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Distributional Patterns, Habitat Overlap and Trophic Interactions of Species Caught by Trawling in the Ragay Gulf, Philippines

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The impact of trawlers on the fisheries ecosystem was investigated using the distribution of trawl fisheries catch in Ragay Gulf, the degree of overlap of species caught with those from other coastal fisheries and the trophic flow structure of the components of the system. Multivariate analysis of the exploratory trawl-fishing survey revealed northern and southern species clusters associated with prevailing circulation patterns and phytoplankton density in the gulf. Further analysis of the trawl catch composition showed two more clusters which indicate spatial distribution and intensity of the trawl fishery. These areas were differentiated as "highly fished" and "less fished." More than 50% overlap in species from these different habitats (coral reef, seagrass, mangrove and soft bottom) caught in the multispecies fisheries has implications on municipal water jurisdictions, especially on coastal communities where trawling is a source of living and food. The 45-yr historical reconstruction of trawl fisheries in the gulf using ECOSIM showed a significant decrease in the biomass of large, high-value fish groups and also an increase in small reef-associated carnivores and cephalopod biomass, because of ecosystem overfishing. The subsequent 100-yr simulation showed a shift to small reef-associated species as an effect of trawling activity. Minimal change on the small reef-associated species is noted when there is a complete ban on trawl fishing in the gulf but shows an increase in large carnivores. Coastal zoning schemes should consider the benefits derived from the ban on trawl fishing as also affirmed by anecdotal fisher accounts. In addition, the implications of the effects of trophic interaction and ontogenetic habitat connectedness have a profound influence on the overall dynamics of the fisheries ecosystem.

Key Words: distribution pattern, ECOSIM, species composition overlap, trawl biomass, trawl fisheries, trophic flow structure

INTRODUCTION

Trawl fishing, which uses more than 3 gross tonnage boats, is the most effective method of commercial fishing in the Philippines, yielding mean catch rates of nearly 130 kilograms per hour (kg h^{-1}) in Ragay Gulf, Philippines (Fig. 1). This method, compared with other commercial fishing methods operating around the gulf, can catch approximately 70% of the marketable fish species (Guarin et al. 1995 unpublished). Consequently, fisheries experts and stakeholders identify trawl fishing in municipal waters to be the major cause of low catches of municipal fisheries (i.e., locally defined as fishing with 3 or less gross tonnage boats) with catch rates of 1–5 kg h^{-1} (Guarin et al. 1995 unpublished). Trawlable areas are limited to the nearshore, soft bottom areas with depths of at most 40 m and inside the 15-km-from-shore municipal water zone, as defined in Republic Act (RA) 8550 in 1998, also known as The Philippine Fisheries Code. For Ragay, this translates to about 220 km^2 or 6% of the 3,600 km^2 spatial extent of the gulf.

Historically, since the 1970s, other types of commercial fishers have been encroaching on the more productive municipal areas of the gulf, particularly in the northernmost portion at water depths of 40–70 m and near its mouth at depths of around 300 m (Ingles 1988; Guarin et al. 1995 unpublished). In 1975, however, Presidential Decree 704 (PD 704) restricted commercial fishing operations nationwide in marine water areas beyond depths of around 12.8 m (7 fathoms) and beyond dis-

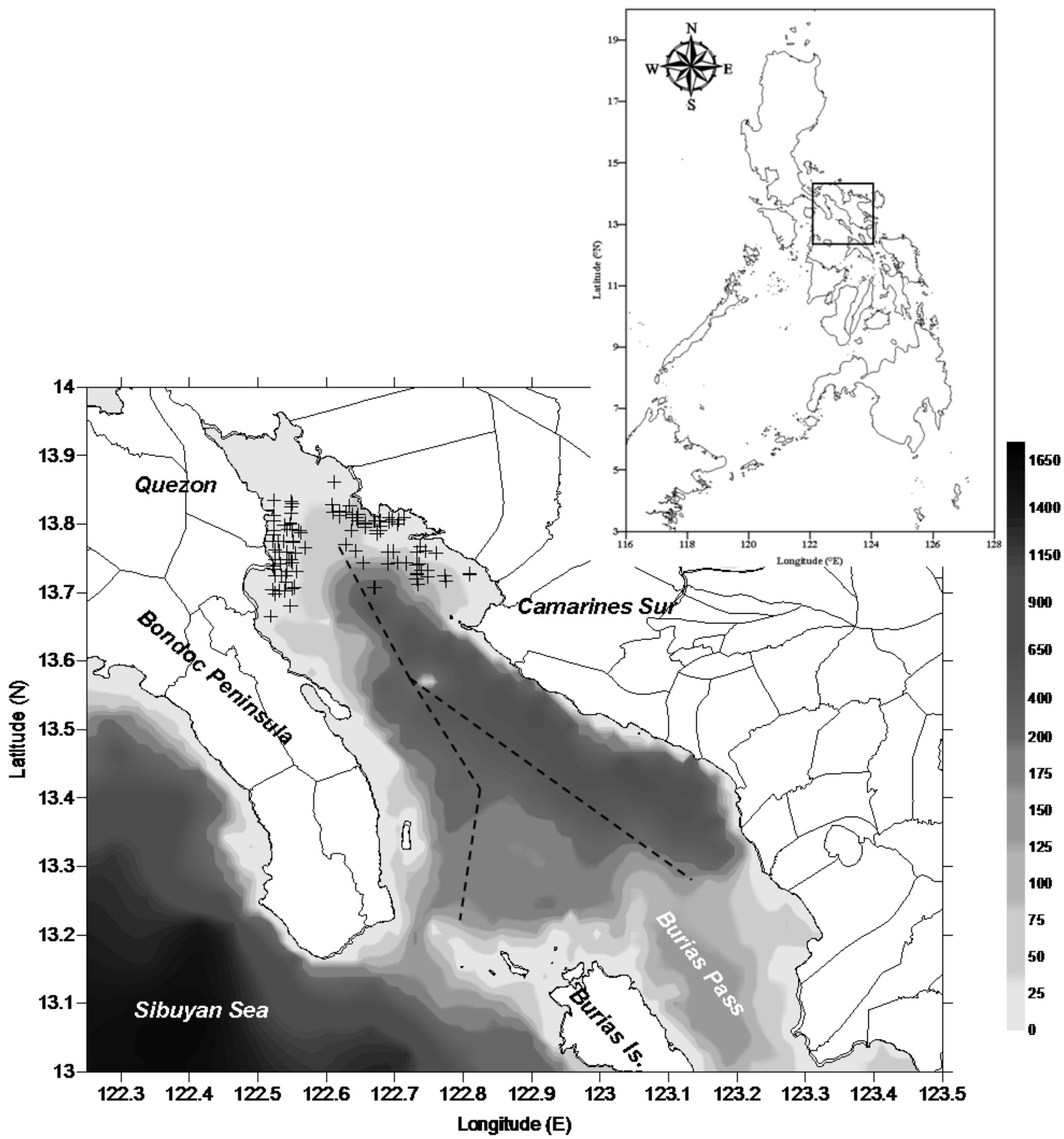

Fig. 1. Location and bathymetric map (depth in meters, m) of Ragay Gulf, Philippines. Small crosses represent the common area for trawl operations. Line boundaries are the coastal barangay's delineation. Broken lines represent the estimated 15-km municipal territorial line.

tances 7 km from the shore. In 1998, RA 8550 superseded this decree. Although it recommends restriction of commercial fisheries beyond 15 km, it gives municipalities the options to allow commercial fishing within 10.1–15 km from the shoreline. RA 8550, along with the enacted Letter of Instruction 1328 (LOI 1328) from Fisheries Administrative Order 156 (FAO 156) in 1986, only restricts certain types of commercial fisheries (e.g., active fishing gears such as commercial trawlers).

Municipal fisheries in the gulf have also been restricted to the nearshore waters because of high fuel and motorized operating costs and the presence of nearly half of the 7,000 operating nonmotorized fishing boats (Hilomen et al. unpublished). Despite these enactments and restrictions, commercial fishing operations still continue inside the gulf and are often within the 15-km boundary of municipal waters, where about 12,500 local municipal fishers operate. Over 40 variants of municipal fishing gears have been introduced and are diffused with a wide range of target species. All these activities have led to a significant overlap between commercial and municipal catches. In 1995, for example, nearly 50% of the species caught by commercial fishers overlapped with catches of municipal fisheries from various types of habitats. As a result, the gulf's fisheries experience resource-use conflicts in terms of spatial overlap in fishing operations and in species caught.

To evaluate the impact of trawlers on the fisheries ecosystem of the gulf, we investigated the distribution of commercial trawl fishing in the gulf, the degree of overlap of species caught with those harvested by other coastal fisheries, and the possible trophic interaction of the species caught. Specifically, (1) we determined the distribution pattern of trawl fish catches in Ragay Gulf in relation to oceanographic factors, (2) investigated to what degree the species caught by trawl fishery overlap with those associated with the different coastal habitats of the gulf and (3) evaluated the role of trawl fisheries in shaping the biomass flow structure of the fisheries ecosystem of Ragay Gulf.

MATERIALS AND METHODS

The information we used in this study belongs to the Philippine Fisheries Information System (PhilFIS), a system developed by the Fisheries Resources Management Project (FRMP) of the Department of Agriculture–Bureau of Fisheries and Aquatic Resources (DA-BFAR) in 1999. Lachica-Aliño et al. (unpublished) described the details of the information used in the analysis.

Estimation of Trawl Biomass

A total of 24 hauls were obtained during two sampling cruises with 12 experimental trawl stations per sampling cruise. Each cruise was limited to trawlable depths of 30–40 m using a semi-pelagic trawl (i.e., a high opening bottom trawl called "Norway") of standard commercial design operating around the gulf. Sampling cruises were chosen to be seasonal representatives: Cruise 1 in July 1994 for the southwest (SW) monsoon, which typically lasts from June to September; and Cruise 2 in January 1995 for the northeast (NE) monsoon, which typically lasts from October to March.

For each station per cruise, the following parameters were calculated: 1) the biomass in weight per unit area (kg km^{-2}) using the swept area method (Pauly 1980) and 2) the catch per unit of effort using the geometric mean estimate (McConnaughey and Conquest 1993). Most sizes of the species identified in the catch were greater than 2.25 cm species; therefore, a catchability coefficient (q), which is the fraction of the biomass actually caught in the effective path swept by the trawl, of 0.5 was used for this particular study. This parameter is comparable with those used in the works of Blaber et al. (1990) where q = 0.47 for >2.25 cm species, and in Pauly (1979) where q = 0.5 for species commonly caught using Southeast Asian bottom trawls.

Temporal Variability and Species / Station Associations

We investigated temporal variability using a summary matrix of the two cruises. The matrix was composed of 38 commonly occurring species (i.e., each species made up >0.1% of the biomass as adapted from Barber et al. [1997] that accounts for 93% of the total biomass). To distinguish the effect of seasonal variability (e.g., species composition and abundance alteration due to migration), it was essential to ensure that the sampling stations of the pooled data are distant from one another on the classification diagram and on the ordination plot (Federizon 1992). Environmental data and fishing pressure were used to analyze association of environmental gradient to temporal variation in species abundance and distribution. Environmental data included current velocity (ms^{-1}) (Fig. 2) (Villanoy and Trayvilla 1995 unpublished), direction of current in radians (Fig. 2) (Villanoy and Trayvilla 1995 unpublished), and phytoplankton (Fig. 3) and zooplankton densities (cells per m^3) (Castillo and Cuevas 1995 unpublished) for each trawl station, that was based on values of the nearest hydrographic survey station at a similar depth. Catch rates (kg h^{-1}) used were the geometric mean per trawl station per cruise (Guarin et al. 1995 unpublished). Association of species/stations and environmental gradients was analyzed using Canonical Correspondence Analysis (CCA) using the canonical community ordination (CANOCO) software (Ter Braak 1988 in McCune and Mefford 1999).

Species/station association analysis per sampling cruise was done using the divisive classification algorithm known as Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979 in McCune and Mefford 1999). This shows the hierarchical relationship between group of species or stations. Two-way cluster analyses were done, that is, clustering stations based on species composition and clustering species on their distribution and abundance in terms of biomass within stations. The most abundant and commonly occurring species (i.e., 20 species for Cruise 1 and 29 species for Cruise 2) were chosen on the basis of prior examination of the biomass data.

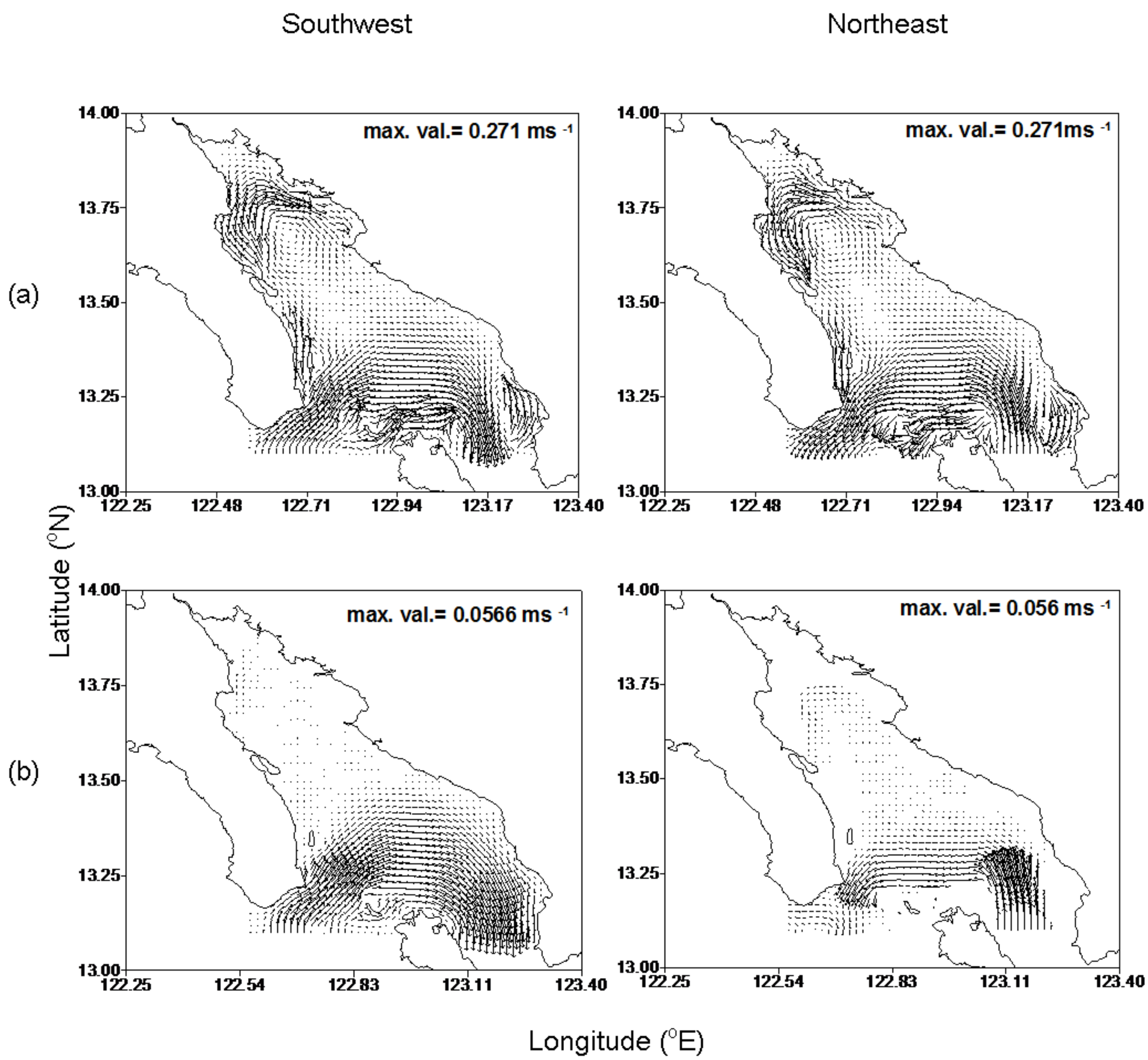

Fig. 2. Upper (a) and lower (b) layer current velocity fields in Ragay Gulf, Philippines during the southwest and northeast winds (adapted from Villanoy and Trayvilla 1995 unpublished).

Trawl Species-Coastal Habitat Overlap Analysis

The species composition of the catches of municipal and other non-trawl commercial fisheries was determined from the capture fisheries assessment study of the said project (Guarin et al. 1995 unpublished). The data were then compared with the species composition in the different habitats around the gulf (coral reef, seagrass, mangrove and soft bottom). Visual census information of coral reef fish was obtained from the coastal habitat assessment study (Nañola et al. 1995 unpublished), while the presence of the species in seagrass and mangroves was based on several published studies: Pinto and Punchihewa (1996), Campbell et al. (2000), de Silva et al. (2001), Corcheret de la Moriniere et al. (2002), Corcheret de la Moriniere et al. (2003), Gillanders et al. (2003) Halpern (2004), Mumby et al. (2004), Chittaro et al. (2005), Dorenbosch et al. (2006), Lugendo et al. (2005), Duffy (2006) and Jelbert et al. (2007). Species composition from the experimental trawl survey represented species associated with soft bottom areas.

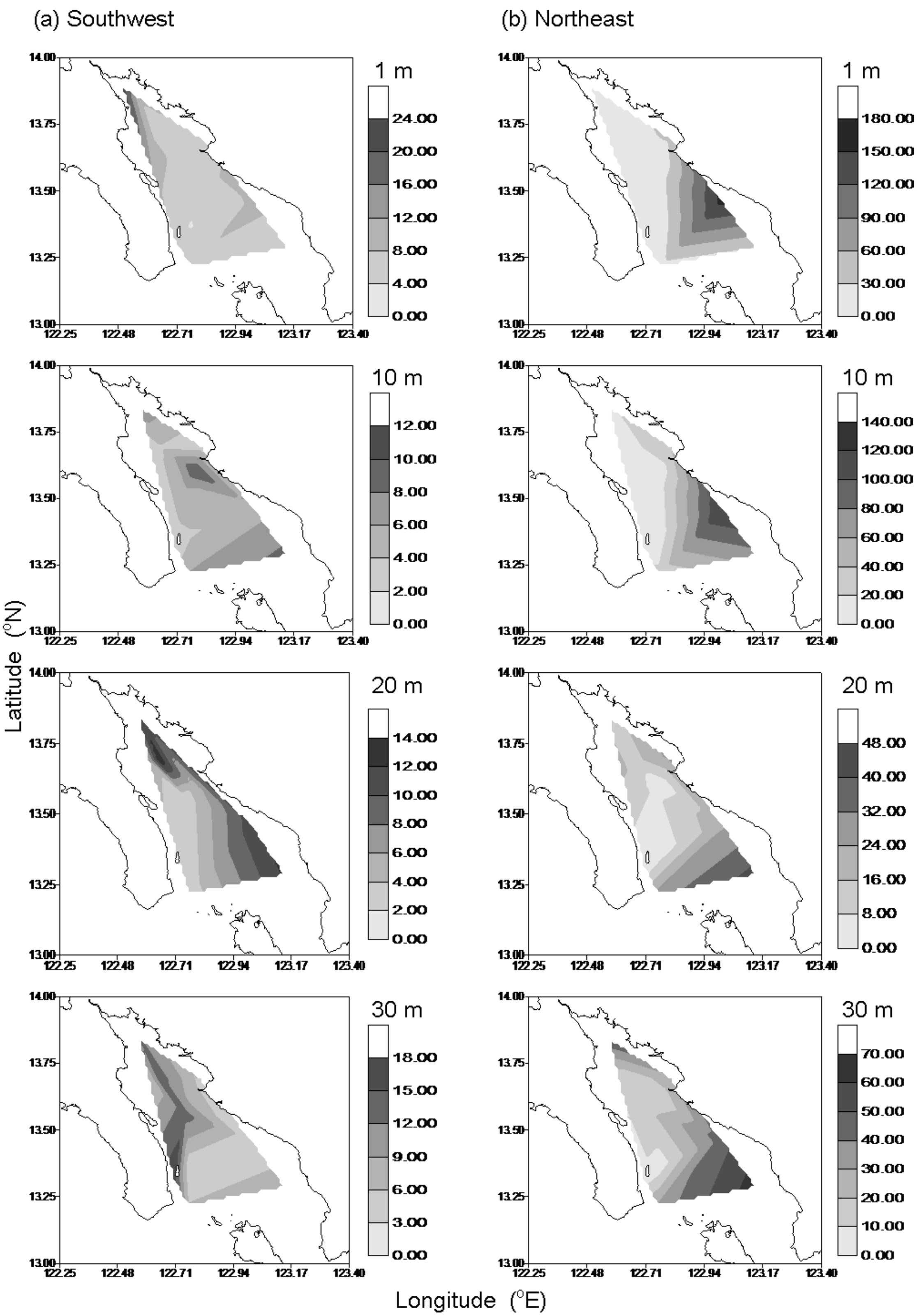

Fig. 3. Phytoplankton density (cells per $m^3 \times 100{,}000$) at 1 m, 10 m, 20 m and 30 m depths during sampling in (a) August (southwest) and (b) November (northeast) 1994 in Ragay Gulf, Philippines (adapted from Castillo and Cuevas 1995 unpublished).

Ecosystem Effect of Trawl Fisheries

The two mass-balanced trophic models (1950 and 1995 models) that were constructed for Ragay Gulf (Lachica-Aliño et al. unpublished) using the ECOPATH with ECOSIM (EwE) software Version 5.1 (Christensen and Pauly 1992) served as the initial ecosystem states (Table 1) for the simulation scenarios explored in this study. The modeled ecosystem covered the entire Ragay Gulf from 13.00–14.00°N and from 122.25–123.50°E, located southeast of the island of Luzon in the Philippine archipelago. It is one of the biggest embayments in the country, encompassing an area of about 3,912 km^2, reaching a depth of 600 m and is surrounded by 17 municipalities. The gulf is bounded on the western side by Quezon Province and Camarines Sur Province on the eastern side with the island province of Masbate at the opening. The components of the system were grouped into functional groups based on the species level ecological similarities (i.e., body size, habitat and diet) from Fishbase.

ECOSIM (Walters et al. 1997; Walters et al. 2000; Christensen and Walters 2004) is the dynamic counterpart of ECOPATH in EwE. The balanced ECOPATH linear equation was re-expressed in terms of the rate of biomass change (dB/dt) using a delay-difference model (www.ecopath.org):

$$dB_i/ dt = g_i \, . \, \Sigma Q_{ij} - \Sigma Q_{ji} + I_i - (M_{0i} + F_i + E_i)B_i \quad (1)$$

The left portion of the equation gives the rate of biomass change of group i in terms of its consumption rate (Q_{ij}), growth efficiency (g), mortality coefficients (F and M_0 excluding predation), migration rates (I and E) and predation loss rate (Q_{ji}). In ECOSIM, the transfer rate (v_{ij}) between two components (vulnerable and invulnerable to predators) of the prey biomass (B_i) re-

Table 1. Initial parameter estimates from actual information and ECOPATH in italics (B - Biomass, P - Production, Q - Consumption).

Functional Group	B (t km^{-2})*		P/B (/year)+		Q/B (/year)++	
	1950	1995	1950	1995	1950	1995
Phytoplankton	*6.49*	3.02	200.00	200.00		
Phytobenthos	*0.85*	*0.96*	15.34	15.34		
Zooplankton	*2.91*	*0.96*	67.00	67.00	192.00	192.00
Zoobenthos	*9.91*	*2.13*	10.00	10.00	50.00	50.00
Cephalopods	*6.68*	*1.11*	2.00	3.10	16.40	16.40
Large crustaceans	*10.24*	*3.09*	2.00	2.80	13.90	13.90
Other benthic invertebrates	8.29	*4.74*	2.00	6.80	25.90	25.90
Shrimps	6.05	*3.46*	2.00	8.40	28.94	28.94
Small reef-associated omnivore	1.57	*0.13*	2.00	2.83	24.26	24.25
Small reef-associated herbivore	-	*2.31*	-	4.12	-	24.25
Small reef-associated detritivore	-	*1.36*	-	2.83	-	24.25
Small reef-associated carnivore	*0.94*	1.27	2.23	4.83	23.24	20.79
Small pelagic herbivore	0.42	0.17	2.66	3.57	92.91	92.90
Small pelagic carnivore	*1.20*	0.27	2.00	3.42	21.10	28.64
Small demersal omnivore	*1.83*	*0.11*	1.80	3.50	25.48	40.60
Small demersal herbivore	1.49	0.06	2.19	4.85	82.05	82.04
Small demersal carnivore	1.00	0.96	2.00	3.69	21.66	24.17
Small benthopelagic carnivore	*1.15*	0.00	1.80	2.60	26.50	15.30
Medium reef-associated carnivore	0.74	0.05	1.31	4.55	23.47	12.60
Medium pelagic carnivore	-	0.06	-	2.84	-	12.40
Medium demersal carnivore	-	*0.00*	-	2.50	-	6.60
Medium benthopelagic carnivore	-	0.00	-	2.34	-	10.90
Medium benthopelagic detritivore	-	*0.00*	-	2.34	-	10.90
Large reef-associated carnivore	0.50	0.01	0.95	1.95	21.97	10.40
Large pelagic carnivore	0.13	0.07	2.23	2.06	9.20	9.20
Large demersal carnivore	-	*0.04*	-	2.00	-	5.63
Large benthopelagic carnivore	-	0.03	-	2.97	-	9.20
Detritus						

*Data from experimental trawl fishing
+Ingles and Pauly (1984), Corpuz et al. (1985) and PhilFIS database
++Data from empirical formula of Palomares and Pauly (1998)

placed the Q_{ij} in the above equation, using its new expression (Christensen and Walters 2004):

$$Q_{ij} = \frac{a_{ij}v_{ij}B_iB_jT_iT_jS_{ij}M_{ij}/D_j}{v_{ij} + v_{ij}T_iM_{ij} + a_{ij}M_{ij}B_jS_{ij}T_j/D_j} \qquad (2)$$

The rate of effective search by predator j for prey i (a_{ij}) represented the Lotka-Volterra mass-action term. This more elaborate expression defined the factors that limit Q_{ij} including relative feeding time (T_i, and T_j), forcing effects such as seasonal or long- term (S_{ij}) and mediation (M_{ij}) and handling time (D_j). The goodness-of-fit (weighted sum of squares [SS] of log biomass observed, $B_{obs.}$ from log biomass predicted $B_{pred.}$) in the "fit to time series" module of ECOSIM was used to search for the controls most sensitive to changes in vulnerabilities:

$$SS = \Sigma[Log\ (B_{obs.}) - Log\ (B_{pred.})]^2 \qquad (3)$$

Two-time series simulation scenarios were done to show the impact of trawl fishing on the biomass of the model components. The first is a 45-yr simulation from 1951–1995 depicting the historical development of trawl fisheries in the gulf, using the 1950 model as baseline and starting point. Fishing effort of historical trawl fishing (f_{trawl}) prototype of the formula used by Cox et al. (2002), Harvey et al. (2003) and Araujo et al. (2006) was computed from the fishing mortality (F_{trawl}) as follows:

$$F_{trawl} = C/B \qquad (4)$$

with C and B being annual aggregated landings in tons (t) of "trawl related species" (TRS) and fish biomass (t* km^{-2}) as derived from survey data (see below), respectively. This equation assumes that f_{trawl} and F_{trawl} are proportional given that q is constant through the years. TRS in the gulf was generated from published fisheries statistics of DA-BFAR. TRS is defined as fish and associated invertebrates living in demersal and benthopelagic environment based on the Fishbase definition of habitats (www.fishbase.org/home.htm). For years with no data, catches were computed by averaging the years with available data.

Subsequently, stock biomass (B in t km^{-2}) was estimated from various trawl surveys for the Philippine seas from 1947–1980 (Silvestre et al. 1986) and from the experimental trawl surveys from 1994–1995. The biomass of these years was used for averaging the years without available data. The TRS was segregated based on the functional group definitions. The biomass of each functional group was computed based on the f_{trawl} and C data.

The computed historical time series was run in a search routine of ECOSIM to estimate vulnerabilities most sensitive to the interactions that would minimize SS (Shannon et al. 2004; Taylor et al. 2008). Vulnerabilities for large-sized and medium-sized functional groups were changed to relatively higher estimates assuming that these species were the most vulnerable species in the catch during this period. The sum of squares (SS) residual of 4.44 for ECOSIM time series fits against f_{trawl} estimates as an index of abundance of the system.

For a second round of simulations, the 100-yr period (1980–2080) using the 1995 ECOPATH model was used to explore the effect of different trawl ban scenarios in the gulf as a coastal resource management (CRM) option formulated in this period. The first scenario (CRM scenario 1) predicted the system's response to a continued operation of trawlers with a moratorium on further expansion of trawling effort after 1995. The relative fishing mortality was thus kept at its original level for a 100-yr period of simulation. In the second scenario (CRM scenario 2), a 5-yr period of a closed season was explored for commercial trawling after 1995. Fishing mortality was reduced to no fishing in the first 5 yr and then returned to the original level for the remaining time period. The third scenario (CRM scenario 3) allowed a complete ban on commercial trawling. Relative fishing mortality rate was thus decreased to zero in the 10-yr period.

Historical time series data from 1980–1995 representing the overfished state of the system was used in the simulation. The search routine of ECOSIM was also used to estimate vulnerabilities most sensitive to the interactions that would minimize SS. The simulation was extended to a duration of 100 yr to check how many years it will take for the fisheries to be restored.

RESULTS AND DISCUSSION

Trawl Catch Distribution Pattern

The different trawl stations from the combined two cruises (Fig. 1) were dominated by small species (60% were from the families Leiognathidae and Clupeidae) with temporal variation strongly influenced by monsoonal shifts in the current circulation and phytoplankton density (Fig. 4). This influence of the monsoons is consistent with the recorded observations of optimum phytoplankton production during the slightly weaker southwesterly winds (Castillo and Cuevas 1995 unpublished). Species/station association clustering patterns also showed a north-south division for Ragay Gulf (Tables 2 and 3). The north station group (Fig. 5), char-

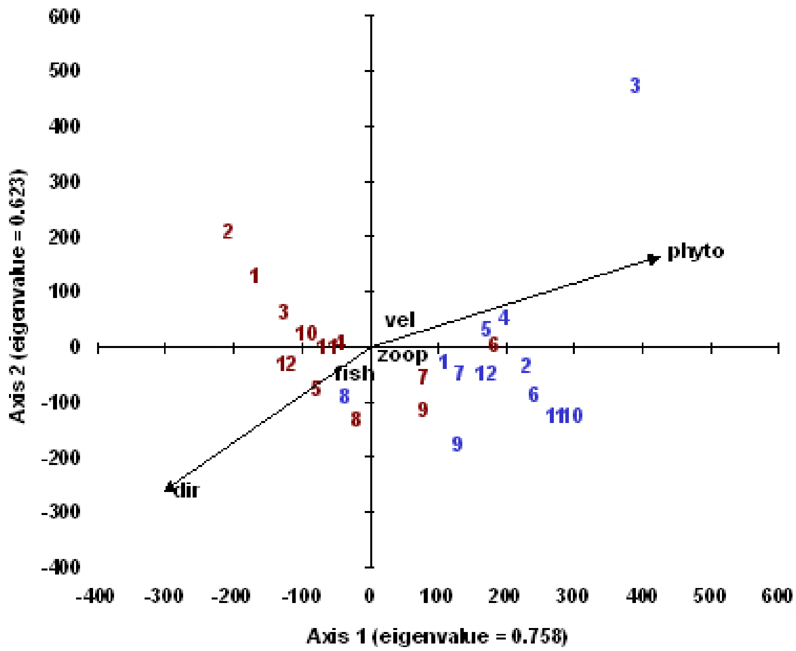

Fig. 4. Combined trawl station (red and blue numbers as station from the two monsoons) associations derived from experimental fishing based on Canonical Correspondence Analysis (CCA): dir – current direction, vel – current velocity, phyt – phytoplankton density, zoop – zooplankton density, fish – fishing pressure.

acterized by a recirculating gyre above 13º30'N, yielded relatively higher biomass estimates. This is most likely because of the potential planktonic biomass build-up from the assimilation of nutrients coming from the Viñas River, one of the major rivers in the gulf draining from the watershed of the Bondoc Peninsula. In contrast, the southern area includes the trawl stations southward of 13º30'N and is characterized by a broad current flowing across the mouth of the gulf and around the tip of Burias Island. During the SW monsoon, offshore Sibuyan Sea waters advect in this area, effectively slowing the flushing rate of the system, while during the NE monsoon, a strong westward flushing of water is not conducive to effectively retain nutrients (Villanoy and Trayvilla 1995 unpublished).

These north and south sectors are further classified into "highly fished" and "less fished" areas based on the second level of division of TWINSPAN (Tables 2 and 3). "Highly fished" areas are those where trawl fishing is frequently observed, with the density of fishers ranging from 33–114 per km of coastline per year, and where LOI 1328 is loosely implemented. "Less fished" areas are those with minimal to no trawl fishing operations because of the strict enforcement of LOI 1328 and with 15–27 fishers per km of coastline per year.

Highly fished areas consisted of stations located in the innermost northern areas of the gulf and nearer to the coastal boundaries of Quezon Province. Aside from a higher yield in this area, municipal fishers are also constrained to fish near shore because of the high cost of acquiring a motorized banca, coupled with high fuel costs. The commercial fishers including trawlers, however, also tend to operate in these more productive municipal waters, mainly because of suitable bathymetric and substrate conditions.

Species composition of the commercial catches changed through the years based on DA-BFAR statistics – from the dominance of demersals (leiognathids) and reef-associated species (nemipterids and synodonthids) in the 1970s to the large pelagics (scombrids and carangids) in the 1980s. Further expansion of commercial fishing gears was observed, with the use of other gears such as bagnet, and small demersals (engraulids) and pelagics (clupeids) in the 1990s, and later the proliferation of high opening bottom trawls. As a consequence, both the surface- and bottom-associated species became vulnerable to commercial trawling activities. Thus, the northern areas of the gulf where trawl fisheries operate have been considered as the main demersal fishing ground since 1938 (Ingles 1988). Change in species composition is fur-

Table 2. Mean catch rate (kg h^{-1}), average biomass (kg km^{-2}) and percentage of species within the three station groups generated by TWINSPAN for Cruise 1 (July 1994, southwest).

Species	ECOPATH Functional Groups	Catch Rate	(%)	Biomass	(%)
1st level TWINSPAN division	North sector (Stations - 6, 7, 8, 9)				
2nd level TWINSPAN division	Highly fished areas				
Stolephorus indicus	small pelagic carnivore	24.99	34.12	22.59	34.1
Sardinella fimbriata	small pelagic herbivore	12.71	17.35	11.49	17.3
Loligo sp.	cephalopods	8.06	11.01	7.29	11
Stolephorus heterolobus	small reef-associated carnivore	6.06	8.28	5.48	8.28
Sardinella gibbosa		5.32	7.27	4.81	7.27
Dussumierra acuta	small pelagic carnivore	4.98	6.80	4.50	6.8
Scomberoides lysan	medium reef-associated carnivore	2.45	3.34	2.21	3.34
Megalaspis cordyla	medium reef-associated carnivore	1.73	2.36	1.56	2.36
Pampus argenteus	small benthopelagic carnivore	1.55	2.12	1.40	2.12
Secutor ruconius	small demersal carnivore	1.47	2.00	1.33	2
Leiognathus splendens	small demersal herbivore	1.22	1.67	1.11	1.67
Sardinella sp.1	small pelagic herbivore	0.61	0.83	0.55	0.83
Rastrelliger brachysoma	small pelagic herbivore	0.57	0.78	0.52	0.78
Trichiuris lepturus	large benthopelagic carnivore	0.38	0.52	0.34	0.52
Rastrelliger faughni	small pelagic carnivore	0.34	0.46	0.30	0.46
Priacanthus hamrur	small reef-associated carnivore	0.24	0.33	0.22	0.33
Sepithiutis sp.	cephalopods	0.23	0.32	0.21	0.32
Atule mate	small reef-associated carnivore	0.17	0.24	0.16	0.24
Alectis ciliaris	small reef-associated carnivore	0.15	0.21	0.14	0.21
Total		73.25		66.22	
Mean		3.86		3.49	
S.d.		6.12		5.53	
1st level TWINSPAN division	North sector (Stations - 4, 5, 10, 11)				
2nd level TWINSPAN division	Less fished areas				
Sardinella longiceps	small pelagic herbivore	175.73	34.50	158.86	34.50
Sardinella fimbriata	small pelagic herbivore	114.30	22.44	103.32	22.44
Leiognathus bindus	small demersal herbivore	86.02	16.89	77.76	16.89
Stolephorus indicus	small pelagic carnivore	29.31	5.75	26.50	5.75
Leiognathus splendens	small demersal herbivore	25.95	5.09	23.46	5.09
Secutor ruconius	small demersal carnivore	12.86	2.52	11.63	2.52
Rastrelliger brachysoma	small pelagic herbivore	11.77	2.31	10.64	2.31
Dussumierra acuta	small pelagic carnivore	10.52	2.06	9.51	2.06
Loligo sp.	cephalopods	6.97	1.37	6.30	1.37
Gazza minuta	small demersal carnivore	6.21	1.22	5.62	1.22
Stolephorus heterolobus	small reef-associated carnivore	5.71	1.12	5.16	1.12
Alepes djeddaba	small reef-associated carnivore	4.87	0.96	4.40	0.96
Mullloidicthys vanicolensis	small reef-associated carnivore	3.56	0.70	3.22	0.70
Selar crumenolphthalmus	medium reef-associated carnivore	3.11	0.61	2.81	0.61
Sphyraena jello	medium reef-associated carnivore	2.83	0.56	2.56	0.56
Secutor insidiator	small demersal carnivore	1.85	0.36	1.67	0.36
Rastrelliger faughni	small pelagic carnivore	1.75	0.34	1.58	0.34
Gazza acclamys	small reef-associated carnivore	1.73	0.34	1.56	0.34
Leiognathus equulus	small reef-associated carnivore	1.44	0.28	1.30	0.28
Trichiuris sp.	large benthopelagic carnivore	0.79	0.16	0.72	0.16
Sardinella gibbosa	small reef-associated carnivore	0.58	0.11	0.52	0.11
Selaroides leptolepis	small reef-associated omnivore	0.58	0.11	0.52	0.11
Upeneus sulphureus	small demersal carnivore	0.57	0.11	0.51	0.11
Megalaspis cordyla	medium reef-associated carnivore	0.36	0.07	0.33	0.07
Total		509.35		460.45	
Mean		21.22		19.19	
S.d.		43.07		38.94	

Table 2 continued.

Species	ECOPATH Functional Groups	Catch Rate	(%)	Biomass	(%)
1st level TWINSPAN division	South sector (Stations - 1, 2, 3, 12)				
2nd level TWINSPAN division	Less fished areas				
Sardinella fimbriata	small pelagic herbivore	393.28	36.65	355.52	36.65
Leiognathus bindus	small demersal herbivore	281.16	26.20	254.17	26.20
Secutor insidiator	small demersal carnivore	205.39	19.14	185.67	19.14
Gazza minuta	small demersal carnivore	156.22	14.56	141.22	14.56
Scomberoides tol	small reef-associated carnivore	21.49	2.00	19.42	2.00
Atule mate	small reef-associated carnivore	4.15	0.39	3.75	0.39
Secutor ruconius	small demersal carnivore	3.10	0.29	2.80	0.29
Decapterus macrosoma	small reef-associated omnivore	2.33	0.22	2.10	0.22
Centriscus sculatus		1.89	0.18	1.71	0.18
Upeneus moluccensis	small reef-associated carnivore	1.72	0.16	1.55	0.16
Leiognathus elongatus	small demersal herbivore	0.70	0.06	0.63	0.06
Leiognathus equulus	small reef-associated carnivore	0.70	0.06	0.63	0.06
Rastreliger kanagurta	small reef-associated carnivore	0.70	0.06	0.63	0.06
Stolephorus indicus	small pelagic carnivore	0.35	0.03	0.32	0.03
Total		1073.16		970.13	
Mean		76.65		69.30	
S.d.		129.66		117.21	

Table 3. Mean catch rate (kg h^{-1}), biomass (kg km^{-2}) and percentage of species in the two station groups generated by TWINSPAN for Cruise 2 (January 1995, northeast).

Species	ECOPATH Functional Groups	Catch Rate	(%)	Biomass	(%)
1st level TWINSPAN division	North sector (Stations - 7, 8, 9)				
2nd level TWINSPAN division	Highly fished areas				
Stolephorus heterolobus	small reef-associated carnivore	115.86	30.14	78.55	30.14
Sardinella fimbriata	small pelagic herbivore	81.13	21.10	55.00	21.10
Loligo sp.	cephalopods	50.33	13.09	34.12	13.09
Stolephorus indicus	small pelagic carnivore	49.73	12.94	33.72	12.94
Leiognathus bindus	small demersal herbivore	17.37	4.52	11.78	4.52
Unidentified #2		13.87	3.61	9.40	3.61
Rastrelliger kanagurta	small reef-associated carnivore	12.92	3.36	8.76	3.36
Sepiothiutis sp.	cephalopods	11.43	2.97	7.75	2.97
Leiognathus splendens	small demersal herbivore	7.21	1.88	4.89	1.88
Trichiuris sp.	large benthopelagic carnivore	6.23	1.62	4.22	1.62
Secutor insidiator	small demersal carnivore	3.88	1.01	2.63	1.01
Scomberoides lysan	medium reef-associated carnivore	3.56	0.93	2.41	0.93
Carangoides uii	medium reef-associated carnivore	2.19	0.57	1.48	0.57
Therapom jarboa	small reef-associated carnivore	2.11	0.55	1.43	0.55
Secutor ruconius	small demersal carnivore	1.66	0.43	1.13	0.43
Alectis indicus	small reef-associated carnivore	1.45	0.38	0.98	0.38
Megalaspis cordyla	medium reef-associated carnivore	0.89	0.23	0.60	0.23
Scomberomorus commerson	medium reef-associated carnivore	0.89	0.23	0.60	0.23
Leiognathus rivulatus	small demersal omnivore	0.44	0.12	0.30	0.12
Nemipterus delagoae	small demersal carnivore	0.28	0.07	0.19	0.07
Chircentrus dorab	small reef-associated carnivore	0.23	0.06	0.15	0.06
Selaroides leptolepis	small reef-associated omnivore	0.22	0.06	0.15	0.06
Alepes vari	small pelagic carnivore	0.20	0.05	0.14	0.05
Gerres filamentosus	small demersal carnivore	0.18	0.05	0.12	0.05
Crenimugil heterocheilus	small demersal omnivore	0.11	0.03	0.08	0.03
Upeneus sulphureus	small demersal carnivore	0.11	0.03	0.08	0.03
Total		384.47		260.67	
Mean		14.24		9.65	
S.d.		28.46		19.30	

Table 3 continued.

Species	ECOPATH Functional Groups	Catch Rate	(%)	Biomass	(%)
1st level TWINSPAN division	North (Stations 4, 5, 6, 10, 11) and South sectors (1, 2, 3, 12)				
2nd level TWINSPAN division	Less fished areas				
Trichiuris lepturus	large benthopelagic carnivore	32.67	14.58	66.46	14.58
Carangoides uii	medium reef-associated carnivore	32.40	14.46	65.89	14.46
Sardinella longiceps	small pelagic herbivore	20.65	9.22	42.01	9.22
Loligo sp.	cephalopods	20.36	9.09	41.41	9.09
Pampus argenteus	small benthopelagic carnivore	19.16	8.55	38.97	8.55
Dussumiera elopsoides	*	16.37	7.31	33.30	7.31
Leiognathus equulus	small reef-associated carnivore	12.30	5.49	25.02	5.49
Stolephorus indicus	small pelagic carnivore	12.14	5.42	24.70	5.42
Leiognathus bindus	small demersal herbivore	8.74	3.90	17.77	3.90
Upeneus sulphureus	small demersal carnivore	8.07	3.60	16.41	3.60
Scomberoides lysan	medium reef-associated carnivore	7.81	3.49	15.89	3.49
Sphyraena putnamiae	medium reef-associated carnivore	6.10	2.72	12.42	2.72
Rastrelliger kanagurta	small reef-associated carnivore	3.63	1.62	7.39	1.62
Caranx ignobilis	small reef-associated carnivore	3.51	1.57	7.14	1.57
Sardinella fimbriata	small pelagic herbivore	3.45	1.54	7.01	1.54
Echeneidae		2.46	1.10	5.01	1.10
Chirocentrus dorab	small reef-associated carnivore	1.80	0.80	3.66	0.80
Rastrelliger brachysoma	small pelagic herbivore	1.56	0.70	3.17	0.70
Sepiothiutis sp.	cephalopods	1.23	0.55	2.50	0.55
Auxis thazard	medium pelagic carnivore	1.18	0.53	2.40	0.53
Unidentified #3		1.14	0.51	2.32	0.51
Selaroides leptolepis	small reef-associated omnivore	0.97	0.43	1.97	0.43
Secutor insidiator	small demersal carnivore	0.84	0.38	1.71	0.38
Gazza minuta	small demersal carnivore	0.78	0.35	1.58	0.35
Priacanthus sp.	small reef-associated carnivore	0.52	0.23	1.05	0.23
Atule mate	small reef-associated carnivore	0.47	0.21	0.95	0.21
Plectorhyncus pictus	medium reef-associated carnivore	0.46	0.21	0.94	0.21
Selar crumenolphthalmus	medium reef-associated carnivore	0.46	0.20	0.93	0.20
Pentaprion longimanus	small demersal carnivore	0.45	0.20	0.92	0.20
Leiognathus elongatus	small demersal herbivore	0.42	0.19	0.86	0.19
Gerres abbreviatus	small reef-associated carnivore	0.41	0.18	0.84	0.18
Synodus sp.	small reef-associated carnivore	0.35	0.16	0.72	0.16
Alectis ciliaris	small reef-associated carnivore	0.26	0.12	0.53	0.12
Priacanthus hamrur	small reef-associated carnivore	0.14	0.06	0.28	0.06
Unidentified #1		0.14	0.06	0.28	0.06
Apogon kiensis	small reef-associated omnivore	0.13	0.06	0.26	0.06
Megalaspis cordyla	medium reef-associated carnivore	0.11	0.05	0.23	0.05
Alectis indicus	small reef-associated carnivore	0.09	0.04	0.18	0.04
Parachaetodon ocillatus	small reef-associated carnivore	0.08	0.04	0.17	0.04
Secutor ruconius	small demersal carnivore	0.08	0.04	0.17	0.04
Pseudocaranx dentex	medium reef-associated carnivore	0.08	0.03	0.15	0.03
Fistularia sp.		0.03	0.01	0.06	0.01
Lutjanus linsulatus	small reef-associated carnivore	0.03	0.01	0.06	0.01
Syngnathidae		0.01	0.01	0.02	0.01
Total		224.07		455.75	
Mean		5.09		10.36	
S.d.		8.42		17.13	

ther illustrated historically in the simulation using ECOSIM. In addition, higher total mortality coefficients (Z) in these highly fished areas of the two most abundant species in the catch – orangefin ponyfish (*Leiognathus bindus*) and fringescale sardinella (*Sardinella fimbriata*) (Lachica 1997) – are a strong indication of a higher fishing pressure here, as is the presence of a considerable biomass of cephalopod species in these areas. Although there are other fishing gears also exploiting these stocks, the impact of the trawl fishery and the non-implementation of fishery laws (e.g., ban of commercial fishing in the gulf) in these

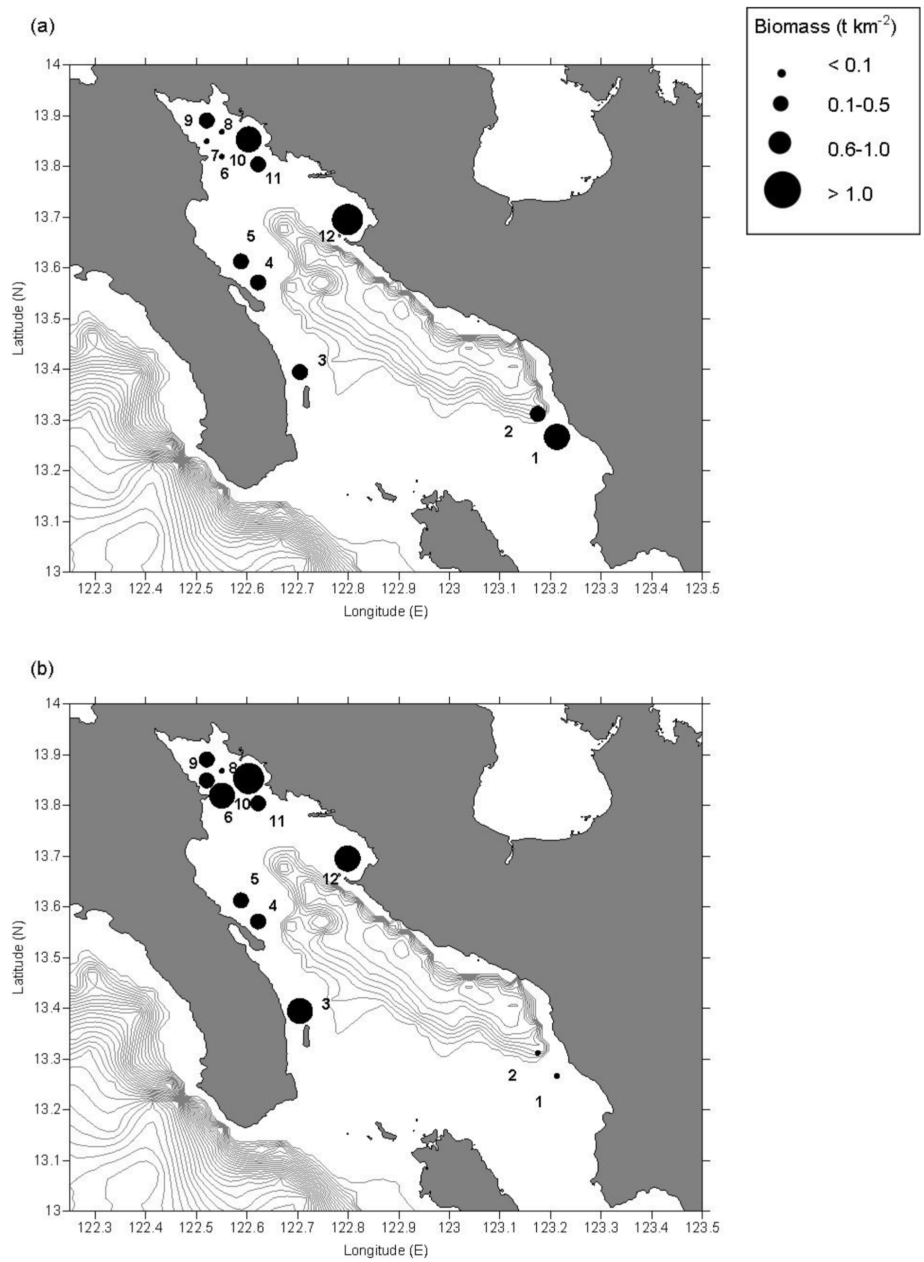

Fig. 5. Station-biomass estimates from experimental trawl fishing: (a) Cruise 1 in July 1994 (southwest) and (b) Cruise 2 in January 1995 (northeast). Lines represent 200 m and beyond bathymetric depth (Lachica 1997).

highly fished areas have contributed to the high exploitation rate (E) estimates (> 0.3) (Lachica 1997).

Less fished areas consisted of stations in the mid-northern areas of the gulf within the eastern coast of Camarines Sur Province and the mid-western coast of Quezon Province, and in the lower southernmost part of the gulf, opening to wider bodies of water such as Sibuyan Sea. The presence of largehead hairtail, *Trichiurus lepturus* (a predator species), in these areas may be an indication of the relatively lower fishing pressure. With strong northeasterly winds, fishing activities are significantly reduced in these areas. We also observed in the northern areas near Camarines Sur that coastal barangay officials, coast guards and members of municipalities strictly enforce the national and local fishery laws. Based on the beneficiaries' perception of the coastal resource management projects, cooperation and compliance with laws on the regulation of fishing activities (e.g., commercial gear operation) was more effective in this area. In addition, a successful implementation of Information, Education and Communication Campaign (IECC) projects such as "Sagipin ang dagat, sagipin ang bukas" ("Save the seas, save the future") was achieved (Hilomen et al. unpublished).

Overlap of Trawl Fisheries Species with those from Coastal Habitats

Various coastal habitats with soft bottom areas covering only 6% of the gulf's spatial extent are part of the Ragay Gulf coastal ecosystem. In more than 50% (Table 4) of the multigear fisheries, catches of the same species overlapped with the four coastal habitats studied (i.e., soft bottom, coral reefs, seagrass and mangrove). These fishing gears competed for the same stocks as suggested by the low genetic variation and high gene flow of some of the dominant species in the catch based on the initial genetic structure analysis of related proxy species (Lachica 1997). Hence, the year-round operations of other fishing gears such as fish corrals in these coastal habitats may have affected the homogenous stocks of the system. The other 50% of the fisheries did not overlap with coastal habitats but with the pelagic realm of the ecosystem. These were mostly bathypelagic and pelagic species that were exploited by other commercial fishing gears such as bagnet.

About 32% of the species associated with soft bottom habitats overlapped with the commercial catch composition, indicating the significant impact of trawl fishing on these habitats (Table 4). Although species recorded from the municipal fisheries catches mainly overlapped with other coastal habitats, such as coral reefs and seagrasses (28%), a considerable proportion of the catches still extended to species living in soft bottom areas (9%). There were 13 fish species belonging to six families and one invertebrate species. Aside from soft bottom habitat, coral reefs showed the second to the highest overlap with commercial fisheries and the highest overlap with municipal fisheries. The abundance of reef-associated species in the catch of trawlers indicates the overlap of other fisheries. This observation implies the interconnectedness of the habitats for shelter (Mumby 2006), food (Kiso and Mahyam 2003) and as nursery areas (Beck et al. 2001; Harpern 2004) for many fish and invertebrates of the coastal fisheries ecosystem.

Table 4. Overlap of commercial fisheries (CF) and municipal fisheries (MF) with associated species from four different coastal habitats. (Note: Rank increases with lower overlaps).

Coastal Habitat	CF	Rank	MF	Rank
Coral reefs, CR	3.95	4	14.20	1
Seagrasses, SG	1.32	11	0.62	13
Mangroves, MG	2.63	7	4.94	4
Soft bottom, SB	31.58	1	8.64	3
CR + SG	1.32	11	14.20	1
CR + MG	2.63	7	3.09	5
CR + SB	3.95	4	1.23	11
SG + MG			1.85	9
SG + SB				
MG + SB	11.84	2	3.09	5
CR + SG + MG	2.63	7	2.47	7
CR + SG + SB	2.63	7	1.23	11
CR + MG + SB	5.26	3	2.47	7
SG + MG + SB	3.95	4	1.85	9
CR + SG + MG + SB				
No Overlap	26.32		40.12	

Fisheries Impact and Trophic Interaction within the Ragay Gulf Fisheries Ecosystem

The impact of trawl fishing was explored by two model simulation schemes (45-yr and 100-yr simulations). The 45-yr simulation mirrored the long history of trawl fisheries within the Ragay Gulf fisheries ecosystem with three major historical periods (Fig. 6): (i) the 1950s to the 1970s when trawl fishing effort significantly increased (Umali 1938,; Warfel and Manacop 1950; Silvestre and Pauly 1989), (ii) the 1970s when the maximum sustainable yield (MSY) with trawl fishing effort reached its peak and (iii) the 1970s onwards when presence of small reef-associated carnivores increased, cephalopod biomass grew and catch rates decreased (Pauly 1985). The effects of these fishing regimes were evaluated for three ecological groups: (a) fish that significantly increased in biomass (more than 10% increase), (b) those with decreasing change in biomass (more than 10% decrease) and (c) those with minimal (10% or less increase or decrease) to no change in biomass.

From the 1950s to the 1970s, larger and more effective types of trawl fishing proliferated in the gulf, such as 30-ton otter trawls (Warfel and Manacop 1950). Trawlers doubled their engine horsepower in 1958 and added carrier vessels in fishing operations in 1964 (Silvestre and Pauly 1989). This led to the shift from pre-war low exploitation levels to a post-war increase in the exploitation rate, specifically with regard to the proportion of the commercial bottom fish species caught as a result of the vast initial profit potential (Pauly 1996). In this period, the simulation produced a stable change in biomass of the functional groups. Most of them returned to their original biomass at the end of the period. In the 1970s, the further expansion of commercial fish-

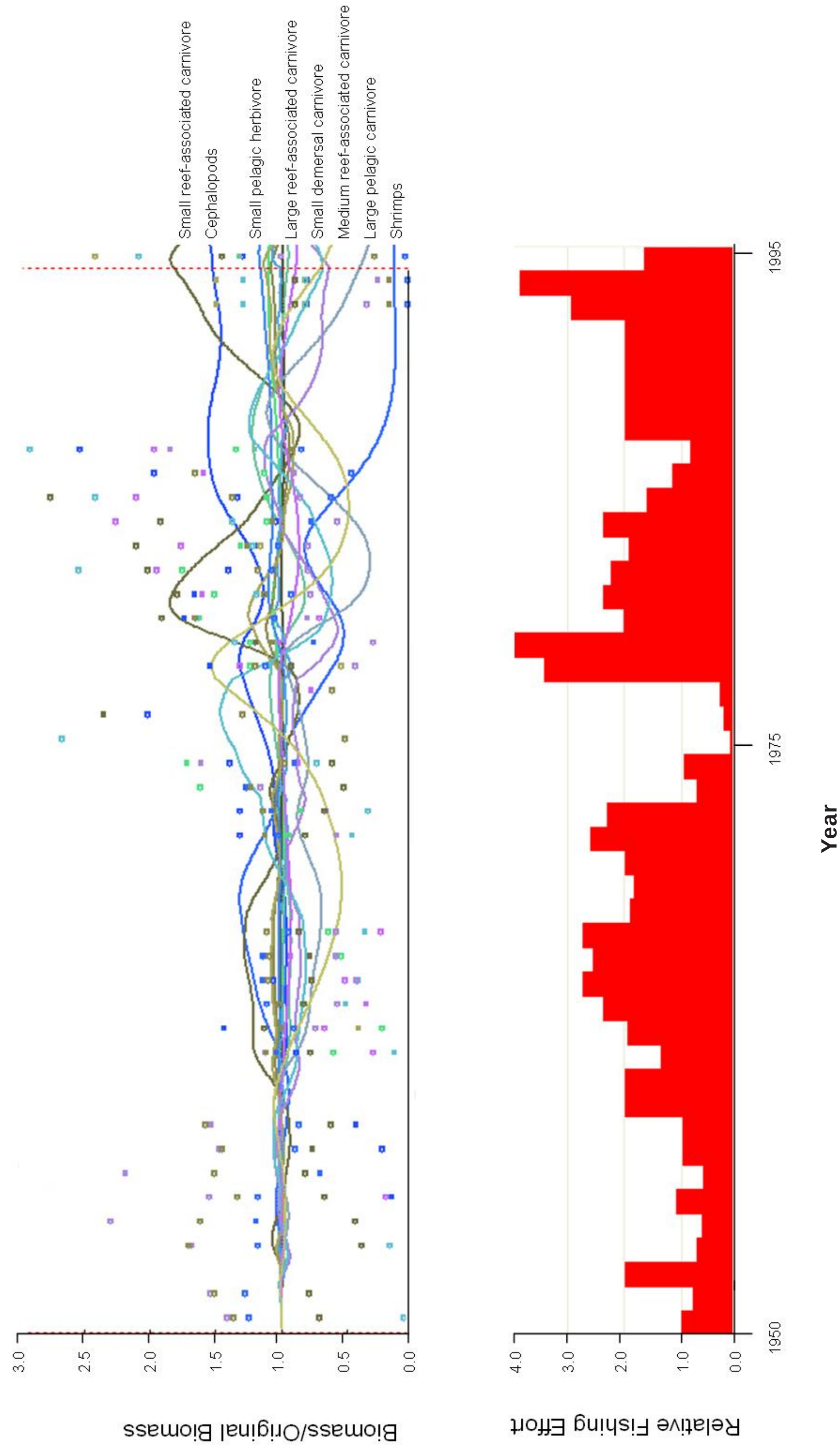

Fig. 6. A 45-yr simulation of the 1950 ECOPATH model using ECOSIM through EwE 6.

ing activities in the gulf started with the addition of bagnet fishing to the existing otter trawl fishing. Mostly large and medium reef-associated species, large pelagics and trawl fisheries targeted species (small demersal carnivores and shrimps) showed a significant trend in decreasing biomass (12–86%) in this period (Table 5). On the other hand, small reef-associated carnivores, and small pelagic herbivores and cephalopods dramatically increased in biomass (17–78%). This finding further supports the general observation that cephalopods often increase when there is overfishing in the ecosystem (Pauly 1985; Pauly 1989).

Hence, the Ragay Gulf fisheries ecosystem has been overfished from the 1970s onwards. High opening bottom trawlers subsequently started their operation in the late 1970s (Silvestre et al. 1986). As a consequence, both the surface- and bottom-associated species became vulnerable to commercial fishing activities. The emergence of several other types of commercial fishing gears (e.g., purse seine, ring net, round haul seine, etc.) in the 1980s significantly increased the volume of landed catches and changes in the catch composition (Pauly 1986; Silvestre and Hilomen 2004 unpublished). As shown in the 45-yr model simulation, large predators (medium and large carnivores) significantly decreased in biomass as inferred from the ecological groups that no longer exist in the system based on the 1995 ECOPATH model.

The 100-yr ECOPATH model simulations (Fig. 7) showed the Ragay Gulf's system behavior under different trawl ban CRM scenarios and how resilient (i.e., relative period of time when the system returns to its relative original biomass) the system is given these scenarios. In the simulated CRM Scenario 1 (with constant trawl fishing effort over 100 yr), which allows continued operation of trawlers with moratorium on further expansion of trawl fishing effort after 1995, the system will take about 50 yr before it returns to its relative original biomass. Most of the functional group is on a decreasing trend. The decrease (from 76% to 12%) in most of the medium and large top predators will result in significant increases (Table 6) in small demersal herbivores (61%) and small reef-associated omnivores (14%). Based on the subsequent scenario, CRM Scenario 2, the system will return to its original biomass in about 30 yr. Most functional groups in the system exhibited the same pattern as in CRM Scenario 1 despite having the 5-yr trawling ban. The last CRM option (CRM Scenario 3), where the system is closed to trawl fishing, also showed earlier return to its initial biomass in about 15 yr with a positive increase in biomass (11–42%) of most of the medium and large fish species. This indicates sensitivity to intervention simulation of trawling moratorium. Note that these are the same group, which showed significant decrease in biomass both when there is continued trawl fishing as seen

Table 5. ECOSIM result from the 45-yr simulation of the 1950 ECOPATH model.

Ecological Groups Targeted by Fisheries	Biomass (start, S)	Biomass (end, E)	Biomass (E/S)	Indicator	(%)
(1) More than 10% increase in biomass					
Small reef-associated carnivore	0.9413	1.6754	1.7797	(+)	77.97
Cephalopods	6.6755	10.3320	1.5477	(+)	54.77
Small pelagic herbivore	0.4157	0.4845	1.1655	(+)	16.55
(2) More than 10% decrease in biomass					
Shrimps	6.0462	0.8446	0.1397	(-)	86.03
Small pelagic carnivore	1.2036	0.4039	0.3355	(-)	66.45
Large pelagic carnivore	0.1255	0.0777	0.6191	(-)	38.09
Medium reef-associated carnivore	0.7383	0.5424	0.7346	(-)	26.54
Small demersal carnivore	1.0020	0.7735	0.7720	(-)	22.80
Large reef-associated carnivore	0.5014	0.4397	0.8769	(-)	12.31
(3) Minimal (10 % or less) to no change in biomass					
Large crustaceans	10.2398	11.1545	1.0893	(=)	8.93
Small benthopelagic carnivore	1.1535	1.2219	1.0593	(=)	5.93
Small demersal herbivore	1.4851	1.5642	1.0533	(=)	5.33
Small reef-associated omnivore	1.5721	1.4954	0.9512	(=)	4.88
Small demersal omnivore	1.8251	1.8753	1.0275	(=)	2.75
Other benthic invertebrates	8.2863	8.1465	0.9831	(=)	1.69

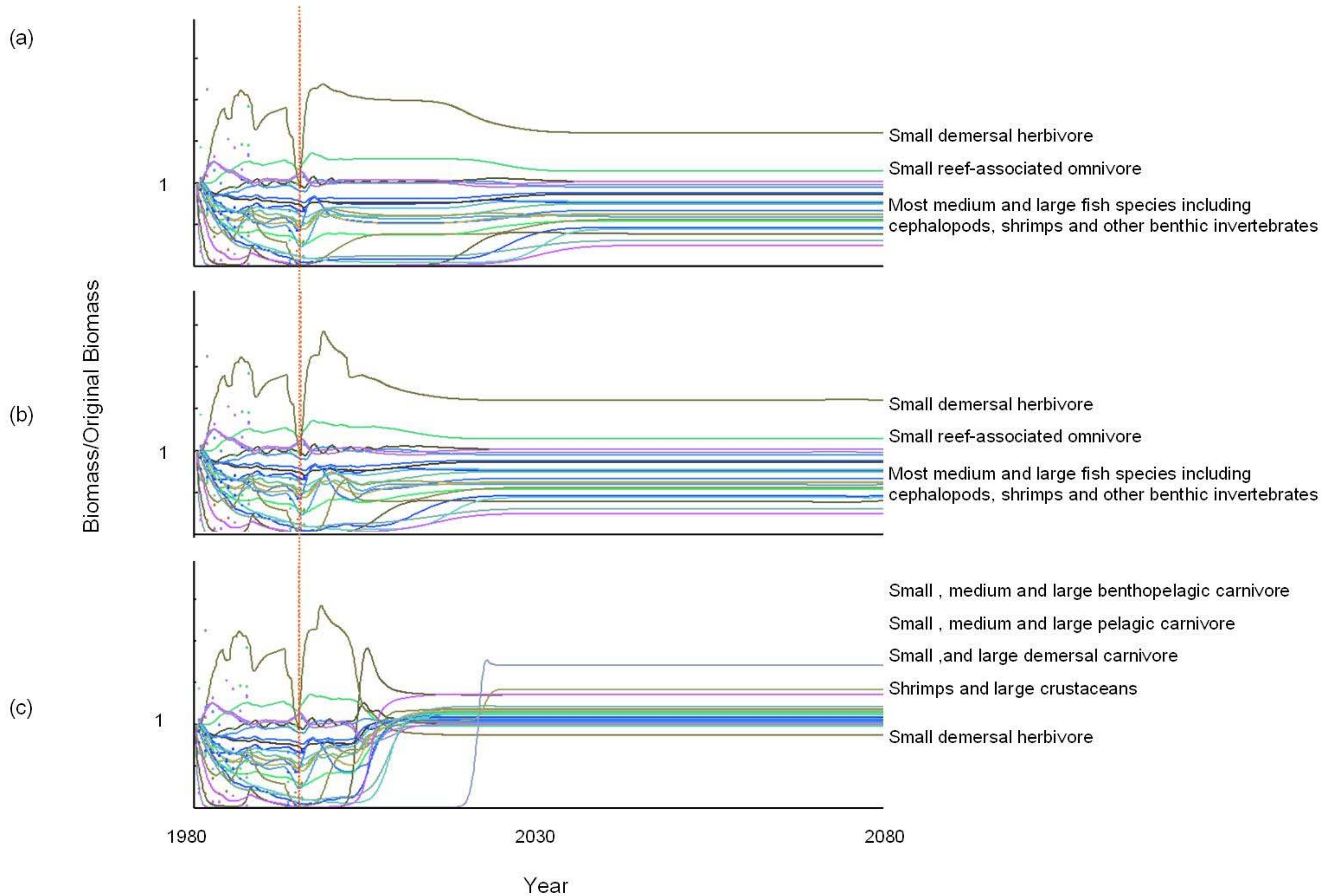

Fig. 7. 100-yr ECOSIM output from the 1995 ECOPATH model based on three CRM scenarios: (a) Scenario 1 – constant trawl fishing effort; (b) Scenario 2 – 5-yr trawl ban; and (c) Scenario 3 – closure of the gulf to trawl fishing. Open circles represent biomass estimates. Vertical red dotted line indicates the start of the simulated scenarios.

Table 6. ECOSIM result from the 100-yr simulation of the 1995 ECOPATH model using coastal resources management (CRM) scenarios.

Scenario	Ecological Groups Targeted by Fisheries	Biomass (E/S)	Indicator	%
CRM Scenario 1	*(1) More than 10% increase in biomass*			
	Small demersal herbivore	1.61	(+)	60.69
	Small reef-associated omnivore	1.14	(+)	14.11
	(2) More than 10% decrease in biomass			
	Large benthopelagic carnivore	0.24	(-)	75.70
	Small demersal omnivore	0.30	(-)	69.79
	Small pelagic herbivore	0.39	(-)	61.43
	Large demersal carnivore	0.44	(-)	56.30
	Shrimps	0.46	(-)	54.37
	Large crustaceans	0.54	(-)	46.15
	Medium reef-associated carnivore	0.56	(-)	44.48
	Medium pelagic carnivore	0.59	(-)	41.06
	Medium benthopelagic carnivore	0.62	(-)	38.27
	Large pelagic carnivore	0.63	(-)	37.43
	Small pelagic carnivore	0.66	(-)	33.58
	Small reef-associated carnivore	0.74	(-)	25.71
	Cephalopods	0.76	(-)	23.99
	Medium benthopelagic detritivore	0.77	(-)	22.81
	Other benthic invertebrates	0.86	(-)	13.87
	Small reef-associated detritivore	0.88	(-)	11.99
	(3) Minimal (10% or less) to no change in biomass			
	Small benthopelagic carnivore	0.00	(=)	100.00
	Small demersal carnivore	0.95	(=)	5.36
	Medium demersal carnivore	0.98	(=)	1.82
	Small reef-associated herbivore	1.02	(=)	1.57
	Large reef-associated carnivore	1.01	(=)	1.47
CRM Scenario 2	*(1) More than 10% increase in biomass*			
	Small demersal herbivore	1.5968	(+)	59.68
	Small reef-associated omnivore	1.1396	(+)	13.96
	(2) More than 10% decrease in biomass			
	Large benthopelagic carnivore	0.2490	(-)	75.10
	Small demersal omnivore	0.3046	(-)	69.54
	Small pelagic herbivore	0.3984	(-)	60.16
	Large demersal carnivore	0.4390	(-)	56.10
	Shrimps	0.4619	(-)	53.81
	Large crustaceans	0.5428	(-)	45.72
	Medium reef-associated carnivore	0.5600	(-)	44.00
	Medium pelagic carnivore	0.5932	(-)	40.68
	Medium benthopelagic carnivore	0.6194	(-)	38.06
	Large pelagic carnivore	0.6288	(-)	37.12
	Small pelagic carnivore	0.6665	(-)	33.35
	Small reef-associated carnivore	0.7458	(-)	25.42
	Cephalopods	0.7633	(-)	23.67
	Medium benthopelagic detritivore	0.7749	(-)	22.51
	Other benthic invertebrates	0.8631	(-)	13.69
	Small reef-associated detritivore	0.8818	(-)	11.82
	(3) Minimal (10% or less) to no change in biomass			
	Small benthopelagic carnivore	0.0000	(=)	100.00
	Small demersal carnivore	0.9477	(=)	5.23
	Medium demersal carnivore	0.9788	(=)	2.12
	Small reef-associated herbivore	1.0174	(=)	1.74
	Large reef-associated carnivore	1.0120	(=)	1.20

Table 6 continued.

Scenario	Ecological Groups Targeted by Fisheries	Biomass (E/S)	Indicator	%
CRM Scenario 3	*(1) More than 10% increase in biomass*			
	Small benthopelagic carnivore	1.7058	(+)	70.58
	Medium benthopelagic carnivore	1.4189	(+)	41.89
	Large benthopelagic carnivore	1.3612	(+)	36.12
	Small pelagic herbivore	1.3536	(+)	35.36
	Small demersal omnivore	1.2151	(+)	21.51
	Medium reef-associated carnivore	1.1777	(+)	17.77
	Large pelagic carnivore	1.1624	(+)	16.24
	Medium pelagic carnivore	1.1533	(+)	15.33
	Large crustaceans	1.1344	(+)	13.44
	Shrimps	1.1156	(+)	11.56
	Large demersal carnivore	1.1141	(+)	11.41
	(2) More than 10% decrease in biomass			
	Small demersal herbivore	0.8705	(-)	12.95
	(3) Minimal (10% or less) to no change in biomass			
	Cephalopods	1.0863	(=)	8.63
	Medium benthopelagic detritivore	1.0796	(=)	7.96
	Small reef-associated carnivore	1.0697	(=)	6.97
	Small pelagic carnivore	1.0640	(=)	6.40
	Other benthic invertebrates	1.0461	(=)	4.61
	Small reef-associated detritivore	1.0450	(=)	4.50
	Small demersal carnivore	1.0253	(=)	2.53
	Small reef-associated omnivore	0.9765	(=)	2.35
	Medium demersal carnivore	1.0105	(=)	1.05
	Small reef-associated herbivore	1.0074	(=)	0.74
	Large reef-associated carnivore	0.9970	(=)	0.30

in CRM Scenario 1 and when the 5-yr trawl ban was lifted in CRM Scenario 2. Some small fish species (22–71%) and shrimps (12%) showed a continued increase in biomass, indicating not only its sensitivity to trawling moratorium but also to predation. Reef-associated fish species, other benthic invertebrates and cephalopods had minimal or no change in biomass; these species can also be attributed to other fisheries that exploit these stocks. However, in the three CRM scenarios formulated in 1995, the system still did not illustrate resiliency because most of the functional groups did not return to their original biomass. The imperatives to reduce fishing effort therefore go beyond the banning of trawl fishing and needs to actualize the conventional wisdom espoused in ecosystem-based fisheries management and the allocation of marine protected areas and no-take areas (Browman and Stergiou 2004).

Despite the enactment of some fisheries laws (e.g., LOI 1328 and RA 8550), there were commercial fishing operations inside the gulf and often within the 15-km boundary of municipal waters. These commercial fishers, specifically trawlers, competed with municipal fisheries on the same stock in the gulf's ecosystem. Variation in the trawl fisheries ecosystem behavior in Ragay Gulf manifested changes in their overall fisheries community structure.

Other fisheries continued to have a profound negative impact on the overall fishing pressure, affecting the overall ecological components of the ecosystem. Even if our study had focused only on trawl commercial fishing, it illustrates that this type of fishing had a profound impact on the overexploited state of the gulf. In addition, considerable efforts are needed to decrease dependence on municipal fisheries in the area aside from implementing restrictions on commercial fishing restrictions within the municipal waters as recommended by Padilla and Morales (2004) for Lingayen Gulf, Northwest Philippines. Difficult challenges remain for Ragay Gulf, especially with the resource constraints and widespread poverty in the area (Christie and White 2007). Opportunities abound in the exemplary efforts seen in the compliance with fishing bans in portions of the gulf and some initial success in slowing accelerated declines. The establishment of marine protected areas around the gulf has also been a hallmark of Philippine fisheries management (Russ and Alcala 1999; Alcala 2001) and would also require the appropriate stock enhancement efforts being initiated to be scaled up to the baywide ecosystem management regime (Licuanan et al. 2006).

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REFERENCES CITED

ALCALA AC. 2001. Marine reserves in the Philippines: historical development, effects and influence on marine conservation policy. Makati City, Philippines: Bookmark. 115 p.

ARAUJO JN, MACKINSON S, STANFORD RJ, SIMS DW, SOUTHWARD AJ, HAWKINS SJ, ELLIS JR, HART PJB. 2006. Modelling food web interactions, variation in plankton production, and fisheries in the western English Channel ecosystem. Marine Ecol Progress Series 309:175-187.

BARBER WE, SMITH RL, VALLARINO M, MEYER RM. 1997. Demersal fish assemblages of the northeastern Chukchi Sea, Alaska. Fishery Bull 95:95-209.

BECK MW, HECK JR, KL, ABLE KW, CHILDERS DL, EGGLESTON DB, GILLANDERS BM, HALPERN B, HAYS CG, HOSHINO K, MINELLO TJ, ORTH RJ, SHERIDAN PF, WEINSTEIN MP. 2001. The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. BioScience 51(8):633-641.

BLABER SJM, BREWER DT, SALINI JP, KERR J. 1990. Biomasses, catch rates and abundances of demersal fishes, particularly predators of prawns, in a tropical bay in the Gulf of Carpentaria, Australia. Marine Biol 107:397-408.

BROWMAN HI, STERGIOU KI. 2004. Perspectives on ecosystem-based approaches to the management of marine resources. Marine Ecol Progress Series 274:269-303.

CAMPBELL H, HERRICK SF, SQUIRES D. 2000. The role of research in fisheries management: the conservation of dolphins in the Eastern Tropical Pacific and the exploitation of southern bluefin tuna in the Southern Ocean. Ocean Dev Int Law 31:347-375.

CHITTARO PM, USSEGLIO P, SALE PF. 2005. Variation in fish density, assemblage composition and relative rates of predation among mangrove, seagrass and coral reef habitats. Environ Biol Fishes 72:175-187.

CHRISTENSEN V, PAULY D. 1992. The ECOPATH II - a software for balancing steady-state ecosystem models and calculating network characteristics. Ecol Modelling 61:169-185.

CHRISTENSEN V, WALTERS CJ. 2004. Trade-offs in ecosystem-scale optimization of fisheries management policies. Bull Marine Sci 74(3):549-562.

CHRISTIE P, WHITE AT. 2007. Best practices for improved governance of coral reef marine protected areas. Coral Reefs DOI 10.1007/s00338-007-0235-9.

CORCHERET DE LA MORINIERE E, POLLUX BJA, NAGELKERKEN I, VAN DER VELDE G. 2002. Post-settlement life cycle migration patterns and habitat preference of coral reef fish that use seagrass and mangrove habitats as nurseries. Estuarine, Coastal and Shelf Sci 55:309-321. DOI:10.1006/ecss.2001.0907.

CORCHERET DE LA MORINIERE E, POLLUX BJA, NAGELKERKEN I, VAN DER VELDE G . 2003. Diet shifts of Caribbean grunts (Haemulidae) and snappers (Lutjanidae) and the relation with nursery-to-coral reef migrations. Estuarine, Coastal and Shelf Sci 57:1079-1089.

COX SP, ESSINGTON TE, KITCHELL JF, MARTELL SJD, WALTERS CJ, BOGGS C, KAPLAN I. 2002. Reconstructing ecosystem dynamics in the central Pacific Ocean, 1952-1998. II. A preliminary assessment of the trophic impacts of fishing and effects on tuna dynamics. Canadian J Fisheries Aquat Sci 59:1736-1747.

DE SILVA SS, AMARASINGHE US, NISSANKA C, WIJESOORIYA WADD, FERNANDO MJJ. 2001. Use of geographical information systems as a tool for predicting fish yield in tropical reservoirs: case study on Sri Lankan reservoirs. Fisheries Manage Ecol 8:47-60.

DORENBOSCH M, GROL MGG, NAGELKERKEN I, VAN DER VELDE G. 2006. Different surrounding landscapes may result in different fish assemblages in East African seagrass beds. Hydrobiologia 563:45-60.

DUFFY JE. 2006. Biodiversity and the functioning of seagrass ecosystems. Marine Ecol Progress Series 311:233-250.

FEDERIZON RR. 1992. Description of the sub-areas of Ragay Gulf, Philippines, and their fish assemblages by exploratory data analysis. Austral J Marine Freshwater Resources 43:379-391.

GILLANDERS BM, ABLE KW, BROWN JA, EGGLESTON DB, SHERIDAN PF. 2003. Evidence of connectivity between juvenile and adult habitats for mobile marine fauna: an important component of nurseries. Marine Ecol Progress Series 247:281-295.

HARPERN BS. 2004. Are mangroves a limiting resource for two coral reef fishes. Marine Ecol Progress Series 272:93-98.

HARVEY CJ, COX SP, ESSINGTON TE, HANSSON S, KITCHELL JF. 2003. An ecosystem model of food web and fisheries interactions in the Baltic Sea. ICES J Marine Sci 60:939-950. DOI 10.1016/S1054-3139(03)00098-5.

INGLES JA. 1988. Management strategies for *Portunus pelagicus* fishery in Ragay Gulf, Philippines. Fisheries Res J Philipp 13(1-2):15-22.

JELBERT JE, ROSS PM, CONNOLLY RM. 2007. Fish assemblages in seagrass beds are influenced by the proximity of mangrove forests. Marine Biol 150:993-1002. DOI 10.1007/s00227-006-0419-9.

KISO K, MAHYAM MI. 2003. Distribution and feeding habitats of juvenile and young John's snapper *Lutjanus johnii* in the Matang mangrove estuary, west coast of Peninsular Malaysia. Fisheries Sci 69:563-568.

LACHICA LQ. 1997. Aspects of the trawl fisheries in Ragay Gulf, Philippines. [M. S. Thesis]. Diliman, Quezon City, Philippines: Marine Science Institute, College of Science, University of the Philippines.

LICUANAN WY, ALIÑO PM, CAMPOS WL, CASTILLO GB, JUINIO-MEÑEZ MA. 2006. A decision support model for determining sizes of marine protected areas: biophysical considerations. Philipp Agric Scientist 89(1):34-47.

LUGENDO BR, PRONKER A, CORNELISSEN I, DE GROENE A, NAGELKERKEN I, DORENBOSCH M, VAN DER VELDE G, MGAYA YD. 2005. Habitat utilisation by juveniles of commercially important fish species in a marine embayment in Zanzibar, Tanzania. Aquatic Living Resources18:149-158. DOI: 10.1051/alr:2005016.www.wdsciences.org/alr

MCCONNAUGHEY RA, CONQUEST LL. 1993. Trawl survey estimation using comparative approach based on lognormal theory. Fishery Bull 91:107-18.

MCCUNE B, MEFFORD MJ. 1999. PC-ORD Multivariate analysis of ecological data. Version 5.0. MjM Software, Gleneden Beach, Oregon, USA.

MUMBY PJ. 2006. Connectivity of reef fish between mangroves and coral reefs: algorithms for the design of marine reserves at seascape scales. Biol Conserv 128:215-222. DOI:10.1016/j.biocon.2005.09.042.

MUMBY PJ, EDWARDS AJ, ARIAS-GONZALEZ JE, LINDERMAN KC, BLACKWELL PG, GALL AJ, GORCZYNSKA ML, HARBORNE AR, PESCOD CL, RENKEN H, WABNITZ CC, LLEWELLYN G. 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427:533-536. DOI:10.1038/nature02286.

PADILLA JE, MORALES AC. 2004. Evaluation of fisheries management alternative for Lingayen Gulf. In: Francisco, de los Angeles, editors. Economy and Environment: Selected Readings in the Philippines. Philippines: EDM Press. p. 25-55.

PAULY D. 1979. Theory and management of tropical multispecies stocks: a review, with emphasis on the Southeast Asian demersal fisheries. ICLARM Studies and Reviews 1.

PAULY D. 1980. A selection of simple methods for the assessment of tropical fish species. FAO Fisheries Circular No. 729. 54 p.

PAULY D. 1985. The population dynamics of short-lived species, with emphasis on squids. NAFO Scientific Council Studies 9:143-154.

PAULY D. 1986. A brief historical review of living marine resources research in the Philippines. In: Pauly D, Saeger J, Silvestre G, editors. Resources, Management and Socioeconomics of Philippine Marine Fisheries. College of Fisheries, University of the Philippines in the Visayas: Dept. Mar. Fish. Tech. Rep. 10. p. 3-18.

PAULY D. 1989. On development, fisheries and dynamite: a brief review of tropical fisheries management. Natural Resource Modeling 3:3:307-329.

PAULY D. 1996. Fleet-operational, economic and cultural determinants of bycatch uses in South East Asia. In: Solving Bycatch: Considerations for Today and Tomorrow. University of Alaska, Fairbanks: Alaska Sea Grant College Program Report No. 96-03. p. 285-288.

PINTO L, PUNCHIHEWA NN. 1996. Utilisation of mangroves and seagrasses by fishes in the Negombo Estuary, Sri Lanka. Marine Biol 126:333-345.

RUSS GR, ALCALA AC. 1999. Management histories of Sumilon and Apo Marine Reserves, Philippines, and their influence on national marine resource policy. Coral Reefs 18:307-319.

SHANNON LJ, CHRISTENSEN V, WALTERS CJ. 2004. Modelling stock dynamics in the Southern Benguela ecosystem for the period 1978-2002. Afric J Marine Sci 26:179-196.

SILVESTRE GT, PAULY D. 1989. Estimates of yield and economic rent from Philippine demersal stocks (1946-1984) using vessel horsepower as an index of fishing effort. UPV Fisheries J 1(2)/2(1/2)/3(1/2):11-24.

SILVESTRE GT, REGALADO RB, PAULY D. 1986. Status of Philippine demersal stocks - inferences from underutilized catch rate data. In: Pauly D, Saeger J, Silvestre G, editors. Resources, Management and Socio-economics of Philippine Marine Fisheries. College of Fisheries, University of the Philippines in the Visayas: Dept. Mar. Fish. Tech. Rep. 10. p. 217.

TAYLOR MH, WOLFF M, VADAS F, YAMASHIRO C. 2008. Trophic and environmental drivers of the Sechura Bay Ecosystem (Peru) over an ENSO cycle. Helgol Marine Res DOI: 10.1007/s10152-007-0093-4.

UMALI AF. 1938. The fishery industries of Ragay Gulf. Philipp J Sci 65(3):175-197.

WALTERS CJ, CHRISTENSEN V, PAULY D. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. Rev Fish Biol Fisheries **7**:139-172.

WALTERS CJ, PAULY D, CHRISTENSEN V, KITCHELL F. 2000. Representing density dependent consequences of life history strategies in aquatic ecosystems: EcoSim II. Ecosystems 3:70-83.

WARFEL HE, MANACOP PR. 1950. Otter trawl exploration in Philippine waters. United States Fisheries and Wildlife Service Department of Interior Research Report 25. p. 49.