB	2.00	2.00	34.30	31.10	32.00	30.00	7.54	7.24	34.00	32.00	8.00	8.20
Grid X	1.50	1.50	41.25	27.45	32.50	30.00	8.76	6.71	33.00	33.00	8.00	8.00
Grid W	4.00	3.00	58.45	21.25	32.00	30.00	11.64	7.20	32.00	31.00	8.00	8.80
Grid R	12.00	17.00	50.80	31.60	31.50	28.00	9.72	7.20	27.00	30.00	8.00	7.50
Grid V	2.00	3.00	45.95	23.25	33.00	31.00	9.64	7.20	34.00	32.00	8.00	7.00
Average	11.73	13.13	44.43	24.50	31.63	29.62	8.76	8.85	31.69	30.69	7.94	7.32
II. Deep areas												
Grid U	15.00	10.00	58.50	33.95	32.00	31.00	6.95	7.15	35.00	30.00	8.00	7.00
Grid 29	22.00	21.00	42.75	31.40	32.00	30.00	8.40	9.48	35.00	35.00	8.00	7.50
Grid 13	32.00	18.00	37.50	20.25	32.00	29.00	6.95	7.78	32.00	30.00	7.00	7.50
Grid 11	17.00	22.00	42.75	28.00	32.00	29.00	8.58	9.60	33.00	33.00	8.00	7.00
Grid 2	56.00	21.00	42.75	32.65	31.75	30.00	9.84	9.60	33.00	33.00	8.00	7.00
Grid AG	49.00	21.00	34.80	30.20	32.00	30.00	8.57	8.22	33.00	30.00	7.80	7.00
Grid 17	23.00	23.00	43.75	26.50	32.00	30.00	8.10	9.84	34.00	34.00	7.00	7.00
Grid 15	20.00	18.00	41.90	36.90	32.00	30.00	8.04	9.48	35.00	32.00	7.10	7.00
Grid 31	19.00	22.00	43.65	27.60	33.00	29.00	8.28	9.36	31.00	31.00	7.10	7.00
Grid 33	19.00	31.00	51.15	28.35	32.00	30.00	6.85	8.03	30.00	30.00	7.10	7.00
Grid 35	25.00	22.00	50.65	19.40	32.00	29.00	8.01	10.16	35.00	33.00	7.90	7.00
Grid 48	19.00	33.00	39.25	24.80	32.50	30.00	10.86	9.60	30.00	29.00	8.00	7.00
Grid 50	26.00	22.00	43.35	19.65	32.50	30.00	7.93	8.03	34.00	34.00	8.00	7.50
Grid 52	29.00	22.00	42.80	22.75	31.00	30.00	7.20	9.54	31.00	35.00	7.90	7.00
Grid 54	31.00	24.00	43.55	33.15	31.00	30.00	8.13	9.60	26.00	28.00	8.00	7.00
Grid 66	20.00	22.00	35.95	35.70	32.00	30.00	8.34	8.52	31.00	32.00	8.00	7.00
Grid 64	16.00	22.00	40.25	30.20	32.00	29.00	8.52	9.60	39.00	31.00	8.00	7.50
Average	25.76	22.00	43.25	28.32	31.99	29.76	8.21	9.03	32.76	31.76	7.70	7.12

Note: - = means no data

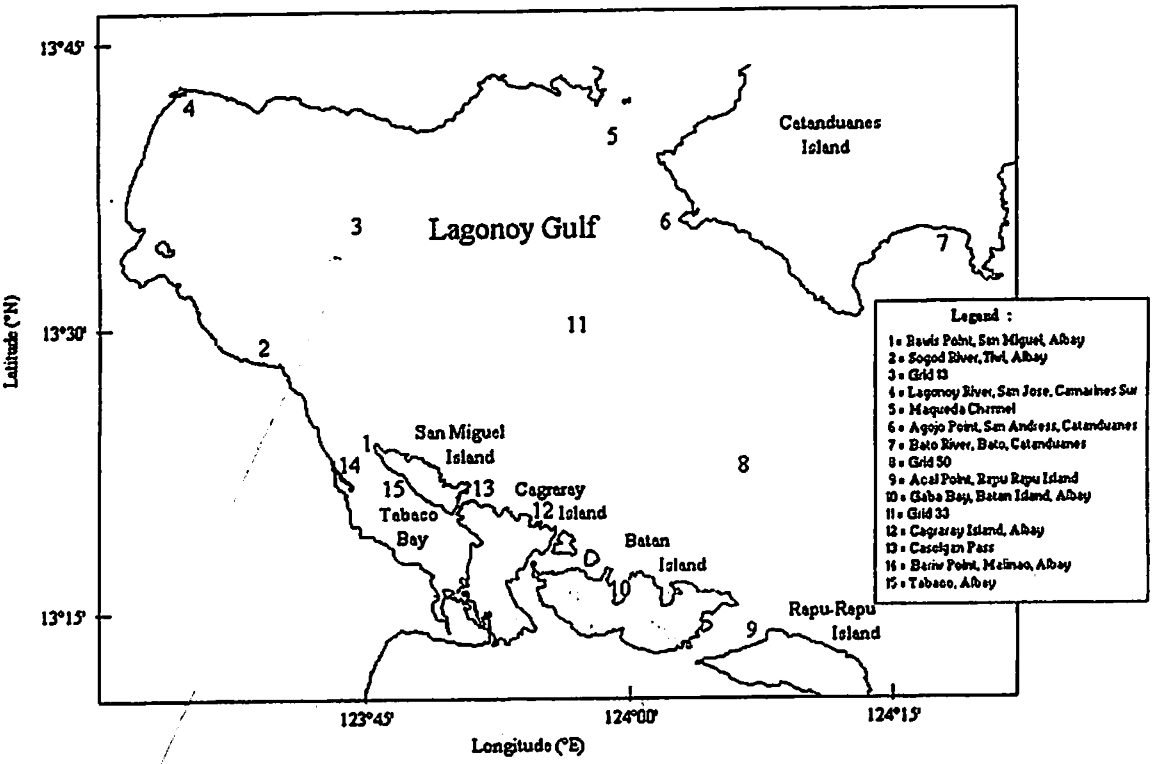

Fig. 1.1. Sampling stations for the assessment of water quality.

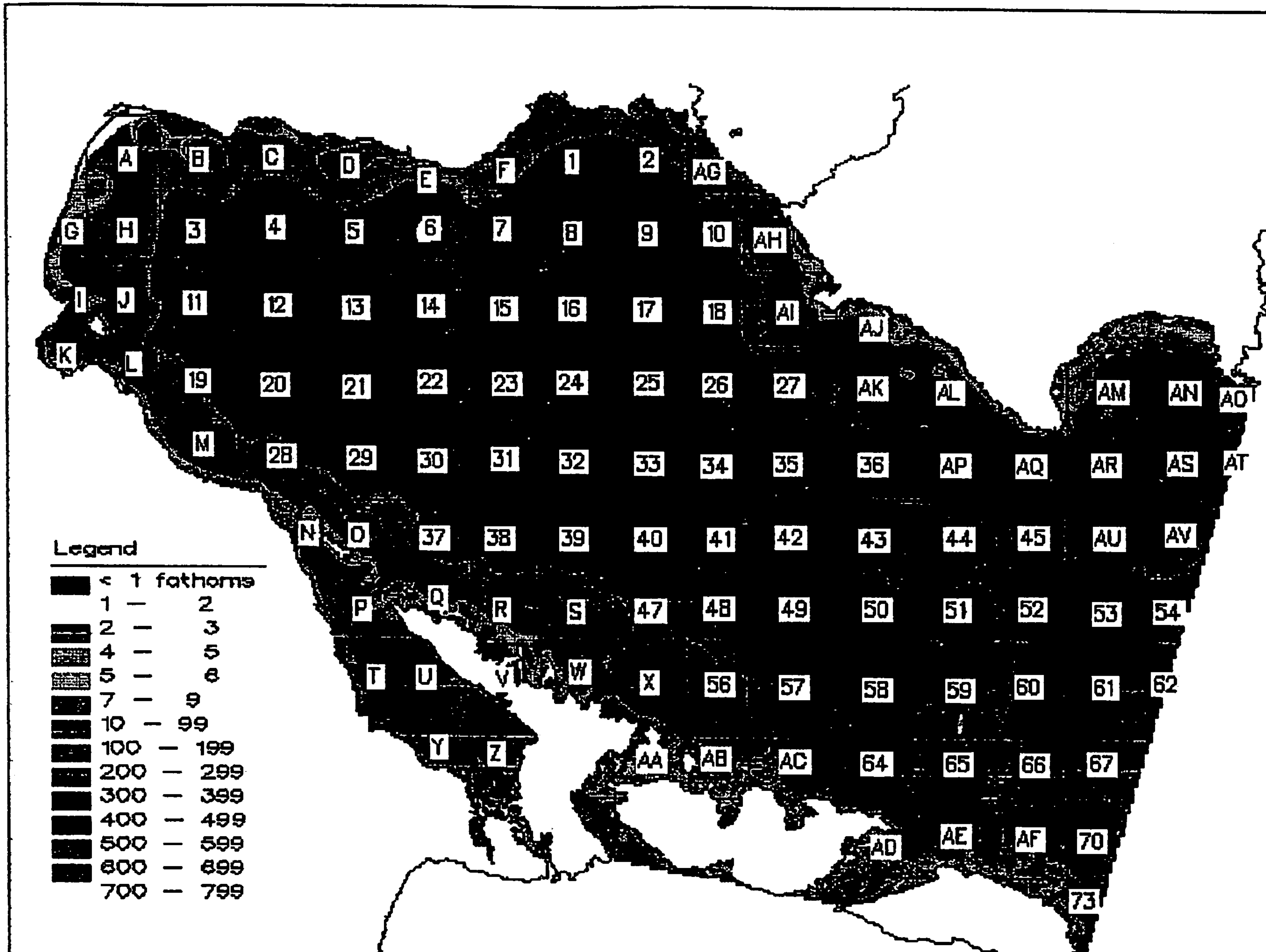

Fig. 1.2. Map grids for spatial sampling of water quality assessment.

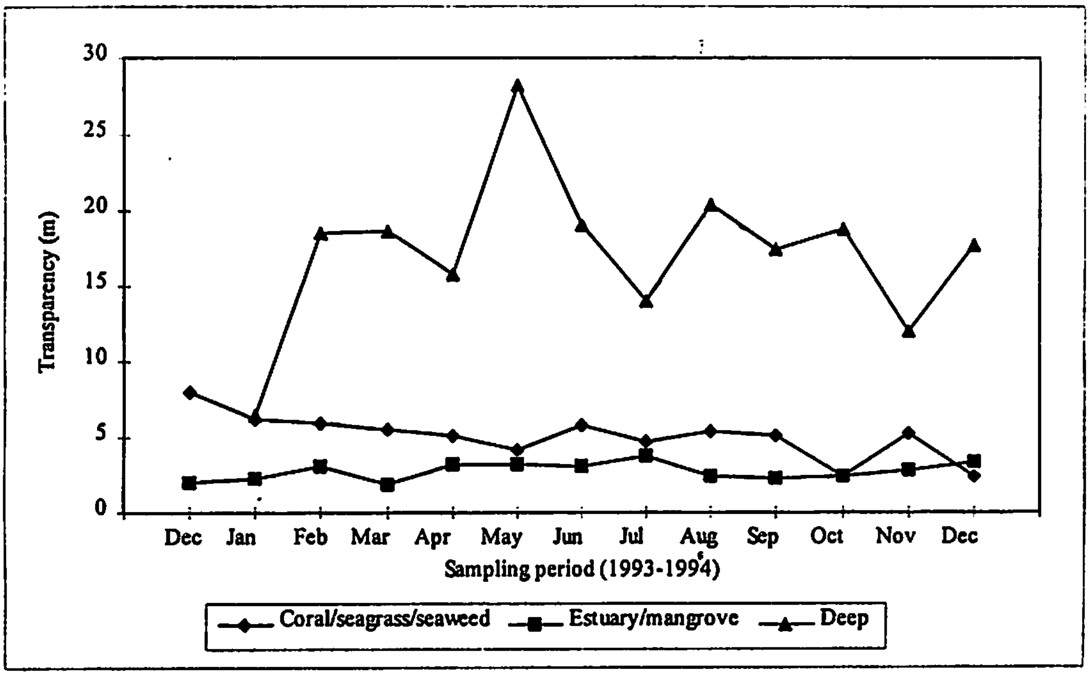

Fig. 1.3. Transparency (m) readings in Lagonoy Gulf, December 1993 - December 1994.

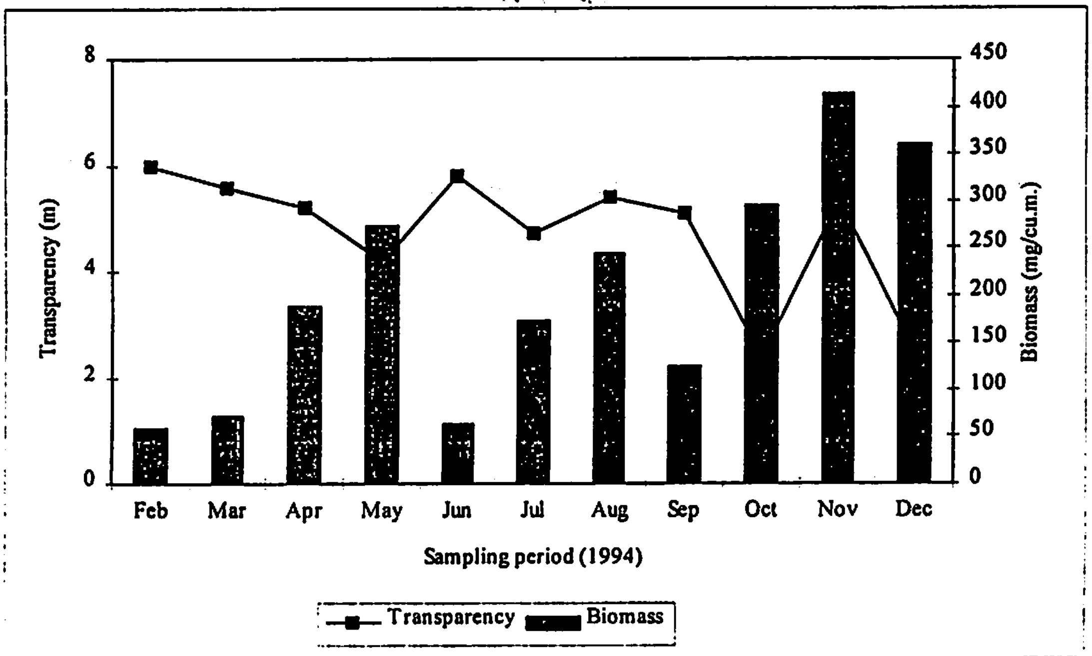

Fig. 1.4. Transparency (m) and zooplankton biomass (mg m^{-3}) in coral/ seagrass/seaweed area.

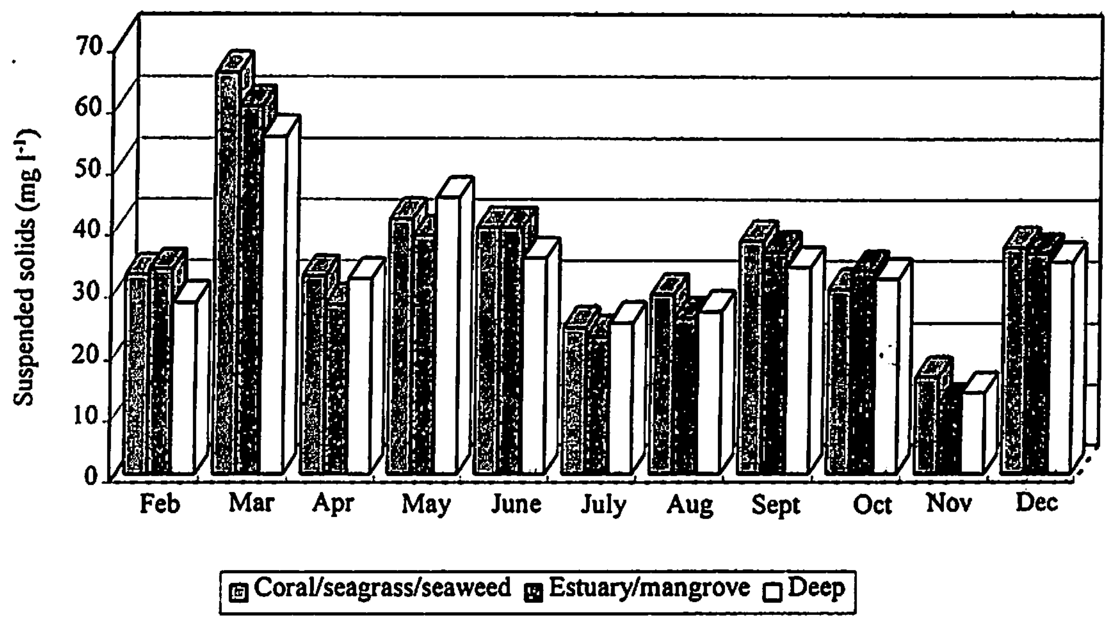

Fig. 1.5. Suspended solids (mg l^{-1}) level in Lagonoy Gulf, February - December 1994.

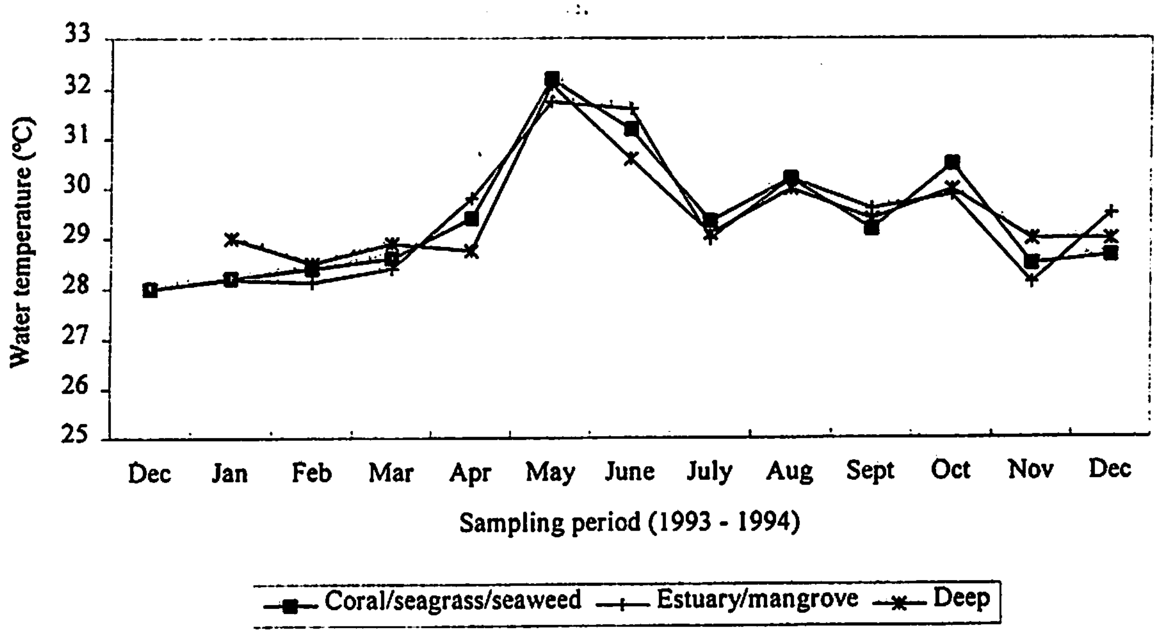

Fig. 1.6. Water temperature (°C) reading in Lagonoy Gulf, December 1993 - December 1994.

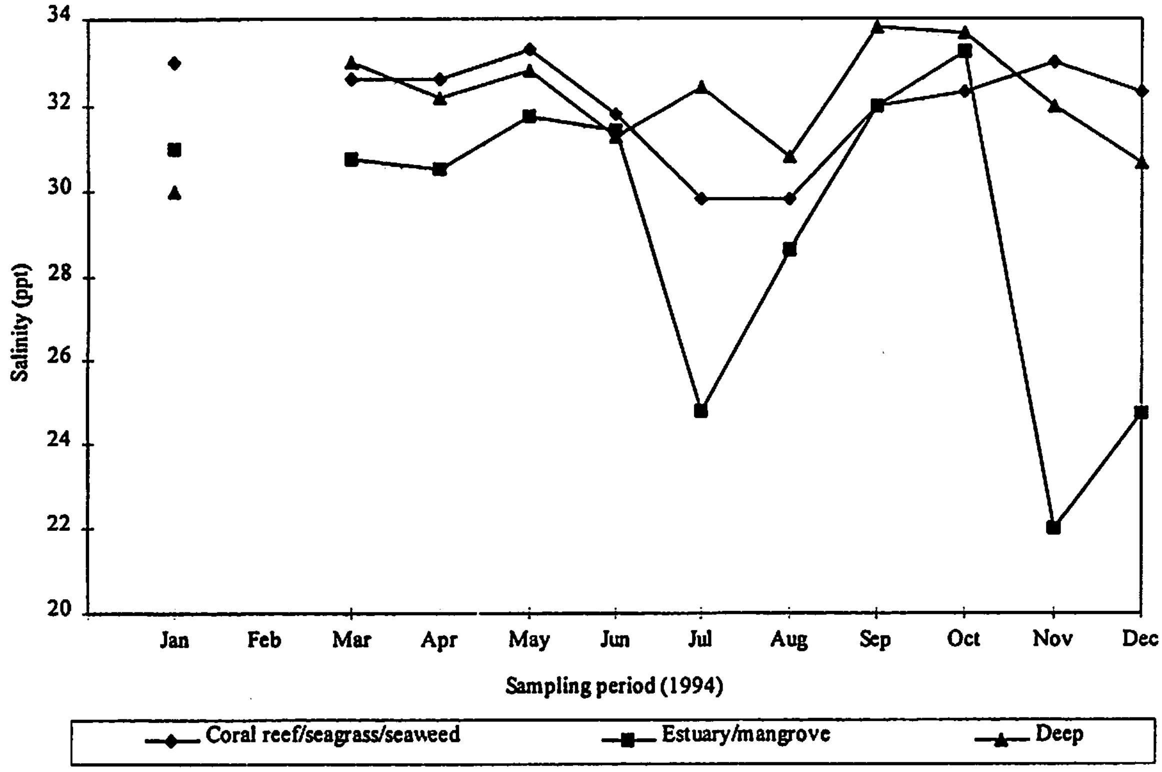

Fig. 1.7. Salinity (ppt) measurements in Lagonoy Gulf, January - December 1994.

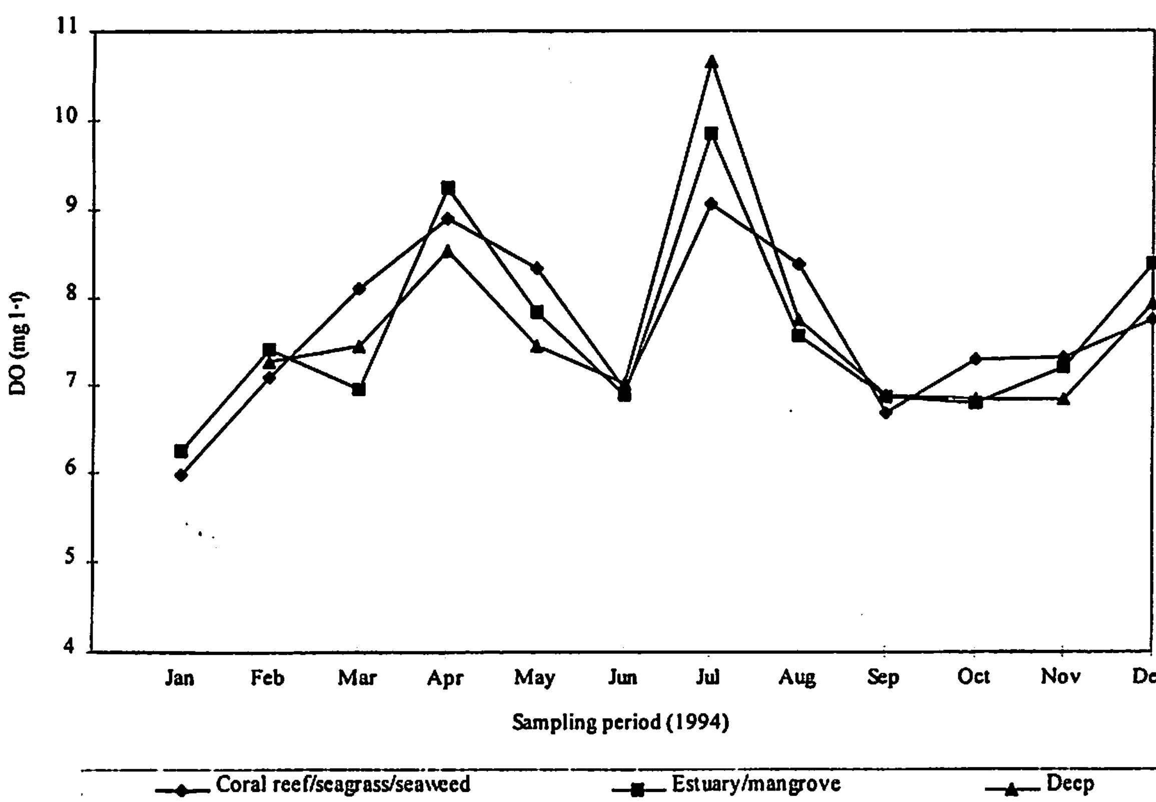

Fig. 1.8. DO (mg l^{-1}) level in Lagonoy Gulf, January - December 1994.

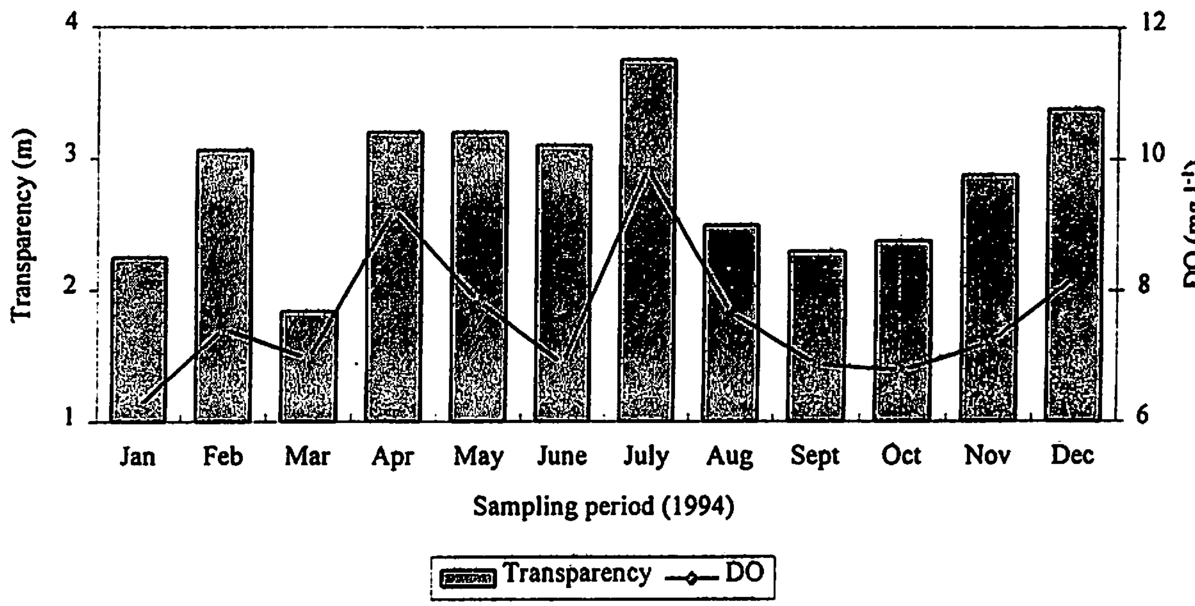

Fig. 1.9. Transparency (m) and DO (mg l^{-1}) in estuary/mangrove area, 1994.

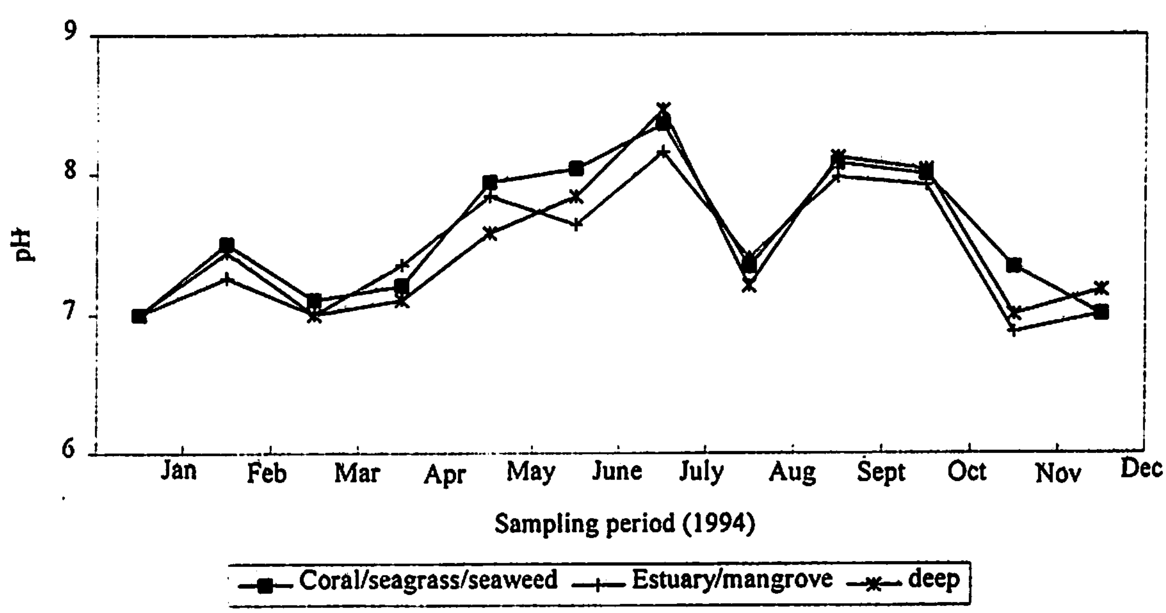

Fig. 1.10. pH levels in Lagonoy Gulf, January - December 1994.

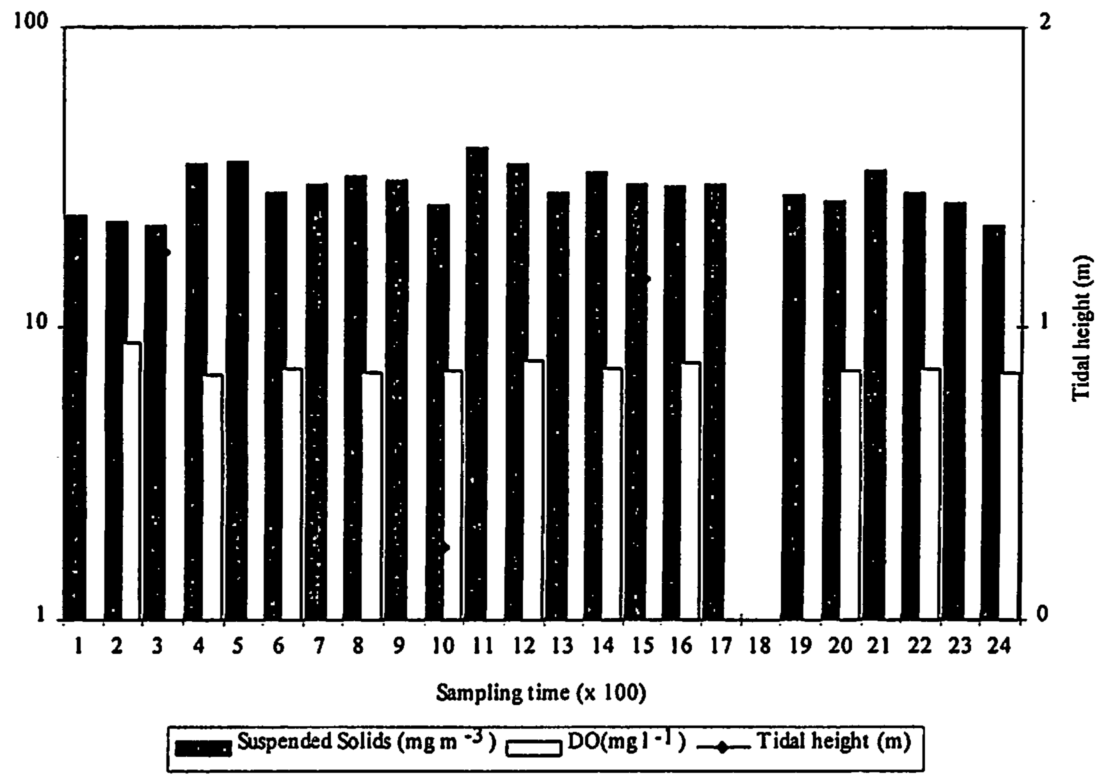

Fig. 1.11. Tidal oscillations, suspended solids and DO in Tabaco Bay, 6 -7 April 1994.

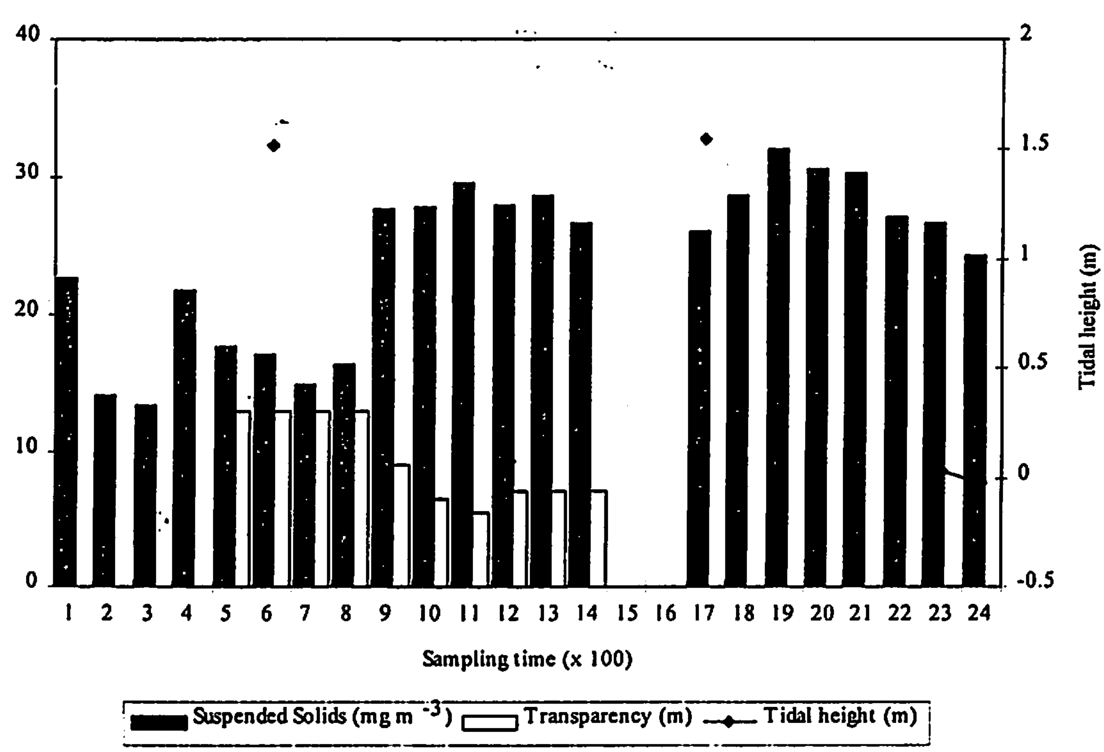

Fig. 1.12. Tidal oscillations, suspended solids and transparency in Lagonoy River, 20 - 21 September 1994.

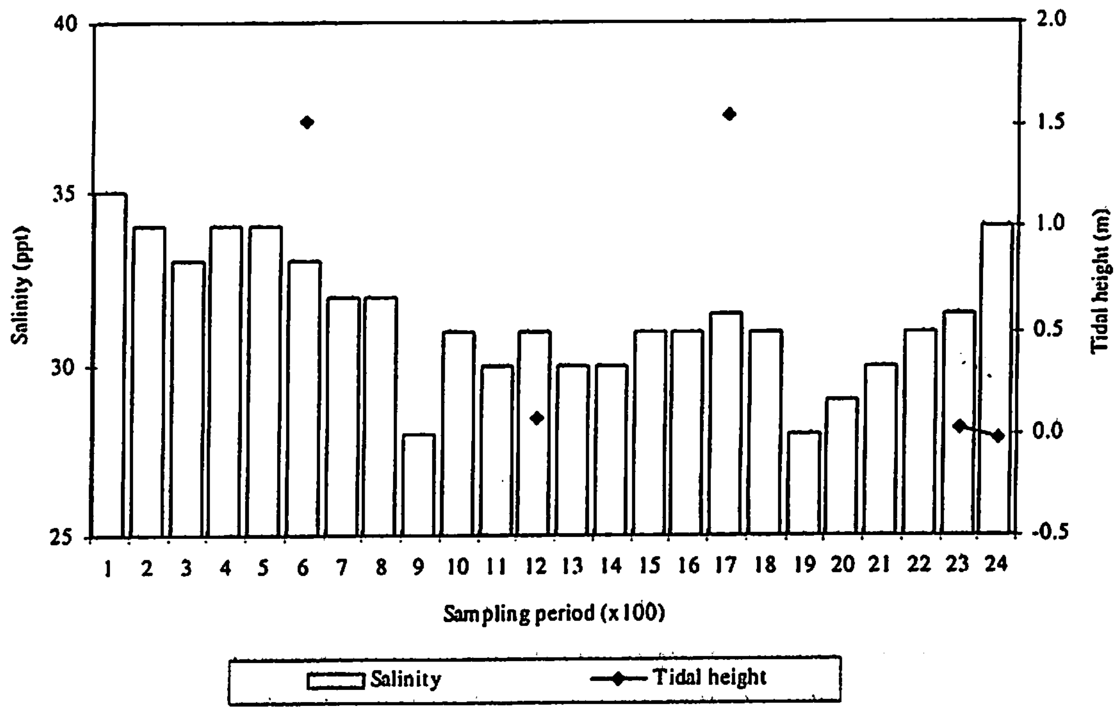

Fig. 1.13. Tidal oscillations and salinity in Lagonoy River, 20 - 21 September 1994.

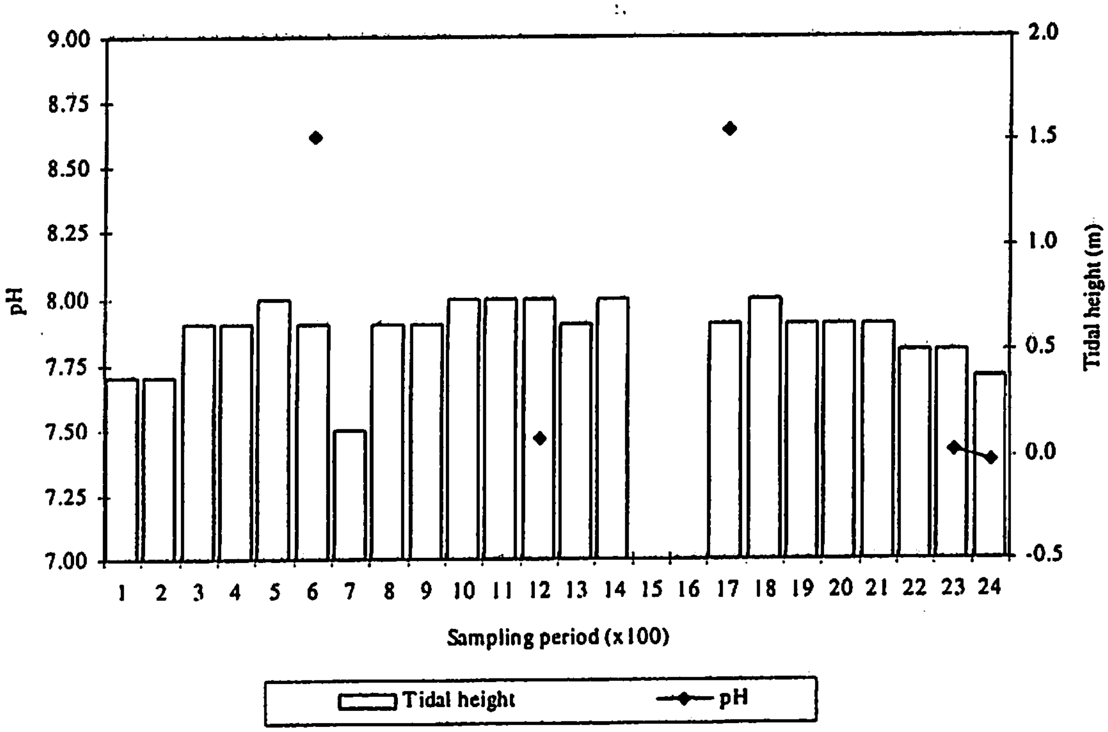

Fig. 1.14. Tidal oscillations and pH levels in Lagonoy River, 20 - 21 September 1994.

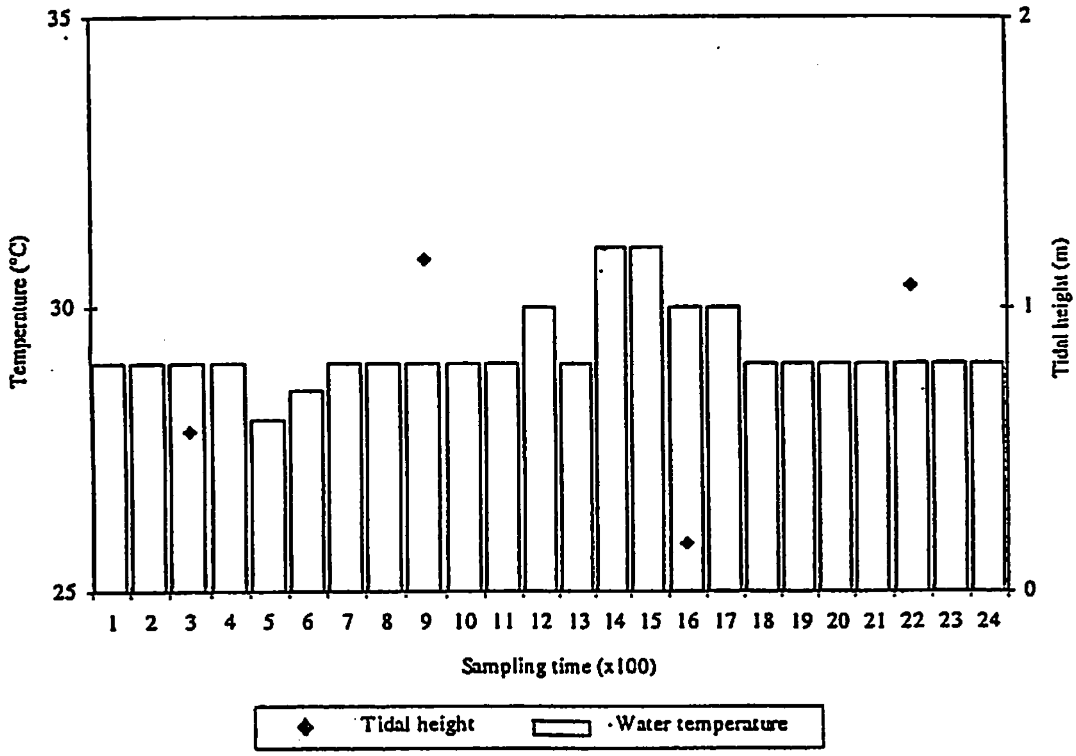

Fig. 1.15. Tidal oscillations and temperature in Sogod River, 17 - 18 April 1994.

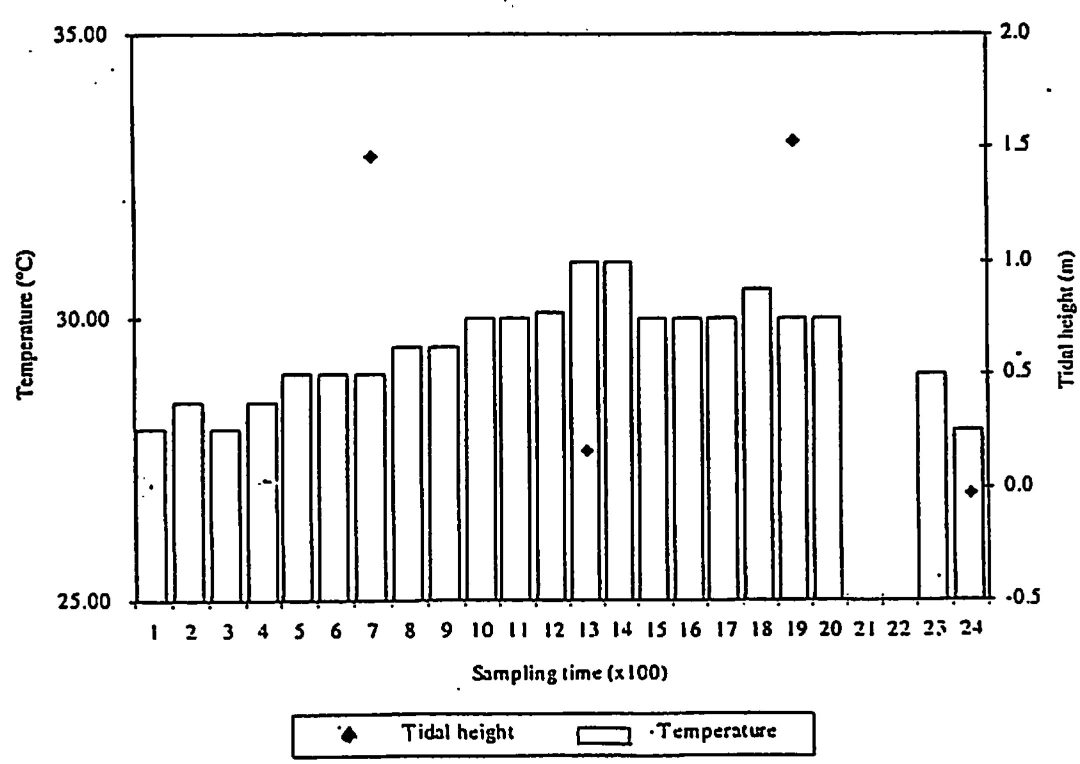

Fig. 1.16. Tidal oscillations and temperature in Sogod River, 21 - 22 September 1994.

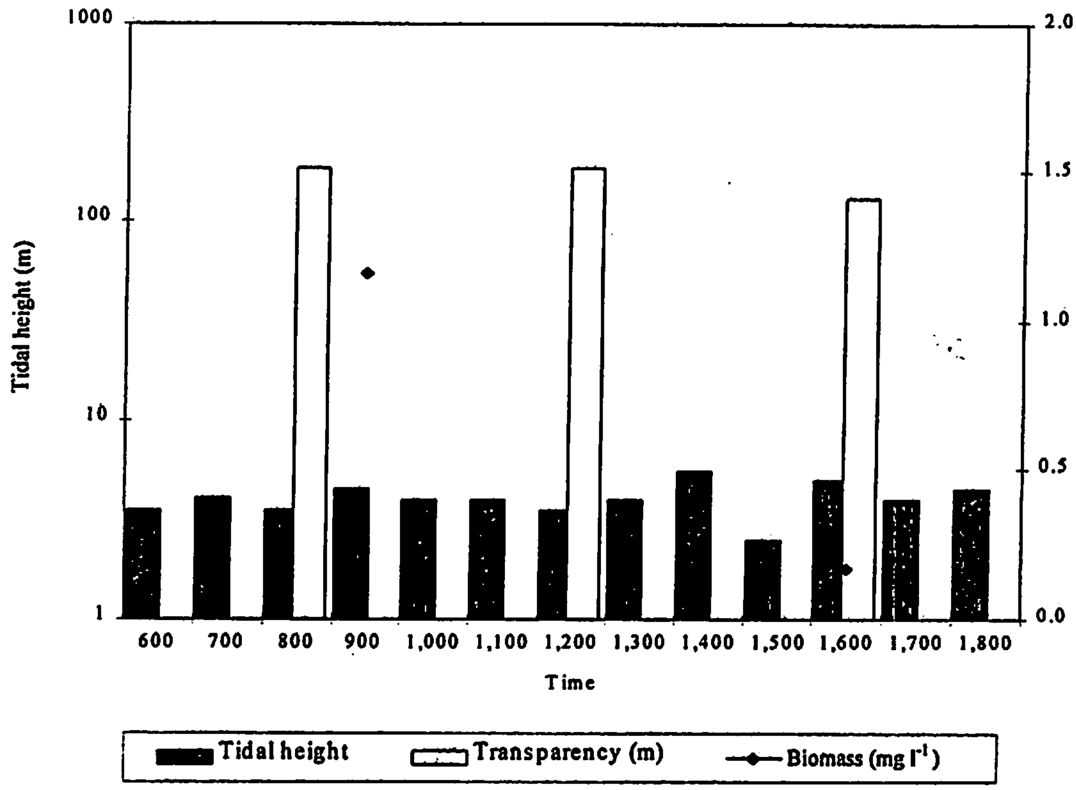

Fig. 1.17. Tidal oscillations, transparency and biomass in Sogod, 18 April 1994.

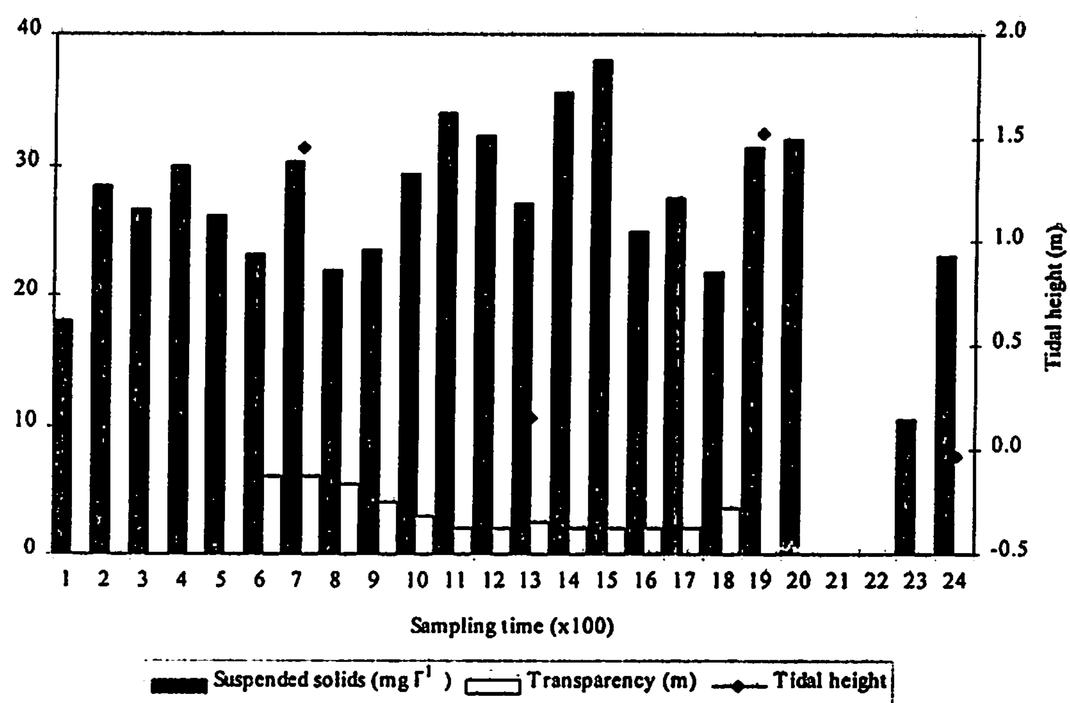

Fig. 1.18. Tidal oscillations, suspended solids and transparency in Sogod, 21 - 22 September 1994.

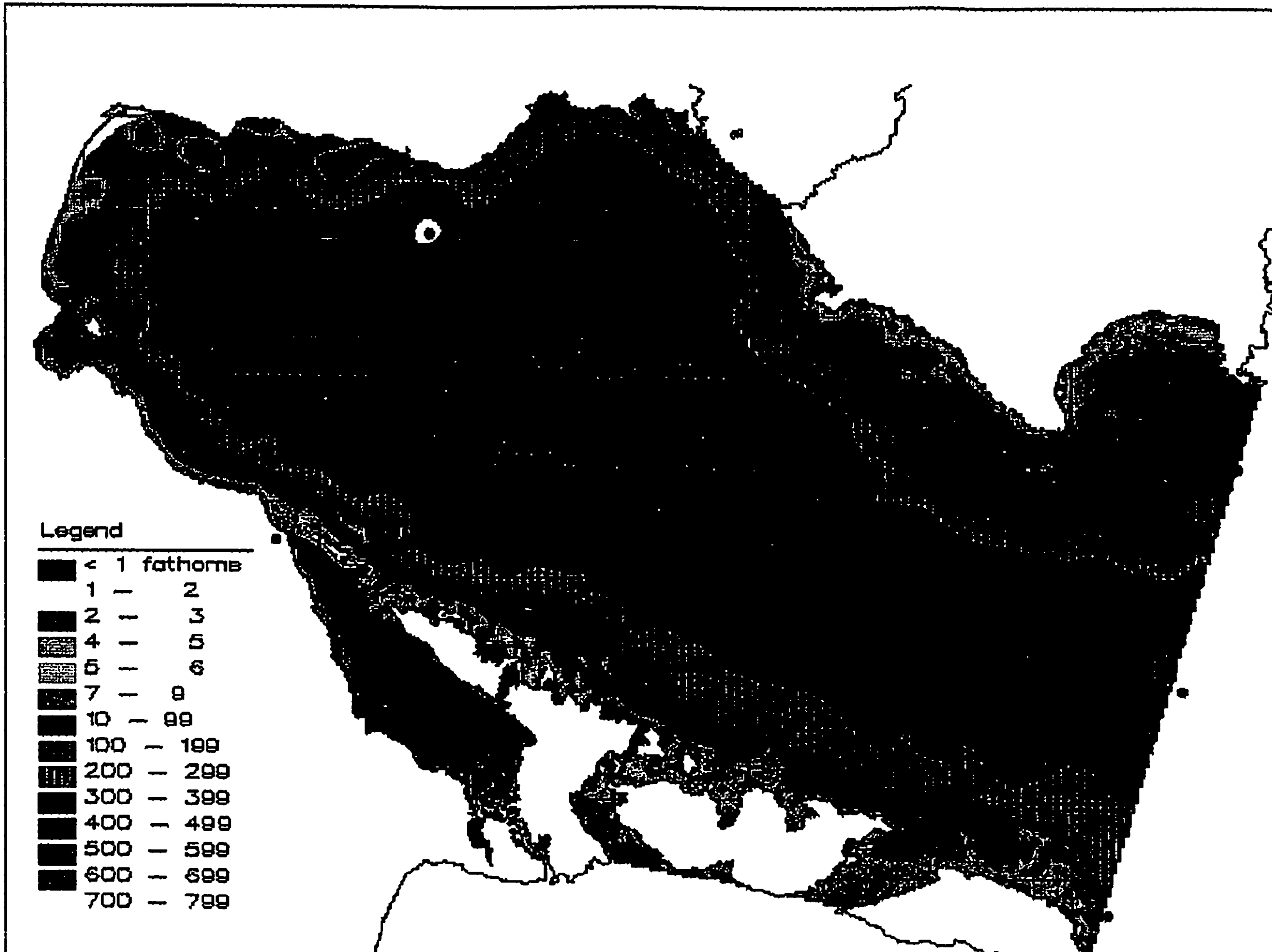

Fig. 1.19. Bathymetric map of Lagonoy Gulf. Source NAMRIA 4715.

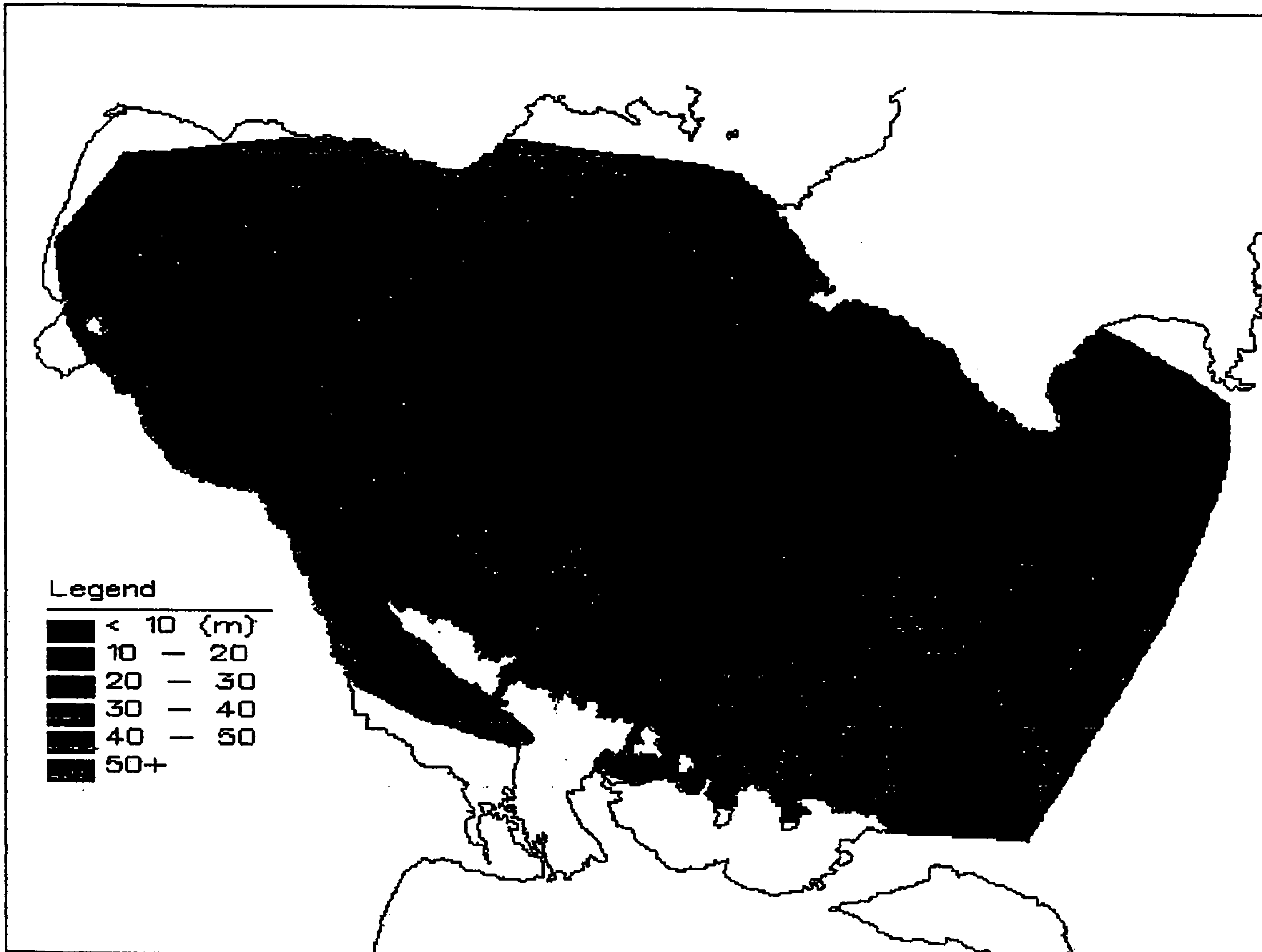

Fig. 1.20. Transparency (m) measurements during spatial sampling, May 1994.

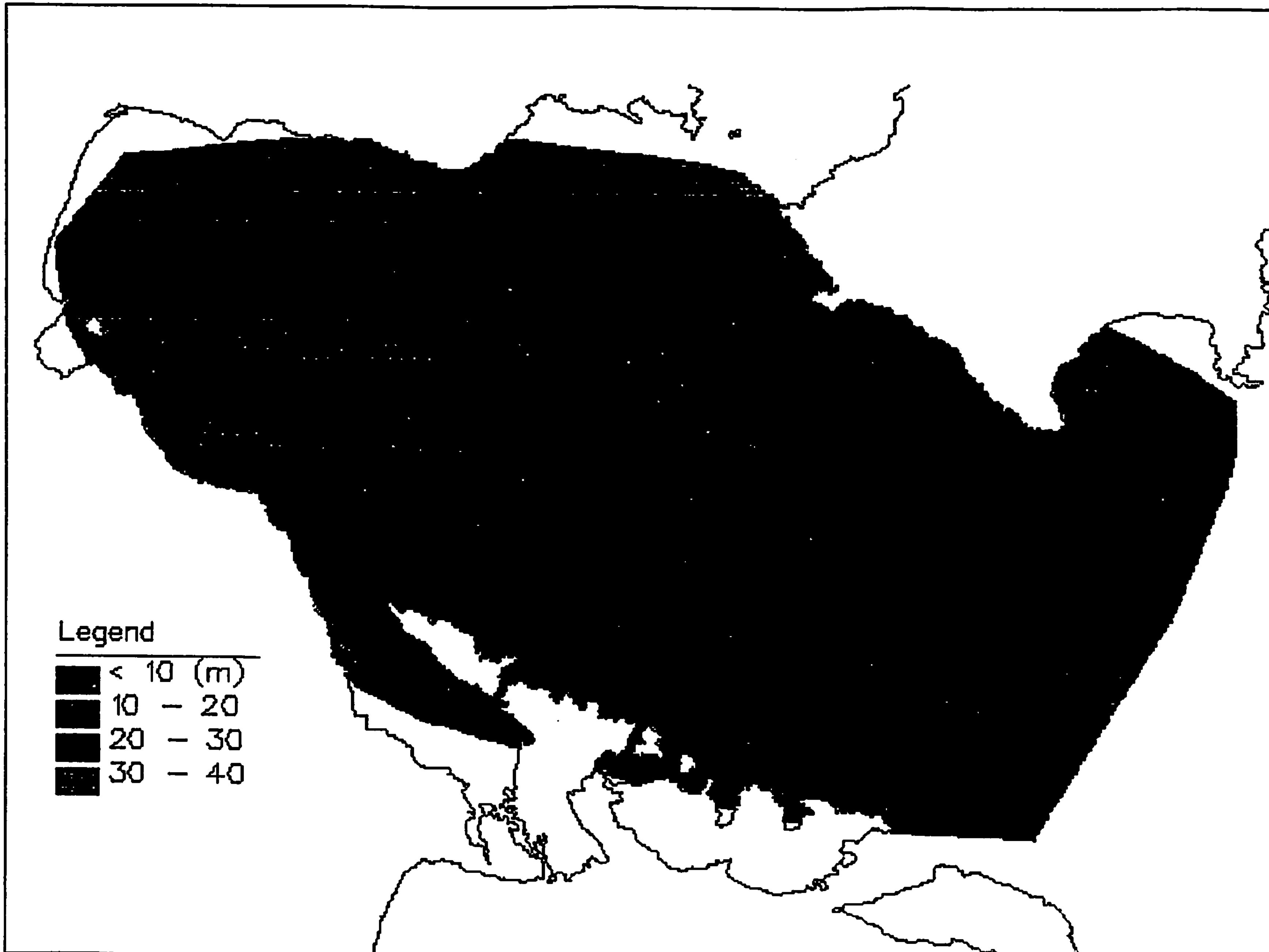

Fig. 1.21. Transparency (m) measurements during spatial sampling, August 1994.

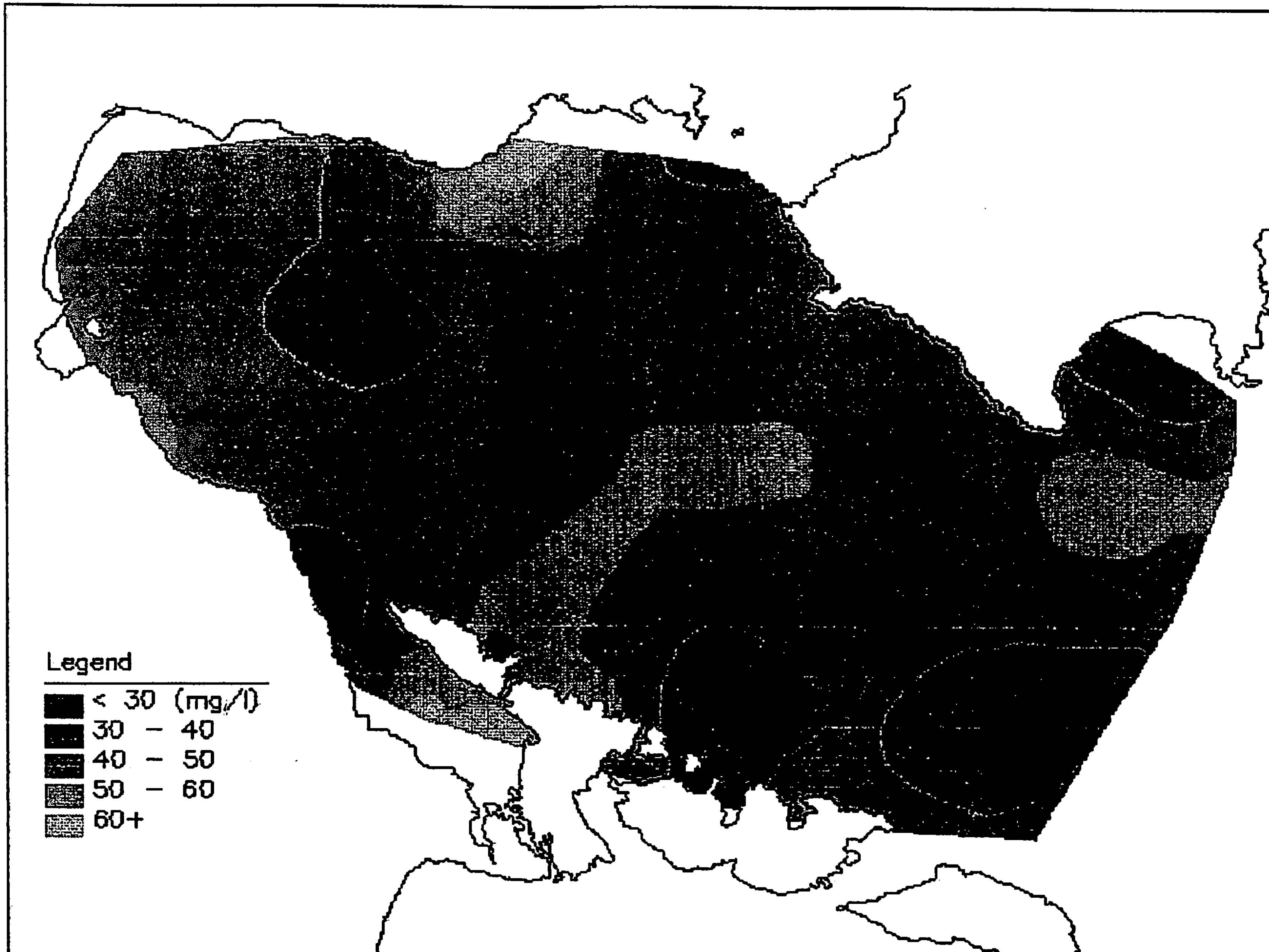

Fig. 1.22. Suspended solids (mg/l) concentration during spatial sampling, May 1994.

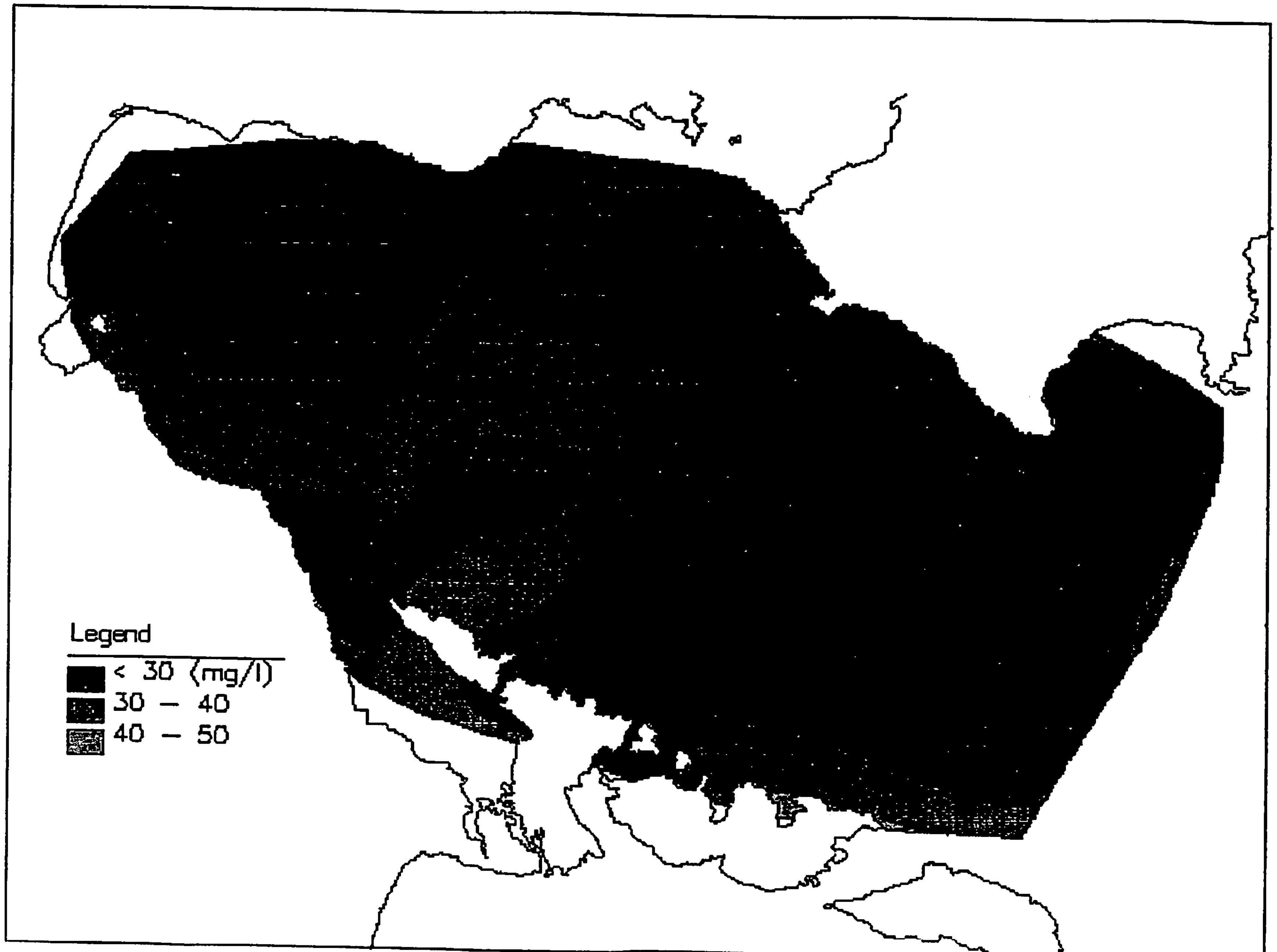

Fig. 1.23. Suspended solids (mg/l) concentration during spatial sampling, August 1994.

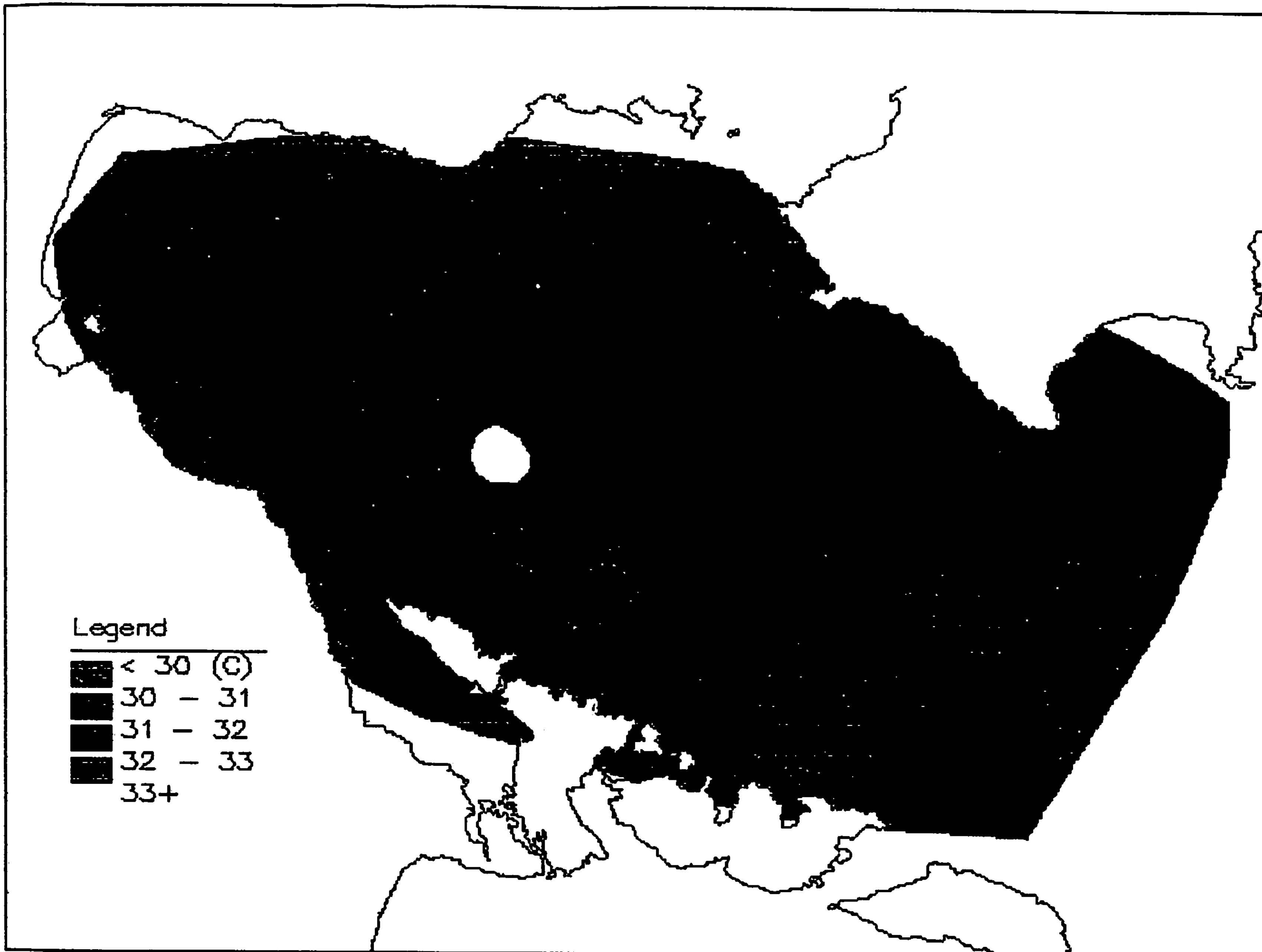

Fig. 1.24. Water temperature (°C) measurements during spatial sampling, May 1994.

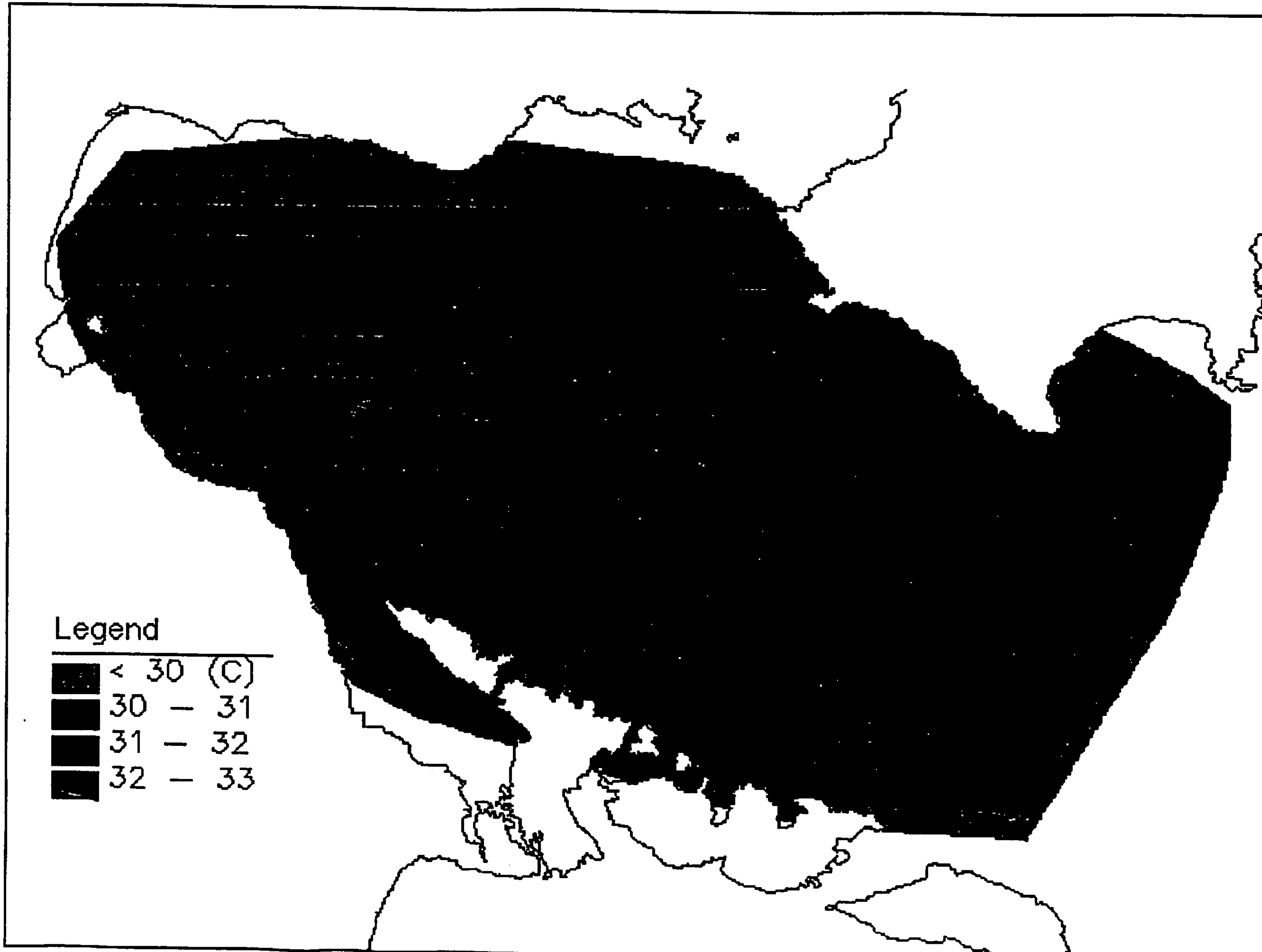

Fig. 1.25. Water temperature (°C) measurements during spatial sampling, August 1994.

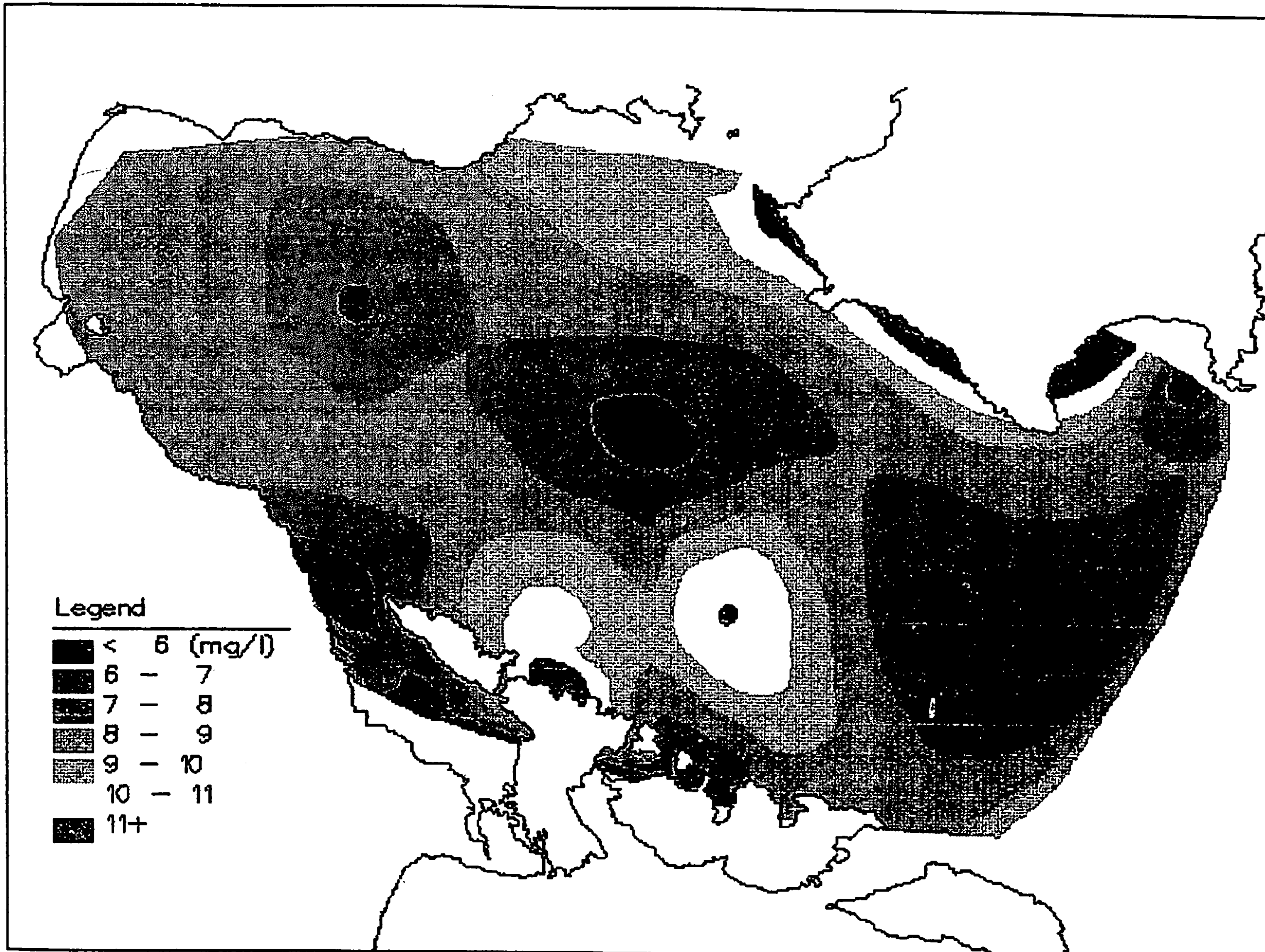

Fig. 1.26. Dissoved oxygen (mg/l) concentration during spatial sampling, May 1994.

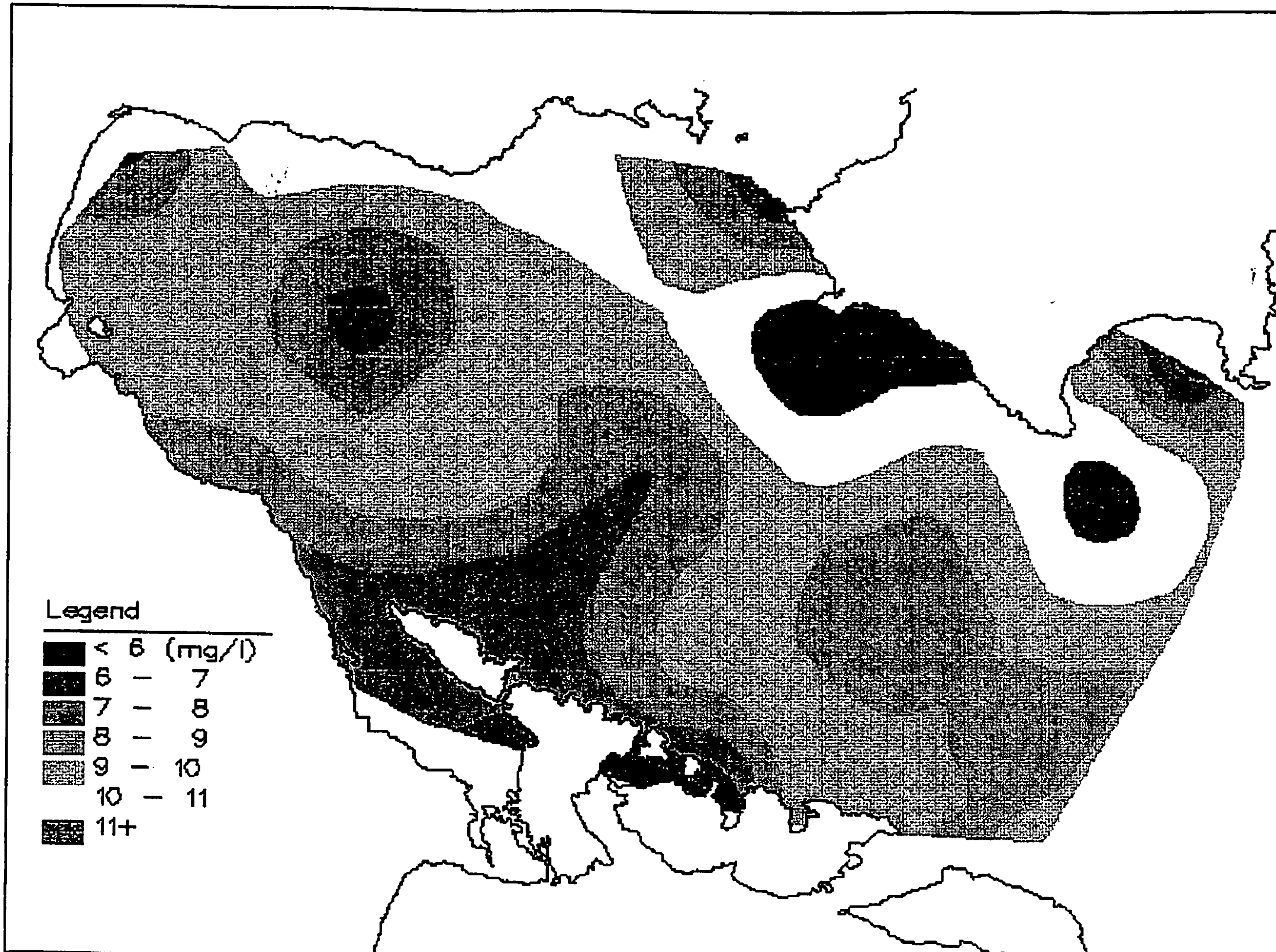

Fig. 1.27. Dissolved oxygen (mg/l) concentration during spatial sampling, August 1994.

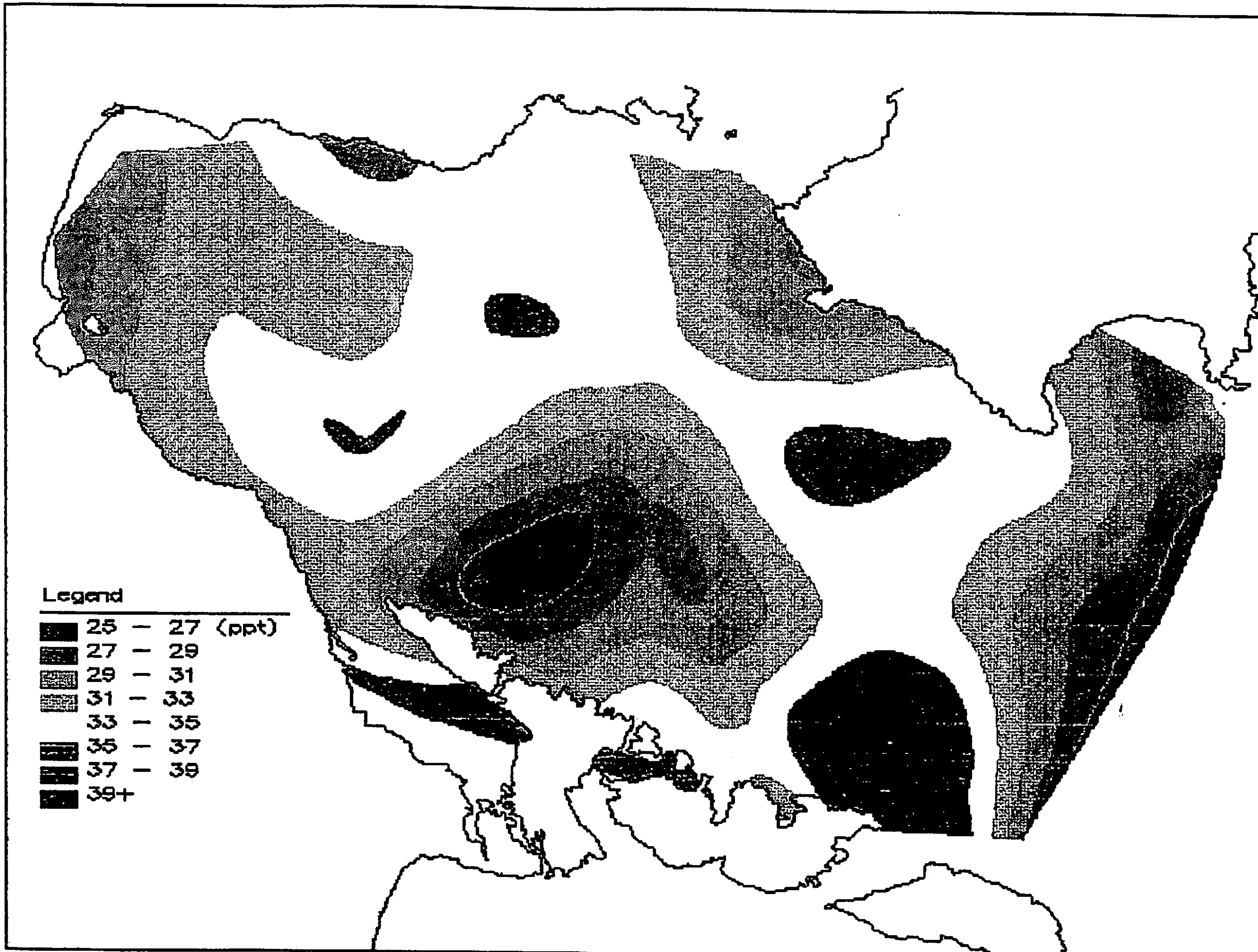

Fig. 1.28. Salinity (ppt) concentration during spatial sampling, May 1994.

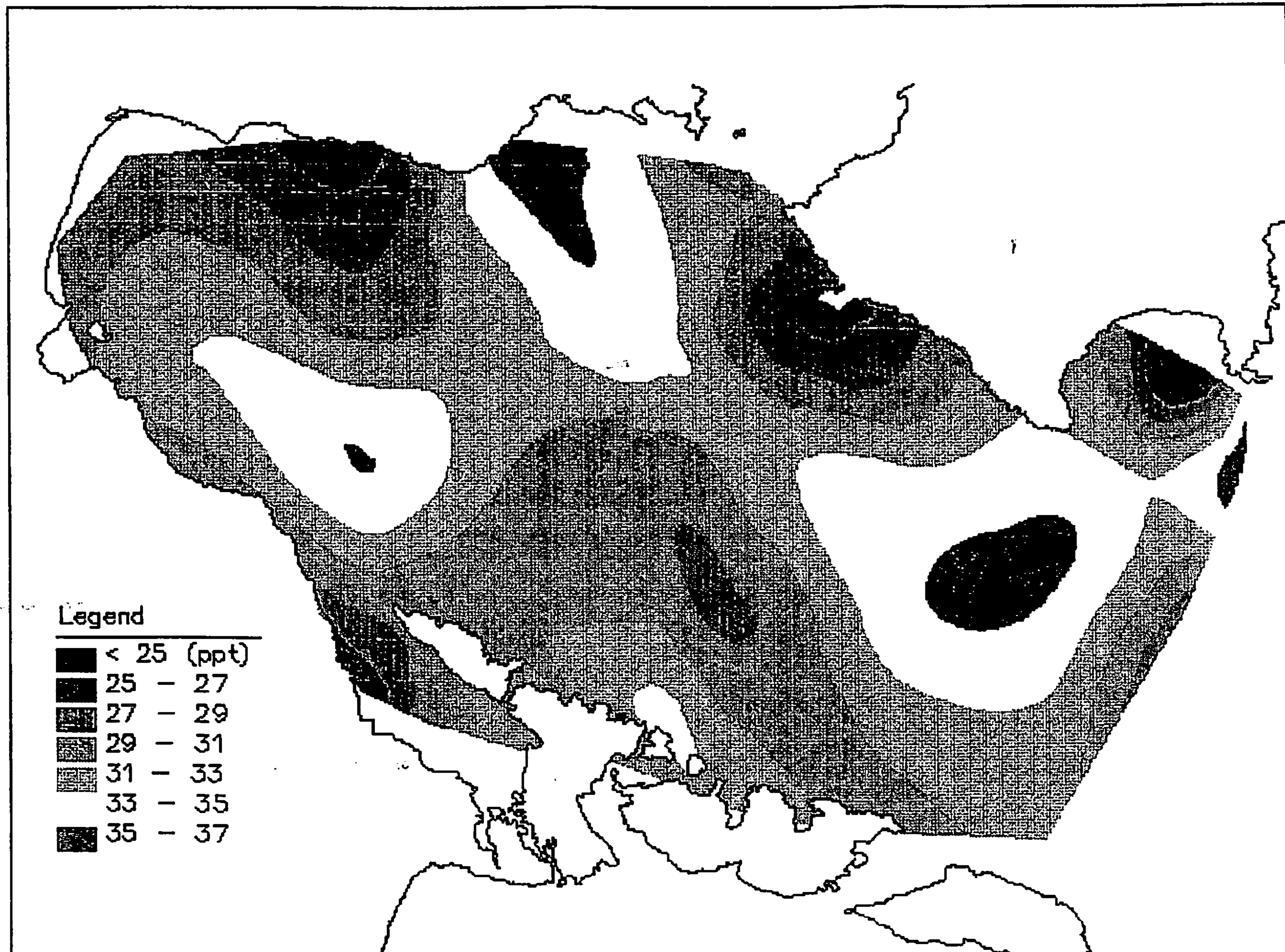

Fig. 1.29. Salinity (ppt) concentration during spatial sampling, August 1994.

9

Assessment of Water Quality in Lagonoy Gulf
Part II. Productivity

by

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Len R. Garces

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Assessment of Water Quality in Lagonoy Gulf
Part II. Productivity

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Brizuela, G., R. A. Valmonte-Santos, L. R. Garces and M. L. San Diego-McGlone. 1995. Assessment of water quality in Lagonoy Gulf. Part II. Productivity. *In* G. Silvestre, C. Luna, V. Soliman and L. Garces (eds.) Resource and ecological assessment of Lagonoy Gulf, Philippines, ICLARM Tech. Rep. 000, 000 p.

Abstract

This paper discusses primary production in Lagonoy Gulf. Three methods were used to estimate primary productivity: light and dark bottle technique which is a more direct method, and the use of chlorophyll a; and nutrient (nitrate) data which are indirect methods. Based on these methods, the highest gross productivity was determined in the deep areas. Lower production estimates were found in coral reef/seagrass/seaweed areas and then estuary/mangrove areas using light and dark bottle technique and nutrient data. However, using chlorophyll estimates, next to the deep areas, estuary and mangrove areas had high productivity values. Chlorophyll concentrations were determined to be higher in coastal sites than deep areas during spatial sampling conducted in summer (May) and southwest monsoon (August). The estimated mean primary production ranged from 122 to 12,284 gC m^{-2} $year^{-1}$ from the light and dark bottle technique, from 13.27 to 430.73 gC m^{-2} $year^{-1}$ from nutrient data, and from 9.43 to 88.66 gC m^{-2} $year^{-1}$ from chlorophyll values. Highest estimates were determined in summer and this may be due to increased light availability and higher temperature.

Introduction

Odum (1971) defined *primary productivity* of an ecological system, community or any part thereof, as the rate at which radiant energy is stored by photosynthetic and chemosynthetic activities of producer organisms (chiefly green plants) in the form of organic substances which can be used as food materials. *Gross primary productivity* is the total rate of photosynthesis including the organic matter used up in respiration during the measurement period while *net primary productivity* is the rate of storage of organic matter in plant tissues exceeding the respiratory use by plants during period of measurement. Primary productivity values can range from 2 to 400 gC m^{-2} $year^{-1}$ for open ocean; from 200 to 4,000 gC m^{-2} $year^{-1}$ for estuaries (Whittaker 1975) and from 2 to 500 gC m^{-2} $year^{-1}$ for coral reefs (Mann 1982). This paper aims to estimate the primary productivity of Lagonoy Gulf using direct (light and dark bottle) and indirect (chlorophyll a and nitrate concentration) methods.

Materials and Methods

Productivity using light and dark bottle technique

Productivities were estimated directly using light and dark method (Strickland and Parsons 1972). Samples were placed in 300-ml biological oxygen demand (BOD) bottles and incubated for 4 hours in a bucket filled with the same seawater where the samples were taken. DO determination using modified Winkler method was done on the sample right after incubation. Direct measurements of productivity were conducted on a quarterly basis.

Productivity estimates using chlorophyll a values

Samples for chlorophyll a content were collected on a monthly basis. These samples were obtained by filtering 1 - 2 liters of water through a membrane filter (0.45 x 47 mm). Filter residue was then stored in an ice chest and submitted to the University of the Philippines Marine Science Institute (UP-MSI) for analysis using the method of Parsons et al. (1984).

To estimate primary productivity from chlorophyll a measurement, a photosynthetic maximum (Pmax) value of 3.15 mgC-$mgChla^{-1}$ $hour^{-1}$ for tropical and nitrate poor water was used to convert chlorophyll a value to productivity estimates (Parsons et al. 1984). The light attenuation coefficient of seawater was calculated from the transparency of seawater (secchi disk depth) using the formula (Poole and Atkins 1929):

$$k = 1.7/d$$

where: k = light attenuation coefficient
d = transparency or secchi disk reading

To calculate light intensity, I:

$$I = I_o e^{-kz}$$

where: $\ln I/I_o = -kz$
at 1% I $\ln 0.01/k = -z$

However, if z at 1% I is greater than actual depth, the actual depth was used instead. The equation for productivity is given as:

$$\text{Productivity } (gC\,m^{-2}\,year^{-1}) = \frac{mg\,chla}{m^{3}} \times P_{max} \times \frac{12\ hour}{day} \times \frac{365\ days}{year} \times 1\%\ depth\ (m) \times \frac{1g}{1000\ mg}$$

Productivity estimates using nitrate concentration

To estimate productivity using nutrient information, nitrate data were utilized since results indicated that Lagonoy Gulf is nitrate-limited. The following equation was used (Polovina 1984):

$$\text{Productivity } (gC\,m^{-2}\,year^{-1}) = \frac{molesN}{L} \times 1\%\ depth\ (m) \times \frac{106\ molesC}{16\ molesN} \times \frac{12\ gC}{molesC} \times \frac{1000L}{m^{3}} \times \frac{70}{year}$$

where: 106C/16N is the Redfield ratio;
70/year is the P/B ratio (photosynthesis to biomass).

Nitrate concentrations which were used for productivity estimates were determined during northeast, summer and southwest monsoons.

Temporal and spatial variation in chlorophyll

The influence of tides on the chlorophyll estimates of the gulf was also determined by collecting samples every three hours over a 24-hour tidal cycle, specifically at the Sogod River, Lagonoy River and Tabaco Bay. This was conducted twice, in April (summer) and in September (southwest monsoon).

Spatial distribution of chlorophyll, which was determined from stations used in the general water quality assessment (part I) (Valmonte-Santos et al., this vol.), was determined twice, in May (summer) and August (southwest monsoon).

Statistical analysis

To test for the relationships and significance of the quantitative parameters (general water quality and chlorophyll), correlation analysis was applied. This is described in Part I (Valmonte-Santos et al., this vol.).

Results and Discussion

Estimates of productivity using light and dark bottle technique

Among the different sites, the deep areas in the gulf had the highest average gross production estimates for the four sampling periods (4,946 gC m^{-2} $year^{-1}$) followed by the coral reef/seagrass/seaweed area (848 gC m^{-2} $year^{-1}$) and the estuary/mangrove stations (505 gC m^{-2} $year^{-1}$) (Table 2.1, Fig. 2.1). Average net production observed also in the deep areas were also high (Fig. 2.2). This implies that the deep areas have the most available food for organic matter formation. In addition, phytoplankton in the deep areas may not be immediately utilized by the consumers (e.g., zooplankton), hence, the number of primary producers outweighed the consumers, leading to more organic matter stored in the system. This finding is supported by the low zooplankton biomass in the deep areas (average of 11.20 mg m^{-3}) throughout the sampling period (Fig. 2.3). The lower rate of gross production in the coral reef/seagrass/seaweed areas may be a function of the efficiency of biological recycling in these systems. The coral polyps have symbiotic algae (i.e., zooxanthellae) within their tissues which process the polyp's waste products before they are excreted thus retaining vital nutrients as phosphates (Salm 1984). In estuary/mangrove areas, the low gross production estimates may be attributed to higher consumer biomass at these sites (Fig. 2.3).

Gross primary productivity was highest in all areas during the second quarter (February - April) and lowest in the third quarter (May - July) (Fig. 2.1). The last month of the northeast monsoon and onset of summer months may have brought in favorable temperature and light conditions which led to higher production in all the areas. On the other hand, the onset of southwest monsoon brought in rainy conditions that led to decreased light intensity in effect reducing photosynthetic activities.

The deep areas had the highest respiration rates in the gulf (6,717 gC m^{-2} $year^{-1}$) followed by the coral reef/seagrass/seaweed areas (904 gC m^{-2} $year^{-1}$) and the estuary/mangrove areas (488 gC m^{-2} $year^{-1}$) (Table 2.1, Fig. 2.4). There were periods and sampling areas where respiration exceeded both gross and net production, and this may be due to increased presence of bacteria and other decomposing organisms in the samples (APHA 1989).

An average gross production/respiration (P/R) ratio of 1.28 was computed for deep areas, 1.68 in estuary/mangrove areas and 1.07 in coral reef/seagrass/seaweed areas (Table 2.1). A P/R ratio greater than 1 indicates that the system is exporting organic matter (Kinsey 1975), or a promotion of autotrophic organisms due to input of fertilizing substances (Stumm and Morgan 1981). On the other hand, a P/R ratio less than 1 indicates that the system imports organic matter to complete nutritional requirement (Kinsey 1975), or the promotion of heterotrophic organism due to input or introduction of biological degradable organic matter (Stumm and Morgan 1981). This is the case in the reef areas of the gulf where the P/R ratio ranged from 0.34 to 2.82. Similar ratios (0.59 - 2.5) were reported for reefs by Mann (1982).

Estimates of productivity using chlorophyll

Table 2.2 shows the chlorophyll concentration measured in the different areas of Lagonoy Gulf. Highest estimates of chlorophyll were determined in the estuary/mangrove areas (0.62 mg m^{-3}) while lowest values were determined in coral reef/seagrass/seaweed stations (0.21 mg m^{-3}, Fig. 2.5). The amount of chlorophyll produced by the marine plants is dependent on several environmental factors which include light intensity, amount of available nutrients and consumer population in the area. In the gulf, chlorophyll was determined to be elevated during northeast monsoon than summer and southwest monsoon in all the areas monitored. A small amount of consumers during northeast monsoon may have favored increased phytoplankton population that led to higher chlorophyll concentration.

Estimates of productivity using chlorophyll a varied monthly for all the areas in Lagonoy Gulf (Table 2.3). Deep areas had the highest productivity values (60 gC m^{-2} year^{-1}) followed by coral reef/seagrass/seaweed sites (20 gC m^{-2} year^{-1}) and estuary/mangrove stations (20 gC m^{-2} year^{-1}). The high production during summer may be due to increased availability of light for photosynthetic processes (Fig. 2.6).

Estimate of productivity using nutrient data (NO_3)

In addition to intensity of radiation and temperature, primary productivity is also affected by the supply of nutrients, especially nitrogen and phosphorus (Schwoerbel 1987). Estimates of productivity using nitrate data at different stations in Lagonoy Gulf are presented in Table 2.4. Deep areas gave the highest productivity throughout the sampling period, ranging from 7 to 1,285 gC m^{-2} year^{-1} with a mean of 228 gC m^{-2} year^{-1}. This is followed by the coral reef/seagrass/seaweed area, 1 - 367 gC m^{-2} year^{-1} with 41 gC m^{-2} year^{-1} as average, and estuary/mangrove area, 1 to 152 gC m^{-2} year^{-1} with mean at 32 gC m^{-2} year^{-1} (Fig. 2.7). Just like in the direct method and chlorophyll estimates, highest production was during summer.

A comparison of the direct and indirect methods used in estimating primary productivity of Lagonoy Gulf revealed similar patterns across stations (Table 2.5, Fig. 2.8). However, production using the direct method was relatively higher. Production from available nutrients may be underestimated because the concentrations being measured may just be a residual of the nutrient which were already taken up. Production using chlorophyll values may be low due to the fact that unlike direct estimates which consider production for different size classes of phytoplankton, smaller plankton such as picoplankton are eliminated during filtration for chlorophyll extraction. This size fraction has been reported to account for about 80 - 90% of the total primary productivity in some waters (Haris 1986).

Effect of tides on chlorophyll

Table 2.6 presents the results of chlorophyll concentration from the three stations monitored on a 24-hour period in Lagonoy Gulf. In Tabaco Bay, a direct relationship exists between chlorophyll and zooplankton biomass as shown by a correlation coefficient of 0.62 at 1% level of significance. As more food becomes available to the consumers, there is a corresponding growth of the consumers population (food chain/web relationships). Chlorophyll levels, an indication of algal biomass, have also affected transparency readings in Lagonoy River ($r = -0.64$ at 10% level of significance).

Spatial distribution

This study was conducted to determine spatial variability in productivity using chlorophyll content and zooplankton biomass. Table 2.7 presents the chlorophyll values during the two sampling periods. Chlorophyll represents available food for the consumers in the food chain. The lower limit for chlorophyll was found to be nil for both areas regardless of sampling periods. However, the upper limit varied from 0.56 to 0.63 mg m^{-3} during summer and southwest monsoon, respectively (Figs. 2.9 - 2.10). Deep stations gave an upper limit of 0.43 mg m^{-3} during summer and 0.35 mg m^{-3} for the southwest monsoon (Table 2.8, Figs. 2.9 - 2.10). The ability of phytoplankton to multiply and become available as food materials in an aquatic ecosystem depends on the nutrient pool of the waters. This means that in addition to favorable climatic conditions (light intensity), nitrogen and phosphorus should be in sufficient amount and in available forms to favor plankton growth and development. Such was the case for Lagonoy Gulf which explains the high amount of chlorophyll in summer compared to southwest monsoon for coastal areas and deep stations.

Zooplankton biomass provides an estimate of the food available for consumption in the upper trophic levels of the food chain. Biomass estimates varied from 5.73 to 1,358.10 mg m^{-3} in summer and from 22.40 to 778.21 mg m^{-3} during southwest monsoon for coastal sites (see Garces and Valmonte-Santos, this vol.). The data indicated that more food may be consumed during summer than southwest monsoon. This is supported by a lower transparency reading in the water column which may be attributed to the presence of zooplankton ($r = -0.45$ at 1% level of significance, Table 2.8). Conditions during summer may be favorable for organisms to multiply and increase their density.

Using the estimated primary production from the three methods which ranged from 2 to 16,887 gC m^{-2} $year^{-1}$ and assuming a 10% efficiency in biomass conversion, the corresponding zooplankton production should approximately be 0.2 - 1,688.7 gC m^{-2} $year^{-1}$. This is within the zooplankton production estimates determined for Lagonoy Gulf (1.2 - 13.1 gC m^{-2} $year^{-1}$, see Garces and Valmonte-Santos, this vol.). Hence if 10% efficiency in biomass conversion is assumed, approximately 0.02 - 168.87 mtC km^{-2} $year^{-1}$ of fish may be supported by Lagonoy Gulf for this zooplankton production. In terms of fish weight, and assuming that carbon is 38% of dry weight and that dry weight is 14% of wet weight (EPAI 1993), an estimated fish production of 0.38 - 3,174 mt wet weight km^{-2} $year^{-1}$ was obtained.

Summary and Conclusion

Deep areas of Lagonoy Gulf were found to exhibit a relatively higher productivity than coral reef/seagrass/seaweed and estuary/mangrove areas using the direct and indirect methods of estimating primary productivity. The occurrence of high nutrient concentrations (nitrogen and phosphorus) in the deep areas may have favored the growth and development of primary producers. Organic matter produced was also stored in the area because of the low consumer population in these stations. Low production in coral reef/seagrass/seaweed areas may be due to the fact that organic matter produced is utilized or trapped within the system thus making it unavailable to other consumers in the area.

Acknowledgement

We wish to acknowledge the assistance of Vilma Dupra of UP-MSI for the analysis of chlorophyll; Zaida Alojado for the maps, Renante Albao, Skorzeny de Jesus, Antonino Mendoza, Ma. Karina Luth Discaya, Leo Pura, Anastacio Cante and Jose Gonzales, Jr. for assistance during field surveys; Cesar Luna and Marcos Jose Vega for technical guidance.

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Table 2.1. Estimates of primary productivity ($gC\ m^{-2}\ year^{-1}$) using light and dark bottle in Lagonoy Gulf, 1994.

Stations	Gross Production					Net production					Respiration					P/R
	2nd qtr	3rd qtr	4th qtr	5th qtr	Average	2nd qtr	3rd qtr	4th qtr	5th qtr	Average	2nd qtr	3rd qtr	4th qtr	5th qtr	Average	ratio
I. Coral reef/seagrass/seaweed area																
1 Rawis	0.00	855.41	228.64	-	344.41	0.00	355.66	0.00	-	118.55	1,401.60	416.98	382.37	-	892.21	0.38
6 Agoho	5,759.70	0.00	5,199.06	814.68	2,943.36	50.37	0.00	356.97	611.45	254.70	4,756.68	1,019.66	4,033.98	169.94	2,495.07	1.18
9 Acal	203.23	713.94	917.17	-	577.43	0.00	611.01	459.90	-	331.42	169.94	85.41	381.06	-	205.13	2.81
10 Gaba Bay	-	0.00	0.00	367.04	122.35	-	0.00	0.00	0.00	0.00	-	204.11	169.94	204.11	192.72	0.63
13 Casolgan	0.00	520.34	0.00	-	250.54	0.00	0.00	0.00	-	0.00	1,487.01	561.08	331.13	-	736.42	0.34
Average	1,490.73	417.94	1,268.97	590.86	847.62	12.59	193.33	163.37	305.73	140.93	1,953.81	457.45	1,059.70	187.03	904.31	1.07
II. Estuary/mangrove area																
2 Sogod	214.18	764.31	458.59	764.31	529.98	0.00	510.27	306.16	510.27	306.16	203.67	212.43	127.46	212.43	195.35	2.71
4 Lagonoy	-	0.00	2,446.67	0.00	724.94	-	0.00	336.38	0.00	99.67	-	2,854.01	1,758.13	21.02	1,173.84	0.62
7 Bato	2,242.56	366.17	446.10	91.98	786.70	509.18	285.58	268.28	0.00	265.76	1,444.31	68.33	148.70	76.21	434.39	1.81
12 Cagraray	0.00	45.99	366.61	-	128.36	0.00	0.00	153.08	-	47.63	427.84	127.46	178.05	-	261.43	0.49
14 Bariw	122.20	641.89	102.05	641.89	377.01	7.56	382.37	91.54	382.37	215.96	95.59	216.81	8.32	216.81	134.38	2.81
Average	644.74	363.67	764.00	374.55	505.40	129.19	235.64	231.09	223.16	187.03	542.85	695.81	444.13	131.62	487.99	1.68
III. Deep area																
3 Grid 13	7,939.19	658.75	7,154.73	-	6,096.38	0.00	0.00	2,199.64	-	706.06	6,940.55	1,906.18	4,127.27	-	5,010.72	1.22
5 Maqueda	4,073.40	0.00	5,711.52	1,473.43	2,814.59	2,041.08	0.00	0.00	0.00	510.27	1,699.44	37,451.19	13,253.88	20,691.56	18,274.02	0.15
8 Grid 50	20,177.78	5,295.42	10,088.89	-	12,284.44	15,697.04	0.00	7,843.70	-	8,322.49	3,738.77	10,374.47	1,869.38	-	5,086.15	2.41
11 Grid 33	-	0.00	0.00	-	0.00	-	0.00	0.00	-	0.00	-	4,765.44	2,634.14	-	4,383.50	-
15 Tabaco	8,129.28	0.00	4,113.92	3,058.99	3,736.19	4,433.00	0.00	431.87	1,834.34	1,464.51	3,080.24	558.89	3,067.75	4,330.94	2,832.05	1.32
Average	10,079.91	1,190.83	5,413.81	2,266.21	4,946.32	5,542.78	0.00	2,095.04	917.17	2,200.66	3,864.75	11,011.23	4,990.48	12,511.25	6,717.29	1.28

Notes: - = no data.

2nd quarter - February - April

3rd quarter - May - July

4th quarter - August- October

5th quarter - November - December

Table 2.2. Chlorophyll a estimates (mg m^{-3}) at different areas in Lagonoy Gulf, 1994.

Station	Sampling period											Average
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
I. Coral reef/seagrass/seaweed area												
1 Rawis Point	0.22	0.43	0.21	0.10	0.16	0.48	0.05	0.29	-	-	-	0.24
6 Agoho Point	0.12	0.10	0.22	0.44	0.36	0.48	0.07	0.38	0.44	0.11	0.46	0.29
9 Acal Point	0.12	0.33	0.32	0.19	0.32	0.38	0.12	0.37	-	-	-	0.27
10 Gaba Bay	0.44	0.65	0.43	0.32	0.22	0.26	0.21	0.39	0.43	0.59	0.22	0.38
13 Casolgan Pass	0.00	0.09	0.50	0.10	0.48	1.06	0.27	0.48	0.33	0.48	0.23	0.36
Average	0.18	0.32	0.33	0.23	0.31	0.53	0.14	0.38	0.24	0.39	0.30	0.21
II. Estuary/mangrove area												
2 Sogod River	0.02	0.32	0.55	0.41	0.38	0.91	0.29	0.42	0.39	0.48	0.58	0.43
4 Lagonoy River	0.44	0.65	0.50	0.13	0.14	1.16	0.63	0.63	0.33	0.37	1.69	0.61
7 Bato River	0.12	0.51	0.10	0.56	0.66	0.22	0.06	0.29	0.43	0.42	0.53	0.35
12 Cagraray Island	-	0.44	0.32	0.10	0.44	0.70	0.43	0.52	-	-	-	0.37
14 Bariw Point	0.44	2.53	1.38	0.32	0.64	1.12	0.26	1.06	0.34	0.74	4.74	1.23
Average	0.20	0.89	0.57	0.30	0.45	0.82	0.33	0.58	0.30	0.50	1.89	0.62
III. Deep area												
3 Grid 13	0.73	0.43	0.00	0.41	0.10	0.21	0.19	0.15	0.33	*	0.65	0.32
5 Maqueda Channel	0.02	0.43	0.33	0.12	0.05	0.38	0.08	0.22	0.65	*	0.00	0.23
8 Grid 50	0.27	0.02	0.10	0.32	0.33	0.16	0.21	0.12	-	-	-	0.19
11 Grid 33	0.00	0.02	0.34	0.00	0.36	0.06	0.44	0.15	-	-	-	0.17
15 Tabaco Bay	0.12	0.21	0.32	0.12	0.19	0.26	0.27	0.36	0.12	0.32	0.75	0.28
Average	0.23	0.22	0.22	0.19	0.21	0.21	0.24	0.20	0.22	0.32	0.47	0.24

Notes: - = no data

*inclement weather did not permit sampling.

Table 2.3. Estimates of productivity using chlorophyll a (gC m^{-2} $year^{-1}$) at different stations in Lagonoy Gulf, 1994.

Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average
I. Coral reef/seagrass/seaweed area												
1 Rawis Point	15.31	52.77	28.28	9.66	26.49	46.36	8.28	35.60	-	-	-	27.84
6 Agoho Point	18.06	7.04	15.25	24.28	29.80	52.98	4.60	18.11	21.25	16.69	25.39	21.22
9 Acal Point	6.62	35.98	22.28	15.73	22.08	26.21	8.28	30.63	-	-	-	20.98
10 Gaba Bay	18.29	26.86	23.51	8.83	9.11	7.17	5.66	21.25	7.33	16.28	6.07	13.67
13 Casolgan	0.00	3.68	13.74	2.76	19.87	21.94	10.97	19.87	11.21	19.04	4.76	11.62
Average	14.95	24.59	24.01	13.33	24.65	34.50	10.53	26.69	13.34	28.45	10.46	20.50
II. Estuary/mangrove area												
2 Sogod River	1.32	13.41	37.60	28.28	20.97	87.89	11.87	11.59	18.83	33.11	56.02	29.17
4 Lagonoy River	18.34	17.91	20.57	7.17	3.86	48.01	25.94	30.42	6.73	5.10	69.95	23.09
7 Bato River	4.10	14.16	7.11	30.91	45.53	9.11	2.48	14.16	17.59	8.69	14.62	15.31
12 Cagraray	-	7.35	8.94	2.07	18.21	19.32	8.80	10.76	-	-	-	9.43
14 Bariw Point	4.57	34.89	19.08	6.62	13.25	-	7.04	14.62	6.95	40.84	98.10	22.36
Average	6.90	22.64	25.18	13.42	19.33	41.08	11.23	16.31	12.52	21.94	59.67	19.87
III. Deep area												
3 Grid 13	192.15	99.92	0.18	181.02	30.35	55.05	48.01	24.29	121.07	*	134.52	88.66
5 Maqueda	4.42	106.04	94.16	81.13	15.18	62.91	23.18	60.71	147.97	*	0.00	59.57
8 Grid 50	81.35	4.14	28.15	114.79	81.95	37.53	64.74	38.08	-	-	-	56.34
11 Grid 33	0.00	4.86	93.54	0.00	109.27	12.42	188.19	48.58	-	-	-	57.11
15 Tabaco Bay	23.81	45.25	22.35	24.83	28.84	25.11	36.56	42.22	21.52	52.98	93.13	37.87
Average	57.99	55.89	47.57	75.48	54.00	41.34	67.08	47.97	96.85	52.98	75.88	59.91

Note: - = no data

*inclement weather did not permit sampling

Table 2.4. Estimates of productivity using nitrate data at different stations in Lagonoy Gulf, 1994.

Classification	Northeast monsoon				Summer				Southwest monsoon				Average
	NO_3		TRANS	PROD	NO_3		TRANS	PROD	NO_3		TRANS	PROD	
	(uM)	(moles l^{-1})	(m)	(gC $m^{-2}year^{-1}$)	(uM)	(moles l^{-1})	(m)	(gC $m^{-2}year^{-1}$)	(uM)	(moles l^{-1})	(m)	(gC m^{-2} $year^{-1}$)	
I. Coral reef/seagrass/seaweed area													
1 Rawis	0.05	5E-08	5.00	1.39	4.61	4.61E-06	7.00	179.58	-	-	-	-	60.32
6 Agoho	0.47	4.7E-07	8.50	22.23	1.13	1.13E-06	4.00	25.15	0.41	4.1E-07	3.50	7.99	18.46
9 Acal	0.42	4.2E-07	4.00	9.35	10.99	1.199E-05	6.00	366.96	-	-	-	-	125.44
10 Gaba	0.74	7.4E-07	3.00	12.35	2.96	2.96E-06	2.00	32.94	0.81	8.1E-07	1.25	5.63	16.98
13 Casolgan	0.64	6.4E-07	7.00	24.93	2.26	2.26E-06	2.00	25.15	0.20	2E-07	2.50	2.78	17.62
Average	0.46	4.6E-07	5.50	14.20	4.39	4.39E-06	4.20	102.61	0.47	4.7E-07	2.42	6.33	41.05
II. Estuary/mangrove area													
2 Sogod	0.50	5E-07	3.00	8.35	3.57	3.57E-06	5.00	99.34	0.42	4.2E-07	3.50	8.18	38.62
4 Lagonoy	0.14	1.4E-07	-	-	4.58	4.58E-06	4.00	101.95	0.16	1.6E-07	1.50	1.34	34.43
7 Bato	0.62	6.2E-07	1.50	5.18	6.84	6.84E-06	4.00	152.26	1.55	1.55E-06	3.00	25.88	61.10
12 Cagraray	0.17	1.7E-07	1.20	1.14	4.68	4.68E-06	1.50	39.07	-	-	-	-	13.40
14 Bariw	0.60	6E-07	0.75	2.50	4.38	4.38E-06	1.50	36.56	0.09	9E-08	1.50	0.75	13.27
Average	0.41	4.06E-07	1.29	2.91	4.81	4.81E-06	3.20	85.66	0.56	5.6E-07	2.38	7.42	32.00
III. Deep area													
3 Grid 13	0.66	6.6E-07	19.00	69.79	2.62	2.62E-06	32.00	466.57	0.16	1.6E-07	27.00	24.04	186.80
5 Maqueda	0.92	9.2E-07	6.50	33.28	2.18	2.18E-06	49.00	594.45	0.18	1.8E-07	16.50	16.53	214.75
8 Grid 50	0.06	6E-08	22.00	7.35	8.88	8.88E-06	26.00	1,284.85	-	-	-	-	430.73
11 Grid 33	-	-	17.00	-	2.95	2.95E-06	19.00	311.92	-	-	-	-	103.97
15 Tabaco	0.41	4.1E-07	14.50	33.08	3.42	3.42E-06	15.00	285.48	0.24	2.4E-07	13.00	17.36	111.98
Average	0.41	4.1E-07	15.80	36.05	4.01	4.01E-06	28.20	629.30	0.19	1.9E-07	18.83	19.91	228.42

Note: - = no data.

Table 2.5. Comparison of primary productivity (gC m^{-2} $year^{-1}$) using direct method, chlorophyll a and nutrient (NO_3) at different areas in Lagonoy Gulf, 1994.

Classification	Direct method			Chlorophyll *A*	Nutrient (NO_3)
	Gross Production	Net Production	Respiration		
I. Coral reef/seagrass/seaweed area					
1 Rawis	344.41	118.55	892.21	27.84	60.32
6 Agoho	2,943.36	254.70	2,495.07	21.22	18.46
9 Acal	577.43	331.42	205.13	20.98	125.44
10 Gaba	122.35	0.00	192.72	13.67	16.98
13 Casolgan	250.54	0.00	736.42	11.62	17.62
Average	847.62	140.93	904.31	20.50	41.05
II. Estuary/mangrove area					
2 Sogod	529.98	306.16	195.35	29.17	38.62
4 Lagonoy	724.94	99.67	1,173.84	23.09	34.43
7 Bato	786.70	265.76	434.39	15.31	61.10
12 Cagraray	128.36	47.63	261.43	9.43	13.40
14 Bariw	377.01	215.96	134.38	22.36	13.27
Average	505.40	187.03	487.99	32.29	32.00
III. Deep areas					
3 Grid 13	6,096.38	706.06	5,010.72	[illegible] 66	186.80
5 Maqueda	2,814.59	510.27	18,274.02	59.57	214.75
8 Grid 50	12,284.44	8,322.49	5,086.15	56.34	430.73
11 Grid 33	0.00	0.00	4,383.50	57.11	103.97
15 Tabaco	3,736.19	1,464.51	2,832.05	37.87	111.98
Average	4,946.32	2,200.66	6,717.29	64.48	228.42

Table 2.6. Levels of chlorophyll *a* (mg m^{-3}) measured every 3-4 hours during summer (April) and southwest monsoon (September) at three stations in Lagonoy Gulf, 1994.

Time	Tabaco Bay		Lagonoy River		Sogod River	
	Summer	Southwest Monsoon	Summer	Southwest Monsoon	Summer	Southwest Monsoon
0100			0.10			
0200		0.16		0.29		0.43
0300	0.51					
0400					0.33	
0500		0.27	0.32	0.23		0.35
0600						
0700	1.34					
0800		0.02		0.21	0.43	0.37
0900			0.97			
1000						
1100	0.43	0.07		0.32		0.42
1200						
1300			0.78			
1400		0.16		0.35		0.35
1500	0.00					
1600					0.43	
1700		0.14	0.33	0.13		0.50
1800						
1900	0.96					
2000		0.22		0.35	0.32	0.37
2100			0.44			
2200						
2300	0.53	0.10		0.49		0.49
2400					0.43	

Table 2.7. Estimates of productivity using chlorophyll a and zooplankton biomass during the grid sampling in Lagonoy Gulf, summer (May) and southwest monsoon (August) 1994.

Station	Chlorophyll *A* (mg m^{-3})		Zooplankton biomass (mg m^{-3})	
	Summer	Southwest monsoon	Summer	Southwest monsoon
I. Coastal areas				
Grid T	0.32	0.26	1358.10	471.64
Grid P	0.10	0.05	43.90	43.63
Grid M	0.41	0.29	40.70	224.03
Grid L	0.10	0.07	22.28	43.63
Grid I	0.22	0.16	24.19	35.37
Grid G	0.32	0.00	126.05	33.02
Grid A	0.13	0.63	135.80	263.61
Grid C	0.00	0.13	5.73	30.66
Grid D	0.00	0.03	9.93	29.48
Grid F	0.43	0.27	26.10	28.30
Grid AH	0.12	0.18	27.37	-
Grid AI	0.44	0.07	129.40	85.54
Grid AP	0.12	0.08	20.37	23.58
Grid AR	0.34	0.15	28.65	25.94
Grid AM	0.27	0.16	20.37	22.40
Grid AN	0.56	0.06	150.70	147.39
Grid AO	0.24	0.31	84.03	33.02
Grid AT	0.10	0.00	23.55	40.09
Grid AF	0.12	0.11	29.92	37.73
Grid AE	0.19	0.12	156.00	409.74
Grid AC	0.12	0.16	23.55	44.81
Grid AB	0.32	0.21	458.40	448.06
Grid X	0.10	0.43	373.50	778.21
Grid W	0.31	0.16	140.06	212.24
Grid R	0.09	0.16	84.67	44.81
Grid V	0.10	0.27	577.20	235.82
Average	0.21	0.17	158.48	145.88
II. Deep areas				
Grid U	0.12	0.27	4.10	9.20
Grid 29	0.22	0.35	4.96	40.09
Grid 13	0.41	0.19	3.90	7.55
Grid 11	0.22	0.08	3.69	36.55
Grid 2	0.12	0.27	16.55	30.66
Grid AG	0.12	0.08	5.90	7.07
Grid 17	0.22	0.00	25.46	20.04
Grid 15	0.43	0.14	21.64	43.63
Grid 31	0.12	0.19	24.19	42.45
Grid 33	0.00	0.44	5.30	8.02
Grid 35	0.24	0.21	20.37	21.22
Grid 48	0.10	0.00	24.83	34.19
Grid 50	0.32	0.21	5.10	7.31
Grid 52	0.12	0.31	19.10	43.63
Grid 54	0.12	0.07	24.19	34.19
Grid 66	0.34	0.16	26.74	40.09
Grid 64	0.12	0.05	66.21	48.34
Average	0.20	0.18	17.78	27.90

Note: - - no data.

Table 2.8. Correlation analysis of water quality variables measured from the different grids of Lagonoy Gulf in summer (May), 1994.

Parameter	Depth	Transparency	Suspended solids	Water temperature	DO	Salinity	pH	Chlorophyll a	Biomass
Depth	1.00	0.85***							-0.45***
Transparency		1.00							
Suspended solids			1.00						
Water temperature				1.00		0.28 *			
DO					1.00				
Salinity						1.00			
pH							1.00		
Chlorophyll a								1.00	
Biomass									1.00

Note: *** - significant at 1% level
** - significant at 5% level
* - significant at 10% level

Table 2.9. Correlation analysis of water quality variables measured from the different grids of Lagonoy Gulf, 1994.

Parameter	Depth	Transparency	Suspended solids	Water temperature	DO	Salinity	pH	Chlorophyll *a*	Biomass
Depth	1.00	0.86 ***		0.33 *			-0.18*	-0.24*	-0.34*
Transparency		1.00			0.22 **		0.58***		-0.54 ***
Suspended solids			1.00	0.71***			0.50***		
Water temperature				1.00	-0.23 **	0.25 **	-0.21**		
DO					1.00			-0.28***	-0.19*
Salinity						1.00			
pH							1.00		0.24 **
Chlorophyll *a*								1.00	0.23 **
Biomass									1.00

Note: *** - significant at 1% level
** - significant at 5% level
* - significant at 10% level

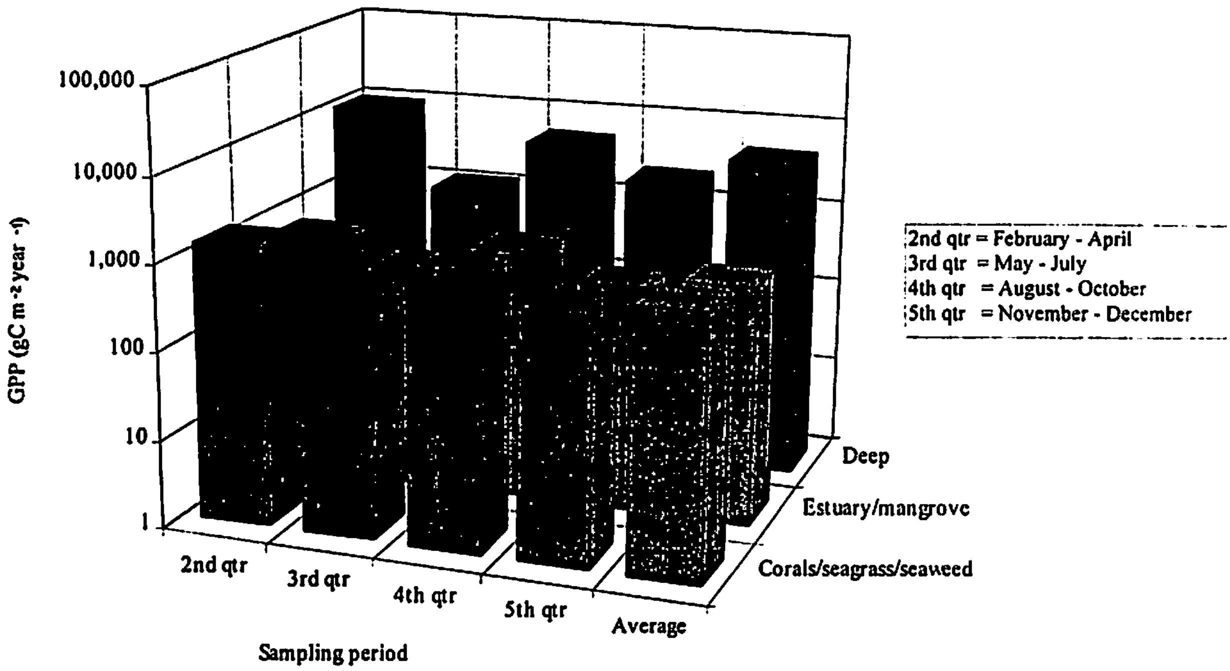

Fig. 2.1. Gross productivity (GPP) estimates using direct method in Lagonoy Gulf, 1994.

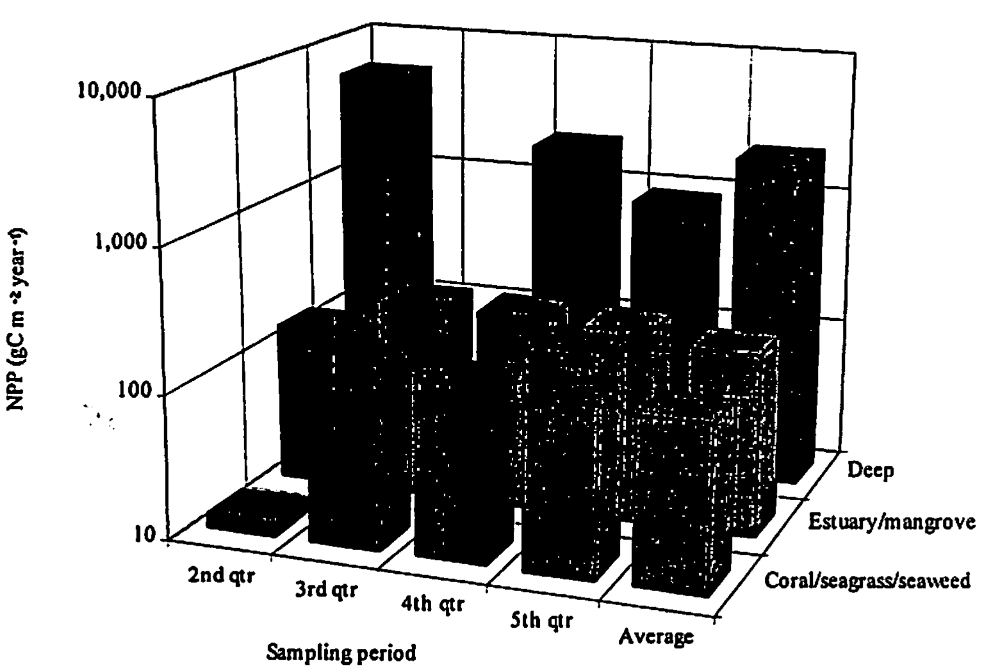

Fig. 2.2. Net productivity (NPP) estimates using direct method in Lagonoy Gulf, 1994.

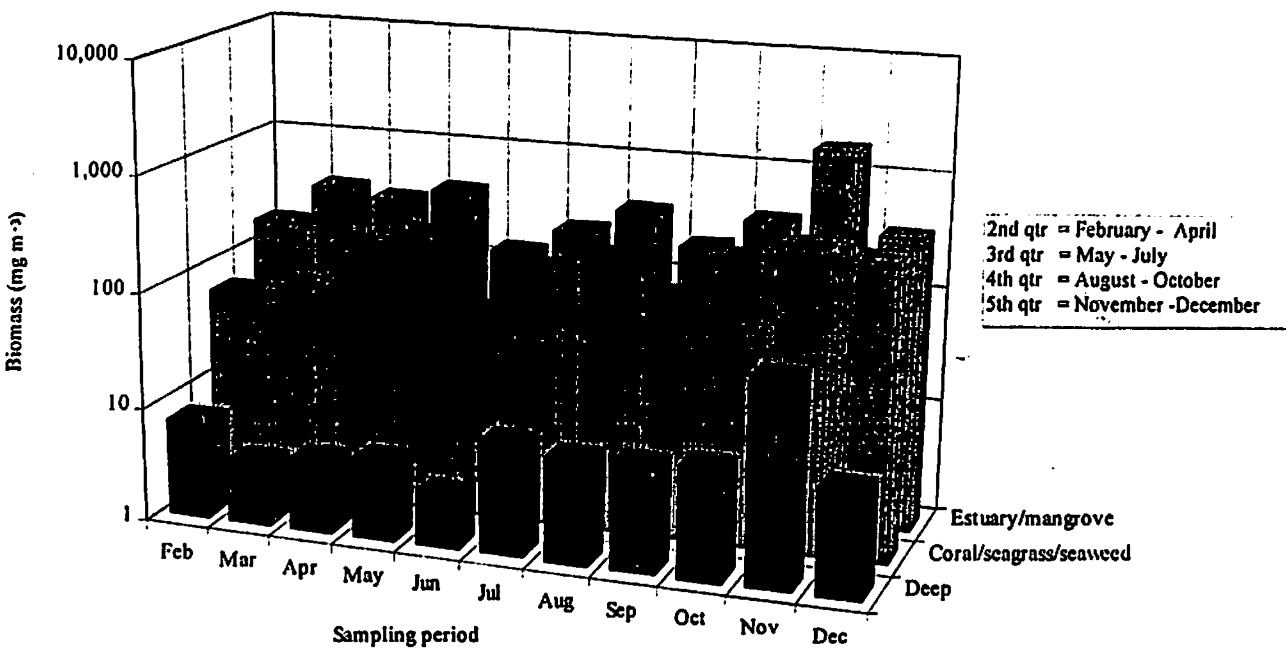

Fig. 2.3. Zooplankton biomass (mg m^{-3}) measured in different areas (1994).

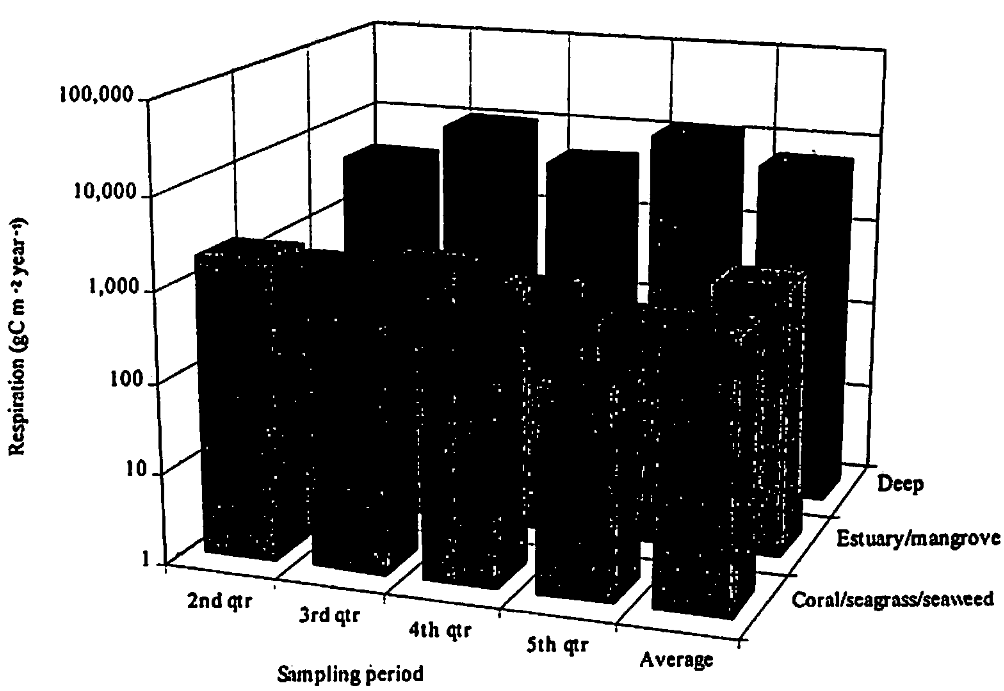

Fig. 2.4. Respiration estimates using direct method in Lagonoy Gulf, 1994.

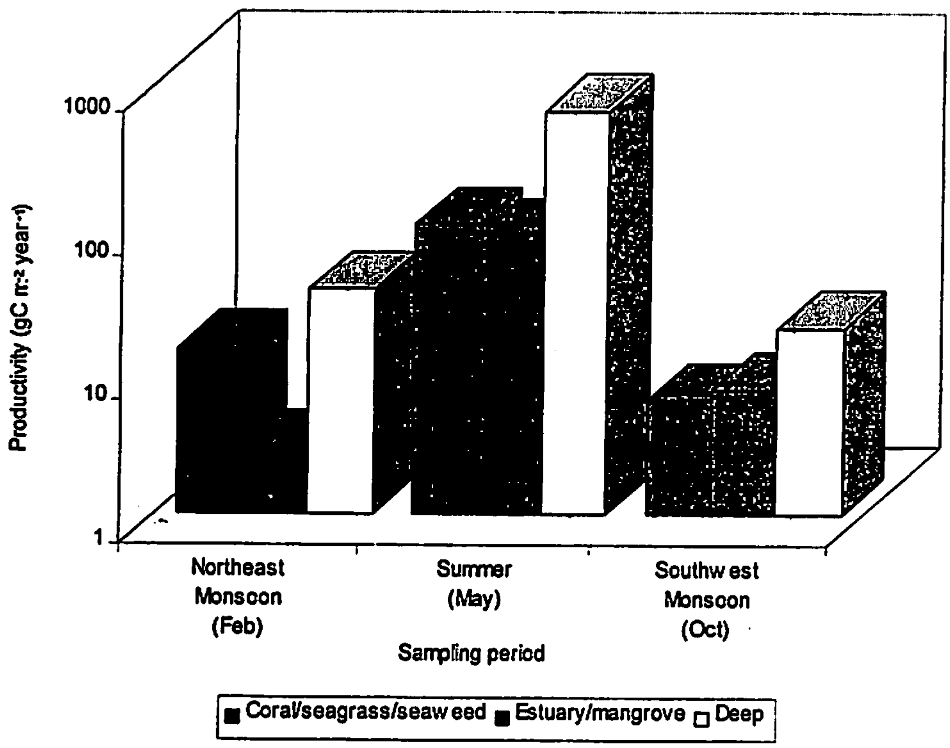

Fig. 2.7. Productivity estimates using nitrate concentrations in Lagonoy Gulf, 1994.

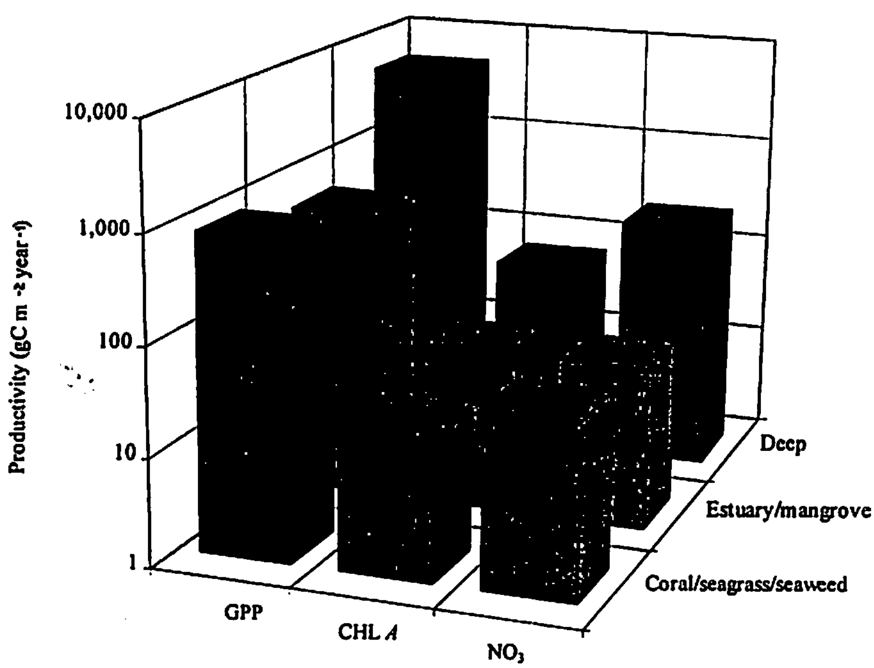

Fig. 2.8. Estimates of productivity in Lagonoy Gulf, 1994.

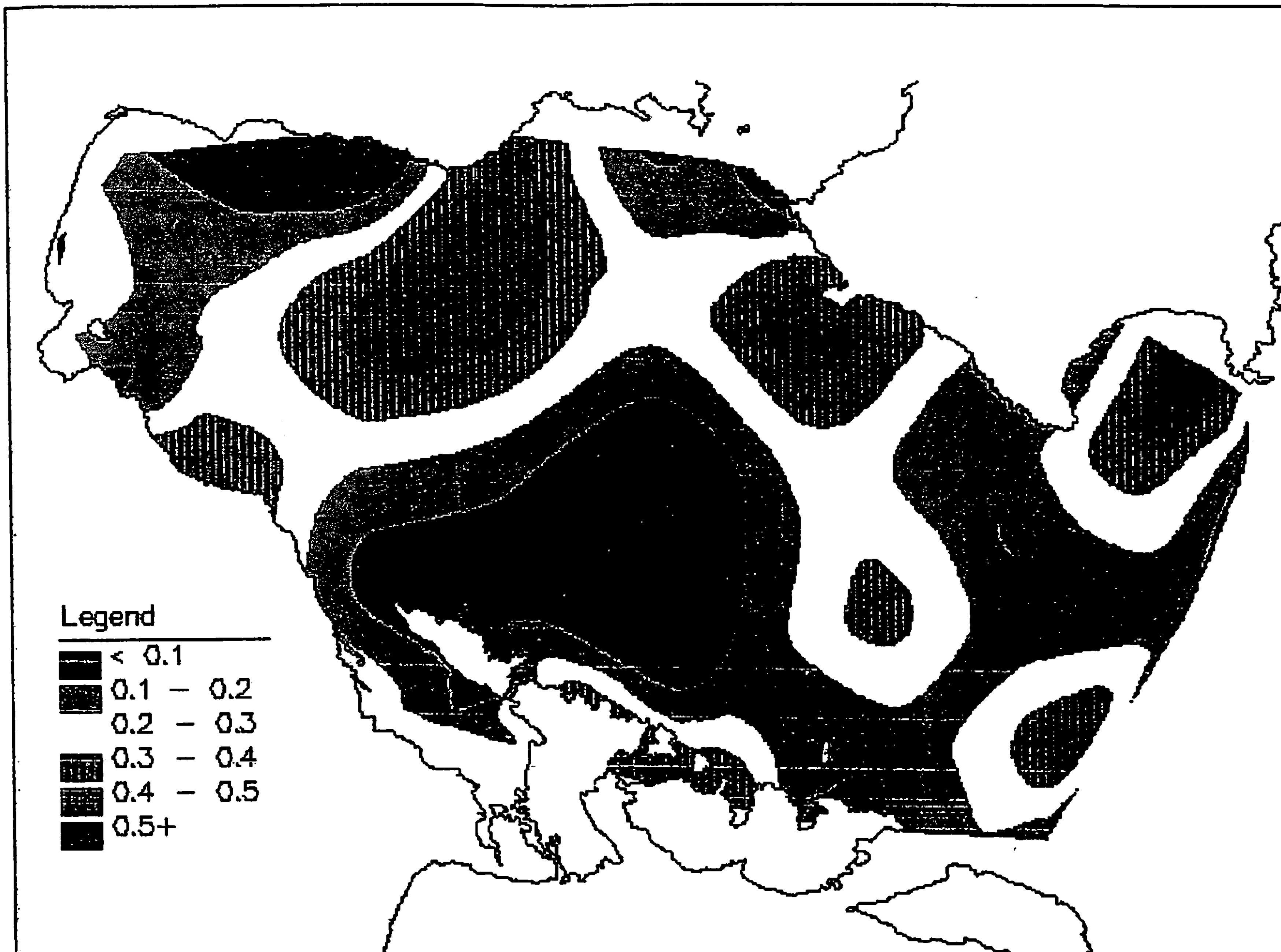

Fig. 2.9. Spatial distribution of chlorophyll a in Lagonoy Gulf (May 1994).

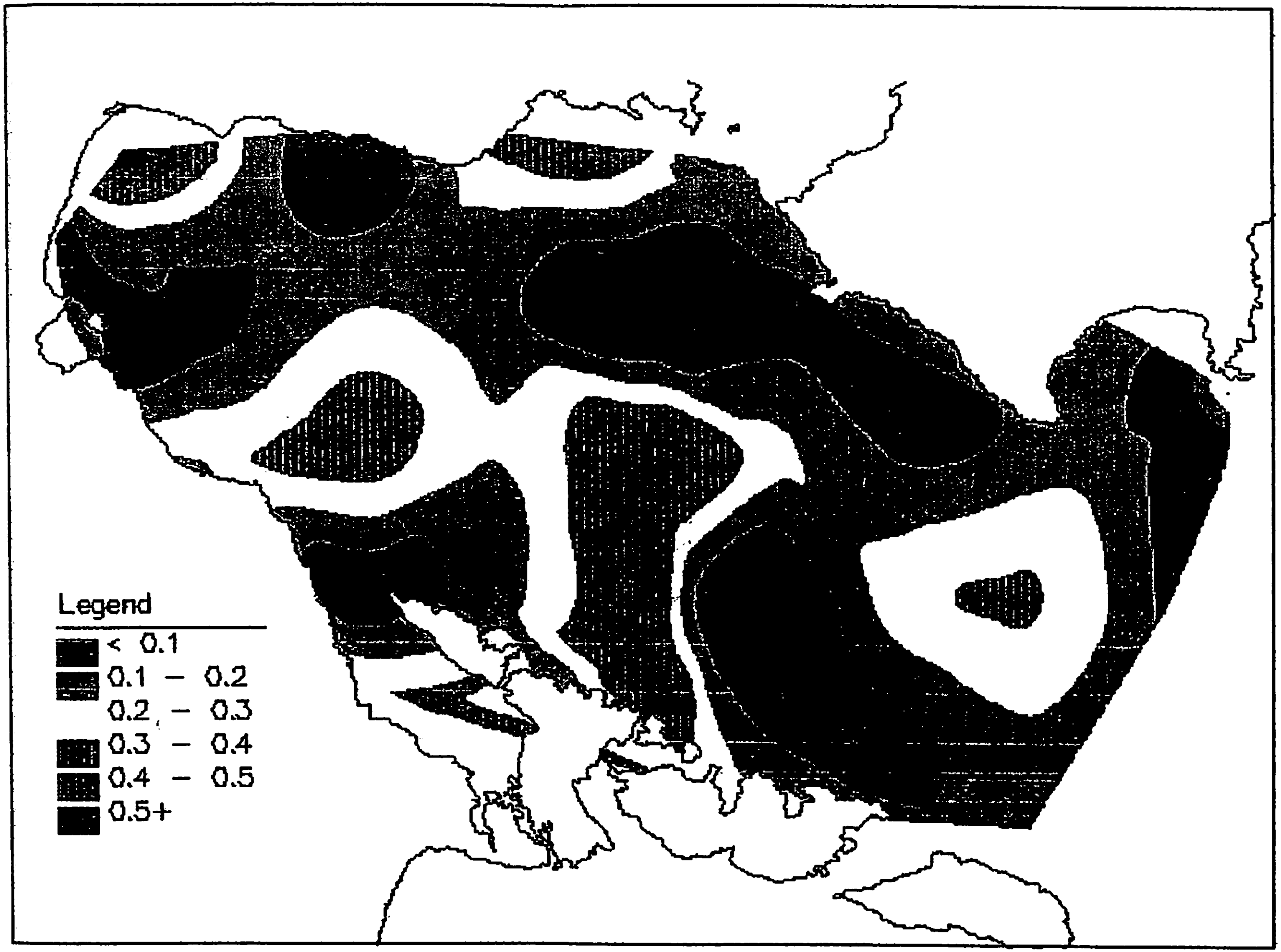

Fig. 2.10. Spatial distribution of chlorophyll a in Lagonoy Gulf (August 1994).

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Assessment of Water Quality in Lagonoy Gulf
III. Pollution Monitoring

by

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and

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Assessment of Water Quality in Lagonoy Gulf
Part III. Pollution Monitoring

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Valmonte-Santos, R.A.V. and M.L. San Diego-McGlone. 1995. Assessment of water quality in Lagonoy Gulf. Part III. Pollution monitoring. *In* G. Silvestre, C. Luna, V. Soliman and L. Garces (eds.) Resource and ecological assessment of Lagonoy Gulf, Philippines, ICLARM Tech. Rep.

Abstract

Water samples were collected from the different stations of Lagonoy Gulf to determine concentrations of trace metals (mercury, arsenic, cadmium and copper), nutrients (nitrogen and phosphorus), coliform (presumptive, fecal and total) and pesticides (organochlorines, organophosphates and pyrethroids) for three sampling periods: northeast monsoon, summer and southwest monsoon. Coliforms were found to be low in count and did not exceed the allowable limit set by Environmental Management Bureau (EMB). Pesticides were not detected in the water samples. During summer, the dominant form of nitrogen was nitrate, however, nitrite and ammonia were abundant during the two other sampling periods. The increase in nutrient concentration with depth resulted from regeneration processes. Within a tidal cycle, higher levels of the nutrients were determined during ebb which may be a signal of industrial and domestic discharges from the rivers.

Among the four metals monitored in the water column, only copper and cadmium had detectable concentrations. The absence of mercury and arsenic in the water and their presence in the sediments imply removal of these metals into the sediments of the gulf. The level of copper and cadmium has slightly exceeded the criteria set by EMB. Possible sources of contamination are: Tiwi Geothermal Power Plant, pulp and paper company (ALENDECO), National Power Corporation (NAPOCOR) power diesel barge and domestic activities.

Introduction

Among the average Filipino's food supply, over 50% of his protein requirement comes from the marine environment (Lowrie 1981). However, as a result of activities relating to industrialization and technological advancement, this food source has become threatened. Inland and coastal waters have become "recipients" of the by-products of such activities. Increased density in human population who settles in the coastal areas has worsened the situation as a result of increased discharges of untreated wastes. The land-based economic options in the area which include agricultural, industrial, mining and domestic activities, have increased pollution in the gulf. The Tiwi Geothermal Plant in Albay which has a total capacity of 330 MW (Balagot 1990) may be a source of not only chemical but thermal pollution as well. The pulp and paper industry (ALENDECO) in Malinao, Albay and the NAPOCOR diesel power barge in Bato River, Bato, Catanduanes, may also contribute to contamination in the gulf.

GESAMP (1986) defined marine pollution as "man's direct or indirect introduction of substances or energy into the marine environment (including estuaries) resulting to deleterious effects such as harm to living resources, hazards to human health, hindrance to marine activities, including fishing, impairment of quality for use of sea water and reduction of amenities". With Lagonoy Gulf's various uses, especially as food source, protection of its coastal waters is of vital concern. This study was conceived to identify possible sources of marine pollution in the gulf and other factors which may cause water quality parameters to exceed allowable values. These parameters are to be compared to the water quality criteria established by EMB, Department of Environment and Natural Resources (DENR).

Materials and Methods

The same stations selected for general water quality studies were occupied for pollution monitoring. Description of each station is given in "Assessment of Water Quality in Lagonoy Gulf, Part I. General Water Quality" (Valmonte-Santos et al., this vol.). The stations are classified as coral reef/seagrass/seaweed areas, estuary/mangrove areas, and deep areas. Sampling was conducted three times in one year, during northeast monsoon (January - February), summer (May) and southwest monsoon (October). The parameters monitored were coliform, pesticides, heavy metals and nutrients.

The influence of tides on these parameters was determined by collecting samples during ebb and flood periods in the gulf, specifically at Sogod River, Lagonoy River and Tabaco Bay. This was conducted twice, in April (summer) and September (southwest monsoon).

Field sampling was done from 0700H to 1700H. A Kemmerer water sampler (1.2 L) was used to collect water samples for heavy metal and nutrient analysis. Samples from different depths were taken to determine vertical variation in the parameters. These depths are 0.5 m - 2 m for surface samples, 50 m for mid-depth and 80 - 250 m for the lowest depth.

Coliform content was determined for samples taken from Sogod River, Lagonoy River, Bariw Point, Tabaco Bay and Grid 13 (Fig. 3.1). This was done in only five sites because of logistical limitations. Sampling for coliform content was done by dipping a one-liter sterilized amber glass bottle just below the water surface. Samples were kept cold and submitted to UP Natural Science Research Institute (UP NSRI, Diliman, Quezon City) within 24 hours of collection for analysis. Presumptive, fecal and total coliforms were determined by multiple tube fermentation technique (APHA 1985).

Sampling for pesticide analysis was done in the same manner as coliform determination. This was limited to the same five stations given above for similar reasons. Samples were frozen and submitted to Bureau of Plant Industry (BPI, San Andres, Manila) for pesticide analysis within 24 hours after collection. Organophosphate, organochlorine and pyrethroids were determined by using gas liquid chromatography.

Samples for heavy metal analysis were collected by filtering water (1.5 l) through 47-mm glass fiber filter (GC 50). Filtered samples were preserved with 15 ml of 50% HCl, stored in 1.5 l polyethylene bottles, sealed with parafilm and placed in a plastic bag to avoid contamination. Filtered samples were kept cold andsubmitted to the Philippine Institute of Pure and Applied Chemistry (PIPAC, Loyola Heights, Quezon City) for mercury, cadmium, copper and arsenic determinations. For mercury, cold vapor atomic absorption spectrophotometry was used while copper and cadmium were analyzed using atomic absorption spectrophotometry. Colorimetry was applied for arsenic determination.

Sediments were sampled using an Ekman grab sampler. Approximately 1kg of collected sediment was placed in a black polyethylene plastic bag, sealed with a rubber band and transported to PIPAC for heavy metal analysis.

Samples for nutrient analysis were collected by filtering 250 ml water through 47-mm glass fiber filter (GC 50). Filtered samples were placed in polyethylene bottles, sealed with parafilm and placed in plastic bags to prevent contamination. Filtered samples were frozen and later transported to UP Marine Science Institute (UP MSI, Diliman, Quezon City) for nitrogen and phosphorus determination. A nutrient autoanalyzer was used in quantifying nitrite (NO_2), nitrate (NO_3), ammonia (NH_4) and phosphate (PO_4) concentrations based on the method of Strickland and Parsons (1972).

As discussed in Part 1, Lagonoy Gulf falls under the Class SC marine waters. Hence comparison of the determined levels will be made with the water quality criteria set by EMB (1990) for Class SC waters.

Results and Discussion

Seasonal variation

Coliform analysis

Coliforms are aerobic and facultative anaerobic, gram-negative, rod-shaped and nonsporing form of bacteria that ferment lactose with gas formation within 48 hours at 35°C. The presence of coliform bacteria in water indicates fecal contamination, i.e., these organisms are the best indicator of microbial pollution as they usually signify the presence of human or animal feces. Bacterial pathogens, such as *Escherichia*, *Enterobacter*, *Shigella*, *Salmonella*, *Yersinia* and *Klebsiella*, are responsible for gastroenteritis, dysentery and typhoid (Mendoza 1993). Results of coliform analysis from the five stations in Lagonoy Gulf are presented in Table 3.1. There are water quality criteria for total coliform but none exists for presumptive and fecal coliform (EMB 1990).

Results show that presumptive coliform has a lower count in the deep area (Grid 13 and Tabaco Bay) for the three sampling periods relative to the estuary/mangrove areas (Sogod River, Lagonoy River and Bariw Point). On the other hand, fecal coliform content did not change in the deep area for the three sampling periods (<30 MPN/100 ml) while estuary/mangrove areas varied from <30 MPN/100 ml to 930 MPN/100 ml. Nevertheless, both estuary/mangrove and deep areas did not exceed the water quality criteria set by EMB (1990) on total coliform for Class SC waters (5,000 MPN/100 ml). For estuary/mangrove areas, total coliform varied from 40 MPN/100 ml to 2,300 MPN/100 ml during northeast monsoon to an upper limit of 930 MPN/100 ml during summer and southwest monsoon. A much lower total coliform count was obtained from the deep station throughout the sampling period (<30 MPN/100 ml). These results indicate that there should be no cause for alarm as far as coliform contamination in Lagonoy Gulf is concerned. Thus, the gulf is considered safe for recreational activities like swimming, skin diving, and commercial and sustenance fishing. This is unlike the Bicol River, a major tributary of San Miguel Bay (also in Bicol Region), where the allowable limits of coliform levels have been exceeded (Mendoza et al. 1993). In situations such as this, eating of raw or partially cooked shellfish taken from these waters poses a human health risk. Another bay with high coliform content is Lingayen Gulf in Pangasinan (Maaliw 1990). Studies showed that the absence of a sewage treatment system and inadequate toilet facilities contributed to the high coliform levels in some localities of Lingayen Gulf, creating serious economic consequences (Maaliw 1990).

Pesticides

Results of pesticide analysis showed that organochlorines, organophosphates and pyrethroids were not detected in estuary/mangrove areas and deep stations of Lagonoy Gulf during the northeast monsoon (February) and summer (May) (Table 3.2a). Thus, pesticide analysis during the southwest monsoon was discontinued. Table 3.2b lists the pesticide residues tested in the water samples from Lagonoy Gulf. Class SC waters should have "nil" organochlorine content as indicated by the EMB water quality criteria (1990), and Lagonoy Gulf satisfies this requirement. The same results were found in the water and sediments of San Miguel Bay (Mendoza et al. 1993).

Trace metal

Metals can be classified as essential and nonessential. The essential metals, which include copper, iron and zinc, are important in many biochemical functions of the organism. They act as components of the electron donor system or function as ligands in complex enzymatic compounds. The essential metals are required only in trace amounts and excess concentrations are regulated by homeostatic control mechanisms. However, if supply is too high, these mechanisms cease to function and the metal will impose acute or chronic effects on the organism (Engel et al. 1981). The nonessential metals have no known beneficial effects on organisms. These include cadmium, arsenic and mercury. Sources of metal pollution in the environment include: (1) geologic weathering; (2) industrial processing of ores and metals; (3) the use of metals and metal components; (4) leaching of metals from garbage and solid waste dumps; and (5) animal and human excretions which contain heavy metals (Forstner and Wittman 1981). EMB (1990) indicated that one possible source of heavy metal contamination in an aquatic ecosystem is pulp and paper industry.

Table 3.3 presents the toxicological tolerance levels of mercury, arsenic, copper and cadmium. Sources of cadmium in the water include contaminated agricultural soils (phosphate fertilizer), mining wastes, mine waters and the industrial use of cadmium. Another important source is municipal sewage effluents and sludges including those of domestic origin (GESAMP 1985).

Based on their proven toxic effects to marine organisms and humans, the trace metals which were monitored in the gulf include mercury (Hg), cadmium (Cd), arsenic (As) and copper (Cu). Their concentrations in Lagonoy Gulf are presented in Table 3.4. Mercury and arsenic were found to be nondetectable from all areas and in all depths (surface, middle and bottom) of Lagonoy Gulf during northeast monsoon, summer and southwest monsoon. The

EMB criteria set for these two elements are 0.002 mg l^{-1} and 0.05 mg l^{-1}, respectively (EMB 1990). A similar behavior for mercury was found in San Miguel Bay waters (Table 3.5) (Mendoza et al. 1993). Lingayen Gulf had detectable mercury (Hg) and cadmium (Cd) levels perhaps from Agno River, a tributary of the gulf, whose mercury and cadmium levels were 0.070 mg l^{-1} and 1.00 mg l^{-1}, respectively (Maaliw 1990). Laguna de Bay, the largest freshwater lake (90,000 ha) in Southeast Asia, was found to contain high concentrations of mercury (0.05 mg l^{-1}) relative to the allowable limit for Class C waters (0.002 mg l^{-1}) (Table 3.5).

In Lagonoy Gulf, the Visitang-Naga River (Fig. 3.2) provides drainage for almost 50% of the geothermal development area (Balagot 1990). This river is the outfall of the geothermal wastewater discharge and is referred to as Sogod River in this study. Unlike the results of this study, As levels in Visitang-Naga River obtained by PGI (1982) exceeded the EMB criteria (Table 3.6). This may be due to the proximity of the PGI samples to the discharge site or a difference in the rate and amount of discharge when samplings were conducted. The concentration of arsenic determined by PGI was two orders of magnitude higher than the allowable limits.

The levels of copper in the gulf during southwest monsoon (Table 3.4) were found to be lowest (0.037 mg l^{-1}) at the deep areas relative to the estuary/mangrove areas (0.053 mg l^{-1}) and the coral reef/seagrass/seaweed areas (0.057 mg l^{-1}) (Fig. 3.3). In the deep areas, copper concentration in bottom samples was slightly higher (0.057 mg l^{-1}) than the surface value (0.037 mg l^{-1}) for this period (Fig. 3.4). Overall, copper concentrations during summer exceeded the northeast and southwest monsoon levels (Table 3.4). In all the areas, copper concentrations were slightly above the EMB criteria of 0.05 mg l^{-1}. This was also the case for San Miguel Bay (Mendoza et al. 1993). Between the two bays, copper content in Lagonoy Gulf is lower than San Miguel Bay, and have only slightly exceeded the EMB criteria (Table 3.5). Concentrations of up to 1 mg l^{-1} have been known to occur in coastal waters near copper deposits (Halstead 1972). Possible sources of copper contamination in Lagonoy Gulf include the Tiwi Geothermal Plant, pulp and paper industry, diesel power barge and human activities. The range of copper concentration (0.04 mg l^{-1} - 0.11 mg l^{-1}) in Visitang-Naga River and Sogod River was similar to each other (Table 3.6) and to other areas as well. These two stations have also slightly exceeded the EMB criteria.

Like copper, lower concentrations of cadmium (0.03 mg l^{-1}) were observed during the southwest monsoon in the deep areas relative to the two other areas (Table 3.4, Fig. 3.5). However, slightly higher cadmium levels were detected during summer (0.043 mg l^{-1}). There was little vertical variation in cadmium content in the deep areas (Table 3.4, Fig. 3.6.). Similar average concentrations of cadmium were determined in Lagonoy Gulf and San Miguel Bay (Table 3.5). Both Visitang-Naga and Sogod Rivers gave cadmium concentrations in the range of 0.01 - 0.08 mg l^{-1}.

In addition to the waters of Lagonoy Gulf, trace metals were determined in the sediments of the tributary rivers of the gulf. Metal concentrations for summer (May) and southwest monsoon (October) are given in Table 3.7. Since no EMB criteria exist for heavy metal content in sediments, the US Environmental Protection Agency (USEPA) criteria was used instead (Table 3.8). Mercury level in the gulf was found to vary from nondetectable during southwest monsoon to 0.11 ug g^{-1} wet weight in summer. Like mercury, arsenic gave higher levels during summer for almost all the river systems except Bariw (Table 3.7). Both metals were below USEPA criteria. Since these two elements were not detected in the water column (Table 3.4), levels of these metals may not be of direct harm to nonbenthic marine organisms. Unlike San Miguel and Lagonoy Bays, mercury content of Laguna de Bay sediments was determined to be higher (0.08 ug g^{-1} mercury, Table 3.8). Thus, cautions must be exercised in eating bivalves and other fishes from this lake.

The behavior of copper concentrations in the sediment for the three sampling periods paralleled that in the water column of Lagonoy Gulf. Copper levels were higher in summer than during the southwest monsoon (Table 3.7). During summer, diagenesis and remobilization processes in the sediments could enhance the transfer of metals across the sediment-water interface thus releasing these metals to the water column. This implies that the sediments could be a source of copper to the waters of the gulf.

Cadmium in the sediments of Lagonoy Gulf varied from nondetectable to 2 ug g^{-1} in summer and 0.20 ug g^{-1} to 0.70 ug g^{-1} during the southwest monsoon. The average concentration of cadmium in Lagonoy Gulf (0.78 ug g^{-1}) is higher than the San Miguel Bay average (0.57 ug g^{-1}, Table 3.8).

Table 3.6 gives a comparison of trace metals in the sediments of Visitang-Naga and Sogod Rivers. Higher levels of mercury, arsenic and copper were found in sediments of Visitang-Naga River than Sogod River. Arsenic was one order of magnitude higher in Visitang-Naga, indicating that the river experiences a more direct influence of the geothermal sources farther upstream. A study conducted by Bermas et al. (1991) on the bioaccumulation of arsenic in bivalves (*Glauconomya virens*) living in the vicinity of the Tiwi Geothermal Power Plant showed high concentrations of arsenic (49.86 +/- 6.48 ug g^{-1} dry weight) in these organisms. This can therefore be a potential health hazard to local inhabitants who regularly consume bivalves. Copper levels in Visitang-Naga were almost triple the values in Sogod River while mercury was two orders of magnitude higher at Visitang-Naga (Table 3.6). Since sediment is a sink for trace metals, the proximity of this river to geothermal sources may explain the difference in the metal content of the sediments.

Nutrient levels

There are a number of ways by which nutrient compounds can enter the coastal waters, through discharges of runoff and groundwater, point source effluent discharges such as sewage, atmospheric fallout, wind-driven upwelling, fixation of atmospheric nitrogen and regeneration from coastal sediments (Gabric and Bell 1993). Carbon, nitrogen and phosphorus are major nutrients that commonly move from land to surface water bodies where they become an essential part of the aquatic food chain (MacKinnon 1987). These elements are essential for growth, however, excessive loads or inputs of nutrients may cause undesirable effects such as eutrophication. For example, increased phosphorus levels may impair growth of the coral skeleton (Kinsley and Davies 1979).

Nitrogen is present in seawater as nitrate (NO_3), nitrite (NO_2) and ammonia (NH_3), the most stable form being NO_3. Nitrate originates from soil leaching, terrestrial runoff (including that from fertilized soils) and waste inputs. The modifying effects of soil and vegetation are particularly important with respect to nitrogen (N) concentrations in runoff waters. All forms of nitrogen, including the N_2 gas, are biochemically interconvertible and are components of the N cycle (APHA 1989).

Nitrite and nitrate concentrations were found to be higher during summer than during the northeast and southwest monsoons in all areas of the gulf (Table 3.9). For the deep areas, bottom waters had higher levels of NO_2 than surface and middle depths. This was also true for nitrate. The increase in bottom water concentrations of nitrite and nitrate could result from regeneration process in the water column.

Among the nitrogen species, ammonia was 80% of the total dissolved inorganic nitrogen during northeast and southwest monsoons with nitrate at 13% and nitrite at 5-11%. However, in summer there was predominance of nitrate (68%) over ammonia (24%) and nitrite

(9%). High nitrate concentrations in summer may be due to river inputs since sampling was done two days after the occurrence of Typhoon Bising.

Phosphorus occurs in natural waters and in wastewaters almost solely as phosphates. The sources of phosphorus include urban and agricultural sewage and detergents. Phosphates may also come from fertilizers applied in agricultural or residential lands (APHA 1989).

Similar to nitrogen, phosphorus is essential to the growth of organisms and can be the nutrient to limit the productivity of a body of water (Payne 1986). In Lagonoy Gulf, higher PO_4 concentrations were determined during summer in all areas (0.20 uM for coral reef/seagrass/seaweed area, 0.38 uM for estuary/mangrove areas and 0.25 uM for deep areas, Table 3.9). Bottom waters of deep areas have higher PO_4 concentrations (0.66 uM) than in the middle depth and surface waters (0.26 uM and 0.25 uM, respectively). Such trend may be explained by the release of PO_4 from regeneration processes. The average nitrogen to phosphorus ratio (using nitrate as the nitrogen source) in the gulf during northeast monsoon was determined to be 2.3:1. In summer, the ratio was 15.8:1 and during southwest monsoon, 5.1:1. Elevated concentration of nitrate in summer may have come from river inputs since sampling was conducted two days after Typhoon Bising passed the Bicol region. Except for the summer ratio, the ratios obtained during northeast and southwest monsoons were lower than the often cited Redfield ratio of 6:1. This indicates nitrogen limitation particularly during these two periods of the year and implies that the system would be sensitive to any significant increase in nitrogen. Hence, the added input of nitrate during summer could enhance biological activities in the gulf.

Table 3.10 presents a comparison of nutrient levels in the waters of Lagonoy Gulf and San Miguel Bay. All forms of nitrogen in Lagonoy Gulf were higher than in San Miguel Bay. On the average, nitrate is the predominant species of nitrogen in Lagonoy Gulf while ammonia and nitrite are the more abundant species in San Miguel Bay. Phosphate concentrations are comparable for both bays.

Tidal variation

Pollution parameters were monitored for one tidal cycle during summer (April) and southwest monsoon (September) at three stations: Sogod River, Lagonoy River and Tabaco Bay.

Results of coliform count and pesticide analysis from samples taken within a tidal cycle at the three stations are given in Table 3.11. Sogod River is the lone station that has exceeded the EMB criteria (1990) for total coliform content. This was determined during southwest monsoon in the ebbing flow of the tide. High density of human population who lives along the riverbanks could be the source of coliform contamination particularly from wastes carried by runoff during rainy periods. The other two stations have smaller amounts of coliform (total, presumptive and fecal), regardless of season and phase of the tide (Table 3.11).

Nondetectable amounts of organochlorines and organophosphates were determined from the three stations during summer (Table 3.11). Because of these results, pesticides analysis was discontinued for the southwest monsoon period.

Trace metal concentrations within a tidal cycle are given in Table 3.12. Mercury and arsenic were nondetectable regardless of the tidal cycle. Copper concentrations were determined to be slightly higher than the EMB criteria in summer for all the stations. This was also the case for cadmium. No tidal variations were observed for both copper and cadmium.

Concentrations of nutrients in Lagonoy Gulf during ebb and flood periods are presented in Table 3.13. Small variation was observed for nitrite during ebb and flood in Sogod and Lagonoy Rivers in summer. However, the concentrations of nitrate, ammonia and phosphate at this time, were determined to be lower during flooding than ebbing. River inputs which carry domestic and industrial (Tiwi Geothermal Plant) wastes could be responsible for the elevated levels of these nutrients during ebb. A similar behavior was seen for these nutrients during southwest monsoon.

In Tabaco Bay, bottom water concentrations were higher for all the nutrients than surface waters during flood and ebb periods but there was no clear trend as seen in the two other rivers.

Summary and Conclusion

Lagonoy Gulf is relatively in an unpolluted state in terms of coliform content, pesticides and heavy metals. Trace metals, copper and cadmium were found to be slightly above the allowable limits set by EMB and thus could potentially be the contaminants in the gulf. However, the small variability in concentrations of these metals in all the areas may indicate that the levels are baseline or ambient in the gulf and perhaps, can be assimilated by the resource. However, because of industrial discharges from the presence of pulp and paper industry (ALENDECO), NAPOCOR diesel power barge, Tiwi Geothermal Plant and domestic discharges which input into the gulf and become pollutants, there is then every reason to properly manage the habitat, water quality and fishery of Lagonoy Gulf.

Acknowledgement

We wish to thank Imelda Velasquez of UPMSI, Grace Brizuela, Renante Albao, Len Garces, Marcos Jose Vega, Skorzeny de Jesus, Antonino Mendoza, Ma. Karina Luth Discaya, Rodrigo Zamudio, Anastacio Cante, Jun Gonzales, Quillon Sarte, Francisco Diaz and Guillermo Divison.

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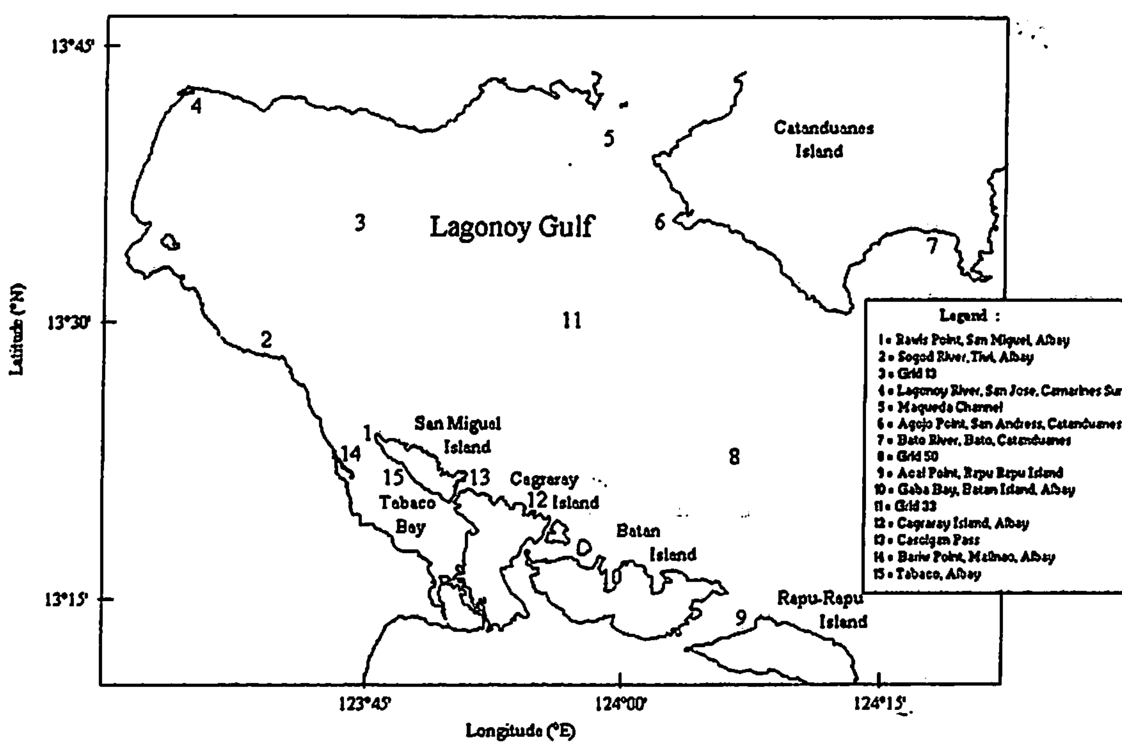

Fig. 3.1. Sampling stations for the assessment of water quality.

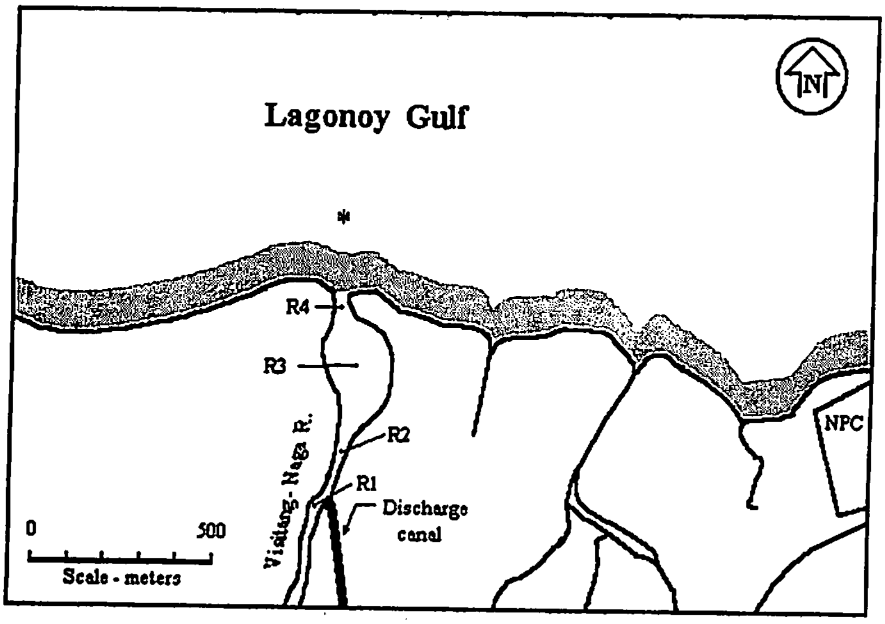

Fig. 3.2. Map showing sampling stations in Visitang - Naga River (R4) and Sogod River (*) in Lagonoy Gulf, Bicol. Source : PGI, 1993 for Visitang - Naga River.

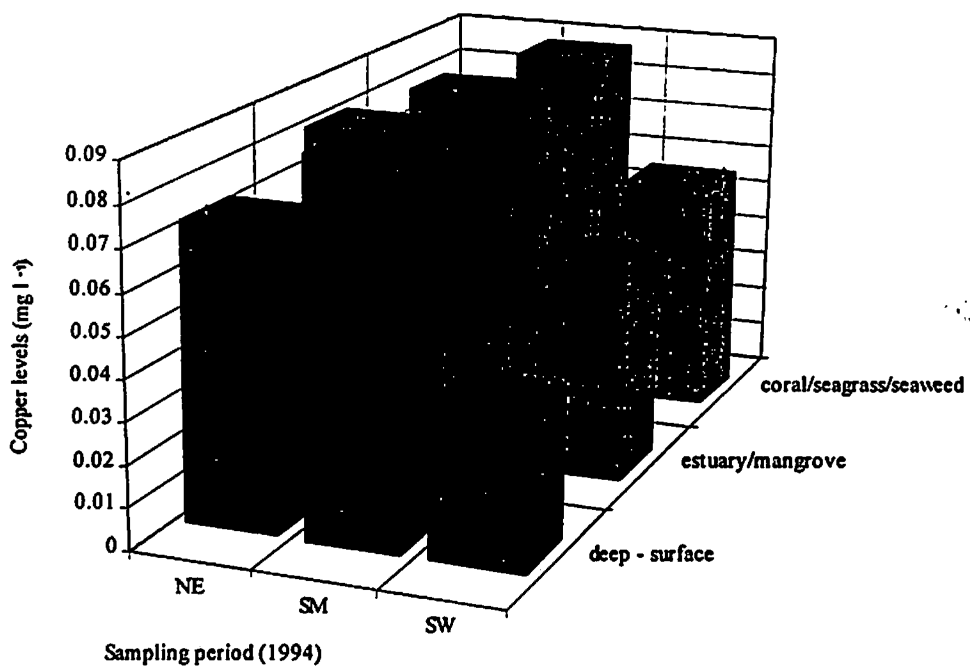

Fig. 3.3. Copper concentration (mg l^{-1}) in different areas of Lagonoy Gulf, 1994.

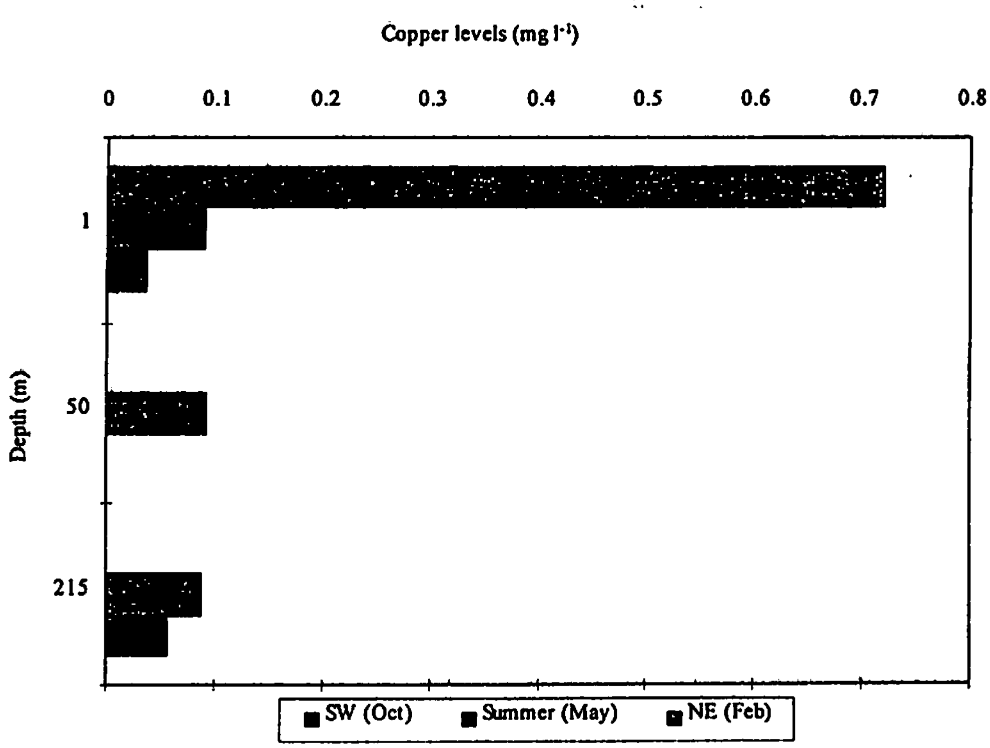

Fig. 3.4. Copper concentration (mg l^{-1}) in the deep areas of Lagonoy Gulf, 1994.

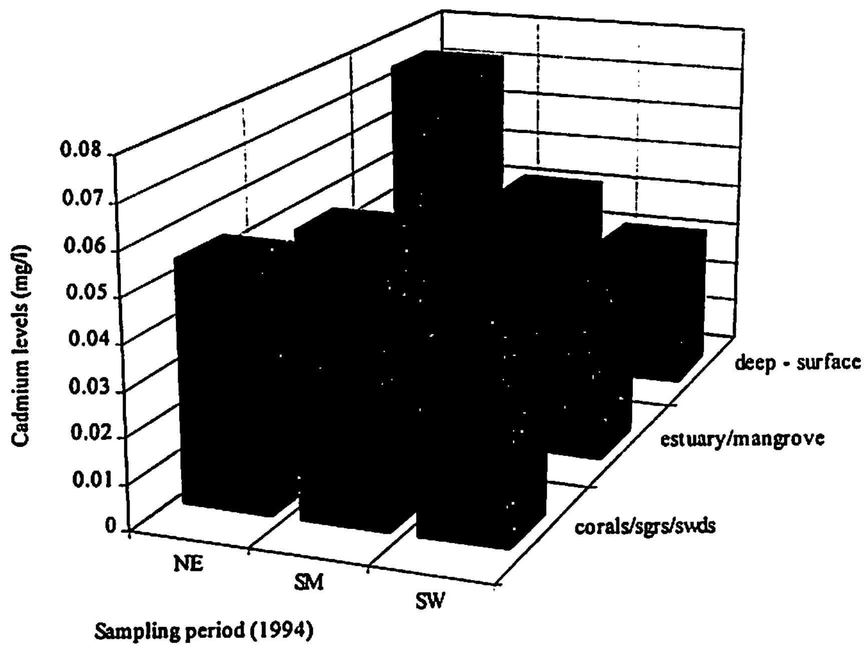

Fig. 3.5. Cadmium concentration (mg l^{-1}) in different areas of Lagonoy Gulf, 1994.

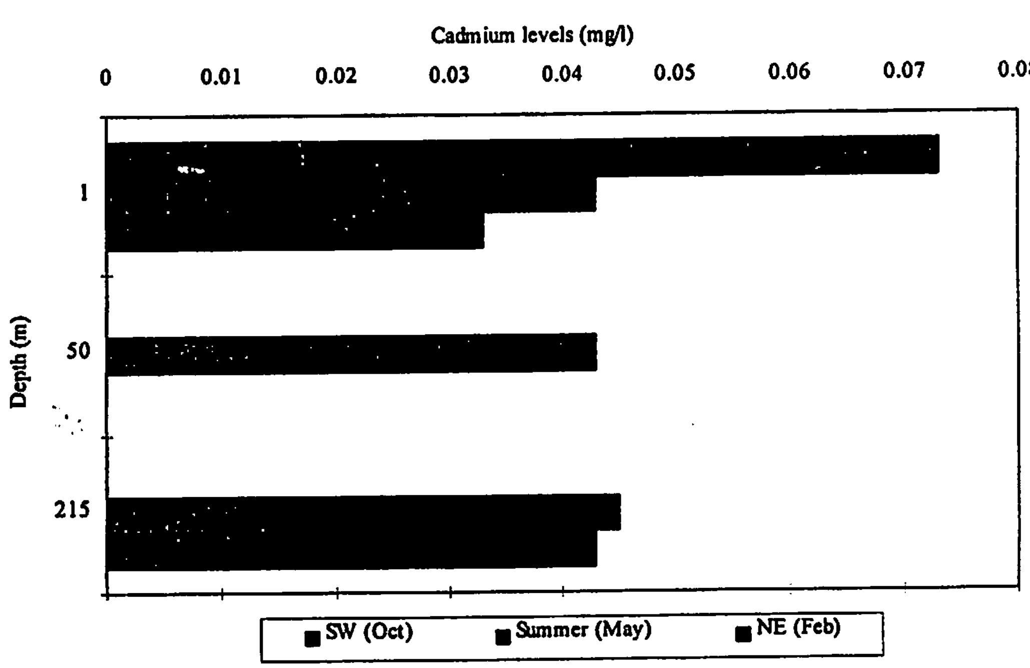

Fig. 3.6. Cadmium concentration (mg l^{-1}) in the deep areas of Lagonoy Gulf, 1994.

Table 3.1. Results of coliform analysis for northeast monsoon (NE; February), summer (May) and southwest monsoon (SW; October) from selected stations in Lagonoy Gulf, 1994.

Station	Fecal analysis (MPN/100 ml)								
	Presumptive coliform			Fecal coliform			Total coliform		
	NE	SUMMER	SW	NE	SUMMER	SW	NE	SUMMER	SW
II. Estuary/mangrove area									
2 Sogod River	40.00	930.00	430.00	40.00	930.00	430.00	40.00	930.00	430.00
4 Lagonoy River	930.00	< 30	< 30	930.00	< 30	< 30	930.00	< 30	< 30
14 Bariw Point	2,300.00	230.00	930.00	900.00	90.00	930.00	2,300.00	90.00	930.00
Average	1,090.00	386.67	453.33	623.33	340.00	453.33	1,090.00	340.00	453.33
III. Deep area									
3 Grid 13	< 30	< 30	90.00	< 30	< 30	< 30	< 30	< 30	< 30
15 Tabaco Bay	< 30	< 30	-	< 30	< 30	-	< 30	< 30	-
Average	< 30	< 30	90.00	< 30	< 30	< 30	< 30	< 30	<30
DENR criteria (1990)	-			-			5000.00		

Note: - = no data.

Table 3.2a. Results of pesticide analysis for northeast monsoon (February), summer (May) and southwest monsoon (October) from selected stati in Lagonoy Gulf, 1994.

Station	Pesticides (ppm)		
	Organophosphates		
	Northeast monsoon	Summer	Southwest monsoon
II. Estuary/mangrove area			-
2 Sogod River	nondetectable	nondetectable	
4 Lagonoy River	nondetectable	nondetectable	
14 Bariw Point	nondetectable	nondetectable	
Average	nondetectable	nondetectable	
III. Deep area			-
3 Grid 13	nondetectable	nondetectable	
15 Tabaco Bay	nondetectable	nondetectable	
Average	nondetectable	nondetectable	
EMB criteria (1990)		-	
	Organochlorines		
II. Estuary/mangrove area			-
2 Sogod River	nondetectable	nondetectable	
4 Lagonoy River	nondetectable	nondetectable	
14 Bariw Point	nondetectable	nondetectable	
Average	nondetectable	nondetectable	
III. Deep area			-
3 Grid 13	nondetectable	nondetectable	
15 Tabaco Bay	nondetectable	nondetectable	
Average	nondetectable	nondetectable	
EMB criteria (1990)		nil	

Note: * - discontinued.

- = no data.

Table 3.2b. List of pesticide residues tested in the Lagonoy Gulf samples, 1994.

Organochlorine compound*	Organophosphate compound*	Pyrethroids*
Aldrin	Azinphos ethyl	Cyfluthrin
Chloedane	Azinphos methyl	Cypermethrin
Chlorothalonil	Chlorpyrifos ethyl	Deltamethrin
DDT	Chlorpyrifos methyl	Fenvalerate
Dieldrin	DDVP	Lambdacyhaluthrin
Endosulfan	Diazinon	Permethrin
Endrin	Dimethoate	Pyrethrins
HCH	Fenitrothion	
Heptachlor	Malathion	
Heptachlor epoxide	Methamidophos	
Lindane	Mevinphos	
PCB	Methyl parathion	
PCNB	Phosphomidon	
2,4 D	Pirimiphos methyl	
	Triazophos	
	Paraquat	

Note: * - limit of detection = 0.01 ppm.

Table 3.3. Toxicological tolerance levels of some metals and compounds (mg l^{-1}).

Element/compou	Biological purification [a]	Self-purification [a]	Crustacean [b]	Fish [b]	Mammal [b]	Man [b]
As-compounds	>0.7		4.00 - 9.10	1 - 23	2 - 15 mg kg^{-1}	2 mg kg^{-1} (0.05 mg l^{-1} chron.)
CdC_{l2} (Cd)	1-5	0.100	0.03 - 0.4	3.0 (trout)	0.07 - 0.15 mg kg^{-1}	50 - 500 mg kg^{-1}
$CuSO_4$ (Cu)	1	0.010	0.08 - 0.8	0.03 - 0.8 (trout)	(8 g)	(8 g)
HgC_{l2} (Hg)		0.018	0.03 - 0.1	0.15 - 0.25 (trout)	(0.1 - 1 g)	

Note: [a] - data after Liebmann (1958).

[b] - data after Jung (1973) and the Hygiene-Institut des Ruhrgebiets, Gelsenkirchen.

Source: Forstner and Wittmann (1981).

Table 3.4. Results of trace metal analysis during the northeast monsoon (February), summer (May) and southwest monsoon (October) in Lagonoy Gulf, 1994.

Station	Sampling Depth (m)	Heavy metals (mg l^{-1})											
		Hg	Cu	Cd	As	Hg	Cu	Cd	As	Hg	Cu	Cd	As
		Northeast monsoon				Summer				Southwest monsoon			
I. Coral reef/seagrass/seaweed area													
1 Rawis	2.00	nd	0.060	0.045	nd	nd	0.110	0.040	nd	-	-	-	-
6 Agoho	2.00	nd	0.100	0.045	nd	nd	0.100	0.050	nd	nd	0.060	0.050	nd
9 Acal	2.00	nd	0.065	0.095	nd	nd	0.085	0.040	nd	-	-	-	-
10 Gaba	2.00	nd	0.100	0.040	nd	nd	0.080	0.055	nd	nd	0.050	0.030	nd
13 Casolgan	1.00	nd	0.060	0.045	nd	nd	0.070	0.050	nd	nd	0.060	0.040	nd
Average	1.80	nd	0.077	0.054	nd	nd	0.089	0.047	nd	nd	0.057	0.040	nd
II. Estuary/mangrove area													
2 Sogod	2.00	nd	0.100	0.045	nd	nd	0.095	0.050	nd	nd	0.060	0.040	nd
4 Lagonoy	1.00	nd	0.100	0.035	nd	nd	0.090	0.040	nd	nd	0.050	0.040	nd
7 Bato	2.00	nd	nd	nd	nd	nd	0.060	0.040	nd	nd	0.050	0.040	nd
12 Cagraray	1.00	nd	0.135	0.055	nd	nd	0.085	0.050	nd	-	-	-	-
14 Bariw	0.50	nd	0.065	0.095	nd	nd	0.095	0.030	nd	nd	0.050	0.040	nd
Average	1.30	nd	0.080	0.046	nd	nd	nd	0.042	nd	nd	0.053	0.040	nd
III. Deep area													
surface													
3 Grid 13	2.00	nd	0.075	0.100	nd	nd	0.080	0.045	nd	nd	0.050	0.040	nd
5 Maqueda Channel	2.00	nd	0.075	0.045	nd	nd	0.090	0.040	nd	nd	0.060	0.030	nd
8 Grid 50	2.00	nd	0.065	0.075	nd	nd	0.095	0.045	nd	-	-	-	-
11 Grid 33	2.00	nd	0.075	0.045	nd	nd	0.095	0.045	nd	-	-	-	-
15 Tabaco Bay	2.00	nd	0.070	0.100	nd	nd	0.090	0.040	nd	nd	nd	0.030	nd
Average	2.00	nd	0.072	0.073	nd	nd	0.090	0.043	nd	nd	0.037	0.033	nd
middle													
3 Grid 13	50.00	-	-	-	-	nd	0.095	0.035	nd	-	-	-	-
5 Maqueda Channel	50.00	-	-	-	-	nd	0.105	0.045	nd	-	-	-	-
8 Grid 50	50.00	-	-	-	-	nd	0.080	0.045	nd	-	-	-	-
11 Grid 33	50.00	-	-	-	-	nd	0.090	0.040	nd	-	-	-	-
15 Tabaco Bay	50.00	-	-	-	-	nd	0.090	0.050	nd	-	-	-	-
Average	50.00	-	-	-	-	nd	0.092	0.043	nd	-	-	-	-
bottom													
3 Grid 13	250.00	-	-	-	-	nd	0.090	0.035	nd	nd	0.060	0.040	nd
5 Maqueda Channel	250.00	-	-	-	-	nd	0.100	0.040	nd	nd	0.060	0.050	nd
8 Grid 50	250.00	-	-	-	-	nd	0.100	0.045	nd	-	-	-	-
11 Grid 33	250.00	-	-	-	-	nd	0.080	0.050	nd	-	-	-	-
15 Tabaco Bay	84.00	-	-	-	-	nd	0.075	0.055	nd	nd	0.050	0.040	nd
Average	216.80	-	-	-	-	nd	0.089	0.045	nd	nd	0.057	0.043	nd
EMB criteria (1990)		0.002	0.05*	0.010	0.050	0.002	0.05*	0.010	0.050	0.002	0.05*	0.010	0.050

Note: nd = nondetectable.

- = no data.

* = limit is in terms of dissolved copper.

Minimum detectable amount for Cd = 0.02 ug ml^{-1}; Cu = 0.02 ug ml^{-1}; As = 0.04 ug ml^{-1}; and Hg=0.001 ug ml^{-1}.

Table 3.5. Comparison of average concentration of trace metals from the waters of different bays.

Trace (mg l^{-1})	Lagonoy Gulf[a]	San Miguel Bay[a]	Lingayen Gulf[a]	Laguna De Bay[b]	EMB criteria
Mercury	nd	nd	<0.18	0.05	0.002
Arsenic	nd	-	-	-	0.05
Copper	0.072	0.31	-	-	0.05
Cadmium	0.047	0.04	<0.07	0.001	0.01
Source:	This report	Mendoza et al. (1993)	Maaliw et al (1989)	LLDA (1989)	EMB (1990)

Note: nd = nondetectable.

[a] = Class SC for marine waters.

[b] = Class C for freshwater.

Both classes SC and C have the same EMB criteria.

Table 3.6. Comparison of trace metal content in the water and sediments of Sogod River and Visitang-Naga River, Tiwi, Albay, 1994.

Trace metals	Sogod River	Visitang-Naga River	EMB criteria
Water samples (mg l^{-1})			(mg l^{-1})
Mercury (Hg)	nd	-	0.002
Arsenic (As)	nd	0.068 - 8.0	0.05
Copper (Cu)	0.06-0.1	0.04 - 0.11	0.05[a]
Cadmium (Cd)	0.04 - 0.05	0.01 - 0.08	0.01
Source:	This report	PGI (1982)	DENR (1990)
Sediment (ug g^{-1})			EPA (ug g^{-1})
Hg	0.005	0.2	0.8
As	7	50	33
Cu	12.75	34	-
Source:	This report	PGI (1993)	Bolton et al. (1985)

Note: a = limit is in terms of dissolved copper.

Minimum detectable amount of Hg for waters = 0.01 mg l^{-1}.

Table 3.7. Concentration of trace metals (ug g^{-1}) in sediments from different estuarine stations of Lagonoy Gulf during summer (SM; June) and southwest monsoon (SW; October), 1994.

Station	Trace metals (ug g^{-1})							
	Mercury		Arsenic		Copper		Cadmium	
	SM	SW	SM	SW	SM	SW	SM	SW
Sogod	0.01	nd	9.00	5.00	16.50	9.00	1.50	0.60
Bariw	nd	nd	0.65	1.00	18.50	11.00	1.00	0.20
Bato	0.11	nd	2.50	2.00	130.00	100.00	2.00	0.70
Lagonoy	0.01	nd	3.00	1.00	16.50	10.00	nd	0.20
Average	0.03	nd	3.79	2.25	45.38	32.50	1.13	0.43

Note: nd = nondetectable.

Minimum detectable amount of mercury for sediment = 0.02 ug g^{-1}.

Table 3.8. Comparison of average concentration of trace metals in the sediments of different bays.

Trace metals (ug g^{-1})	Lagonoy Gulf	San Miguel Bay	Lingayen Gulf	Laguna de Bay	EPA (ug g^{-1})
Mercury	0.016	0.02	5.94	0.08	SC - 0.8
Arsenic	3.019	-	-		SC - 33
Copper	38.938	9.83	145.90	109.75	-
Cadmium	0.775	0.57	1.37	<0.01	-
Source:	This report	Mendoza et al. -1993	De la Rosa et al. -1980	LLDA (1989)	Bolton et al. -1985

Note: SC = Class for marine waters

Table 3.9. Nutrient concentrations in Lagonoy Gulf for the northeast monsoon (January - February), summer (May) and southwest monsoon (October), 1994.

Station	Sampling Depth (m)	Nutrients (uM)											
		Nitrite			Nitrate			Ammonia			Phosphate		
		NE	SUMMER	SW	NE	SUMMER	SW	NE	SUMMER	SW	NE	SUMMER	SW
I. Coral reef/seagrass/seaweed area													
1 Rawis	2.00	0.2300	0.6300	-	0.0500	4.6050	-	1.3090	0.8060	-	0.1100	0.3000	-
6 Agoho	2.00	0.3400	0.5375	0.2000	0.4700	1.1275	0.4100	2.0140	1.1850	3.7140	0.1400	0.1600	0.0800
9 Acal Point	2.00	0.3100	0.7700	-	0.4200	10.9925	-	1.8882	0.5690	-	0.1700	0.2000	-
10 Gaba Bay	2.00	0.3300	0.5475	0.1700	0.7400	2.9550	0.8100	2.3285	1.0428	2.3830	0.2000	0.2100	0.1100
13 Casolgan	2.00	0.4400	0.3525	0.1400	0.6400	2.2600	0.2000	3.2975	1.0665	2.8730	0.3600	0.2500	0.0500
Average	2.00	0.3300	0.5675	0.1700	0.4640	4.3880	0.4733	2.1674	0.9339	2.9900	0.1960	0.2240	0.0800
II. Estuary/mangrove area													
2 Sogod River	2.00	0.3300	0.4900	0.2300	0.5000	3.5700	0.4200	2.1902	1.0430	2.7330	0.0900	0.4700	0.1800
4 Lagonoy River	0.50	0.3400	0.4650	0.1000	0.1400	4.5750	0.1600	2.7690	2.2280	2.5230	0.1400	0.3400	0.0700
7 Bato River	2.00	0.3200	0.6325	0.1100	0.6200	6.8400	1.5500	1.8380	1.6592	0.7010	0.2200	0.5800	0.1200
12 Cagraray	2.00	0.3000	0.4225	-	0.1700	4.6850	-	2.2530	0.9008	-	0.1100	0.1700	-
14 Bariw Point	0.50	0.5500	0.4200	0.1100	0.6000	4.3850	0.0900	2.5428	0.8768	2.0670	0.2000	0.3200	0.1300
Average	1.40	0.3680	0.4860	0.1375	0.4060	4.8110	0.5550	2.3186	1.3416	2.0060	0.1520	0.3760	0.1250
III. Deep area													
surface													
3 Grid 13	2.00	0.4700	0.6925	0.1100	0.6600	2.6250	0.1600	3.0210	0.8298	2.2430	0.1700	0.2200	0.0500
5 Maqueda Channel	2.00	0.3800	0.2650	0.2300	0.9200	2.1825	0.1800	1.6615	1.6590	2.8030	0.3150	0.2200	0.0700
8 Grid 50	2.00	0.3400	0.6200	-	0.0600	8.8850	-	3.1720	0.6282	-	0.1300	0.2800	-
11 Grid 33	2.00	0.3200	1.1050	-	nd	2.9500	-	3.3735	2.0502	-	0.1700	0.2900	-
15 Tabaco Bay	2.00	0.3600	0.5100	0.1200	0.4100	3.4200	0.2400	3.2728	0.7112	3.0840	0.2600	0.2600	0.1000
Average	2.00	0.3740	0.6385	0.1533	0.4100	4.0125	0.1933	2.9002	1.1757	2.7100	0.2090	0.2540	0.0733
middle													
3 Grid 13	50.00	-	0.3400	-	-	3.6625	-	-	2.7850	-	-	0.3200	-
5 Maqueda Channel	50.00	-	0.9600	-	-	2.5975	-	-	1.1375	-	-	0.2600	-
8 Grid 50	50.00	-	0.6400	-	-	1.3950	-	-	0.7345	-	-	0.2800	-
11 Grid 33	50.00	-	0.5300	-	-	4.9575	-	-	3.2235	-	-	0.2200	-
15 Tabaco Bay	50.00	-	0.4225	-	-	3.3625	-	-	1.4460	-	-	0.2400	-
Average	50.00	-	0.5785	-	-	3.1950	-	-	1.8653	-	-	0.2640	-
bottom													
3 Grid 13	250.00	-	0.5825	0.1600	-	4.8175	1.3800	-	1.3035	5.0110	-	0.4100	0.1700
5 Maqueda Channel	250.00	-	1.2250	0.2100	-	21.6525	0.7700	-	0.9718	3.1190	-	0.7400	0.2400
8 Grid 50	250.00	-	1.2650	-	-	12.5450	-	-	0.3790	-	-	0.7500	-
11 Grid 33	250.00	-	1.7325	-	-	9.2062	-	-	0.9010	-	-	0.8800	-
15 Tabaco Bay	84.00	-	0.6825	0.1500	-	11.8125	3.0500	-	1.2560	0.2100	-	0.5000	0.2000
Average	216.80	-	1.0975	0.1733	-	12.0067	1.7333	-	0.9623	2.7800	-	0.6560	0.2033

Note: - = no data.

nd = nondetectable.

Table 3.10. Comparison of nutrient levels in Lagonoy Gulf and San Miguel Bay.

Nutrient (uM)	Lagonoy Gulf*			San Miguel Bay		
	Min.	Max.	Average	Min.	Max.	Average
Nitrite	0.23	1.73	0.41	nd	0.76	0.35
Nitrate	nd	21.65	2.52	nd	5.47	0.97
Ammonia	0.21	5.01	1.86	nd	6.49	1.13
Phosphate	0.09	0.88	0.24	0.04	1.54	0.39
Source:	This study			Mendoza et al. (1993)		

Note: nd = nondetectable.

Table 3.11. Coliform and pesticide levels measured in one tidal cycle from three stations in Lagonoy Gulf during summer (SM; April) and southwest monsoon (SW; September), 1994.

Station	Coliform (MPN/100 ml)						Pesticides (ppm)			
	Presumptive		Fecal		Total		Organochlorines		Organophosphates	
Sogod River	SM	SW	SM	SW	SM	SW	SM	SW*	SM	SW*
ebb	110	11,000	70	11,000	110	11,000	nd	-	nd	-
flood	125	4,600	110	4,600	125	4,600	nd	-	nd	-
Lagonoy River										
ebb	155	4,600	110	4,600	140	4,600	nd	-	nd	-
flood	< 20	36	< 20	36	< 20	36	nd	-	nd	-
Tabaco Bay										
ebb	140	430	125	430	140	430	nd	-	nd	-
flood	140	<30	125	<30	125	<30	nd	-	nd	-
EMB criteria (1990	-		-		5,000		nil		-	

Note: - = means no data.

nd = nondetectable.

Table 3.12. Trace metal concentration (mg l^{-1}) in the water for one tidal cycle [during summer (SM; April) and southwest monsoon (SW; September), 1994] from three stations in Lagonoy Gulf.

Stations	Sampling Depth (m)	Trace metals (mg l^{-1})							
		Mercury		Arsenic		Copper		Cadmium	
		SM	SW	SM	SW	SM	SW	SM	SW
Sogod River									
ebb	2	nd	nd	nd	nd	0.08	nd	0.04	0.03
flood	2	nd	nd	nd	nd	0.08	nd	0.04	0.03
Lagonoy River									
ebb	1	nd	nd	nd	nd	0.08	nd	0.04	nd
flood	1	nd	nd	nd	nd	0.08	0.05	0.04	0.03
Tabaco Bay									
ebb	2	nd	nd	nd	nd	0.07	0.05	0.04	0.04
	50	nd	nd	nd	nd	0.09	0.05	0.04	0.03
	84	nd	nd	nd	nd	0.07	0.05	0.04	0.04
flood	2	nd	nd	nd	nd	0.09	0.06	0.04	0.05
	50	nd	nd	nd	nd	0.08	0.05	0.04	0.04
	84	nd	nd	nd	nd	0.09	0.06	0.04	0.04
EMB criteria (1990)		0.002		0.05		0.05		0.01	

Note: nd = nondetectable.

Table 3.13. Concentration of nutrients (uM) measured in one tidal cycle during summer (April) and southwest monsoon (September) from three stations in Lagonoy Gulf, 1994.

Station	Tidal cycle	Sampling depth (m)	Nutrients (uM)							
			Nitrite		Nitrate		Ammonia		Phosphate	
			SM	SW	SM	SW	SM	SW	SM	SW
Sogod River	ebb	2	0.25	0.11	0.18	nd	1.80	3.33	0.15	0.23
	flood	2	0.26	0.14	0.08	0.06	1.39	2.66	0.12	0.07
Lagonoy River	ebb	2	0.27	0.11	0.37	0.36	1.52	4.42	0.14	0.11
	flood	2	0.29	0.17	0.12	nd	1.78	3.78	0.13	0.14
Tabaco Bay	ebb	2	0.25	nd	0.31	0.41	4.03	2.73	0.13	0.05
		50	0.62	0.69	0.82	1.70	2.53	2.87	0.53	0.14
		84	0.90	0.26	3.74	1.65	1.79	2.66	0.75	0.29
	flood	2	0.44	0.11	1.05	0.16	4.06	2.59	0.19	0.05
		50	0.62	0.23	0.53	0.72	0.73	2.45	0.22	0.15
		84	0.65	0.19	2.86	1.45	2.02	3.01	0.69	0.25

Note: Limit of detection 0.06 uM for nitrogen
nd = non-detectable

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Assessment of Water Quality in Lagonoy Gulf
Part IV. Species Composition and Biomass of Plankton Communities

by

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and

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Assessment of Water Quality in Lagonoy Gulf: Part IV. Species Composition and Biomass of Plankton Communities

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Abstract

A qualitative and quantitative study of plankton in Lagonoy Gulf was conducted in 15 stations from February to December 1994. A total of 46 phytoplankton and 33 zooplankton species/taxa were observed. The plankton density in the gulf followed some spatial and seasonal trends. A marked increase in plankton density in all sampling stations was observed in November, which coincided with the onset of the northeast monsoon. Riverine/estuarine and nearshore areas had higher concentrations/density of plankton as compared to the sampling stations in deep areas. Advection and turbulence affected the abundance of plankton in November. Also, the nutrient-rich run-offs from land and rivers apparently favored the growth and reproduction of plankton. In terms of spatial distribution, higher zooplankton biomasses were observed in nearshore areas than in deep areas of the gulf. Zooplankton biomass is positively correlated with chlorophyll *a* concentrations and pH.

Introduction

Plankton are pelagic organisms that float and drift under the action of water movement. Plankton may be classified as either phytoplankton, those that are capable of synthesizing some of their own material by photosynthesis, or zooplankton, those that feed on existing material.

Estimates of plankton productivity are essential in determining the overall status of a given body of water because they indicate how much biomass or energy is at the base of the food network of all living resources in the system. For Lagonoy Gulf, the phytoplankton and zooplankton communities were studied within a general space-time dimension of 15 stations and a 12-month sampling period. Specifically, this study aimed at: (1) determining the distribution and abundance of phytoplankton in the gulf; and (2) obtaining a quantitative distribution and biomass estimates of invertebrate zooplankton.

Materials and Methods

Fifteen sampling stations were selected for the plankton study in Lagonoy Gulf. These are described and classified according to the habitats in the General Water Quality report (see Santos et al., this vol.). Sampling should have been performed within the same tidal phase, however, due to climatological constraints and distance among stations, samplings were conducted for seven days during each sampling month. Field sampling was conducted from 0700 hours up to 1700 hours.

Zooplankton Biomass

Zooplankton biomass was quantified monthly from February to December 1994. Samples from February to June 1994 were collected by vertically towing the plankton net which has 20 micron mesh size, 500 mm mouth diameter, and 1,000 mm length. A plankton net with 69 microns mesh size (300 mm mouth diameter and 1,000 mm length) was then used from July to December 1994. Towing depth varied among the stations and was determined by lowering the net with a meter clearance between the cod end jar and sea bottom. This was done in coral reef, seagrass/seaweed and estuary/mangrove areas. For sampling stations in deep areas of the gulf, a 50-m towing depth was applied. At each sampling station, the plankton net was lowered at 1 m sec^{-1} and raised at 0.75 m sec^{-1}. Samples were placed in 1-l polyethylene, preserved with 10% seawater formalin and sealed with parafilm to avoid contamination. Three replicates were collected per station. In the laboratory, samples were oven-dried and ash-free weights were determined by following the procedure given in Appendix 1. Biomass was calculated by using the formula:

$$\text{Biomass (mg m}^{-3}\text{)} = \frac{\text{Ash-free wt. (mg)} - \text{Initial wt. (mg)}}{\text{volume (m}^3\text{)}}$$

where:

$$\text{volume (m}^3\text{)} = \text{towing depth (m)} \times \text{mouth area of plankton net (m}^2\text{)}$$

Plankton Density and Abundance

For phytoplankton and zooplankton species identification and determination of species diversity, the same sampling method as in the determination of zooplankton biomass was applied. However, sampling frequency was done on a quarterly basis, that is, February, May, August and November 1994. Phytoplankton samples were obtained using a plankton net with 20 microns mesh size while zooplankton were sampled using a 69 microns mesh size plankton net. Samples were then submitted to the University of the Philippines, Marine Science Institute (UPMSI) in Diliman, Quezon City for sorting, species identification and counting.

To determine zooplankton abundance and density, a 1-l sample was sieved with 500 microns mesh size net. For samples greater than 500 microns (or those organisms which did not pass through the sieve), full counts of organisms were applied. Subsampling was applied for those organisms with less than 500 microns, that is, from a known volume of sample, a stempel pipette was used to collect 1-ml of sample (crosswise stroke without agitating the sample) and placed in a gridded petridish. Counting of organisms was performed under a binocular microscope. The following formulae were used in the computation of zooplankton density and abundance:

$$\text{Full counts of} > 500\text{ um (nos./m}^3) = \frac{\text{Number of organisms}}{\text{Actual volume filtered (m}^3)}$$

$$\text{Sub-sampling of} < 500\text{ um (nos./m}^3) = \frac{\text{Number of organisms}}{\text{volume of aliquot (ml)}} \times \text{dilution volume (ml)} \times \frac{1}{\text{actual volume filtered (m}^3)}$$

$$\text{Total plankton density (nos.m}^3) = \text{Density of} > 500\text{ um} + \text{Density of} < 500\text{ um}$$

For phytoplankton identification and counting, samples were examined using a Sedgewick-Rafter counting cell under a compound microscope. The number of cells per milliliter obtained was multiplied by a correction factor to adjust for sample dilution or concentration. The identification of various species used was done using the taxonomic keys of Allen and Cupp (1934) and Cupp (1943). The density of phytoplankton was derived using the formula:

$$\text{Density of phytoplankton (no./m}^3) = F \times 1 / V(\text{m}^3)$$

where:
F = No. of cells counted
V = Volume of water filtered by net

The mean density values of plankton species/taxa were utilized for the computation of species diversity indices. The following formulae were used (Odum 1971):

Shannon's index of general diversity:

$$H = -\Sigma[(ni/N) \times \log(ni/N)]$$

where:
ni = importance value of each species (i.e., mean density)
N = total importance value of all species

Simpson's index of dominance:

$$c = \Sigma(ni/N)^2$$

where:

ni = importance value for each species (i.e., mean density)
N = total importance values of all species

Pielou's evenness index:

$$e = H/\log S$$

where:

S = number of species
H = Shannon's index of general diversity

Results

Plankton Density and Diversity

A total of 46 phytoplankton species/taxa were obtained over the four sampling periods from February to December 1994 (Table 1). The top five species include *Tricodesmium* (21.8%), *Chaetoceros* (19.5%), *Coscinodiscus* (13.8%), *Thalassionema* (7.6%), and *Thalassiosira* (6.3%). The remaining 31.1% consists of 41 other species (Fig. 1). About 65% of the individuals counted per cubic meter in the gulf were phytoplankton with an annual average density of 16,258 individuals m^{-3} (Table 2).

For zooplankton, a total of 33 taxa were identified. The dominant forms were mainly the calanoid copepods (38.0%), copepod naupli (22.7%), herpacticoid copepods (10.3%) and cyclopoid copepods (6.4%). Together, they comprise about 80% of the total numbers/density of zooplankton in the gulf (Fig 2). The annual average density of zooplankton is about 42 m^{-3} and 8,742 m^{-3} for organisms with size greater than 500 microns and less than 500 microns, respectively. Zooplankton contributed to about 35% of the total plankton density in the gulf during the sampling period.

Preliminary results of the study indicated trends in plankton density in the different portions of the gulf. Thus, the 15 sampling stations were grouped into riverine/estuarine areas (stations no. 2, 4, 7, 12, and 14), coral reef areas (stations no. 1, 6, 9, 10 and 13), and deep areas (stations 3, 5, 8, 11 and 15). In each area, the average plankton density per sampling month was computed using the density values of the assigned stations.

The riverine/estuarine areas in the gulf had the highest annual average in plankton density of about 131,936 m^{-3} (Table 3). A marked increase in plankton density in the riverine areas occurred in August and its peak was observed in November with an average plankton density of 477,802 m^{-3} (Fig. 3). Lowest density occurred in May (7,085 m^{-3}).

The average annual plankton density (21,660 m^{-3}) in coral reef/seagrass areas was second highest in the gulf. The seasonal variations were different when compared with the two other areas. The first marked increase in plankton density occurred in May (20,868 m^{-3}) then dropped in August (16,491 m^{-3}). The plankton density again increased in November (59,205) which is almost twice the plankton density in May.

In the deep (middle portion) areas in the gulf, the seasonal trend was almost similar with the riverine areas but at extremely lower density readings (Fig. 3). The highest plankton density in deep areas also occurred in November (17,143 m^{-3}) and lowest in May (136 m^{-3}). The deep areas had the lowest annual average plankton density (1,562 m^{-3}) in the gulf.

Tables 4 and 5 present the species diversity indices of the phytoplankton and zooplankton communities, respectively. In terms of habitat, the highest average index of species diversity (i.e., Shannon index of general diversity) of phytoplankton species in coral reef/seagrass areas was highest in February (1.70) and May (1.78) while estuarine areas had the highest in August (1.74) and November (2.04). In terms of the evenness index, similar trends were observed. The species diversity and evenness indices followed the observations from plankton density where riverine/estuarine areas giving the highest plankton density in November while for coral reef/seagrass areas, it was in May. The variations in species diversity among the stations and sampling periods are illustrated in Figs. 4 and 5. The Shannon index of general diversity indicates the species richness in a given area. The higher the Shannon index, the more species present, thus the higher biodiversity. Evenness index, on the other hand, indicates the equitability of the species in terms of importance values (ie., plankton densities) in the area. Higher evenness values suggest a more or less equal distribution of species, thus more diverse plankton community. The dominance index indicates the presence of dominant species, that is, the higher the dominance index, the lower the diversity.

Zooplankton Biomass

Monthly estimates of zooplankton biomass are presented in Table 6. Biomass ranged from 2.2 mg m^{-3} (a deep area stations in April) to 2,994 mg m^{-3} in Lagonoy River (a riverine/estuary station). As observed in plankton density, zooplankton biomasses were highest in estuarine areas with an annual average biomass of 424.68 mg m^{-3} followed by reef areas 206.86 mg m^{-3} and deep areas 11.2 mg m^{-3} (Fig. 6). However, zooplankton biomass was observed to have three peaks: the first one in May then the second in August then the highest in November (Fig. 7). Moreover, zooplankton biomass in deep areas in the gulf showed a constant biomass (less than 10 mg m^{-3}) except in November which was observed in only one station due to rough sea conditions in the middle portion of the gulf.

Spatial Distribution

In conjunction with the grid sampling to determine spatial distribution of water quality parameters (see Santos et al., this vol.), Figs. 8 and 9 show the spatial distribution patterns of zooplankton biomass in May and August 1994, respectively. The thematic maps were generated using a Geographic Information System to process/analyze the biomass data collected in the two sampling periods.

Estimates of biomass in coastal (nearshore) areas ranged from 5.73 to 1,358.10 mg m^{-3} in May and 22.40 to 778.21 mg m^{-3} in August for coastal areas. The same behavior was observed in deep stations with zooplankton biomasses ranging from 3.69 to 66.21mg m^{-3} and 7.07 to 48.34 mg m^{-3} in May and August, respectively. The data indicated that higher zooplankton biomass were observed in nearshore areas than in deep areas of the gulf (Figs. 8 and 9). With regard to the effect of water parameters on zooplankton biomass. Positive correlation with chlorophyll *a* and pH was observed while negative correlation with respect to transparency and depth was noted (Table 7).

Discussion

The scale of patchiness of plankton distribution extends from the order of 100 km or more down to a few decimeters, big patches comprising aggregations of smaller patches. Several types of process appear to be responsible: physical, reproductive and feeding (Barnes and Hughes 1988). Amongst the physical processes are those resulting in local turbulence, including the special case of Langmuir circulation. This is characterized by weak to moderate winds blowing persistently across the sea in established long, parallel rotating cylinders of water, with adjacent cylinders rotating in opposite direction. The Langmuir circulation comprises alternate streaks of downwelling and upwelling which may extend for tens of kilometers and be separated by some ten of meters. Buoyant particles will aggregate in the downwellings and sinking particles in the upwellings. This produces advection and turbulence which affect the distribution of plankton (Parsons et al. 1984). Coastal currents (e.g., fronts) result in convergence and eddies and in turn tend to accumulate pelagic organisms and also play a role in the distribution of plankton (Wolanski and Hammer 1988).

In May, the reefs had the highest plankton concentration while estuarine areas had the highest in November. The increase in plankton density in the reef areas in May can be attributed to spawning of some coral species (Fadlallah 1983; Harrison et al. 1984). Corals releases several thousands of plannulae during spawning. Newly released plannulae are planktonic larval stage of corals.

The highest plankton concentration (in terms of density and biomass) in November coincided with the onset of the northeast monsoon (November to March). Water conditions in the gulf during this time were characterized by turbulence, resulting in the scouring of the sea bed. The scouring could also have caused particulate deposits on the sea bed to be transported to the sea surface, increasing nutrient concentrations over limited areas and lead to increased phytoplankton production available for zooplankton consumption.

Pronounced rainfall also accompanied the northeast monsoon (Villanoy et al., this vol.). Rainfall has a positive correlation with volume of land and river run-offs. The increase in the volume of land and river run-offs could have favored the increase in plankton density by providing the nutrients needed for growth and reproduction. The effects of the alternating northeast and southwest monsoon seasons were manifested in the disparities between monthly plankton biomass. In months when the prevailing monsoon was from the southwest, plankton biomass and density were relatively low. The results of this study are similar with the observations on distributional and seasonal trends in plankton density in San Miguel Bay (Remoto et al., in press). The bay is another priority site of the Fisheries Sector Program in the Bicol region which also experiences similar moonsonal patterns.

Using zooplankton biomass estimates ranging from 43.6 to 530.2 mt C km^{-2} yr^{-1} and a P/B ratio of 0.25 (Longhurst and Pauly 1987), zooplankton production could range from 10.9 - 132.6 mt C km^{-2} yr^{-1}. Assuming a 10% efficiency in biomass conversion, roughly about 1.1 - 13.3 mt C km^{-2} yr^{-1} may be supported by water column production in Lagonoy Gulf. In terms of fish weight, and assuming that carbon is 38% of dry weight and that dry weight is 14% of wet weight (EPAI 1993), an estimated potential fish production of 20.7 - 250.0 mt km^{-2} yr^{-1} wet weight may be supported.

Acknowledgments

We thank Ms. Elealyn Baybay and Ms. Luwalhati Lachica of UPMSI for the laboratory analysis of the plankton samples; Mr. Renante Albao and Mr. Rodrigo Zamudio for their help during the collection of samples; Mr. Dan Bonga, Mr. Leo Pura, Mr. Antonino Mendoza and Ms. Karina Luth Discaya for their help in the tabulation of data and preparation of summary tables; Dr. Liana T. McManus of UPMSI for her guidance; and Ms. Elsie Tech for her review of the manuscript.

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Table 1. Checklist of plankton species observed in Lagonoy Gulf (1994).

Type	Phylum	Genus
Phytoplankton	Bacillariophyta	*Asterionella*
		Bacillaria
		Bacteriastrum
		Biddulphia
		Cerataulina
		Chaetoceros
		Coscinodiscus
		Ditylum
		Fragillaria
		Lauderia
		Leptocylindrus
		Licmophora
		Melosira
		Navicula
		Nitzchia
		Pleurosigma
		Rhabdonema
		Rhizosolenia
		Skeletonema
		Stephanopyxis
		Streptotheca
		Striatella
		Thalassionema
		Thalassiosira
		Thalassiothrix
		Vorticella
	Cyanophyta	*Richelia*
		Tricodesmium
	Pyrrophyta	*Amphidinium*
		Ceratium
		Dinophysis
		Gymnodinium
		Noctiluca
		Peridinium
		Phalacroma
		Polykrikos
		Prorocentrum
	Other species	*Acnanthia*
		Bellerochea
		Cocolithus
		Cocosphere

Table 1. (continued)

Type	Phylum	Genus
		Halosphaera
		Hyalodiscus
		Paralia
		Phaeocystis
		Rhabdosphaera
Zooplankton	Annelida	*Callizona*
		Greffia
		Polychaete
	Arthropoda	*Calanus*
		Cancer
		Carcinus
		Ebalia
		Jaxea
		Maia
		Megaryctiphanes
		Microcalanus
		Microstella
		Oithona
		Pandalina
		Pandalus
		Paracalanus
		Pilumnus
		Rhincalanus
		Thysanoesa
	Chaetognatha	*Sagitta*
	Chordata	*Clavelina*
		Doliolum
		Fritillaria
		Oikopleura
	Coelenterata	*Bougainvillea*
		Cladonema
		Eucheilota
		Obelia
	Mollusca	*Alvania*
		Amphiura
		Glycymeris
		Spiratella
	Protozoa	*Tintinnopsis*

Table 2. Average density (individuals/cu.m.) of zooplankton and phytoplankton in Lagonoy Gulf.

Plankton Type	Sampling Period					Percentage
	Feb	May	Aug	Nov	Average	
Phytoplankton	542	721	473	63,294	16,258	64.92
Zooplankton > 500 µm	40	6	45	77	42	0.17
Zooplankton < 500 µm	5,078	8,635	9,438	11,817	8,742	34.91
Total	5,660	9,363	9,956	75,188	23,627	100

Table 3. Average plankton density (individuals/cu.m.) in different areas of Lagonoy Gulf (1994).

CLASSIFICATION	SAMPLING PERIOD				Annual Average
	Feb	May	Aug	Nov	
I. CORAL REEF/SEAGRASS/SEAWEED AREA					
1 Rawis Point	1332	1309	4108	-	2250
6 Agoho Point	488	4063	7630	24059	9060
9 Acal Point	1487	4055	4394	-	3312
10 Gaba Bay	33833	64378	49831	59144	51796
13 Casolgan Pass	696	30536	*	94412	41881
Reef areas	7567	20868	16491	59205	21660
II. ESTUARY/MANGROVE AREA					
2 Sogod River	7563	753	15307	106881	32626
4 Lagonoy River	18734	9285	14068	74809	29224
7 Bato River	4479	2887	10115	63010	20123
12 Cagraray Island	-	17415	*	-	17415
14 Bariw Point	9279	5083	*	1666509	560290
Estuarine areas	10014	7085	13164	477802	131936
III. DEEP AREA					
3 Grid 13	305	134	1901	-	780
5 Maqueda Channel	385	247	1376	-	669
8 Grid 50	315	113	545	-	324
11 Grid 33	207	64	442	-	238
15 Tabaco Bay	132	121	*	17143	5799
Average	269	136	1066	17143	1562
Average (all areas)	5950	9363	10240	184717	51719

Note: - - no data.

* - no phytoplankton data.

Table 4. Diversity indices for phytoplankton communities in different areas of Lagonoy Gulf (1994).

CLASSIFICATION/ SAMPLING STATIONS	Shannon Index of General Diversity				Evenness Index				Dominance Index			
	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov
I. CORAL REEF/SEAGRASS/SEAWEED AREA												
1 Rawis Point	1.93	1.73	1.27	-	0.78	0.83	0.47	-	0.19	0.33	0.50	-
6 Agoho Point	1.59	1.72	2.22	1.47	0.56	0.63	0.71	0.57	0.27	0.26	0.21	0.03
9 Acal Point	1.65	1.93	0.92	-	0.69	0.66	0.34	0.57	0.27	0.27	0.65	-
10 Gaba Bay	1.77	1.73	1.65	1.45	0.64	0.62	0.59	0.66	0.24	0.35	0.38	0.31
13 Casolgan Pass	1.58	1.77	-	2.04	0.66	0.57	-	0.82	0.28	0.33	-	0.16
Average	1.70	1.78	1.52	1.65	0.67	0.66	0.53	0.66	0.25	0.31	0.44	0.17
II. ESTUARY/MANGROVE AREA												
2 Sogod River	1.56	1.42	2.26	1.99	0.63	0.47	0.73	0.61	2.35	0.44	0.15	0.20
4 Lagonoy River	1.51	1.01	1.31	1.36	0.53	0.39	0.42	0.57	0.31	0.45	0.48	0.18
7 Bato River	1.85	1.94	1.64	2.41	0.77	0.63	0.52	0.78	0.34	0.25	0.47	0.12
12 Cagraray Island	-	1.81	-	-	-	0.63	-	0.72	-	0.33	-	
14 Bariw Point	1.42	1.88	-	2.41	0.57	0.78	-		0.38	0.21	-	0.12
Average	1.59	1.61	1.74	2.04	0.63	0.58	0.56	0.67	0.85	0.34	0.37	0.16
III. DEEP AREA												
3 Grid 13	1.45	1.10	1.18	*	0.50	0.41	0.42	*	0.32	0.57	0.50	*
5 Maqueda Channel	1.37	1.58	0.88	*	0.59	0.55	0.36	*	0.37	0.41	0.60	*
8 Grid 50	1.69	1.50	0.95	-	0.68	0.54	0.49	-	0.27	0.39	0.56	-
11 Grid 33	1.03	1.66	1.08	-	0.40	0.55	0.41	-	0.58	0.38	0.53	-
15 Tabaco Bay	1.90	1.87	-	2.07	0.77	0.65	-	0.70	0.20	0.27	-	0.17
Average	1.49	1.54	1.02	2.07	0.59	0.54	0.42	0.70	0.35	0.40	0.55	0.17

Note: - - no data.

* - turbulent waters did not permit sampling.

Table 5. Diversity indices for zooplankton communities in different areas of Lagonoy Gulf (1994).

CLASSIFICATION/ SAMPLING STATIONS	Shannon Index of General Diversity				Evenness Index				Dominance Index			
	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov
I. CORAL REEF/SEAGRASS/SEAWEED AREA												
1 Rawis Point	1.50	1.02	1.10	-	0.52	0.37	0.44	-	0.37	0.55	0.43	-
6 Agoho Point	1.26	0.22	1.40	0.97	0.43	0.11	0.56	0.37	0.42	0.90	0.28	0.58
9 Acal Point	1.62	0.12	1.00	-	0.55	0.07	0.40	-	0.29	0.96	0.48	-
10 Gaba Bay	1.27	0.52	1.30	1.22	0.40	0.20	0.52	0.46	0.36	0.78	0.36	0.36
13 Casolgan Pass	1.47	0.37	1.24	1.16	0.49	0.14	0.46	0.44	0.32	0.84	0.43	0.42
Average	1.42	0.45	1.21	1.12	0.48	0.18	0.48	0.42	0.35	0.81	0.40	0.45
II. ESTUARY/MANGROVE AREA												
2 Sogod River	1.15	1.01	1.43	1.25	0.35	0.39	0.53	0.52	0.42	0.42	0.28	0.35
4 Lagonoy River	1.23	0.08	1.46	0.80	0.36	0.28	0.57	0.37	0.39	0.55	0.26	0.50
7 Bato River	0.87	0.14	1.14	1.19	0.28	0.06	0.49	0.47	0.48	0.95	0.38	0.37
12 Cagraray Island	-	0.03	1.31	-	-	0.01	0.53	-	-	0.99	0.30	-
14 Bariw Point	1.21	1.66	1.35	1.44	0.47	0.63	0.51	0.53	0.39	0.23	0.30	0.34
Average	1.12	0.58	1.34	1.17	0.37	0.27	0.53	0.47	0.42	0.63	0.30	0.39
III. DEEP AREA												
3 Grid 13	1.43	0.57	1.28	*	0.52	0.21	0.46	*	0.28	0.75	0.39	*
5 Maqueda Channel	1.40	1.14	0.48	*	0.45	0.52	0.22	*	0.30	0.41	0.76	*
8 Grid 50	1.41	0.35	1.56	-	0.49	0.15	0.56	-	0.33	0.83	0.25	-
11 Grid 33	1.95	0.65	1.18	-	0.66	0.26	0.47	-	0.17	0.64	0.37	-
15 Tabaco Bay	1.66	0.47	1.22	1.12	0.54	0.23	0.44	0.44	0.28	0.78	0.36	0.39
Average	1.57	0.64	1.14	1.12	0.53	0.27	0.43	0.44	0.27	0.68	0.43	0.39

Note: - - no data.

* - turbulent waters did not permit sampling.

Table 6. Estimates of productivity using zooplankton biomass (mg m^{-3}) in different areas of Lagonoy Gulf, 1994.

CLASSIFICATION	SAMPLING PERIOD											Annual Average
	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
I. CORAL REEF/SEAGRASS/SEAWEED AREA												
1 Rawis Point	50.90	16.60	12.70	43.90	63.70	68.78	43.63	41.80	-	-	-	42.75
6 Agoho Point	17.00	76.40	32.90	129.40	95.50	53.06	82.54	212.24	133.63	28.30	106.12	87.92
9 Acal Point	74.30	20.50	45.30	156.00	35.00	153.28	409.74	49.52	-	-	-	117.96
10 Gaba Bay	123.10	135.80	42.40	458.40	57.30	424.48	448.06	94.33	365.52	1025.82	318.36	317.60
13 Casolgan Pass	29.70	114.60	814.90	577.20	72.20	-	235.82	229.93	389.11	188.66	660.30	301.13
Average	59.00	72.78	189.64	272.98	64.74	174.90	243.96	125.56	296.09	414.26	361.59	206.86
II. ESTUARY/MANGROVE AREA												
2 Sogod River	42.40	237.70	57.30	40.70	74.30	72.71	224.03	-	176.87	235.82	56.99	110.80
4 Lagonoy River	191.00	365.00	195.20	135.80	161.30	259.40	253.61	224.03	754.63	2994.93	318.36	532.11
7 Bato River	89.10	70.00	30.80	150.70	72.20	121.84	147.39	88.43	182.76	1190.90	102.19	204.21
12 Cagraray Island	-	806.40	997.40	373.50	67.90	448.06	778.21	224.03	-	-	-	461.94
14 Bariw Point	322.60	365.00	280.10	1358.10	305.60	253.51	471.64	294.78	400.90	795.90	919.70	524.35
Average	161.28	368.82	312.16	411.76	136.26	231.10	374.98	207.82	378.79	1739.18	349.31	424.68
III. DEEP AREA												
3 Grid 13	9.30	3.50	2.50	3.90	3.70	9.43	7.55	7.07	8.73	*	8.25	6.39
5 Maqueda Channel	7.00	5.90	3.70	5.90	3.20	10.38	7.07	8.49	8.49	*	7.07	6.72
8 Grid 50	5.40	2.70	9.80	5.10	2.50	9.43	7.31	8.73	-	-	-	6.37
11 Grid 33	6.80	2.70	2.20	5.30	2.50	9.20	8.02	8.25	-	-	-	5.62
15 Tabaco Bay	7.20	3.00	3.30	4.10	2.50	8.49	9.20	-	9.90	57.78	9.43	11.49
Average	7.14	3.56	4.30	4.86	2.88	9.39	7.83	8.14	9.04	57.78	8.25	11.20

Note: - - no data.

* - turbulent waters did not permit sampling.

Table 7. Correlation analysis of water quality variables measured from the different grids of Lagonoy Gulf in May and August 1994.

PARAMETER	DEPTH	TRANS-PARENCY	SUSPENDED SOLIDS	WATER TEMPERATURE	DO	SALINITY	PH	CHLOROPHYLL A	BIOMASS
Depth	1.00	0.86***		0.33*					-0.34*
Transparency		1.00			0.22**		-0.18*	-0.24*	-0.54***
Suspended solids			1.00	0.71***			0.58***		
Water temperature				1.00	-0.23**	0.25**	0.50***		
DO					1.00		-0.21**	-0.28***	-0.19*
Salinity						1.00			
pH							1.00		0.24**
Chlorophyll *a*								1.00	0.23**
Biomass									1.00

Note: *** - significant at 1% level

** - significant at 5% level

* - significant at 10% level

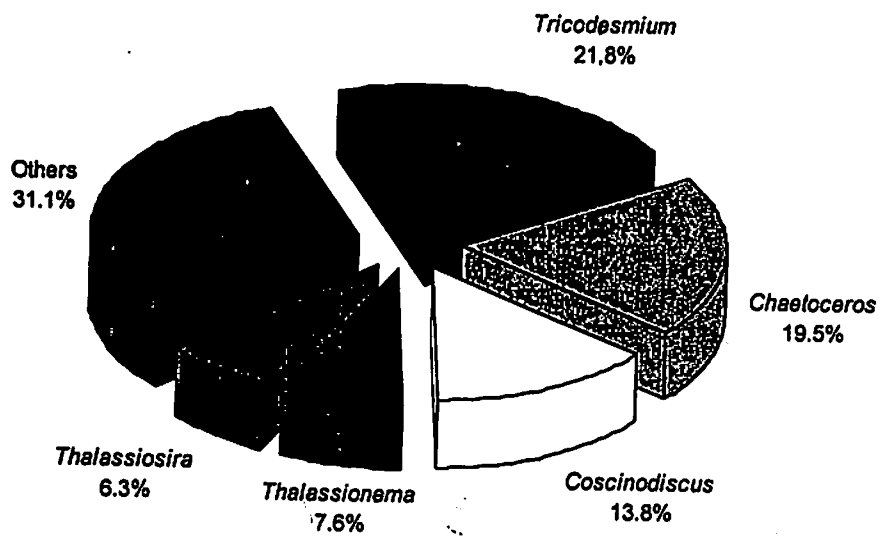

Fig. 1. Relative abundance of phytoplankton in Lagonoy Gulf (1994).

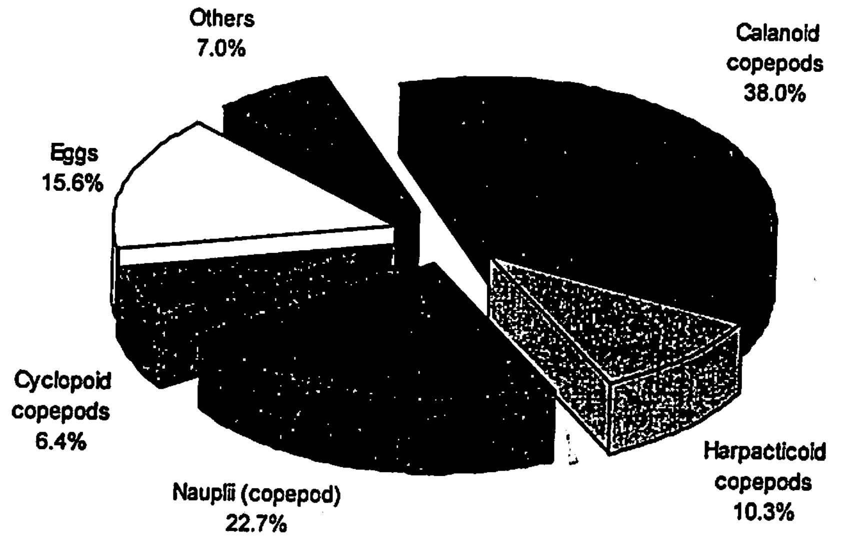

Fig. 2. Relative abundance of zooplankton in Lagonoy Gulf (1994).

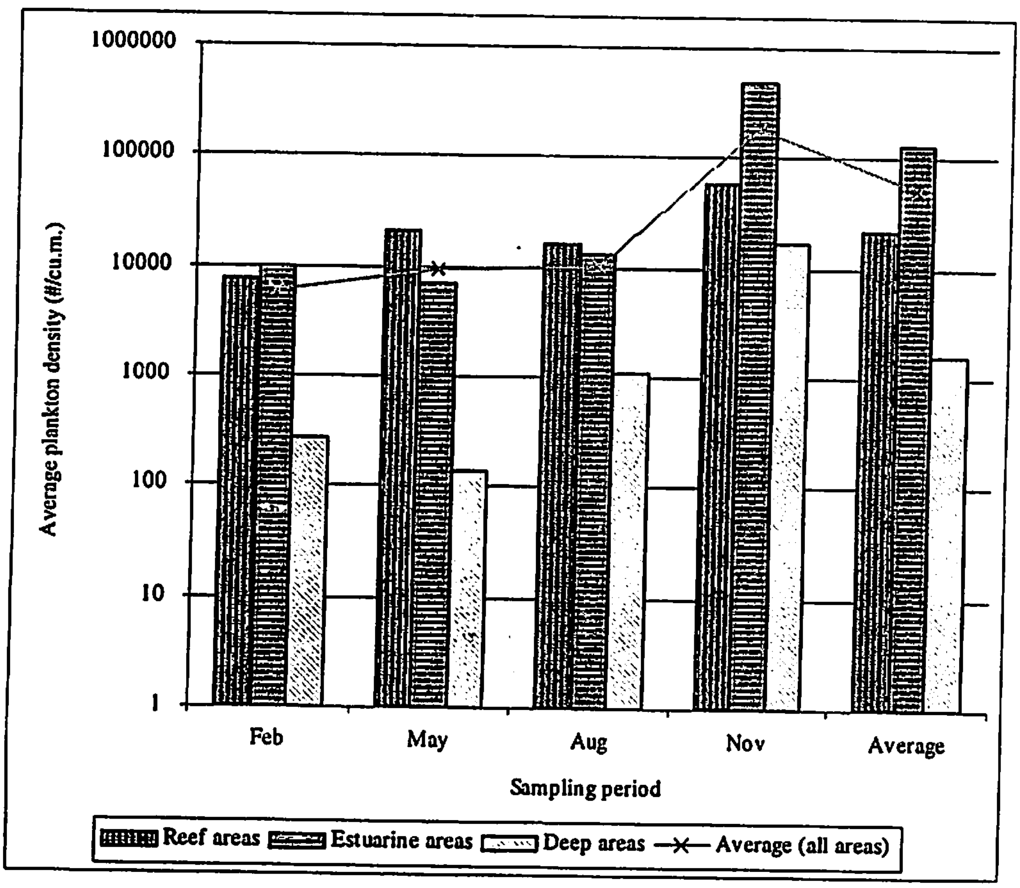

Fig. 3. Average plankton densities in selected areas of Lagonoy Gulf.

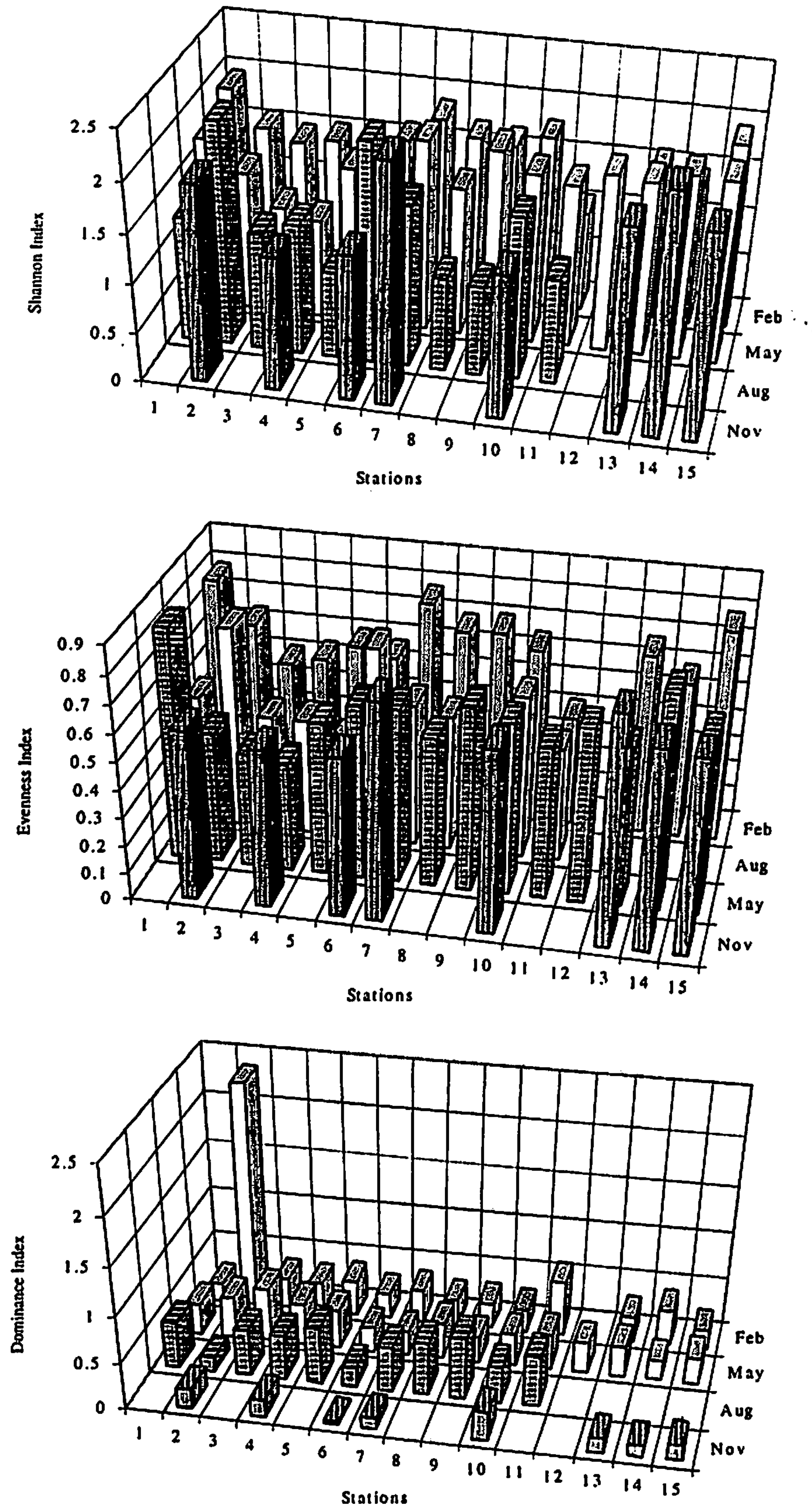

Fig. 4 Phytoplankton species diversity indices.

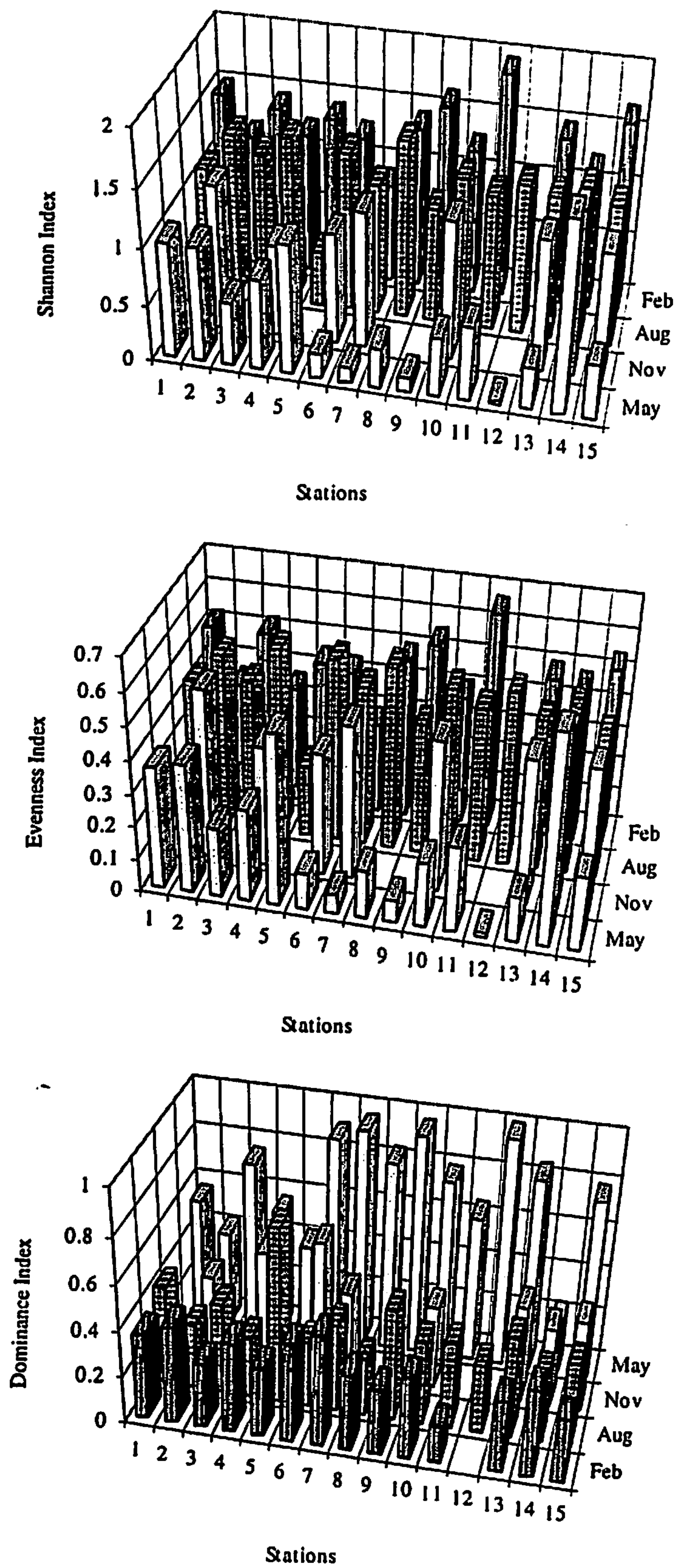

Fig. 5. Zooplankton species diversity indices.

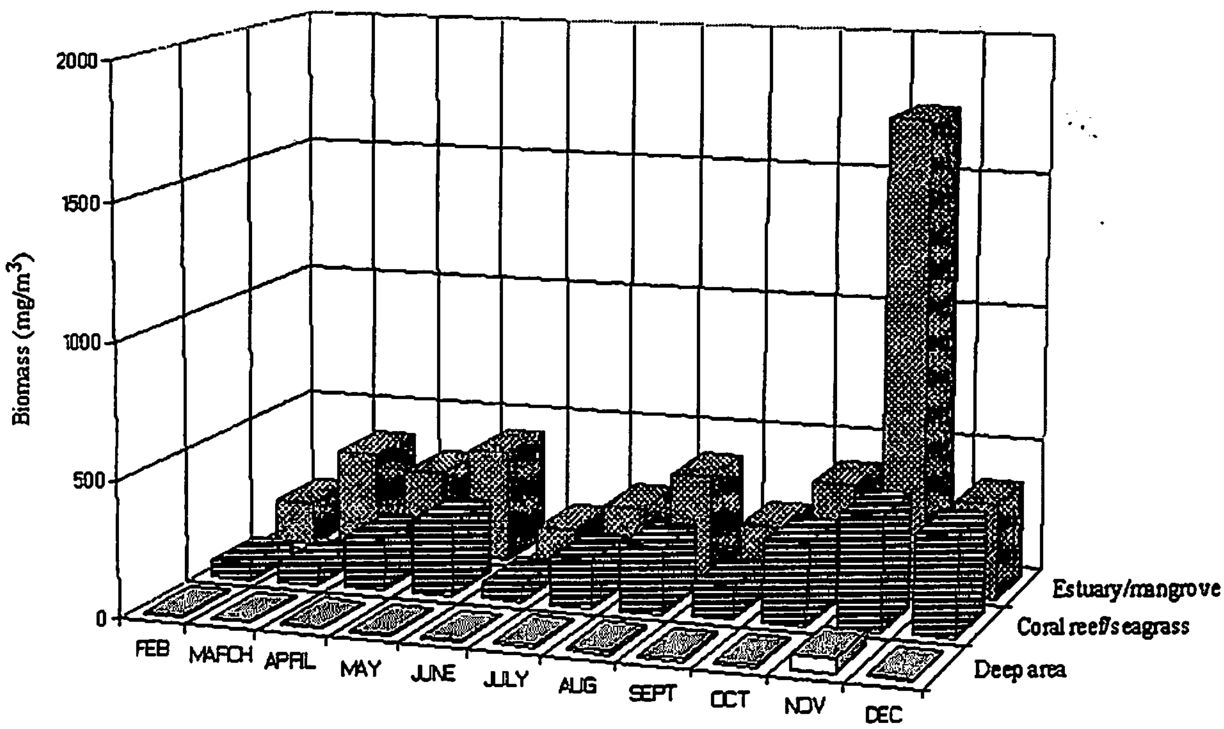

Fig. 6 Zooplankton biomass (mg/m^3) measured in different areas, 1994.

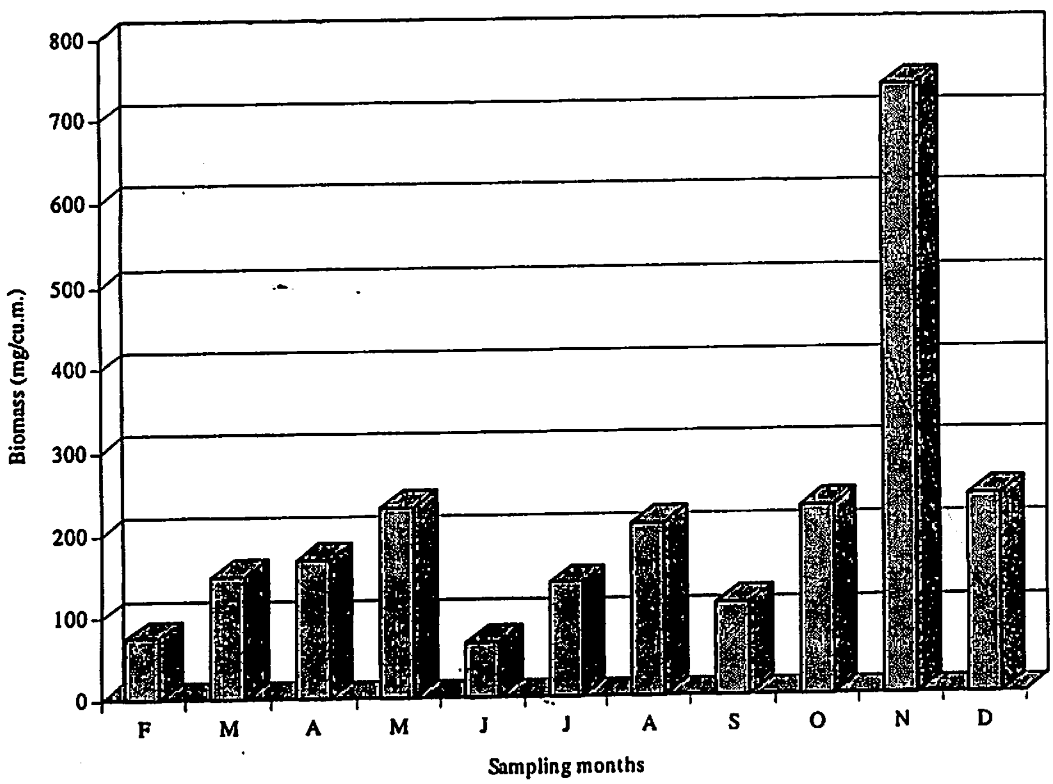

Fig. 7. Mean monthly Zooplankton biomass in Lagonoy Gulf (1994).

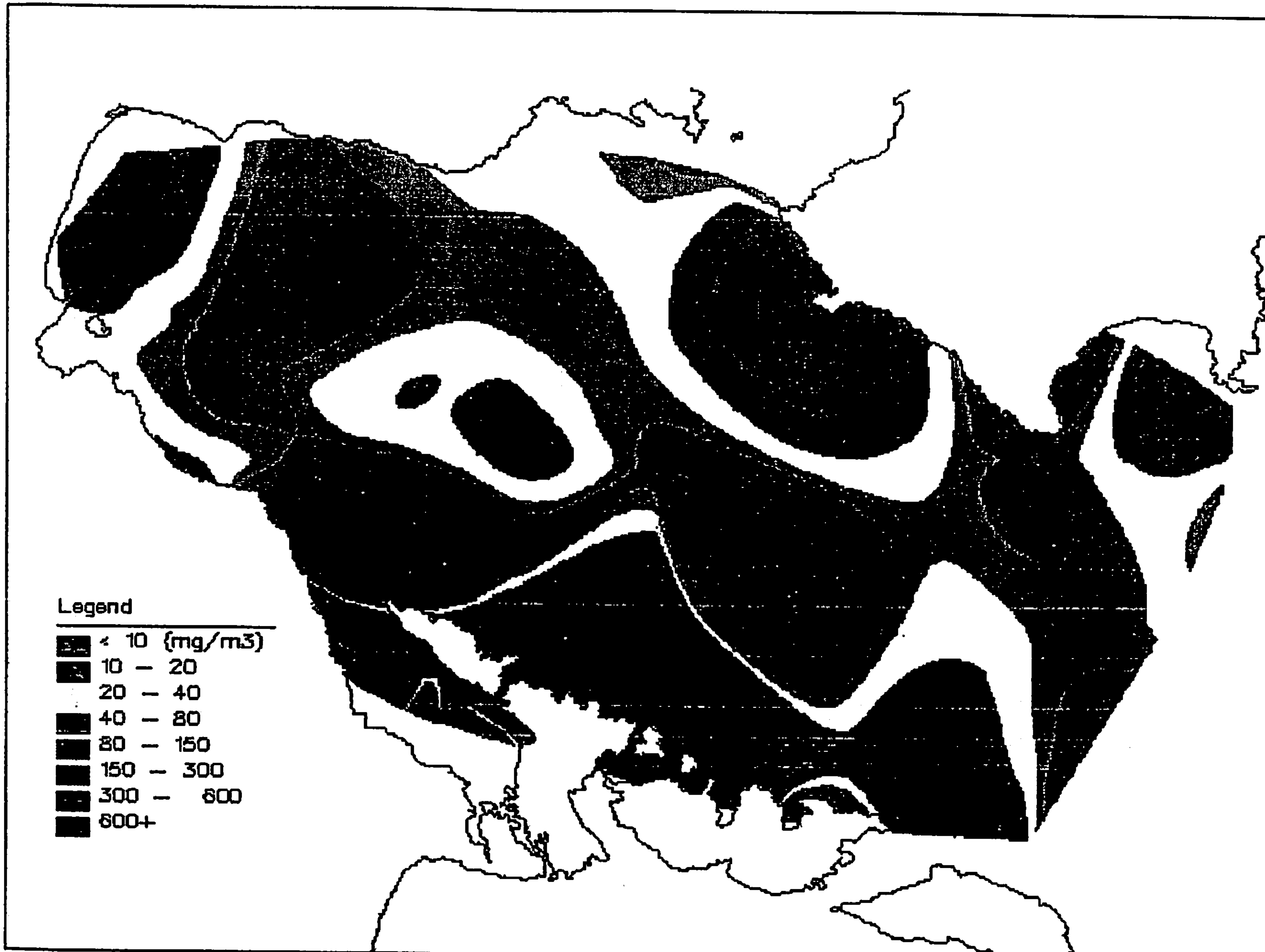

Fig. 8. Spatial distribution of zooplankton biomass (May 1994).

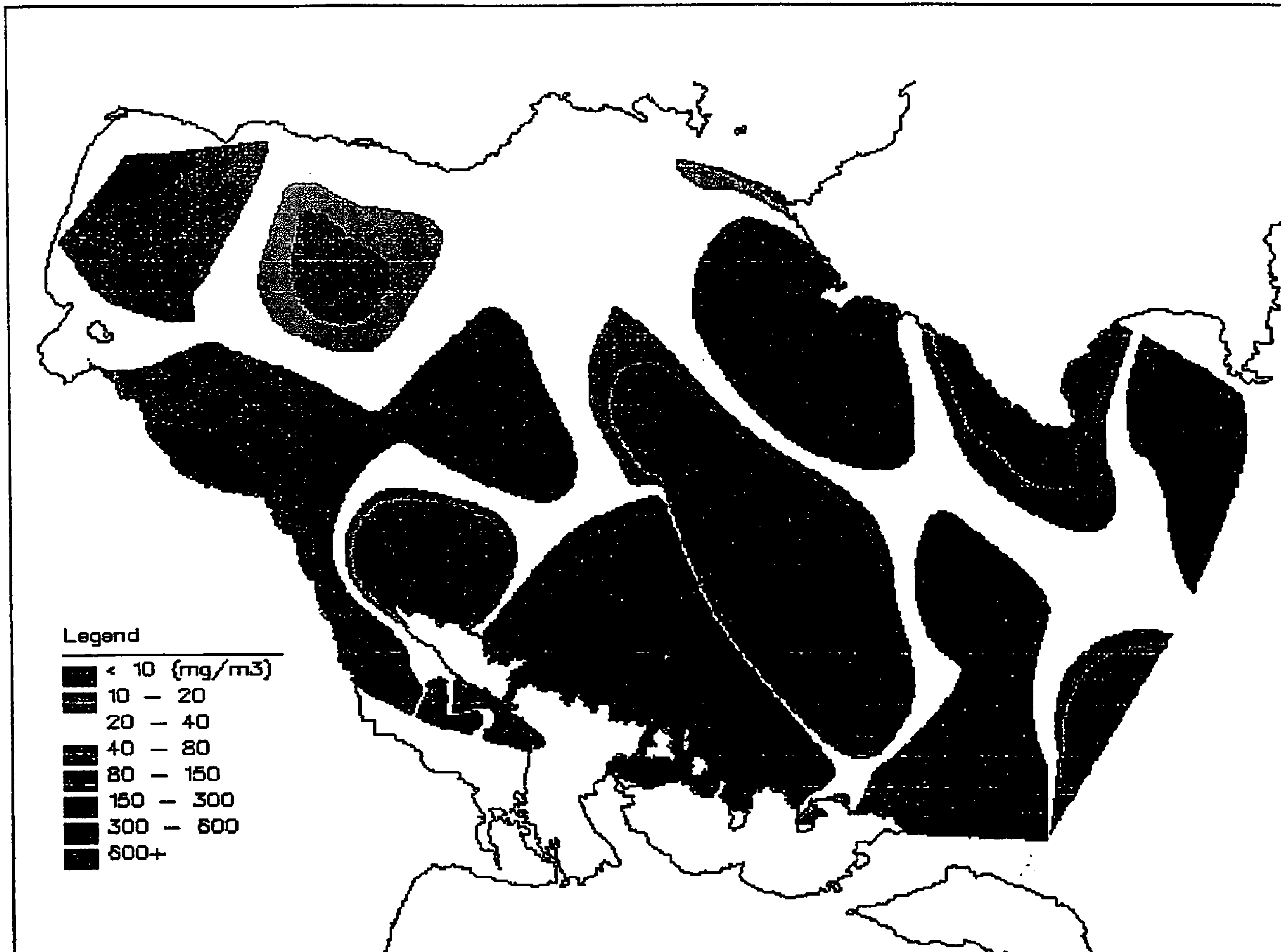

Fig. 9. Spatial distribution of zooplankton biomass (August 1994).

Assessment of the Coral Reef Resources of Lagonoy Gulf

by

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Abstract

A total of 40 transect stations from 18 sampling areas in Lagonoy Gulf were surveyed to assess the status of the coral reef resources in the area. Live coral cover (both hard and soft corals) ranged from 15.6% to 73.6%. Sixty-one percent of the sampling areas fall within 25-49.9% coral cover range. The ratio of vacant space to available habitat space, was also applied as an alternative index of the reefs' health. Divisive ordination using TWINSPAN showed that the reefs are divided into areas that are exposed to NE monsoon, SW monsoon and/or areas located in the inner portion of the gulf. The marine reserves and fish sanctuaries in Agoho, Gaba and Atulayan, established as part of the Fisheries Sector Program activities, were analyzed.

Introduction

Coral reefs are highly productive ecosystems. The diversity of organisms supported by coral reefs are rivaled only by those in tropical rain forests. Reefs contain harvestable resources including seaweeds, invertebrates and fin fishes. In fisheries, coral reefs are regarded as critical habitats because a large number of fish species reside in reefs at some stage in their life cycle and some non-resident species are known to forage in reefs. Reefs and the sandy beaches that they help stabilise are usually the basis of tourism in the coastal area. Coral reefs have a particular social importance because they are among the few resources that are accessible to marginalized coastal communities. Reef fisheries, for example, are typically artisanal.

The coral reefs in Lagonoy Gulf comprise 16,616 ha and are concentrated mainly in Albay. About 43 percent of the fish species in the Gulf are reef-resident while 57 percent are known to visit the reefs in search of food (Dioneda et al., this vol.).

This report contains the results of the survey of reefs around Lagonoy Gulf conducted between 1993-1994 as part of the Resource and Ecological Assessment of the Gulf. Information from earlier assessments of the Gulf's reefs are also presented.

Methodology

Reef areas around Lagonoy Gulf were subjected to one-time surveys in December 1993 and January and April 1994. Eighteen sampling areas were selected from a map of the Gulf's coastal habitats, which was prepared from 1987 SPOT satellite imageries by the National Mapping and Resource Information Authority. Among the areas surveyed were the marine reserves and fish sanctuaries established in each province under the Fisheries Sector Program.

In each sampling area manta tows were conducted to select transect sites with moderate to high live coral cover. A total of 40 transects sites were surveyed (Table 1 and Fig. 1). Sampling area coordinates were determined using a Magellan NAV 1000 Plus Global Positioning System. Reef slopes were surveyed using shallow (3m) and/or deep (10m) transects as required to adequately represent the reef at a locality. Deeper transects were required in some cases.

In Table 1 the areas that are simply referred to by name (ie., no "shallow" or "deep" attached) were surveyed at the 10m-depth. "Shallow" or "deep" are attached to the name of the area to indicate that 3m and 10m transects were conducted. Where transects deeper than 10m were used, the depth follows the name of the area.

The life form transect method described in Dartnall and Jones (1986) was used to survey benthic life forms. In each transect site SCUBA divers laid a 100-m transect line along a depth contour. Life form categories along the transect were identified and their lengths were recorded as estimates of cover.

To explore patterns among transect sites, data sets were classified by divisive ordination using the Two-Way Indicator Species Analysis software (TWINSPAN, Hill 1979).

Results and Discussion

Benthic Lifeforms

The percentage cover of lifeforms obtained from 40 transects are presented in Appendix A. This information is summarised for the major lifeform categories in Table 2. Live coral cover ranged from 15.6 percent at Agoho Fish Sanctuary-Deep to 73.6 percent at Curangon Shoal-15m. Ranges of the other major lifeforms are presented in Table 3. The areas surveyed are briefly described below together with findings of previous studies.

At Acal Point off Rapu-rapu Island, about half of the cover was accounted for by live coral, which consisted mainly of massive and encrusting *Acropora* species. Foliose corals were conspicuous at one of the transects. Dead coral comprised 1/4 to 1/3 of the area's cover.

Live coral cover at Gaba off Batan Island was below 50 percent, consisting mainly of massive corals and a few encrusting corals. Dead corals ranged from 19-26 percent. Coral rubble was present.

The shallow and deep areas off Namanday in Cabaluan Island had low live coral cover of 31 percent and 38 percent, respectively. At both depths dead coral accounted for almost 1/5 of the cover. Table *Acropora* and encrusting corals dominated the shallow depth while encrusting and foliose corals dominated the 10m depth.

At Cagraray Island live corals comprised more than 50 percent of the cover with massive and encrusting corals as the dominant lifeforms. Some *Acropora* species were represented. The algae *Halimeda* sp. was abundant. Dead coral accounted for a relatively low 15 percent.

Live coral cover at the northern tip of San Miguel Island, Rawis, and its southern tip, Dakulang Puro, were almost equal (42.2 percent and 42.8 percent, respectively). At Dakulang Puro branching and table *Acropora* species and massive and encrusting non-*Acropora* species comprised the area's live coral cover. One of the transects had a high algal cover of 36 percent. Dead coral ranged from 12-34 percent. The reef off Rawis is dominated by massive and encrusting corals with some branching and table *Acropora*. Sand, rubble and rock devoid of (macro) lifeforms were significant. One transect had almost 30 percent dead coral.

In a nation-wide survey of reefs in 1981, the Marine Science Center (MSC, now Marine Science Institute) of the University of the Philippines conducted two transects in the vicinity of Rawis. One of the transects had only 13.0 percent live coral cover while the other had 25.1 percent (Gomez *et al.* 1981).

Three transects at 10m and an additional transect at 15m were surveyed at Curangon shoal off Tiwi. At 10m, live coral cover was relatively high at 59.3 percent. The area has an abundance of branching and table *Acropora* with massive and encrusting corals also well represented. The area at 15m is noted for having the highest live coral cover (73.6 percent) and lowest dead coral (11.5 percent) among all areas surveyed in this study (Table 3). Massive and encrusting non-Acropora corals account for 45 percent of the cover. The 10m and 15m areas at Curangon Shoal contain the highest amount of live coral among the reefs in Albay.

Information on an additonal five reef areas off Tiwi are available in an environmental study of the Tiwi submarine outfall which was conducted by Woodward-Clyde, Ltd. in association with the Envrionmental Primemovers of Asia Inc. (Woodward-Clyde/EPAI 1993). Table 4, which is taken from that report, presents the results of the environmenal study together with the 1981 survey results of the MSC. The most notable features of these reefs are their high abiotic cover (coral rubble, rock and sand) and very low dead coral cover, which are even lower than those found at Curangon Shoal-15m.

The north and south sides of the Atulayan Marine Reserve, which is a belt around the Atulayan Fish Sanctuary (see below), were surveyed. In addition, the 20m depth close to the 10m sampling area at the south side was also surveyed. At the south side live coral cover at the 10m area was a high 65.7 percent, which is next only to Curangon Shoal-15m (Table 2). This area contains the transect with the highest live coral cover at 81.4 percent. Branching *Acropora* species dominate this area, although table *Acropora* and massive and encrusting non-*Acropora* species are also abundant. Dead coral ranged from 18-31 percent. At 20m live coral cover was still relatively high at 65.7 percent. Massive and encrusting non-*Acropora* species were dominant.

At the north side of the Atulayan Marine Reserve, live coral cover was much lower at 44.5 percent and dead coral comprised 44.6 percent, the highest in the gulf. The 1979 survey of this area by the MSC reported live coral cover at 40.6 percent (Gomez and Alcala 1979), which is close to the figure obtained in this study.

The reef at Rosa Island had low live coral cover of 33.4 percent dominated by soft corals and massive non-*Acropora* corals. Macro algae were conspicuous. Two transects had 28 percent and 35 percent dead coral.

The shallow and deep areas at the Agoho Fish Sanctuary are among the three areas with the lowest live coral cover. Three of the four shallow transects contained less than 25 percent live coral cover. The fourth transect had 52 percent live coral cover dominated by massive and encrusting corals. At the deep transects, live coral ranged from 7-28 percent, giving the lowest average live coral cover among all areas surveyed. Barren sand and rocks and algae were prominent at both shallow and deep areas. One transect was surveyed just outside the marine reserve, close to the sanctuary. It contained a low live coral cover of 37 percent and a relatively high dead coral content of 27 percent. The few hard corals were dominated by massive and encrusting non-*Acropora* species. Sand, rubble and rock comprised 22 percent of this transect.

Live coral cover at the shallow and deep areas off Nagumbuaya are low, ranging from 17-34 percent. At the shallow area massive non-*Acropora* species are the most abundant corals. Dead coral covers 1/4 to 1/3 of the area. At the deep area corals are few while the sand and algal (*Halimeda* sp.) components are prominent.

In comparing the areas surveyed, some general features can be observed. Where non-*Acropora* corals are abundant, they tend to be massive and encrusting, which are adapted to strong currents. The *Acropora* species are usually branching and tabulate; other forms (e.g., encrusting) are less common.

The surveyed areas are compared with regard to the amount of live coral, dead coral and others in Fig. 2. Gomez et al. (1981) designated the condition of reefs based on percent live coral cover using to the following scheme: excellent = 75-100 percent live coral cover; good = 50-74.9 percent; fair = 25-49.9 percent; and poor = 0-24.9 percent. These ranges, despite their obvious arbitrariness, are widely used in reporting the conditions of Philippine coral reefs. According to this scheme, of the 18 areas surveyed in this study, one area (5.6 percent) is in poor condition, 11

(61.1 percent) are fair, six (33.3 percent) are good and none is excellent. If the five areas in the Woodward-Clyde/EPAI (1993) study are included, the distribution will be: poor, one site or 4.3 percent; fair, 16 sites or 69.6 percent; and good, 6 sites or 26.1 percent. The national average based on 742 sites is as follows: poor, 22.6 percent; fair, 39.0 percent; good, 25.2 percent; and excellent, 5.3 percent (Gomez 1991). Thus, by comparison the reefs of Lagonoy Gulf appear to be better than average; though none are in excellent condition, very few are poor and a relatively large proportion is in the fair category. This comparison should be treated with caution since most of the surveys cited in Gomez (1991) used different field methods.

Recently, Gomez et al. (1994) acknowledged the disadvantages of relying solely on live coral cover as an index of reef health. A reef that is not subjected to natural or man-induced stress may still have low coral cover because, among other things, there might not be enough substrate suitable for coral colonisation and growth. Gomez et al. (1994) suggested the ratio of vacant space to total available habitat space as a possible alternative index of reef health. Total habitat space refers to the space occupied by both live and dead corals. This index has the advantage of incorporating more information than just live coral content.

The index suggested above is applied in this study in Fig. 3, which may be used in conjunction with Fig. 2 to compare the areas surveyed. As in Fig. 2, the areas towards the top of Fig. 3 are more stressed while the areas towards the bottom are healthier. The areas that have *both* low coral cover *and* high ratio of dead coral to total habitat space are the deep and shallow areas of Agoho Fish and Nagumbuaya. For some areas, the stressed condition may not be immediately obvious in Fig. 2 but become evident in Fig. 3. That is, these areas may have moderate live coral cover but a significant proportion of their total habitat space is made up of dead coral. The most prominent example of such areas is the north side of Atulayan Marine Reserve. This area would be described as fair (or even "nearly good") if percent live coral cover were the only factor considered. However, dead coral in this area is nearly 50 percent, which is the highest in the Gulf (Fig. 2). Thus Fig. 3 indicates that this is the second most stressed area. Fig. 4 (which is Fig. 2 re-drawn to depict total habitat space) shows that the north and south sides of the reserve have almost equal habitat space. This suggests that the north side would resemble the south side (ie., have higher live coral cover) if the area was not being subjected to stress. Other areas that do not appear stressed on the basis of live coral cover but are shown to be stressed by the dead coral to total habitat space ratio are the area outside the Agoho Marine Reserve and Rosa Island.

Destructive fishing methods, particularly blastfishing and to a lesser extent cyanide fishing, appear to be the main source of stress on the reefs of the Gulf. This was often cited in consultations with decision makers and stakeholders (see Luna et al., this vol.) and is also documented in the proposal for a fish sanctuary and marine reserve in Agoho and in the 1981 survey reports of the MSC (Gomez et al. 1981).

The least stressed reefs in the Gulf according to Fig. 2 are found in Curangon Shoal (both at 10m and 15m) and in the south side of the Atulayan Marine Reserve (both at 10m and 20m). In Fig. 3 Putsan, Joroan, Visitang Naga and Coral Island appear to be the least stressed due to their low dead coral content. Note, however, that the latter sites are among those with the smallest total habitat space (Fig. 4).

Ordination Results

The results from the divisive ordination using TWINSPAN indicated that the transect sites that were visited for the assessment of coral reefs in the gulf can be divided into areas exposed to NE monsoon, SW monsoon and areas located in the inner portion of the gulf (Fig. 5). This may be influenced by physical factors such as wave exposure and depth on the growth forms of the coral communities in the area. These factors are known to have a significant influence on the zonation of corals (Licuanan and Gomez 1988). For example, algal turf with mixed corals of encrusting to submassive/massive forms are found to characterize wave-exposed areas. In this study, the transect sites exposed to NE monsoon were characterized by the predominance of foliose corals. The ordination results are also comparable with the TWINSPAN results of the reef fish study (see Nañola and Cabansag, this vol.) which indicated that the grouping can be differentiated in terms of monsoons and degree of embayment.

Marine reserves and fish sanctuaries

As part of FSP's coastal management activities, municipal fish sanctuaries and marine reserves were established in each province around the Gulf. Fishing is not allowed within the sanctuary, which functions as the core area of the reserve (see Salm and Clark 1984). Around the sanctuary is a buffer zone, or a marine reserve in FSP's terminology, which is reserved mostly for artisanal fishing gears. The reserves and sanctuaries are patterned after successful examples in the Visayas such as the Apo Island Marine Reserve in Dumaguete (Alcala 1988). Russ and Alcala (1994) have documented the positive effects of these reserves, which include increased fish populations both within and outside the reserves and the consequent increase in revenues from fishing. In Apo Island, the reserve has become a tourist attraction and is providing residents an alternative income source. The residents have continued the management of the reserve long after the departure of community workers who initiated its establishment. The residents have also taken on other environmental projects such as agroforestry (White 1989).

For a sanctuary to function as intended, it must be a reasonably healthy reef that can attract and provide food and shelter to fish populations. A healthy reef can also supply coral larvae which could be transported by currents to damaged reefs and begin the process of re-colonisation and rehabilitation. Thus, it is unfortunate that much has been invested in establishing a fish sanctuary and marine reserve at Agoho Point. Apparently, it is one of the least suited reef areas for a reserve in the Gulf. The technical proposal for the reserve suggests that it currently enjoys popular local support. This support can be sustained if tangible benefits such as increased fish yields will accrue to the community. Whether these benefits will materialise at all is rather doubtful, given the condition of the reef.

The reserve at Gaba, Albay was also surveyed. Several manta tows were conducted to identify areas with at least moderate coral cover, after which more detailed benthic lifeform surveys were to be done. However, the manta tows indicated that the area had poor coral cover. In general, the substrate was mostly sand and silt with occasional coral patches. Thus, there was no point in conducting lifeform transects.

In contrast to the Agoho reserve, there are apparently few or no management activities currently going on at the Gaba reserve. It may still be feasible to establish an alternative reserve for the province of Albay. From a biophysical perspective, Curangon Shoal is the most suitable area for a marine reserve in Albay. Reef conditions in the area are among the best encountered in this survey. Also, currents move southward from Curangon Shoal (Villanoy and Encisa, this vol.) and could conceivably carry coral larvae to rehabilitate the damaged reefs at the southern part of the bay. Nearby Putsan, Joroan, Visitang Naga or Coral Island may not be suitable because of small habitat space, despite being top performers in terms of the dead coral to total habitat space index.

Atulayan Island is a good choice for a reserve from a biophysical perspective, although the problem at its northern side must be dealt with. This could be one of the management objectives of the reserve. In addition to the high coral cover, juvenile fish were abundant at the southern side of the island. The reef drops down to more than 20m and is quite extensive. Village tourism with SCUBA diving as the main attraction could be a viable community enterprise.

There is, however, a potential problem with the boundaries of the reserve. Fig 6a shows the intended design of the reserve while Fig. 6b shows the actual shape of the boundaries based on the coordinates listed in the municipal resolution establishing the reserve. Note that the boundaries of the fish sanctuary and the marine reserve actually cross. This may have serious implications when the time comes to legally enforce the boundaries. The municipality of Sagnay will have to amend their resolution. If they choose to do so, they might as well re-design the reserve and consider the coordinates of the boundaries based on Fig.6a which was generated from Table 5. . The most effective design is a simple one. Four corners enclosing the reef surrounding the island could define the buffer zone (or marine reserve). These could be easily marked by buoys. The sanctuary need not be a belt surrounding the island. It is better to have a rectangular area enclosing the healthiest portion of the reef, with two corners on the reef marked by buoys and the two other corners on the island marked by poles. The sanctuary would extend from the land to the seaward edge of the reef. The location of the transects conducted on the southern part of the island most probably coincide with the healthiest part of the entire reef surrounding the island.

Conclusion

The conditions of the reefs were assesssed by the living coral cover *per* se and generally, the reefs are in fair conditon. An additional index, the ratio of vacant space to total available habitat space, was applied to the data sets to determine the health of the reefs and to acknowledge the disadvantages of relying solely on live coral cover index. Such index would delineate areas that are stressed, but are apparently in fair condition using only coral cover values. TWINSPAN results suggests the important influences of wave exposure and depth to the zonation of corals.

A reevaluation of the marine reserves and fish sanctuaries established around the gulf must be made. Strong biophysical indicators of a healthy reef coupled with popular local support are necessary elements in the implementation of protected areas. Such gauges are fundamental in the success of the management of the reefs.

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Table 1. Surveyed reef areas in Lagonoy Gulf.

Area Surveyed	Location		Transect	Depth
	Latitude	Longitude		(m)
Acal Point, Rapu-rapu Is.	13 14.07N	124 07.45E	Acal 1 Acal 2	10 10
Agoho Fish Santuary - Shallow	13 35.93N	124 02.65E	Agoho 1 Agoho 2 Agoho 3 Agoho 4	3 3 3 3
Agoho Fish Sanctuary - Deep	13 35.93N	124 02.65E	Agoho 5 Agoho 6 Agoho 7 Agoho 8	10 10 10 10
Agoho-Outside Marine Reserve	13 35.55N	124 02.55E	Agoho 9	10
Atulayan Marine Reserve North	13 35.54N	124 34.24E	Atulayan 1	10
Atulayan Marine Reserve South	13 34.67N	124 34.28E	Atulayan 2 Atulayan 3	10 10
Atulayan Marine Reserve South-20m	13 34.66N	124 32.27E	Atulayan 4	20
Cagraray (North Shore)	13 20.54N	123 54.67E	Cagraray 1	10
Curangon Shoal	13 27.45N	123.43.00E	Curangon 1 Curangon 2 Curangon 3	10 10 10
Curangon Shoal-15m	13 27.45N	123 43.00E	Curangon 4	15
Dakulang Puro, San Miguel Is.	13 22.58N	123 51.44E	Dakulang Puro 1 Dakulong Puro 2 Dakulong Puro 3	10 10 10
Gaba Bay, Batan Is.	13 17.52N	123 59.50E	Gaba 1 Gaba 2	10 10
Nagumbuaya-Shallow, Bato	13 33.24N	124 18.97E	Nagumbuaya 1 Nagumbuaya 2 Nagumbuaya 3	3 3 3
Nagumbuaya-Deep, Bato	13 33.24N	124 18.97E	Nagumbuaya 4 Nagumbuaya 5 Nagumbuaya 6	10 10 10
Namaday-Shallow, Cabaluan Is.	13 19.74N	123 56.39E	Namanday1	3
Namaday-Deep, Cabaluan Is.	13 19.74N	123 56.39E	Namanday 2	10
Rawis, San Miguel Is.	13 24.88N	123 45.75E	Rawis 1 Rawis 2 Rawis 3	10 10 10
Rosa Is.	13 41.83N	123 40.25E	Rosa 1 Rosa 2 Rosa 3 Rosa 4	10 10 10 10

Table 2. Percentage cover of the major benthic lifeforms in the surveyed sites in Lagonoy Gulf.

Area Surveyed	Transect	Major categories							
		Hard corals		Soft Coral	Total Live Coral	Dead Coral	Algae	Other Fauna	Abiotic
		Acropora	non-Acropora						
Acal Point, Rapu-rapu Is:	Acal 1	3.3	40.2	1.0	44.5	32.6	2.8	0.1	19.9
	Acal 2	7.4	46.9	2.2	56.5	25.1	1.8	0.1	16.6
	Average	5.3	43.6	1.6	50.5	28.9	2.3	0.1	18.2
Agoho Fish Sanctuary-Shallow	Agoho 1	7.6	16.2	0.1	23.9	24.4	9.5	2.3	40.0
	Agoho 2	1.1	18.8	0.0	19.9	21.5	3.3	0.1	55.2
	Agoho 3	1.7	20.0	0.2	21.9	8.2	47.3	0.0	22.7
	Agoho 4	8.6	43.0	0.0	51.6	26.9	8.8	0.7	12.1
	Average	4.8	24.5	0.1	29.3	20.3	17.2	0.8	32.5
Agoho Fish Sancturay-Deep	Agoho 5	2.6	22.1	3.3	28.0	11.0	22.8	0.6	37.7
	Agoho 6	3.3	6.8	0.4	10.5	2.1	16.8	0.7	70.0
	Agoho 7	0.4	6.5	0.2	7.1	36.4	35.5	0.2	20.9
	Agoho 8	2.5	13.0	1.2	16.7	9.0	32.5	3.8	38.0
	Average	2.2	12.1	1.3	15.5	14.6	26.9	1.3	41.6
Agoho-Outside Marine Reserve	Agoho 9	1.3	35.5	0.0	36.8	26.6	13.6	0.1	22.9
Atulayan Marine Reserve North	Atulayan 1	6.6	32.5	5.4	44.5	42.6	2.6	4.1	6.3
Atulayan Marine Reserve South	Atulayan 2	9.8	39.0	1.2	50.0	31.3	5.1	0.1	13.6
	Atulayan 3	47.9	31.7	1.8	81.4	17.6	0.9	0.0	0.2
	Average	28.8	35.3	1.5	65.7	24.4	3.0	0.1	6.9
Atulayan Marine Reserve South-20m	Atulayan 4	10.7	46.7	2.6	60.0	23.5	2.7	0.3	13.5
Cagraray (North Shore)	Cagraray	8.9	43.6	0.6	53.1	15.5	21.7	1.2	8.6
Curangon Shoal	Curangon 1	39.0	17.8	1.9	58.7	16.4	1.7	0.7	22.6
	Curangon 2	22.5	35.4	0.8	58.7	20.5	0.3	2.2	17.9
	Curangon 3	11.2	44.4	4.9	60.5	19.9	0.3	0.2	19.2
	Average	24.2	32.5	2.5	59.3	18.9	0.7	1.0	19.9
Curangon Shoal-15m	Curangon 4	9.6	56.5	7.5	73.6	11.5	9.0	0.3	5.5
Dakulang Puro, San Miguel Is.	Dakulang Puro 1	10.7	31.6	2.5	44.8	19.6	13.2	1.1	21.3
	Dakulang Puro 2	9.5	30.7	1.0	41.2	34.0	12.8	0.2	11.9
	Dakulang Puro 3	15.1	24.3	1.4	40.8	18.7	36.3	0.1	4.2
	Average	11.8	28.8	1.6	42.2	24.1	20.8	0.5	12.4
Gaba Bay, Batan Is.	Gaba 1	4.3	42.2	0.3	46.8	26.6	0.2	0.2	26.1
	Gaba 2	8.4	33.1	0.8	42.3	19.1	1.2	0.2	37.2
	Average	6.4	37.7	0.5	44.6	22.8	0.7	0.2	31.7
Nagumbuaya-Shallow	Nagumbuaya 1	10.9	22.6	1.2	34.6	25.6	13.1	0.6	25.9
	Nagumbuaya 2	0.5	31.4	0.0	31.9	33.6	9.0	0.2	25.4
	Nagumbuaya 3	6.8	20.5	0.0	27.4	33.0	10.5	0.4	28.7
	Average	6.1	24.8	0.4	31.3	30.7	10.9	0.4	26.6
Nagumbuaya-Deep	Nagumbuaya 4	4.0	25.2	1.0	30.1	19.9	22.7	3.3	24.0
	Nagumbuaya 5	1.3	18.3	0.0	19.6	17.2	19.1	0.4	43.8
	Nagumbuaya 6	9.6	22.3	0.2	32.1	29.6	15.3	1.3	21.7
	Average	4.9	21.9	0.4	27.2	22.2	19.0	1.7	29.8
Namanday-Shallow	Namanday 1	11.5	19.6	0.1	31.2	19.0	26.5	0.4	22.9
Namanday-Deep	Namanday 2	5.1	32.3	0.3	37.7	18.0	10.1	1.2	33.1
Rawis, San Miguel Is.	Rawis 1	12.2	27.2	1.2	40.6	19.6	0.0	1.7	38.1
	Rawis 2	10.1	42.3	1.2	53.5	8.4	0.0	1.1	37.0
	Rawis 3	8.2	21.8	4.4	34.4	29.8	1.8	3.4	30.7
	Average	10.2	30.4	2.3	42.8	19.2	0.6	2.1	35.3
Rosa Is.	Rosa 1	2.8	16.1	6.5	25.3	11.6	19.8	5.7	37.6
	Rosa 2	5.0	15.7	16.8	37.4	15.8	8.4	5.5	32.8
	Rosa 3	0.2	19.6	18.3	38.0	27.7	2.6	9.9	22.1
	Rosa 4	5.8	14.4	12.7	32.9	35.2	15.8	3.4	12.7
	Average	3.4	16.5	13.6	33.4	22.6	11.6	6.1	26.3

18 8.9 31.93 235

Table 3. Ranges of cover of major benthic lifeforms across areas surveyed and across transects.

Benthic lifeform		Across areas surveyed		Across transect	
		Percent Cover	Area	Percent Cover	Transect
Total live cover					
	Lowest	15.6	Agoho Fish Sanctuary - deep	7.1	Agoho 7
	Highest	73.6		81.4	Atulayan 3
Acropora					
	Lowest	1.3	Agoho-outside marine reserve	0.2	Rosa 3
	Highest	28.8	Atulayan Marine Reserve South	47.9	Atulayan 3
Non-Acropora					
	Lowest	12.1	Agoho Fish Sanctuary-deep	6.5	Agoho 7
	Highest	56.5	Curangon Shoal-15m	56.5	Curangon 4
Soft coral					
	Lowest	0.0	Atulayan Marine Reserve South	0.0	Agoho 9
	Highest	13.6	Rosa Island	18.3	Rosa 3
Dead coral					
	Lowest	11.5	Curangon Shoal-15m	2.1	Agoho 6
	Highest	42.6	Atulayan Marine Reserve North	42.6	Atulayan 1
Algae					
	Lowest	0.6	Rawis	0.0	Rawis 1&2
	Highest	26.9	Agoho Fish Sanctuary-deep	47.3	Agoho 3
Other fauna					
	Lowest	0.1	Agoho-outside marine reserve and Acal Point	0.0	Atulayan 3
	Highest	6.1	Rosa Island	9.9	Rosa 3
Abiotic	Lowest	5.5	Curangon Shoal-15m	0.2	Atulayan 3
	Highest	41.6	Agoho Fish Sanctuary-deep	70.0	Agoho 6

*Percent dead coral of five areas off Tiwi reported in Woodward-Clyde/EPAI (1993) had a range of 0.80-9.14%.

Table 4. Comparison of benthic lifeform surveys in Tiwi, Albay in 1981 and 1991-1992. Source: Woodward-Clyde/EPAI (1993).

Area	Year	Hard Coral	Soft Coral	Total Live Coral	Dead Coral	Abiotic
Putsan	1981	29.40	9.00	38.40	22.90	37.50
	1991	29.38	5.73	35.11	6.05	10.11
	1992	35.35	2.14	37.49	5.18	38.19
	Ave('91-'92)	32.37	3.94	36.30	5.62	24.15
Visitang Naga (Cogon)	1981	21.70	0.80	22.50	42.10	51.50
	1991	24.39	1.52	25.91	0.35	55.27
	1992	35.18	13.96	49.14	1.55	36.36
	Ave ('91-'92)	29.79	7.74	37.53	0.95	45.82
South of effluent (Nahulugan)	1981	25.00	3.10	28.10	5.50	66.30
	1991	35.40	0.88	36.28	9.14	46.88
	1992	43.24	0.17	43.41	24.03	30.28
	Ave ('91-'92)	39.32	0.53	39.85	16.59	38.58
Joroan	1981	36.30	3.80	40.10	36.10	15.40
	1991	20.87	10.80	31.67	0.93	50.05
	1992	39.87	8.11	47.98	7.19	37.70
	Ave ('91-'92)	30.37	9.46	39.83	4.06	43.88
Coral Island	1981	44.50	3.10	47.60	10.40	23.00
	1992	33.26	0.46	33.72	0.80	63.66

Table 5. Technical description of the proposed boundaries of Atulayan fish sanctuary and marine reserve based on design in Fig 6a.

Fish Sanctuary	Marine Reserve
123° 34'11"E 13° 35'47"N	123° 34'11"E 13° 35'35"N
123° 33'26"E 13° 35'18"N	123° 33'18"E 13° 35'17"N
123° 33'48"E 13° 34'46"N	123° 33'43"E 13° 34'43"N
123° 34'27"E 13° 34'40"N	123° 34'27"E 13° 34'35"N
123° 34'51"E 13° 34'57"N	123° 34'57"E 13° 34'57"N
123° 34'45"E 13° 35'21"N	123° 34'50"E 13° 35'24"N

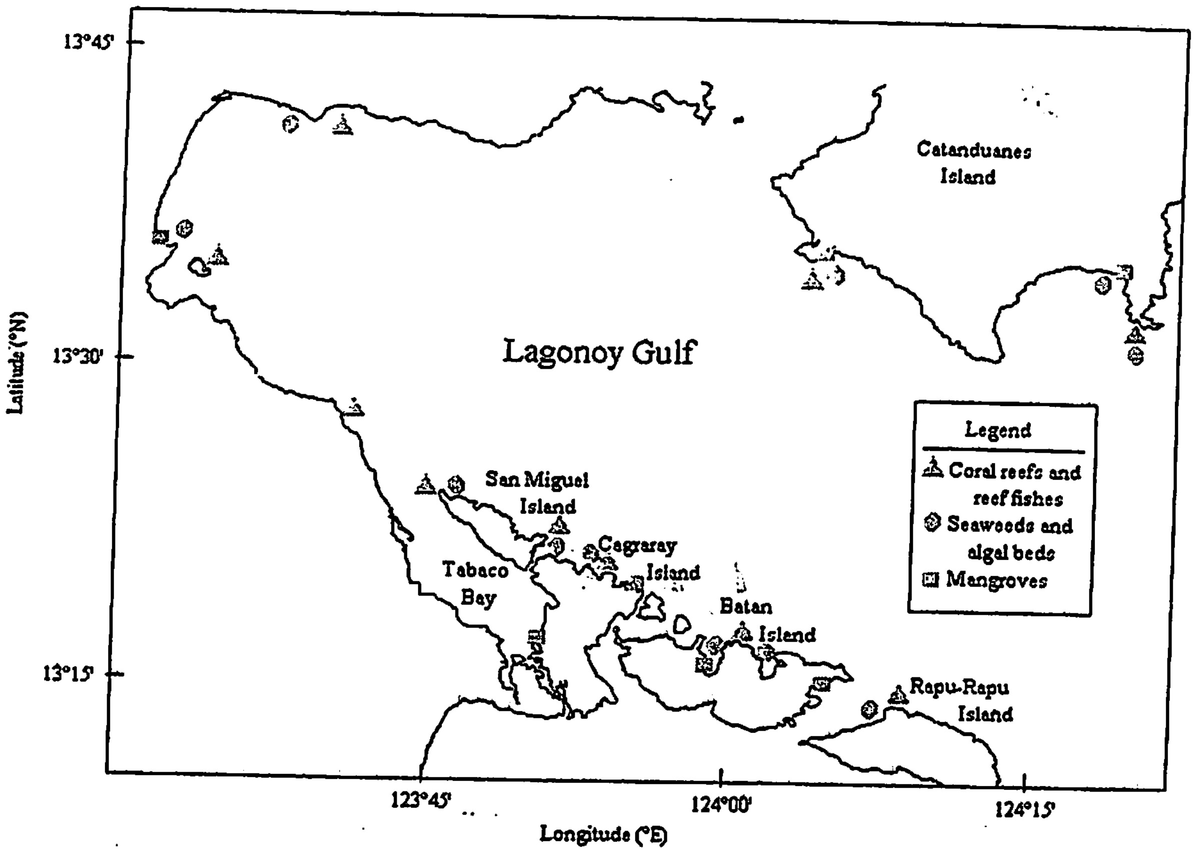

Fig. 1. Transect stations for the assessment for coral reefs, seagrass and algal beds, and mangroves.

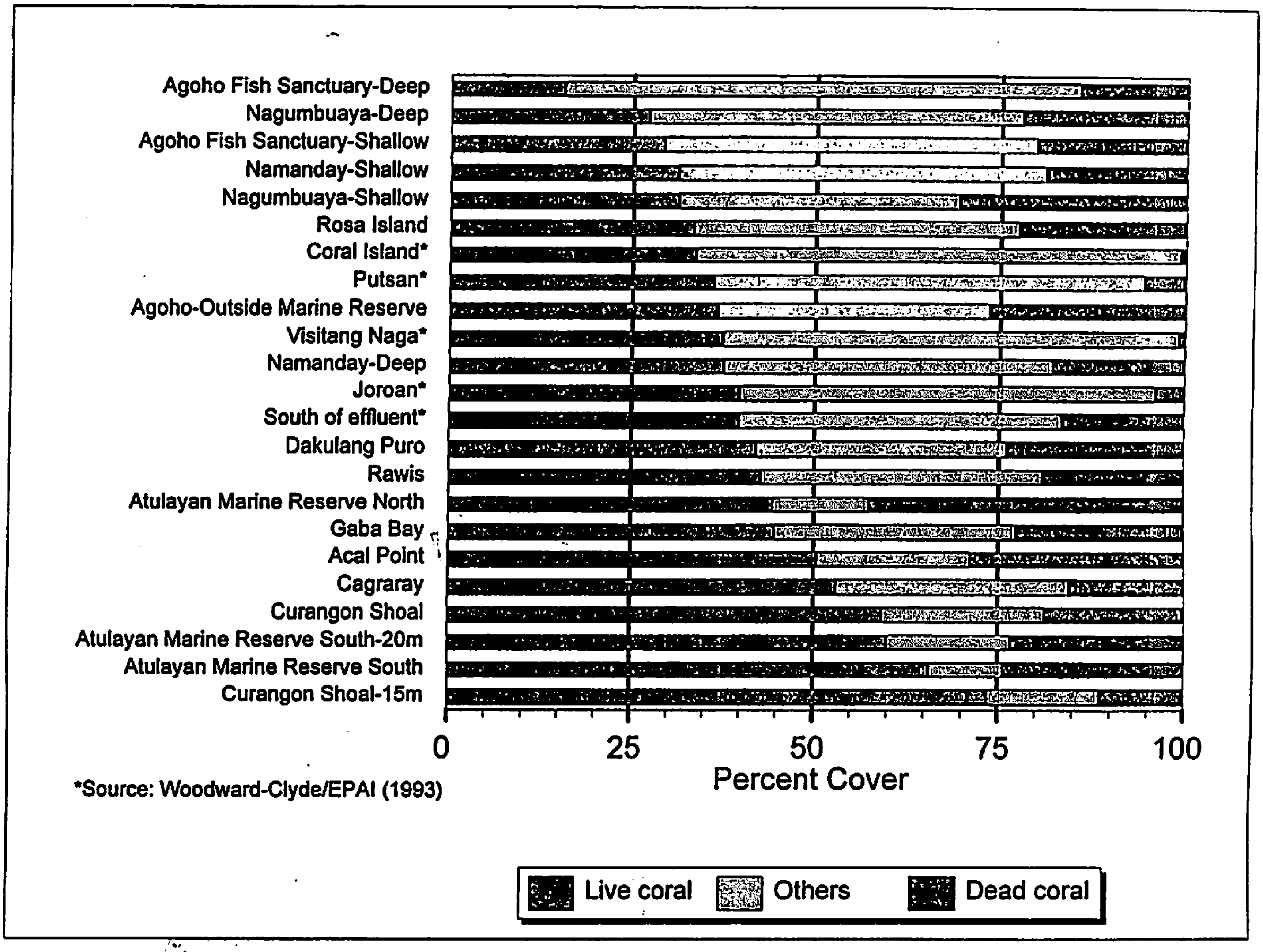

Fig. 2. Percent coral cover of fine corals, dead corals and other lifeforms at the reef areas surveyed.

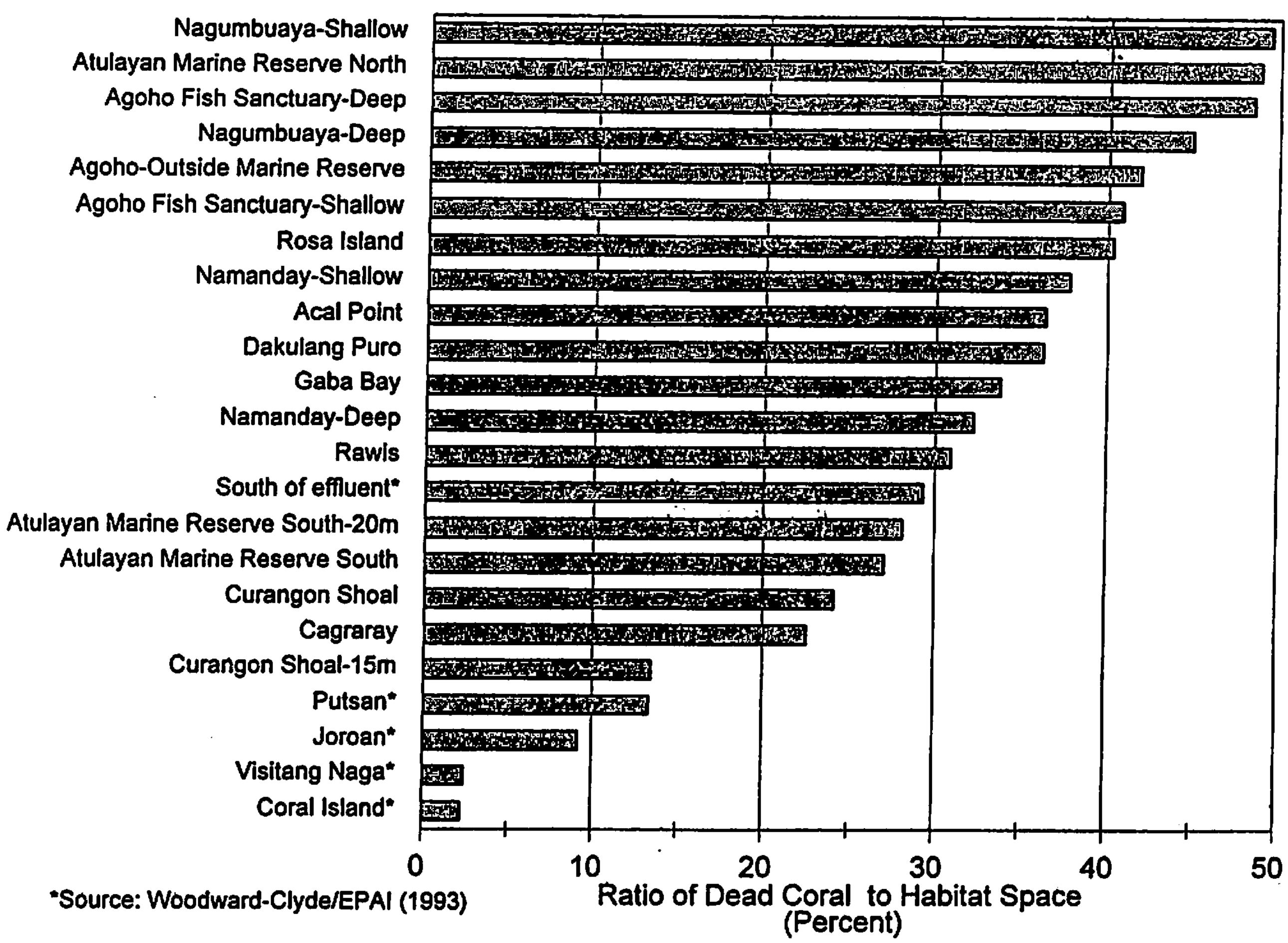

Fig. 3. Ratio of dead coral to total habitat space of the reef areas surveyed.

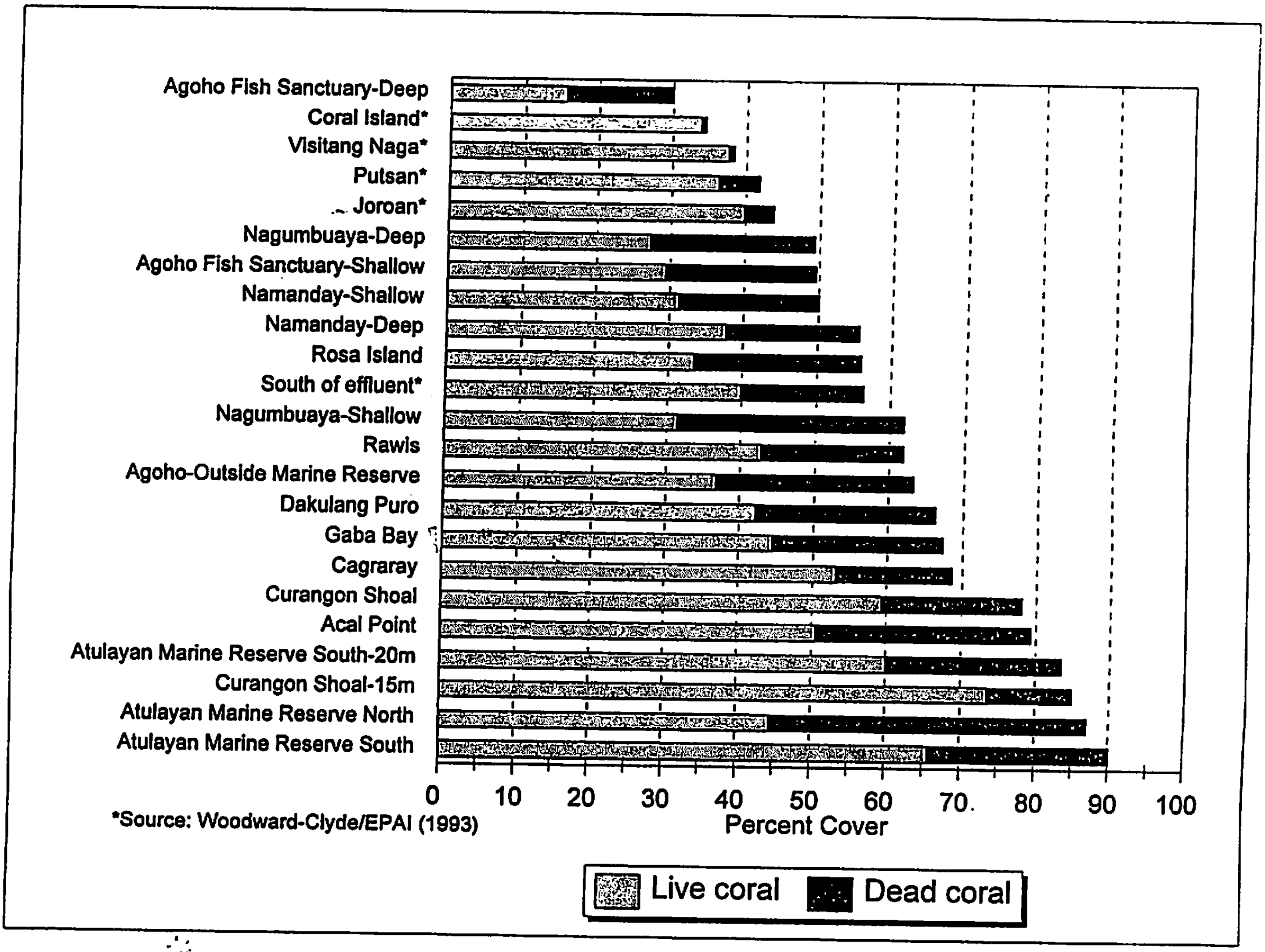

Fig. 4. Total habitat space (live coral plus dead coral) of the reef areas surveyed.

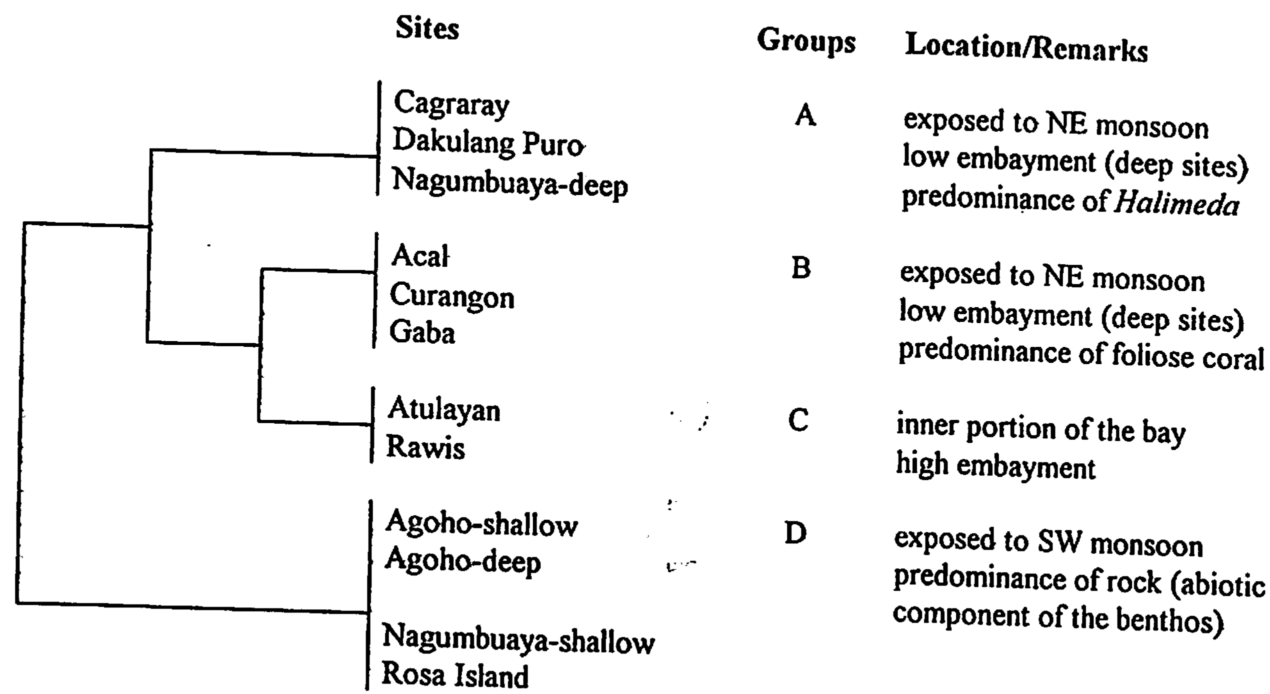

Fig. 5. The dendrogram generated from the output of TWINSPAN showing 4 clusters/groups formed.

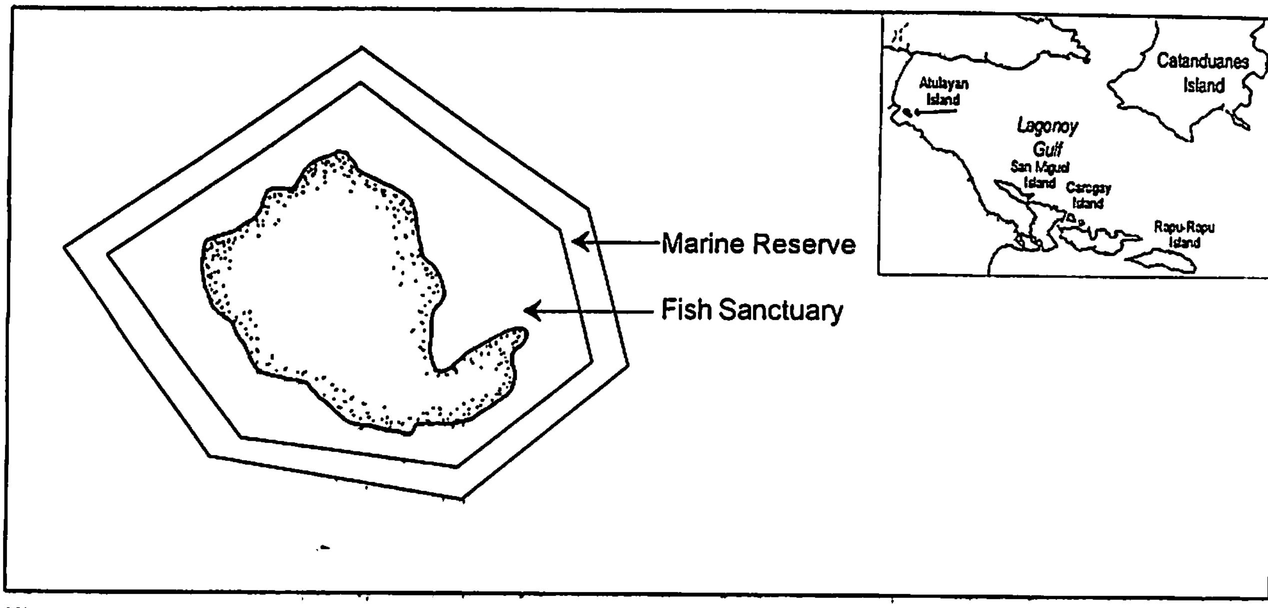

Fig. 6a. The intended design of the Atulayan Fish Sanctuary and Marine Reserve.

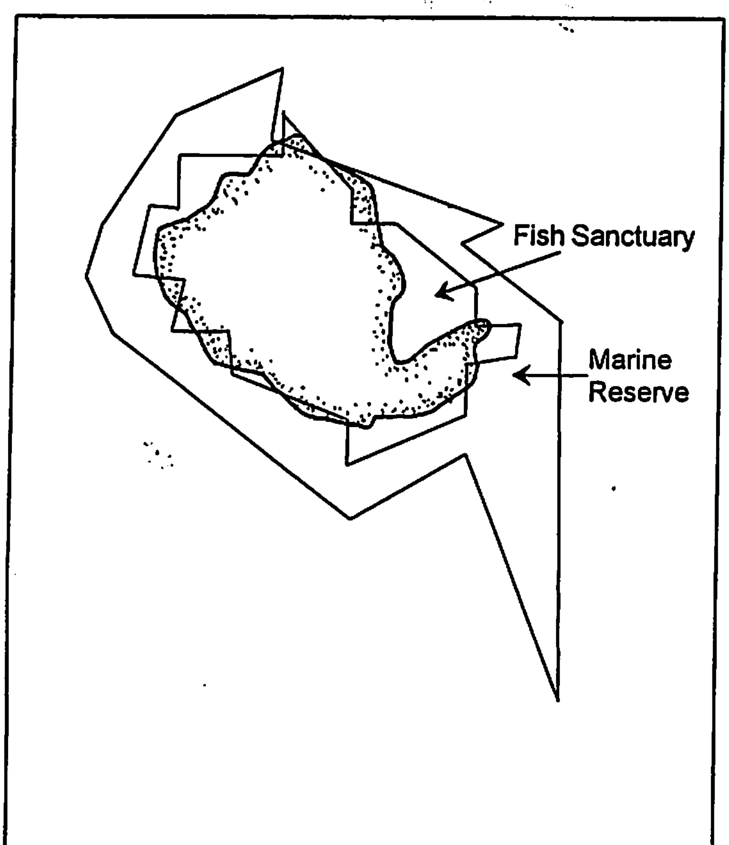

Fig. 6a. The actual shape of the reserve as defined by the coordinates in the municipal resolution establishing the Atulayan Fish Sanctuary and Marine Reserve.

Appendix A. Percent... cover of cover of benthic lifeforms in coral reefs in Lagonoy Gulf.

Transects	Acal 1	Acal 2	Agoho 1	Agoho 2	Agoho 3	Agoho 4	Agoho 5	Agoho 6	Agoho 7	Agoho 8	Agoho 9	Atulayan 1	Atulayan 2	Atulayan 3	Atulayan 4
Lifeform															
Hard coral	43.47	54.30	23.77	19.59	21.67	51.60	24.65	10.08	6.87	15.54	36.76	39.06	46.75	79.6	57.39
Acropora	3.25	7.42	7.6	1.1	1.67	8.64	2.58	3.26	0.4	2.53	1.3	6.58	9.79	47.87	10.66
ACB	3.10	6.13	1.28	0.23	1.58	4.02	2.36	0.11	0.1	0.65	1.00	3.62	2.1	35.2	2.65
ACT	0.00	0.82	2.50	0.31	0.00	2.88	0.20	3.15	0.30	0.90	0.30	0.50	7.05	12.67	8.01
ACE	0.00	0.47	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.57	0.00	0.87	0.00	0.00	0.00
ACS	0.15	0.00	3.82	0.56	0.09	1.49	0.02	0.00	0.00	0.41	0.00	1.59	0.64	0.00	0.00
Non-Acropora	40.22	46.88	16.17	16.79	20.00	42.96	22.07	6.82	6.47	13.01	35.46	32.48	38.96	31.73	46.73
CB	3.69	0.66	1.19	0.00	0.24	3.62	3.41	0.00	0.00	0.32	5.22	2.67	17.04	2.32	3.36
CM	20.00	17.84	8.55	5.94	7.24	15.90	11.14	6.24	4.20	7.40	13.23	18.06	8.47	10.09	13.45
CE	12.63	10.34	5.81	8.67	7.62	18.99	7.14	0.58	2.07	2.93	14.16	7.77	9.45	13.85	23.36
CS	1.00	0.63	0.32	0.86	2.01	2.14	0.34	0.00	0.20	1.24	1.10	2.96	4.00	0.96	0.15
CF	2.50	17.21	0.30	3.32	2.89	2.31	0.00	0.00	0.00	0.55	1.75	0.52	0.00	3.52	4.86
CMR	0.40	0.15	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.50	0.00	0.99	1.25
CME	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.30
CHL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dead coral	32.63	25.14	24.44	21.50	8.22	26.86	10.97	2.11	36.38	9.02	26.62	42.61	31.27	17.57	23.53
DC	16.60	2.98	5.37	5.64	0.11	2.90	4.18	0.99	0.44	3.76	2.00	4.14	10.72	3.71	2.16
DCA	16.03	22.16	19.07	15.86	8.11	23.96	6.79	1.12	35.94	5.26	24.62	38.47	20.55	13.86	21.36
Algae/Seagrass	2.84	1.77	9.47	3.26	47.25	8.76	22.80	16.75	35.61	32.50	13.62	2.59	5.10	0.93	2.74
MA	0.38	0.55	0.14	0.00	11.54	0.44	6.57	0.10	6.81	0.02	2.60	1.05	0.00	0.45	0.48
TA	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.20	0.00	0.00	0.00	0.30	0.45
CA	0.00	0.00	0.10	0.00	0.00	0.52	0.69	0.04	0.00	0.08	0.00	0.32	0.00	0.18	0.15
HA	0.16	0.97	3.50	0.19	4.80	2.17	4.04	6.93	0.43	15.84	2.67	1.10	0.00	0.00	1.66
AA	2.30	0.25	5.73	3.07	30.91	5.63	11.07	9.68	28.27	16.36	8.35	0.12	5.10	0.00	0.00
SG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other fauna	1.14	2.23	2.37	0.12	0.20	0.68	3.89	1.05	0.39	4.95	0.10	9.49	1.32	1.76	2.90
SC	0.99	2.15	0.10	0.00	0.20	0.00	3.31	0.40	0.19	1.15	0.00	5.40	1.22	1.76	2.60
SP	0.05	0.08	0.28	0.10	0.00	0.68	0.09	0.00	0.00	1.70	0.00	1.36	0.00	0.00	0.30
ZO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
OT	0.10	0.00	1.99	0.02	0.00	0.00	0.49	0.65	0.20	2.10	0.10	2.73	0.10	0.00	0.00
Abiotic	19.92	16.56	39.95	55.23	22.66	12.10	37.69	69.98	20.85	37.99	22.90	6.25	13.56	0.15	13.45
S	9.97	5.31	17.72	9.24	13.55	6.22	19.54	16.19	15.01	23.13	7.60	4.29	6.24	0.00	0.00
R	2.15	0.62	1.20	12.97	6.14	3.30	1.64	6.22	1.15	3.14	2.90	0.83	0.00	0.00	0.00
SI	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
WA	7.68	10.28	0.25	0.56	2.97	0.48	2.97	0.00	4.59	0.00	0.45	0.50	0.00	0.15	11.10
RCK	0.00	0.35	20.78	32.46	0.00	2.10	13.54	47.57	0.10	11.72	11.90	0.63	7.32	0.00	2.35

Appendix A. continued

Transects	Cagraray	Curangon 1	Curangon 2	Curangon 3	Curangon 4	Dakulang Puro 1	Dakulang Puro 2	Dakulang Puro 3	Gaba 1	Gaba 2	Nagumbuaya 1	Nagumbuaya 2	Nagumbuaya 3
Lifeform													
Hard coral	62.50	56.79	57.92	55.58	66.15	42.29	40.2	39.32	46.54	41.55	33.45	31.91	27.36
Acropora	8.88	39.01	22.49	11.2	9.62	10.72	9.5	15.05	4.31	8.42	10.9	0.54	6.82
ACB	2.42	25.46	11.85	5.83	5.17	3.27	4.77	3.53	2.99	7.41	7.80	0.35	3.97
ACT	6.15	11.74	8.64	4.17	2.58	5.40	2.01	10.26	0.65	0.65	0.10	0.00	0.77
ACE	0.00	0.00	0.00	0.00	1.25	0.00	0.00	0.48	0.00	0.21	0.00	0.00	0.00
ACS	0.31	1.81	2.00	1.20	0.62	2.05	2.72	0.78	0.67	0.15	3.00	0.19	2.08
Non-Acropora	43.62	17.78	35.43	44.38	56.53	31.57	30.70	24.27	42.23	33.13	22.55	31.37	20.54
CB	0.04	1.31	2.50	1.07	1.67	0.30	1.11	3.87	2.79	1.33	2.35	7.93	2.66
CM	20.99	6.41	15.65	13.26	20.88	11.04	14.60	6.17	26.57	21.15	15.19	11.61	10.27
CE	21.67	4.59	13.38	24.42	24.96	18.89	13.72	8.74	5.22	7.15	3.41	5.96	2.75
CS	0.92	3.08	0.14	2.84	3.79	0.80	1.27	2.30	4.44	0.27	1.38	5.57	4.10
CF	0.00	0.88	2.06	1.54	3.57	0.42	0.00	2.46	1.82	2.26	0.10	0.00	0.76
CMR	0.00	1.51	1.70	1.25	1.66	0.12	0.00	0.20	1.39	0.97	0.12	0.30	0.00
CME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00
Dead coral	15.51	16.37	20.49	19.90	11.54	19.61	33.97	18.65	26.64	19.05	25.61	33.58	32.97
DC	5.02	5.75	6.52	4.43	1.40	2.02	3.46	5.96	16.64	3.38	2.62	3.43	1.24
DCA	10.49	10.62	13.97	15.47	10.14	17.59	30.51	12.69	10.00	15.67	22.99	30.15	31.73
Algae/Seagrass	21.71	1.65	0.26	0.25	9.00	13.24	12.79	36.28	0.24	1.19	13.10	8.95	10.54
MA	4.14	0.00	0.00	0.05	2.61	0.00	0.40	0.60	0.00	0.35	1.60	0.74	0.60
TA	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	2.29	0.00
CA	0.00	0.06	0.16	0.00	0.61	0.18	0.20	0.00	0.24	0.00	0.10	0.23	0.21
HA	17.28	1.59	0.00	0.00	4.06	13.06	10.34	24.31	0.00	0.39	3.35	1.98	2.45
AA	0.29	0.00	0.10	0.20	1.72	0.00	1.65	11.37	0.00	0.45	8.05	3.71	7.28
SG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other fauna	1.72	2.55	3.00	5.08	7.78	3.62	1.17	1.53	0.44	1.01	1.71	0.20	0.44
SC	0.55	1.90	0.79	4.88	7.47	2.52	0.97	1.43	0.26	0.79	1.15	0.00	0.00
SP	0.61	0.00	0.17	0.00	0.13	0.06	0.00	0.00	0.00	0.12	0.26	0.20	0.44
ZO	0.00	0.00	1.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OT	0.56	0.65	1.04	0.20	0.00	1.04	0.20	0.10	0.18	0.10	0.30	0.00	0.00
Abiotic	8.55	22.64	17.88	19.19	5.52	21.25	11.85	4.22	26.14	37.20	25.89	25.36	28.69
S	3.10	0.00	3.30	3.40	0.00	2.74	0.15	1.23	5.22	4.63	6.30	7.60	1.52
R	3.13	8.09	1.55	0.30	0.53	2.09	0.45	1.02	5.37	18.38	4.45	7.72	0.27
SI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.74	0.00	0.00
WA	2.32	7.64	12.16	15.49	4.99	6.44	10.56	0.91	15.21	7.01	3.54	10.04	1.99
RCK	0.00	6.91	0.87	0.00	0.00	9.98	0.70	1.06	0.34	7.18	8.86	0.00	24.91

Appendix A. continue.

Transects	Nagumbuaya 4	Nagumbuaya 5	Nagumbuaya 6	Namanday 1	Namanday 2	Rawis 1	Rawis 2	Rawis 3	Rosa 1	Rosa 2	Rosa 3	Rosa 4
Lifeform												
Hard coral	29.11	19.57	31.92	31.16	37.38	39.4	52.34	29.99	18.85	20.62	19.78	20.18
Acropora	3.96	1.27	9.61	11.54	5.05	12.18	10.06	8.23	2.76	4.95	0.15	5.77
ACB	2.09	0.81	3.48	3.59	3.45	8.02	6.81	6.01	1.19	4.61	0.00	3.89
ACT	0.30	0.46	0.61	7.11	1.6	4.16	3.15	1.95	0.95	0.00	0.00	1.13
ACE	0.00	0.00	5.52	0.15	0	0.00	0.00	0.12	0.00	0.00	0.00	0.30
ACS	1.57	0.00	0.00	0.69	0	0.00	0.10	0.15	0.62	0.34	0.15	0.45
Non-Acropora	25.15	18.30	22.31	19.62	32.33	27.22	42.28	21.76	16.09	15.67	19.63	14.41
CB	4.09	6.19	1.00	4.9	1.25	0.54	0.92	1.12	3.98	0.00	0.20	1.85
CM	11.41	5.38	14.57	2.99	3.95	14.26	25.69	8.42	8.48	10.42	13.70	8.20
CE	8.06	5.46	5.12	9.3	17.98	11.35	13.11	3.72	1.82	4.08	1.25	2.62
CS	0.05	1.12	1.33	1.68	0	0.88	1.44	6.76	1.05	0.28	3.73	1.59
CF	0.17	0.00	0.00	0.75	9.05	0.09	0.50	0.15	0.76	0.03	0.00	0.05
CMR	1.37	0.15	0.29	0	0.1	0.10	0.62	1.59	0.00	0.86	0.75	0.10
CME	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHL	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dead coral	19.94	17.17	29.58	19.04	18.04	19.60	8.36	29.77	11.58	15.81	27.69	35.21
DC	3.11	4.24	0.57	6.48	0.5	6.79	4.46	16.71	2.48	5.99	7.87	4.62
DCA	16.83	12.93	29.01	12.56	17.54	12.81	3.90	13.06	9.10	9.82	19.82	30.59
Algae/Seagrass	22.74	19.09	15.28	26.53	10.05	0.00	0.00	1.75	19.78	8.43	2.55	15.83
MA	0.00	1.22	0.00	0.64	2.75	0.00	0.00	0.00	12.79	3.41	2.55	5.56
TA	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CA	0.00	0.00	0.00	0.82	0.2	0.00	0.00	1.75	0.65	3.26	0.00	1.34
HA	16.23	15.57	7.13	22.36	1.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA	6.51	2.30	8.15	2.71	5.4	0.00	0.00	0.00	6.34	1.76	0.00	8.93
SG	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other fauna	4.26	0.38	1.31	0.40	1.45	2.86	2.31	7.78	12.18	22.29	28.12	16.13
SC	0.95	0.00	0.19	0.05	0.3	1.20	1.19	4.40	6.48	16.78	18.26	12.73
SP	3.07	0.00	1.32	0	0.45	0.00	0.00	0.05	0.00	0.05	0.00	1.41
ZO	0.00	0.00	0.00	0	0.55	0.00	0.00	0.00	0.00	0.05	5.42	0.00
OT	0.24	0.38	0.00	0.35	0.15	1.66	1.12	3.33	5.70	5.41	4.44	1.99
Abiotic	23.93	43.79	21.71	22.87	33.13	38.14	37.00	30.71	37.64	32.84	22.08	12.65
S	7.21	10.02	13.31	0	5.5	13.60	19.09	15.88	12.57	4.39	6.28	5.11
R	6.03	1.68	0.48	0	1.45	9.53	2.71	1.59	1.62	1.96	0.71	0.06
SI	3.09	0.00	0.48	0	0	0.75	3.44	0.59	0.00	0.00	0.27	0.00
WA	4.58	31.22	6.14	22.87	18.25	6.20	8.05	0.40	13.16	0.00	0.00	4.55
RCK	3.04	0.87	1.30	0	7.93	8.06	3.71	12.25	10.29	26.49	14.82	2.93

Coral Reef Fish Species and Abundance of Lagonoy Gulf

by

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Coral Reef Fish Species and Abundance of Lagonoy Gulf

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Nañola, C.L. and J.P. Cabansag. 1995. Coral reef fish species and abundance of Lagonoy Gulf, p. 000-000. *In* G. Silvestre, C. Luna, V. Soliman and L. Garces (eds.) Resource and ecological assessment of Lagonoy Gulf, Philippines. ICLARM Tech. Rep. 000, 000 p.

Abstract

Ten sites were surveyed on 3 different occasions using underwater fish visual census technique in the reefs along the coast of Lagonoy Gulf to determine the coral reef fish species composition and abundance. A total of 260 species from 30 families were identified. Dominant fish species in terms of total abundance were *Pomacentrus moluccensis* (15%), *P. lepidogenys* (13%) and *P. bankanensis* (8%). In terms of fish biomass, the most dominant species were *Ctenochaetus strigosus* (7%), *Pomacentrus bankanensis* (5%) and *P. lepidogenys* (5%). Cluster analysis showed widespread distribution of majority of the species. The fish communities observed were differentiated by monsoon and embayment, however, fish composition varied only in terms of fish densities. Geographic attributes manifested through current flows influenced fish larval distribution.

Introduction

This study was conducted under the ecological/habitat component of the Resource and Ecological Assessment (REA) of Lagonoy Gulf. The study aims to describe and characterize the coral reef fish communities around the gulf and to provide inputs for coastal resource management. This report summarizes the data obtained in January, April and August 1994 using fish visual census technique.

Methods

Study area

The study was conducted in shallow reef areas (2 - 10 m) along the coast of Lagonoy Gulf which lies between 13.22 - 13.70° N and 123.50 - 124.40° E (Fig. 1). The gulf has a total area of approximately 2,700 km^2 of which only about 6% is coral reef. The reefs along the coast are very narrow extending to less than 1 km from the shore to a depth of 13 - 17 m. Few isolated reef mounds are observed along the coast of Curangon with a shallow depth of 6 m extending down to 17 m. During the northeast monsoon (i.e., November to March) the southeast coast is exposed to high wave action while the northeast coast is exposed during the southwest monsoon (i.e., June to October). The area experiences a calm period during easterlies (i.e., April to May).

A total of 10 sites were established around the gulf (Fig. 1). Sites were selected arbitrarily to represent the gulf. In some cases, two transects were laid on a single site due to the extensiveness of the reef and the steepness of the slope. Sites 1 and 2 had two transects each. Site 1 had a shallow (1a) and a deep (1b) station while Site 2 had both shallow stations (2a and 2b). Shallow sites ranged from 2 to 3 m while the deep sites ranged from 7 to 10 m. The coordinates of all the study sites were obtained using a hand-held Global Positioning System (GPS) (Table 1).

Data collection

Data were collected in January, April and July of 1994. In January, six sites were surveyed with eight transects: Sites 1a, 1b, 2a, 2b, 3, 5, 6, and 7. Calm weather in the succeeding months allowed the survey of more sites. In April, two sites were added (Sites 9 and 10). During the last sampling, two more sites were added (Sites 4 and 8).

A modified fish visual census technique (English et al. 1994) was used. This was done by laying a 100 m transect line following the depth contour. Fishes within 5 m on both sides and on top of the transect line were identified to the species level and counted. Individual standard length estimates (SL) in cm were also obtained. In a similar manner, juvenile fishes were also surveyed using the same transect line, but using a narrower width (1 m) to increase observation efficiency. During the second survey, the direction of the transect lines were laid opposite to the direction of the previous sampling. For the third sampling, however, transect lines were laid in between the position of the two previous transects.

Data analyses

Fish biomass estimates per site were determined through the size estimates using the relationship $W=aL^b$, where W is the weight (g), L is the length (cm) and a and b are the constants. The a and b values used in this study were obtained from published L-W relationship data (e.g.

Kubilchi et al. 1993). Indices of diversity were also determined per site such as the Shannon-Wiener diversity index (H') and Evenness (J) (Zar 1984).

For the fish community structure, multivariate analysis was used. This involves the Two Way Indicator Species Analysis (TWINSPAN) developed by Hill (1979). TWINSPAN is a divisive classification technique involving both ordination and classification methods. For this analysis, only the top 100 (95% of the total counts) species of counts data were used and presented. The initial result of the analysis involving all species did not show a clear pattern of the fish community structure. Hence, species which were encountered once were not included in the analysis.

Results and Discussion

Species composition and abundance

A total of 260 species belonging to 38 families were observed during the 3 sampling periods. Dominant fish species based on numerical abundance and biomass per site are shown in Tables 2a and 2b, respectively. In terms of counts, species consistently found in the top 10 per site were mostly pomacentrids (*Pomacentrus moluccensis, P. lepidogenys, P. bankanensis*) and occasionally caesionids (*Caesio trilineata, Pterocaesio tile, P. pisang*). In terms of biomass, the species that were consistently found in the top 10 were the same species of pomacentrids mentioned above. Other species that were abundant in some of the sites were the same as the caesionids mentioned above with the addition of *Caesio cuning*, some acanthurids (*Ctenochaetus strigosus, Acanthurus pyroferus*) and a scarid (*Scarus rhoduropterus*).

In terms of overall abundance, most dominant by numerical abundance were the pomacentrid species, *Pomacentrus moluccensis* (15% of the total counts), *P. lepidogenys* (14%), *P. bankanensis* (7%), *P. vaiuli* (6%), and *Chromis retrofasciata* (3%). In terms of biomass, dominant species were *Ctenochaetus strigosus* (8% of the total biomass), *P. lepidogenys* (5%), *P. vaiuli* (4%), *P. moluccensis* (4%), and *P. bankanensis* (4%) (Table 3). A complete list of the species observed during the 3 sampling periods with their corresponding dominance by counts and biomass is provided in Appendix 1.

Fig. 2 shows the counts, biomass estimates and diversity indices of fish from the 10 sites. Highest counts were observed in Sites 3 (747 ± 513 indiv. 1,000 m^{-2}), 5 (815 ± 195 indiv. 1,000 m^{-2}), 6 (770 ± 379 indiv. 1,000 m^{-2}), and 9 (778 ± 272 indiv. 1,000 m^{-2}). These were mostly due to three species of pomacentrids, *P. moluccensis* (Sites 5, 6 and 9), *P. lepidogenys* (Sites 3 and 5) and *P. bankanensis* (Site 3). Highest fish biomasses were observed in Sites 3 (6.0 ± 2.8 kg 1,000 m^{-2}) and 5 (8.1 ± 1.1 kg 1,000 m^{-2}). Both sites were dominated by *Ctenochaetus strigosus*. *Caesio trilineata* was also dominant in Site 5 (Table 3). Most of the abundant species observed in these sites were planktivores except for *C. strigosus* which is a herbivore. The number of species were relatively the same except for Site 2b, which has the lowest value. The H' and J indices were comparable for all sites.

Based on the estimated biomass of 4.19 ± 1.62 mt 1,000 m^{-2} and the P/B ratio of 1.5 (Polovina 1984), the fish production estimate is 6.29 ± 2.43 mt 1,000 m^{-2} yr^{-1}.

Juvenile fish composition

Table 4 shows the species composition and abundance of juvenile fishes per sampling period. Juvenile fish species observed were mostly pomacentrids dominated by *Pomacentrus* *moluccensis* and *P. lepidogenys*. Other species observed were the labrids (*Cirrhilabrus cyanopleura, Halichoeres melanurus*) and a plotosid (*Plotosus lineatus*).

The spatial distribution of the juvenile fishes is shown in Fig. 3. Highest counts were observed at the most exposed sites (1a, 1b, 9, 10). The number of species were relatively higher in sites situated along the southwest coast (Sites 5, 7, 9 and 10).

Seasonality among juvenile fishes was not observed due to unavailability of the data in some of the sites particularly during the January sampling. Pomacentrids dominated the juvenile fishes in all sampling periods.

Community structure

The output of TWINSPAN as shown in the dendrogram formed four groups/clusters of fish communities (Fig. 4). Based on geographical features, the groupings can be differentiated in terms of monsoons and degree of embayment. Group A (Sites 3, 4 and 8) is at the inner portion of the bay (high embayment) except for Site 8. Group B (Sites 1a, 2a and 2b) is composed of shallow sites and is exposed particularly during the southwest monsoon. Group C (Sites 5, 6, 7 and 9) is composed of sites exposed during the northeast monsoon, and Group D (Sites 1b and 10) is composed of sites at the outer portion of the gulf (low embayment) and exposed during both monsoons.

In terms of species composition, very few were classified as ubiquitous, i.e. present in all of the sites (Appendix 2). These were *Labroides dimidiatus, Chaetodon kleinii, Halichoeres melanurus, Pomacentrus vaiuli* and *Pomacentrus lepidogenys*. However, majority of the species were present in almost all of the groups formed. There were also several species that were present only in a particular group or groups. The species *Ptereleotris evides, Pomacentrus coelestis* and *Scarus schlegeli* were present only in Groups A and B and absent in Groups C and D. The only difference between the two was in terms of densities. There were relatively more of these species in Group B than in Group A. Groups C and D also shared the following species: *Chaetodon octofasciatus, Cheilodipterus quinquelineata, Chromis ternatensis, Chrysiptera rollandi* and *Chromis retrofasciata* which are absent in Groups A and B. In similar manner, they differ in terms of densities. There were more of these species in Group C than in Group D. In addition, Group C has greater abundance of *Caesio trilineata* which is absent in the 3 groups. Group D has the presence of *Lutjanus kasmira* which is absent in other groups.

Based on the trophic classifications, there were no distinct patterns observed (see Appendix 2). The feeding classifications identified (i.e. planktivores, carnivores, herbivores, omnivores and coral feeders) were widely distributed throughout the gulf except for the caesionids which showed high abundance along the southeast coast.

The results suggest that the fish faunal composition of Lagonoy Gulf is differentiated in terms of monsoons and degree of embayment which is similar to the case of Calauag Bay (Nañola et al. in press). However, there is a very thin boundary that differentiates the communities as revealed by the distribution and the trophic classification of the species observed. The majority of the species were widely distributed and differed only in terms of densities. The probable reason for this is due to the geographic attributes of the gulf. The gulf is not a "closed system" (conical type) as compared with other systems such as Calauag Bay and Ragay Gulf. Strong currents flow from Maqueda Channel eastward and vice versa during northeast and southwest monsoons, respectively (Villanoy and Encisa, this vol.). This may facilitate a high flushing rate in and out of the gulf, making it unique. In most systems with high embayment, there is a strong salinity gradient, which creates distinct communities.

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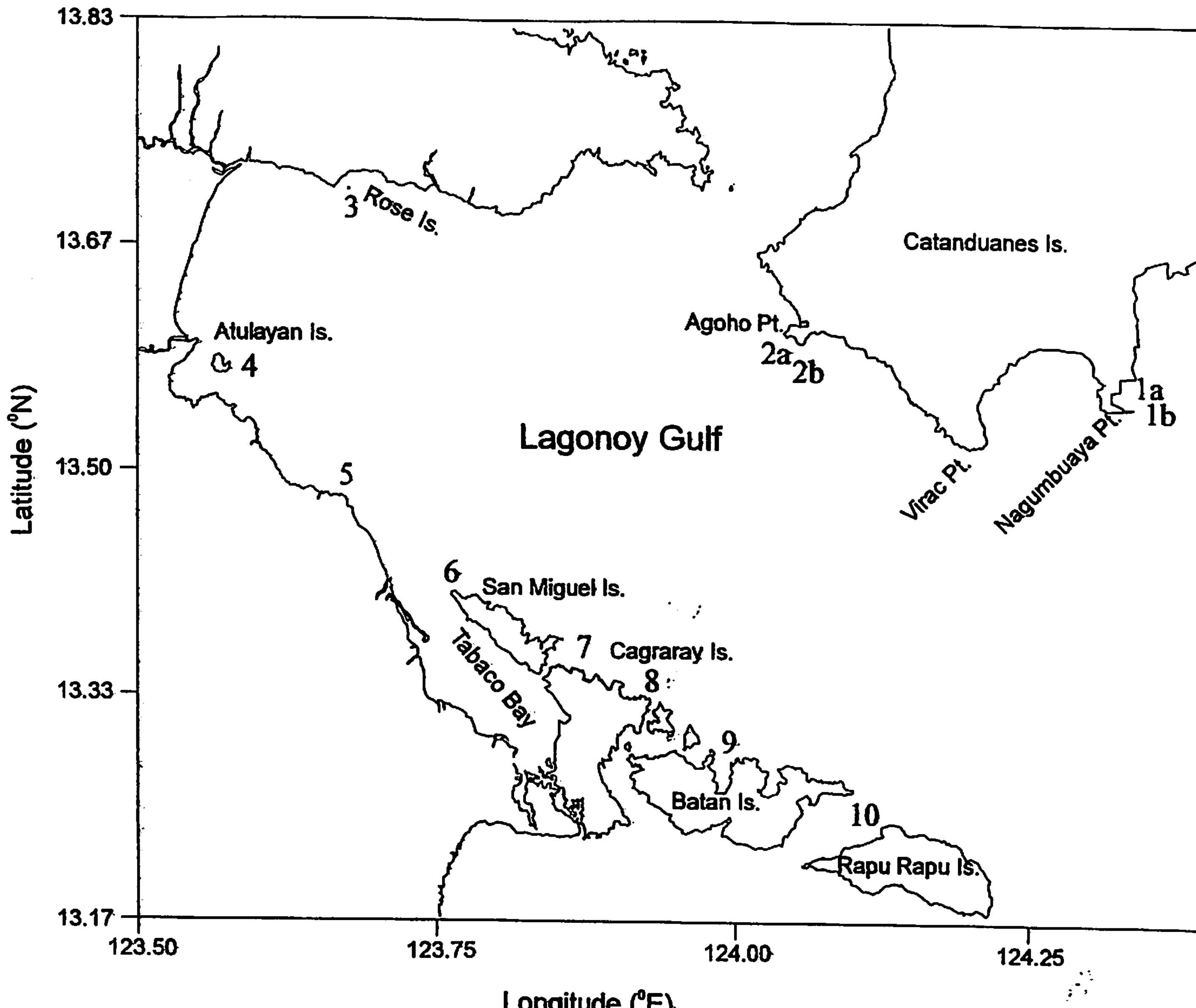

Fig. 1. Map of Lagonoy Gulf showing the location of the 10 study sites. (1a=Nagumbuaya shallow 1b=Nagumbuaya deep, 2a and 2b=Agoho (shallow), 3=Rose Is., 4=Atulayan, 5=Curangon 6=Rawis, 7=Casulgan, 8=Cagragay, 9=Gaba and 10=Rapu-rapu; map modified from Villanoy 1994).

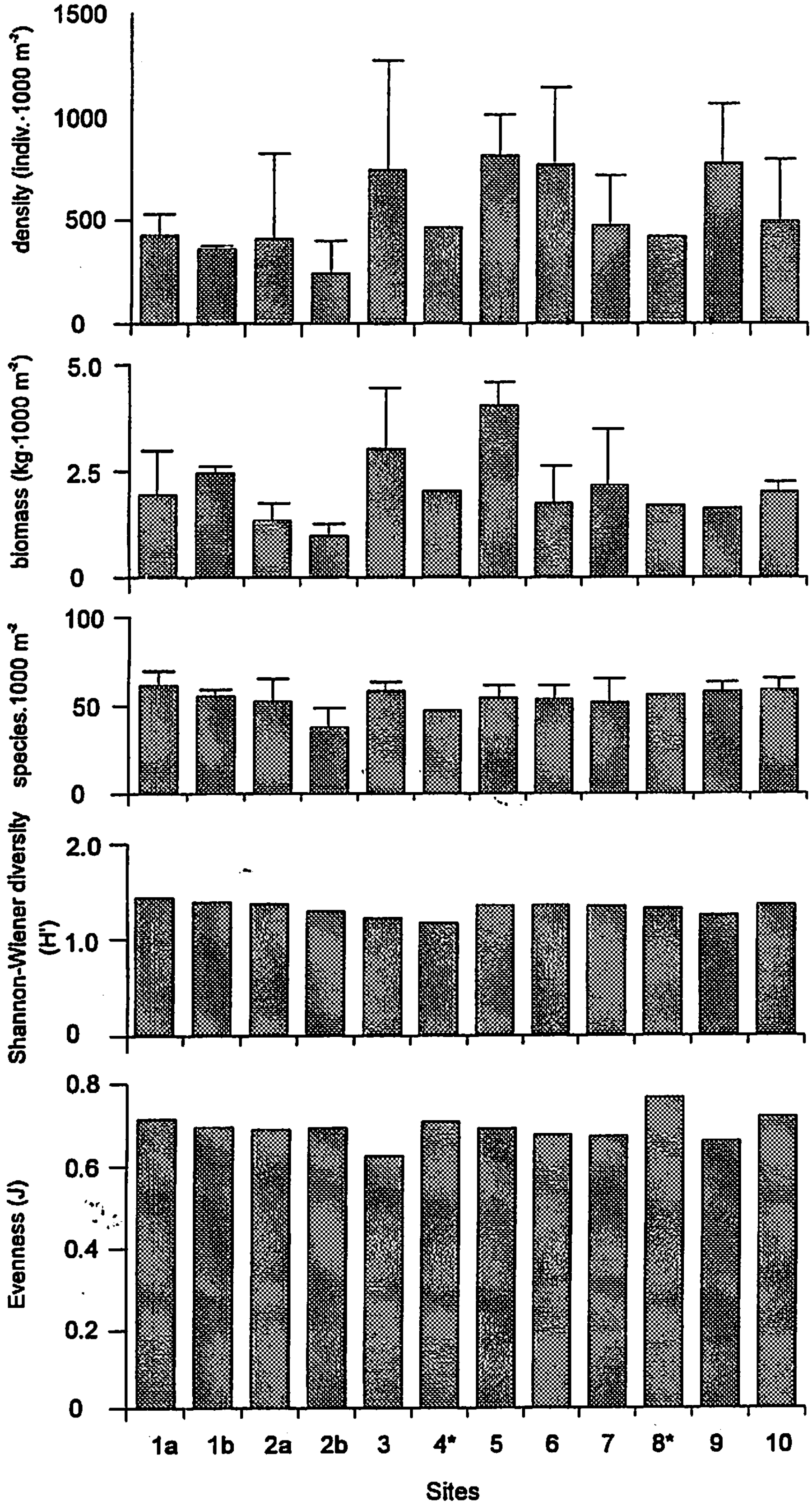

Fig.2. Estimated biomass, total abundance and diversity indices per site. Error bars are the standard deviation. (* surveyed once).

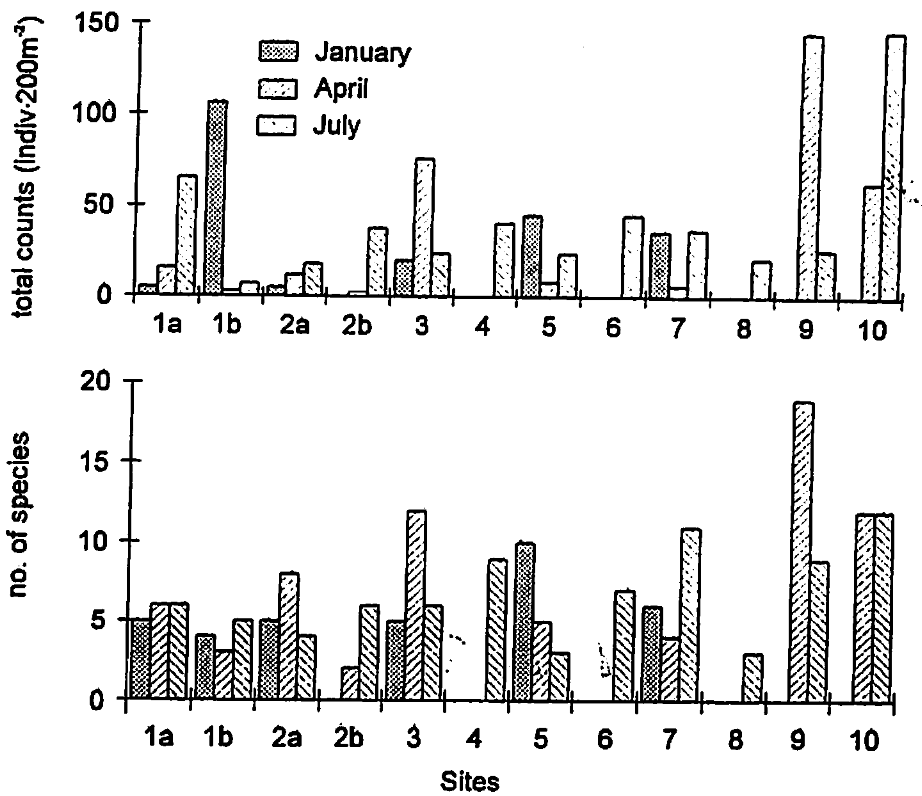

Fig. 3. Total counts and number of species of juvenile fishes observed from January to July 1994. See Table 1 for site names. (Blanks indicate data not available).

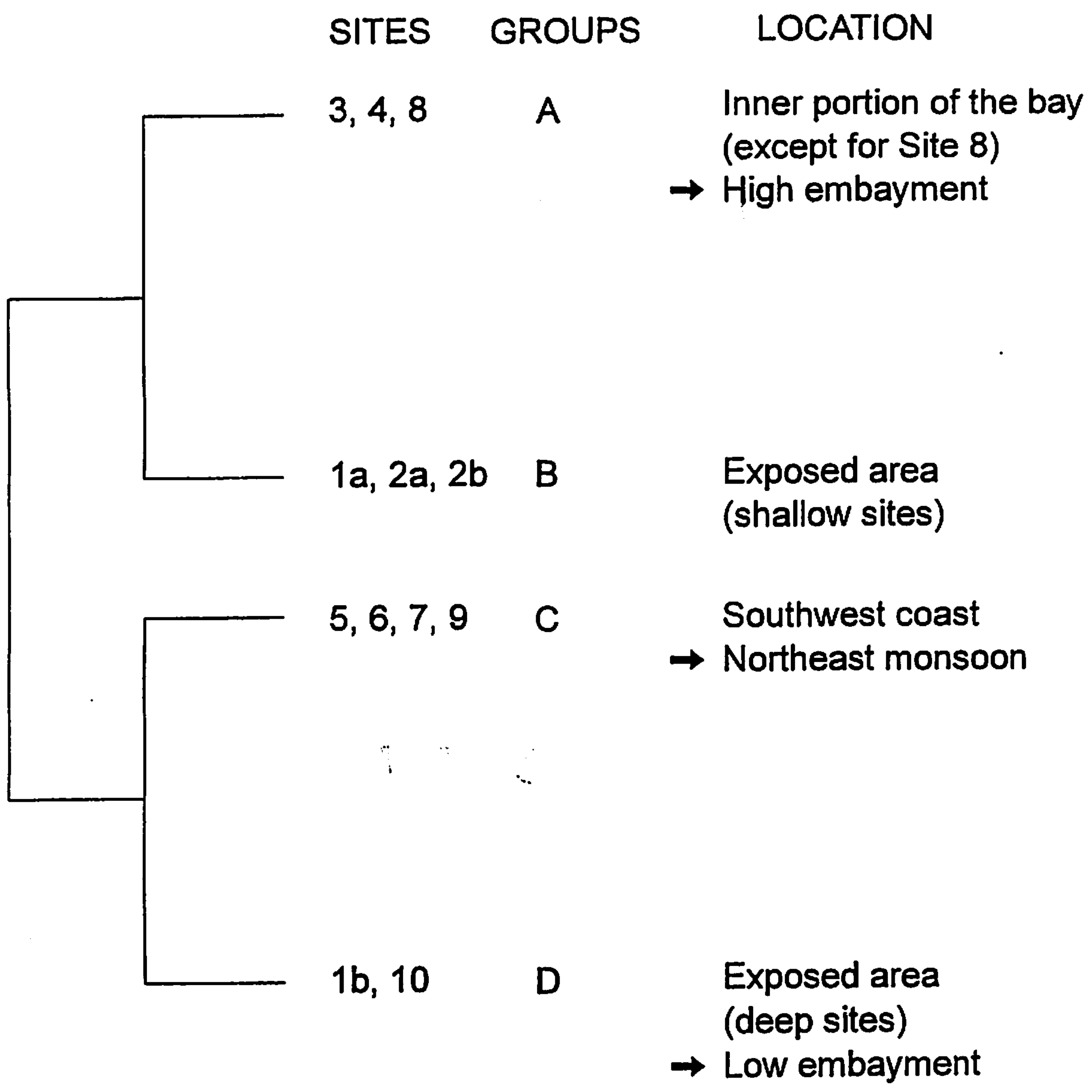

Fig. 4. The dendrogram generated from the output of TWINSPAN showing the 4 clusters/groups formed.

Table 1. Coordinates of the study sites using GPS.

Sites	Location	Coordinates	
1a	Nagumbuaya (shallow)	13°33.24'N	124°98.97'E
1b	Nagumbuaya (deep)	13°33.24'N	124°98.97'E
2a	Agoho (shallow)	13°35.93'N	124°02.65'E
2b	Agoho (shallow)	13°35.93'N	124°02.65'E
3	Rose Is.	13°41.83'N	123°40.25'E
4	Atulayan	13°35.54'N	123°34.24'E
5	Curangon	13°27.45'N	123°43.00"E
6	Rawis	13°24.88'N	123°45.75'E
7	Dakulang Puro	13°22.58'N	123°51.44'E
8	Cagragay	13°20.45'N	123°54.67'E
9	Gaba Bay	13°17.52'N	123°59.50'E
10	Acal	13°14.07'N	124°07.45'E

Table 2. Top species per site by A) counts and B) biomass (g). Total area surveyed per site is 1,000 m^2.

Site 1a

No.	Taxon	Count	%
1	*Pomacentrus lepidogenys*	75.00	17.51
2	*Pomacentrus vaiuli*	66.00	15.41
3	*Chrysiptera rex*	57.67	13.46
4	*Pomacentrus bankanensis*	19.33	4.51
5	*Pomacentrus philippinus*	17.00	3.97
6	*Pterocaeslo tile*	11.00	2.57
7	*Acanthurus nigrofuscus*	9.67	2.26
8	*Thalassoma hardwicke*	9.33	2.18
9	*Cirrhilabrus cyanopleura*	8.67	2.02
10	*Paracirrhites arcatus*	6.67	1.56
	107 other species	148.00	34.55
	Total counts	428.33	100.00

Site 1b

No.	Taxon	Count	%
1	*Pomacentrus vaiuli*	66.33	18.32
2	*Plotosus lineatus*	50.00	13.81
3	*Neoglyphidodon nigroris*	39.67	10.96
4	*Amblyglyphidodon leucogaster*	20.00	5.52
5	*Pomacentrus alexanderae*	19.00	5.25
6	*Pomacentrus lepidogenys*	18.00	4.97
7	*Pomacentrus philippinus*	15.67	4.33
8	*Pomacentrus moluccensis*	14.67	4.05
9	*Cirrhilabrus cyanopleura*	13.67	3.78
10	*Pterocaesio pisang*	6.67	1.84
	104 other species	98.33	27.16
	Total counts	361.99	100.00

Site 2a

No.	Taxon	Count	%
1	*Pomacentrus lepidogenys*	91.00	22.11
2	*Pomacentrus vaiuli*	61.00	14.82
3	*Pomacentrus moluccensis*	49.00	11.90
4	*Pomacentrus bankanensis*	17.67	4.29
5	*Scarus sordidus*	15.33	3.72
6	*Neoglyphidodon nigroris*	14.67	3.56
7	*Chromis viridis*	11.00	2.67
8	*Halichoeres melanurus*	9.67	2.35
9	*Pomacentrus sp.*	8.33	2.02
10	*Diproctacanthus xanthurus*	8.00	1.94
	102 other species	126.00	30.61
	Total counts	411.67	100.00

Site 2b

No.	Taxon	Count	%
1	*Pomacentrus vaiuli*	45.00	18.32
2	*Pomacentrus coelestis*	44.67	18.18
3	*Plotosus lineatus*	33.33	13.57
4	*Dascyllus reticulatus*	20.33	8.28
5	*Halichoeres nebulosa*	11.33	4.61
6	*Pomacentrus amboinensis*	8.33	3.39
7	*Scolopsis bilineatus*	7.00	2.85
8	*Coris variegata*	5.67	2.31
9	*Cirrhilabrus cyanopleura*	4.33	1.76
10	*Scarus schlegeli*	4.33	1.76
	76 other species	61.33	24.97
	Total counts	245.67	100.00

Site 3

No.	Taxon	Count	%
1	*Pomacentrus lepidogenys*	218.00	29.18
2	*Pomacentrus bankanensis*	133.00	17.80
3	*Pomacentrus moluccensis*	58.00	7.76
4	*Ctenochaetus strigosus*	35.33	4.73
5	*Dascyllus reticulatus*	26.67	3.57
6	*Chrysiptera talboti*	25.67	3.44
7	*Pomacentrus brachialis*	22.00	2.95
8	*Ctenochaetus binotatus*	18.67	2.50
9	*Halichoeres melanurus*	17.33	2.32
10	*Chrysiptera rex*	16.67	2.23
	94 other species	175.67	23.52
	Total counts	747.00	100.00

Site 4

No.	Taxon	Count	%
1	*Pomacentrus bankanensis*	170.00	36.48
2	*Ctenochaetus strigosus*	30.00	6.44
3	*Cirrhitichthys falco*	29.00	6.22
4	*Ptereleotris evides*	23.00	4.94
5	*Halichoeres nebulosa*	21.00	4.51
6	*Thalassoma lutescens*	18.00	3.86
7	*Pomacentrus moluccensis*	17.00	3.65
8	*Halichoeres melanurus*	15.00	3.22
9	*Pomacentrus lepidogenys*	14.00	3.00
10	*Centropyge vroliki*	14.00	3.00
	47 other species	115.00	24.68
	Total counts	466.00	100.00

Table 2a. (continued)

Site 5

No.	Taxon	Count	%
1	*Pomacentrus moluccensis*	144.67	17.75
2	*Pomacentrus lepidogenys*	139.67	17.14
3	*Chromis retrofasciata*	79.33	9.73
4	*Chrysiptera talboti*	39.67	4.87
5	*Amblyglyphidodon leucogaster*	35.33	4.34
6	*Ctenochaetus strigosus*	33.33	4.09
7	*Caesio trilineata*	31.67	3.89
8	*Pomachromis richardsoni*	26.67	3.27
9	*Chromis viridis*	23.00	2.82
10	*Zebrasoma scopas*	17.33	2.13
	95 other species	244.33	29.98
	Total counts	814.99	100.00

Site 6

No.	Taxon	Count	%
1	*Pomacentrus moluccensis*	178.67	28.45
2	*Chromis retrofasciata*	58.00	9.24
3	*Pomacentrus lepidogenys*	41.00	6.53
4	*Dascyllus reticulatus*	38.00	6.05
5	*Pomacentrus bankanensis*	32.00	5.10
6	*Caesio trilineata*	23.33	3.72
7	*Amblyglyphidodon leucogaster*	19.00	3.03
8	*Pomacentrus alexanderae*	15.00	2.39
9	*Chrysiptera rollandi*	14.67	2.34
10	*Chromis viridis*	14.33	2.28
	106 other species	194.00	30.89
	Total counts	628.00	100.00

Site 7

No.	Taxon	Count	%
1	*Pomacentrus moluccensis*	127.00	20.54
2	*Pomacentrus lepidogenys*	92.33	14.93
3	*Pomacentrus bankanensis*	71.00	11.48
4	*Plotosus lineatus*	66.67	10.78
5	*Chromis retrofasciata*	24.33	3.94
6	*Dascyllus reticulatus*	17.00	2.75
7	*Chrysiptera rex*	13.33	2.16
8	*Scarus sordidus*	11.00	1.78
9	*Chrysiptera talboti*	10.67	1.73
10	*Pomacentrus philippinus*	10.00	1.62
	106 other species	175.00	28.30
	Total counts	618.33	100.00

Site 8

No.	Taxon	Count	%
1	*Pomacentrus bankanensis*	66.00	15.68
2	*Pomacentrus lepidogenys*	66.00	15.68
3	*Pomacentrus moluccensis*	48.00	11.40
4	*Chrysiptera rex*	35.00	8.31
5	*Pomacentrus vaiuli*	27.00	6.41
6	*Pomacentrus philippinus*	18.00	4.28
7	Scarid	13.00	3.09
8	*Ctenochaetus strigosus*	12.00	2.85
9	*Chaetodon xanthurus*	10.00	2.38
10	*Scarus sordidus*	9.00	2.14
	56 other species	117.00	27.79
	Total counts	421.00	100.00

Site 10

No.	Taxon	Count	%
1	*Pomacentrus moluccensis*	247.00	31.73
2	*Amblyglyphidodon leucogaster*	68.00	8.73
3	*Pomacentrus alexanderae*	53.00	6.81
4	*Chromis viridis*	48.50	6.23
5	*Chrysiptera rollandi*	42.00	5.39
6	*Pomacentrus lepidogenys*	36.00	4.62
7	*Chromis ternatensis*	27.50	3.53
8	*Chromis retrofasciata*	27.00	3.47
9	*Pomacentrus philippinus*	19.00	2.44
10	*Cirrhilabrus cyanopleura*	19.00	2.44
	82 other species	191.50	24.60
	Total counts	778.50	100.00

Site 10

No.	Taxon	Count	%
1	*Pomacentrus moluccensis*	89.00	17.98
2	*Pomacentrus alexanderae*	68.50	13.84
3	*Amblyglyphidodon leucogaster*	47.00	9.49
4	*Pomacentrus vaiuli*	37.50	7.58
5	*Neoglyphidodon nigroris*	30.50	6.16
6	*Lutjanus kasmira*	25.00	5.05
7	*Pomacentrus lepidogenys*	23.00	4.65
8	*Pomacentrus philippinus*	15.00	3.03
9	Labrid sp.	10.00	2.02
10	*Heniochus varius*	9.50	1.92
	83 other species	140.00	28.28
	Total counts	495.00	100.00

Table 2b. (continued)

Site 1a

No.	Taxon	Biomass (g)	%
1	*Pomacentrus vaiuli*	376.32	9.64
2	*Acanthurus nigrofuscus*	343.80	8.81
3	*Thalassoma hardwicke*	246.21	6.31
4	*Scarus sordidus*	238.39	6.11
5	*Pomacentrus lepidogenys*	234.58	6.01
6	*Parapercis clathrata*	161.49	4.14
7	*Scarus globiceps*	150.00	3.84
8	*Thalassoma lutescens*	140.57	3.60
9	*Stethojulis trilineata*	122.92	3.15
10	*Halichoeres melanochir*	102.99	2.64
	107 other species	1786.73	45.77
	Total biomass (g)	3904.00	100.00

Site 1b

No.	Taxon	Biomass (g)	%
1	*Diodon liturutus*	894.50	18.16
2	*Neoglyphidodon nigroris*	582.64	11.83
3	*Pomacentrus vaiuli*	378.79	7.69
4	*Pterocaesio pisang*	357.60	7.26
5	*Pomacentrus alexanderae*	292.64	5.94
6	*Amblyglyphidodon leucogaster*	251.03	5.10
7	*Myripristis murdjan*	241.90	4.91
8	*Halichoeres melanochir*	240.05	4.87
9	*Scarus sordidus*	121.79	2.47
10	*Pomacentrus philippinus*	102.50	2.08
	104 other species	1463.35	29.70
	Total biomass (g)	4926.80	100.00

Site 2a

No.	Taxon	Biomass (g)	%
1	*Scarus sordidus*	270.93	10.08
2	*Pomacentrus vaiuli*	264.61	9.84
3	*Neoglyphidodon nigroris*	213.83	7.95
4	*Pomacentrus lepidogenys*	114.74	4.27
5	*Parapercis clathrata*	103.80	3.86
6	*Scolopsis bilineatus*	100.28	3.73
7	Scarid dark	92.68	3.45
8	*Halichoeres melanurus*	77.48	2.88
9	*Pomacentrus bankanensis*	72.00	2.68
10	*Thalassoma hardwicke*	71.45	2.66
	102 other species	1306.25	48.59
	Total biomass (g)	2688.05	100.00

Site 2b

No.	Taxon	Biomass (g)	%
1	*Pomacentrus vaiuli*	182.68	9.41
2	*Scolopsis bilineatus*	168.44	8.68
3	*Pomacentrus coelestis*	161.31	8.31
4	*Ctenochaetus binotatus*	137.79	7.10
5	*Priacanthus macracanthus*	114.81	5.92
6	*Halichoeres nebulosa*	108.19	5.57
7	*Halichoeres melanochir*	87.50	4.51
8	*Parapercis clathrata*	83.50	4.30
9	*Acanthurus pyroferus*	77.05	3.97
10	*Pterocaesio pisang*	73.13	3.77
	76 other species	746.33	38.46
	Total biomass (g)	1940.73	100.00

Site 3

No.	Taxon	Biomass (g)	%
1	*Ctenochaetus strigosus*	1187.76	19.60
2	*Pomacentrus bankanensis*	587.97	9.70
3	*Pomacentrus lepidogenys*	476.16	7.86
4	*Ctenochaetus binotatus*	425.86	7.03
5	*Thalassoma lunare*	415.02	6.85
6	*Zebrasoma scopas*	227.16	3.75
7	*Pomacentrus brachialis*	195.75	3.23
8	*Chaetodon kleinii*	176.43	2.91
9	*Acanthurus nigrofuscus*	152.98	2.52
10	*Chaetodon xanthurus*	141.32	2.33
	94 other species	2074.88	34.23
	Total biomass (g)	6061.30	100.00

Site 4

No.	Taxon	Biomass (g)	%
1	*Pomacentrus bankanensis*	739.57	18.07
2	*Thalassoma lunare*	350.85	8.57
3	*Chaetodon kleinii*	294.18	7.19
4	*Ctenochaetus strigosus*	251.44	6.14
5	*Thalassoma lutescens*	249.10	6.09
6	*Halichoeres nebulosa*	226.38	5.53
7	*Parapercis clathrata*	220.08	5.38
8	*Macropharyngodon meleagris*	209.66	5.12
9	*Acanthurus pyroferus*	194.19	4.74
10	*Chaetodon xanthurus*	159.34	3.89
	47 other species	1198.26	29.28
	Total biomass (g)	4093.05	100.00

Table 2b. (continued)

Site 5

No.	Taxon	Biomass (g)	%
1	*Ctenochaetus strigosus*	1444.64	17.83
2	*Caesio trilineata*	1001.04	12.35
3	*Amblyglyphidodon leucogaster*	620.43	7.66
4	*Pomacentrus lepidogenys*	566.96	7.00
5	*Pomacentrus moluccensis*	379.74	4.69
6	*Zebrasoma scopas*	328.02	4.05
7	*Labrichthys unilineatus*	219.04	2.70
8	*Pomacentrus philippinus*	205.50	2.54
9	*Neoglyphidodon nigroris*	181.75	2.24
10	*Chromis retrofasciata*	176.97	2.18
	95 other species	2978.39	36.76
	Total biomass (g)	8102.47	100.00

Site 6

No.	Taxon	Biomass (g)	%
1	*Pomacentrus moluccensis*	361.52	10.29
2	*Caesio trilineata*	286.49	8.16
3	*Pomacentrus bankanensis*	238.72	6.80
4	*Pomacentrus lepidogenys*	211.94	6.04
5	*Chaetodon xanthurus*	173.91	4.95
6	*Ctenochaetus strigosus*	171.83	4.89
7	*Pomacentrus philippinus*	162.88	4.64
8	*Chaetodon baronessa*	110.63	3.15
9	*Amblyglyphidodon leucogaster*	88.51	2.52
10	*Pomacentrus vaiuli*	86.84	2.47
	106 other species	1618.42	46.09
	Total biomass (g)	3511.69	100.00

Site 7

No.	Taxon	Biomass (g)	%
1	*Pomacentrus moluccensis*	451.55	10.38
2	*Pomacentrus lepidogenys*	386.94	8.90
3	*Ctenochaetus strigosus*	269.48	6.20
4	*Scarus sordidus*	241.07	5.54
5	*Parupeneus barberinus*	233.61	5.37
6	*Pomacentrus bankanensis*	232.13	5.34
7	*Caesio trilineata*	178.80	4.11
8	*Zanclus cornutus*	132.39	3.04
9	*Labrichthys unilineatus*	124.19	2.86
10	*Halichoeres hortulanus*	110.23	2.53
	106 other species	1988.51	45.72
	Total biomass (g)	4348.90	100.00

Site 8

No.	Taxon	Biomass (g)	%
1	*Halichoeres melanochir*	381.73	11.23
2	*Pomacentrus bankanensis*	345.70	10.17
3	*Acanthurus pyroferus*	267.89	7.88
4	*Pomacentrus vaiuli*	162.55	4.78
5	*Pomacentrus philippinus*	160.15	4.71
6	*Epinephelus fasciatus*	159.22	4.69
7	*Pomacentrus lepidogenys*	157.96	4.65
8	*Chaetodon xanthurus*	119.95	3.53
9	*Ctenochaetus strigosus*	106.25	3.13
10	*Chaetodon baronessa*	105.16	3.09
	56 other species	1431.87	42.13
	Total biomass (g)	3398.43	100.00

Site 9

No.	Taxon	Biomass (g)	%
1	*Pomacentrus moluccensis*	269.71	8.26
2	*Zanclus cornutus*	252.24	7.72
3	*Amblyglyphidodon leucogaster*	251.98	7.72
4	*Labrichthys unilineatus*	161.08	4.93
5	*Halichoeres melanochir*	146.44	4.48
6	*Caesio cuning*	145.24	4.45
7	*Pomacentrus philippinus*	136.05	4.17
8	*Halichoeres melanurus*	127.18	3.90
9	*Ctenochaetus strigosus*	100.86	3.09
10	*Cirrhilabrus cyanopleura*	97.94	3.00
	82 other species	1576.49	48.28
	Total biomass (g)	3265.18	100.00

Site 10

No.	Taxon	Biomass (g)	%
1	*Neoglyphidodon nigroris*	450.81	11.20
2	*Lutjanus kasmira*	340.15	8.45
3	*Plectorhinchus chaetodonoides*	211.56	5.26
4	*Caesio cuning*	210.81	5.24
5	*Ctenochaetus strigosus*	199.27	4.95
6	*Amblyglyphidodon leucogaster*	185.43	4.61
7	*Pomacentrus vaiuli*	178.13	4.43
8	*Halichoeres melanurus*	155.97	3.87
9	*Labrichthys unilineatus*	130.15	3.23
10	*Acanthurus pyroferus*	119.25	2.96
	83 other species	1843.99	45.81
	Total biomass (g)	4025.50	100.00

Table 3. Top most abundant fish species by a) density and b) biomass (g).
(area surveyed per site 1000 sq.m.).

A. Density abundance

Rank	Taxon	Counts	%	Cum
1	*Pomacentrus moluccensis*	976.33	15.22	15.22
2	*Pomacentrus lepidogenys*	816.33	12.72	27.94
3	*Pomacentrus bankanensis*	514.17	8.01	35.95
4	*Pomacentrus vaiuli*	346.00	5.39	41.34
5	*Amblyglyphidodon leucogaster*	203.67	3.17	44.52
6	*Chromis retrofasciata*	195.83	3.05	47.57
7	*Pomacentrus alexanderae*	156.83	2.44	50.01
8	*Chrysiptera rex*	150.17	2.34	52.35
9	*Plotosus lineatus*	150.00	2.34	54.69
10	*Ctenochaetus strigosus*	140.67	2.19	56.88
	255 all other species	2766.49	43.12	100.00
	Total counts	6416.49	100.00	
	Total no. of species	265		

B. Estimated biomass (g)

Rank	Taxon	Biomass (g)	%	Cum
1	*Ctenochaetus strigosus*	3742.65	7.45	7.45
2	*Pomacentrus bankanensis*	2331.05	4.64	12.08
3	*Pomacentrus lepidogenys*	2308.04	4.59	16.67
4	*Pomacentrus vaiuli*	1924.53	3.83	20.50
5	*Pomacentrus moluccensis*	1814.96	3.61	24.11
6	*Neoglyphidodon nigroris*	1607.21	3.20	27.31
7	*Amblyglyphidodon leucogaster*	1474.30	2.93	30.24
8	*Caesio trilineata*	1466.33	2.92	33.16
9	*Halichoeres melanochir*	1274.47	2.54	35.70
10	*Scarus sordidus*	1223.27	2.43	38.13
	255 all other species	31099.29	61.87	100.00
	Total biomass (g)	50266.09	100.00	

Table 4. Top most abundant juvenile fish species by total counts observed per sampling period.

January 1994 (total of 8 transects)

No.	Species	Total	%
1	*Plotosus lineatus*	100	46.08
2	*Pomacentrus moluccensis*	50	23.04
3	*Halichoeres melanurus*	16	7.37
4	*Cirrhilabrus cyanopleura*	11	5.07
5	Pomacentrid sp.	10	4.61
6	*Chromis retrofasciata*	7	3.23
7	*Pomacentrus lepidogenys*	3	1.38
8	*Labrichthys unilineatus*	2	0.92
	18 other species	18	8.29

April 1994 (total of 10 transects)

No.	Species	Total	%
1	*Chromis ternatensis*	70	21.15
2	*Pomacentrus lepidogenys*	43	12.99
3	Apogonid	30	9.06
4	*Pomacentrus moluccensis*	22	6.65
5	*Neoglyphidodon nigroris*	21	6.34
6	*Pomacentrus bankanensis*	19	5.74
7	*Cirrhilabrus cyanopleura*	14	4.23
8	*Pomacentrus vaiuli*	12	3.63
9	*Pomacentrus alexanderae*	10	3.02
10	*Chrysiptera talboti*	10	3.02
11	Unidentified juvenile	10	3.02
12	*Pomacentrus philippinus*	9	2.72
13	*Halichoeres melanurus*	6	1.81
14	*Amphiprion clarkii*	5	1.51
15	*Pomacentrus brachialis*	5	1.51
16	*Thalassoma lunare*	4	1.21
17	*Labrichthys unilineatus*	4	1.21
18	*Amblyglyphidodon leucogaster*	4	1.21
19	*Pseudocheilinus hexataenia*	4	1.21
	19 other species	29	8.76

Table 4. (continued)

July 1994 (total of 12 transects)

No.	Species	Total	%
1	*Pomacentrus moluccensis*	118	23.98
2	*Pomacentrus alexanderae*	54	10.98
3	*Diproctacanthus xanthurus*	48	9.76
4	*Amblyglyphidodon leucogaster*	37	7.52
5	*Pomacentrus coelestis*	32	6.50
6	*Pomacentrus bankanenesis*	30	6.10
7	*Chromis retrofasciata*	27	5.49
8	*Halichoeres melanurus*	26	5.28
9	*Pmacentrus lepidogenys*	17	3.46
10	*Cheilodipterus quinquelineatus*	15	3.05
11	*Chrysiptera talboti*	12	2.44
12	*Chaetodon baronessa*	12	2.44
13	*Chrysiptera rex*	11	2.24
14	Unidentified juvenile	7	1.42
15	*Chrysiptera rollandi*	7	1.42
16	*Labroides dimidiatus*	5	1.02
17	*Pomacentrus amboinensis*	4	0.81
	20 other species	30	6.10

Appendix 1. List of fish species observed during the 3 sampling period.
Counts and biomass are cumulative average of 12 transects.

Family	Taxon	Counts	Rank	Weight (g)	Rank
Acanthuridae					
1	*Acanthurus gahhm*	1.50	174	28.22	148
2	*Acanthurus grammoptilus*	0.33	227	0.64	257
3	*Acanthurus japonicus*	0.33	226	13.10	189
4	*Acanthurus lineatus*	0.33	233	5.08	217
5	*Acanthurus nigrofuscus*	20.50	47	785.64	22
6	*Acanthurus pyroferus*	19.00	50	776.02	23
7	*Ctenochaetus binotatus*	57.33	20	1052.35	12
8	*Ctenochaetus marginatus*	2.33	148	26.79	151
9	*Ctenochaetus striatus*	6.33	93	300.41	41
10	*Ctenochaetus strigosus*	140.67	10	3742.65	1
11	*Gnatonodon speciosus*	0.50	222	5.30	213
12	*Naso annulatus*	0.33	230	43.42	133
13	*Naso lituratus*	5.67	99	175.29	60
14	*Zebrasoma fiavescens*	2.00	157	36.85	139
15	*Zebrasoma scopas*	49.17	28	808.54	20
16	*Zebrasoma veliferum*	0.67	213	4.66	220
Apogonidae					
17	*Apogon compressus*	1.67	165	0.94	253
18	*Apogon* sp.	8.33	80	1.06	252
19	Apogonid	3.33	127	0.12	265
20	*Cheilodipterus lineatus*	0.33	229	13.97	183
21	*Cheilodipterus macrodon*	1.33	182	83.70	95
22	*Cheilodipterus quinquelineatus*	25.50	44	23.30	155
Aulostomidae					
23	*Aulostomus chinensis*	1.83	164	14.00	182
Balistidae					
24	*Balistapus undulatus*	3.67	123	65.88	108
25	*Melichthys vidua*	0.33	224	10.09	194
26	*Rhinecanthus aculeatus*	0.67	209	7.52	199
27	*Sufflamen bursa*	2.00	163	48.68	127
28	*Sufflamen chrysoptera*	2.00	153	84.00	94
Blenniidae					
29	*Atrosalarias fuscus*	2.33	149	6.68	202
30	Blenny	2.00	162	1.57	248
31	*Cirripectes polyzona*	0.33	260	1.63	247
32	*Meiacanthus grammistes*	17.00	54	30.54	146
33	*Plagiotremus laudandus*	42.67	30	38.22	136
34	*Plagiotremus rhinorhynchus*	0.33	259	0.57	258
35	*Salarias fasciatus*	1.00	193	2.60	235
Caesionidae					
36	*Caesio cuning*	18.00	51	356.05	34
37	*Caesio trilineata*	58.33	19	1466.33	8
38	*Pterocaesio pisang*	8.33	79	430.74	30
39	*Pterocaesio tile*	17.67	53	209.89	50
Centriscidae					
40	*Aeoliscus strigatus*	0.50	220	49.47	126

Appendix 1. (continuation).

Family	Taxon	Counts	Rank	Weight (g)	Rank
Chaetodontidae					
41	*Chaetodon argentatus*	11.33	67	125.23	72
42	*Chaetodon auriga*	0.33	261	13.81	185
43	*Chaetodon baronessa*	34.50	34	641.06	24
44	*Chaetodon citrinellus*	5.00	105	57.91	117
45	*Chaetodon kleinii*	54.00	22	875.67	17
46	*Chaetodon lineolatus*	0.67	201	31.65	144
47	*Chaetodon lunula*	1.00	190	50.61	121
48	*Chaetodon melannotus*	0.33	264	5.17	215
49	*Chaetodon octofasciatus*	19.00	48	79.08	99
50	*Chaetodon oxycephalus*	0.33	255	2.69	234
51	*Chaetodon plebeius*	1.33	176	15.41	175
52	*Chaetodon punctatofasciatus*	8.83	76	111.16	80
53	*Chaetodon reticulatus*	0.33	246	6.24	207
54	*Chaetodon trifascialis*	3.50	126	36.96	138
55	*Chaetodon trifasciatus*	11.17	68	196.70	52
56	*Chaetodon ulietensis*	1.00	198	6.65	203
57	*Chaetodon unimaculatus*	0.67	214	4.17	225
58	*Chaetodon vagabundus*	0.33	243	1.16	251
59	*Chaetodon xanthurus*	52.33	24	871.45	18
60	*Chelmon rostratus*	0.67	216	32.27	141
61	*Coradion chrysozonus*	0.33	240	0.70	255
62	*Forcipiger longirostris*	2.33	152	88.43	90
63	*Heniochus acuminatus*	0.33	241	0.32	262
64	*Heniochus chrysostomus*	9.33	75	57.74	118
65	*Heniochus varius*	25.33	45	337.55	37
66	*Parachaetodon ocellatus*	1.00	184	15.09	178
Cirrhitidae					
67	*Cirrhitichthys falco*	53.67	23	166.17	62
68	*Paracirrhites arcatus*	7.67	85	79.84	97
69	*Paracirrhites forsteri*	1.00	185	19.04	165
Diodontidae					
70	*Diodon lituratus*	0.33	254	894.50	15
Ephippidae					
71	*Platax pinnatus*	1.00	189	56.41	119
Fistulariidae					
72	*Fistularia petimba*	2.67	143	15.67	174
Gobiidae					
73	*Amblyeleotris steinitzi?*	0.67	205	7.64	198
74	*Yongeichthys criniger*	0.33	250	1.92	242
Grammistidae					
75	*Diploprion bifasciatus*	10.50	70	71.19	104
76	*Grammistes sexlineatus*	0.33	253	2.31	239

Appendix 1. (continuation).

Family	Taxon	Counts	Rank	Weight (g)	Rank
Haemulidae					
	77 *Plectorhinchus chaetodonoides*	6.17	94	244.58	46
	78 *Plectorhinchus diagrammus*	1.00	188	6.49	205
	79 *Plectorhinchus goldmanni*	3.17	131	74.45	102
	80 *Plectorhinchus pictus*	0.33	242	5.93	208
Holocentridae					
	81 *Myripristis murdjan*	5.33	104	244.38	47
	82 *Myripristis* sp.	0.67	212	9.18	195
	83 *Neoniphon sammara*	1.67	170	130.37	68
	84 *Sargocentron caudimaculatum*	0.33	265	13.74	187
Labridae					
	85 *Anampses caeruleopunctatus*	0.67	207	16.22	172
	86 *Anampses meleagrides*	1.67	168	9.16	196
	87 *Anampses neoguinaicus*	4.50	114	61.88	111
	88 *Anampses twistii*	5.50	101	159.63	64
	89 *Bodianus axillaris*	1.00	196	10.62	192
	90 *Bodianus mesothorax*	4.83	111	97.20	88
	91 *Cheilinus bimaculatus*	1.00	183	7.38	200
	92 *Cheilinus chlorourus*	3.67	124	68.63	106
	93 *Cheilinus diagrammus*	1.67	167	50.25	124
	94 *Cheilinus fasciatus*	1.67	169	19.94	162
	95 *Cheilinus trilobatus*	3.83	119	85.19	92
	96 *Cheilinus unifasciatus*	4.00	116	173.98	61
	97 *Choerodon anchorago*	0.83	200	18.80	166
	98 *Cirrhilabrus cyanopleura*	65.00	17	236.06	48
	99 *Coris gaimard*	2.00	156	31.48	145
	100 *Coris variegata*	13.33	66	192.19	56
	101 *Diproctacanthus xanthurus*	16.50	56	104.78	87
	102 *Epibulus insidiator*	1.67	173	116.52	76
	103 *Gomphosus varius*	8.67	77	257.79	44
	104 *Halichoeres biocellatus*	3.00	132	94.13	89
	105 *Halichoeres hortulanus*	13.67	63	251.04	45
	106 *Halichoeres margaritaceous*	2.00	155	16.76	170
	107 *Halichoeres marginatus*	7.33	87	121.77	73
	108 *Halichoeres melanochir*	33.67	36	1274.47	9
	109 *Halichoeres melanurus*	78.83	16	823.28	19
	110 *Halichoeres nebulosa*	50.50	25	461.07	29
	111 *Halichoeres prosopeion*	17.83	52	260.57	43
	112 *Halichoeres scapularis*	0.67	208	6.63	204
	113 *Halichores melanochir*	1.00	195	64.97	109
	114 *Hemigymnus fasciatus*	8.50	78	198.92	51
	115 *Hemigymnus melapterus*	2.00	158	80.92	96
	116 *Hologymnosus doliatus*	0.33	258	31.94	143
	117 *Labrichthys unilineatus*	50.17	26	945.37	14
	118 Labrid	0.33	257	0.43	260
	119 Labrid sp.	15.00	60	23.08	156
	120 *Labroides dimidiatus*	38.00	33	44.83	129

Appendix I. (continuation).

Family	Taxon	Counts	Rank	Weight (g)	Rank
	121 *Labropsis manabei*	7.33	88	14.63	181
	122 *Macropharyngodon meleagris*	17.00	55	464.05	28
	123 *Macropharyngodon negrosensis*	3.00	136	14.84	180
	124 *Pseudocheilinus evanidus*	4.67	113	5.17	216
	125 *Pseudocheilinus hexataenia*	16.17	57	15.81	173
	126 *Pseudocheilinus octotaenia*	0.67	211	0.34	261
	127 *Stethojulis bandanensis*	3.00	133	59.14	114
	128 *Stethojulis strigiventer*	3.33	128	44.67	130
	129 *Stethojulis trilineata*	10.50	71	343.68	35
	130 *Thalassoma amblycephala*	3.67	121	43.44	132
	131 *Thalassoma hardwicke*	19.00	49	408.85	31
	132 *Thalassoma janseni*	3.67	120	68.18	107
	133 *Thalassoma lunare*	28.00	41	1010.43	13
	134 *Thalassoma lutescens*	29.33	39	493.70	27
Lutjanidae					
	135 *Lutjanus decussatus*	3.00	135	79.48	98
	136 *Lutjanus fulvus*	0.50	221	53.08	120
	137 *Lutjanus kasmira*	25.00	46	340.15	36
	138 *Macolor macularis*	0.33	251	4.54	223
	139 *Macolor niger*	0.33	248	27.34	150
Microdesmidae					
	140 *Nemateleotris magnifica*	0.67	203	5.82	210
	141 *Ptereleotris evides*	31.67	37	129.87	69
Monacanthidae					
	142 *Amanses scopas*	1.00	192	20.96	159
	143 *Oxymonacanthus longirostris*	6.50	92	19.25	164
	144 *Paraluteres prionurus*	1.50	175	2.36	238
	145 *Pervagor aspricaudus*	1.33	178	1.96	241
Mullidae					
	146 *Parupeneus barberinoides*	5.00	107	74.98	101
	147 *Parupeneus barberinus*	7.83	84	331.81	38
	148 *Parupeneus trifasciatus*	5.00	109	117.69	74
	149 *Upeneus tragula*	2.00	159	47.37	128
Nemipteridae					
	150 *Pentapodus macrurus*	1.00	191	15.27	176
	151 *Scolopsis bilineatus*	29.00	40	545.79	25
	152 *Scolopsis ciliatus*	2.67	139	84.20	93
	153 *Scolopsis lineatus*	2.33	146	11.32	190
Ostraciidae					
	154 *Ostracion cubicus*	0.83	199	2.69	233
	155 *Ostracion meleagris*	1.00	197	5.26	214
	156 *Ostracion solorensis*	0.33	249	2.57	236
Pempheridae					
	157 *Pempheris oualensis*	2.67	140	64.42	110

Appendix 1. (continuation).

Family	Taxon	Counts	Rank	Weight (g)	Rank
Pinguipedidae					
158	*Parapercis clathrata*	13.67	64	880.11	16
159	*Parapercis cylindrica*	5.83	97	106.54	84
Plotosidae					
160	*Plotosus lineatus*	150.00	9	41.50	135
Pomacanthidae					
161	*Centropyge bicolor*	0.67	219	2.03	240
162	*Centropyge bispinosus*	10.33	72	21.79	158
163	*Centropyge colini?*	0.33	252	0.45	259
164	*Centropyge shepardi*	0.67	217	1.69	246
165	*Centropyge tibicen*	8.00	82	10.57	193
166	*Centropyge vroliki*	42.83	29	106.34	85
167	*Chaetodontoplus mesoleucus*	0.67	218	30.44	147
168	*Pygoplites diacanthus*	0.33	247	6.38	206
Pomacentridae					
169	*Amblyglyphidodon aureus*	7.50	86	125.72	71
170	*Amblyglyphidodon curacao*	15.50	59	109.51	81
171	*Amblyglyphidodon leucogaster*	203.67	5	1474.30	7
172	*Amphiprion clarkii*	13.83	62	284.13	42
173	*Amphiprion frenatus*	7.33	89	49.75	125
174	*Amphiprion melanopus*	7.00	91	114.02	78
175	*Amphiprion ocellaris*	2.50	144	10.75	191
176	*Chromis analis*	2.67	141	76.95	100
177	*Chromis atripes*	1.00	194	2.80	232
178	*Chromis caerulea*	1.33	177	5.70	212
179	*Chromis margaritifer*	10.67	69	142.60	65
180	*Chromis retrofasciata*	195.83	6	385.74	32
181	*Chromis ternatensis*	39.50	31	180.95	58
182	*Chromis vanderbilti*	0.33	245	0.69	256
183	*Chromis viridis*	101.50	15	179.65	59
184	*Chromis weberi*	0.33	244	2.54	237
185	*Chromis xanthura*	3.67	122	60.27	112
186	*Chrysiptera cyanea*	2.33	145	0.72	254
187	*Chrysiptera oxycephala*	2.33	147	1.16	250
188	*Chrysiptera reticulata*	0.33	262	0.15	264
189	*Chrysiptera rex*	150.17	8	117.06	75
190	*Chrysiptera rollandi*	62.83	18	17.09	169
191	*Chrysiptera talboti*	109.67	14	50.32	123
192	*Dascyllus reticulatus*	115.50	12	229.63	49
193	*Dascyllus trimaculatus*	6.17	95	4.59	222
194	*Neoglyphidodon melas*	5.67	100	59.65	113
195	*Neoglyphidodon nigroris*	112.83	13	1607.21	6
196	*Neoglyphidodon* sp.	0.33	263	1.22	249
197	*Plectroglyphidodon dickii*	6.00	96	13.92	184

Appendix 1. (continuation).

Family	Taxon	Counts	Rank	Weight (g)	Rank
198	*Plectroglyphidodon lacrymatus*	15.83	58	195.53	55
199	Pomacentrid A	15.00	61	22.58	157
200	*Pomacentrus alexanderae*	156.83	7	503.03	26
201	*Pomacentrus amboinensis*	25.83	43	37.62	137
202	*Pomacentrus bankanensis*	514.17	3	2331.05	2
203	*Pomacentrus brachialis*	38.17	32	327.06	40
204	*Pomacentrus chrysurus*	5.00	106	31.95	142
205	*Pomacentrus coelestis*	49.67	27	163.64	63
206	*Pomacentrus emarginatus?*	0.33	256	3.59	227
207	*Pomacentrus lepidogenys*	816.33	2	2308.04	3
208	*Pomacentrus moluccensis*	976.33	1	1814.96	5
209	*Pomacentrus nagasakiensis*	1.00	186	1.75	244
210	*Pomacentrus philippinus*	127.33	11	1099.63	11
211	*Pomacentrus simsiang*	0.33	239	0.22	263
212	*Pomacentrus* sp.	26.00	42	111.87	79
213	Pomacentrus sp. (from Myers)	5.33	102	43.30	134
214	Pomacentrus sp.2	2.67	142	20.37	161
215	*Pomacentrus stigma*	2.67	138	18.74	167
216	*Pomacentrus taeniometopon*	1.33	180	3.93	226
217	*Pomacentrus vaiuli*	346.00	4	1924.53	4
218	*Pomachromis richardsoni*	29.83	38	140.04	67
219	*Stegastes nigricans*	0.67	206	1.72	245
Priacanthidae					
220	*Priacanthus macracanthus*	0.67	202	114.81	77
Pseudochromidae					
221	*Ogilbyina queenslandiae*	4.33	115	142.01	66
222	Pseudochromid	3.32	130	4.94	219
223	*Pseudochromis porphyreus?*	0.33	232	3.05	229
Scaridae					
224	*Calotomus japonicus*	0.33	231	2.95	231
225	*Hipposcarus longiceps*	5.33	103	196.60	53
226	Scarid	13.50	65	69.03	105
227	Scarid dark	7.00	90	107.74	83
228	*Scarus bowersi*	2.33	151	128.24	70
229	*Scarus forsteni*	1.00	187	58.12	116
230	*Scarus frenatus*	2.00	154	25.40	152
231	*Scarus ghobban*	0.33	228	3.16	228
232	*Scarus globiceps*	3.50	125	328.39	39
233	*Scarus harid*	3.00	134	25.02	153
234	*Scarus microrhinus*	3.83	118	27.80	149
235	*Scarus niger*	5.00	108	105.61	86
236	*Scarus rivulatus*	1.33	179	88.35	91
237	*Scarus schlegeli*	8.00	83	59.13	115
238	*Scarus sordidus*	54.17	21	1223.27	10

Appendix 1. (continuation).

Family	Taxon	Counts	Rank	Weight (g)	Rank
239	*Scarus* sp.	0.67	215	16.51	171
Scorpaenidae					
240	*Dendrochirus zebra*	0.33	236	4.50	224
241	*Pterois antennata*	0.33	225	3.04	230
242	*Pterois volitans*	0.33	235	5.78	211
Serranidae					
243	*Anyperodon leucogrammicus*	0.50	223	33.74	140
244	*Cephalopholis boenack*	1.67	166	13.75	186
245	*Cephalopholis urodeta*	2.33	150	108.64	82
246	*Epinephelus fasciatus*	5.83	98	385.34	33
247	*Epinephelus merra*	3.33	129	185.68	57
Siganidae					
248	*Siganus corallinus*	0.67	204	4.63	221
249	*Siganus fuscescens*	4.67	112	20.41	160
250	*Siganus spinus*	5.00	110	44.25	131
251	*Siganus virgatus*	1.67	171	15.17	177
252	*Siganus vulpinus*	8.17	81	73.13	103
Syngnathidae					
253	*Doryrhamphus dactyliophorus*	0.33	234	17.30	168
254	*Hemitaurichthys polylepis*	0.67	210	14.90	179
Synodontidae					
255	*Saurida gracilis*	1.33	181	1.88	243
256	*Synodus binotatus*	0.33	238	6.79	201
257	*Synodus variegatus*	2.00	160	24.54	154
Tetraodontidae					
258	*Arothron nigropunctatus*	1.67	172	195.83	54
259	*Cantherhines pardalis*	0.33	237	5.06	218
260	*Canthigaster amboinensis*	2.00	161	13.41	188
261	*Canthigaster benetti*	2.83	137	8.37	197
262	*Canthigaster solandri*	9.33	74	50.44	122
263	*Canthigaster valentini*	4.00	117	19.36	163
Zanclidae					
265	*Zanclus cornutus*	34.17	35	798.22	21
Unidentified					
264	Juvenile (bw)	10.00	73	5.92	209
	Total counts/biomass	6416.49		50266.09	

Appendix 2. Two-way ordered table generated by TWINSPAN using abundance data of top 100 species.

No.	Sites Taxon	11 0b	5679	### aab	348		Feeding habits
92	*Oxymonacanthus longirostris*	--	11-2	-1-	---	111	Omnivore
80	*Apogon* sp.	--	-3--	---	---	111	Planktivore
73	Juvenile	--	--4-	---	---	111	Planktivore
61	Labrid sp.	-4	3---	---	---	111	Carnivore
60	Pomacentrid A	--	4---	---	---	111	Planktivore
51	*Caesio cuning*	-3	---4	---	---	111	Planktivore
49	*Chaetodon octofasciatus*	-2	1322	---	---	111	Coral feeder
46	*Lutjanus kasmira*	-5	----	---	---	111	Carnivore
44	*Cheilodipterus quinquelineatus*	1-	43-3	---	---	111	Planktivore
31	*Chromis ternatensis*	1-	3-25	1--	---	111	Planktivore
19	*Caesio trilineata*	--	552-	---	---	111	Planktivore
18	*Chrysiptera rollandi*	13	-415	---	---	111	Planktivore
6	*Chromis retrofasciata*	-3	5555	---	1--	111	Planktivore
94	*Plectorhinchus chaetodonoides*	12	11-1	---	1--	110	Carnivore
89	*Labropsis manabei*	11	1--2	-11	---	110	Coral feeder
86	*Amblyglyphidodon aureus*	21	1--1	1--	1--	110	Planktivore
81	*Siganus vulpinus*	-2	2-11	-1-	--1	110	Herbivore
79	*Pterocaesio pisang*	3-	----	--1	---	110	Planktivore
75	*Heniochus chrysostomus*	12	1112	11-	1--	110	Coral feeder
74	*Canthigaster solandri*	--	122-	---	2--	110	Carnivore
68	*Chaetodon trifasciatus*	22	1111	11-	---	110	Coral feeder
45	*Heniochus varius*	13	3222	11-	1--	110	Coral feeder
38	*Pomachromis richardsoni*	1-	51-1	1--	1--	110	Planktivore
30	*Plagiotremus laudandus*	-3	4114	-1-	2-2	110	Carnivore
15	*Chromis viridis*	--	5425	-4-	1--	110	Planktivore
14	*Chrysiptera talboti*	13	5444	---	51-	110	Planktivore
7	*Pomacentrus alexanderae*	45	14-5	11-	1--	110	Planktivore
5	*Amblyglyphidodon leucogaster*	55	5415	1--	4-1	110	Planktivore
35	*Zanclus cornutus*	13	2223	1-1	2-2	101	Omnivore
34	*Chaetodon baronessa*	-1	3333	-1-	223	101	Coral feeder
32	*Pomacentrus brachialis*	1-	-223	---	5--	101	Planktivore
26	*Labrichthys unilineatus*	12	4123	21-	322	101	Coral feeder
1	*Pomacentrus moluccensis*	45	5555	25-	545	101	Planktivore
96	*Plectroglyphidodon dickii*	1-	12--	11-	---	100	Planktivore
84	*Parupeneus barberinus*	12	-12-	111	---	100	Carnivore
78	*Hemigymnus fasciatus*	11	1111	11-	1--	100	Carnivore
69	*Chromis margaritifer*	1-	3---	2--	1--	100	Planktivore
59	*Amblyglyphidodon curacao*	13	11-1	13-	1--	100	Planktivore
56	*Diproctacanthus xanthurus*	11	211-	-3-	--2	100	Coral feeder
43	*Pomacentrus amboinensis*	1-	1331	1-3	2--	100	Planktivore
21	*Scarus sordidus*	21	2143	34-	--3	100	Herbivore
17	*Cirrhilabrus cyanopleura*	4-	3224	322	1--	100	Planktivore
13	*Neoglyphidodon nigroris*	55	3-13	241	2-2	100	Planktivore
11	*Pomacentrus philippinus*	44	4444	42-	1-4	100	Planktivore
9	*Plotosus lineatus*	5-	--5-	--5	---	100	Carnivore
100	*Neoglyphidodon melas*	1-	11--	11-	1--	011	Planktivore

Appendix 2. (continued)

98	*Parapercis cylindrica*	-1	-11-	111	---	011	Carnivore
95	*Dascyllus trimaculatus*	--	---2	1-1	---	011	Planktivore
93	*Ctenochaetus striatus*	-1	-11-	---	1-2	011	Herbivore
91	Scarid dark	-1	--1-	-21	---	011	Herbivore
87	*Halichoeres marginatus*	-1	--11	21-	-1-	011	Carnivore
77	*Gomphosus varius*	11	111-	11-	1-1	011	Carnivore
72	*Centropyge bispinosus*	1-	2---	211	---	011	Omnivore
58	*Plectroglyphidodon lacrymatus*	11	211-	22-	12-	011	Planktivore
53	*Pterocaesio tile*	--	3---	4--	---	011	Planktivore
52	*Halichoeres prosopeion*	13	2-12	111	112	011	Carnivore
48	*Thalassoma hardwicke*	-1	-211	33-	---	011	Planktivore
42	*Pomacentrus* sp.	-3	-2-2	231	---	011	Planktivore
36	*Halichoeres melanochir*	32	2111	222	--3	011	Carnivore
33	*Labroides dimidiatus*	22	3223	122	222	011	Carnivore
22	*Chaetodon kleinii*	31	2221	232	342	011	Coral feeder
16	*Halichoeres melanurus*	13	2233	331	442	011	Carnivore
12	*Dascyllus reticulatus*	11	-542	--5	53-	011	Planktivore
4	*Pomacentrus vaiuli*	55	4334	555	215	011	Planktivore
2	*Pomacentrus lepidogenys*	45	5555	552	545	011	Planktivore
64	*Halichoeres hortulanus*	1-	-22-	111	-12	010	Carnivore
62	*Amphiprion clarkii*	--	1211	1-1	13-	010	Planktivore
57	*Pseudocheilinus hexataenia*	1-	2-11	13-	121	010	Carnivore
50	*Acanthurus pyroferus*	-2	1112	112	123	010	Herbivore
28	*Zebrasoma scopas*	1-	4121	21-	422	010	Herbivore
24	*Chaetodon xanthurus*	-1	3321	-11	344	010	Coral feeder
20	*Ctenochaetus binotatus*	12	4122	222	4-3	010	Herbivore
10	*Ctenochaetus strigosus*	-3	5332	11-	554	010	Herbivore
99	*Naso lituratus*	--	-11-	211	1--	001	Carnivore
97	*Epinephelus fasciatus*	--	1-11	1--	112	001	Carnivore
90	*Amphiprion melanopus*	--	-1--	-1-	2--	001	Planktivore
85	*Paracirrhites arcatus*	1-	----	3--	1--	001	Carnivore
71	*Stethojulis trilineata*	-1	--1-	212	121	001	Carnivore
70	*Diploprion bifasciatus*	1-	-111	--1	13-	001	Carnivore
66	*Coris variegata*	1-	-11-	113	122	001	Carnivore
65	Scarid	--	---1	---	--4	001	Herbivore
63	*Parapercis clathrata*	--	-111	211	121	001	Carnivore
55	*Meiacanthus grammistes*	21	-11-	211	122	001	Carnivore
54	*Macropharyngodon meleagris*	--	121-	-11	123	001	Carnivore
47	*Acanthurus nigrofuscus*	11	-1--	32-	212	001	Herbivore
41	*Thalassoma lunare*	-1	1121	111	43-	001	Planktivore
40	*Scolopsis bilineatus*	11	-221	123	222	001	Carnivore
39	*Thalassoma lutescens*	-1	-111	31-	14-	001	Planktivore
29	*Centropyge vroliki*	1-	1111	131	442	001	Omnivore
25	*Halichoeres nebulosa*	-1	-121	314	153	001	Carnivore
23	*Cirrhitichthys falco*	--	122-	1-1	452	001	Carnivore
8	*Chrysiptera rex*	-1	1441	531	435	001	Planktivore
3	*Pomacentrus bankanensis*	11	155-	442	555	001	Planktivore
88	*Amphiprion frenatus*	-1	--1-	2-2	---	000	Planktivore
83	*Centropyge tibicen*	1-	----	211	2-1	000	Omnivore

Appendix 2. (continued)

82	*Scarus schlegeli*	--	----	-12	-2-	000	Herbivore
76	*Chaetodon punctatofasciatus*	21	----	31-	---	000	Coral feeder
67	*Chaetodon argentatus*	2-	----	311	---	000	Coral feeder
37	*Ptereleotris evides*	--	----	211	25-	000	Planktivore
27	*Pomacentrus coelestis*	--	----	-25	-1-	000	Planktivore
		00	0000	111	111		
		00	1111	000	111		
	Groupings	D	C	B	A		

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Assessment of Seagrass and Seaweed Communities in Lagonoy Gulf

by

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Bonga, D.A., M.J.M. Vega, S. de Jesus, L. Basmayor and G. Eva. 1995. Assessment of seagrass and seaweed communities in Lagonoy Gulf. *In* G. Silvestre, C. Luna, V. Soliman and L. Garces (eds.) Resource and ecological assessment of Lagonoy Gulf, Philippines. ICLARM Tech. Rep. 000, 000p.

Abstract

Data on the cover, frequency, dry standing crop and associated coastal features of 12 seagrass and seaweed communities in Lagonoy Gulf were collected. Ten species of seagrasses and 55 species of seaweeds were identified. Differences in the communities' ecological indices are attributed to salinity, depth, substrate composition and water movement. Mean dry standing crop range from 3.57 gm^{-2} to 200.23 gm^{-2}. *Enhalus acoroides* and *Halophila ovalis* exhibited a bimodal abundance, with highest values in May and November. On the other hand, abundance is low in August and high in May in the *Sargassum* spp. beds. Abundances in seagrasses is attributed to water temperature and nutrient runoff while that of *Sargassum* bed, to its phenology. A list of associated macrofauna in the seagrass/seaweed communities is presented.

Introduction

The seagrass and seaweed communities in Lagonoy Gulf comprise 4,751 ha, as indicated by a coastal resources map prepared by the National Mapping and Resource Information in 1987. These communities play an important ecological role in the balance of shallow-marine ecosystem and function as habitats and spawning and nursery sites to fishes and marine invertebrates.

The roles of seagrasses in the near-shore processes are well reported in the literature. These include reduction in water movement (Fonseca and Çahalan 1992, Fonseca et al. 1982); trapping and binding of sediments (Scoppin 1970) and organic detritus (Walker and McComb 1985); provision of stable surface for colonization by epiphytes (Harlin 1975); high rates of production (Hillman et al. 1989); contributions to herbivore and detrital foodchains (Klumpp et al. 1989, Harrison and Mann 1975); contribution of calcium carbonate by epiphyte deposition to sediments (Walker and Woelkerling 1988); and essential roles in nutrient trapping and recycling (Hemminga et al. 1991).

Seaweeds also contribute in growth and productivity of the reef ecosystem (Doty 1971). Carbonate sediments from calcareous algae contribute in the formation of reef and low islands. Other species are major nitrogen-fixing agents in this calcareous environment. They are important sources of organic compounds and energy on which other members of the food chain depend.

Baseline data and information is available on the present status of the seagrasses and seaweed communities at and in the vicinity of the submarine outfall of the Tiwi Geothermal Power Project in Albay (PGI 1993). The study recognized 7 species of seagrasses and 37 species of seaweeds.

This report summarizes the results of the assessment of seagrass and seaweed communities in Lagonoy Gulf. Their species composition, frequency , cover, standing crop, distribution and seasonality are discussed.

Methods

Study area

Twelve stations were surveyed during the sampling period from February to November, 1994 (Table 1). Four quarterly sampling surveys were conducted on seven stations. Nato, Busdak and Acal were surveyed thrice while Kalanaga and Batalay, once.

Sampling procedure

Two parallel 100-m transect lines were laid perpendicular to the shore at each site. Two 0.5 m x 0.5 m quadrat were dropped every 10 meters, one at each side of the transect. The percentage cover (C) and frequency (F) of each seagrass/macrobenthic algae found inside the quadrat were recorded following the method of Saito and Atobe (1970). Identification of samples were done to species level whenever possible.

Computation of ecological indices

The mean percentage frequency values of seagrasses and seaweeds were used for the computation of species ecological indices. In the computation of Shannon-Wiener general index of diversity (H), evenness (e) and dominance (D), natural logarithms were employed. Formulas for each index are based from Odum (1983).

Determination of water movement

Clod cards (calcium sulfate blocks) were used to measure the totality of natural factors that contribute to diffusion of materials through water movement caused by currents, wave action and other external influences present in the sampling sites (Fortes 1987). In May, 1994, three sets of two pre-weighed clod cards were deployed in each of 8 sites. They were retrieved after 24 hours, carefully rinsed in freshwater, thoroughly dried and weighed. The Diffusion Index Factor (DIF) was calculated as:

$$DIF = \frac{\text{weight loss of clod card in the field (Wi-Wf)(g)}}{\text{calibrated value K (g)}}$$

Due to logistical limitations, the clod cards were deployed only once in each site. Also, the clod cards were not deployed simultaneously but were distributed among the sites within one week. A sensitive analysis can be achieved with a simultaneous deployment done regularly for longer period.

Determination of dry standing crop

Dry standing crop were collected February and August to cover northeast and southwest monsoons, respectively. After estimating frequency and cover of each species, the plants were harvested, placed in sealed plastic bags and squirted with concentrated formalin to preserve the specimen. In the laboratory, each above ground parts of the plants were rinsed in fresh water, cleaned of adhering debris and epiphytes and sorted to species level. Each sorted plants were dried in an oven at $60^{o}C$ to constant weight.

Determination of seasonality of abundance

Stations with similar associated coastal features and sharing the same dominant species were grouped together. Three sites were distinctly separated from the arbitrary grouping because of their different features. Data from frequency and cover of the dominant species were used for the analysis. Data were transformed using arcsine transformation before a one-way or two-way ANOVA was done. Any significant differences were later on subjected to Tukey Test. A missing datum in Gaba was estimated by:

$$X_{ijl} = \frac{aA_i + bB_j - \sum_{i=1}^{a} \sum_{j=1}^{b} \sum_{l=1}^{n_{ij}} X_{ijl}}{N + 1 - a - b}$$

Attendant to such estimation is a slight modification in the analysis (Zar 1984).

Associated fauna

To determine species composition and density of associated fauna, one SCUBA diver swims along one side of the transect line used for the determination of frequency and cover. The survey was conducted using a belt transect (5 m width) method.

Results and Discussions

Of the 12 stations surveyed (Fig.1), 10 are mixed populations of seagrass and seaweed but are predominantly seagrasses. Two are *Sargassum* spp. beds with associated seaweeds (Table 1).

Species composition

Ten species of seagrasses and 55 species of seaweeds were identified (Appendices 1-4). Among the seaweeds, 27 species belong to Chlorophyta , 9 species to Phaeophyta and 19 species to Rhodophyta . The seagrasses *Cymodocea rotundata, Enhalus acoroides, Thalassia hemprichii, Halophila ovalis* and *H. minor* are the most common species, observed in eight stations. *Halophila spinulosa* is found only in Acal. Mean frequency and cover values show that *Syringodium isoetifolium* (F=25.83, C=8.96), *Cymodocea rotundata* (F=23.88, C=9.57), *Thalassia hemprichii* (F=20.76, C=9.46) and *Enhalus acoroides* (F=20.38, C=9.46) are the most abundant seagrasses. *Sargassum* sp. 1 (F=11.25, C=2.27) and *Halimeda* sp. (F=9.33, C=3.34), on the other hand, are the most abundant seaweeds.

Diversity

Table 1 shows the description of the sites surveyed. The seagrass/seaweed communities were associated with estuaries, coastal bays, leeward sides of islands, reef platforms and the mainland as these sites provide protection from rough weather conditions. The mean species richness, measured as the number of species per site, and the mean diversity indices across the sites ranged from 4.50 and 0.44 to 30.25 and 2.12 (Fig. 2, Appendix 5), respectively. However, both indices measured lowest in sites associated with estuary and coastal bays. This could be a function of low salinity and low water circulation in estuary and bays, respectively. Lee-Long et al. (1993), in similar study, accounted that low species richness at estuary-associated sites may be due to stresses caused by low salinity during monsoonal runoff periods or exposure at low tides. Both areas are characterized by muddy-sandy substrates and are almost exclusively dominated by *Enhalus acoroides*. Gaba has a mean dominance index of 0.76, Casolgan, 0.61 and Batalay, 0.44.

Agoho, Bitaogan, Rawis and San Pablo are island and reef associated sites with highest indices for species richness and diversity. This is probably a reflection of the general protection resulting from substrate stability (Bridges et al. 1982) and the shallow, high exposure nature of these sites provide. These sites have coarser sediments with shell fragments and dead corals, rocks and sand. They are dominated by *Cymodocea rotundata, Syringodium isoetifolium* and *Thalassia hemprichii.*

Acal, the deepest site, show intermediate to low species richness (13.25). Depth probably influences the seagrass/seaweed distribution in this site. Lee-Long et al. (1993) recorded decrease in species richness with an increase in depth. Also, the substrate at Acal is characterized by shifting sand. In areas with extensive sand spits, the shifting sand may be so rapid that seagrasses have little opportunity to develop (Bridges et al. 1982).

Acal is dominated by *Halophila ovalis* and *Halophila spinulosa. Halophila* species are found in shallow, high energy areas or in deep water. Their ability to grow in low light intensities may give this genus a competitive advantage over other species in deep or turbid waters (Young and Kirkman 1975, Josselyn et al. 1986, Lee-Long et al. 1993).

The *Sargassum* spp. beds in Nato and Busdak are typical of the wave-exposed, high energy communities. They have high species richness and diversity indices. Analysis of variance and Tukey tests ($p < .05$) showed that the mean diffusion factor of Nato is significantly higher than all remaining sites (Fig. 3). In terms of diffusion factor, the sites compare as follows:

Acal=Casolgan<Gaba<Rawis<Agoho=Alto=Bitaogan<Nato

Standing crop

The dry standing crop (gm^{-2}) collected in May and August is presented in Table 2 and Figure 4. Dry standing crop values include the calcium carbonate of the calcareous species (e.g. *Halimeda, Jania*, etc.). Nato had the highest standing crop (200.23 gm^{-2}) in the Gulf while Kalanaga had the lowest (3.57 gm^{-2}) . There was an increase in standing crop in August in Agoho, Casolgan, Rawis and Gaba. The seagrass *Enhalus acoroides* was the primary standing crop species in 44% of the sites surveyed.

Halimeda spp. contribute substantially (15.26 - 74.07 gm^{-2}) to the standing crop in reef associated sites in Agoho, Rawis and Bitaogan. The calcium carbonate component of *Halimeda* comprises up to 90% of dry weight (Drew and Abel 1983). Underscoring their importance in reef-building, Drew and Abel (1983) and Pitcher et al. (1992), noted that calcareous materials from dead *Halimeda* are quantitatively more important than the carbonate materials from corals and coralline red algae. Agoho, Rawis and Bitaogan are among the coral reef transect sites monitored in the Gulf.

Seasonality

Table 3 and 4 show the ANOVA and Tukey tests performed to assess the seasonality of dominant species in the sites. *Enhalus acoroides* and *Halophila ovalis* showed a bimodal abundance. It is significantly high in May and November but is low in February. Fortes (1986), reported that density in local seagrasses is generally bimodal, with highest values in summer (March - May) and in the wet season (July - November). This phenomenon could be a function both of increased water temperature in summer and nutrient runoff during the wet season. Lagonoy Gulf registered a mean of 28°C in February and 30°C in May (Santos et al. 1995). Larkum et al. (1984), Barber and Behrens (1985) and Thorne-Miller and Harlin (1984), showed that seagrass growth is a function of water temperature while Brouns and Heijs (1986) reported that leaf growth in *Enhalus acoroides* increase 1.8 mm/d for an increase of 1°C in water temperature.

Lagonoy Gulf experiences the wet season in November to February. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) station in Virac , Catanduanes recorded high precipitation during October to December (350-437 mm/month) and low precipitation during February to April (90-118 mm/month). Incidental to a pronounced rainfall is an increase in the volume of land and river run-offs and thence to an increase in nutrients that will be made available to the seagrass/seaweed communities.

Halophila spinulosa also showed significant increase in abundance in May and a decrease in February. *Syringodium isoetifolium*, however, showed an inverse effect to an increase in water temperature. It registered low abundance in May and an increase in August. McMillan (1984), reported that *Syringodium* is the least tolerant to high temperature while the most tolerant are *Enhalus* and *Halodule*.

Abundances for *Sargassum* beds is high in May and low in August. Similar results were obtained in Calauag Bay (EPAI 1993), where standing crop of *Sargassum* was lowest in August, increasing in November to February and reaching a peak in May. The low standing crop in

August is the senescence and die-back stage of the bed. This seasonality is also reflected by frequency and cover data.

The analyses also showed that *Enhalus acoroides* is more abundant in Gaba than in Casolgan and that *Cymodocea rotundata* and *Syringodium isoetifolium* are more abundant in Agoho and Bitaogan than in Rawis.

Trends in temporal variation of the ecological indices (Fig.5) show a reflection on the variation of species richness and the seasonality of abundances. Acal, Casolgan-Gaba and Agoho-Bitaogan-Rawis groups, which show significant temporal differences in their dominant species' abundances, exhibited high diversity indices in February. This coincides with low abundances and higher species richness. This indicates that the ephemeral and more opportunistic species take advantage of the availability of space and light (EPAI 1993). A reversal of trend is markedly exhibited in May, when the dominance indices are also at its highest.

In sites where abundance of their dominant species did not exhibit variation, high diversity indices coincided in May when both light and water temperature are at their optimum level for growth.

Faunal associates

A list of macrofauna associated with the 12 seagrass/seaweed communities is shown in Table 5. Echinodermata, mollusca and porifera are the most commonly surveyed taxonomic groups (Fig. 6). Consistently, Gaba, showed highest macrofaunal density among the stations for three sampling periods (Fig. 7).

Conclusion

Majority of the surveyed sites in the 4,751 ha seagrass and seaweed communities are seagrass habitats, two are Sargassum beds. These communities are associated with areas that provide protection from rough weather conditions. The range of dry standing crop (3.57 - 200.23 gm^{-2}) compare well with those obtained from five sites in the Philippines with sizeable areas of seagrass meadows (total dry leaf biomass = 8.00 - 132.15 gm^{-2}, Rollon and Fortes 1989). Generally, the seagrasses are abundant during summer (May) and wet (November) seasons while the Sargassum beds reaches a peak (in terms of frequency and cover) in May. Most of the associated fauna are commonly used as food and as raw materials for the shellcraft industry.

Baseline information about the distribution, seasonality and associated fauna are important parameters for management and conservation of the seagrass and seaweed habitats. Inevitably, several areas of seagrass/seaweed habitat along the Lagonoy Gulf coastline face potential development. Such activity must be tied to a sustainable resource management.

Table 1. Seagrass and seaweed sampling stations.

Sampling Station	Date surveyed	Latitude	Longitude	Substrate	Exposure	Depth (m)	Dominant seagrass/seaweed species
Batalay	17 Mar 94			sandy-muddy	estuary	3	*Enhalus acoroides*
Casolgan	18 Feb 94 21 May 94 26 Aug 94 14 Nov 94	13° 21.60 N	123° 50.90 E	sandy-muddy	embayment	2	*Enhalus acoroides*
Gaba	24 Feb 94 21 May 94 30 Aug 94 15 Nov 94	13° 17.04 N	123° 58.97 E	sandy-muddy	embayment	2	*Enhalus acoroides*
Kalanaga	23 Feb 94	13° 15.65 N	124° 01.74 E	sandy-muddy	embayment	2	*Halodule pinifolia*
Agoho	02 Dec 94 21 Feb 94 23 May 94 28 Aug 94 21 Nov 94	13° 35.93 N	124° 03.17 E	rocky-sandy	island and reef associated	1-2	*Cymodocea rotundata* *Syringodium isoetifolium*
Bitaogan	22 Feb 94 23 May 94 29 Aug 94 21 Nov 94	13° 33.41N	124° 19.02 E	rocky-sandy	island and reef associatted	1-2	*Cymodocea rotundata* *Syringodium isoetifolium*
Rawis	17 Feb 94 19 May 94 26 Aug 94 13 Nov 94	13° 24.47N	123° 46.14 E	rocky-sandy	island and reef associated	1-2	*Cymodocea rotundata* *Syringodium isoetifolium*
Busdak	22 May 94 30 Aug 94 14 Nov 94	13° 20.04 N	123° 55.23 E	rocky-corally	reef associated	4	*Sargassum sp.1*
Nato	24 May 94 27 Aug 94 13 Nov 94	13° 36.29 N	123° 33.22 E	rocky-sandy	reef associated	4	*Sargassum sp.1*
Acal	23 Feb 94 29 Aug 94 15 Nov 94	13° 13.50 N	124° 06.51 E	sandy	island associated	8	*Halophila ovalis* *Halophila spinulosa*
Alto	01 Dec 94 20 Feb 94 24 May 94 27 Aug 94	13° 42.11 N	123° 32.57 E	rocky-sandy	mainland associated	4	*Halodule uninervis*
San Pablo	19 Mar 94 25 May 94 26 Aug 94 26 Nov 94	13° 20.14 N	123° 54.61 E	rocky-sandy	island associated	1-2	*Thallasia hemprichii*

Table2. Mean standing crop (gm/m2) in seagrass/seaweed sites.

Ranking	Site	Mean standing crop (gm/m^2)	1^o standing crop species (% standing crop relative to the bed)
1	Nato	200.23	*Sargassum spp.* (95.44)
2	Busdak	190.87	*Sargassum spp.* (87.47)
3	Agoho	178.66	*Halimeda spp.* (74.07)
4	Rawis	112.72	*Halimeda spp.* (15.26) *Sargassum spp.* (28.23)
5	Bitaogan	82.02	*Halimeda spp.* (41.58)
6	Gaba	51.15	*Enhalus acoroides* (72.71)
7	Casolgan	44.59	*Enhalus acoroides* (91.46)
8	Alto	31.08	*Halodule uninervis* (58.86)
9	Batalay	19.48	*Enhalus acoroides* (98.20)
10	Acal	18.49	*Enhalus acoroides* (38.45)
11	San Pablo	16.95	*Thalassia hemprichii* (74.84)
12	Kalanaga	3.57	*Enhalus acoroides* (66.59)

Table 3. Two-way ANOVA and Tukey test for frequency and cover of dominant species in the sites.

Groupings	Dominant Species	Parameter	Period	Station	Interaction	Tukey (p<.05)
Casolgan-Gaba	*Enhalus acoroides*	Frequency Cover	2.37 ^{ns} 19.55**	8.73* 14.53*	1.39^{ns} 3.30 ^{ns}	Casolgan<Gaba Feb=Aug<May=November Casolgan<Gaba
Busdak-Nato	*Sargassum sp.1*	Frequency Cover	38.87 ** 19.24 *	.003 ^{ns} .623 ^{ns}	9.95 * 10.77 *	Aug<May Aug<May
Rawis-Agoho-Bitaogan	*Cymodocea rotundata*	Frequency Cover	1.70 ^{ns} 1.29 ^{ns}	21.01* * 12.07* *	1.62 ^{ns} 1.56 ^{ns}	Rawis<Agoho=Bitaogan Rawis<Agoho=Bitaogan
	Syringodium isoetifolium	Frequency Cover	5.90 * 5.95 *	23.88* * 42.16* *	1.61 ^{ns} 2.63 ^{ns}	May<Aug Rawis<Agoho=Bitaogan May<Aug Rawis<Agoho<Bitaogan

** - highly significant (p< .01)
* - significant (p< .05)
ns - not significant

Table 4. One-way ANOVA and Tukey test for frequency and cover of dominant species in the sites.

Site	Dominant Species	Parameter	Period	Tukey (p<.05)
Acal	*Halophila ovalis*	Frequency Cover	5.60 ^{ns} 16.36*	Feb<May=Aug=November
	Halophila spinulosa	Frequency Cover	8.48 ^{ns} 9.64 *	Feb<May
Alto	*Halodule uninervis*	Frequency Cover	0.67 ^{ns} 2.57 ^{ns}	
San Pablo	*Thalassia hemprichii*	Frequency Cover	0.56^{ns} 1.45 ^{ns}	

* - significant (p< .05)
ns - not significant

Table 5. Faunal associates in seagrass/seaweed communities.

Mollusca		**Echinodermata**	**Coelenterata/Cnidaria**
Anadara antiquata	*Mitra conularis*	*Acanthaster planci*	*Actinodendron* sp.
Angaria delphinula	*Mitra exasperatum*	*Actinophyga echinites*	*Aglaonema* sp.
Angaria sphaerula	*Mitra eremitarum*	*Actinopyga miliaris*	*Cassiopea* sp.
Astracea calcar	*Mitra verrucosa*	*Astropyga radiata*	*Halocordyle* sp.
Atrina sp.	*Modiolus metcalfei*	*Bohadschia marmorata*	*Isis* sp.
Atys naucum	*Oliva annulata*	Comasteridae	*Lobophyton* sp.
Aulicina vespertilio	*Oliva carneola*	*Culcita novae-guinea*	*Nepthya* sp.
Barbatia sp.	*Octopus* sp.	*Diadema setosum*	*Radianthus* sp.
Bursa rubeta	*Ostrea hyotis*	*Echinometra oblonga*	*Sarcophyton trocheliophorum*
Cardium hemicardium	*Pinna* sp.	*Echinometra matthei*	*Sinularia* sp.
Cerithium sp.	*Placenta sella*	*Echinometra picta*	*Spirobranchus* sp.
Circe scripta	*Polinices tumidus*	*Echinotrix calamaris*	
Chicoreus brunneus	*Pinctada margaritifera*	*Echinotrix diadema*	**Annelida**
Conus ammiralis	*Peristernia* sp.	*Holothuria coluber*	*Amphitrite* sp.
Conus betulinus	*Pteria* sp.	*Holothuria rigida*	*Sabellastarte* sp.
Conus generalis	*Pteria signata*	*Holothuria scabra*	*Spirobranclus* sp.
Conus lividus	*Pyrene flava*	*Linckia laevigata*	
Conus litteratus	*Pyrene punctada*	*Mespilia globulus*	**Platyhelminthes**
Conus magus	*Raphia* sp.	*Nardoa tuberculata*	*Notoplana* sp.
Conus marmoreus	*Rhinoclavis nobilis*	*Ophiocoma* sp.	
Conus miles	*Sepioteuthis lessoniana*	*Ophidiaster granifer*	**Nemertinea**
Conus mustelinus	*Spondylus* sp.	*Ophiodesoma grisea*	*Baseodiscus* sp.
Conus quercinus	*Spondylus barbatus*	*Ophiodesoma glabra*	
Conus omaria	*Strombus aurisdianae*	*Oreaster nodosus*	**Tunicates**
Conus striatus	*Strombus urceus*	*Pentaceropsis tyloderma*	*Polycarpa* sp.
Cymatium nicobaricum	*Tectus fenestrus*	*Phyllacanthus imperialis*	*Didemnum* sp.
Cyprea arabica	*Tectus pyramis*	*Salmacis sphaeroides*	
Cyprea errones	*Tellina* sp.	*Synapta maculata*	**Porifera**
Cyprea lutea	*Trachycardium* sp.	*Toxopneustes chlorocanthus*	*Aphysilla sulfurea*
Cyprea lynx	*Trachycardium egmontianum*	*Tripneustes gratilla*	*Dysidea fragilis*
Cyprea vitellus	*Tridacna crocea*		
Distorsio anus	*Tridacna squamosa*	**Crustacea**	**Bryozoa**
Dolabella auricularis	*Trochus maculatus*	*Calappa* sp.	Bryozoan
Glycemeris violacens	*Turbo chryostomus*	*Dronia erythopus*	
Isognomon isognomon	*Vasum ceramicum*	*Dromidis* sp.	
Lambis lambis	*Vasum turbinellus*	*Gonodactylus* sp.	
Lopha cristagalli	*Vexillum caffrum*	*Pagurus* sp.	
Maleus maleus	*Vexillum plicardium*	*Portunus pelagicus*	
		Stenopus hispidus	

Appendix 1.

Mean percentage frequency and cover of seagrasses in Lagonoy Gulf, February 1994.

	Casolgan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Kalanaga		Batalay		Acal		Gaba		Mean	
SPECIES	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Potamogetonacea																						
Cymodocea rotundata	0.00	0.00	53.09	10.02	0.28	0.11	64.73	18.43	74.00	26.31	16.73	4.05	0.00	0.00	0.73	0.21	16.00	5.01	0.37	0.22	22.59	6.43
Cymodocea serrulata	0.00	0.00	2.64	0.21	35.27	9.80	33.28	11.61	46.09	16.30	2.73	1.49	0.00	0.00	0.00	0.00	5.55	1.28	0.00	0.00	12.55	4.07
Enhalus acoroides	38.82	7.67	0.00	0.00	0.00	0.00	22.10	6.61	11.28	4.48	52.91	27.06	2.91	0.96	22.55	10.65	5.54	2.23	66.82	21.73	22.29	8.14
Halodule pinifolia	0.00	0.00	0.00	0.00	2.00	0.22	0.00	0.00	0.73	0.11	1.27	0.21	66.91	23.65	0.00	0.00	9.09	5.97	0.00	0.00	8.00	3.01
Halodule uninervis	0.00	0.00	9.82	2.03	96.46	46.45	14.64	3.62	25.55	5.86	39.27	12.36	0.00	0.00	36.18	7.45	26.82	5.86	0.00	0.00	24.87	8.36
Syringodium isoetifolium	0.00	0.00	57.55	7.78	11.73	3.84	78.00	20.35	75.64	26.31	0.00	0.00	0.00	0.00	0.00	0.00	12.18	1.71	0.00	0.00	23.51	6.00
Hydrocharitaceae																						
Halophila minor	0.00	0.00	0.00	0.00	1.36	0.64	0.09	0.11	1.00	0.43	5.45	1.28	0.91	0.11	0.00	0.00	6.00	1.39	6.64	1.28	2.15	0.52
Halophila ovalis	2.45	0.85	20.19	3.41	5.45	1.07	8.09	2.03	20.64	3.52	33.82	9.80	1.27	0.32	0.00	0.00	27.73	5.01	0.00	0.00	11.96	2.60
Halophila spinulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.09	1.92	0.00	0.00	0.91	0.19
Thalassia hemprichii	17.55	3.83	40.00	10.76	2.37	0.00	41.64	10.65	15.73	6.18	34.00	14.48	0.00	0.00	0.00	0.00	15.55	3.09	14.64	5.97	18.15	5.50

Appendix 1. (continued)

Mean percentage frequency and cover of seaweeds in Lagonoy Gulf, February 1994.

SPECIES	Casolgan F	Casolgan C	Rawis F	Rawis C	Alto F	Alto C	Agoho F	Agoho C	Bitaogan F	Bitaogan C	San Pablo F	San Pablo C	Kalanaga F	Kalanaga C	Batalay F	Batalay C	Acal F	Acal C	Gaba F	Gaba C	Mean F	Mean C
CHLOROPHYTA																						
Ulvales																						
Enteromorpha sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.91	3.62	3.64	2.03	0.00	0.00	0.85	0.56
Enteromorpha clathrata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladophorales																						
Chaetomorpha sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.55	3.41	0.00	0.00	0.45	0.34
Siphonocladales																						
Avrainvillea lacerata	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Boergesenia forbesii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.64	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.05
Caulerpa lentillifera	0.00	0.00	1.37	0.43	0.00	0.00	0.00	0.00	2.73	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.09
Caulerpa peltata	0.00	0.00	0.37	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03
Caulerpa racemosa	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.05
Caulerpa serrulata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caulerpa sertularoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorodesmis comosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Codium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.37	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.03
Dictyosphaeria sp.	0.00	0.00	0.55	0.75	0.00	0.00	2.64	2.03	2.09	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.35
Halimeda macroloba	0.00	0.00	0.00	0.00	0.00	0.00	19.45	3.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	1.95	0.37
Halimeda opuntia	0.00	0.00	10.36	1.91	0.00	0.00	19.36	4.79	0.00	0.00	3.82	2.12	0.00	0.00	0.00	0.00	0.64	0.11	0.00	0.00	3.42	0.89
Halimeda sp.	0.00	0.00	1.09	0.21	0.00	0.00	0.00	0.00	8.37	3.20	0.18	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.36
Halimeda tuna	0.00	0.00	0.91	0.22	0.00	0.00	4.45	1.49	6.91	2.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.39
Udotea sp.	0.00	0.00	3.00	0.64	0.00	0.00	0.46	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.10
Valonia aegagropila	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.22	1.46	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.07
Valonia ventricosa	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.11	0.55	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.05
Dasycladales																						
Acetabularia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.43	2.36	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.09
Bornetella nitida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.27	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.15
Halicoryne wrightii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05
Neomeris sp.	0.00	0.00	0.09	0.11	4.91	1.49	4.18	1.17	1.28	0.75	0.55	0.43	1.55	0.43	0.00	0.00	0.00	0.00	0.09	0.11	1.26	0.45

Appendix .. (continued)

Mean percentage frequency and cover of seaweeds in Lagonoy Gulf, February 1994. (continued)

SPECIES	Casolgan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Kalanaga		Batalay		Acal		Gaba		Mean	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
PHAEOPHYTA																						
Dictyotales																						
Dictyota dichotoma	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dictyota sp.	0.00	0.00	0.00	0.00	0.36	0.21	0.00	0.00	0.00	0.00	0.36	0.43	0.00	0.00	0.00	0.00	0.64	0.43	0.00	0.00	0.14	0.11
Padina japonicum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04
Padina minor	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.21	0.00	0.00	0.20	0.04
Padina sp.	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	4.18	0.75	0.36	0.43	0.00	0.00	0.36	0.43	0.00	0.00	0.00	0.00	0.50	0.17
Fucales																						
Hormophysa sp.	0.00	0.00	0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02
Sargassum sp.1	0.00	0.00	16.91	12.36	1.36	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.83	1.30
Sargassum sp.2	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Turbinaria sp.	0.00	0.00	2.36	1.81	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.19
RHODOPHYTA																						
Nemaliales																						
Actinotrichia fragillis	0.00	0.00	2.46	1.07	0.00	0.00	0.00	0.00	0.82	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.14
Galaxaura sp.	0.00	0.00	0.00	0.00	0.55	0.32	0.00	0.00	0.18	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.06
Liagora sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.21	0.00	0.00	0.19	0.07
Gelidiales																						
Gelidiella acerosa	0.00	0.00	0.91	0.43	0.00	0.00	0.00	0.00	0.82	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.06
Cryptonemiales																						
Amphiroa foliacea	0.00	0.00	8.00	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.17
Amphiroa fragilissima	0.00	0.00	4.91	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.13
Lithothamnium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mastophora rocea	0.00	0.00	3.82	0.96	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.11
Halymenia sp.	0.00	0.00	0.36	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03
Jania sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gigartinales																						
Euchema sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gracilaria sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.11	0.00	0.00	0.02	0.01
Hypnea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceramiales																						
Laurencia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 2.

Mean percentage frequency and cover of seagrasses in Lagonoy Gulf, May 1994.

SPECIES	Casolgan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Busdak		Nato		Acal		Gaba		Mean	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Potamogetonacea																						
Cymodocea rotundata	0.00	0.00	24.82	10.54	2.64	1.81	78.82	31.11	76.36	29.83	37.64	13.85	0.00	0.00	0.00	0.00	1.09	0.32	0.00	0.00	22.14	8.75
Cymodocea serrulata	0.00	0.00	0.00	0.00	52.27	17.25	10.64	2.55	32.91	13.85	23.82	9.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.96	4.31
Enhalus acoroides	60.64	41.55	0.00	0.00	0.00	0.00	16.82	6.49	4.36	2.23	31.73	16.19	0.00	0.00	0.00	0.00	4.91	2.77	71.00	40.05	18.95	10.93
Halodule pinifolia	0.00	0.00	0.09	0.11	0.00	0.00	0.73	0.11	2.82	0.74	0.00	0.00	0.00	0.00	0.00	0.00	3.18	0.53	0.00	0.00	0.68	0.15
Halodule uninervis	0.00	0.00	36.45	12.68	97.36	58.17	7.00	1.81	30.55	6.60	24.36	8.95	0.00	0.00	0.00	0.00	22.36	6.18	0.00	0.00	21.81	9.44
Syringodium isoetifolium	0.00	0.00	2.73	0.64	39.55	13.64	64.82	17.36	81.36	39.63	62.18	21.31	0.00	0.00	0.00	0.00	3.45	0.53	0.00	0.00	25.41	9.31
Hydrocharitaceae																						
Halophila minor	1.09	0.22	0.00	0.00	0.73	0.21	0.73	0.43	2.73	0.64	0.45	0.21	0.00	0.00	0.00	0.00	11.27	4.26	0.73	0.21	1.77	0.62
Halophila ovalis	2.55	0.64	51.64	13.74	1.18	0.21	3.00	1.06	22.45	5.96	16.36	5.11	0.00	0.00	0.00	0.00	81.82	40.38	0.00	0.00	17.90	6.71
Halophila spinulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46.36	25.14	0.00	0.00	4.64	2.51
Thalassia hemprichii	1.09	0.75	43.18	15.13	0.00	0.00	39.45	11.50	14.91	7.77	56.00	24.18	0.00	0.00	0.00	0.00	0.27	0.11	0.09	0.11	15.50	5.95

Appendix 2. (continued)

Mean percentage frequency and cover of seaweeds in Lagonoy Gulf, May 1994.

SPECIES	Casolgan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Busdak		Nato		Acal		Gaba		Mean	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
CHLOROPHYTA																						
Ulvales																						
Enteromorpha sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01
Enteromorpha clathrata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Cladophorales																						
Chaetomorpha sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.21	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.03
Siphonocladales																						
Avrainvillea lacerata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boergesenia forbesii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.21	0.00	0.00	0.73	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.03
Caulerpa lentilifera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
Caulerpa peltata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	2.36	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.12
Caulerpa racemosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.43	2.55	1.92	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.23
Caulerpa serrulata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.53	0.00	0.00	0.00	0.00	0.13	0.05
Caulerpa sertularoides	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.42	0.09	0.11	0.00	0.00	0.27	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.06
Chlorodesmis comosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01
Codium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Dictyosphaeria sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.32	7.64	3.51	0.00	0.00	0.27	0.32	0.91	0.32	0.00	0.00	0.00	0.00	0.91	0.45
Halimeda macroloba	0.00	0.00	0.00	0.00	0.00	0.00	2.36	1.06	0.45	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.13
Halimeda opuntia	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.43	0.36	0.21	0.00	0.00	0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.07
Halimeda sp.	0.00	0.00	0.45	0.11	0.00	0.00	31.55	10.01	14.36	5.11	44.45	17.58	5.18	2.23	4.45	1.59	0.00	0.00	0.00	0.00	10.05	3.66
Halimeda tuna	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03
Udotea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.32	0.00	0.00	0.00	0.00	1.00	0.85	0.09	0.11	0.00	0.00	0.00	0.00	0.14	0.13
Valonia aegagropila	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.06
Valonia ventricosa	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.21	0.82	0.53	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.08
Dasycladales																						
Acetabularia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.04
Bornetella nitida	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.32	1.00	0.53	0.00	0.00	0.27	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.11
Halicoryne wrightii	0.36	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.11	0.06
Neomeris sp.	0.18	0.11	0.00	0.00	13.18	3.61	0.27	0.32	1.09	0.85	0.09	0.11	0.00	0.00	0.82	0.32	0.00	0.00	0.18	0.21	1.58	0.55

Appendix [illegible] continued)

Mean percentage frequency and cover of seaweeds in Lagonoy Gulf, May 1994. (continued)

SPECIES	Casolgan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Busdak		Nato		Acal		Gaba		Mean	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
PHAEOPHYTA																						
Dictyotales																						
Dictyota dichotoma	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.11	0.00	0.00	0.00	0.00	0.02	0.01
Dictyota sp.	0.82	0.32	0.00	0.00	4.73	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.43	0.00	0.00	0.00	0.00	0.63	0.23
Padina japonicum	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Padina minor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Padina sp.	0.00	0.00	0.00	0.00	0.18	0.21	0.00	0.00	0.82	0.32	0.09	0.11	0.27	0.21	10.00	3.83	0.00	0.00	0.00	0.00	1.14	0.47
Fucales																						
Hormophysa sp.	0.00	0.00	0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.45	1.92	8.36	3.41	0.00	0.00	0.00	0.00	1.20	0.54
Sargassum sp.1	0.55	0.21	14.45	12.15	1.55	0.53	0.00	0.00	0.00	0.00	0.36	0.11	83.82	59.98	72.91	46.77	0.00	0.00	0.00	0.00	17.36	11.97
Sargassum sp.2	0.00	0.00	4.55	3.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.27	13.64	0.00	0.00	0.00	0.00	0.00	0.00	2.38	1.70
Turbinaria sp.	0.00	0.00	0.00	0.00	0.45	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.05
RHODOPHYTA																						
Nemaliales																						
Actinotrichia fragillis	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	6.64	2.76	1.00	0.43	0.82	0.53	1.91	0.85	0.00	0.00	0.00	0.00	1.05	0.47
Galaxaura sp.	0.00	0.00	0.00	0.00	1.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.21	0.73	0.64	0.00	0.00	0.00	0.00	0.24	0.13
Liagora sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Gelidiales																						
Gelidiella acerosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	3.18	0.74	2.73	1.92	0.00	0.00	0.00	0.00	0.60	0.28
Cryptonemiales																						
Amphiroa foliacea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphiroa fragilissima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.11	1.82	0.43	0.55	0.11	0.00	0.00	0.00	0.00	0.25	0.06
Lithothamnium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.55	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.17
Mastophora rocea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.32	0.00	0.00	2.27	1.17	4.73	1.70	0.00	0.00	0.00	0.00	0.75	0.32
Halymenia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jania sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Gigartinales																						
Euchema sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01
Gracilaria sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.21	0.00	0.00	0.00	0.00	0.45	0.11	0.00	0.00	0.00	0.00	0.08	0.03
Hypnea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.21	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03
Ceramiales																						
Laurencia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.18	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.05

Appendix :

Mean percentage frequency and cover of seagrasses in Lagonoy Gulf, August 1994.

SPECIES	Casolagan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Busdak		Nato		Acal		Gaba		Mean	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Potamogetonacea																						
Cymodocea rotundata	0.45	0.21	60.55	30.25	7.55	1.92	66.45	22.58	77.45	31.21	29.73	9.37	0.00	0.00	0.00	0.00	2.55	0.74	0.09	0.11	30.60	12.05
Cymodocea serrulata	0.00	0.00	6.55	1.60	46.00	14.06	20.45	6.28	23.27	6.60	0.18	0.11	0.00	0.00	0.00	0.00	0.82	0.21	0.00	0.00	12.16	3.61
Enhalus acoroides	50.09	17.25	3.91	1.60	0.00	0.00	18.73	5.11	7.82	3.08	1.00	0.43	0.00	0.00	0.00	0.00	16.09	7.46	52.00	22.58	18.70	7.19
Halodule pinifolia	0.00	0.00	0.00	0.00	1.55	0.32	0.55	0.21	5.82	1.60	0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.28
Halodule uninervis	1.09	0.21	4.91	3.51	94.00	52.20	22.82	4.58	19.55	5.11	14.73	4.05	0.00	0.00	0.00	0.00	4.55	0.85	0.00	0.00	20.20	8.81
Syringodium isoetifolium	0.00	0.00	70.45	28.66	0.00	0.00	75.18	25.14	94.18	35.05	6.27	2.45	0.00	0.00	0.00	0.00	9.09	1.17	0.00	0.00	31.90	11.56
Hydrocharitaceae																						
Halophila minor	0.00	0.00	0.09	0.11	0.00	0.00	0.18	0.11	0.36	0.21	0.00	0.00	0.00	0.00	0.00	0.00	10.45	2.34	0.00	0.00	1.39	0.35
Halophila ovalis	7.45	1.28	12.00	3.29	7.09	1.49	13.91	3.30	10.27	2.98	42.18	10.65	0.00	0.00	0.00	0.00	55.18	25.78	0.00	0.00	18.51	6.10
Halophila spinulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.55	5.75	0.00	0.00	2.44	0.72
Thalassia hemprichii	10.36	5.32	52.64	25.35	0.00	0.00	49.55	21.20	21.73	7.56	63.64	26.31	0.00	0.00	0.00	0.00	12.09	4.37	11.18	3.62	27.65	11.72

Appendix 3. (continued)

Mean percentage frequency and cover of seaweeds in Lagonoy Gulf, August 1994.

SPECIES	Casolgan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Busdak		Nato		Acal		Gaba		Mean	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
CHLOROPHYTA																						
Ulvales																						
Enteromorpha sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Enteromorpha clathrata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.09	0.11	0.45	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.05
Ulva sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Cladophorales																						
Chaetomorpha sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.05
Siphonocladales																						
Avrainvillea lacerata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.73	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.07
Boergesenia forbesii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.05
Caulerpa lentilifera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caulerpa peltata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.07
Caulerpa racemosa	0.00	0.00	0.73	0.21	0.00	0.00	0.27	0.21	1.36	0.43	0.00	0.00	0.91	0.43	0.18	0.11	0.00	0.00	0.00	0.00	0.43	0.17
Caulerpa serrulata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.18	0.11	0.09	0.11	0.00	0.00	0.00	0.00	0.05	0.04
Caulerpa sertularoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorodesmis comosa	0.00	0.00	0.36	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01
Codium edule	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.11	0.00	0.00	0.45	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08
Codium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01
Dictyosphaeria sp.	0.00	0.00	0.73	0.32	0.09	0.11	0.18	0.21	1.82	1.28	0.18	0.21	4.73	2.13	0.55	0.43	0.00	0.00	0.00	0.00	1.03	0.58
Halimeda macroloba	0.00	0.00	0.55	0.21	0.00	0.00	0.55	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.07
Halimeda opuntia	0.00	0.00	1.73	0.85	0.00	0.00	0.09	0.11	0.27	0.32	0.00	0.00	0.91	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.23
Halimeda sp.	0.00	0.00	17.73	4.47	0.00	0.00	54.73	20.88	9.27	2.87	0.09	0.11	5.27	2.02	0.91	0.32	0.00	0.00	2.00	0.85	11.25	3.94
Halimeda tuna	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.32	0.18	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.07
Udotea sp.	0.00	0.00	2.45	0.85	0.00	0.00	0.00	0.00	0.27	0.32	0.00	0.00	7.27	2.66	0.09	0.11	0.00	0.00	0.00	0.00	1.26	0.49
Valonia aegagropila	0.00	0.00	0.91	0.43	0.00	0.00	4.18	1.91	1.55	0.85	0.00	0.00	4.27	2.45	0.09	0.11	0.00	0.00	0.00	0.00	1.38	0.72
Valonia ventricosa	0.00	0.00	0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
Dasycladales																						
Acetabularia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.21	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04
Bornetella nitida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.36	0.96	0.27	0.11	0.18	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.16
Bornetella spherica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.03
Halicoryne wrightii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.11	0.00	0.00	0.09	0.11	0.00	0.00	0.03	0.03
Neomeris sp.	0.09	0.11	0.45	0.21	0.36	0.43	0.18	0.21	0.00	0.00	0.09	0.11	0.36	0.43	0.36	0.43	0.09	0.11	0.27	0.32	0.28	0.29

Appendix 3. (continued)

Mean percentage frequency and cover of seaweeds in Lagonoy Gulf, August 1994.

SPECIES	Casolgan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Busdak		Nato		Acal		Gaba		Mean	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
PHAEOPHYTA																						
Dictyotales																						
Dictyota dichotoma	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.53	0.27	0.21	0.00	0.00	2.82	0.96	0.00	0.00	0.47	0.21
Dictyota sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.09	0.11	0.00	0.00	0.45	0.32	0.45	0.32	0.00	0.00	0.00	0.00	0.14	0.11
Padina japonicum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Padina minor	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03
Padina sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.11	0.00	0.00	1.64	0.74	0.00	0.00	0.27	0.11	0.27	0.12
Fucales																						
Hormophysa sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.64	0.82	0.43	0.00	0.00	0.00	0.00	0.20	0.13
Sargassum sp.1	0.00	0.00	13.09	6.50	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	46.82	21.09	60.45	41.12	0.00	0.00	0.00	0.00	15.06	8.60
Sargassum sp.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.21	0.00	0.00	0.00	0.00	0.05	0.03
Turbinaria sp.	0.00	0.00	0.73	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.21	0.09	0.11	0.09	0.11	0.00	0.00	0.19	0.13
RHODOPHYTA																						
Nemaliales																						
Actinotrichia fragillis	0.00	0.00	5.91	1.92	0.00	0.00	0.00	0.00	0.82	0.64	0.00	0.00	5.09	1.81	0.55	0.32	0.00	0.00	0.00	0.00	1.55	0.59
Galaxaura sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.45	1.28	0.36	0.32	0.00	0.00	0.00	0.00	0.35	0.20
Liagora sp.	0.00	0.00	0.27	0.11	0.00	0.00	0.00	0.00	1.45	0.64	0.00	0.00	2.09	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.23
Gelidiales																						
Gelidiella acerosa	0.00	0.00	2.09	0.64	0.00	0.00	1.36	0.43	1.09	0.64	0.09	0.11	4.36	2.02	1.00	0.43	0.00	0.00	0.00	0.00	1.25	0.53
Cryptonemiales																						
Amphiroa foliacea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphiroa fragilissima	0.00	0.00	2.73	1.60	0.00	0.00	0.09	0.11	1.55	0.74	0.00	0.00	6.00	2.66	1.82	0.74	0.00	0.00	0.00	0.00	1.52	0.73
Lithothamnium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.11
Mastophora rocea	0.00	0.00	3.45	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.82	1.70	5.36	1.81	0.00	0.00	0.00	0.00	1.45	0.58
Chondrococcus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04
Halymenia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jania sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.43	0.36	0.21	0.00	0.00	0.00	0.00	0.13	0.08
Gigartinales																						
Euchema sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gelidiopsis sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.01	0.01
Gracilaria sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hypnea esperi	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Hypnea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceramiales																						
Acanthopora sp.	0.00	0.00	1.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.64	0.11	0.00	0.00	0.00	0.00	0.24	0.04
Laurencia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.08

Appendix 4.

Mean percentage frequency and cover of seagrasses in Lagonoy Gulf, November, 1994.

SPECIES	Casolgan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Busdak		Nato		Acal		Gaba		Mean	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Potamogetonacea																						
Cymodocea rotundata	0.82	0.21	8.27	5.33	0.00	0.00	79.45	39.31	71.73	43.79	34.18	15.02	15.82	3.83	0.00	0.00	0.18	0.11	0.00	0.00	26.31	13.45
Cymodocea serrulata	0.00	0.00	2.45	0.53	0.00	0.00	1.45	0.53	15.73	6.50	20.18	4.47	3.36	1.92	0.00	0.00	0.00	0.00	0.00	0.00	5.40	1.74
Enhalus acoroides	55.36	23.43	0.64	0.11	0.00	0.00	18.00	5.00	6.82	2.44	40.55	18.42	8.73	2.02	0.00	0.00	2.82	2.13	69.64	50.71	25.32	13.03
Halodule pinifolia	0.00	0.00	1.18	0.32	0.00	0.00	0.18	0.11	6.64	2.77	2.82	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35	0.53
Halodule uninervis	1.27	0.32	37.27	12.25	0.00	0.00	6.27	1.06	14.73	3.19	43.09	12.25	18.18	3.94	0.00	0.00	1.45	0.53	0.00	0.00	15.28	4.19
Syringodium isoetifolium	0.00	0.00	13.27	4.15	0.00	0.00	63.18	19.81	78.55	43.36	24.55	7.99	48.45	14.06	0.00	0.00	3.00	0.96	0.00	0.00	28.88	11.29
Hydrocharitaceae																						
Halophila minor	0.09	0.11	0.18	0.11	0.00	0.00	0.00	0.00	0.36	0.21	1.36	0.64	0.00	0.00	0.00	0.00	2.27	0.74	0.00	0.00	0.53	0.23
Halophila ovalis	3.09	0.53	12.82	4.68	0.00	0.00	9.64	1.49	12.27	3.83	22.82	5.53	25.91	4.79	0.00	0.00	67.73	28.55	0.00	0.00	19.28	6.18
Halophila spinulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.00	13.10	0.00	0.00	3.50	1.64
Thalassia hemprichii	12.55	2.02	30.45	8.84	0.00	0.00	29.91	14.16	33.64	12.36	63.91	19.71	40.45	13.21	0.00	0.00	0.45	0.11	6.73	4.26	27.26	9.33

Appendix 4. inued)

Mean percentage frequency and cover of seaweeds in Lagonoy Gulf, November, 1994.

SPECIES	Casolgan F	Casolgan C	Rawis F	Rawis C	Alto F	Alto C	Agoho F	Agoho C	Bitaogan F	Bitaogan C	San Pablo F	San Pablo C	Busdak F	Busdak C	Nato F	Nato C	Acal F	Acal C	Gaba F	Gaba C	Mean F	Mean C
CHLOROPHYTA																						
Ulvales																						
Enteromorpha sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Enteromorpha clathrata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ulva sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladophorales																						
Chaetomorpha sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01
Siphonocladales																						
Avrainvillea lacerata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boergesenia forbesii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01
Caulerpa lentilifera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Caulerpa peltata	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.53	0.00	0.00	0.00	0.00	0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.08
Caulerpa racemosa	0.00	0.00	0.00	0.00	0.00	0.00	2.36	1.28	0.09	0.11	0.00	0.00	0.55	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.20
Caulerpa serrulata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.21	0.00	0.00	0.09	0.11	0.27	0.11	0.00	0.00	0.00	0.00	0.16	0.05
Caulerpa sertularoides	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.53	0.18	0.21	0.00	0.00	0.36	0.21	1.00	0.43	0.00	0.00	0.00	0.00	0.34	0.17
Chlorodesmis comosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Codium edule	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.21	0.00	0.00	0.00	0.00	0.05	0.03
Codium sp.	0.00	0.00	0.36	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.73	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.11
Dictyosphaeria sp.	0.00	0.00	0.64	0.53	0.09	0.11	0.18	0.11	2.45	1.17	0.55	0.11	0.91	0.85	0.09	0.11	0.00	0.00	0.00	0.00	0.61	0.37
Halimeda macroloba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.27	0.11	0.00	0.00	0.04	0.01
Halimeda opuntia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.64	2.88	2.55	1.28	0.00	0.00	0.00	0.00	0.00	0.00	1.77	0.52
Halimeda sp.	0.00	0.00	5.27	1.17	0.00	0.00	39.18	18.43	8.82	4.68	49.73	20.35	9.73	2.76	4.18	2.02	0.00	0.00	0.00	0.00	14.61	6.18
Halimeda tuna	0.45	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.21	0.00	0.00	0.13	0.04
Udotea sp.	0.00	0.00	3.09	0.64	0.00	0.00	0.18	0.21	0.45	0.11	0.00	0.00	7.00	2.44	0.82	0.32	0.00	0.00	0.00	0.00	1.44	0.46
Valonia aegagropila	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.53	0.09	0.11	0.64	0.43	5.09	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.29
Valonia ventricosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Dasycladales																						
Acetabularia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.21	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.04
Bornetella nitida	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.21	0.27	0.21	0.00	0.00	0.36	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.11
Bornetella spherica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03
Halicoryne wrightii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Neomeris sp.	2.09	0.64	0.00	0.00	0.36	0.43	0.73	0.53	0.00	0.00	0.09	0.11	1.00	0.96	0.09	0.11	0.09	0.11	0.00	0.00	0.56	0.36
PHAEOPHYTA																						
Dictyotales																						
Dictyota dichotoma	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dictyota sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.55	6.82	0.00	0.00	1.64	0.53	0.00	0.00	2.02	0.92
Padina japonicum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Padina minor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01
Padina sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.64	0.09	0.11	0.00	0.00	0.00	0.00	0.16	0.09

Appendix 4. (continued)

Mean percentage frequency and cover of seaweeds in Lagonoy Gulf, November, 1994.

	Casolgan		Rawis		Alto		Agoho		Bitaogan		San Pablo		Busdak		Nato		Acal		Gaba		Mean	
SPECIES	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Fucales																						
Hormophysa sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.45	1.81	1.00	2.56	0.00	0.00	0.00	0.00	0.43	0.55
Sargassum sp.1	0.00	0.00	17.27	11.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.64	10.01	73.73	49.64	0.55	0.21	0.00	0.00	13.77	8.94
Sargassum sp.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turbinaria sp.	0.00	0.00	0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.91	2.02	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.27
RHODOPHYTA																						
Nemaliales																						
Actinotrichia fragillis	0.00	0.00	3.18	0.85	0.00	0.00	0.55	0.32'	1.00	0.74	0.73	0.43	0.82	0.74	0.91	0.53	0.00	0.00	0.00	0.00	0.90	0.45
Galaxaura sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	1.18	0.43	0.00	0.00	0.00	0.00	0.16	0.07
Liagora sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03
Gelidiales																						
Gelidiella acerosa	0.00	0.00	1.64	0.64	0.00	0.00	0.00	0.00	2.45	1.38	0.00	0.00	1.09	0.64	0.36	0.11	0.00	0.00	0.00	0.00	0.69	0.35
Cryptonemiales																						
Amphiroa foliacea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphiroa fragilissima	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.36	0.43	0.00	0.00	0.73	0.43	0.36	0.32	0.00	0.00	0.00	0.00	0.19	0.16
Lithothamnium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mastophora rocea	0.00	0.00	4.55	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.21	6.00	2.45	0.00	0.00	0.00	0.00	1.40	0.48
Chondrococcus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Halymenia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jania sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gigartinales																						
Euchema sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gelidiopsis sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gracilaria sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.04
Hypnea esperi	0.00	0.00	0.00	0.00	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Hypnea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.04
Ceramiales																						
Acanthopora sp.	0.00	0.00	0.36	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01
Digenea simplex													1.09	0.43								
Laurencia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 5.

Ecological Indeces

	February	May	August	November	MEAN
CASOLGAN					
# of species	3	8	6	8	6.25
Shannon	0.77	0.49	0.87	0.91	0.76
Evenness	0.7	0.11	0.48	0.44	0.43
Dominance	0.53	0.81	0.55	0.56	0.61
RAWIS					
# of species	24	10	27	19	20
Shannon	2.23	1.69	2.15	2.19	2.07
Evenness	0.7	0.73	0.65	0.74	0.71
Dominance	0.15	0.21	0.17	0.15	0.17
ALTO					
# of species	13	13	8		11.33
Shannon	1.29	1.45	1.02		1.25
Evenness	0.5	0.57	0.49		0.52
Dominance	0.41	0.3	0.45		0.39
AGOHO					
# of species	20	20	22	20	20.5
Shannon	2.17	1.86	2.04	1.86	1.98
Evenness	0.72	0.62	0.66	0.62	0.66
Dominance	0.15	0.2	0.16	0.2	0.18
BITAOGAN					
# of species	29	33	31	28	30.25
Shannon	2.27	2.17	2.04	2	2.12
Evenness	0.67	0.62	0.59	0.6	0.62
Dominance	0.15	0.17	0.2	0.2	0.18
SAN PABLO					
# of species	13	18	19	17	16.75
Shannon	1.83	2.06	1.51	2.18	1.9
Evenness	0.71	0.71	0.51	0.77	0.68
Dominance	0.19	0.14	0.27	0.13	0.18
BUSDAK					
# of species		26	30		28
Shannon		1.55	2.18		1.87
Evenness		0.48	0.64		0.56
Dominance		0.41	0.24		0.33
NATO					
# of species		16	21	15	17.33
Shannon		1.37	1	0.79	1.05
Evenness		0.49	0.33	0.29	0.37
Dominance		0.45	0.64	0.94	0.68
ACAL					
# of species	18	9	13	13	13.25
Shannon	2.37	1.44	1.82	1.15	1.69
Evenness	0.82	0.66	0.71	0.45	0.66
Dominance	0.12	0.31	0.23	0.45	0.28
GABA					
# of species	5	5	6	2	4.5
Shannon	0.73	0.09	0.65	0.3	0.44
Evenness	0.46	0.06	0.36	0.43	0.33
Dominance	0.6	0.97	0.65	0.84	0.76
KALANAGA					
# of species	6				
Shannon	0.43				
Evenness	0.24				
Dominance	0.83				
BATALAY					
# of species	5				
Shannon	0.97				
Evenness	0.6				
Dominance	0.44				

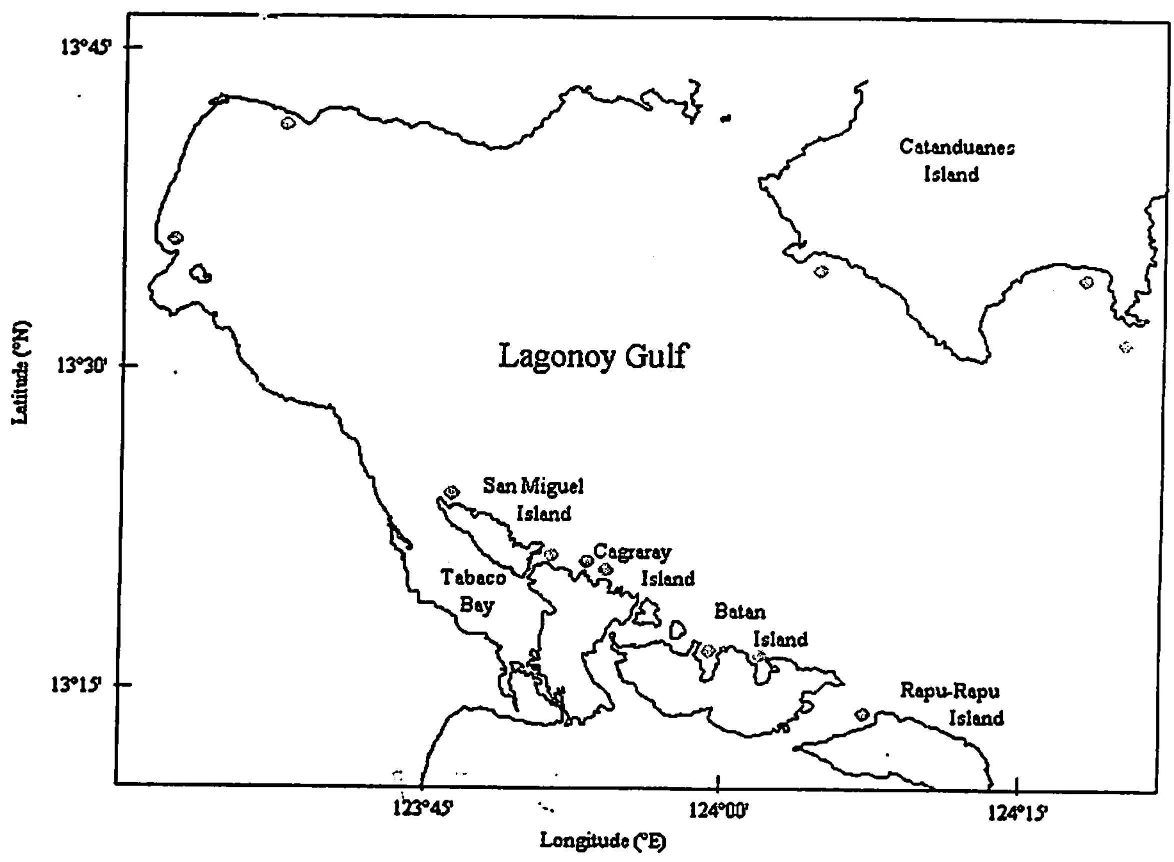


Fig.1. Transect stations for assessment of seagrass and agal beds.

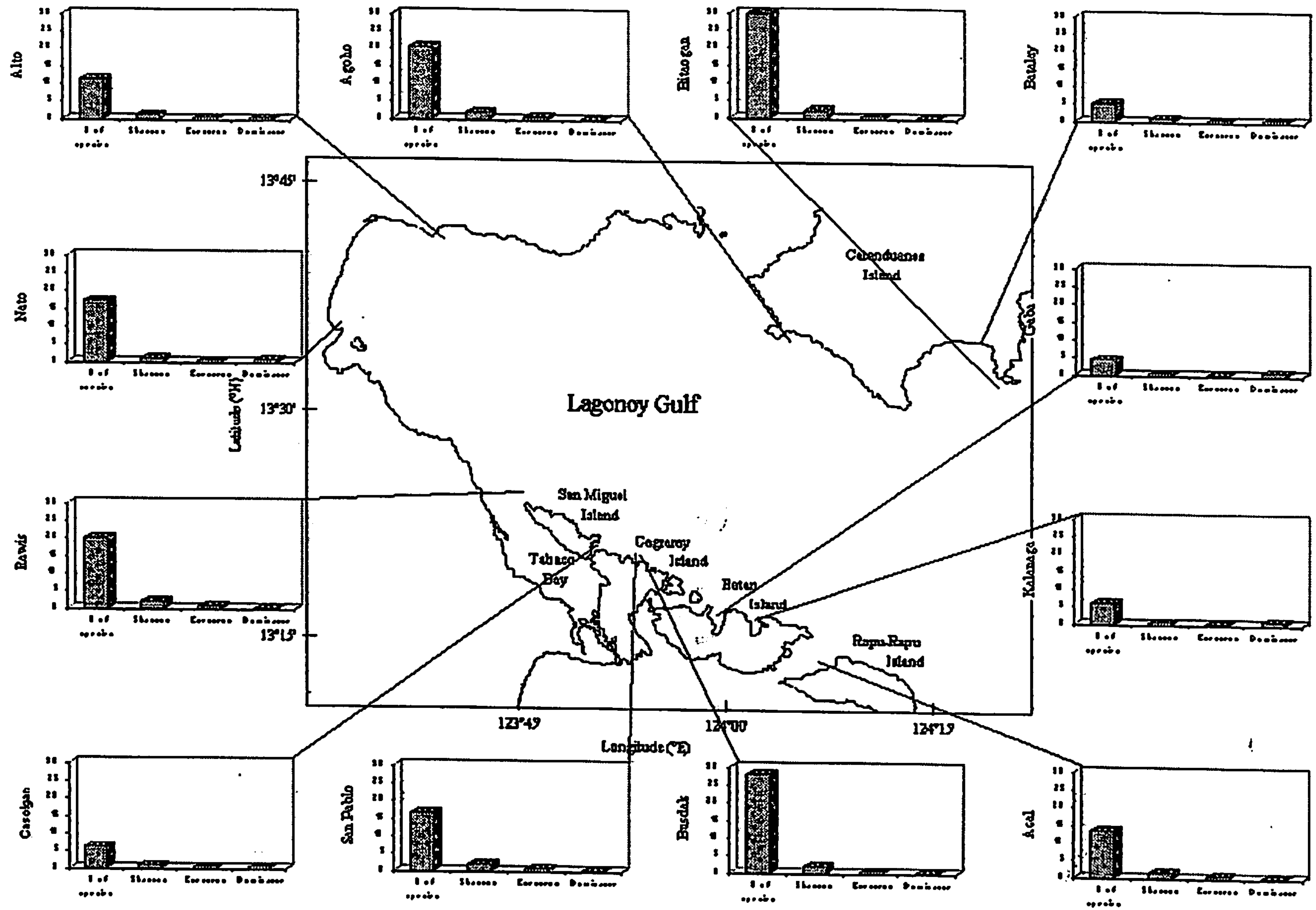


Fig.2. Diversity across sites.

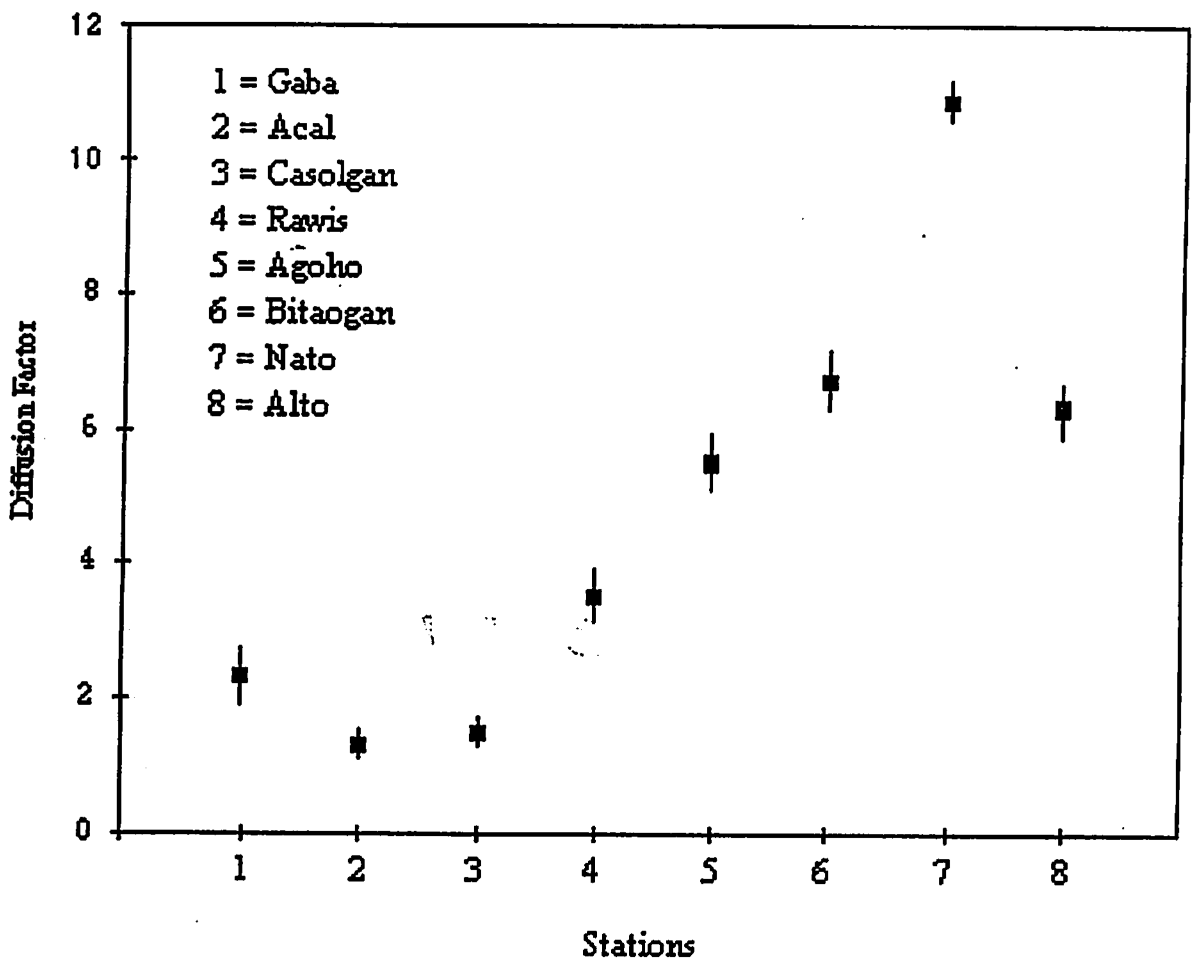


Fig 3. Mean diffusion Factor (+/sd) at different seaweed/seagrass sampling stations.

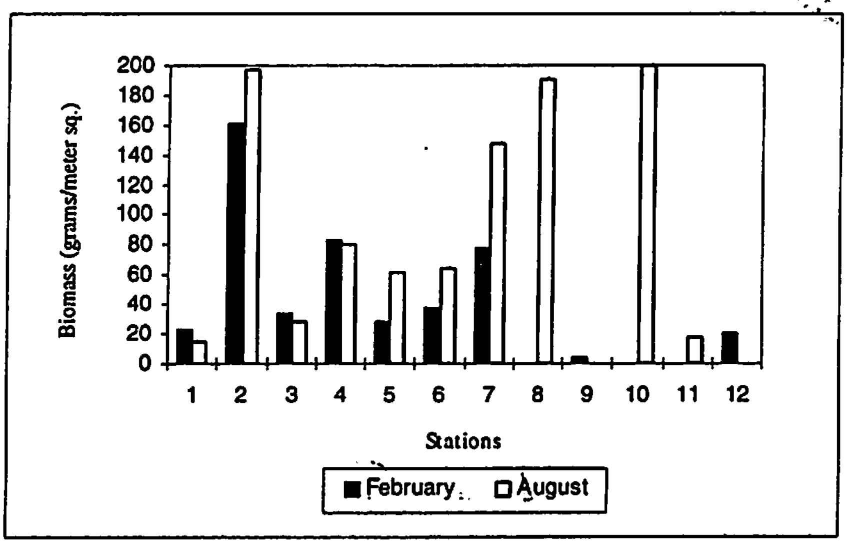


Fig. 4. Biomass (grams/meter sq.) at seagrass/seaweed sites in Lagonoy Gulf. (1=Acal; 2=Agoho; 3=Alto; 4=Bitaogan; 5=Casolgan; 6=Gaba; 7=Rawis; 8=Busdak; 9=Kalanaga; 10=Nato; 11=San Pablo; 12=Batalay)

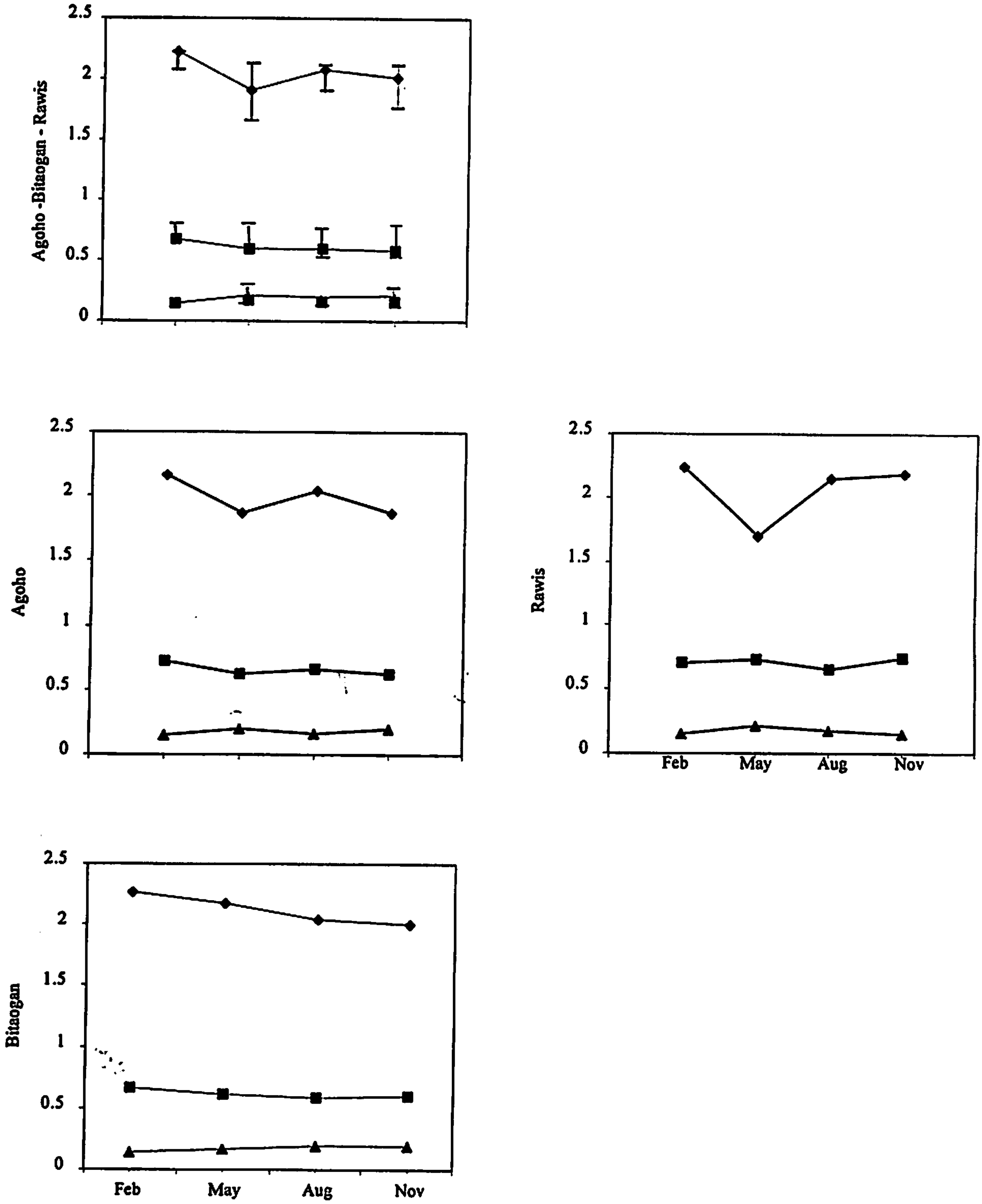


Fig. 5. Temporal variation in ecological indices across sites.

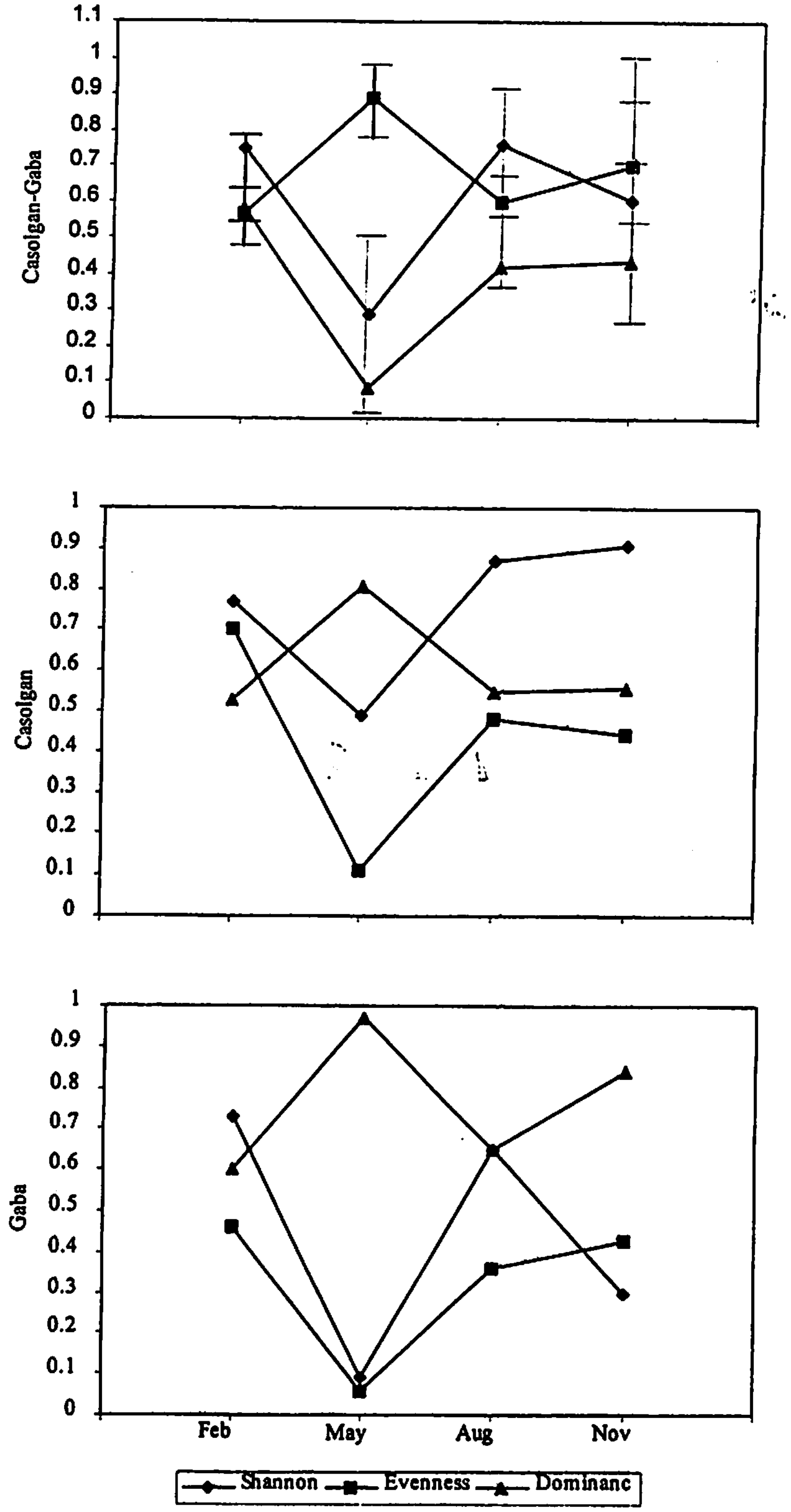
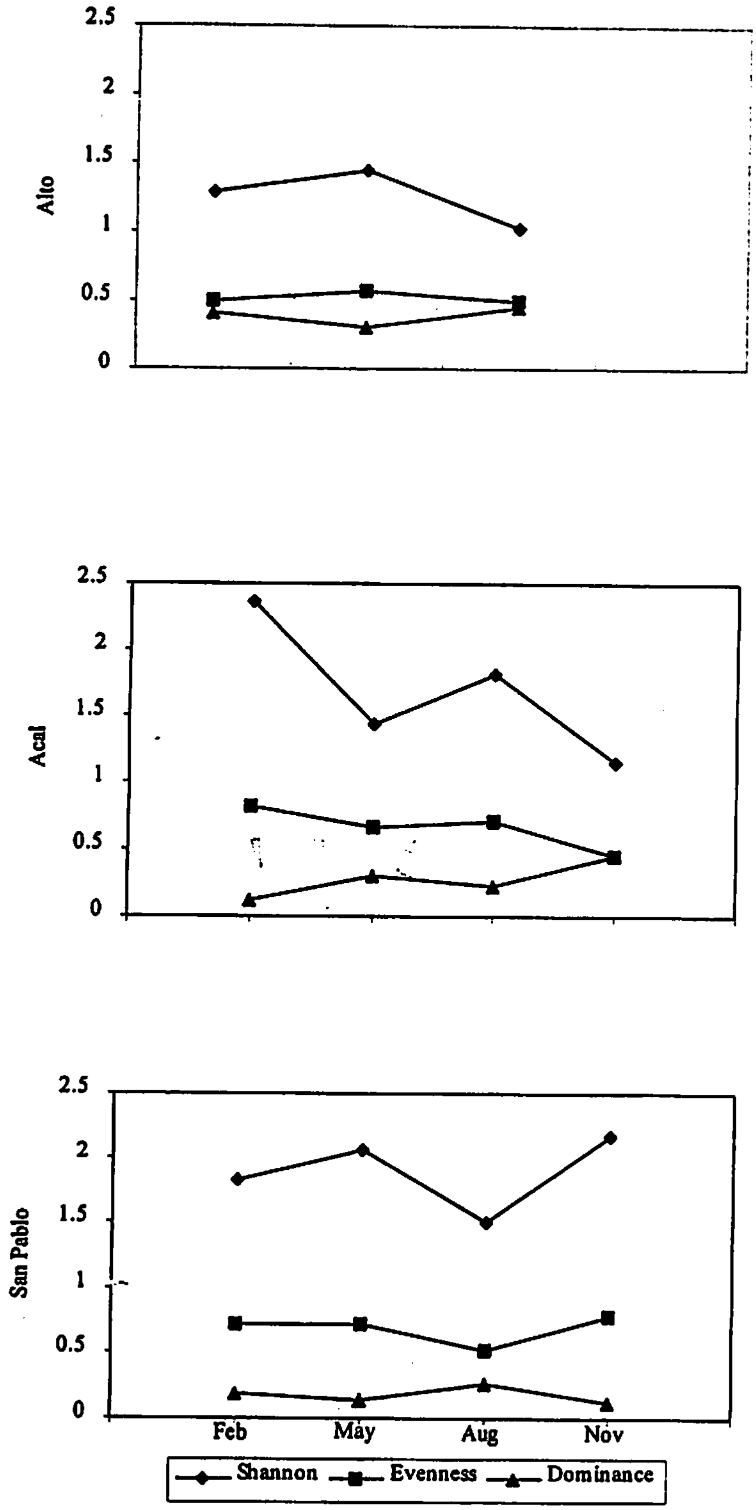


Fig. 5. (continuation)



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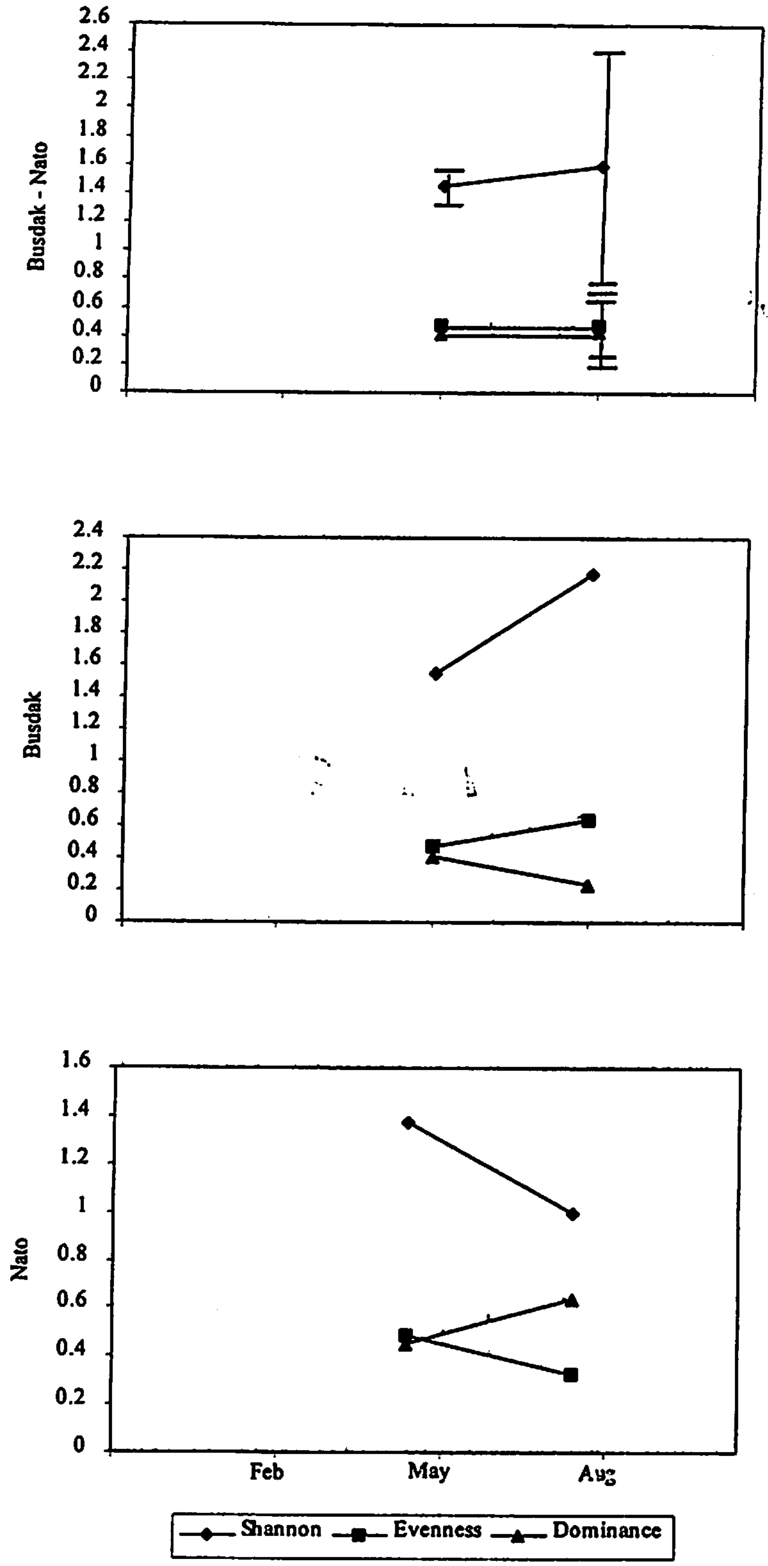

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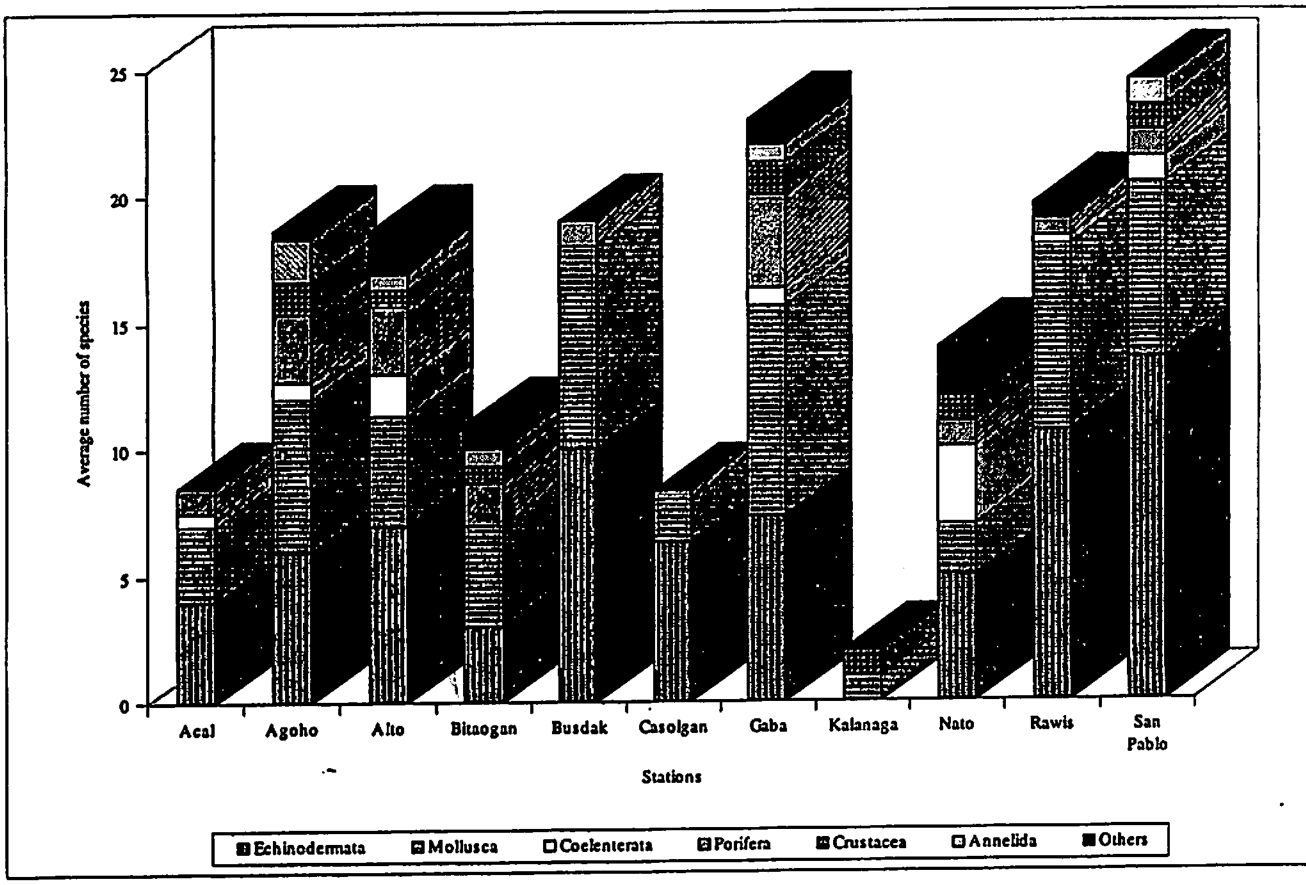

Fig. 6. Average number of major macrofaunal taxa across sites.

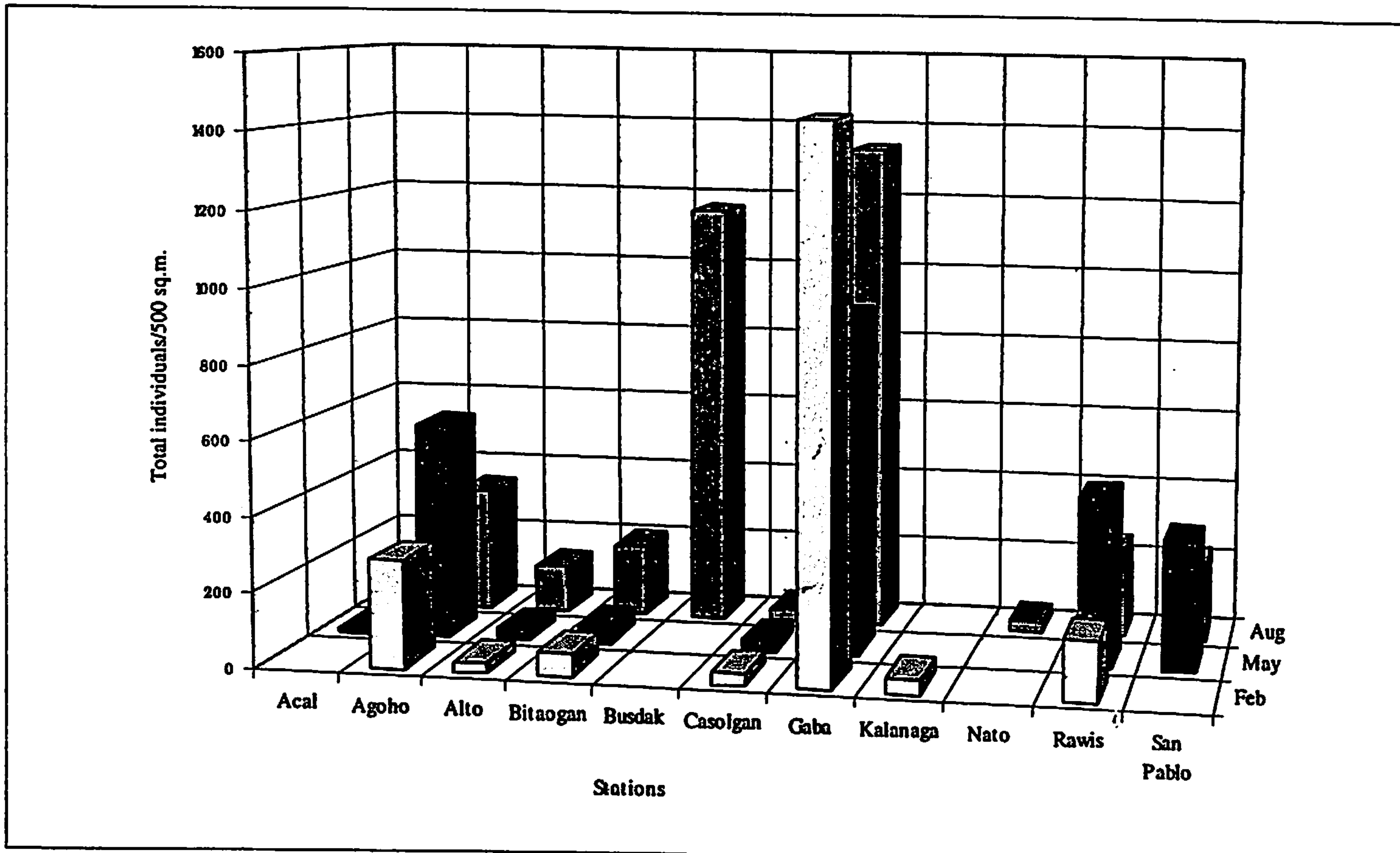

Fig. 7. Temporal variation in macrofaunal density across sites.

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Assessment of Mangroves in Lagonoy Gulf

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Abstract

Ten species of mangroves were identified in a survey of six stations in Lagonoy Gulf. *Avicennia marina* was present in all stations. The station at Nato exhibited the highest diversity despite considerable dominance by *A. officinalis*. Analysis of available maps indicates that the present mangrove cover of 1,316.09 ha represents 66% of the cover in the 1950s. About 59% of the existing mangroves cannot be more than 30 years old. A preliminary analysis indicated that about 1,256 ha are suitable for mangrove reforestation.

Introduction

The term "mangrove" refers either to the constituent plant species of tropical intertidal forests or the community itself (Tomlinson 1986). This habitat performs a variety of ecological functions. It imports inorganic nutrients from land and exports organic matter to the sea (Christensen 1982). Mangroves contribute to water quality maintenance by extracting nutrients from circulating waters, thus minimizing the eutrophication potential of nearshore waters. Mangrove sediments have a limited ability to sequester and detoxify common pollutants (Snedaker and Getter 1985). The effects of strong winds and waves on coastal areas are buffered by mangroves, which are particularly advantageous during typhoons. They also slow down freshwater runoff from land and thus stabilize nearshore salinity (Birkeland and Grosenbaugh 1985).

Some commercial fish species spend entire or parts of their life cycles in waters next to mangroves. In San Miguel Bay, 42% of trawl-caught fish landed at survey sites are known dwellers of mangrove areas. This suggests the importance of mangroves as a supporting habitat for fisheries (Vega et al., in press).

Mangroves are also sources of forest products, including poles for house and fish corral construction; extractives like dyes, resins, viscose rayon; pulp for paper; firewood and charcoal; nipa sap for vinegar, alcohol and sugar; shingles for roofing (Serrano and Fortes 1987; Zamora 1989;).

This report summarizes two types of assessments of the mangroves of Lagonoy Gulf. Field surveys conducted in March and July 1994 provide detailed information on selected sampling areas. An analysis of available maps using Geographical Information System (GIS) provides a synoptic view of the status of mangroves and suggests areas that are suitable for reforestation.

Methodology

Field surveys

Six sampling sites (Fig. 1) were selected from areas identified as mangroves in a coastal resources map prepared by the National Mapping and Resource Information Authority (NAMRIA). Table 1 lists the coordinates of each site. All stations were surveyed in March except for the Bunga station which was surveyed in July.

In each site the transect line plot method described in Dartnall and Jones (1986) was used with some modification. Starting from the seaward extent of the mangrove area, a transect line was extended perpendicular to the shore until the landward boundary of the mangrove area. In the case of the extensive mangrove area at Agoho, the transect was extended only up to 300 m due to time constraints (Table 1). A lensatic compass guided the person laying the transect line.

At 10-m intervals along the line, mangroves within a 10 x 10 m plot were measured with a fiberglass measuring tape. Those over 12.5 cm in circumference (4-cm diameter at breast height, DBH) were recorded as trees, those under 12.5 cm in circumference but over 1-m high were recorded as saplings, and the rest were counted as seedlings.

Comparison of the sites was done by computing the following ecological indices: the Shannon-Weiner index of diversity, Simpson's index of dominance, Pielou's evenness index and the species richness index. The formulae of the indices are listed in Appendix A.

To compare the species encountered, relative density, relative frequency (i.e., occurrence) and relative dominance of each species were computed. Dartnall and Jones (1986) define these indices for the species as follows:

$$\text{Relative density} = \frac{\text{individuals of the species}}{\text{sum of all individuals}}$$

$$\text{Relative frequency} = \frac{\text{frequency of the species}}{\text{sum of frequencies for all species}}$$

$$\text{Relative dominance} = \frac{\text{basal area for the species}}{\text{total of basal areas for all species}}$$

Zonation patterns were determined by examining the relative dominance of the species in each plot.

Analysis of available maps

The coastal resources map from NAMRIA, which is based largely on 1987 SPOT multispectral data, and a 1956 USCG topographic map were digitized and entered into the SPANS Geographic Information System (GIS) to facilitate comparison of past and present mangrove cover.

To determine suitable areas for mangrove reforestation, maps on soil type, slope and landuse of the coastal area were used in addition to the above maps. The GIS was used to identify suitable areas based on specified criteria.

Results and Discussion

Field surveys

Ten species were identified at the six sampling stations (Table 2). *Avicennia marina* was present in all stations. Two species, *A. officinalis* and *Rhizophora apiculata* were the next most represented in the gulf. *Lumnitzera littorea* was found only at the Gaba station.

A comparison of the stations in terms of ecological indices is presented in Table 3. To interpret the indices, it is helpful to bear in mind that dominance is *generally* inversely related to diversity, and richness and evenness are components of diversity (Odum 1971). The Bunga station is like no other station with its extremely high dominance and extremely low diversity, richness, and evenness. This is because Bunga is nearly a pure stand of *A. officinalis*. The Agoho station ranks next to Bunga in having low diversity and high dominance. Next to these two stations, in the order of increasing diversity, are the following: Gaba and Masaga (the two are comparable), Batalay and Nato. Nato, the most diverse station, also exhibits relatively high dominance, which makes it an exception to the general rule of dominance and diversity being inversely related.

Tables 4, 5 and 6 present the relative density, relative frequency and relative dominance, respectively, of the major mangrove species encountered. Relative density and relative frequency are closely related indices that may be interpreted as estimates of the likelihood of encountering a species. On the other hand, relative dominance, which is derived from basal area measurements, indicates the relative size or mass of a species. Thus, these indices, particularly the relative density index, are useful for shedding light on dominance and diversity in each station.

As mentioned earlier, the Bunga station is nearly a pure stand of *A. officinalis*, which explains the values for this station in Tables 4-6. The reason for the high Simpson's dominance and low Shannon diversity index values at Agoho (Table 3) is readily seen in Tables 4 and 5. The station has only three species and a single species, *A. officinalis*, accounts for 78.7% of all individuals.

The Gaba station is dominated by the species *Sonneratia alba* in terms of all three relative indices (Tables 4-6). *A. marina*, though few in number, is important in terms of total area occupied. *A. marina* and *R. apiculata*, the dominant species in Masaga, have almost equal relative density. Thus, the station has slightly higher evenness and (consequently) diversity than Gaba (Table 3).

At Batalay, *A. officinalis*, *R. apiculata* and *S. alba* account for almost 90% of all individuals, and these individuals are almost equally divided among the three species. This adds to the evenness of the station. Three more species add to the species richness of the area, giving it a diversity index that is next only to Nato.

The Nato station contains seven species, the most number of species at any station. The relative density of most species is comparable, with the exception of *A. officinalis* (Table 4). The latter species accounts for 60.6% of all individuals, giving this station a dominance index second only to Agoho. This explains why this station has the uncommon characteristic of having both high dominance and high diversity (Table 3).

R. apiculata has high relative density and relative frequency in Agoho, Batalay, Masaga and Gaba (Tables 4 and 5). In terms of relative dominance, however, *R. apiculata* is relatively insignificant (Table 6). That is, a relatively high number of *R. apiculata* individuals are found at these stations but these individuals as a group do not occupy much space.

The average DBH of the mangrove trees are presented in Table 7. Except for *Avicennia* and *Sonneratia* the average DBH of the species barely meets the inclusion minimum criteria of 4 cm. This indicates the relative immaturity of the stands. While *Avicennia* spp. and *Sonneratia* may have larger average diameters, these are often crowned trees, i.e., the branches above a certain height are harvested. This decreases the litter fall which contributes to the nutrient flows into the gulf. Other functions of the mangrove such as shoreline stabilization may not be as affected.

Table 8 presents the density of seedlings and saplings at the sampling sites. The density of seedlings was highest at Masaga and Gaba and was at least three times higher than the other sites. No seedlings were encountered at Bunga. Saplings were most dense at Batalay.

The zonation patterns of the stations are presented in Figs. 2-6. In Nato, *Avicennia* spp. occurred throughout the transect. *Aegiceras corniculatum* and *R. apiculata* occurred within the first 30 m of the transect. *S. alba* appeared only after 60 m. Nipa was present at 120 m. Terrestrial vegetation (coconuts) was observed at 140 m. *Avicennia* spp. dominated the first 50 m and last 40 m of the transect (Fig. 2).

In Agoho *A. officinalis* was present from the shore until 60 m. *R. apiculata* was observed from 80 m onwards. A gap occurred from 140 to 150 m. *A. officinalis* dominated the first 80 m while *R. apiculata* dominated the last 40 m (Fig. 3).

Batalay did not exhibit clear zonation. The species present were dispersed over the transect. Terrestrial vegetation appeared at 140 m (Fig. 4).

The first 40 m of Masaga was dominated by *R. apiculata*. A 70-m belt of *A. marina* began at 60 m. *Bruguiera parviflora* and *R. apiculata* were present at the transition to the terrestrial zone (Fig. 5).

Gaba is similar to Batalay in having no clearly defined zonation except for a 40-m band dominated by *S. alba* between 60 and 100 m from shore (Fig. 6). The lack of distinct zonation at Batalay and Gaba may be attributed to the creeks that traverse these areas. These modify inundation patterns and hence the species distribution.

Analysis of available maps

The overlay of the 1987 coastal resources map and the 1956 landuse map is presented in Fig. 7. The mangrove cover of 1,988.82 ha in 1956 was reduced to 1,316.09 ha in 1987 or 66% of the original cover. Mangroves lost between the two periods amounted to 1,449.36 ha, or 73% of the original cover, while retained mangroves total 521.44 ha (26%).

Afforested mangroves, or the new growths which cannot be more than 30 years old, total 781.19 ha and account for 59% of the existing mangroves. This is consistent with field observations on the relative immaturity of the stands and the low average DBH values.

In San Miguel Bay, the present cover of mangroves represents only one-third of the cover during the 1950s (Vega et al., in press). Nationwide mangrove cover plunged from an estimated 238,164 ha in 1970 to 132,645 ha in 1989. Of the remaining stands, only 5% are old growths. The mangrove depletion rate accelerated in the 1950s. This coincided with large-scale conversion into fishponds (Bennagen and Cabahug 1991).

Fig. 8 indicates the suitable areas for mangrove reforestation which were identified on the basis the criteria listed in Table 9. Under this scheme, the preferred areas are those with hydrosol, clay loam or clay soils and slopes of 3% or less. Points are given for proximity to a water source, especially to an area with estuarine conditions. Areas with minimal human activity are preferred, as indicated by the landuse categories. The areas that meet all the criteria are labelled as most suitable, while areas that meet majority of the criteria are identified as suitable. Table 10 presents the distribution of these sites by province.

The identification of potential mangrove reforestation sites is preliminary and will require ground truthing. Other factors must be considered such as exposure to waves or proximity to a community that is eager to participate in reforestation and maintenance.

Conclusion

The present mangrove cover of the Lagonoy Gulf coastal area represents two-thirds of the cover in the 1950s. However, majority of these stands are under 30 years old and only 26% of the original cover has been retained. This represents considerable ecological and economic losses.

The current mangrove management program of the Department of Environment and Natural Resources has commendable objectives. This study identified areas where their reforestation efforts might be expanded. Ground truthing of the identified areas is recommended. The preservation of mangrove stands at Nato, Batalay, Masaga and Gaba should be considered in view of the higher diversity observed in those areas.

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Table 1. Location of mangrove stations in Lagonoy Gulf.

Locality	Latitude	Longitude	Transect length (m)
Nato River	13° 36.14' N	123° 32.38'E	130
Agoho	13° 36.19'N	124° 02.86'E	300
Batalay	13° 35.80'N	124° 18.51'E	130
Masaga	13° 14.97'N	124° 04.17'E	200
Gaba Bay	13° 16.63'N	123° 58.85'E	200
Bunga	13° 20.23'N	123°53.67'E	200

Table 2. Major mangrove species present in Lagonoy Gulf.

Taxon	Nato	Agoho	Batalay	Masaga	Gaba	Bunga
Avicenniaceae						
Avicennia alba	X					
Avicennia officinalis	X	X	X	X		X
Combretaceae						
Lumnitzera littorea					X	
Myrsinaceae						
Aegiceras corniculatum	X		X		X	
Rhizophoraceae						
Rhizophora apiculata	X	X	X	X	X	
Ceriops tagal			X		X	
Bruguiera parviflora				X	X	
Sonneratiaceae						
Sonneratia alba	X		X	X	X	

Legend

X Present

O Identification uncertain

Table 3. Some ecological indices of mangrove communities in Lagonoy Gulf.

Index	Nato	Agoho	Batalay	Masaga	Gaba	Bunga
Simpson's dominance	30.33	53.00	4.11	5.44	9.57	215.00
Shannon's diversity	1.71	0.63	1.46	1.38	1.54	0.03
Species richness	1.23	0.43	1.24	0.99	1.29	0.18
Pielou's eveness	0.88	0.57	0.81	0.86	0.67	0.04

Table 4. Relative density of major mangroves in Lagonoy Gulf.

Taxon	Nato	Agoho	Batalay	Masaga	Gaba	Bunga
Avicenniaceae						
Avicennia alba	3.0					
Avicennia eucalyptifolia	3.0					
Avicennia marina	13.6	4.6	5.3	37.5	7.8	0.5
Avicennia officinalis	60.6	78.7	29.8	7.1		99.5
Combretaceae						
Lumnitzera littorea					1.9	
Myrsinaceae						
Aegiceras corniculatum	0.8		5.3		1.0	
Rhizophoraceae						
Rhizophora apiculata	0.8	16.7	28.1	35.7	13.6	
Ceriops tagal			1.8		15.5	
Bruguiera parviflora				8.9	16.5	
Sonneratiaceae						
Sonneratia alba	18.2		29.8	10.7	43.7	

Table 5. Relative frequency of major mangroves in Lagonoy Gulf.

Taxon	Nato	Agoho	Batalay	Masaga	Gaba	Bunga
Avicenniaceae						
Avicennia alba	11.1					
Avicennia eucalyptifolia	5.6					
Avicennia marina	11.1	5.6	13.3	37.5	9.4	6.2
Avicennia officinalis	44.4	44.4	26.7	6.3		93.8
Combretaceae						
Lumnitzera littorea					6.3	
Myrsinaceae						
Aegiceras corniculatum	5.6		13.3		3.1	
Rhizophoraceae						
Rhizophora apiculata	5.6	50.0	26.7	31.3	18.8	
Ceriops tagal			6.7		18.8	
Bruguiera parviflora				12.5	15.6	
Sonneratiaceae						
Sonneratia alba	16.7		13.3	12.5	28.1	

Table 6. Relative dominance of major mangroves in Lagonoy Gulf.

Taxon	Nato	Agoho	Batalay	Masaga	Gaba	Bunga
Avicenniaceae						
Avicennia alba	11.7					
Avicennia eucalyptifolia	0.2					
Avicennia marina	10.6	4.6	3.9	91.6	28.5	0.4
Avicennia officinalis	54.7	94.5	30.2	0.9		99.6
Combretaceae						
Lumnitzera littorea					0.3	
Myrsinaceae						
Aegiceras corniculatum	0.1		4.1		0.1	
Rhizophoraceae						
Rhizophora apiculata	0.1	0.9	9.5	4.9	1.6	
Ceriops tagal			0.5		1.5	
Bruguiera parviflora				0.8	7.6	
Sonneratiaceae						
Sonneratia alba	22.7		51.8	1.8	60.5	

Table 7. Average DBH (cm) of mangroves at Lagonoy Gulf.

Taxon	Nato	Agoho	Batalay	Masaga	Gaba	Bunga
Avicenniacea						
Avicennia alba	34.8					
Avicennia eucalyptifolia	5.6					
Avicennia marina	14.0	20.0	6.31	20.2	28.2	5.9
Avicennia officinalis	13.0	19.9	7.3	5.5		5.4
Combretaceae						
Lumnitzera littorea					6.0	
Myrsinaceae						
Aegiceras corniculatum	5.7		6.5		4.8	
Rhizophoraceae						
Rhizophora apiculata	6.7	4.7	4.5	5.4	5.4	
Ceriops tagal			4.1		4.8	
Bruguiera parviflora				4.6	7.7	
Sonneratiaceae						
Sonneratia alba	15.6		9.0	5.8	14.6	

Table 8. Density of seedling and saplings per hectare in Lagonoy Gulf.

Station	Nato	Agoho	Batalay	Masaga	Gaba	Bunga
Seedlings	2,692	867	3,000	9,500	9,300	0
Saplings	385	1,933	3,857	1,200	1,500	750

Table 9. Weights (%) and points (0-10) of criteria in site selection for mangrove reforestation.

Map	Weight	Points
Former distribution	25	10
Soil type	20	
hydrosol		10
clay-loam		10
clay		10
silt-clay-loam		8
sand-clay-loam		8
silt-loam		7
fine-sand-loam		6
loam		5
Slope	20	
0-3%		10
3-8%		3
Proximity to rivers and sea	15	
within 0.5 km from both		10
0.5 km/1 km		10
1 km/0.5km		5
0.5 km/1.5 km		5
1.5 km/0.5 km		3
1.5 km/1 km		3
1 km/1.5 km		3
1 km/1 km		1
1.5 km/1.5 km		1
Landuse	10	
grass		5
shrub		5
coconut		5
beach		5
Present distribution	10	-1

Table 10. Distribution by province of areas (ha) for mangrove reforestation.

Class	Albay	Camarines Sur	Catanduanes	Total
Most suitable	56.19	4.80	34.05	95.04
Suitable	591.19	164.84	405.37	1,161.40
Total	647.38	169.64	439.42	1,256.44

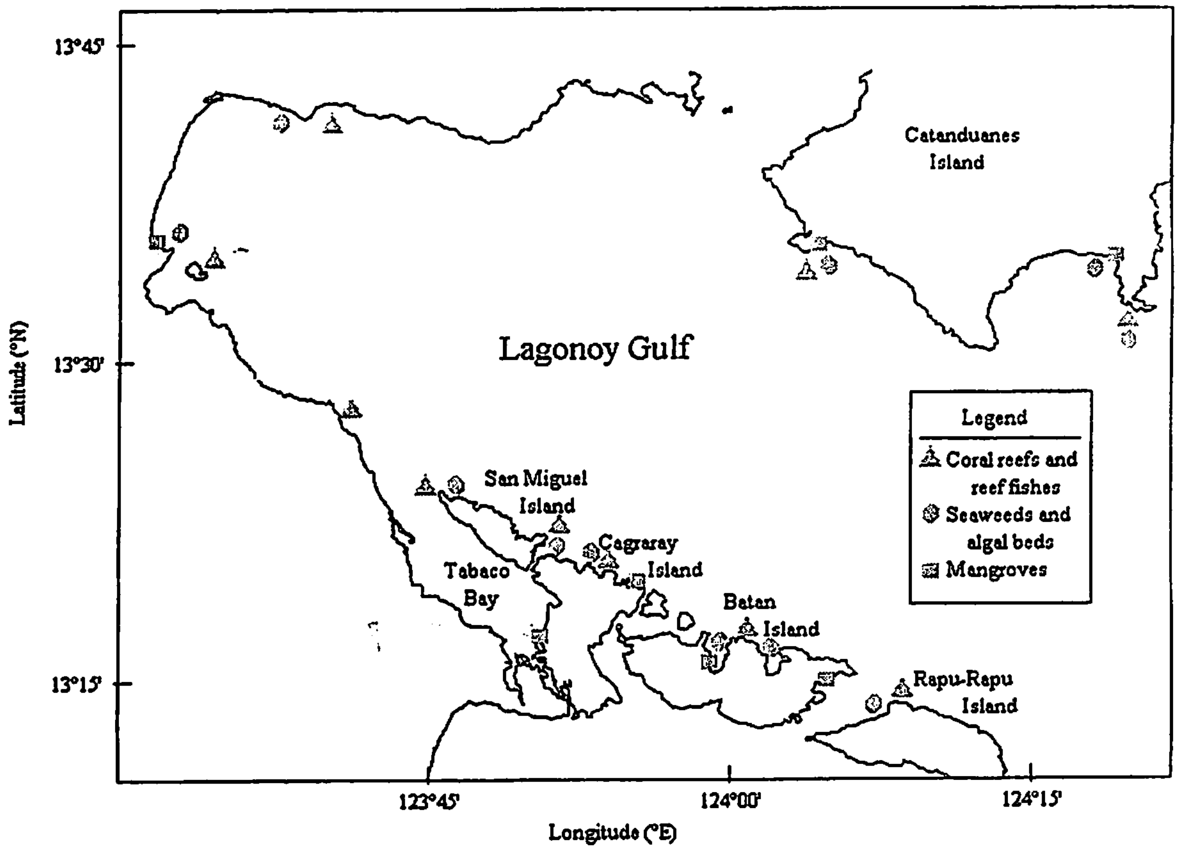

Fig. 1. Transect stations for the assessment of mangroves. Sampling stations for coral reefs, seagrass and algal beds are also shown.

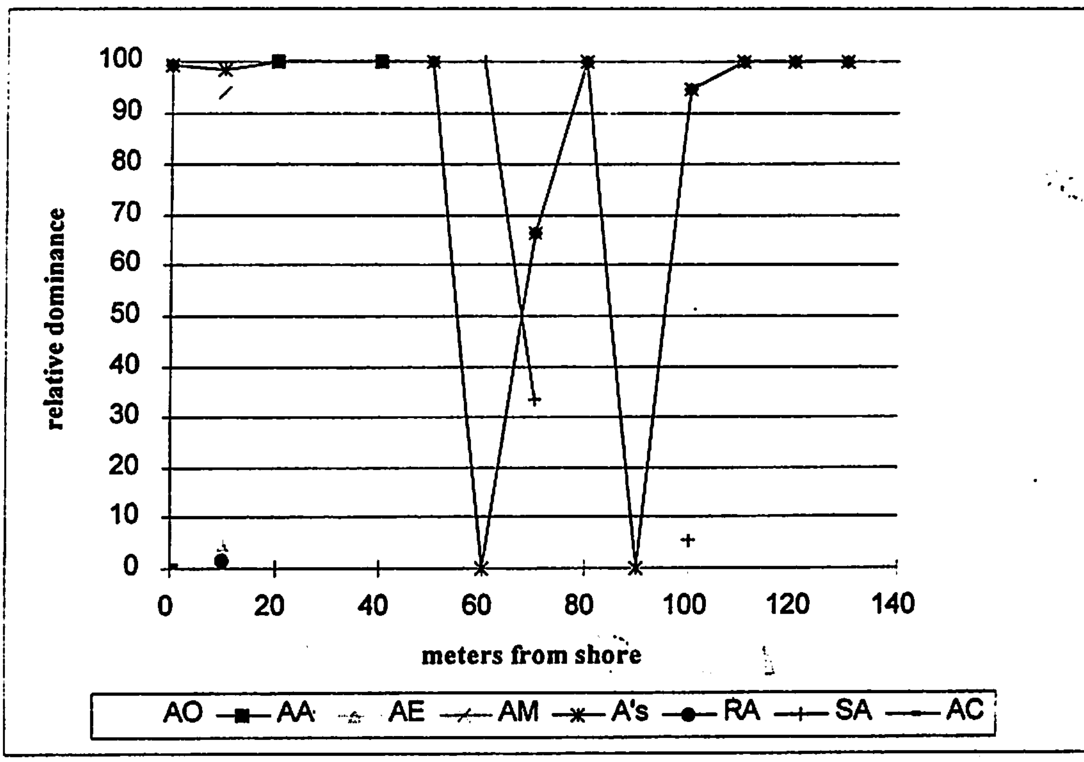

Fig. 2. Zonation pattern at the Nato station. (AV - *Avicenia* spp.; RA - *R. apiculata*; SA - *S. alba*; AC - *A. corniculatum*).

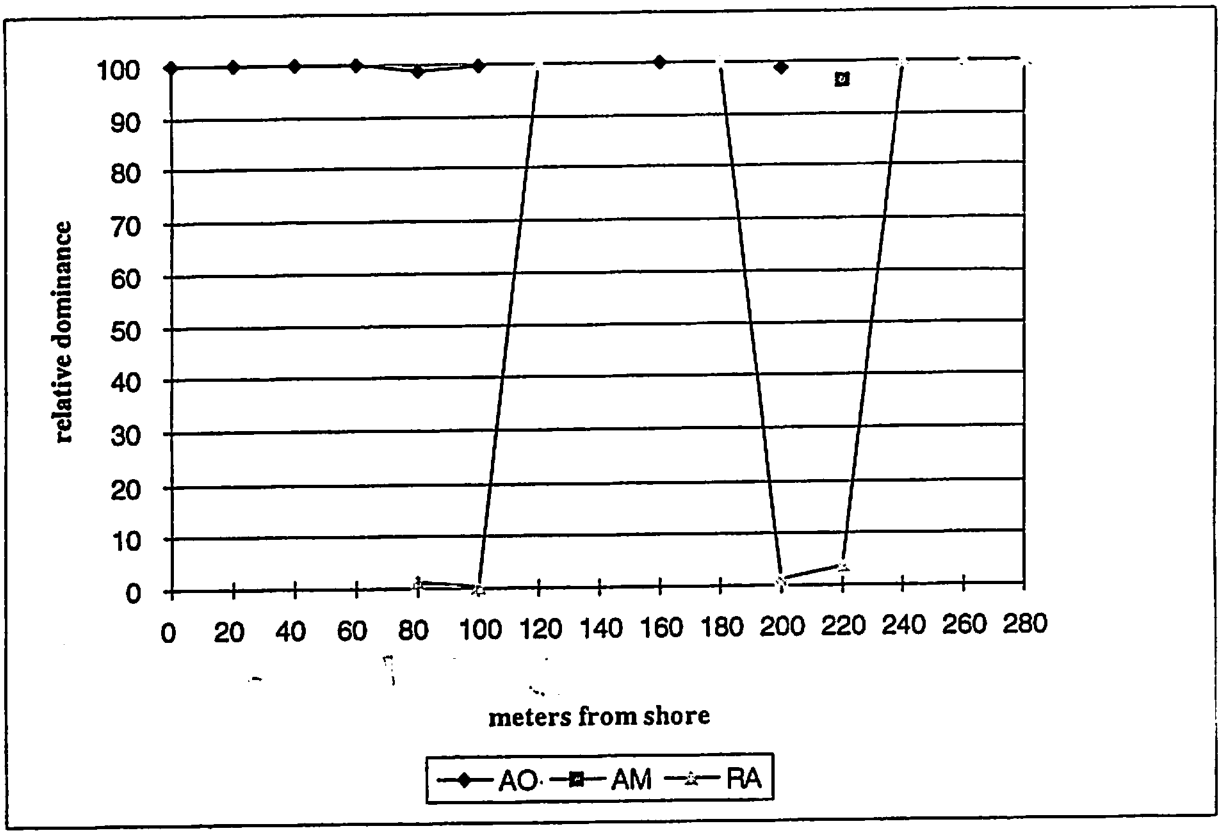

Fig. 3. Zonation pattern at the Agoho station. (AO - *A. officinalis*; AM - *A. marina*; RA - *R. apiculata*).

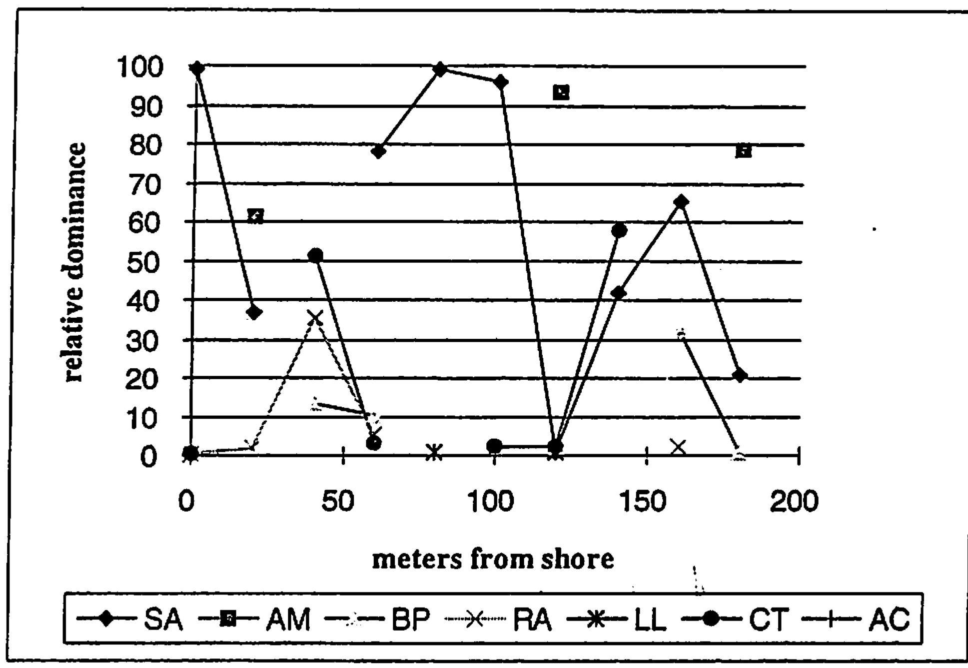

Fig. 4. Zonation pattern at the Batalay station. (AO - *A. officinalis*; AM - *A. marina*; RA - *R. apiculata*; SA - *S. alba*; CT - *C. tagal*; Ac - *A. corniculatum*).

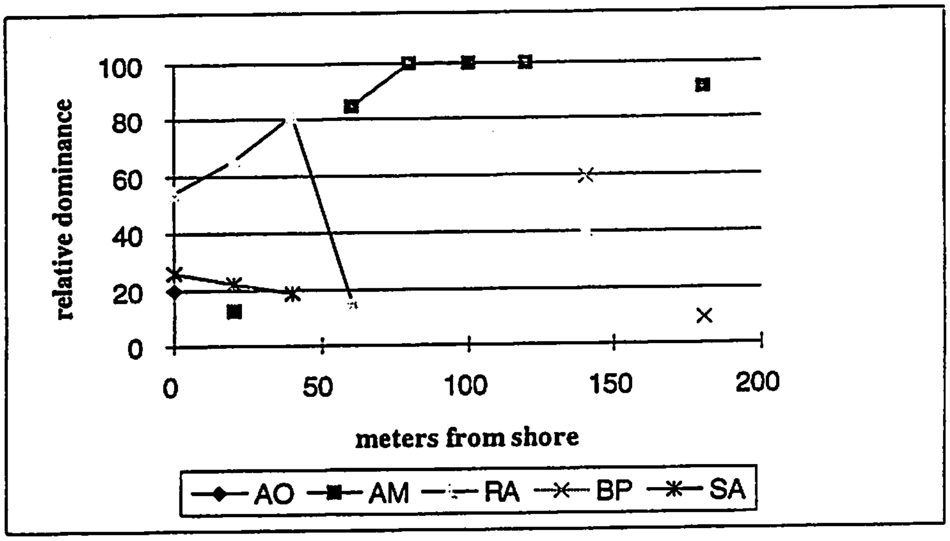

Fig. 5. Zonation pattern in the Masaga station. (AO - *A. officinalis*; AM - *A. marina*; RA - *R. apiculata*; BP - *B. parviflora*; SA - *S. alba*).

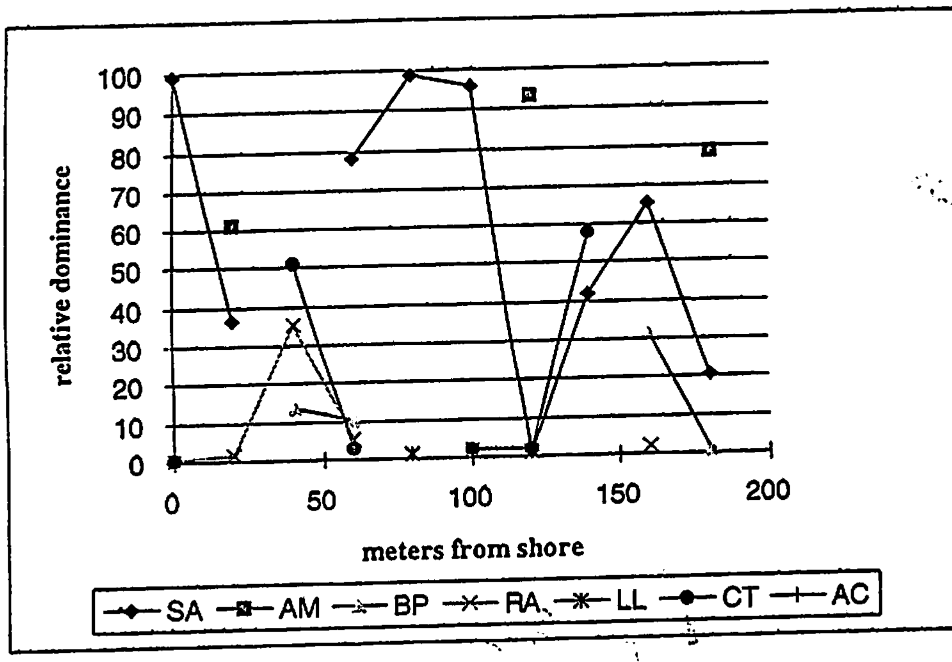

Fig. 6. Zonation pattern at the Gaba station. (SA - *S. alba*; AM - *A. marina*; BP - *B. parviflora*; RA - *R. apiculata*; LL - *L. littorea*; CT - *C. tagal*).

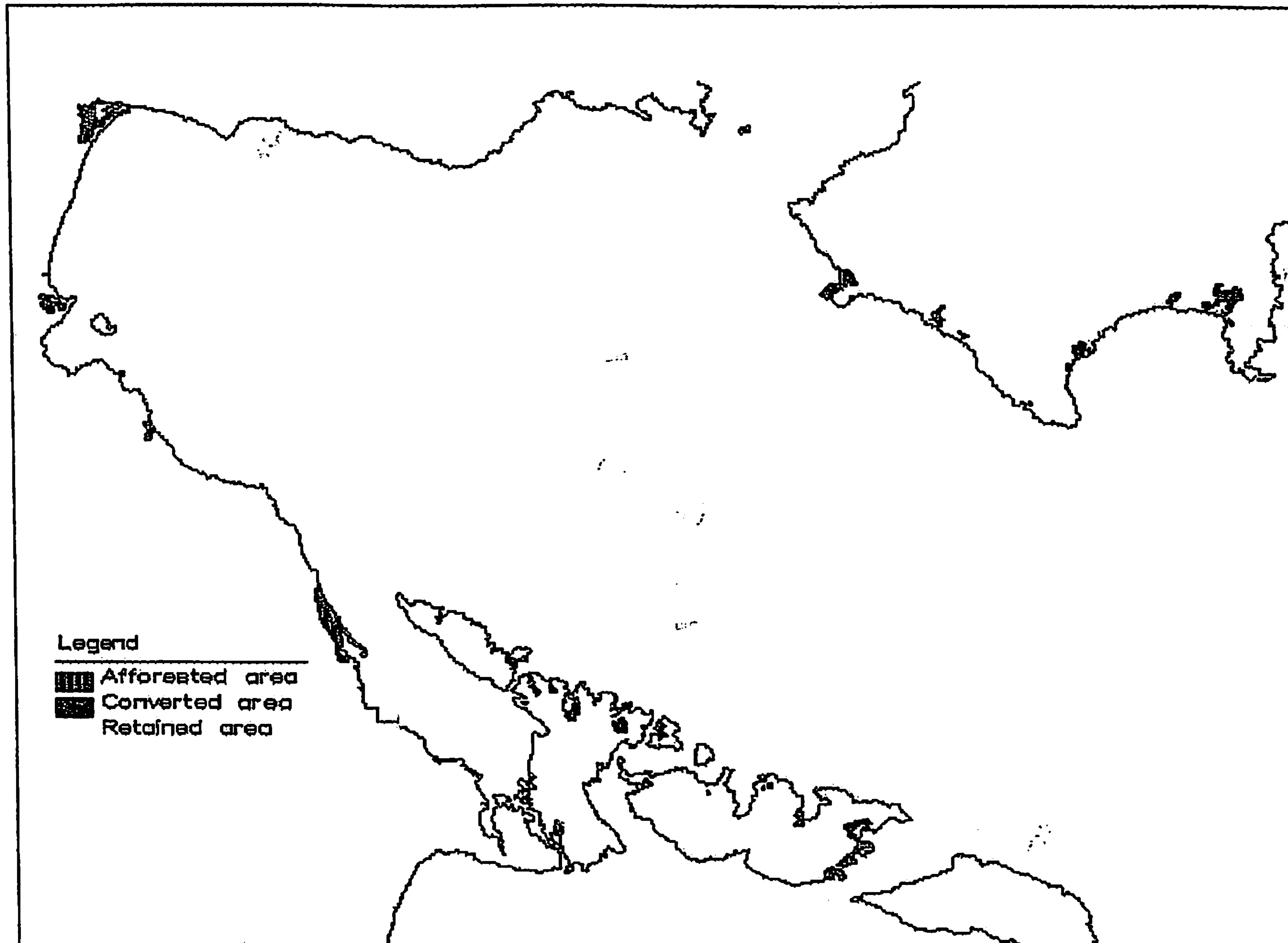

Fig. 7. Overlay of the 1987 coastal resources map and the 1956 topographic map.

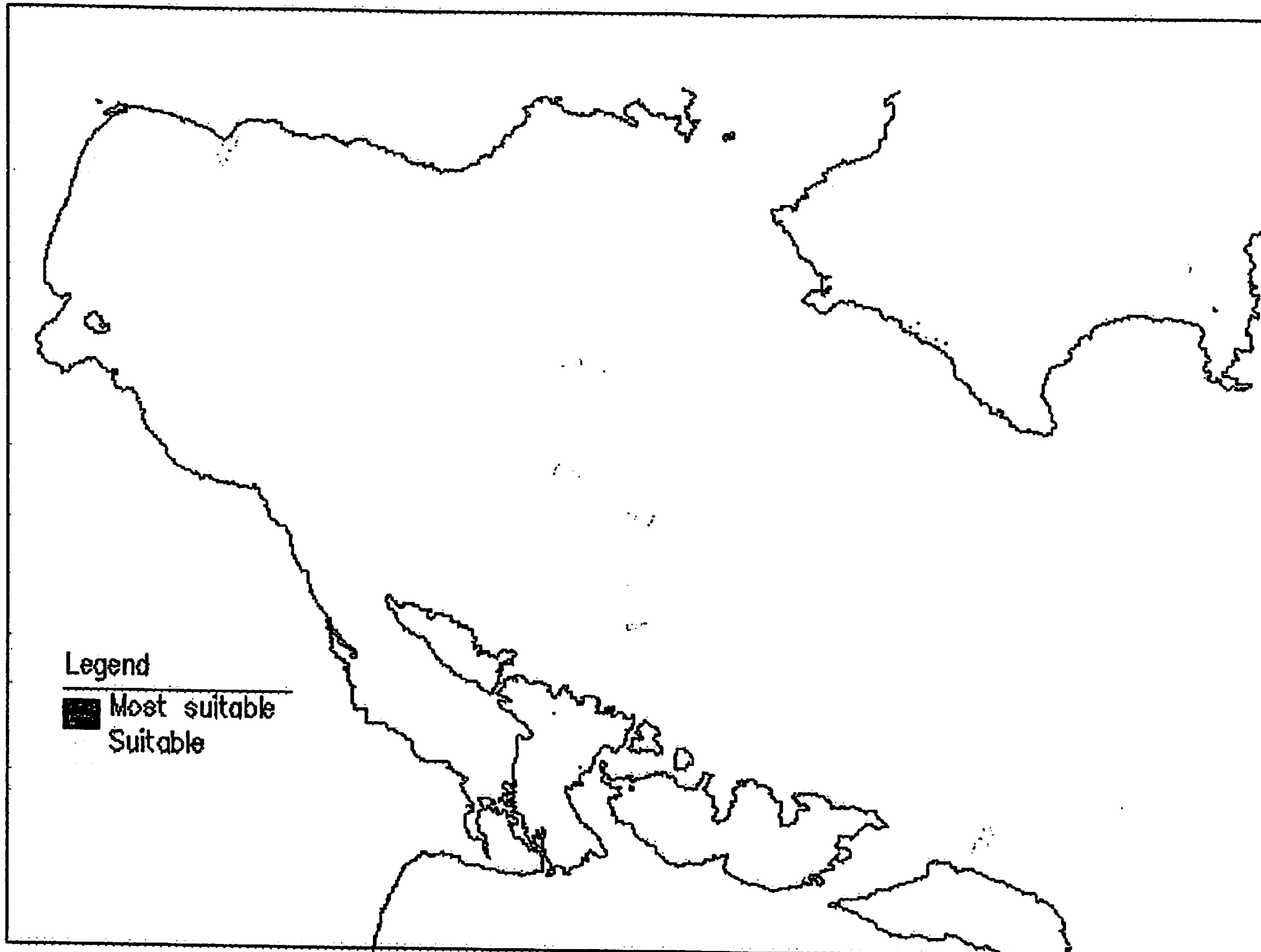

Fig. 8. Suitable areas for mangrove reforestation.

Appendix A
Formulae of Ecological Indices Used

Shannon's Index

$$H = -\Sigma P_i \log P_i$$

where :

n_i = importance value for each species
N = total of importance values
P_i = importance probability for each species = n_i/N

Simpson's dominance

$$c = \Sigma n_i (n_i(n_i-1)/N(N-1))$$

where:

n_i = importance value for each species
N = total of importance values

Pielou's Evenness

$$e = H/\log S$$

where:

H = Shannon's index
S = number of species

Species richness

$$d = S-1/\log N$$

Source: Odum, E.P. 1983. Basic Ecology. CBS College Publishing. Saunders College Publishing. Holt, Rinehart and Winston. The Dryden Press.

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Evaluating Resource Management Options for Lagonoy Gulf using Decision Analysis

by

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Luna, C.Z., M.L.G. Gorospe and V.S. Soliman. 1995. Evaluating resource management options for Lagonoy Gulf using decision analysis, p. 000-000. *In* G. Silvestre, C. Luna, V. Soliman and L. Garces (eds.) Resource and ecological assessment of Lagonoy Gulf, Philippines. ICLARM Tech. Rep. 000, 000 p.

Abstract

Decision analysis was used to help the Interim Planning Committee (IPC) of the Lagonoy Gulf Management Council to structure its planning process. Seven alternatives were evaluated, namely: closing the gulf to commercial fishing, law enforcement campaign against illegal fishing, closed season, establishment of marine sanctuaries, mangrove reforestation, watershed reforestation and the status quo. Six criteria were used to represent the ecological, economic, social, political and administrative objectives of resource management. The preferences of IPC members were assessed individually and as a group using the Simple Multiattribute Rating Technique. The law enforcement campaign was clearly the most preferred alternative. The results of a sensitivity analysis could be used as a basis for categorizing alternatives.

Introduction

Decision analysis is a quantitative method for analyzing decisions using expected utility as the criterion for identifying the preferred decision alternative (Corner and Kirkwood 1991). Luna, in press, a and b provides an overview of decision analysis. Briefly, decision analysis involves four steps: (1) problem structuring, which includes clarifying objectives, specifying attributes or criteria to measure the attainment of objectives and identifying alternatives; (2) assessing possible impacts of the alternatives; (3) determining the preferences of decision makers; and (4) evaluating and comparing alternatives and conducting sensitivity analysis (Keeney 1982).

When the International Center for Living Aquatic Resources Management (ICLARM) conducted a resource and ecological assessment (REA) of San Miguel Bay in 1992, it used decision analysis for evaluating projects to be included in a management plan for the bay (see Luna, in press, a and b). Decision analysis proved to be an effective framework for identifying key information relevant to resource management. In addition, the method showed a way to integrate these information, which were of various types since these were produced by the different components of the REA. The method ensured that these information were used by local decision makers to evaluate alternatives. It also helped the decision makers, which included stakeholders with conflicting interests, to achieve consensus.

Thus, it was decided that decision analysis would again be conducted as part of the REA of Lagonoy Gulf. The decision analysis process was initiated during the Consultative Workshop on Integrated Fisheries Management for Lagonoy Gulf held in July 1994 in Tabaco, Albay. Representatives of municipal fishers' organizations, commercial fishers, nongovernmental organizations (NGOs), educational institutions, local government units (LGUs), government line agencies and other sectors participated in the workshop. ICLARM and Bicol University College of Fisheries (BUCF) researchers presented initial findings regarding coastal issues in the gulf based on secondary information. Using San Miguel Bay as a case study, decision analysis was presented as a framework for identifying and evaluating courses of action to resolve the issues.

Workshop participants then formed separate discussion groups on resource utilization issues, environmental issues, socioeconomic issues and legal and institutional aspects. Initial inputs to the decision analysis were elicited from the discussion groups. For example, for each issue the discussion groups listed stakeholder groups, the objectives of each group and possible solutions to the issues. The legal and institutional discussion group had the special task of recommending an organizational structure for the Lagonoy Gulf Resource Management Council (LGRMC) to take charge of managing the gulf's coastal resources.

After the workshop, two activities were simultaneously pursued, namely, (1) organizing the LGRMC and (2) formulating a management plan for the gulf. An Interim Organizational Group (IOG) formed during the workshop took charge of the first activity. For the second activity, the IOG created an Interim Planning Committee (IPC) which was charged with preparing the management plan to be presented to the LGRMC for approval. The authors, representing ICLARM and BUCF, were asked to recommend IPC members and to guide the IPC in its planning activities. Representatives of stakeholders listed by the workshop discussion groups were invited to be part of the IPC. Table 1 presents the composition of the IPC.

In this context the IPC members were the decision makers while the authors served as both decision analysts and technical experts on resource and environmental assessment. This paper describes the decision analysis conducted with the IPC over several meetings between July 1994 and January 1995.

Problem Structuring

Clarifying objectives. The first task in problem structuring involves clarifying objectives. This is facilitated by constructing an objectives tree which depicts the hierarchy of objectives. For this activity, separate meetings were initially conducted with IPC members by province, mainly because of the difficulty in assembling all 22 IPC members. After these separate meetings, the IPC met as a group to agree on the objectives.

The first meeting was held with the IPC members from Albay. To facilitate the structuring of objectives, the objectives tree produced in San Miguel Bay was presented to the group. The group evaluated the relevance of each objective in the San Miguel Bay tree by discussing its associated problem(s) or issue(s). If a similar problem or issue exists in the gulf, the associated objective(s) were included in the group's objectives tree. The group also modified some objectives as needed. Fig. 1 presents the tree produced in this meeting.

The objectives tree of the Albay group was then presented in a meeting with IPC members from Camarines Sur as a basis for discussion. The Camarines Sur members made several modifications on the Albay tree. With the ecological objectives, they made a distinction between the protection of the environment and its rehabilitation. They added a new second level objective of "coastal resource/environment enhancement", under which they placed the third level objectives "rehabilitate coral reefs" and "rehabilitate mangroves". All third level objectives under "habitat protection" were retained, but the word "protect" was substituted for "rehabilitate" in reference to coral reefs and mangroves.

The Camarines Sur IPC members added "poverty alleviation" as a new second level economic objective. According to the group, poverty alleviation can be pursued by providing alternative livelihood. The group added two more political objectives, namely "promote active participation by local government units" (under which they placed no third level objective) and "enhance the role of fishers' organizations". Under the latter, they placed a third level objective of "provide education, training and technology". Finally, the group added "organize an effective management body" as an administrative objective. The objectives tree of the Camarines Sur IPC members would prove to be very similar to the final objectives tree agreed upon by all IPC members.

The objectives tree of the Camarines Sur group was used as basis for discussion by the IPC members from Catanduanes. The Catanduanes group agreed with all of the objectives of their counterparts in Camarines Sur. In addition, they raised the issue of poaching. Thus, they added the objective "minimize poaching by transient fishers" under "promote equitable distribution of benefits".

The IPC then met as a group to agree on the final structure of objectives, among other things. During the first meeting of all members, the substantive discussion focused on destructive fishing, i.e., whether the objective should be to minimize it or to eliminate it entirely. Some were worried that using the word "eliminate" would specify an objective that, in all likelihood, would not be attained. However, others explained that the point was to make a strong and clear statement of intent. Whether or not the objective will be completely realized is beside the point, they argued. The final agreement was to rephrase the objective as "stop the use of destructive fishing methods", which is simpler and more direct. The objectives tree agreed upon by the IPC members is shown in Fig. 2.

Generating alternatives. The generation of alternatives was done in stages, namely: (1) listing possible alternatives, (2) reducing the number of alternatives to focus the analysis on critical options, (3) identifying alternatives that need not be evaluated (due to their obvious importance), and (4) transforming the alternatives into projects to make the objects of evaluation more concrete.

During the separate meetings with the IPC members by province, a preliminary list of alternatives was elicited from each group. As in the construction of objectives trees, each group built upon the list of the group that met before it. In the case of the Albay group, the first group to meet, the alternatives suggested during the consultative workshop were used to start the discussion.

The result of the above was a long list of alternatives. As a step towards trimming down the list, the alternatives were matched with objectives, thus facilitating the grouping of similar ideas and the elimination of marginally relevant suggestions. The result (shown in Appendix A) was also used during the meeting of all members to stimulate more discussion on the alternatives and to emphasize the link between objectives and alternatives.

Next, "requisite" alternatives were identified. These alternatives would provide the LGRMC with the institutional capabilities to manage the coastal resources of the gulf. Without the means to manage, it is useless to evaluate alternatives for management. Therefore, the importance of these alternatives need not be established by the decision analysis. The requisite alternatives identified are the following: (1) institutional development for the LGRMC; (2) establishment and/or strengthening of fishers organizations; (3) upgrading law enforcement capabilities; (4) establishment of a resource and environmental monitoring system. Similar alternatives are found in the San Miguel Bay Integrated Coastal Fisheries Management Plan (FSP/SMBMC/ICLARM 1994) which served as a useful model in this planning exercise.

Also exempted from evaluation are the alternative livelihood projects. Socioeconomic and investment opportunities studies conducted in Lagonoy Gulf identified several alternative livelihood projects (PRIMEX 1993). Although some technical details of these projects need to be worked out, in principle the need for alternative livelihood is unquestionable because they are ultimate means of reducing dependence and pressure on coastal resources.

What were left to evaluate were alternatives that directly address the major resource management issues in the gulf and involve substantive tradeoffs (e.g., many stakeholders impacted or high administrative costs). Table 2 lists the alternatives and a brief description of each. The project briefs prepared for these alternatives are presented in Appendices B-G.

Specifying criteria. Keeney and Raiffa (1976) list the characteristics that a set of attributes or criteria should possess. Among other things, the number of criteria should be kept small, around five to eight. This was done in this analysis by specifying criteria to represent the major second level objectives, as shown in Fig. 3. Note that objectives that were not used for specifying criteria were not disregarded; their essence were incorporated into the projects.

Scales were constructed to permit the quantitative application of the criteria (Tables 3-7). No scale is necessary for project costs since this criterion is already quantified.

Assessment of Impacts of Alternatives

To assess the probable political impacts of the alternatives, nine respondents including five IPC members were interviewed. Using Table 7, they were asked to estimate the percentage of the coastal population that would fall under each impact level. This was done for all alternatives. The average responses are presented in Table 8.

Projects costs had been estimated earlier alongside the production project briefs. For the other criteria, the authors assessed the impacts of the alternatives. Table 9 presents a matrix of impacts of the alternatives on each criterion. To assist the IPC in understanding the impacts and their implications, a qualitative version of Table 9 was prepared, which is shown in Table 10.

Assessment of Preferences of Decision Makers and Evaluation of Alternatives

The preferences of the IPC members were assessed individually and as a group. The main purpose of the individual decision making sessions was to prepare the members for the group decision making session, in which it was hoped that consensus on the evaluation of alternatives could be reached. Of the 22 IPC members, 15 members (68%) went through an individual decision making exercise. All sectors listed in Table 1 were represented by the 15 members.

Tables 9 and 10 contain the key technical or objective inputs to the decision to be made. Given the impacts of the alternatives on the criteria, the task of the decision maker is to make a *value judgment* on the relative importance of the criteria or, more accurately, on the objectives represented by the criteria. The evaluation of alternatives is done by combining technical assessments and value judgements.

One important point should be clarified before the assessment of preferences is described. Before the group decision making session the IPC members were told that quantitative prioritization of the alternatives would not be an end in itself. Rather, it would be used as a starting point for involved discussions on the alternatives and on the values of the IPC, especially with regard to aspects not captured by the analysis.

Individual decision making

Each individual decision making session started with a review of the alternatives and their implications. Table 10 was particularly useful for this purpose. The Simple Multiattribute Rating Technique, or SMART (Edwards and Newman 1982) was used to assess preferences. Each IPC member was asked to rank the objectives according to importance and to rate each objective by assigning a score between zero and 100. The scores were then normalized (i.e., each score was divided by the sum of scores) to derive the weights. The ranks, scores and weights assigned by the IPC members are presented in Table 11.

To simplify the analysis, risk preferences of the decision makers were not assessed, i.e., all single attribute utility functions were assumed to be linear. This assumes that attitudes toward risk are not important to the decision or equivalently, that the decision makers are risk neutral (see Luna in press, a and b).

The utility of each alternative was then calculated using the formula (Edwards and Newman 1982):

$$U_j = \sum_{i=1}^{n} w_i u_{ij}$$

where U_j = overall utility for the jth option
w_i = normalized weight assigned to the ith attribute
u_{ij} = utility of the jth option on the ith attribute.

Table 12 presents the utility points and the priority of the alternatives. The computation of points was done using the Multiattribute Trade-Off System program (Brown et al. 1986), which allowed immediate presentation of results to the decision maker. The IPC members were given the option to repeat the exercise if they disagreed with the resulting ranking of the alternatives.

Most members agreed with their results after conducting the exercise just once. However, there were exceptions. The two representatives of the private industrial sector agreed with their results only after their second attempt. The representative of commercial fishers conducted the exercise six times in an unsuccessful attempt to obtain a low priority for the closing of the gulf to commercial fishing. Since he was not satisfied with any of his results, his responses and results were not listed in Tables 11 and 12.

The law enforcement campaign was rated as top priority (Table 12b) and was ahead of the next highest alternative by a wide margin of utility points in all cases (Table 12a). This alternative would have very positive impacts on most of the criteria (Tables 9 and 10). The campaign would protect coral reefs and mangroves and would also reduce fishing effort to an extent. It would also promote equity since the benefits currently accruing to destructive resource users would be distributed among the greater majority who are using legal harvest methods. According to the respondents interviewed regarding the acceptability of interventions, a law enforcement campaign would be welcomed by the majority. After seeing their results, several IPC members affirmed the importance of law enforcement and commented that if only existing laws would be enforced, a number of the gulf's problems would be solved.

On the other hand, all members except one rated the status quo or the option of doing nothing as the least preferred alternative (Table 12b). Some members commented that it was fairly obvious that implementing any one of the alternatives is preferred to doing nothing, given the situation in the gulf. The last listed member in Table 12 rated the status quo above watershed reforestation. Unlike other members who rated watershed reforestation low but would not object to its implementation, this member would rather not have watershed reforestation at all. This member agreed with the implication when it was explained to him, arguing that the high cost of reforestation does not make it worthwhile.

The listing of IPC members in Table 12b groups together members with the same prioritization of alternatives. The first eight members listed form one group with the same prioritization, the members numbered 9 to 12 form another group, while the last two members have unique prioritization.

Comparing the first eight members and the members numbered 9 to 12, there was a switch in priority between closing the gulf to commercial fishing and mangrove forestation and between the closed season for siganids and watershed reforestation. Note that the closing of the gulf to commercial fishing and the closed season for siganids are fisheries management alternatives with positive impacts on reducing fishing effort (Table 9). Also, next to the status quo these two alternatives are the least costly. On the other hand, the reforestation projects score relatively high on habitat protection/enhancement. In Table 11c the members numbered 9 to 12 weighed habitat protection/enhancement considerably above sustainable exploitation (at least four percentage points higher). This contrasts with the first eight members who weighed sustainable exploitation over habitat protection/enhancement and/or weighed the two objectives closely. Weighing sustainable exploitation over habitat protection/enhancement adds utility points to the fisheries management alternatives for their reduction in fishing effort. Weighing the two objectives closely allows the low costs of the fisheries management alternatives to compensate for their lack of impact on habitat protection/enhancement.

The prioritization of the vice mayor (No. 13) appears to blend the prioritization of the two groups. Based on utility points (Table 12a), his results are closer to those of the first eight members. In his case mangrove reforestation edged out closing the gulf to commercial fishing because his weight on minimizing administrative costs was not too far from his weight on his most important objective (Table 11c). Therefore, the effect of high project cost, which reduces the utility of mangrove reforestation, was lessened.

As for the president of the federation of fishers' organizations (No. 14), his unique prioritization of alternatives naturally follows from his unique scoring of the objectives. He was the only one who ranked minimizing administrative costs as the most important objective, which favors the status quo. Also, his use of 10-point increments to score the objectives (Table 11b) resulted in the most widely spread (i.e., highest deviation) set of weights (Table 11c).

Group decision making

When the IPC members met to decide as a group, the authors presented the average scores assigned to the objectives in Table 11b and the resulting prioritization of the alternatives in Table 13. We emphasized that these were being shown primarily to initiate discussion. We suggested that as a group the IPC should evaluate each objective and achieve consensus on their relative importance, since taking the average of individual scores is a rather mechanical and arbitrary means of aggregating preferences. However, a member argued that since the average scores and the resulting prioritization represent the average opinion of the majority of the members, then these results could represent the group decision. In addition, another member pointed out that a sufficient number of IPC members had conducted the individual decision making exercise to represent the majority. The rest of the members agreed with these views.

As mentioned earlier, the quantitative prioritization of alternatives was only a means for initiating evaluation that would encompass qualitative aspects as well. Thus, the discussion shifted to a re-examination of the alternatives, beginning with the proposal to close the gulf to commercial fishing. The authors pointed out that the closure will have little impact on sustainability, which is one of the usual justifications for excluding commercial fishers. The closure does score high on equity, but it gets high priority mainly because of its high acceptability and relatively low administrative costs. We asked the IPC if they really wanted to phase out commercial fishing on this basis. The response was that closure should be pursued primarily for legal reasons. Since 94% of the gulf is within municipal waters (15 km from the coast), by law the commercial fishers should only operate at the small area in the middle of the gulf. The commercial fishers admit that they fish within 15 km of the shore because fishing is not viable at the center of the gulf, which is more than 500 fathoms deep. To be practical in implementing the law, the exclusion of commercial fishing in the entire gulf is necessary.

Other points were raised in favor of the closure. The commercial fisher was given several opportunities to respond, but the gist of what he said is that he could not commit to anything without consulting other affected commercial fishers.

The members also argued that the mangrove and watershed reforestation projects will have positive impacts on equitable distribution of benefits, as opposed to the "no impact" assessment of the authors (Tables 10 and 11). It was pointed out that mangroves and upland forests are resources used primarily by low income groups. Also, reforestation is only a component of a larger program mangrove management, which would also cover existing mangroves. In both cases, community involvement is sought through stewardship agreements. The representative from the Department of Environment and Natural Resources, which conducts reforestation projects, was asked to quantify the impacts using the scale in Table 6. He said that reforestation projects would have a moderate impact on equity and gave both a rating of 2.

The effect of this change was to break the tie between the closing of the gulf to commercial fishing and mangrove reforestation (Table 13), with the latter ranked second in priority while the former was ranked third. Also, with the additional points watershed reforestation now outranked the closed season. All members present agreed with the new prioritization.

Sensitivity Analysis

Sensitivity analysis was conducted on the weights of the IPC's group decision to see how changes in the weights would affect the prioritization of alternatives. The first result in Table 13 was used for this analysis. Figs. 4a to 4c show the sensitivity graphs of the criteria. The vertical axis of a sensitivity graph indicates the utilities while the horizontal axis shows the weight given to the objective. For each alternative, a line indicates how its relative utility changes as the weight on an objective is varied from zero (on the left side of the graph) to a hundred percent (on the right side).

In each sensitivity graph a lone vertical line indicates the weight on the objective assigned during the group decision making session of the IPC. From the top, the vertical line first intersects the law enforcement line, which was ranked highest. Next, it simultaneously cuts through the lines of mangrove reforestation and the closing of the gulf to commercial fishing, since these two alternatives were tied at No. 2 priority in the group's first result (Table 13). The next line to be intersected is that of the closed season, followed by marine sanctuaries, watershed reforestation and the status quo, which is consistent with the prioritization in Table 13.

As can be seen from the graphs, moving the vertical line to the left or to the right would cause changes in the prioritization. Obviously, any movement would break the tie between the closing of the gulf to commercial fishing and mangrove reforestation. But which criteria is the decision most sensitive to? In other words, which criteria, if weighted slightly differently, would produce the next change in priority? Changes in priority occur in the vicinity of the intersection of two or more lines of alternatives. Thus, by visual inspection of each graph, one can identify an intersection that is closest to the vertical line. One can then compare the graphs to see where the distance between the vertical line and the next intersection is smallest. In this analysis, this distance is shortest in the case of the sustainable exploitation criteria (Fig. 4a). A slight decrease of two to three percentage points on the weight on this criteria would move closed season down to fifth priority while marine sanctuaries would move up to fourth place.

The rest of the criteria are comparable in this respect. The weight of each must be varied by six to eight percentage points before the next change in priority occurs. Also, for all criteria the next change would involve the switching of the ranks of closed season and marine sanctuaries.

The sensitivity graphs also indicate that in general only extreme changes in weights would dislodge law enforcement and the status quo from the first and last priority, respectively. There is some possibility of ranking the status quo above watershed reforestation by putting more weight on minimizing costs (Fig. 6b). The rank of watershed reforestation seems stable at sixth place, although some switching is relatively likely with changes on the weights on sustainable exploitation and minimizing costs.

One use of the sensitivity analysis is to provide a basis for classifying the alternatives. In San Miguel Bay, the top four alternatives with highest utility were categorized as "urgent", the next four were called "necessary" and the last four were labelled "desirable but deferrable" (see Luna in press, a and b). The use of three categories and the equal distribution of the alternatives among the categories was rather arbitrary. For Lagonoy Gulf, perhaps the IPC could label law enforcement as extremely urgent, since it is clearly the highest ranking alternative. Mangrove reforestation *and* the ban on commercial fishing could be categorized as urgent. The closed season *and* marine sanctuaries could be classified as necessary. Watershed reforestation could be called desirable but deferrable. The IPC could label the categories differently, but the point is that some alternatives should be placed in the same category because for practical purposes they are of equal merit, as shown by the tendency to switch ranks given relatively small changes in weights.

Conclusion

The decision analysis was designed to aid the IPC in its planning process. The IPC now has the main building blocks for a management plan. These include six recommendations, which have been carefully evaluated and prioritized. Its planning process is documented and the manner in which it arrived at its decisions is transparent. The IPC can also expound on its management philosophy by referring to the hierarchy of objectives. To complete the management plan, the work that remains will essentially involve packaging.

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Table 1. Members of the Interim Planning Committee (IPC).

Title/Position of Member	Name of Organization/Unit	Sector/Institution Represented
Bay Coordinator for Lagonoy Gulf	Project Management Office Fisheries Sector Program (FSP) Department of Agriculture (DA)	FSP national implementing agency
Special Assistant for Fisheries Development	DA, Region 5	FSP regional mplementing agency/Regional line agency for fisheries
Research Specialist	Department of Environment and Natural Resources (DENR) Region 5	Regional line agency for environmental management
Mayor	Municipality of Rapu-rapu	Local government units (LGUs) of Albay
Mayor	Municipality of Bacacay	"
Bay Leader for Lagonoy Gulf, Albay side	Provincial Fisheries Management Unit (PFMU)	"
Mayor and Chairman of the IPC and the LGRMC	Municipality of Lagonoy	LGUs of Camarines Sur
Vice Mayor	Municipality of Tigaon	"
Bay Leader for Lagonoy Gulf, Camarines Sur side	PFMU	"
Mayor	Municipality of Bato	LGUs of Catanduanes
Bay Leader for Lagonoy Gulf, Catanduanes side	PFMU	"
Field Office Manager	Philippine Rural Reconstruction Movement (PRRM)	Nongovernmental organizations
Executive Director	Development Research and Resource Productivity (DRRP)	"
President	Samahan ng Maliliit na Mangingisda ng Pongco Bonga	Municipal fishers of Albay
Chairperson	Samahan ng Maliliit na Mangingisda ng Tabaco	"
President	Federation of Fishermen's Organizations of Lagonoy Gulf (Camarines Sur)	Municipal fishers of Camarines Sur
President	Sta. Cruz Fishermen-Farmers' Multi-Purpose Cooperative	"
Manager/Vice Chairperson	Batalay Fishermen's Multi-Purpose Cooperative	Municipal fishers of Catanduanes
Ring net owner/operator	-	Commercial fishers
Operations Superintendent	Philippine Geothermal Inc. (PGI)	Private/Industrial Sector
Director	Albay Agro-Industrial Development Corp. (ALINDECO)	"

Table 2. Resource management alternatives for Lagonoy Gulf. Refer to Appendices B-G for details.

Alternative	Description
Status quo	The option of not introducing any new resource management measure.
Closing of Lagonoy Gulf to commercial fishing	Ban on commercial fishing or fishing with vessels of more than 3 GT within the gulf.
Law enforcement campaign against destructive fishing	Enforcement of laws against blast fishing, cyanide fishing, other illegal methods and also illegal cutting of mangroves.
Closed season to protect the siganid fishery	All forms of fishing will be disallowed during siganid spawning runs at delineated sites in seagrass beds that are known routes of the spawning runs.
Establishment and managemenent of marine sanctuaries	In each province a community-managed sanctuary will be established. Fishing will not be allowed in the core area. Other activities may be regulated in specified zones.
Mangrove reforestation	Reforestation of 300 ha.
Watershed reforestation	Reforestation of 700 ha.

Table 3. Scale for measuring reduction of fishing effort.

Impact Level	Reduction of fishing effort
0	No or negligible impact.
1	Low overall reduction.
2	Low to moderate overall reduction. Will protect a few species.
3	Low to moderate overall reduction. Will protect a number of species.
4	High overall reduction.

Table 4. Scale for measuring habitat protection and enhancement.

Impact Level	Habitat Protection/Enhancement
0	No or negligible impact.
1	Direct protection/enhancement of one of the following:(1) coral reefs, (2) mangroves or (3) the watershed. No indirect protection/enhancement.
2	Direct protection/enhancement of one of the above, and indirect protection/enhancement of one of the remaining.
3	Direct protection/enhancement of one of the above, and indirect protection/enhancement of the rest.
4	Direct protection/enhancement of two of the above. No indirect protection/enhancement.
5	Direct protection/enhancement of two of the above, and indirect protection/enhancement of the remaining.
6	Direct protection/enhancement of all of the above.

Table 5. Scale for measuring increase in income from nonfishing sources.

Impact Level	Incomes from nonfishing sources
0	No or negligible impact.
1	Will slightly increase incomes from nonfishing sources.
2	Will moderately increase incomes from nonfishing sources.
3	Will strongly increase incomes from nonfishing sources.

Table 6. Scale for measuring equitable distribution of benefits from the exploitation of coastal resources.

Impact Level	Distribution of benefits
-1	Will promote an inequitable distribution of benefits (i.e, penalize low income fishers/coastal inhabitants or favor higher income groups.)
0	No or negligible impact.
1	Will slightly promote equitable distribution of benefits (i.e., favor low income fishers/coastal inhabitants).
2	Will moderately promote equitable distribution of benefits.
3	Will strongly promote equitable distribution of benefits.

Table 7. Constructed scale for measuring political acceptability. Adopted from Luna (in press a).

Impact level	Political impact
0	People will take serious actions to oppose the intervention. Examples of such actions include calling the attention of national officials, filing law suits, organizing demonstrations, civil disobedience, etc.
1	People will take less forceful actions to oppose the intervention.
2	People will express strong resentment of the intervention in public hearings or when interviewed.
3	People will express moderate resentment of the intervention in public hearings or when interviewed.
4	No reaction or general indifference.
5	People will express moderate approval of the intervention in public hearings or when interviewed.
6	People will express strong approval of the intervention in public hearings or when interviewed.
7	People will actively participate in implementing selected portions of the intervention.
8	People will actively participate in implementing most or all aspects of the intervention.

Table 8. Political acceptability of the alternatives. The values shown are averages. See Table 7 for impact levels.

Respondent \ Alternative	1	2	3	4	5	6
IPC members						
Pres. of Federation of F.O.'s	6.4	5.8	(1.0)	7.2	(3.2)	4.0
PRRM Field Office Manager	7.7	6.0	2.3	(2.0)	7.4	5.8
Tigaon Vice Mayor	6.6	7.2	4.2	6.6	8.0	(3.5)
IPC Chairman	8.0	5.6	3.8	7.0	8.0	6.3
Bay Leader, Cam. Sur side	7.7	(7.9)	3.8	5.0	7.8	4.4
Other respondents						
Officer of fisheries cooperative	7.9	6.1	(6.5)	6.0	5.6	5.8
Ring net operator	6.9	6.8	1.8	5.5	4.7	(7.5)
Fish vendor	7.9	(4.8)	5.8	6.0	7.6	6.3
Municipal agricultural officer	(5.7)	6.9	4.5	4.9	5.0	5.2
Average	7.4	6.3	3.7	6.1	6.8	5.4

N.B.

1 - Closing of Lagonoy Gulf to commercial fishing

2 - Law enforcement campaign against destructive fishing

3 - Closed season to protect the siganid fishery

4 - Establishment and management of marine sanctuaries

5 - Mangrove reforestation

6 - Watershed reforestation

Note: Values in parenthesis were not used in computing the average to minimize the standard deviation.

Table 9. Likely impacts of the alternatives. Refer to Tables 3-7 for impact levels.

ALTERNATIVE \ CRITERIA	[1]	[2]	[3]	[4]	[5]	[6]
Present Situation	0	0	0	0	3.0	0
Closing of Lagonoy Gulf to Commercial Fishing	1	0	0	2	7.4	1,707,000
Law Enforcement Campaign Against Destructive Fishing	2	4	0	1	6.3	5,109,000
Closed Season to Protect the Siganid Fishery	3	0	0	-1	3.7	928,000
Establishment and Management of Marine Sanctuaries	0	1	1	0	6.1	6,426,000
Mangrove Reforestation	0	2	2	0	6.8	9,180,000
Watershed Reforestation	0	2	1	0	5.4	20,879,000

[1] - Reduction of fishing effort
[2] - Habitat protection/enhancement
[3] - Incomes from nonfishing sources
[4] - Distribution of benefits
[5] - Political acceptability
[6] - Estimated cost of project/alternative

Table 10. Qualitative description of the likely impacts of resource management alternatives.

CRITERIA / ALTERNATIVE	Reduction of Fishing Effort	Condition of Coral Reefs	Mangrove Cover	Watershed Area Identified as Non-Point Pollution Source	Incomes from Non-Fishing Sources	Distribution of Benefits or Equity	Political Acceptability	Estimated Cost of Alternative/Project (Pesos)
Present Situation	Localized overexploitation in some nearshore areas. The Gulf as a whole is not overexploited..	Of 40 sites surveyed, one site or 2.5% is in excellent condition (75-100% Live Coral Cover or LCC), nine sites (22.5%) are good (50%-74% LCC), 18 sites or 45% are fair (25%-49% LCC), and 12 sites or 30% are poor (less than 24% LCC)	The gulf's mangrove cover of 1,989 hectares during the 1950's has been reduced to 1,316 hectares	About 4,392 hectares in the watershed are critical non-point pollution sources. In addition, about 15,582 hectares are in the sub-critical category. About 2,836 hectares (64.6%) of the critical areas are suitable for reforestation.			The majority are not satisfied with the present situation.	
Closing of Lagonoy Gulf to Commercial Fishing	Will reduce annual fishing effort by about 1.7% (total effort of 19 ring netters).	No impact.		No impact.	No impact.	Will favor small fishers.	The majority will actively participate in implementing the alternative, ranging from partial to full participation. About 19 ring netters will be affected.	1,707,000
Law Enforcement Campaign Against Destructive Fishing	Will reduce fishing effort exerted by blast fishing and the use of poisons.	Will stop the destruction of coral reefs.	Will probably also include stricter enforcement of laws against illegal harvesting of mangroves.	No impact.	No impact.	Catches of destructive gear may be redistributed among a larger group of fishers.	The majority will express strong approval while some will actively participate in implementing selected portions of the alternative.	5,109,000
Closed Season to Protect the Siganid Fishery.	Will reduce fishing effort in the reef flats and protect siganids.	Negligible impact.		No impact.	No impact.	Gears that will be affected are: gillnets, spear gun, pull net, baby bagnet, beach seine and fish corral (mostly small-scale).	The majority will express will be indifferent while some will express moderate resentment.	928,000
Establishment and Management of Marine Sanctuaries.	Fishing will stop within the sanctuaries. Overall effort reduction will be minimal or negligible. (Fishes will grow and increase in numbers within the sanctuaries. Some will move to nearby fishing grounds. In such areas, catches will increase.)	Coral reefs within the sanctuaries will be preserved and will supply coral larvae to recolonize damaged reefs.	Mangroves within the sanctuaries will be protected.	No impact.	Communities will manage the sanctuaries where tourism and other non-extractive activities will be promoted	Exclusive use rights for some communities. Overall impact will be negligible.	The majority will express strong approval.	6,426,000

Table 10. Qualitative description of the likely impacts of resource management alternatives. (continuation)

CRITERIA / ALTERNATIVE	Reduction of Fishing Effort	Condition of Coral Reefs	Mangrove Cover	Watershed Area Identified as Non-Point Pollution Source	Incomes from Non-Fishing Sources	Distribution of Benefits or Equity	Political Acceptability	Estimated Cost of Alternative/Project (Pesos)
Mangrove Reforestation	(Mangroves function as nurseries and feeding grounds of fish and other aquatic organisms, thus helping sustain fisheries.)	Mangroves export nutrients to adjacent reefs and help rehabilitate damaged reefs.	Proposed reforestation of 300 hectares.	No impact.	Contract reforestation/stewardship will provide additional income.	No impact.	The majority will actively participate in implementing portions of the intervention while some will express strong approval.	9,180,000
Watershed Reforestation		Will reduce		Reforestation of 700 hectares (24.7% of area suitable for reforestation and 15.9% of critical area).	Contract reforestation/stewardship will provide additional income. Some coastal communities will benefit because some sites will be near the coast.	No impact.	The majority will express moderate to strong approval.	20,879,000

Table 11a. Ranks (in the order of importance) assigned to the objectives during individual sessions with the IPC members.

Objective \ Member	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	3	3	1	1	1	2	1	1	3	2	5	5	3	2
B	2	1	2	2	2	2	5	1	1	1	1	4	1	4
C	4	5	4	3	4	4	3	3	4	3	2	2	2	3
D	5	4	3	4	3	1	2	2	3	4	4	3	5	5
E	1	2	5	5	6	3	4	4	2	5	3	1	4	6
F	6	6	6	6	5	5	6	5	5	6	6	3	6	1

Table 11b. Scores assigned to the objectives during individual sessions with the IPC members.

Objective \ Member	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Ave	Rank
	75	70	95	100	100	70	100	90	70	75	70	30	93	80	83.8	2
B	80	80	90	95	90	70	70	90	90	100	90	55	98	60	87.5	1
C	70	60	75	94	75	60	85	70	60	55	85	65	95	70	67.5	4
D	68	65	80	90	85	80	95	80	70	50	72	60	85	50	73.8	3
E	90	75	70	80	60	65	80	65	80	40	80	75	90	40	66.3	5
F	65	55	60	75	70	55	60	50	50	30	25	60	80	90	47.5	6

Table 11c. Weights (%) derived by normalizing the above scores.

Objective \ Member	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	17	17	20	19	21	18	20	20	17	21	17	9	17	21
B	18	20	19	18	19	18	14	20	21	29	21	16	18	15
C	16	15	16	18	16	15	17	16	14	16	20	19	18	18
D	15	16	17	17	18	20	19	18	17	14	17	17	16	13
E	20	19	15	15	13	16	16	15	19	11	19	22	17	10
F	15	14	13	14	15	14	12	11	12	9	6	17	15	23

N.B.

A - Sustainable exploitation
B - Habitat protection/enhancement
C - Maximize benefits from the utilization of resources
D - Promote equitable distribution of benefits
E - Maximize acceptability of interventions
F - Minimize administrative costs

1 - IPC Chairman
2 - Mayor of Bato
3 - SAFD
4 - Camarines Sur Bay Leader
5 - PGI Superintendent
6 - PRRM Field Office Manager
7 - DRRP Executive Director
8 - Manager, Batalay Fishermen's Multi-Purpose Cooperative
9 - DENR Research Specialist
10 - Catanduanes Bay Leader
11 - ALINDECO Director
12 - Chairperson, Samahan ng Maliliit na Mangingisda ng Tabaco
13- Vice Mayor of Tigaon
14 - Pres., Federation of Fishermen's Organizations of Lagonoy Gulf

Table 12a. Utility points of the alternatives obtained during individual sessions with IPC members.

Alternative / Member	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Law enforcement campaign	0.690	0.699	0.693	0.674	0.693	0.682	0.655	0.694	0.704	0.726	0.659	0.636	0.675	0.678
Close Lagonoy Gulf to commercial fishing	0.489	0.474	0.450	0.456	0.452	0.485	0.477	0.441	0.446	0.363	0.413	0.520	0.465	0.471
Mangrove reforestation	0.484	0.471	0.443	0.455	0.431	0.453	0.443	0.438	0.473	0.429	0.478	0.531	0.472	0.446
Marine sanctuaries	0.426	0.414	0.388	0.399	0.384	0.413	0.400	0.382	0.412	0.342	0.391	0.476	0.412	0.401
Closed season for siganids	0.343	0.331	0.326	0.328	0.336	0.323	0.329	0.310	0.313	0.278	0.255	0.325	0.333	0.405
Watershed reforestation	0.316	0.314	0.293	0.292	0.275	0.298	0.289	0.298	0.326	0.309	0.345	0.334	0.302	0.239
Status quo	0.258	0.245	0.226	0.239	0.237	0.248	0.232	0.212	0.232	0.164	0.173	0.299	0.250	0.301

Table 12b. Prioritization of the alternatives obtained during individual sessions with the IPC members.

Alternative / Member	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Law enforcement campaign	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Close Lagonoy Gulf to commercial fishing	2	2	2	2	2	2	2	2	3	3	3	3	3	2
Mangrove reforestation	3	3	3	3	3	3	3	3	2	2	2	2	2	3
Marine sanctuaries	4	4	4	4	4	4	4	4	4	4	4	4	4	5
Closed season for siganids	5	5	5	5	5	5	5	5	6	6	6	6	5	4
Watershed reforestation	6	6	6	6	6	6	6	6	5	5	5	5	6	7
Status quo	7	7	7	7	7	7	7	7	7	7	7	7	7	6

N.B.

1 - IPC Chairman
2 - Mayor of Bato
3 - SAFD
4 - Camarines Sur Bay Leader
5 - PGI Superintendent
6 - PRRM Field Office Manager
7 - DRRP Executive Director
8 - Manager, Batalay Fishermen's Multi-Purpose Cooperative
9 - DENR Research Specialist
10 - Catanduanes Bay Leader
11 - ALINDECO Director
12 - Chairperson, Samahan ng Maliliit na Mangingisda ng Tabaco
13 - Vice Mayor of Tigaon
14 - Pres., Federation of Fishermen's Organizations of Lagonoy Gulf

Table 13. Prioritization of the alternatives as agreed upon by the IPC during its group decision making session.

Alternative	First result		Result after changing impacts*	
	Utility	Priority	Utility	Priority
Law enforcement campaign	0.683	1	0.683	1
Mangrove reforestation	0.459	2	0.543	2
Close Lagonoy Gulf to commercial fishing	0.459	2	0.459	3
Marine sanctuaries	0.402	3	0.402	4
Closed season for siganids	0.324	4	0.324	6
Watershed reforestation	0.301	5	0.385	5
Status quo	0.237	6	0.237	7

* - The impacts of mangrove reforestation and watershed reforestation on equitable distribution of benefits were changed from 0 (no impact) to 2 (moderate impact).

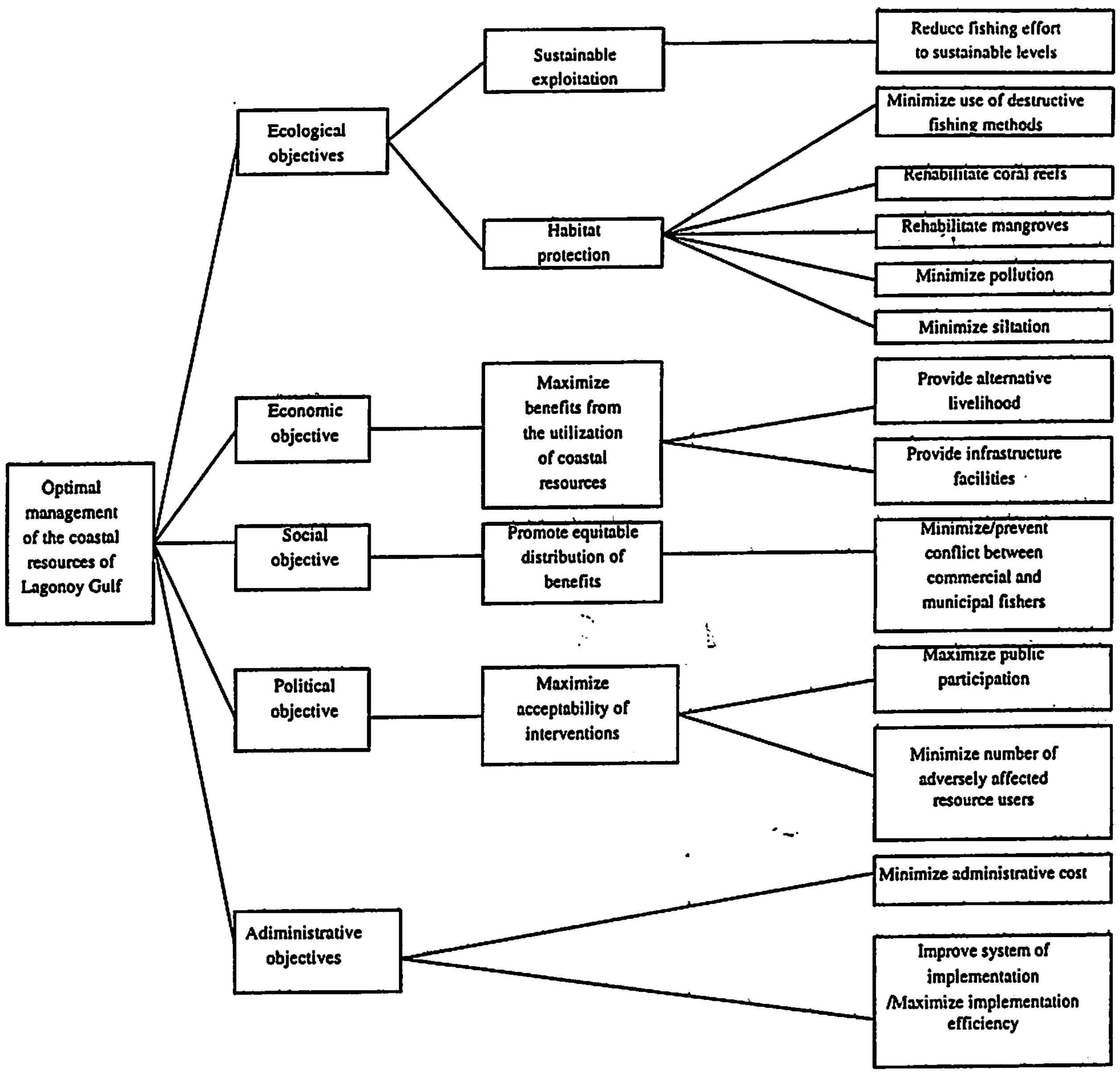


Fig. 1. The objectives tree produced by the IPC members from Albay.

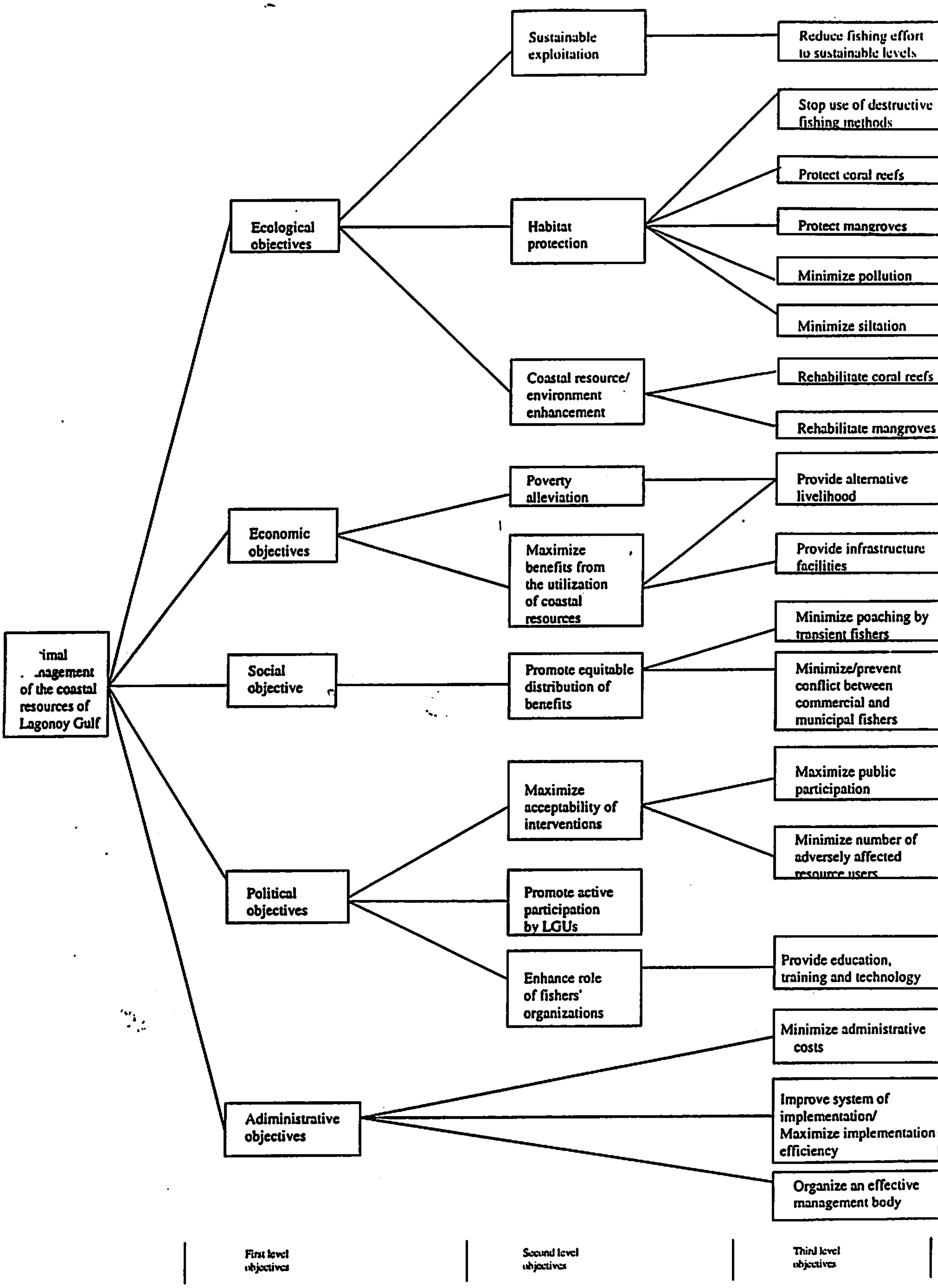


Fig. 2. The final objectives tree agreed upon by the IPC.

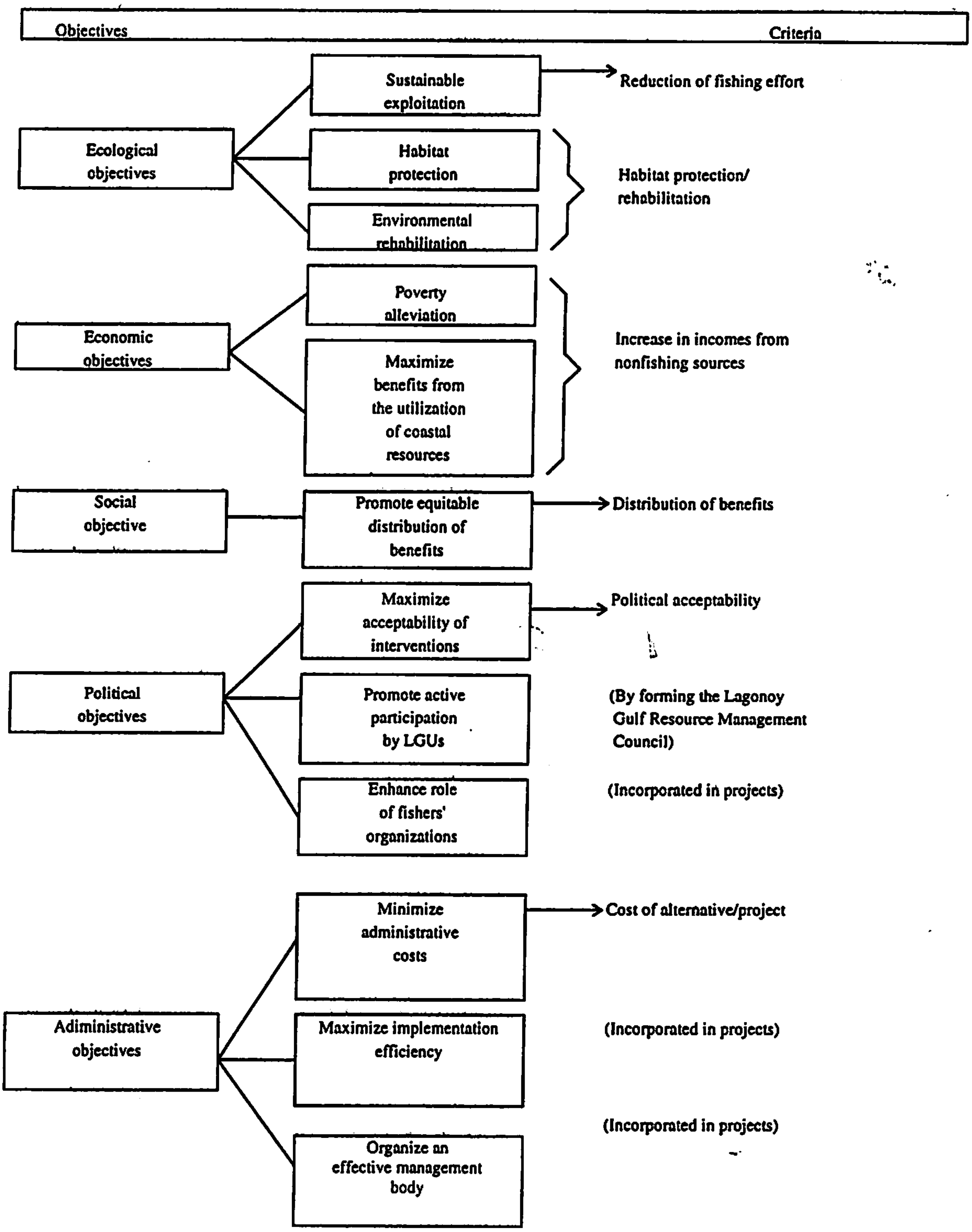


Fig. 3. Criteria derived from second-level objectives.

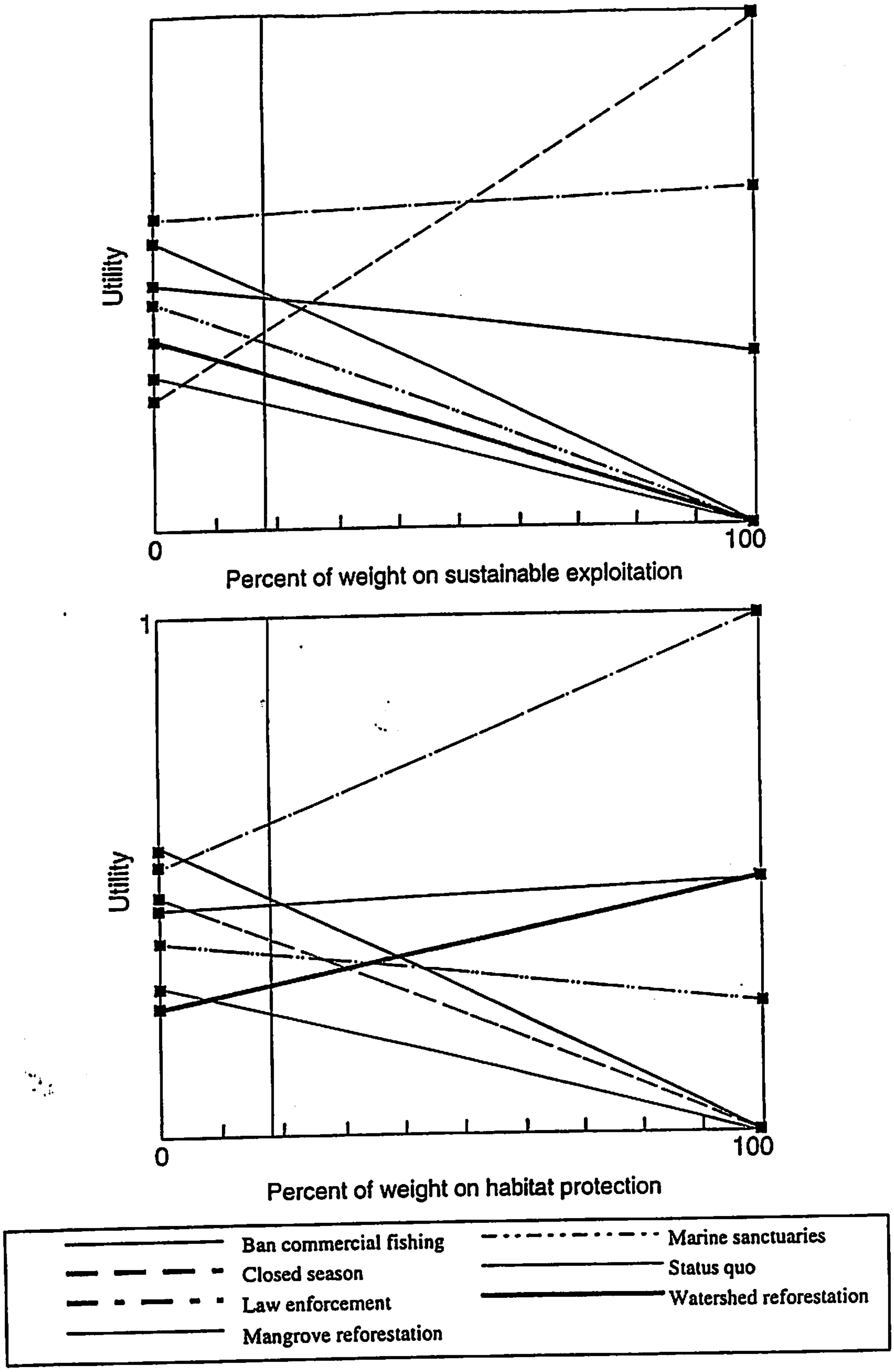


Fig. 4a. Sensitivity graphs of the weights on sustainable exploitation (top) and habitat protection/enhancement (bottom).

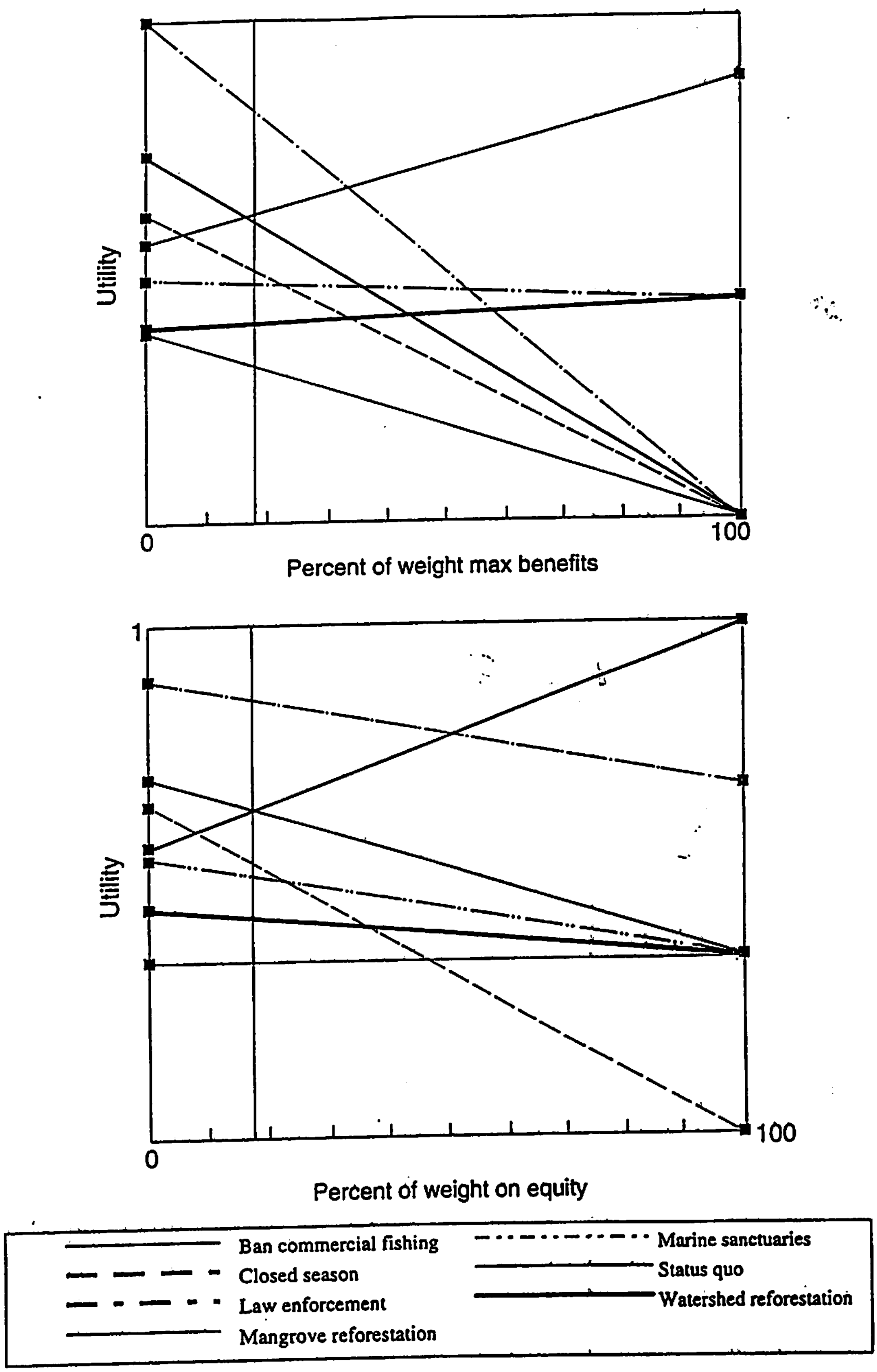


Fig. 4b. Sensitivity graphs of the weights on maximizing benefits from the utilization of fishery resources (top) and promoting equitable distribution of benefits (bottom).

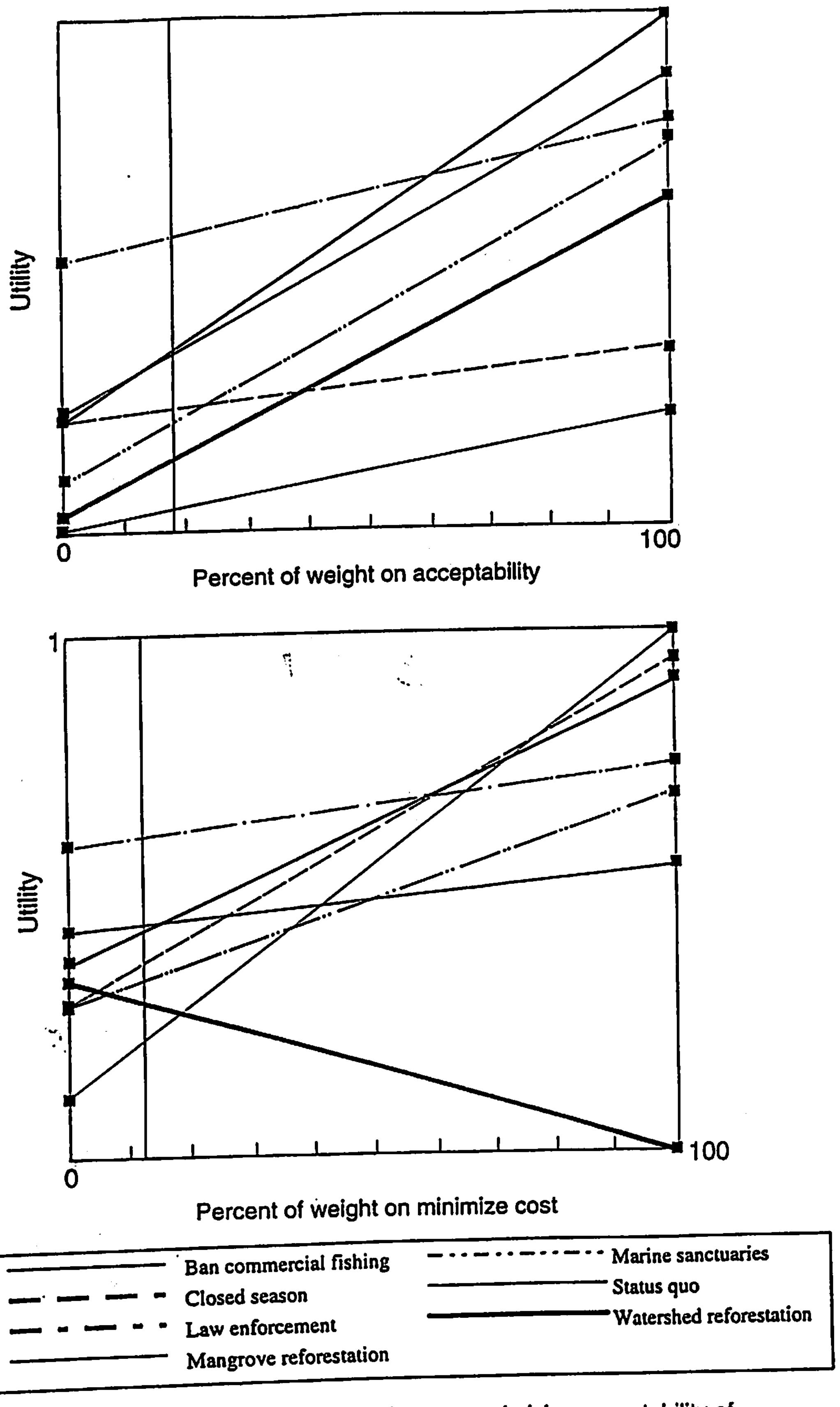


Fig. 4c. Sensitivity graphs of the weights on maximizing acceptability of interventions (top) and minimizing administrative costs (bottom).

APPENDIX A

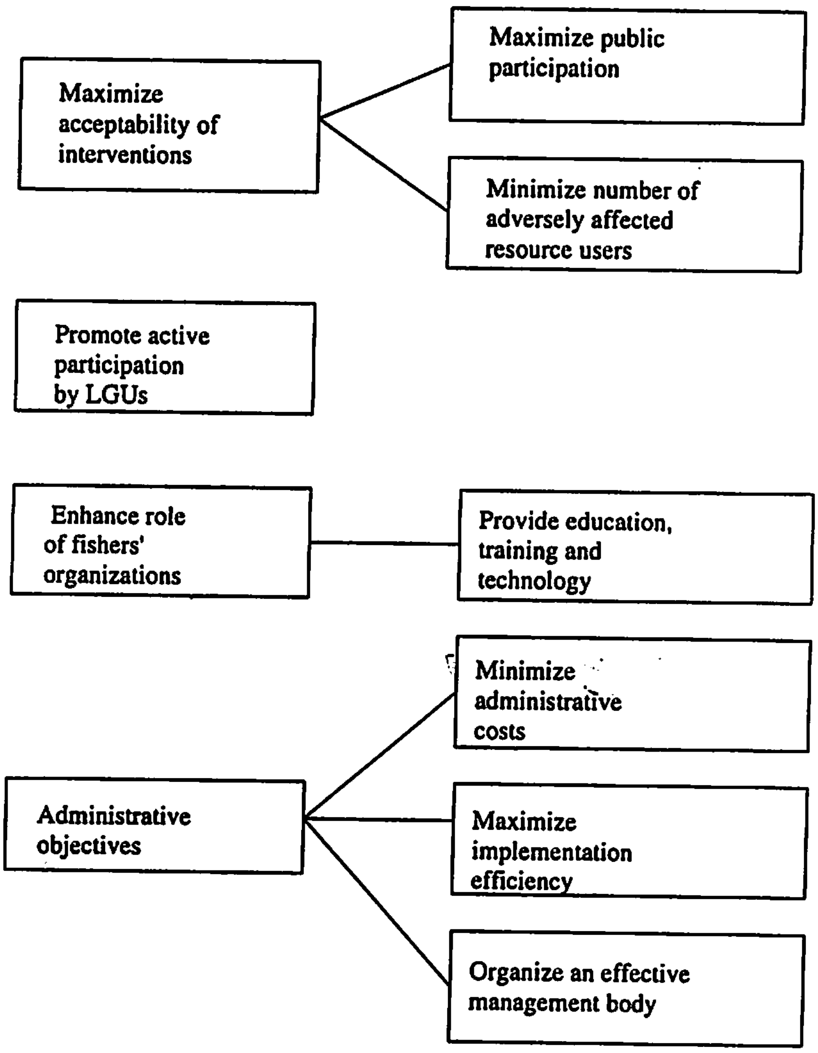
PRELIMINARY LIST OF ALTERNATIVES MATCHED AGAINST THE OBJECTIVES

Objectives		Alternatives
Sustainable exploitation	Reduce fishing effort to sustainable levels	Prohibit use of fine mesh nets (e.g., beach seine) Prohibit bangus fry gathering Strenghten measures to keep commercial fishers out of municipal water, e.g., prohibit commercial fishing in the gulf Regulate the gathering of sea cucmbers, sea urchins and juvenile crabs Regulate issuance of permits for fish corrals Closed seasons (e.g., for the Siganid fishery) Co-management of fishing grounds (with exclusive use rights)
Habitat protection	Minimize use of destructive fishing methods	Strict enforcement of laws on fisheries and conservation of corals Law enforcement training
	Protect coral reefs	Add/create items for fish examiners Monitor sales, supplies and usage of NaCN and other chemicals Inspect fishing vessels transient fishermen before issuing municipal permits Establish a cyanide detection laboratory in Bicol
	Protect mangroves	Strict enforcement of laws on mangrove conservation Require bakeries to use alternative fuel sources
	Minimize pollution	*(See next page)*
	Minimize siltation	*(See next page)*

Objectives		Alternatives
Habitat protection	Minimize pollution	Include a subject about environmental protection in the school curriculum Use of organic fertilizers and bio-pesticides Construction of landfill Find outlets for recycled waste products Proper waste disposal Focus anti-pollution campaigns on rivers and estuaries (domestic pollution) Prohibit the disposal of of garbage by boats in transit
	Minimize siltation	Reforestation Relocation of upland dwellers outside affected areas Annulment of titles (in public lands) Land classification (to keep public lands intact) Intensified farming systems
Environmental rehabilitation	Rehabilitate coral reefs	Establish protected areas/ sanctuaries Establish permanent anchor sites Study and protection of turtle nesting sites
	Rehabilitate mangroves	Mangrove reforestation

Objectives		Alternatives
Poverty alleviation; Maximize benefits from the utilization of coastal resources	Provide alternative livelihood	Livelihood projects recommended by the Socio-Economic and Investment Opportunities Studies Backyard swine production Smallholder broiler production Duck (mallard) egg production - 100 bird level Four-head cattle combined breeding-fattening Coconut-based multiple cropping Smallholder tilapia cage culture Smallholder oyster farming Smallholder mussel production Smallholder seaweed farming Village rice mill Agricultural machinery repair Small-scale fish processing Coconut food processing Coconut charcoal briquette production Concrete product (hollow blocks) manufacturing Handicraft manufacturing Garment production Give fishers' organizations access to/ownership of abandoned fishponds thru stewardship
Maximize benefits from the utilization of coastal resources	Provide infrastructure facilities	Establish post-harvest facilities
Promote equitable distribution of benefits	Minimize poaching by transient fishers	
Promote equitable distribution of benefits	Minimize/prevent conflict between commercial and municipal fishers	

Objectives	Alternatives



Community organizing
Information and education campaign

Uniform municipal ordinances

APPENDIX B

PROJECT: CLOSING OF LAGONOY GULF TO COMMERCIAL FISHING

Description

The Lagonoy Gulf Management Council is considering the banning of commercial fishing in the gulf. The main reason given is that 94% (2894.72 km^2) of the gulf's waters are within 15 km of the shoreline. This leaves only 6% (169.79 km^2) beyond the boundaries of municipal waters where commercial fishing boats may operate if the municipal governments decide to ban commercial fishing in their areas. Fishing beyond 15 km at the center of the gulf may not be economically viable because of the low productivity associated with such depths. Also, it would be much easier to implement a ban on commercial fishing in the entire gulf than to enforce the 15 km boundary.

Activities

Public hearings will be conducted during the first quarter of the first year before the ban takes effect. It is expected that violations (and enforcement costs) will be high during the first two years and will decrease in succeeding years.

Funding Requirements (Closing of Lagonoy Gulf to Commercial Fishing)

	Y1	Y2	Y3	Y4	Y5
Additional enforcement costs/mun./mo.	3,000	2,000	1,000	1,000	1,000
Annual cost for 15 municipalities	540,000	360,000	180,000	180,000	180,000
Public hearings	50,000				
Annual costs	590,000	360,000	180,000	180,000	180,000
Inflation factor (10% annual)		1.10	1.21	1.33	1.46
Inflated costs	590,000	396,000	217,800	239,580	263,538
Total cost	1,706,918				
Rounded to nearest 1000	1,707,000				

Notes:

[1] The other costs (e.g., for equipment) will come from "Upgrade law enforcement capabilities".

[2] Additional costs will be high during the first two years. Thereafter, a small amount will be needed to guard against occassional transients.

APPENDIX C

PROJECT: LAW ENFORCEMENT CAMPAIGN AGAINST DESTRUCTIVE FISHING

Description

Blast fishing, cyanide fishing and other destructive fishing methods kill fish indiscriminately and destroy productive aquatic habitats such as coral reefs. The use of destructive fishing methods in Lagonoy Gulf is apparently widespread. Destructive fishing will be reduced in part by the provision of alternative livelihood opportunities and by information campaigns that emphasize environmental protection. These activities should be complemented by an efficient law enforcement campaign, which is an indispensable component of any strategy to eliminate destructive fishing. This project will implement the said law enforcement campaign.

Activities

Year 1

1. Establishment of a Committee on Law Enforcement under the Lagonoy Gulf Management Council.

2. The Committee will formulate a scheme for implementing an effective law enforcement campaign against destructive fishing.

Years 2-5

1. Implementation of the law enforcement campaign.

Funding Requirements (Intensified Law Enforcement Campaign Against Illegal Fishing)

	Y1	Y2	Y3	Y4	Y5
Additional enforcement costs/mun./mo.	7,000	5,600	4,480	3,584	2,867
Annual cost for 15 municipalities	1,260,000	1,008,000	806,400	645,120	516,096
Public hearings	150,000				
Annual costs	1,410,000	1,008,000	806,400	645,120	516,096
Inflation factor (10% annual)		1.10	1.21	1.33	1.46
Inflated costs	1,410,000	1,108,800	975,744	858,655	755,616
Total cost	5,108,815				
Rounded to nearest 1000	5,109,000				

Notes:

[1] The other costs (e.g., for equipment) will come from "Upgrade law enforcement capabilities".

[2] Additional costs are assumed to decrease annually by 20% due to the effectiveness of the campaign.

APPENDIX D

PROJECT: CLOSED SEASON TO PROTECT THE SIGANID FISHERY

Description

Siganids are highly valued fish species caught mainly in the seagrass beds near the islands off Albay. These species gather in large numbers during their spawning runs, which occur a few days after the full moon from February to April. Unregulated catching of siganids during their reproductive period has resulted in overexploitation, as evidenced by smaller size ranges and dwindling catches.

This project will introduce a closed season on all forms of fishing from February to April at seagrass beds and/or reef flats that are known routes of the spawning runs. Areas where the closed season will apply shall be clearly demarcated. (If possible, natural markers will be used, e.g., the edge of the reef flat where the waves break.) Fishing will be allowed outside the demarcated areas.

As more specific information on the seasonality of the spawning runs becomes available, the length of season or the affected areas may be re-adjusted. To adequately protect spawners and juveniles, it is recommended that the closed season should be imposed from the start of the full moon before the first spawning run (probably in February) to a month after the full moon of the last spawning run (probably in April).

Activities

Year 1

1. Demarcation of zones where the closed season will apply. Adjustment of the closed season (if necessary). The selection of the zones and the actual season will be done in consultation with affected parties.

2. Drafting of a uniform municipal ordinance on the closed season.

3. Announcement of the impending closed season and public hearings.

Year 2

1. Implementation of the closed season from in 50% of the identified sites.

2. Start of on-site monitoring activities.

Year 3-5

1. Implementation of the closed season in all identified sites.

Funding Requirements (Closed Season to Protect the Siganid Fishery)

	Y1	Y2	Y3	Y4	Y5
Drafting of Ordinance/Public hearings	75,000				
Additional enforcement costs/mun./mo.		10,000	15,000	15,000	15,000
Cost for 4 municipalities for 3 months	0	120,000	180,000	180,000	180,000
Annual costs	75,000	120,000	180,000	180,000	180,000
Inflation factor (10% annual)		1.10	1.21	1.33	1.46
Inflated costs	75,000	132,000	217,800	239,580	263,538
Total cost	927,918				
Rounded to nearest 1000	928,000				

Notes:

[1] The other costs (e.g., for equipment) will come from "Upgrade law enforcement capabilities".

APPENDIX E

PROJECT: ESTABLISHMENT AND MANAGEMENT OF MARINE SANCTUARIES

Description

Educational and organizational activities will be conducted to encourage communities to actively participate in managing marine sanctuaries and fishery reserves in each of the three provinces.

Activities

1. Site selection

The designated sanctuaries in Brgy., Agojo, San Andres, Catanduanes, and in Gaba, Rapu-rapu, Albay have fair to poor coral cover. The site in Gaba is particularly ill-suited for a fish sanctuary. It may be necessary to consider alternative sites for sanctuaries in Catanduanes and Albay, particularly in the case of Albay.

The designated marine sanctuary in Brgy. Atulayan, Sagnay, Camarines Sur contains a sizeable area with high living coral cover and fish in moderate abundance, making it suitable as a sanctuary. Community organizing and resource management activities described below may be initiated at this site.

2. Activities in each site

a. A general information campaign on community education designed for residents of the three municipalities, which will emphasize the benefits of proper resource management will be implemented. Specific informal educational programs and a training in marine park management designed for local government officials and fishers who show an interest in conserving reef resources will be conducted to develop their potentials as community leaders. A community center will be set up in each municipality for these activities. Marine education programs through print and broadcast media will further instill consciousness in community members. Community organizations will be formalized and strengthened and will assist in the campaign.

b. A marine reserve management committee will be formed to encourage ecologically sustainable fishing practices. Other activities will include zoning, formation of the sanctuaries management committee and installation of markers and signs. Marine parks sanctuary laws will be drafted and ratified.

c. Periodic monitoring will involve resource users, concerned government agencies, and local academic and research institutions who could extend technical assistance at the same time, to emphasize the tangible benefits of marine parks.

Funding Requirements (Establish. & Manage. Marine Sanctuaries)

Cost per site	Y1	Y2	Y3	Y4	Y5
Site selection (for Albay and possibly for Catanduanes)	40,000				
Community education	500,000	250,000	100,000	100,000	100,000
Construction of community center	300,000				
Patrol boat	90,000				
Personnel and consultancies	120,000	75,000	50,000	50,000	50,000
Contingencies (10% of all of the above)	93,000	25,000	10,000	10,000	10,000
Total	1,143,000	350,000	160,000	160,000	160,000
Inflation factor (10% annual)		1.10	1.21	1.33	1.46
Inflated costs	1,143,000	385,000	193,600	212,960	234,256
Total cost per site	2,168,816				
Cost for 3 sites	6,426,448				
Rounded to nearest 1000	6,426,000				

APPENDIX F

PROJECT: MANGROVE REFORESTATION

Description

Mangrove forests protect coastlines, export nutrients to nearby aquatic habitats and serve as nurseries for various marine species and as habitat for wildlife. Mangroves are directly utilized in forestry and fisheries production. In Lagonoy Gulf, uncontrolled and destructive use patterns have led to a decrease in cover from almost 1,989 ha in 1956 to only 1,002 ha in 1990. This means that almost half of the mangrove forests had disappeared within 34 years.

Preliminary estimates using a Geographic Information System indicate that there are about 1,161 ha that are suitable for mangrove reforestation. The project intends to reforest 300 ha or about 25% of these areas initially identified as suitable. More detailed surveys and evaluation will be conducted to select the most suitable reforestation sites.

Activities

Year 1

1. Finalization of delineation of suitable and most suitable sites based on EHA and SE studies for reforestation

    - mapping and ground truthing surveys to verify potential sites
    - sorting of public and private lands
    - cross-checking of areas that are actually covered by similar programs (e.g., existing reforestation contracts with DENR)

2. Contracting of the sites to qualified FOs

    - training of FO members on mangrove reforestation (species suitability, source of propagules, spacing, etc.) with assistance from NGOs
    - creation of detailed workplan, budget, working areas, manpower and time schedule
    - procurement of appropriate tree stocks and equipment

3. Start of information campaign

    - educational programs for stakeholders such as residents near mangrove areas, mangrove users, local government officials, enforcement personnel and school children, emphasizing ecological and economic values of mangrove ecosystems as natural resources through multimedia audiovisuals, indepth education via lectures and dialogues and workshops

Years 2-5

1. Reforestation of 75 ha per year.

2. Monitoring

   - collaboration of government agencies and local academic and research institutions to help in monitoring activities

3. Continuation of information dissemination

Funding Requirements (Mangrove Reforestation)

	Y1	Y2	Y3	Y4	Y5
Site selection, plan preparation, contracting and other preparatory activities	300,000				
Information campaign	300,000	150,000	75,000	37,500	18,750
No. of ha reforested/yr		75	75	75	75
Per ha cost (P15,000/ha)		15,000	15,000	15,000	15,000
Reforestation and site selection	600,000	1,275,000	1,200,000	1,162,500	1,143,750
Personnel (25% of refo/site selection)	150,000	318,750	300,000	290,625	285,938
Contingencies (10% of all of the above)	75,000	159,375	150,000	145,313	142,969
Annual costs	825,000	1,753,125	1,650,000	1,598,438	1,572,656
Inflation factor (10% annual)		1.10	1.21	1.33	1.46
Inflated annual costs	825,000	1,928,438	1,996,500	2,127,520	2,302,526
Grand total	9,179,984				
Rounded to nearest 1000	9,180,000				

APPENDIX G

PROJECT: WATERSHED REFORESTATION

Description

The absence of forest cover in watershed areas results in accelerated erosion which impacts the coastal area. Analysis of the current landuse, slopes, soil types, erodability and other characteristics of watershed areas that drain into Lagonoy Gulf indicates that 4,392 ha are in critical need of reforestation.

Reforestation is expensive. Thus, the project will reforest only 700 ha (about 25%) of the critical areas. Priority will be given to sites that contribute the most amount of siltation and sites that impact productive coastal habitats (e.g., coral reefs).

Activities

Year 1

1. Conduct of feasibility study for final delineation of suitable sites for reforestation which involves mapping and ground truthing surveys.

2. Nursery establishment and other preparatory activities.

3. Contracting of sites to qualified NGOs.

4. Training of NGOs.

Year 2-5

1. Reforestation of 175 ha per year and maintenance of each site for three years.

Funding Requirements (Watershed Reforestation)

	Y1	Y2	Y3	Y4	Y5
Site selection (mapping, etc.), contracting and other preparatory activities	500,000				
Establishment of nursery	500,000				
No. of ha reforested/yr		175	175	175	175
Replanting and maintenace cost/ha		16,533	16,533	15,948	14,778
Subtotal	1,000,000	2,893,275	2,893,275	2,790,900	2,586,150
Personnel (25% of subtotal)	250,000	723,319	723,319	697,725	646,538
Contingencies (10% of all of the above)	125,000	361,659	361,659	348,863	323,269
Annual costs	1,375,000	3,978,253	3,978,253	3,837,488	3,555,956
Inflation factor (10% annual)		1.10	1.21	1.33	1.46
Inflated annual costs	1,375,000	4,376,078	4,813,686	5,107,696	5,206,276
Grand total	20,878,736				
Rounded to nearest 1000	20,879,000				

Notes:
Planting and 3 years maintenance = P16,533/ha
Planting and 2 years maintenance = P15,948/ha
Planting and 3 years maintenance = P14,778/ha