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Dynamics of fish diversity across an environmental gradient in the Seribu Islands reefs off Jakarta

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ABSTRACT

Madduppa HH, Subhan B, Suparyani E, Siregar AM, Arafat D, Tarigan SA, Alimuddin, Khairudi D, Rahmawati F, Bramandito A. 2013. Dynamics of fish diversity across an environmental gradient in the Seribu Islands reefs off Jakarta. Biodiversitas 14: 17-24. The reefs of Seribu Islands have been affected by multitude of anthropogenic pressures. However, the biodiversity of reef fishes across the archipelago linked to environmental condition is poorly known. This study aimed to investigate the biodiversity and the trophic level of fish communities across the archipelago. The study on reef fish communities was conducted on 33 reef sites associated with islands or shoal randomly chosen from each zone along environmental gradients from the inshore water nearest of Jakarta Bay to the offshore water of the outer islands. The study sites represented each sub-districts within the archipelago, namely Pari, Tidung, Panggang, Kelapa, and Harapan. A total of 46,263 individual fishes were counted, belonging to 216 species and 29 families. The multivariate analysis of fish abundance using the Bray Curtis similarity index and non-metric multidimensional scaling (MDS) clearly showed the clustering of sub-districts, near and far from Jakarta Bay. The results showed that the sub-districts can be clustered into three groups. Group one consists of one sub-district (Pari) located in the southern part of the Seribu Islands near Jakarta Bay. Group two consists of three sub-districts (Tidung, Panggang, Kelapa) located in mid of the archipelago. The third group consists of one sub-district (Harapan) located in the northern part of the Seribu Islands. Based on species richness and fish diversity indices, the sub-districts can be clustered into two groups (1 = Pari and Tidung, 2 = Panggang Kelapa, Harapan). However, levels of similarities among sub-districts varied. The fish community in sub-district of Pari was dominated by carnivorous, omnivorous and herbivorous fishes, while those in the rest of sub-districts were dominated by omnivorous and carnivorous fishes. The present study results showed that the biodiversity of reef fishes across the Seribu Islands seemed to be linked to the environmental conditions.

Key words: Fish-habitat association, species diversity, anthropogenic stress, multivariate analysis

INTRODUCTION

Coral reefs are heavily influenced by the human activities through pollution and habitat loss throughout the world (Burke et al. 2011), and sea level rise or the increase of ocean temperature due to the global change (Hughes et al. 2003). In Indonesia, marine communities have been impacted by an increase in eutrophication and sedimentation levels as shown in the waters of Jakarta Bay (Verstappen 1988; Marques et al. 1997; Renema 2008). As a result of increased sedimentation, nutrient loading, and chemical contamination, coral reefs became degraded (Rees et al. 1999; Williams et al. 2000). Furthermore, reef degradation could affect the coral reef fish communities due to their strong relationship.

The Seribu Islands (or Thousand Islands, Kepulauan Seribu), which consists of 110 islands spread from the Jakarta Bay to as far as 80 km to the north of the Java Sea, have been threatened by different kinds of anthropogenic pressures including coral mining, fishing, anchor damage, oil spills, resort construction and the discharge of industrial and domestic effluents (Rees et al. 1999; Rachello-Dolmen and Cleary 2007; Willoughby 1986; Uneputty and Evans 1997). In the 1980s, the archipleago reefs also experienced bleaching phenomenon due to ENSO (El Niño Southern Oscillation) resulting in the death of mainly branching species of the genera of *Acropora* and *Pocillopora* (Brown and Suharsono 1990).

Regions of the Seribu Islands are divided into three zones according to environmental gradient from the inshore water of Jakarta Bay to the offshore water of the outer islands (Hutomo and Adrim 1985). Since reef studies in 1920s, the reefs surrounding Onrust Island, located in Jakarta Bay, have been excluded from reef studies due to measurable anthropogenic influences (Zaneveld and Verstappen 1952). The environmental pressures on Jakarta Bay have increased until today and have been noted in several studies (e.g. Tomascik et al. 1997). A number of studies also show that reef coverage in Jakarta Bay is very low and shifts toward the Seribu Islands, as a result of diminishing human activities and pollution (Verstappen 1988; Cleary et al. 2006).

The gradient of environmental quallity has changed the marine biodiversity across Seribu Islands, such as sponges (de Voogd and Cleary 2008), mollusc (van der Meij et al. 2009) and corals (Cleary et al. 2006). Complexity of coral reefs and spatial variability affect the trophic structure of the fish community. For instance, the decrease of live corals has increased the coverage of algae which in turn gives benefit to Herbivoreous fishes (Madduppa et al. 2012). Therefore, the current study aimed to investigate the biodiversity dynamics and the trophic levels of fish communities across the archipelago.

MATERIALS AND METHODS

Study sites

The Seribu Islands Marine National Park has been declared as a National Reserve in 1982 (Uneputty and Evans 1997). Since 2006, the Seribu Islands is administratively divided into two districts (Estradivari et al. 2007). First, The District of North Seribu Islands which covers 79 islands within three sub-districts i.e. Kelapa (36 islands), Harapan (30), and Panggang (13). Second, The District of South Seribu Islands which is divided into three sub-

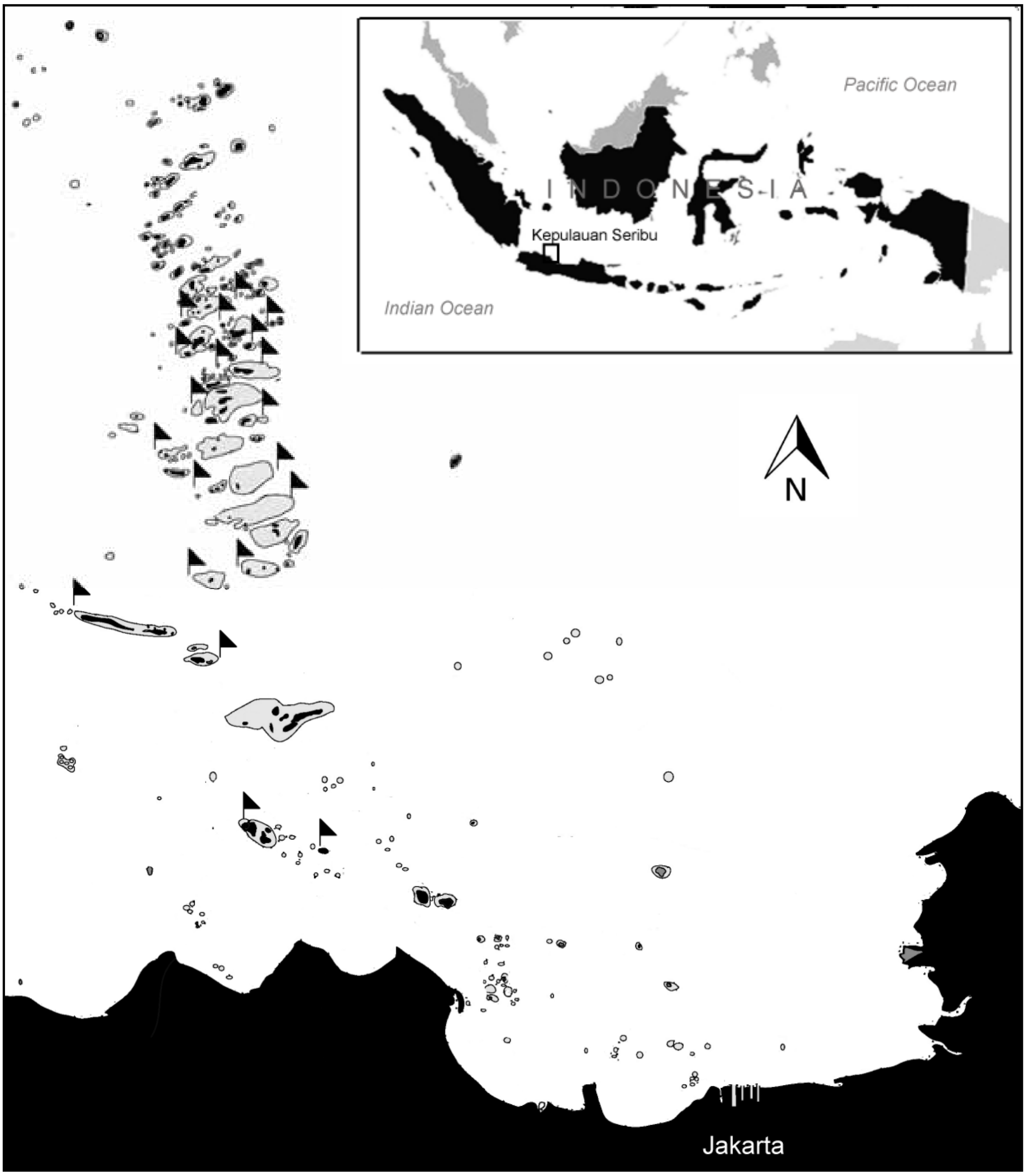

Figure 1. Location of the Seribu Islands, north of Jakarta, Java Island, Indonesia. The map at the upper right shows the position of Seribu Islands relative to Indonesia. The sampling sites indicated by flag.

districts covering 31 islands. The Seribu Islands Marine National Park which covers an area of 107.489 ha or approximately 20% of the total region. Two different seasons are affecting the Seribu Islands, namely ‘wet’ season (November-March) during the northwest monsoon, and ‘dry’ season (May-September) during the southeast monsoon (Rees et al. 1999). Figure 1 shows the study sites at Seribu Islands.

The study on reef fish communities was conducted at 33 reef sites associated with islands or shoal which were randomly chosen from each zone along environmental gradients from the inshore water nearest of Jakarta Bay to the offshore water of the outer islands and represented each sub-districts wihtin the archipelago, namely Pari (Lancang Is., Bokor Is.), Tidung (Tidung Besar Is., Payung Besar Is., Karang Beras), Panggang (Karang Bongkok, Gosong Air, Kotok Kecil Is., Karang Congkak, Sekati Is., Semak Daun Is., Air Barat Is., Kotok Besar Is.), Kelapa (Genteng Is., Jukung Is., Kaliage Besar Is., Kaliage Kecil Is., Kayu Angin Semut Is., Kelapa Is., Lipan Is., Malinjo Is., Matahari Is., Melintang Is., Satu Is., Semut Besar Is., Semut Timur Is.), and Harapan (Opak Besar Is., Opak Kecil Is., Sepa Besar Is., Sepa Kecil Is.). Two different depths (3 and 10 m) for each sampling site at reef slope were selected (English et al. 1997).

Data collection

Sampling was carried out at each site between 09.00 and 16.30, November 10-20, 2011 during a coral reef expedition by Marine Biology Laboratory, Bogor Agricultural University. Reef fish communities were assessed by underwater visual census (UVC) on a transect line of 50 meters at each depth (English et al. 1997). In an attempt to reduce daily variability of fish density data (caused by differences in nocturnal and diurnal behaviour), sampling excluded the high activity periods of early morning and late afternoon (Colton and Alevizon 1981; English et al. 1997). During each census, the observer waited for 5 to 10 minutes before beginning the data recording along the transect in order to allow the fishes to resume their normal behaviours (Brock 1982; Halford and Thompson 1994). Only individuals within 2.5 m on either side and 5 m above along the transect, were counted. Each individual (cryptic and large pelagic species were excluded) was counted and identified to species level. In order to avoid the influence of temporal recruitment events, fish recruits up to a size of ~3-5 cm were excluded from the count. After data collection, reef fish identification was confirmed by using standard fish identification books (i.e. Allen 2000; Kuiter 1992). The trophic level for each species was confirmed with the Fishbase (Froese and Pauly 2010).

Data analysis

The community Shannon-Wiener diversity index H’ was calculated on a natural logarithm (ln) basis (Magurran 1988; Shannon and Weaver 1949). Poisson regression analysis was used to test the statistical significance of differences in fish abundance among sites (sub districts), as well diversity and species richness, using statistical package STATISTICA 7.0.

Multivariate analysis of the fish community data were conducted using the program PRIMER 5.2.9 (Clarke and Gorley 2001; Kruskal 1964). Fish abundance, species richness, and species diversity data were fourth-root transformed prior to analysis to reduce the influence of some overlay abundant species and give more weight to rare species while retaining the information value of relative abundances, an approach frequently used in the multivariate analysis of community data (Clarke and Green 1988; Field et al. 1982).

Bray-Curtis similarity and Non-metric Multidimensional Scaling (MDS) were performed to visualize differences in fish communities from the different sites (Kruskal 1964; Shepard 1962). MDS was based on Bray-Curtis similarities, and 100 restarts were used for the calculations.

RESULTS AND DISCUSSION

A total of 46,263 individual fishes were counted, belonging to 216 species and 29 families (Table 1). A total of 49 and 78 fish species were recorded from sub-districts of Pari and Tidung, 109 and 148 from sub-districts of Panggang and Kelapa, and 106 from sub-district of Harapan. The values of species richness in this study were almost similar to that observed by Estradivari et al. (2007) in 2004-2005 in the Seribu Islands (211 species). In addition, the species richness of the Seribu Islands were also similar in range to those observed at other Indonesian coral reefs, such as Togean Islands and Weh Island (Allen and Werner 2002). The low species richness in the sub-districts of Seribu Islands near from Jakarta Bay (e.g. Pari and Tidung) might be related to the pressures on the environment such as bleaching resulting from the 1982/83 ENSO event (Brown and Suharsono 1990; Hoeksema 1991), and anthropogenic factors such as land-based contaminants, man-made objects, oil pollution, domestic and industrial refuse (Willoughby 1986; Uneputty and Evans 1997; Rees et al. 1999).

Table 1. Total number and trophic level of fish species at each subdistrict in the Seribu Islands

Family Species	Trophic	Pari	Tidung	Panggang	Kelapa	Harapan
Acanthuridae						
Acanthurus sp.	Herbivore	0	1	1	0	0
Ctenochaetus striatus	Omnivore	0	1	0	4	0
Apogonidae						
Apogon angustatus	Carnivore	0	0	0	7	0
Apogon apogonides	Carnivore	0	0	80	23	0
Apogon aureus	Carnivore	0	0	11	37	89
Apogon cavitienis	Carnivore	0	0	20	0	0
Apogon chrysopomus	Carnivore	0	13	0	0	0
Apogon compressus	Carnivore	2	20	331	293	192
Apogon novemfasciatus	Carnivore	0	0	24	0	43
Apogon sealei	Carnivore	20	0	0	0	0
Apogon semiornatus	Carnivore	0	0	17	0	2

Archamea fucata	Carnivore	0	0	3	0	0
Cheilodipterus artus	Carnivore	0	0	52	33	88
Cheilodipterus isostigmus	Carnivore	2	0	0	0	0
Cheilodipterus sp.	Carnivore	0	0	0	24	0
Sphaeramia nematoptera	Carnivore	0	0	0	22	0
Aulostomidae						
Aulostomus chinensis	Carnivore	0	0	0	3	0
Balistidae						
Balistoides sp.	Carnivore	0	1	0	0	0
Melichthys indicus	Omnivore	0	0	7	0	2
Caesionidae						
Caesio cuning	Planktivore	0	0	429	209	116
Caesio teres	Planktivore	0	260	372	906	475
Pterocaesio digramma	Carnivore	0	0	0	0	50
Pterocaesio tile	Planktivore	0	0	38	80	0
Centriscidae						
Aeoliscus strigatus	Carnivore	4	2	0	24	16
Chaetodontidae						
Chaetodon collare	Herbivore	1	0	0	0	0
Chaetodon meyeri	Herbiivore	0	0	5	5	0
Chaetodon octofasciatus	Coralivore	0	57	131	196	66
Chelmon rostratus	Coralivore	0	0	3	9	2
Chaetodon melanopus	Coralivore	0	0	0	0	2
Coradion trifasciatus	Coralivore	0	0	3	0	6
Heniochus chrysostomus	Coralivore	0	1	0	0	0
Heniochus pleurotaenia	Coralivore	0	3	2	0	4
Heniochus varius	Coralivore	0	0	11	7	1
Cirrhitidae						
Paracirrhites sp.	Carnivore	1	0	0	0	0
Dasyatidae						
Taeniura lymma	Carnivore	0	0	1	1	0
Echeneidae						
Remora sp.	Omnivore	2	0	0	0	0
Ephippidae						
Platax pinnatus	Omnivore	0	0	2	0	0
Platax teira	Omnivore	1	2	2	3	0
Gobiidae						
Exyrias belissimus	Omnivore	0	0	0	1	0
Istigobius decorates	Omnivore	0	0	7	8	1
Haemulidae						
Plectorhinchus chaetodontoides	Carnivore	0	0	0	2	0
Plectorhinchus chrysotaenia	Carnivore	0	0	8	0	0
Plectorhinchus vittatus	Carnivore	0	0	0	2	0
Hemirhamphidae						
Hemirhamphus far	Omnivore	0	0	1	0	0
Holocentridae						
Myripristis berndti	Carnivore	0	1	0	0	0
Myripristis sp.	Carnivore	0	0	0	5	0
Sargocentron diadema	Carnivore	0	0	20	0	0
Sargocentron rubrum	Carnivore	0	2	0	0	0
Sargocentron sp.	Carnivore	0	0	0	19	0
Sargocentron tiereoides	Carnivore	0	0	11	0	0
Labridae						
Anampses sp.	Carnivore	0	0	0	1	0
Bodianus mesothorax	Carnivore	1	6	19	27	24
Cheilinus chlorourus	Carnivore	0	0	0	7	0
Cheilinus diagramma	Carnivore	0	0	0	15	0
Cheilinus fasciatus	Carnivore	0	29	67	96	19
Cheilinus hortulanus	Carnivore	0	0	15	8	0
Cheilinus oxyrhynchus	Carnivore	0	0	0	6	0
Cheilinus trilobatus	Carnivore	0	0	0	3	0
Cheilinus unifasciatus	Carnivore	0	0	0	6	0
Choerodon anchorago	Carnivore	1	10	2	32	0
Choerodon fasciatus	Carnivore	0	0	4	25	23
Cirrhilabrus cyanopleura	Planktivore	400	1402	1930	3782	1770
Ctenochaetus striatus	Omnivore	0	0	7	0	0
Diproctacanthus xanthurus	Corallivore	1	16	2	27	52
Epibulus insidiator	Carnivore	0	1	0	6	0
Gomphosus varius	Carnivore	0	0	0	9	0
Halichoeres binotopsis	Carnivore	0	5	0	2	1
Halichoeres biocellatus	Carnivore	0	0	18	39	19
Halichoeres chloropterus	Carnivore	0	0	45	30	0
Halichoeres chrysotaenia	Carnivore	0	5	7	21	0
Halichoeres dussumieri	Omnivore	0	0	21	0	53
Halichoeres hortulanus	Carnivore	3	17	29	80	20
Halichoeres leucurus	Omnivore	4	13	45	58	39
Halichoeres marginatus	Omnivore	0	4	15	41	22
Halichoeres melanochir	Omnivore	0	0	28	48	5
Halichoeres melanurus	Omnivore	3	11	67	47	29
Halichoeres nigrescens	Carnivore	14	2	2	1	0
Halichoeres ornatissimus	Carnivore	0	0	12	30	0
Halichoeres richmondi	Carnivore	0	9	28	22	11
Halichoeres scapularis	Carnivore	1	0	0	0	0
Halichoeres sp.	Omnivore	6	8	74	8	1
Halichoeres vrolikii	Omnivore	5	0	0	1	0
Hemigymnus melapterus	Carnivore	3	4	10	26	4
Labroides chrysotaenia	Omnivore	0	0	0	0	2
Labroides dimidiatus	Carnivore	6	16	44	61	27
Macropharyngodon negrosensis	Omnivore	0	0	2	7	8
Neoglyphidodon melas	Omnivore	0	0	0	0	0
Pseudocheilinus hexataenia	Omnivore	0	0	5	7	11
Pseudojuloides cerasinus	Omnivore	0	0	18	0	18
Pteragogus amboinensis	Omnivore	0	0	0	0	22
Stethojulis trilineata	Omnivore	0	11	0	0	3
Thalassoma lunare	Omnivore	24	78	132	195	45
Thalassoma lutescens	Omnivore	0	2	0	0	5
Thalassoma purpureum	Carnivore	0	0	11	7	22
Thalassoma quinquevittatum	Carnivore	0	0	16	0	19
Lethrinidae						
Lethrinus erythropterus	Carnivore	0	0	0	12	0
Lutjanidae						
Lutjanus biguttatus	Carnivore	0	2	4	26	0
Lutjanus decussatus	Carnivore	0	6	25	25	3
Lutjanus kasmira	Omnivore	0	0	0	6	0
Lutjanus russellii	Carnivore	0	0	0	4	0
Mullidae						
Parupeneus barberinus	Carnivore	0	0	0	5	0
Muraenidae						
Gymnothorax javanicus	Carnivore	0	0	0	1	0
Nemipteridae						
Pentapodus caninus	Carnivore	0	0	46	28	28
Pentapodus sp.	Carnivore	0	0	0	1	0
Pentapodus vitta	Carnivore	0	0	0	18	0
Scolopsis bilineatus	Carnivore	3	22	29	50	17
Scolopsis ciliatus	Carnivore	0	3	0	9	0
Scolopsis lineatus	Carnivore	0	0	17	14	17
Scolopsis margaritifer	Carnivore	0	6	0	41	0
Scolopsis sp.	Carnivore	0	0	0	4	0
Scolopsis temporalis	Carnivore	1	0	0	0	0
Scolopsis trilineatus	Carnivore	1	0	0	26	12
Pempheridae						
Pempheris oualensis	Carnivore	0	0	0	15	36
Pempheris sp.	Carnivore	50	0	0	0	0
Pomacanthidae						
Centropyge vrolikii	Herbivore	0	1	0	0	0
Chaetodontoplus mesoleucus	Herbivore	0	19	57	199	69
Pomacanthus sextriatus	Herbivore	0	0	2	0	0
Pomacentridae						
Abudefduf bengalensis	Omnivore	0	0	0	91	25
Abudefduf curacao	Omnivore	0	0	0	18	0
Abudefduf septemfasciatus	Omnivore	3	0	19	0	0
Abudefduf sexfasciatus	Omnivore	0	111	107	204	121
Abudefduf sordidus	Omnivore	0	0	49	0	0
Abudefduf vaigiensis	Omnivore	0	94	119	139	61
Acanthochromis polyancanthus	Omnivore	0	0	0	11	13
Amblyglyphidodon aureus	Omnivore	0	2	0	25	2
Amblyglyphidodon batunai	Omnivore	0	0	49	79	87
Amblyglyphidodon curacao	Omnivore	20	114	519	560	451
Amblyglyphidodon leucogaster	Omnivore	0	16	226	342	163
Amblyglyphidodon nigroris	Omnivore	0	39	0	0	0
Amphiprion akallopisos	Omnivore	2	0	2	12	0
Amphiprion akindinos	Omnivore	0	0	0	0	5
Amphiprion clarkii	Omnivore	0	0	0	3	3
Amphiprion ocellaris	Omnivore	0	0	0	0	6
Amphiprion perideraion	Omnivore	0	0	0	0	2
Amphiprion sandaricinos	Omnivore	0	0	0	0	4
Cheiloprion labiatus	Omnivore	0	0	0	3	0
Chlororus sordidus	Omnivore	0	0	0	2	0
Chromis amboinensis	Omnivore	0	90	50	93	94
Chromis atripectoralis	Omnivore	0	39	708	500	878

Chromis fumea	Planktivore	80	0	0	50	303
Chromis nitida	Omnivore	0	0	0	5	0
Chromis scotochilopterus	Planktivore	0	0	24	0	34
Chromis smithi	Omnivore	0	0	0	17	0
Chromis ternatensis	Planktivore	14	52	2	926	712
Chromis viridis	Omnivore	0	142	159	372	177
Chromis xanthura	Planktivore	0	0	69	78	70
Chrysiptera cyanea	Omnivore	0	0	10	0	0
Chrysiptera hemicyanea	Omnivore	0	0	21	21	9
Chrysiptera parasema	Planktivore	0	0	30	22	32
Chrysiptera sp.	Omnivore	6	0	0	0	0
Dascyllus melanurus	Omnivore	0	0	0	1	0
Dascyllus reticulatus	Omnivore	0	0	0	1	0
Dascyllus trimaculatus	Omnivore	0	1	0	80	10
Diproctacanthus xanthurus	Corallivore	0	1	0	2	0
Dischistodus melanotus	Herbivore	0	0	47	48	35
Dischistodus perspicillatus	Herbivore	0	0	0	10	0
Dischistodus prosopotaenia	Herbivore	0	24	64	101	32
Hemiglyphidodon plagiometopon	Herbivore	0	0	3	24	5
Neoglyphidodon bonang	Omnivore	0	0	2	0	0
Neoglyphidodon crossi	Omnivore	0	25	167	58	94
Neoglyphidodon leucogaster	Carnivore	0	25	0	0	0
Neoglyphidodon melas	Omnivore	2	19	27	111	117
Neoglyphidodon nigroris	Omnivore	3	18	37	129	17
Neoglyphidodon thoracotaeniatus	Omnivore	0	0	0	88	0
Neopomacentrus anabatoides	Planktivore	0	0	0	38	0
Neopomacentrus bankieri	Carnivore	0	0	0	0	20
Neopomacentrus cyanomos	Carnivore	0	0	0	156	0
Neopomacentrus filamentosus	Planktivore	0	0	120	178	71
Pomacentrus alexanderae	Omnivore	1	1338	2320	4058	1335
Pomacentrus amboinensis	Omnivore	0	0	0	57	0
Pomacentrus brachialis	Omnivore	6	0	0	0	0
Pomacentrus burroughi	Herbivore	1	22	23	77	5
Pomacentrus coelestis	Omnivore	0	0	56	0	12
Pomacentrus cuneatus	Omnivore	7	0	0	0	0
Pomacentrus javanicus	Omnivore	0	14	0	0	0
Pomacentrus lepidogenys	Planktivore	13	33	33	514	98
Pomacentrus littoralis	Omnivore	0	18	0	0	0
Pomacentrus milleri	Omnivore	5	14	0	56	11
Pomacentrus moluccensis	Omnivore	5	306	378	297	103
Pomacentrus simsiang	Omnivore	0	0	0	16	0
Pomacentrus smithi	Omnivore	50	657	775	2760	239
Pomacentrus sp.	Omnivore	5	1	0	9	2
Pomacentrus xanthosternus	Omnivore	0	12	0	0	0
Premnas biaculatus	Omnivore	1	0	0	2	0
Pristotis obtusirostris	Omnivore	0	0	18	0	23
Scaridae						
Chlorurus bleekeri	Herbivore	0	0	1	18	0
Chlorurus microrhinos	Herbivore	0	0	8	29	0
Chlorurus sordidus	Omnivore	0	9	33	107	39
Scarus chameleon	Herbivore	0	0	0	0	4
Scarus dimidiatus	Herbivore	0	0	6	0	21
Scarus flavipectoralis	Herbivore	0	0	6	0	18
Scarus frenatus	Herbivore	0	0	5	0	10
Scarus ghobban	Herbivore	0	0	2	17	1
Scarus globiceps	Herbivore	0	2	5	7	18
Scarus niger	Herbivore	2	7	27	37	5
Scarus quoyi	Herbivore	0	8	8	8	0
Scarus rivulatus	Herbivore	0	42	17	35	13
Scarus sordidus	Herbivore	0	0	0	5	0
Scarus sp.	Herbivore	2	26	0	11	1
Scarus xanthopleura	Herbivore	0	0	0	5	0
Scorpaenidae						
Pterois volitans	Carnivore	0	0	0	1	0
Serranidae						
Cephalopholis argus	Carnivore	0	0	0	26	0
Cephalopholis boenak	Carnivore	4	1	0	13	0
Cephalopholis microprion	Carnivore	1	4	4	16	2
Cephalopholis sp.	Carnivore	1	0	0	1	0
Diploprion bifasciatum	Carnivore	0	1	0	0	0
Epinephelus fasciatus	Carnivore	0	0	0	1	0
Epinephelus merra	Carnivore	0	0	0	2	0
Epinephelus rivulatus	Carnivore	0	0	7	6	6
Epinephelus sexfasciatus	Carnivore	0	0	5	1	4
Siganidae						
Siganus argenteus	Herbivore	0	0	0	0	1
Siganus canaliculatus	Herbivore	0	7	0	0	0
Siganus guttatus	Herbivore	0	0	0	12	0
Siganus virgatus	Herbivore	0	3	0	16	0
Siganus vulpinus	Herbivore	0	3	0	0	0
Zanclidae						
Zanclus cornotus	Herbivore	0	0	0	2	0

The composition of the five most diverse fish families that were observed in all sub-districts are given in Table 2. The most abundant families at sub district of Pari were Labridae (wrasses), followed by Pomacentridae (dam-selfishes). The most abundant families at the rest sub-districts were Pomacentridae (damselfishes), followed by the Labridae (wrasses). Overall, the most diverse families in the reef community were Pomacentridae and Labridae. This pattern was also observed in the previous study at the islands (Estradivari et al. 2007), and at other locations in Indonesia (Ferse 2008).

Table 2 The composition of the 5 most diverse fish families (%)observed in all sub-districts

Family	Pari	Tidung	Panggang	Kelapa	Harapan
Apogonidae	3.0	-	5.0	2.2	4.5
Caesionidae	-	4.8	7.8	6.0	6.4
Chaetodontidae	-	1.1	1.4	-	-
Labridae	59.8	30.5	24.7	23.9	24.8
Nemipteridae	0.6	-	-	-	-
Pempheridae	6.3	-	-	-	-
Pomacentridae	28.4	59.6	57.6	62.2	59.7
Scaridae	-	1.7	-	1.4	1.4

The Shannon-Wiener diversity indices of the fish communities, the average species richness and the average fish abundance are shown in Figure 2. The sub-district Pari as the nearest to Jakarta Bay, had the lowest fish abundance, species richness, fish diversity, while the sub-district Harapan as the outlier islands had the highest ones. The fish abundance ranged from 265 ± 140 (sub-district of Pari) to 1154 ± 208 ind/250m^2 (sub-district of Harapan). Similar patterns were also found for the diversity indices (H') which ranged between 1.8 ± 0.15 (Pari) and 2.5 ± 0.17 (Harapan), and for the species richness which ranged from 20 ± 7 (Pari) to 36 ± 5 species/250m^2 (Harapan) over the entire study period. The pattern showed that values on the fish abundance, diversity index and species richness increase toward north of Seribu Islands. The high abundance and species richness might be related to live coral coverage. The nearest region to Jakarta Bay has lowest live coral coverage and the live coral coverage increase toward to the north of the islands (Estradivari et al. 2007). In the present study, the sub-district's reefs did have a significant influence on fish abundance and species richness, but not for diversity index (Table 3). Multiple studies have reported a positive correlation with the structural complexity of a coral reef habitat for fish abundance (e.g. Walker et al. 2009), species richness (e.g. Wilson et al. 2007), and species diversity (e.g. Öhman and Rajasuriya 1998).

Table 3 Results of Poisson regression for abundance, species richness, and diversity of fish assemblages (*<0.001, *n.s.* not significant)

Variable	Factor	df	W.S	p	
Abundance	Site	4	1868.0	0.00	*
Species richness	Site	4	21.083	0.00	*
Shannon-Wiener index (H')	Site	4	0.50872	0.97	n.s

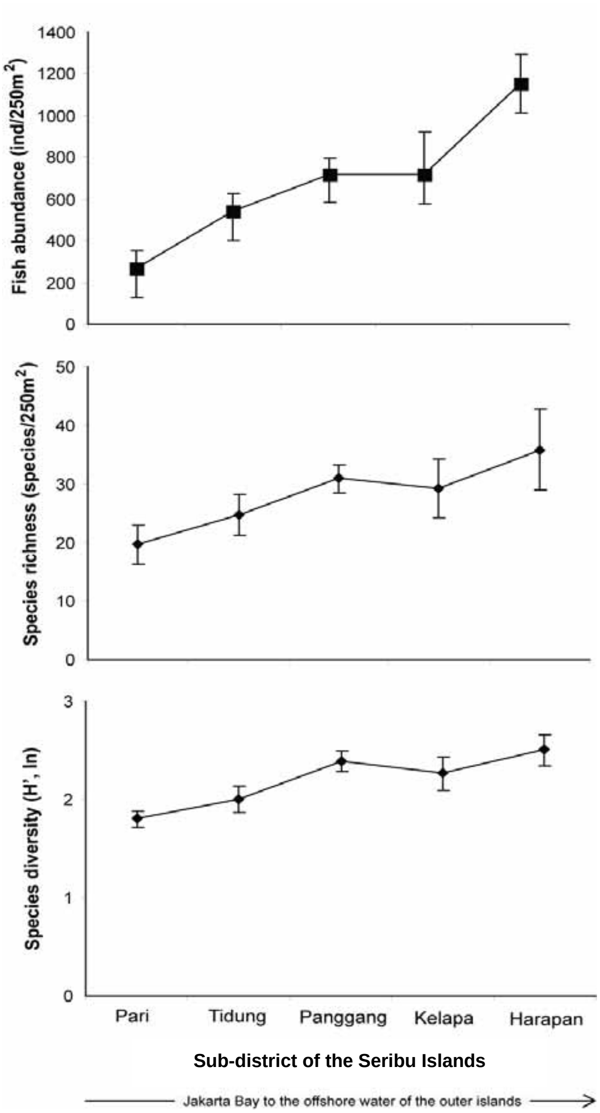

Figure 2. The average values of (a) fish abundance, (b) species richness, and (c) species diversity (Shannon-Wiener Index; ln basis) of fish assemblages at the sampling sites. The arrow shows the direction from Jakarta Bay to the offshore water of the outer islands.

Besides being used as a territory (Waldner and Robertson 1980; Patton 1994), coral reefs are source of food for fishes (Reese 1981). The percentage of trophic level of total fish species at each sub-districts is shown in Figure 3. The trophic level of species at each sub-district varied. The fish community in sub-district of Pari was dominated by carnivorous, omnivorous and herbivorous fishes, while those in the rest sub-districts were dominated by omnivorous and carnivorous fishes. Even though there is a strong correlation between coral and fish, only few of the species found in a coral reef ecosystem depend specifically on scleractinian corals (Munday et al. 2007). A study indicated that the fish communities were likely not structured by habitat-mediated factors such as predation impact or available space, but different factors such as recruitment or migration were playing a stronger role (Madduppa et al. 2012). However, no significant differences in diversity indices were found among the sub-districts (Table 3). This might be explained by feeding specialization among coral fishes. The specialization in food can reduce competition within a reef (Gladfelter and Johnson 1983; Ross 1986), and increase species diversity. A study found that some species such as scarids appeared in only specific habitat which had the lowest amount of live coral but the highest amount of dead coral and algae (Madduppa et al. 2012). Other species such as Chaetodonts have been observed to appear on high percentage of live coral which they use for food or shelter (Cox 1994).

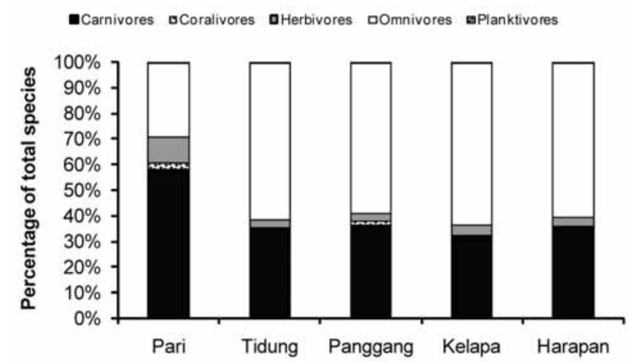

Figure 3. Distribution and mean composition of reef fish per sub districts at Seribu Islands based on trophic categories

The multivariate analysis of fish abundance, species richness and fish diversity were done using the Bray Curtis similarity index and non-metric multidimensional scaling (MDS). The MDS plot and Bray-Curtis similarity have distinctly clustered the sub-districts from southern and toward north of the Seribu Islands based on fish abundance, species richness and fish diversity. The results showed that the sub-districts can be clustered into 3 groups based on fish abundance, with 0 stress value (Figure 4). Group one consists of one sub-district (Pari) located in the southern part of the Seribu Islands near Jakarta Bay. Group two consists of three sub-districts (Tidung, Panggang, and Kelapa) located in mid of the archipelago. The third group consists of one sub-district (Harapan) located in the northern part of the Seribu Islands. The species richness and fish diversity indices showed that the sub-districts can be clustered into two groups (1=Pari and Tidung, 2= Panggang Kelapa, Harapan). These figures showed that the islands within archipelago seemed to be linked to the environmental factors such sedimentation, pollution and other human activities in Jakarta Bay and Seribu Islands (Rees et al. 1999; Rachello-Dolmen and Cleary 2007; Willoughby 1986).

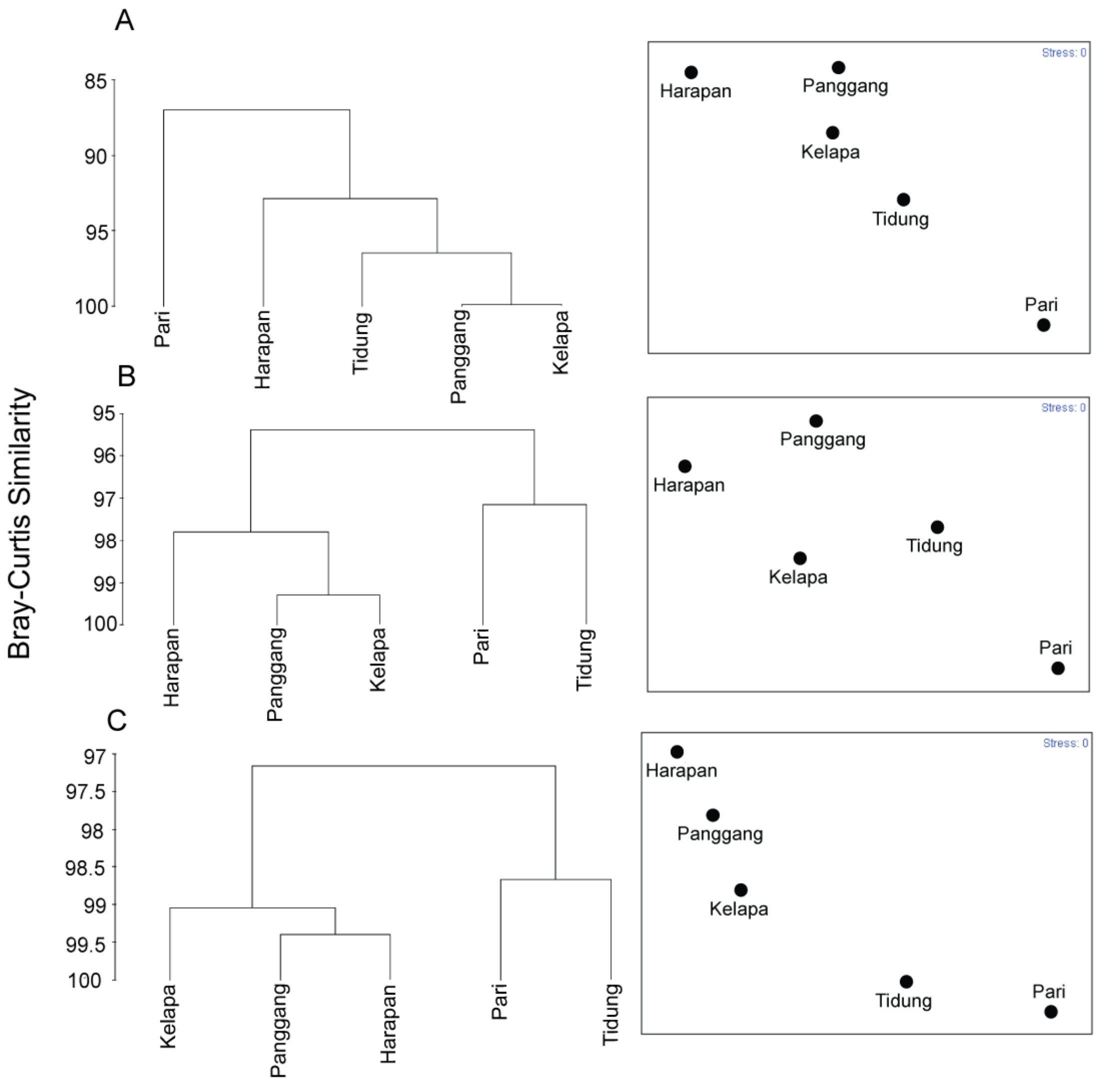

Figure 4. Dendogram based on Bray-curtis similarity (left) and MDS plot (right) of fish communities at the Seribu Islands, showing pattern of association among 216 species based on abundance (a), species richness (b) and fish diversity (c)

CONCLUSION

Altogether, in spite of low replicate of transects in each studied reefs, the present study results showed that the biodiversity of reef fishes across the Seribu Islands seems to be linked to environmental condition such as turbidity and level of pollution from Jakarta Bay toward the northern of the islands. Further studies of reef fish communities and habitat characteristics throughout the region are needed to document environmental changes over time.

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REFERENCES

Allen GR. 2000. Marine fishes of South-East Asia. Periplus Editions (HK) Ltd, Singapore.

Allen GR, Werner TB. 2002. Coral Reef Fish Assessment in the ‘Coral Triangle’ of Southeastern Asia. Environ Biol Fish 65: 209-214.

Brock RE. 1982. A critique of the visual census method for assessing coral reef fish populations. Bul Mar Sci 32: 269-276.

Brown BE, Suharsono. 1990. Damage and recovery of coral reefs affected by El Niño related seawater warming in the Thousand Islands, Indonesia. Coral reefs 8: 163-170.

Burke L, Reytar K, Spalding M, Perry A. 2011. Reefs at Risk Revisited. World Resources Institute (WRI), Washington DC.

Clarke KR, Gorley NR. 2001. PRIMER v5: Unser manual/tutorial. PRIMER-E Ltd., Plymouth.

Clarke KR, Green RH. 1988. Statistical design and analysis for a ‘biological effects’ study. Mar Ecol Prog Ser 46: 213-226.

Cleary DFR, Suharsono, Hoeksema BW. 2006). Coral diversity across a disturbance gradient in the Pulau Seribu reef complex off Jakarta, Indonesia. Biodiversity and Conservation. 15: 3653-3674.

Colton DE, Alevizon WS. 1981. Diurnal variability in a fish assemblage of a Bahamian coral reef. Environ Biol Fish 6: 341-345.

Cox EF. 1994. Resource use by Corallivorous Butterflyfishes (Family Chaetodontidae) in Hawaii. Bull Mar Sci 54: 535-545.

de Voogd NJ, Cleary DFR. 2008. An analysis of sponge diversity and distribution at three taxonomic levels in the Thousand Islands⁄Jakarta Bay reef complex,West-Java, Indonesia. Mar Ecol 29: 205-215

English S, Wilkinson C, Baker V. 1997. Survey manual for tropical marine resources. Australian Institute of Marine Science (AIMS), Townsville.

Estradivari, Syahrir M, Susilo N, Yusri S, Timotius S. 2007. Coral Reef Jakarta: long-term observations of coral reefs Seribu Islands (2005-2007). Yayasan TERANGI, Jakarta. [Indonesian].

Ferse SCA. 2008. Artificial reef structures and coral transplantation: fish community responses and effects on coral recruitment in North Sulawesi/Indonesia. [Dissertation]. University of Bremen, Bremen, Germany.

Field JG, Clarke KR, Warwick RM. 1982. A practical strategy for analysing multispecies distribution patterns. Mar Ecol Prog Ser 8: 37-52.

Froese R, Pauly D. 2010. FishBase. World Wide Web electronic publication. www.fishbase.org

Gladfelter WB, Ogden JC, Gladfelter EH. 1980. Similarity and Diversity Among Coral Reef Fish Communities: A comparison between Tropical Western Atlantic (Virgin Islands) and Tropical Central Pacific (Marshall Islands) Patch Reefs. Ecology 61: 1156-1168.

Halford AR, Thompson AA. 1994. Visual census surveys of reef fish. Long-term monitoring of the Great Barrier Reef. Australian Institute of Marine Science (AIMS), Townsville.

Hoeksema BW. 1991. Control of bleaching in mushroom coral populations (Scleractinia: Fungiidae) in the Java Sea: stress tolerance and interference by life history strategy. Mar Ecol Prog Ser 74: 225-237.

Hughes TP, Baird AH, Bellwood DR, Card M, Connolly SR, Folke C, Grosberg R, Hoegh-Guldberg O, Jackson JBC, Kleypas J, Lough JM, Marshall P, Nystrom M, Palumbi SR, Pandolfi JM, Rosen B, Roughgarden J. 2003. Climate change, human impacts, and the resilience of coral reefs. Science 301: 929-933.

Hutomo M, Adrim M. 1985. Distribution of reef fish along transects in Bay of Jakarta and Kepulauan Seribu. In: Human induced damaged to coral reefs. Unesco Reports in Mar. Sci. 40: 135-156.

Kruskal JB. 1964. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. Psychometrika 29: 1-27.

Kuiter RH. 1992. Tropical reef-fishes of the Western Pacific, Indonesia and adajacent waters. Gramedia, Jakarta.

Madduppa HH, Ferse SCA, Aktani U, Palm HW. 2012. Seasonal trends and fish-habitat associations around Pari Island, Indonesia: setting a baseline for environmental monitoring. Environ Biol Fish 95:383-398.

Magurran AE. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton.

Marques JC, Pardal MÂ, Nielsen SN, Jørgensen SE. 1997. Analysis of the properties of energy and biodiversity along an estuarine gradient of eutrophication. Ecol Modell 102, 155-167.

Munday PL, Jones GP, Sheaves M, Williams AJ, Goby G. 2007. Vulnerability of fishes on the Great Barrier Reef to climate change. In: Johnson J, Marshall P (eds) Climate change and the Great Barrier Reef. Great Barrier Reef Marine Park Authority, Townsville.

Öhman MC, Rajasuriya A. 1998. Relationships between habitat structure and fish communities on coral. Environ Biol Fish 53: 19-31.

Patton WK. 1994. Distribution and ecology of animals associated with branching corals (Acropora spp.) from the Great Barrier Reef, Australia. Bul Mar Sci 55:193-211

Rachello-Dolmen PG, Cleary DFR. 2007. Relating coral traits to environmental conditions in the Jakarta Bay⁄Pulau Seribu reef complex, Indonesia. Estuar Coast Shelf Sci 73: 816-826.

Rees JG, Setiapermana D, Sharp VA, Weeks JM, Williams TM. 1999. Evaluation of the impacts of land-based contaminants on the benthic faunas of Jakarta Bay, Indonesia. Oceanologica Acta 22: 627-640.

Renema W. 2008. Habitat selective factors influencing the distribution of larger benthic foraminiferal assemblages over the Kepulauan Seribu. Mar Micropaleontol 68: 286-298.

Ross ST. 1986. Resource partitioning in fish assemblages: a review of field studies. Copeia 1986:352-388

Shannon CE, Weaver W. 1949. The mathematical theory of communication. University of Illinois Press, Urbana.

Shepard R. 1962. The analysis of proximities: multidimensional scaling with an unknown distance function. II. Psychometrika 27: 219-246.

Tomascik T, Mah A J, Nontji A, Moosa MK. 1997. The Ecology of the Indonesian Seas, Part One and Two. Periplus, Hongkong.

Uneputty PA, Evans SM. 1997. Accumulation of beach litter on Islands of the Kepulauan Seribu Archipelago, Indonesia. Mar Poll Bull 34 (8): 652-655.

van der Meij SET, Moolenbeek RG, Hoeksema BW. 2009. Decline of the Jakarta Bay molluscan fauna linked to human impact. Mar Poll Bull 59: 101-107.

Verstappen HTh. 1988. Old and new observations on coastal changes of Jakarta Bay: an example of trends in urban stress on coastal environments. J Coast Res 4 (4): 573-587.

Waldner RE, Robertson DR. 1980. Patterns of habitat partitioning by eight species of territorial Caribbean damselfishes (Pisces: Pomacentridae). Bul Mar Sci 30:171-186

Walker BK, Jordan LKB, Spieler RE. 2009. Relationship of Reef Fish Assemblages and Topographic Complexity on Southeastern Florida Coral Reef Habitats. J Coast Res 39-48.

Williams TM, Rees JG, Setiapermana D. 2000. Metals and trace organic compounds in sediments and waters of Jakarta Bay and the Pulau Seribu Complex, Indonesia. Mar Poll Bull 40 (3): 277-285.

Willoughby NG. 1986. Man-made litter on the shores of the Thousand Island Archipelago, Java. Mar Poll Bull 17: 224-228.

Wilson S, Graham N, Polunin N. 2007. Appraisal of visual assessments of habitat complexity and benthic composition on coral reefs. Mar Biol 151: 1069-1076.

Zaneveld JS, Verstappen HTH. 1952. A recent investigation about the geomorphology and the flora of some coral islands in the Bay of Djakarta. J Sci Res 3: 58-68.