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First Insight on the Fish Species Composition at Two Artificial Reef Areas, Narathiwat Province, Thailand

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Abstract. In 2010 hundreds of unused vehicles were sunk off the coast of Narathiwat province, Southern Gulf of Thailand, to serve as artificial reefs for new fishing grounds. Our goal was to list and analyze the species composition of reef fish in two different artificial reef areas. Census were performed in four tanks and three train wagons, abundance of each species per structure were recorded. An intensive search was posteriorly performed in order to identify and record different species present in the habitats. A total of 53 species were found, from 21 different families; in which the richest were snappers (7), damselfishes (4) and wrasses (4). Dominant species was *Neopomacentrus cyanomos* in both areas, but only the tanks held large fish aggregations. Diversity index was slightly higher in wagons (*H*=1.45), but no significant difference was found between areas. Higher complexity attracts a greater number of small cryptic and gregarious fishes to the tanks; however, their dominance lowered the diversity in the area. Although a smaller number of directly associated taxa, wagons had more species hovering around its surroundings, probably due to the low physical complexity but wider occupied area. Artificial reefs of Narathiwat hold a typical reef fish community and may act as a shelter for those species, including economical important groups like the snappers, and endangered species like the humphead parrotfish.

Keywords: Reef Fish, Community, Gulf of Thailand, Species list.

1. Introduction

The use of artificial reefs (ARs) is an important strategy for reef conservation nowadays. Often adopted to build new substrate for species colonization, either to lower the impacts of touristic activities over natural coral reefs or to increase fish biomass and diversity at local scales for fisheries purposes (Carr and Hixon 1997; Grossman et al. 1997; Harris 2009). Those structures have been used in Thai waters since 1978, the main goal being to increase fish stocks, especially for small scale fisheries (Phongsuwan et al. 1994; Satapoomin, 1994). In a recent project conducted in 2010 hundreds of structures were deployed off the shore of Narathiwat province, in the South of Thailand, being 25 tanks, 273 train wagons and 198 garbage trucks, expecting to improve fish productivity for local fisheries.

The aim of this study was to create a preliminary list of reef fish species that colonized the station after 9 years, focusing on two of the three types of structures, train wagons and tanks, and to briefly describe differences of abundance and species composition between tanks and wagons.

2. Materials and Methods

2.1 Study area

The surveyed station is located at approximately 9km off the coast of Narathiwat province, in the southwest of the Gulf of Thailand, where structures were deployed at around 6° 29’ N, 101° 55’ W (Figure 1). The artificial reefs are scattered in a matrix of sand, at depths of 22m to 23m. During the surveys, horizontal visibility was approximately 10m. Tanks dimensions are 6m length (excluding the cannon), 3.2 m width and 2m tall, thus occupying a volume close to 38.4m³, while wagons measures are 6.5*x*2.2*x*2.2m, occupying around 31.5m³ (). A and B respectively). Both areas comprise the same station since they are approximately 50m apart, and at some points divers can swim between tanks and wagons.

2.2 Census methods

Surveys comprised tanks and train wagons' areas, each being treated as a different group. Visual censuses were conducted at four different tanks and three different wagons by one surveyor, following the same method at every object: the census started at the top, followed by a full swim around the object, then the inside area (and below in the case of tanks) was surveyed. Each object was treated as an independent replica, where fish were identified and abundances were estimated as specimen per volume, considering all fishes directly occupying the structure or interacting with it at a maximum distance of half a meter horizontally and one meter above the object (what later accounted for the density calculations). Following the abundance censuses, intensive search was conducted in both areas, were the diver swam freely, registering any species not sighted previously, until the time limit for the working depth was reached (approximately 15 minutes). Fish were identified to species level *in situ*, and dubious taxa were later double checked with the aid of photographs and identification books (Allen et al 2012; Lieske & Myers 2001). Classification of taxa followed Nelson et al. (2016).

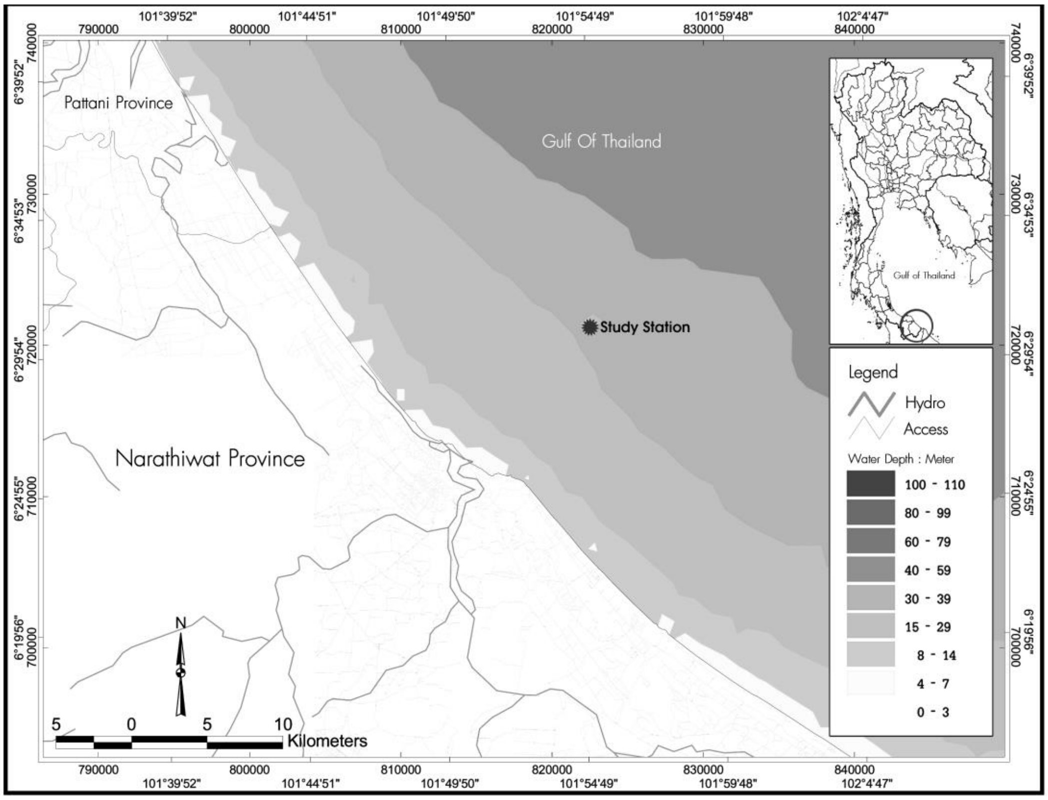

Figure 1. Geographical position of the study station in the South West Gulf of Thailand

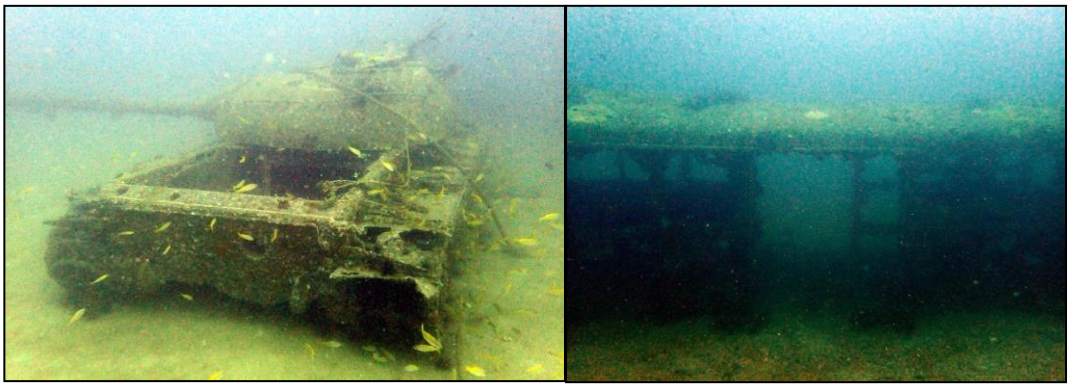

Figure 2. Photographies of the surveyed ARs. A: Tank; B: Wago

2.3 Data analysis

Data was compiled in digital worksheets and analyzed in R Software for Statistical Analysis. The non-parametric Wilcoxon *U* test was performed to try for differences in distribution between tanks and wagons. Lastly, indices of "true diversity" were calculated on Vegetarian package, (*sensu* Jost 2006), separately for tanks and wagons as well as for the whole community, following Hill numbers of effective species (^{q}D) (Hill 1973), with q = 1, equivalent to Shannon's entropy.

3. Results

We registered 53 fish species in total, grouped in 21 different families. Thirty-two species were recorded during tanks' census (μ = 15.25±3.3 spp/census) and 25 found amidst the trains (μ = 14.7±2.9 spp/census), while 13 more were registered during intensive search. In total, 17 species were shared between areas (tanks and wagons). Lutjanidae was the richest family with 7 species, followed by Apogonidae and Pomacentridae with 5 species each, joined by Labridae and Caesionidae (4 each), these five families account for almost half of the total richness.

Figure 3. Individual of *Dendrochirus zebra* registered sheltering in a tank.

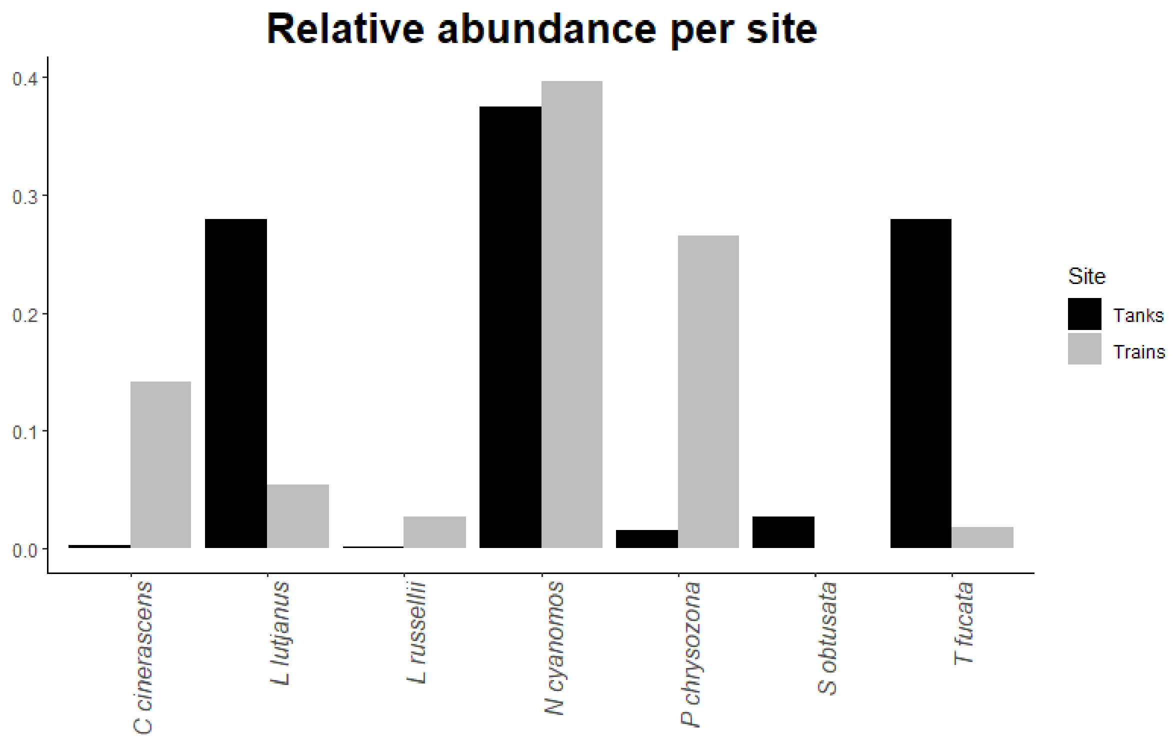

Figure 4. Relative abundance of the five most dominant species in tanks (*Neopomacentrus cyanomos*, *Lutjanus lutjanus*, *Taeniamia fucata*, *Sphyraena obtusata* and *Pterocaesio chrysozona*), and trains, (*Neopomacentrus cyanomos*, *Pterocaesio chrysozona*, *Chromis cinerascens*, *Lutjanus lutjanus* and *Lutjanus russellii*)

Table 1. List of recorded species and their density per 100m³ at each surveyed area. Species recorded during intensive search (I.S.), are indicated in a separated column (TR represents trains and TA tanks). Families are arranged in evolutive order according to Nelson et al. (2016).

FAMILY	SPECIES	Tanks	Trains	I.S.
Holocentridae	*Sargocentron rubrum* (Forsskål, 1775)	0	0.43	
Apogonidae	*Cheilodipterus macrodon* (Lacepède, 1802)	0.28	0	
	Ostorhinchus cyanosoma (Bleeker, 1853)	1.98	0.43	
	Ostorhinchus endekataenia (Bleeker, 1852)	0.57	0	
	Taeniamia fucata (Cantor, 1849)	595.24	8.68	
	Taeniamia zosterophora (Bleeker, 1856)	2.83	0	
Gobiidae	*Valenciennea puellaris* (Tomiyama, 1956)	1.13	0	
Pomacentridae	*Abudefduf vaigiensis* (Quoy & Gaimard, 1825)	-	-	TR
	Amphiprion clarkii (Bennet, 1830)	-	-	TR
	Chromis cinerascens (Cuvier, 1830)	7.09	69.44	
	Neopomacentrus cyanomos (Bleeker, 1856)	575.40	195.31	
	Pomacentrus cuneatus Allen, 1991	0	1.30	
Carangidae	*Alectis ciliaris* (Bloch, 1787)	-	-	TA
	Carangoides ferdau (Forsskål, 1775)	-	-	TR
	Selaroides leptolepis (Cuvier, 1833)	14.17	0	
Sphyraenidae	*Sphyraena obtusata* Cuvier, 1829	56.69	0	
Labridae	*Halichoeres nigrescens* (Bloch & Schneider, 1801)	0.57	0.43	
	Halichoeres scapularis (Bennett, 1832)	0.28	0	
	Labroides dimidiatus (Valenciennes, 1839)	2.27	2.60	
	Thalassoma lunare (Linnaeus, 1758)	1.98	6.94	
Scaridae	*Bolbometopon muricatum* (Valenciennes, 1840)	0	0.43	
	Scarus ghobban Forsskål, 1775	-	-	TR
Serranidae	*Cephalopholis boenak* (Bloch, 1790)	2.27	0.87	
	Cephalopholis formosa (Shaw, 1812)	0.57	1.30	
	Diploprion bifasciatum Cuvier, 1828	0	2.17	
Chaetodontidae	*Coradion chrysozonus* (Cuvier, 1831)	0.28	0	
	Heniochus acuminatus (Linnaeus, 1758)	1.42	0.87	
Pomacanthidae	*Pomacanthus annularis* (Bloch, 1787)	-	-	TR
Haemulidae	*Diagramma pictum* (Thunberg, 1792)	0.28	0	
	Plectorhinchus gibbosus (Lacepède, 1802)	-	-	TA
Lutjanidae	*Lutjanus argentimaculatus* (Forsskål, 1775)	0.85	0	
	Lutjanus carponotatus (Richardson, 1842)	0.57	0	
	Lutjanus fulviflamma (Forsskål, 1775)	0.28	2.60	
	Lutjanus lutjanus Bloch, 1790	595.24	26.91	
	Lutjanus quinquelineatus (Bloch, 1790)	0.28	0	
	Lutjanus russellii (Bleeker, 1849)	4.25	13.45	
	Lutjanus vitta (Quoy & Gaimard, 1824)	0.57	0.87	
Caesionidae	*Caesio caerulaurea* Lacepède, 1801	0	13.02	
	Caesio cuning (Bloch, 1791)	0	8.68	
	Caesio teres Seale, 1906	-	-	TR
	Pterocaesio chrysozona (Cuvier, 1830)	34.01	130.21	
Siganidae	*Siganus guttatus* (Bloch, 1787)	0.85	0	
	Siganus punctatus (Schneider & Forster, 1801)	-	-	TR
Scorpaenidae	*Dendrochirus zebra* (Cuvier, 1829)	-	-	TA
	Pterois russelii Bennett, 1831	0.28	0	
Ephippidae	*Platax teira* (Forsskål, 1775)	0	0.43	
Nemipteridae	*Scolopsis affinis* Peters, 1877	0.85	0.43	
Nemipteridae	*Scolopsis bilineata* (Bloch, 1793)	0	0.43	
	Scolopsis vosmeri (Bloch, 1792)	0.57	3.47	
Ostraciidae	*Lactoria cornuta* (Linnaeus, 1758)	0.28	0	

FAMILY	SPECIES	Tanks	Trains	I.S.
Tetraodontidae	*Arothron mappa* (Lesson, 1831)	-	-	TR
	Arothron stellatus (Anonymous, 1798)	-	-	TR
Diodontidae	*Diodon liturosus* Shaw, 1804	-	-	TR

Density was higher within tanks, were it averaged 21.2±1.5 fishes/m³, while in the wagons' site the mean was 4.9±0.3 fishes/m³. *Neopomacentrus cyanomos* was the most abundant species in both environments. The five species with highest abundance represented almost 98% of the tanks' total, while the same share accounted for approximately 88% of fish abundance within wagons (Figure 4). Shannon's entropy resulted in a calculated alpha diversity of H=1.34 for the whole community, separately wagons had a slightly higher value of H=1.45, while for tanks H=1.27. No significant difference was found between communities, with p=0.45.

4. Discussion

Species recorded in the area indicate a typical reef associated community, where all 53 species are commonly found in natural coral reef areas (Choat and Bellwood 1991; Bellwood and Wainwright 2002; Allen et al. 2012), and most of the families described in the "consensus list" of reef fish, were registered with the exception of Blenniidae and Mullidae (Bellwood 1996). The different groups also comprise the main niches described in coral reef fishes communities, in which trophic categories include Carnivores, Planktivores and Herbivores (e.g. Serranidae, Caesionidae and Scaridae respectively), as well as different levels of specialization e.g. *Lutjanus fulviflamma* (generalist) and *Sphyraena obtusata* (specialist) (Bellwood 1999; Carpenter 1999a, 1999b; Bachok et al. 2004; Kamukuru and Mgaya 2004). In addition, several species here recorded have economic value and are targeted by small scale fisheries, like those belonging to Carangidae, Scaridae, Serranidae, Lutjanidae, Caesionidae and Nemipteridae, commonly sough for human consumption (Carpenter and Niem 1999).

Although several species of Snappers are often recorded in coral reefs, it is uncommon for this group to represent the richest family, as more often groups like Pomacentridae, Labridae, or Gobiidae present the highest counts (Satapoomin 2000, 2011). The poor representation of Gobiidae can be explained by the lack of small crevices and holes in the structures, where species of this family, mostly bottom dwellers, inhabit (Lieske and Myers 2001; Nelson et al. 2016). Similarly, several damselfishes rely on shelter provided by corals, or are strongly associated with branching corals, *e.g. Dascyllus* spp. (Allen and Erdmann 2012), thus, the low complexity and lack of corals in the area probably restricts the colonization by coral associated damselfishes as well. Lastly, most wrasses feed on mobile invertebrates found within or in adjacent areas to coral reefs, and while more generalist species might feed on a broad set of organisms, some other seek for crustaceans and mollusks directly associated with corals, or feed directly on the coral mucus, and might find it harder to grow viable populations in the studied ARs (Westneat 1999).

Associated with unsuitable conditions for the groups cited above, the great richness of snappers might be a consequence of favorable conditions for the group, especially regarding their carnivorous diet (Nelson et al. 2016). In natural areas, several *Lutjanus* spp. can be found around reefs, either above sandy bottoms or forming large schools next to reef walls and slopes (Lieske and Myers 2001; Allen et al. 2015). The scattered disposition of tanks and wagons provide a wide matrix of sand, where small sand associated fishes and invertebrates can be easily found, in addition to creating a propitious environment for large schools. (Anderson and Allen 1999; Lieske and Myers 2001; Allen and Erdmann 2012). Our observations indicate a widespread distribution of *Lutjanus* spp. individuals between both structures and areas, whereas the main difference is the presence of large *L. lutjanus* schools around tanks solely. Thus, although both areas provide suitable habitats for snappers, the presence of large schools might be restricted to tanks because these provide more shelter than the wagons.

Complimentarily, all large aggregations observed were restricted to the tanks' area, composed by the above cited snappers, the damselfish *N. cyanomos* and cardinalfish *T. fucata*. Those three species are responsible for the greater abundance found on tanks, and when excluded, similar densities are found between areas. The similarity is corroborated by the rejection of significant difference between groups (*p*=0.45). The higher structural complexity of tanks, with a sheltered interior area and several holes, is appropriate for small bottom associated species (see), like *N. cyanomos* which, although feeding on the water column, remains always next to a hard substrate (Lieske and Myers 2001; Allen et al. 2015). The cave-like area inside tanks is also ideal for nocturnal fishes that rest during daytime like *T. fucata* (Lieske and Myers 2001; Allen et al. 2015). Lastly, higher structural complexity entails higher richness, a pattern extensively described for natural ecosystems and thus replicated by our results, where tanks exhibit a larger number of associated species (Roberts and Ormond 1987; Morinière et al. 2003; Gratwicke and Speight 2005; Newman et al. 2015).

Despite showing a lower density, the train site had a higher diversity (*H* = 1.45), what can be explained by the great dominance of the three most abundant species (*N. cyanomos*, *L. lutjanus* and *T. fucata*) around the tanks. The open plain surfaces of the wagons offer a more exposed area, not so attractive for protection schools or small body species (), thus instead of few large schools, only small groups (N < 50) were observed swimming through or nearby wagons. Hence although present in such structures, those species were not so dominant as in the tanks, and a more even community is found. Similar observations can be made for the hovering species registered by intensive searches. Although trains had a smaller number of closely associated species, more taxa were sighted swimming around it when compared to tanks, what can be explained by the larger surface covered by the former. Thus, implying that a great richness might be found among trains, however, animals are scattered in a larger area, and not concentrated in a single structure. If more surveys are to be conducted, it is probable that richness counts for both areas tend to a higher similarity.

Community compositions in the ARs of Narathiwat province are in accordance with previous records for reef fish assemblages in Thai waters. A monitoring study in Ranong province registered similar composition of species, although the total richness was almost double of what was found here (Satapoomin 1994). However, different species counts are expected, since Ranong province is located at the Andaman Sea coast of Thailand, were richness is indeed about two times greater than in the Gulf waters (see Satapoomin 2000, 2011). In fact, our results hold a similar number of taxa to previous studies within the Gulf of Thailand (Manthachitra and Cheevaporn 2007; Songploy et al. 2013, 2017). In addition, this is a preliminary study and future surveys might reveal a greater richness for the area. Lastly, the species *Dendrochirus zebra*, herein recorded was never before registered inside the Gulf of Thailand (**Error! Reference source not found.**). This species has a wide distribution around the Indian-Pacific, and its absence in inner waters within the gulf is still not well understood, however, the geographical limits of its distribution seem to include the bordering waters between the Gulf of Thailand and the main portion of the South china sea, since records have been made in Lopi pinnacle and Ko Losin, south of the gulf (personal observation).

This is the first attempt to list and describe the composition of reef fish inhabiting the artificial reefs of Narathiwat province. The annotated checklist of 53 species serves as a baseline for future studies, as well as an insight of the reef fish community composition within the area, 9 years after the deployment of the structures. The typical reef like assemblage here observed, indicates the area works properly as shelter for those organisms, including endangered species like *Bolbometopon muricatum*. A great richness and abundance of species of commercial interest, especially the snappers, implies that the tanks and train wagons reached the desired goal of attracting species targeted by traditional fisheries to the area.

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References

Allen G, Steene R, Humann P, DeLoach N (2015) Reef Fish Identification: Tropical Pacific. New World Publications, Jacksonville, Florida USA

Allen GR, Erdmann MV (2012) Reef Fishes of the East Indies. Conservation

International Foundation, Perth, Australia

Anderson WD, Allen GR (1999) Lutjanidae. In: FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 5. Bony Fishes Part 3 (Menidae to Pomacentridae) FAO, Rome, pp 2840–2853 http://www.fao.org/3/y0770e/y0770e00.htm

Bachok Z, Mansor MI, Noordin RM (2004) Diet composition and food habits of demersal and pelagic marine fishes from Terengganu waters, east coast of Peninsular Malaysia. NAGA 27(4):8

Bellwood DR (1996) The Eocene fishes of Monte Bolca: the earliest coral reef fish assemblage. Coral Reefs 15(1):11–19 http://link.springer.com/10.1007/BF01626074

Bellwood DR (1999) Scaridae. In: FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 6. Bony Fishes Part 4 (Labridae to Latimeriidae), Estuarine Crocodiles, Sea Turtles, Sea Snakes and Marine Mammals. FAO, Rome, pp 3468–3476 http://www.fao.org/3/y0870e/y0870e00.htm

Bellwood DR, Wainwright PC (2002) Chapter 1 - The History and Biogeography of Fishes on Coral Reefs. In: Coral Reef Fishes (Sale PF, Ed.). Academic Press, San Diego, pp 5–32

Carpenter KE (1999a) Caesionidae. In: FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 5. Bony Fishes Part 3 (Menidae to Pomacentridae) FAO, Rome, pp 2919–2930 http://www.fao.org/3/y0770e/y0770e00.htm

Carpenter KE (1999b) Serranidae. In: FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 4. Bony Fishes Part 2 (Mugilidae to Carangidae) FAO, Rome, pp 2442–2473 http://www.fao.org/3/x2400e/x2400e00.htm

Carpenter KE, Niem VH (1999) FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volumes 4 to 6. FAO, Rome http://www.fao.org/3/w7191e/w7191e00.htm

Carr MH, Hixon MA (1997) Artificial Reefs: The Importance of Comparisons with Natural Reefs. Fisheries 22(4):28–33 http://doi.wiley.com/10.1577/1548-8446(1997)022<0028:ARTIOC>2.0.CO;2

Choat JH, Bellwood DR (1991) Reef fishes: their history and evolution. In: The Ecology of Fishes on Coral Reefs Elsevier, pp 39–66

Gratwicke B, Speight MR (2005) The relationship between fish species richness, abundance and habitat complexity in a range of shallow tropical marine habitats. J Fish Biol 66(3):650–667

Grossman GD, Jones GP, Seaman WJ (1997) Do Artificial Reefs Increase Regional Fish Production? A Review of Existing Data. Fisheries 22(4):17–23 http://doi.wiley.com/10.1577/1548-8446(1997)022<0017:DARIRF>2.0.CO;2

Harris LE (2009) Artificial Reefs for Ecosystem Restoration and Coastal Erosion Protection with Aquaculture and Recreational Amenities. 1(1):12

Hill MO (1973) Diversity and Evenness: A Unifying Notation and Its Consequences. Ecology 54(2):427–432

Jost L (2006) Entropy and diversity. Oikos 113(2):363–375

Kamukuru AT, Mgaya YD (2004) The food and feeding habits of blackspot snapper, Lutjanus fulviflamma (Pisces: Lutjanidae) in shallow waters of Mafia Island, Tanzania. Afr J Ecol 42(1):49–58 https://onlinelibrary.wiley.com/doi/abs/10.1111/j.0141-6707.2004.00487.x

Lieske E, Myers R (2001) Reef Fishes of the World Indo-Pacific and Caribbean. Collins, London

Manthachitra V, Cheevaporn V (2007) Reef fish and coral assemblages at Maptaput, Rayong Province. Songklanakarin J Sci Technol 29(4):907–918

Morinière EC de la, Nagelkerken I, Meij H van der, Velde G van der (2003) What attracts juvenile coral reef fish to mangroves: habitat complexity or shade? Mar Biol 144(1):139–145

Nelson JS, Grande T, Wilson MVH (2016) Fishes of the World. John Wiley & Sons, Hoboken, New Jersey

Newman SP, Meesters EH, Dryden CS, Williams SM, Sanchez C, Mumby PJ, Polunin NVC (2015) Reef flattening effects on total richness and species responses in the Caribbean. J Anim Ecol 84(6):1678–1689 http://doi.wiley.com/10.1111/1365-2656.12429

Phongsuwan N, Chansang H, Satapoomin U (1994) Colonization of fouling communities and associated fauna at artificial reefs in Ranong Province, Thailand. In: The Effect of Artificial Reef Installation on the Biosocioeconomics of Small-Scale Fisheries in Ranong Province, Thailand. Bay of Bengal Programme, Madras, India, pp 10

Roberts C, Ormond R (1987) Habitat complexity and coral reef fish diversity and abundance on Red Sea fringing reefs. Mar Ecol Prog Ser 41:1–8 http://www.int-res.com/articles/meps/41/m041p001.pdf

Satapoomin U (1994) Fish aggregation at the artificial reefs, in Ranong Province, Thailand. In: The Effect of Artificial Reef Installation on the Biosocioeconomics of Small-Scale Fisheries in Ranong Province, Thailand. Bay of Bengal Programme, Madras, India, pp 21

Satapoomin U (2000) A preliminary checklist of coral reef fishes of the Gulf of Thailand, South China Sea. Raffles Bull Zool 48(1):31–54

Satapoomin U (2011) The fishes of southwestern Thailand, the Andaman Sea-a review of research and a provisional checklist of species. Phuket Mar Biol Cent Res Bull 70:29–77

Songploy S, Chavanich S, Kuanui P, Viyakarn V (2017) Diversity of reef fish at Royal Thai Naval Base, Sattahip, Chonburi Province, Thailand. Indian J Mar Sci 46(06):7

Songploy S, Hemachandra W, Chavanich S, Viyakarn V (2013) Fish assemblages in coral communities at Chao Lao Beach, Chanthaburi Province, Thailand. Galaxea J Coral Reef Stud 15(Supplement):189–194

Westneat MW (1999) Labridae. In: FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 6. Bony Fishes Part 4 (Labridae to Latimeriidae), Estuarine Crocodiles, Sea Turtles, Sea Snakes and Marine Mammals. FAO, Rome, pp 3381–3403 http://www.fao.org/3/y0870e/y0870e00.htm