CORAL FISH POPULATION CHANGES IN THE SURROUNDING ARTIFICIAL REEFS OF THE LEBAH COASTAL WATERS, KARANGASEM, BALI

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ABSTRACT

The Directorate General of Fisheries deployed some artificial reefs in 1991 for habitat enhancement in Lebah coastal waters that have already degraded. This study was the 4th time monitoring of fifteen years of restoration period that aimed to identify changes of coral fish population in the vicinity of the artificial reefs. The study used dual approaches of old and new data gathering. The changes occurred in terms of restoration processes of the artificial reefs addressed to some progresses of coral fish taxonomy and ecological indices. These included increases in the number of species from 41 to 192, density from 0.20 to 23.32, diversity indices from 1.69 to 2.99, diversity number (N1) from 5.44 to 19.85, and diversity number (N2) from 4.23 to 12.31. Fish communities were in the relatively steady condition throughout the period of restoration with in which there was no extremely population dominance. A small number of target fishes were unseen from the study sites on the other hand a large number of major fishes were existed.

KEYWORDS: **artificial reefs, evaluation, rehabilitation, coral fishes, Bali**

INTRODUCTION

During 1991 and 1994, the collaboration between Central Research Institute for Fisheries and Bali Provincial Fisheries Services was established to develop a technical assistance project for the Lebah coastal waters rehabilitation (Ilyas *et al.*, 1993). The project aimed to deploy some artificial reefs and enhance aquatic habitats that might recover aquatic resource degradation and resolve fisheries management conflicts. The project was implemented for three fiscal years of 1990/1991, 1991/1992, and 1992/1993 respectively and this activity was terminated in 1994 (Anonymous, 1993).

Monitoring and evaluation to identify impacts of the project to the habitat rehabilitation have been carried out during the period of restoration in the vicinity of the artificial reefs. The project monitoring carried out for the first time of artificial module deployment in 1991. A small number of coral fishes aggregated around the artificial reefs were identified successfully (Wasilun *et al.*, 1991). The affinity of the coral fish to the artificial reefs was gradually increased in number, especially in 1994, the second year monitoring activity was conducted (Edrus *et al.*, 1996). Ten years after the project terminated, a thorough evaluation was carried out by an external evaluator to study on the impacts of the project to the social and institutional aspect of community participation as well as to the ecological aspect of the artificial reefs restorations. In 1994, a shift in the dominance of benthic lifeforms was detected, from the pioneer organisms to hard corals (acropore and non acropore) and other organisms with the average of percent cover of 19.25. In 2001, additional nine new life forms were noted among the artificial reefs. The data show that the percent cover of the benthic lifeforms was sharply increased from 21.5% in 1991 to 88.3% in 2001. This implied that the diversity of organisms around the artificial reefs could approximately reach the diversity in the natural reefs within a decade (Appendix 1). The study also shows that a tremendous growth of fish population was identified in the vicinity of the artificial reefs in 2001 (Edrus, 2002).

The last project impact evaluation was carried out in 2006 with the aim to identify the artificial reef capabilities in the preservation of coral fish biodiversity closer to the natural process in a coral reefs community. Their biological impacts depend relatively on the migration of the surrounding resources to the artificial reefs or FADs to which many fish and non fish species have a strong affinity (Chou, 1991; FAO, 1991). For this reason, a study of fish population growth is essential to assess periodically the nature process of artificial reefs rehabilitation. The results provide basic knowledge to increase the positive impacts and decrease the negative impacts of introducing technology, especially for the future artificial reefs development.

The objective of this study is to identify changes of coral fish population in the vicinity of the artificial reefs by using the indices of ecology, such as diversity, richness and evenness.

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MATERIALS AND METHODS

Field data collections were conducted in July 2006. Study sites located at the coastal waters of Lebah Hamlet, Purwakerti Village, Karangasem, Bali (Figure 1). Two ways of data collection was implemented, field measurement and collection of secondary data. The later was employed to compile and analyse the initial data related to similar indicators at the similar sites. Table 1 shows geographic positions of the transect sites in which data of coral fish were obtained by using visual census on a line transects with the 250 square meter census area (English *et al.*, 1994). Four units of artificial reefs per sites have been observed. An observer swam using SCUBA diving equipment along 5 m length of the line transects. All fish species found and their individual numbers were counted and recorded on a waterproof sheet. Fish photograph guide books were used to identify the fish species (Kuiter, 1992; Lieske & Myers, 1997).

Table 1. Geographic positions of the transect locations and materials of artificial reefs

Transect sites		
1	**2**	**3**
Concrete modules	Concrete modules	Tire modules
08°20'0.40" SL	08°20'01.1" SL	08°20'15.6" SL
115°39'12.6" EL	115°39'08.4" EL	115°39'39.2" EL

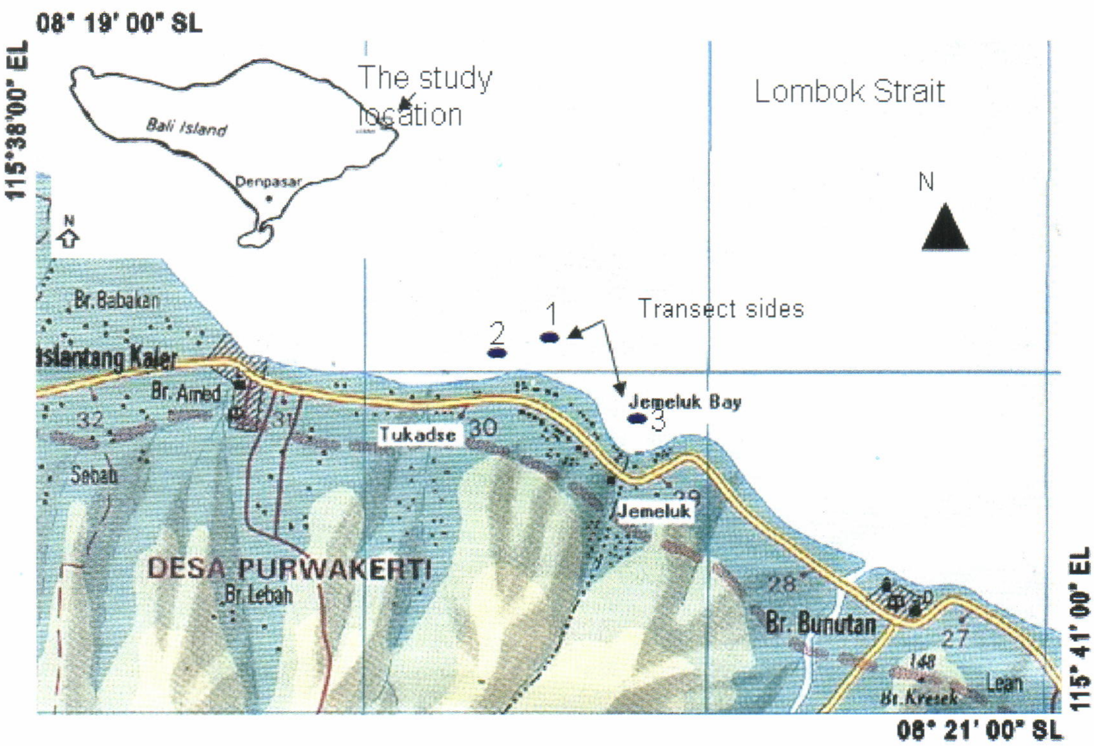

Figure 1. Map showing the study sites in Lebah Hamlet, Purwakerti, Bali.

Coral fishes were grouped into three categories showing their status, the major fish species group, the target species and the indicator species (English *et al.*, 1994). The major species group consisted of the coral fishes that are usually found in coral reefs areas as a resident species and are known as ornamental fish. The target species are the coral fishes that are caught for consumption purposes. Most of the target species are having a great affinity to the coral reefs as intruders. Indicator species are coral fishes include in the family of Chaetodontidae that are usually used to determine the health of the coral reef community.

Data Analysis

The computed values of the coral fish on the artificial reefs derived from the calculation of Margalef Richness index (R), Simpson (dominance) index (D), Shannon-Weaver diversity index (H), Hill's diversity number (N1 & N2), and square meter density following Ludwig & Reynold (1988).

The formulas for calculating the indices are:

Margalef index: $[R=(S-1)/\ln(n)]$

where:
- S = total number of species
- n = total number of individual of all species

Shannon-Weaver diversity index: $[H=\Sigma\{(n_i/N)\ \ln(n_i/N)]$

Simpson index: $[\lambda=\Sigma\{(n_i(n_i-1)/(N(N-1)]$

Dominance Index: $[D=\Sigma(n_i/N)^2]$

where:
- n_i = number of individual of species i
- N = total number of individual of entire species
- H = Shannon index

Hill-diversity number: $[N_1=e^H]$

$[N_2=1/\lambda]$

where:
- N_1 = number of abundant species
- N_2 = number of very abundant species
- H = Shannon index
- e = natural number (e=2.7182818)
- λ = Simpson index

Pielou (Evenness) index: $[E=\{H/\ln(S)]$

where:
- S = total number of species
- H = Shannon index

The significant changes of selected indicators in terms of different years of measurement of 1991, 1994, 2001, and 2006 were analyzed by using the graphical trend. Some indicators to be compared in different times consisted of number of family, genera, species, diversity indices, dominance indices, evenness indices, diversity numbers, and fish density.

RESULTS AND DISCUSSION

It was likely that changes of quality and quantity of coastal resources, particularly coral fish as a result of the restoration process of the artificial reef ecosystem between 1991 and 2006 were occurred. Comparison of coral fish population changes in the vicinity of the artificial reefs based on the analysis of primary data and compiled secondary data have also been detected (Table 2).

For fifteen years of the period of restoration there were at least 267 species of coral fishes attracted to the three locations of artificial reefs in the study areas (Appendix 2). A study in 2001 at the same region for five locations found a number of 314 species of coral fishes (Edrus & Suprapto, 2005). It was likely that the natural reef functions have well replaced by the artificial reefs since in the certain areas there has no longer natural reefs for long time.

The restoration project has succeded to enhance the coral fishes poor areas into the high population density areas for around one decade.

Table 2. Ecological indices showing improvement of coral fish population in the vicinity of the artificial reefs in Lebah coastal waters

Indicators	Measurement Years										
	1991*		1994**			2001***			2006****		
	Locations										
	1	3	1	2	3	1	2	3	1	2	3
Species Numbers	20	31	37	54	61	119	93	89	76	64	80
Genus Numbers	18	22	30	35	37	59	57	53	50	45	54
Family Numbers	15	14	18	21	24	31	31	28	29	29	29
Square Density	0.20	2.26	8.23	19.25	7.21	18.68	23.32	19.91	19.60	17.40	17.4
Richness Indices (R)	4.12	4.27				12.91	9.82	9.95	8.83	7.4	9.43
Dominance Indices (D)	0.15	0.24				0.09	0.08	0.09	0.09	0.1	0.09
Diversity Indices (H)	2.30	1.69	1.90	2.49	2.71	2.97	2.95	2.86	3.13	2.99	2.99
Evenness Indices (E):	0.77	0.49				0.62	0.65	0.64	0.72	0.72	0.68
Diversitry Number (N1)	9.98	5.44				19.45	19.03	17.44	22.92	19.83	19.85
Diversitry Number (N2)	6.73	4.23				10.58	12.31	11.33	11.6	10.37	11.68

Sources : * Wasilun et al. (1991); ** Edrus et al. (1996); *** Edrus (2002); **** Primary data

From taxonomic data in term of the total number of species, genus, and family it is appear that the identified fishes from 1991 to 2001 has increased and a moderately decrease occurred from 2001 to 2006 (Table 2 and 3, Figure 2). These phenomena were also happened to the richness indices and density (Table 2 and Figure 3).

Possible reasons of the last five declining numbers of those were due to the lost some species in visual census activities; vulnerable artificial reefs fish during fishing seasons and temporal migration of fish. Some species of the target fishes group like grouper (Serranidae), soldierfishes (Holocentridae), sweetlips (Haemulidae), emperors (Lethrinidae), fusiliers (Caesionidae), parrotfishes (Scaridae), surgeonfishes (Acanthuridae), and trevallies (Carangidae), were likely temporary missing from the census area and no longer found in the 2006. Figure 4 shows that the percentage composition of the target fishes group tend to decrease after an increasing number during 1991 to 2001.

Table 3. Total number of species, genus, and family found in the artificial reefs in the Lebah coastal waters, Bali

Description	Measurement years			
	1991*	1994**	2001***	2006****
	Location	Location	Location	Location
	1 and 3	1, 2, and 3	1,2, and 3	1, 2, and 3
Species numbers	41	103	192	124
Genus numbers	29	53	77	71
Family numbers	18	30	38	39

Sources: * Wasilun *et al.* (1991); ** Edrus *et al.* (1996); *** Edrus (2002); **** Primary data

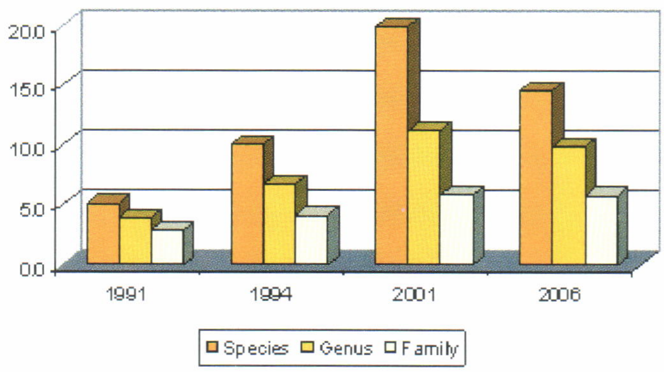

Figure 2. Percentage composition of species, genus, and family of the target fish group during 1991 and 2006.

Unlike major fishes group that always settle inside and on surface of the modules, most of the target fishes group were moving across the areas with high mobility and migrated far away from the modules. It was known that behaviour of a small number of target fishes group, and certain major fishes provide a cryptic and or nocturnal (Kakimoto, 1979; 1984), such as rock cods, grouper (Serranidae), and soldierfishes (Holocentridae). Groupers or rock cods migrate from reef areas to deeper waters. Some of those have strong affinity to natural reefs and artificial reefs protecting them, especially for juveniles, and other several fishes. Most groupers or rock cods were possibly avoided census taker and others hiding from crowded or went out to seek favorable areas at deeper waters.

In addition, one unit volume of the artificial reefs is probably too narrow for accomodating a great number of coral fish species. Unlike natural reefs that have more ecological niches and capable to support the higher biodiversity of fishes, artificial reefs quite depend on building volumes and surfaces area occupied by hard corals and other fauna to provide spaces, niches, and services.

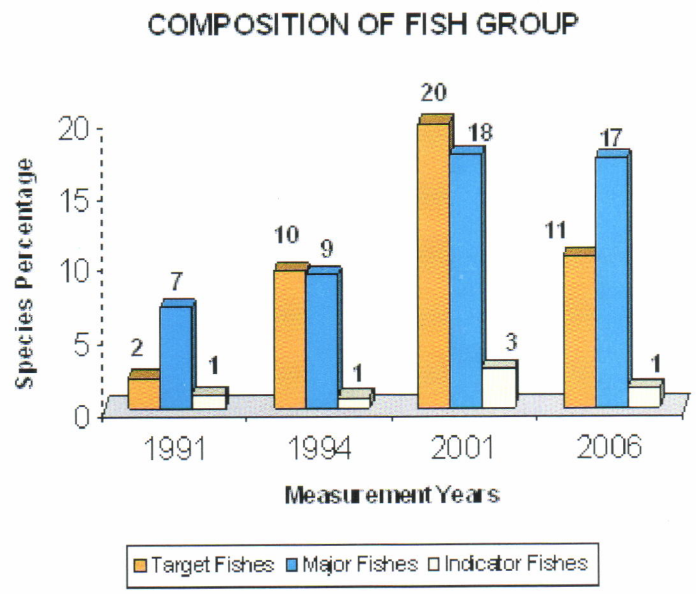

Figure 4. Average composition of coral fish groups in the vicinity of the artificial reefs during 1991-2006.

Table 2 also indicates that the dominance indices were low for the whole sites and time. However the relatively higher indices occurred for the first time the modules deployed compare with the following period. When the modules were deployed first time in 1991, spaces of the modules were dominated by colonies of *Anthias* spp., *Apogon* spp., and *Dascyllus trimaculatus*. Afterward, there were new arrivals of a large number of fish populations to make evenness of community occupied in the artificial reefs.

The diversity number (N1 and N2) indicated more present of colony species within the artificial reef community, especially for major species that linearly improved their composition during 1991 and 2006 (Table 2, Figure 3 and 4). The major species colony that provide abundance species (N1) include *Plotosus lineatus, Pholidichthys leucotaenia, Anthias* spp., *Apogon* spp., *Cheilodipterus quinqueleneatus, Abudefduf vaigiensis, Dascyllus* spp., *Pomacentrus auriventris,* and *Neopomacentrus cyanomus*. The very abundance (N2) of major species group include *Anthias* spp., *Apogon* spp., *Cheilodipterus lineatus, Lutjanus* spp., *Chaetodon kleiini, Chaetodon vagabundus, Chromis* spp., *Halichoeres* spp., *Labroides dimidiatus, Psedocoris heteroptera, Thallosomma lunare, Zebrasoma scopas, Odonus niger, Sufflamen chrysopterus*, and *Canthigaster compressa.*

For this reason the evenness indices of fish community seem to be steady in the whole sites during the last period restoration. As a result, diversity index was significantly improved during 1991 and 2006 (Figure 3). The increase of the diversity index also show that there was no extreme population dominance in the last five period of restoration compare with those in the first time. The lower dominance was likely due to the limited spaces and niches for growing major fish populations inside the modules. Some major fishes group had the same opportunity to grow and to occupy some favorable conditions of the inside part of artificial reefs. It likely that there was no extreme conditions of waters in the vicinity of the artificial reefs leading to a blooming individual of a certain major fishes that will force the others.

The major fishes have a ceratin territory and have more access to ecological niches inside the modules than that of the target fishes. Mostl of the major fishes spatially aggregated in the inside part of the modules and guarded the areas enclosing one or more resources of food, shelter, or potential mates or nesting sites. Major fishes that roam in the inside areas of artificial reefs are known as home ranging species. They may carry with them a portable territory with in which competitors are not allowed. Many home ranging species may be relatively sociable during times of abundant resources, but become aggressive during lean times. Hence, both major fishes and target fishes might share territories while some species may need quite large territories. However, a growing population of major fishes might have limited living spaces in the inside part of the modules. Certain target fishes might be attracted outwardly and distribute in a wider scale of territories (Lieske & Myers, 1997).

Target fishes and indicator fishes group (butterfly fish), may have territories for certain purposes or search some favourable proper areas. Certain target fish may become a daily intruder or a daily moving around in artificial reef areas as well as indicator fishes. Like indicator fishes, certain target fishes may also be unseen during the census activities especially in times of unfavourable conditions.

Low present of indicator fishes (Figure 4) in the artificial reef areas might indicate low diversity and kind numbers of hard corals (Nash, 1989). There were five butterfly fish species still existed in the areas while the other twelve species were missed. This possibly due to recruitment progresses of benthic lifeform of the artificial reefs have not yet fully attracted for butterfly fishes or major fish that have already blooming, and these become a non favored site for them. Mostl of the indicator fishes are the primary omnivores. Many indicator fishes feed on a variety of small invertebrates and coral polyps, taking a little of each over a large home range (Lieske & Myers, 1997).

CONCLUSION

The typical changes of coral fish population engaged during fifteen year period of restoration in the artificial reefs are as follows:

1. The number of species, genus and family of coral fish increased during 1991 until 2001 and moderately decreased during 2001 until 2006. The similar fluctuations were also occurred in richness indices and density.

2. Diversity index of coral fish was improved significantly during 1991 until 2006.

3. Several species of major fishes had continued to occupy the artificial reefs for fifteen years with gradually increases in percent compositions. However, a small number of target fishes and indicator fishes were no longer found in the artificial reefs in 2006.

4. From evenness indices of coral fish community indicated a steady condition for all sites during the last period of restoration and it was due to a low dominance of fish populations.

Some implications are as follows:

1. The artificial reef volume capacity is likely too narrow for growing coral fish communities.

2. The typical niches or habitats are continuously structuring the artificial reefs to support bio diversity.

3. The artificial reefs are vulnerable toward disturbances such as over-exploitation or any physical destruction.

4. Small scale areas of artificial reef development may offer low expected impacts for coral fish population growth and fishing productivity. The number of artificial reef units was insufficient to support high production of target fishes. Furthermore, the artificial reefs have not fully performed yet to reach the optimum level of restoration. These were indicated by the absences of large numbers of major fish and indicator fish species, such as Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae that provide the main families generally inhabit the natural reefs. However, artificial reefs have a specific capability to preserve marine biodiversity on their substrate coverage as well as progressive recruitment of benthic lifeforms.

5. It is important to develop artificial reefs in a larger scale of areas and purposes, such as fishing ground, conservation, and marine tourism. A higher fish productivity in artificial reef areas quite depends on a large number of artificial reef units tol be deployed on degraded areas.

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Appendix 1. The 2006 progressive recruitment of benthic lifeforms on artificial reefs in Lebah Coastal waters, Karangasem, Bali

Appendix 2. Fish species identified in the vicinity of the artificial reefs in Lebah Costal waters, Karangasem, Bali.

Families and species	Measurement years											Group
	1991*		1994**			2001***			2006****			
	Sites		Sites			Sites			Sites			
	1	2	1	2	3	1	2	3	1	2	3	
Dasyatidae (*Stingrays*)												
Dasyatis kuhlii	-	-	-	-	-	8	6	-	-	-	-	T
Muraenidae (*Moray eels*)												
Gymnothorax javanicus	-	-	-	-	-	6	4	-	-	-	-	M
Congridae (Garden eels)												
Gorgasia maculata	-	-	-	-	-	-	-	-	135	56	-	M
Plotosidae (*Eel catfishes*)												
Plotosus lineatus	-	-	-	++	-	-	-	1.000	-	-	300	M
Pholidichthydae (*Blennies*)												
Pholidichthys leucotaenia	-	-	-	-	-	-	-	1.000	-	-	-	M
Sinodontidae (*Lizardfishes*)												
Saurida gracilis	-	-	-	-	+	-	-	-	-	-	-	M
Saurida sp.	-	-	-	-	+	-	-	-	-	-	-	M
Synodus jaculum	-	-	-	-	-	-	5	-	-	3	-	M
Synodus ulae	-	-	-	-	-	-	-	20	-	-	-	M
Synodus sp.	2	1	-	-	-	-	-	-	2	-	-	M
Holocentridae (*Soldierfishes*)												
Myripristis adusta	-	-	-	-	-	-	-	20	-	-	-	T
Myripristis melanosticta	-	-	-	-	-	50	60	30	-	-	-	T
Myripristis murjan	8	-	-	+	-	100	100	8	4	-	-	T
Myripristis vittata	-	-	-	-	-	-	-	4	-	-	3	T
Sargocentron cornutum	-	-	-	-	-	15	-	-	-	-	-	T
Sargocentron spiniferum	-	-	-	-	-	6	20	12	-	-	-	T
Sargocentron rubrum	-	-	-	-	-	20	20	-	-	-	-	T
Sargocentron sp.	2	-	-	-	-	-	-	-	-	6	-	T
Aulostomidae (*Trumppetfishes*)												
Aulostomus chinensis	2	2	+	-	-	6	16	20	1	1	1	M
Syngnathidae (*Pipefishes*)												
Corythoichthys intestinalis	-	-	-	-	-	-	1	-	-	-	-	M
Fistulariidae (*Cornetfishes*)												
Fistularia petimba	-	-	+	-	-	-	-	-	-	-	-	M
Scorphaenidae (*Scorpionfishes*)												
Dendrochirus zebra	-	-	-	-	-	-	-	3	-	-	-	M
Dendrochirus brachypterus	-	-	-	-	-	-	-	-	-	1	-	M
Pterois antennata	-	-	-	-	-	-	4	-	2	2	2	M
Pterois radiate	1	-	-	-	-	-	-	-	-	-	-	M
Pterois volitans	-	1	+	+	-	1	4	-	-	-	3	M
Scorpaenopsis sp.	-	-	+	+	-	-	-	-	-	-	-	M
Scorpaenopsis cirrhosa	-	-	-	-	-	-	-	-	1	-	-	M
Serranidae (*Gropers*)												
Aethaloperca rogaa	-	-	+	-	-	2	-	-	-	-	-	T
Cephalopholis argus	-	-	-	-	+	2	-	1	-	1	-	T
Cephalopholis boenak	-	-	-	-	-	1	-	-	-	-	-	T
Cephalopholis microprion	-	-	-	-	+	-	1	1	-	-	1	T
Cephalopholis miniata	-	-	-	+	+	4	20	1	-	-	2	T

Appendix 2. Continue

Families and species	Measurement years											Group
	1991*		1994**			2001***			2006****			
	Sites		Sites			Sites			Sites			
	1	2	1	2	3	1	2	3	1	2	3	
Cephalopholis sonnerati	-	-	+	+	+	1	2	-	-	-	-	T
Cephalopholis sp.	-	-	+	-	-	-	1	-	-	-	-	T
Cephalopholis urodeta	-	-	-	-	-	5	-	-	1	-	-	T
Ephinephelus areolatus	-	-	-	+	+	-	1	-	-	-	-	T
Ephinephelus chlorostigma	-	-	+	+	-	-	-	-	-	-	-	T
Ephinephelus fasciatus	-	-	-		+	-	-	-	-	-	-	T
Ephinephelus maculatus	-	-	+	+	-	-	-	1	-	-	-	T
Ephinephelus malabaricus	-	-	-	-	-	-	1	-	-	-	-	T
Ephinephelus merra	-	-	-	-	-	-	2	-	-	-	-	T
Ephinephelus sp.	1	1	-	+	-	-	-	-	-	-	-	T
Plectropomus leopardus	-	-	-	-	-	1	-	-	-	-	-	T
Plectropomus sp.	-	-	+	-	-		-	-	-	-	-	T
Variola louti	-	-	-	-	-	-	1	1	-	-	1	T
Anthiidae *(Anthiases)*												
Anthias dispar	-	-	-	++	-	1.500	1.500	300	1.000	1.000	-	M
Anthias sp.	30	200	-	-	++	-	-	-	-	-	-	M
Anthias squamipinnis	-	2	++	++	-	500	500	-	300	150	1.200	M
Pseudanthis cooperi	-	-	-	-	-	500	750	-	-	-	-	M
Pseudanthias hutchtii	-	-	-	-	-	-	-	-	500	300	800	M
Pseudanthis hypselosoma	-	-	-	-	-	500	750	-	-	-	-	M
Psedanthias luzonensis	-	-	++	++	++	500	800	-	60	30	-	M
Pseudanthis pleurotaenia	-	-	-	-	-	-	-	50	-	-	-	M
Nemipteridae *(Spinecheeks)*												
Pentapodus emeryii	-	-	-	-	-	-	2	-	-	-	-	T
Scolopsis affinis	-	-	-	-	-	10	30		6	2		T
Scolopsis bilineatus	-	1	-	-	-	6	-	4	-	-	3	T
Scolopsis ciliata	-	-	-	-	+	15	-	30	-	-	30	T
Scolopsis margaritifer	-	-	-	-	-	-	-	12	-	-	-	T
Theraponidae *(Whiptails)*												
Terapon jarbua	-	-	-	-	-	-	-	6	-	-	2	T
Priacanthidae *(Fin bulls eye)*												
Priacanthus cruentatus	-	-	-	+	-	2	-	-	-	-	-	T
Haemulidae *(Sweetlips)*												
Diagramma pictum	-	-	-	-	-	8	15	-	4	6	2	T
Plectorhyncus obscurus	-	-	-	-	-	-	6	-	-	-	-	T
Plectorhyncus picus	1	1	-	-	+	1	-	-	-	-	-	T
Plectorhyncus polytaenia	-	-	-	-	-	4	2	2	4	2	2	T
Plectorhyncus vittatus	-	-	-	-	-	2	-	6	-	-	-	T
Apogonidae *(Cardinafishes)*												
Apogon apogonides	-	-	-	-	-	-	-	-	600	800	800	
Apogon aureus	20	200	++	++	++	2.000	2.000	400	1.000	1.000	600	M
Apogon chrysotaenia	-	-	-	-	++	100	200	1.000	150	200	500	M

Appendix 2. Continue

Families and species	Measurement years											Group
	1991*		1994**			2001***			2006****			
	Sites		Sites			Sites			Sites			
	1	2	1	2	3	1	2	3	1	2	3	
Apogonidae (Cardinafishes)												
Apogon compressus	-	250	-	-	-	-	-	500	-	-	-	M
Apogon frenatus	-	-	-	++	++	-	-	-	100	60	100	M
Apogon quadrifasciatus	4	-	-	-	-	-	-	-	-	-	-	M
Apogon ventrifasciatus	-	-	-	-	-	500	200	-	-	-	-	M
Cheilodipterus lineatus	-	-	-	-	-	500	500	-	50	65	-	M
Cheilodipterus quinqueleneatus	-	-	-	-	-	-	-	-	-	-	100	M
Apogon fragilis	-	-	-	++	-	500	500	-	80	-	-	M
Centropomidae (Barramundi)												
Lates calcarifer	-	-	-	-	-	10	-	-	-	-	-	T
Malacanthidae (Sand tilefishes)												
Malacanthus latovittatus	-	-	-	-	-	-	-	10	-	-	-	M
Lutjanidae (Snappers)												
Lutjanus argentimaculatus	-	-	-	-	-	1	-	-	-	-	-	T
Lutjanus bohar	-	-	-	-	-	2	-	-	46	38	-	T
Lutjanus boutton	-	-	-	-	-	-	-	-	60	-	-	T
Lutjanus decussatus	-	-	-	-	-	1	-	1	1	-	-	T
Lutjanus fulvus	-	-	-	-	+	5	5	6	-	-	-	T
Lutjanus gibbus	-	-	-	-	-	1	-	1	1	-	-	T
Lutjanus johnni	-	-	-	-	+	4	-	-	-	-	-	T
Lutjanus kasmira	-	-	++	++	-	-	1.000	-	50	62	-	T
Lutjanus lutjanus	-	-	-	-	-	-	-	-	-	38	24	T
Lutjanus monostigma	-	-	-	-	-	-	16	-	-	-	-	T
Lutjanus rivulatus	-	-	-	+	+	-	50	-	6	8	3	T
Lutjanus sp.	1	-	+	+	-	1	-	-	-	-	-	T
Lutjanus sebae	-	-	-	+	-	-	-	-	-	-	-	T
Lutjanus vulfiflamma	-	-	-	++	-	30	-	-	-	-	-	T
Macolor macularis	-	-	-	-	-	2	12	-	-	-	4	T
Macolor niger	-	-	-	-	-	2	8	2	2	-	-	T
Caesionidae (Fusiliers)												
Caesio cuning	-	-	++	++	++	200	-	-	-	-	-	T
Caesio teres	-	-	-	++	-	-	-	-	65	60		T
Caesio caerulaurea	-	-	-	-	-	150	100	100	36	40	-	T
Caesio xanthonata	-	-	-	-	-	-	-	10	-	-	-	T
Pterocaesio marri									25	25	-	T
Pterocaesio pisang	-	-	++	++	-	200	200	100	32	48	-	T
Pterocaesio tile	-	-	-	++	-	300	-	-	-	-	-	T
Pterocaesio trilineata	-	-	++	++	-	-	-	-	-	-	-	T
Pterocaesio tessellata	-	-	-	-	-	-	-	50	-	-	-	T

Appendix 2. Continue

Families and species	Measurement years											Group
	1991*		1994**			2001***			2006****			
	Sites		Sites			Sites			Sites			
	1	2	1	2	3	1	2	3	1	2	3	
Lethrinidae (*Emperors*)												
Lethrinus conchyliatus	-	-	-	-	-	-	-	2	-	-	-	T
Lethrinus erythracanthus	-	-	-	-	-	2	-	4	-	-	2	T
Lethrinus harak	-	-	-	-	+	1	-	-	-	-	-	T
Lethtrinus obsoletus	-	-	-	-	-	-	-	1	-	-	-	T
Lethrinus olivaceus	-	-	-	-	+	-	14	4	2	3	-	T
Lethrinus ornatus	-	-	-	-	+	-	-	-	-	-	-	T
Lethrinus sp.	-	-	+	+	-	-	-	-	-	-	-	T
Monotaxix grandoculus	-	-	+	-	-	2	-	-	-	-	-	T
Mullidae (*Goatfishes*)												
Mulloides flavolineatus	-	-	-	+	+	-	8	30	-	-	32	T
Parupeneus barbarinus	-	-	-	-	+	4	-	-	-	-	2	T
Parupeneus bifasciatus	-	-	-	-	-	-	-	10	-	-	2	T
Parupeneus heptacanthus	-	-	-	+	-	-	-	-	-	-	3	T
Parupeneus indicus	-	-	+	-	-	4	6	-	-	-	-	T
Parupeneus macronema	-	-	-	-	-	+	-	-	-	-	-	T
Parupeneus multifasciatus	-	-	-	-	+	2	12	12	2	1	2	T
Parupeneus rubescens	-	-	-	-	-	-	-	1	-	-	-	T
Upeneus luzonius	-	-	-	-	-	-	-	4	-	-	-	T
Kyphosidae (*Rudderfishes*)												
Kyphosus vagiensis	-	-	-	-	-	5	2	-	6	-	-	M
Phempherididae (*Sweeperfishes*)												
Phempheris oualensis	-	-	-	-	-	-	-	-	-	-	11	M
Ephippidae (*Spadefishes*)												
Platax orbicularis	-	-	+	-	-	-	-	-	-	3	-	M
Platax pinnatus	-	-	-	+	+	-	-	-	-	-	-	M
Chaetodontidae (*Butterflyfishes*)												
Chaetodon adiergastos	-	-	-	-	-	12	4	2	-	-	-	IF
Chaetodon auriga .	2	-	-	-	-		6	-	-	-	-	IF
Chaetodon baronessa	-	-	-	-	-	6	-	-	-	-	-	IF
Chaetodon citrinellus	-	-	-	-	-	2	-	-	-	-	-	IF
Chaetodon kleiini	2	2	++	++	++	-	-	60	32	24	16	IF
Chaetodon lunula	-	-	-	-	+	-	-	-	-	-	-	IF
Chaetodon meyeri	-	-	-	-	-	2	2	1	-	-	-	IF
Chaetodon ocellicaudus	-	-	-	-	-	-	-	2	-	-	-	IF
Chaetodon ornatissimus	-	-	-	-	-	8	-	-	-	-	-	IF
Chaetodon refflesii	-	-	-	-	-	6	-	-	-	-	-	IF
Chaetodon semeion	-	-	-	-	-	-	-	1	-	-	-	IF
Chaetodon speculum	-	-	-	-	-	-	-	-	-	-	2	IF
Chaetodon trifasciatus	-	2	-	-	-	-	-	-	-	-	-	IF
Chaetodon vagabundus	-	-	-	+	-	4	2	2	30	16	8	IF
Heniochus diphreutes	-	2	-	+	-	20	30	-	6	11	5	IF
Heniochus singularis	-	-	-	-	-	-	2	-	-	-	-	IF
Heniochus varius	-	-	-	-	-	4	-	-	-	-	4	IF

Appendix 2. Continue

Families and species	Measurement years											Group
	1991*		1994**			2001***			2006****			
	Sites		Sites			Sites			Sites			
	1	2	1	2	3	1	2	3	1	2	3	
Pomacanthidae (*Anglefishes*)												
Centropyge bicolor	-	-	-	-	-	16	-	-	-	-	-	M
Centropyge eibli	-	-	-	-	-	3	6	1	-	-	-	M
Centropyge flavicauda	-	-	-	-	-	-	-	-	-	-	-	M
Centropyge heraldi	-	-	-	-	-	30	-	-	-	-	-	M
Centropyge tibecen	-	-	-	-	-	-	-	2	3	-	13	M
Centropyge vrolikii	-	-	-	-	-	2	-	-	-	-	-	M
Pomacanthus imperator	-	-	+	+	+	-	8	6	2	4	8	M
Pomacanthus xanthometopon	-	-	-	-	-	-	-	1	-	-	-	M
Pygoplites diacanthus	-	-	-	-	-	1	-	-	-	-	-	M
Pomacentridae (*Damselfishes*)												
Abudefduf septemfasciatus	-	4	-	-	-	-	-	-	-	-	-	M
Abudefduf sexfasciatus	-	-	-	-	-	60	20	-	-	-	-	M
Abudefduf vaigiensis	-	-	-	-	-	50	-	-	120	80	100	M
Amblyglyphidodon curacao	-	-	-	-	-	50	-	100	-	-	-	M
Amphiprion perideraion	2	-	-	-	-	-	-	-	-	-	-	M
Chromis alleni	-	2	-	-	-	-	-	-	-	-	-	M
Chromis analis	-	-	-	-	-	-	10	-	-	-	-	M
Chromis caudalis	-	-	++	-	-	100	-	-	-	-	-	M
Chromis cinerascens	-	-	-	-	-	-	-	50	-	-	-	M
Chromis fumea	-	-	-	-	-	-	80	-	-	-	-	M
Chromis leucurus	3	3	-	-	-	-	-	-	-	-	-	M
Chromis margaritifer	-	-	-	++	-	-	160	-	-	-	-	M
Chromis scotochilopterus	-	-	-	-	-	-		250	20	-	-	M
Chromis lepidolepis	-	2	+	++	++	100	50	200	-	-	42	M
Chromis ternatensis	-	-	-	-	-	-	-	-	-	-	36	M
Chromis weberi	-	-	-	-	-	-	-	-	35	-	60	M
Chrysiptera leucopoma	-	-	-	-	-	25	-	-	-	-	-	M
Chrysiptera parasema	-	-	-	-	-	20	-	-	-	-	-	M
Dascyllus reticulatus	-	-	-	-	++	-	100	600	150	320	220	M
Dascyllus trimaculatus	13	400	++	++	++	-	1.000	500	100	100	200	M
Dischistodus pseudochrysoppoecilus	-	-	-	-	-	-	30	30	-	-	-	M
Neopomacentrus cyanomus	-	-	-	-	+	-	-	100	90	100	-	M
Neopomacentrus violaceus	-	-	+	++	++	-	-	-	85	120	55	M
Plectroglyphidodon lacrymatus	-	-	-	-	++	20	-	-	-	-	12	M
Pomacentrus amboinensis	-	-	-	-	-	-	-	-	-	-	20	M
Pomacentrus auriventris	-	-	-	-	-	100	300	30	100	200	80	M
Pomacentrus bankanensis	-	-	-	-	-	20	-	-	-	-	-	M
Pomacentrus coelestis	-	-	-	-	++		-	-	-	-	-	M
Pomacentrus moluccensis	-	-	-	-	-	20	-	-	-	-	-	M
Pomacentrus nagasakiensis	-	+	-	-	+	-	-	-	12	8	5	M
Pomacentrus simsiang	-	-	-	-	-	-	-	-	-	-	15	M

Appendix 2. Continue

Families and species	Measurement years											Group
	1991*		1994**			2001***			2006****			
	Sites		Sites			Sites			Sites			
	1	2	1	2	3	1	2	3	1	2	3	
Cirrhitidae (*Hawkfishes*)												
Cirrhitichthys falco	-	2	-	-	-	10	6	-	-	-	-	M
Cirrhitichthys oxycephalus	-	-	-	+	-	-	-	-	60	36	-	M
Labridae (*Wrasses*)												
Anampses meleagrides	-	1	-	-	-	-	-	-	-	-	-	M
Bodianus diana	-	-	+	+	+	5	60	-	45	60	20	M
Bodianus mesothorax	-	2	+	-	-	-	-	-	2	-	8	M
Cheilinus sp.	-	-	-	-	+	-	-	-	-	-	-	M
Cheilinus trilobatus	-	-	-	+	-	6	-	-	-	-	6	M
Cheilinus undulatus	-	-	-	-	-	1	-	-	-	-	-	T
Choerodon anchorago	-	-	-	-	-	-	2	2	-	-	-	M
Halichoeres chrysus	-	-	++	++	++	-	30	-	84	95	92	M
Halichoeres dussimieri	-	-	-	-	-	-	-	2	-	-	-	M
Halichoeres hartzffeldi	-	-	-	+	-	-	-	-	15	9	-	M
Halichoeres hortulanus	-	-	-	-	-	20	-	-	21	18	12	M
Halichoeres sp.	-	-	-	-	+	-	-	-	-	-	-	M
Labroides bicolor	-	-	-	-	+	-	-	-	-	-	-	M
Labroides dimidiatus	2	2	+	+	+	60	30	20	15	30	32	M
Psedocoris heteroptera	-	-	-	-	-	-	-	-	150	120	-	M
Labridae (*Wrasses*)												
Psedocheilinus yamashiroi	-	-	-	-	-	-	-	-	32	21	-	M
Stethojulis sp.	-	30	-	-	-	-	-	-	-	-	-	M
Thallosomma hardwicke	-	3	-	-	-	4	-	-	-	-	-	M
Thallosomma janseni	-	-	-	-	-	-	-	-	-	-	-	M
Thallosomma lunare	1	2	+	+	+	12	30	60	60	60	30	M
Thallosomma lutescens	-	3	-	-	-	-	-	-	-	-	12	M
Thallosomma purpureum	-	-	-	-	-	-	-	-	-	2	-	
Scaridae (*Parrotfishes*)												
Bolbometopon muricatum	-	-	-	-	-	-	-	4	-	-	-	T
Cetoscarus bicolor	-	-	-	-	-	1	-	-	-	-	-	T
Scarus bleekeri	-	-	-	-	+	-	-	-	-	-	3	T
Scarus dimidiatus	-	-	-	-	+	-	-	-	-	-	-	T
Scarus ghoban	-	-	-	-	+	5	1	10	-	-	6	T
Scarus oviceps	-	-	-	-	-	2	-	-	-	-	-	T
Scarus rubroviolaceus	-	-	-	-	-	12	-	-	-	-	2	T
Scarus schlegeli	-	-	-	-	-	4	1	2	-	-	-	T
Scarus sordidus	-	-	-	-	-	2	-	-	-	-	-	T
Scarus tricolor	-	-	-	-	+	2	3	-	-	-	-	T
Pinguipedidae												
Parapercis millepunctata	-	-	-	-	-	-	-	-	6	12	-	M
Blenniidae												
Salarias fasciatus	-	-	-	-	-	-	-	-	-	-	1	M

Appendix 2. Continue

Families and species	Measurement years											Group
	1991*		1994**			2001***			2006****			
	Sites		Sites			Sites			Sites			
	1	2	1	2	3	1	2	3	1	2	3	
Sphyraenidae (*Barracudas*)												
Sphyraena barracuda	-	-	-	-	-	-	-	-	-	-	2	T
Mugilidae (*Mullets*)												
Crenimugil crenilabis	-	-	-	-	-	-	-	-	-	-	12	T
Siganidae (*Rabbitfishes*)												
Siganus corallinus	-	-	-	+	+	-	-	-	-	-	-	T
Siganus puellus	-	-	-	-	-	-	-	-	4	-	-	
Siganus punctatus	-	-	-	-	+	-	-	-	5	9	-	T
Siganus stellatus	-	-	-	-	-	8	-	-	-	-	-	T
Siganus virgatus	-	-	-	-	-	2	-	-	-	-	-	T
Siganus vulpinus	-	-	-	-	-	4	-	-	-	-	-	T
Acanthuridae (*Surgeonfishes*)												
Acanthurus bariene	-	-	-	-	++	-	-	1	-	-	-	T
Acanthurus leucocheilus	-	-	-	++	++	20	-	40	30	18	40	T
Acanthurus lineatus	-	-	-	-	-	50	30	-	-	-	-	T
Acanthurus maculiceps	-	-	++	++	-	-	10	-	-	-	-	T
Acanthurus mata	1	-	-	-	-	-	-	-	-	-	-	T
Acanthurus nigricans	-	3	-	-	-	10	-	-	-	-	-	T
Acanthurus olivaceus	-	-	-	-	-	-	1	-	-	-	-	T
Acanthurus pyroferus	-	-	-	-	+	-	5	2	-	-	8	T
Acanthurus sp.	-	-	+	-	+	-	-	2	-	-	-	T
Acanthurus triostegus	-	-	-	-	-	2	-	-	-	-	-	T
Acanthurus xanthopterus	-	+	-	++	-	-	-	-	-	-	-	T
Ctenochaetus striatus	-	-	-	-	-	-	-	2	4	-	-	T
Naso hexacanthus	-	-	-	-	-	7	30	-	20	32	12	T
Naso lituratus	-	-	-	++	-	6	6	-	6	4	4	T
Naso unicornis	-	-	-	-	++	-	1	6	-	-	-	T
Naso vlamingii	-	-	-	-	-	2	10	4	4	5	3	T
Zebrasoma scopas	-	2	-	-	-	-	25	4	-	-	6	M
Zebrasoma veliferum	-	-	-	-	-	2	-	-	-	-	-	M
Zanclidae (*Moorish idols*)												
Zanclus cornutus	-	-	-	-	+	12	2	1	6	6	4	M
Zanclus carnescens	-	-	-	-	-	-	40	20	-	-	-	M
Balistidae (*Triggerfishes*)												
Balistapus undulatus	1	-	-	-	-	-	12	8	-	-	5	M
Balistoides conspicillum	-	-	-	-	-	-	1	-	-	-	-	M
Balistoides viridescens	-	-	-	-	+	2	4	1	-	-	-	M
Melichthys indicus	-	-	-	-	-	25	-	-	-	-	-	M
Melichthys vidua	-	-	+	-	-		-	-	4	-	-	M
Odonus niger	-	-	+	-	-	25	-	-	52	35	40	M
Pseudobalistes flavimarginatus	-	-	-	-	-	1	-	-	-	-	1	M
Rhinecanthus verrucosus	-	-	-	-	-	15	-	-	-	-	2	M
Sufflamen chrysopterus	-	-	-	-	-	-	-	-	16	12	21	M

Appendix 2. Continue

Families and species	Measurement years											Group
	1991*		1994**			2001***			2006****			
	Sites		Sites			Sites			Sites			
	1	2	1	2	3	1	2	3	1	2	3	
Monacanthidae (*Filefishes*)												
Aluterus scriptus	-	-	-	-	-	-	-	1	-	-	-	M
Paraluteres prionurus	-	-	-	-	-	-	40	30	12	15	9	M
Ostraciidae (*Boxfishes*)												
Ostracion meleagris	-	-	-	-	-	2	10	-	-	-	-	M
Ostracion solorensis	-	2	-	-	+	-	-	-	1	1	-	M
Diodontidae (*Porcupinefishes*)												
Diodon histrix	-	-	-	-	-	-	1	-	-	-	-	M
Tetraodontidae (*Puffers*)												
Arothron nigropunctatus	-	-	-	-	-	1	10	2	-	-	1	M
Canthigaster compressa	-	-	-	-	-	1	-	2	20	15	-	M
Canthigaster solandri	-	-	-	-	-	-	6	-	2	-	1	M
Canthigaster valentini	3	-	-	+	+	1	5	4	-	-	-	M
Carangidae (*Trevallys*)												
Carangoides ferdau	-	-	-	-	-	-	6	2	-	-	-	T
Carangoides sp.	-	-	++	++	-	-	-	-	-	-	-	T
Caranx melampygus	-	-	-	-	-	12	-	-	1	-	-	T
Caranx sem	-	-	-	-	-	-	-	6	1	1	2	T
Caranx sp.	-	-	-	-	++	-	-	-	-	-	-	T
Chanidae												
Chanos chanos	-	-	-	-	-	-	-	-	-	-	15	T

Sources: * Wasilun *et al.* (1991); ** Edrus *et al.* (1996); *** Edrus (2002); **** Primary data
Remarks: - = absence; '+ = present; M = major fishes; T = target fishes; IF = indicator fishes