The Comparative Study of Capture Techniques for Taxonomic Study of Wrasses

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ABSTRACT

This study considers the variation of catch methods of wrasses for taxonomic study. Since most wrasses live in coral reefs, non-destructive methods are preferred. Four methods of a small spear gun, gill net, scoop net and baited hook were used to collect the fish samples. The gill net was the most successful capture method in terms of specimens and number of individuals caught, followed by the scoop net, baited hook and small spear gun. Given the diversity of sizes caught, the catch was divided into small (4-10cm), medium (11-20 cm) and large (21-100 cm) sizes. The gill net proved to be the most successful capture method for all sizes, while the small spear gun and baited hook were successful only for medium and large fish, respectively. However, the scoop net was suitable for the capture of small and medium sized wrasses, although the quantity and diversity were less than the gill net. Wrasses are usually solitary or occur in pairs, but some form small schools, particularly in the juvenile phase. Accordingly, this study also divided the species caught into those that were solitary or in pairs, and schooling. Again, the gill net proved to be the most successful catch method, following by the scoop net, baited hook and small spear gun. The gill net is suitable equipment for both solitary and schooling wrasses, while the baited hook is effective only for solitary fish.

Keywords: baited hook, fish, gill net, scoop net, spear gun

INTRODUCTION

The family Labridae (wrasse) is the third largest fish family, containing approximately 60 genera and 500 species (Nelson 1994). Wrasses are widely distributed, and fulfill important ecological roles on reefs in tropical and temperate regions around the world (Choat & Bellwood 1998, Nelson 1994, Wainwright & Bellwood 2002), including a dominant group of benthic carnivores, which consume a wide variety of preys (Williams & Hatcher 1983). Wrasses are most common in shallow waters in a diverse range of habitats, including coral and rocky reefs, and substrates characterized by sand, sea grass, and algae, but are rarely found in muddy areas. However, one of potential

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importance is the habitat-specific nature of some species, which make them useful indicators of habitat and marine system health (Willis & Anderson 2003, Tuya *et al.* 2009). So, accurate identification is vital for investigating this role.

Wrasses are generally small, but range in length from 4.5 cm for the minute wrasse (*Minilabrus striatus*) of the Red Sea, to over 2 meters for the humphead wrasse (*Cheilinus undulates*) of the Indo-Pacific region (Nelson 1994), with many species of wrasses being less than 20 cm. in length. Even within a single species, there is a diverse range of colors, which often varies considerably depending on the gender and life stages (Randall *et al.* 1990, Costello 1991). Many species are capable of gender change (protogyny) and associated dimorphism. Usually, juveniles are a mix of males and females (the initial phase), with the largest adults becoming territory-holding males (the terminal phase), and organize others into harem-based social systems (dominated by one male) (Costello 1991). This morphological diversity makes them a challenge to identify. With the high level of multimorphism, it is important to capture live fish to track life history and morphological changes, for ensuring accurate identification.

While the taxonomy of the family is well understood, the relative capture efficiency of various techniques is poorly reported (Treasurer 1996, 2000). In this study, we assessed capture techniques commonly used for small wrasses when undertaking taxonomic study. The selection of capture techniques tested was also influenced by our experience with wrasse behavior and size. The rationale for the study was to maximizecapture efficiency of species targeted for taxonomic study and minimize by-catch.

MATERIALS AND METHODS

Study sites

Three different study areas were selected within the Northern Andaman Sea for this study, which were located in one inshore island, Phuket, and two offshore islands, Mu Koh Surin (Surin) and Mu Koh Similan (Similan). In each of them, five sampling sites were set to capture a wide diversity of wrasse species. Phuket is the largest inshore island in Thailand. It tends to be suffered from elevation of nutrient levels of the water due to tourism and urban development, especially during the rainy season (Reopanichkul *et al.* 2010). The sampling sites in Phuket are set in Karon Bay, Nai Yang Bay, Patong Bay, Racha Island, and Mai Thon Island. The two offshore islands, Surin and Similan are designated as Marine National Parks, where are under a minimal impact from the coastal development (see Reopanichkul *et al.* 2009). Surin is reputed as one of the best coral reef areas with the highest species diversity among them in the shallow water in Thailand, while Similan is considered to be one of the best diving sites in Thailand (RFD 2002). The sampling sites in Surin are set in Mai Ngam Bay, Suthep Bay, Mae Yai Bay, Chong Khad Bay, and Torinla Island, while those in Similan are located in Hu Yong Island, Payang Island, Miang Island, Payu Island and Similan Island (Fig. 1).

Figure 1. Sampling sites in the three study areas, Surin, Similan and Phuket, in Southern Thailand

Data collection

The Northern Andaman Sea is influenced by the south-west monsoon (wet season) from May to October. Therefore, the surveys were conducted in the dry season between 2008 and 2010, when the turbidity of the water was low. The surveys in Phuket were conducted in January to February each year, while those in Surin and Similan were carried out in February to March and November, respectively. In the present study, four different popular catch methods were tested (Fig. 2). They are a small spear gun with 0.2 cm in diameter, 25 cm in length, a baited hook size4/0, a scoop net with net opening of 20 cm in diameter, and a monofilament gill net with a mesh size of 1 cm in diameter, 100 cm in length, height after hanging was 50 cm.

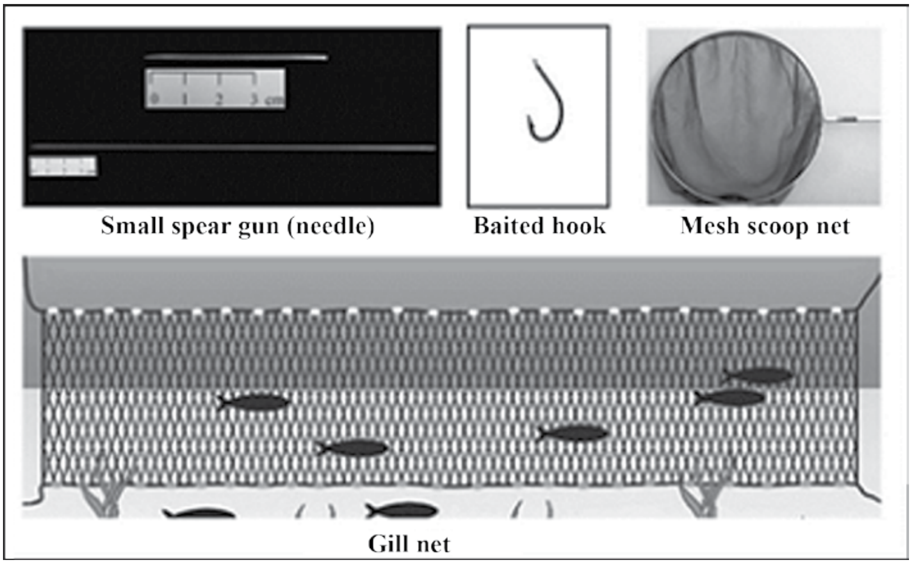

Figure 2. Catching gears tested for the wrasses in the present study

The wrasses were captured twice with each of the four different methods, at all of the five sampling sites in each study area (10 SCUBA in total dives for each capture method at each of the three study areas). Only 1 catching gear was tested at each dive. The operator of the sampling gears swam over the reef, parallel to the shoreline for 40 minutes, and attempted to catch whatever species were seen within the target size range (<100 cm). The capture attempt continued until no wrasses remained within reach of the operator. However, the species of the sighted individuals were identified, and their numbers were counted. Species which were not caught due to size, inappropriateness of the capture methods, or ignored during the catch process of other individuals were also counted as a species counted in order to investigate the capture efficiency. The mean count of species over the 40 dives in each study area was used as an indicator of species abundance, while the number of species was used as a measure of species diversity.

Data analysis

Since the present study focused on the comparison of capture efficiency of the wrasses among the four different capture methods, statistical significance on the differences in the number and species diversity of the captured fish among the four different capture methods was evaluated with the results of chi square test. The capture efficiency of each capture method was analyzed in the multivariate domain using Principal Component Analysis (PCA) on untransformed, standardized capture techniques and study site variables (Clarke & Gorley 2006), complemented by Analysis of Variance (ANOVA) (Underwood 1981).

RESULTS

In the present study, 59 species of wrasses were identified in total, but 24 species of them were not captured because the capture methods were not appropriate to the size of the fish (11 species) or behavioral characteristics (e.g. fast moving) (17 species) (Table 1). Some species escaped the capture by sheltering in holes, crevices and galleries of the corals, or burrowing in the sand and/or soft substrate. In total, 35 species of 295 specimens were captured using the four methods (Table 2).

Table 1. The species list of wrasse, which were identified, but not captured by any capture methods mainly due to their sizes and living behaviors

Species not captured	Size	Living behavior	Species abundance
Iniistius baldwini	L	So	1
Paracheilinus mccoskeri	S	So	2
Anampses twistii	M	So	2
Halichoeres kallochroma	M	So	2
Hologymnosus annulatus (adult)	L	So	2
Hologymnosus doliatus	L	So	2
Iniistius pavo	L	So	2
Suezichthys sp.	M	So	3
Cheilinus undulatus	L	So	3
Cheilinus oxycephalus	M	So	4
Novaculichthys taeniourus	M	So	4
Pteragogus cryptus	M	So	4
Anampses lineatus	M	So	4
Halichoeres melanurus	M	So	4
Labroides bicolor	S	So	5
Anampses melanurus	M	So	5
Bodianus neilii	M	So	5
Oxycheilinus orientalis	M	So	5
Cheilinus trilobatus	L	So	5
Bodianus axillaries	M	So	6
Pseudocheilinus hexataenia	M	So	8
Bodianus mesothorax	M	So	8
Stethojulis bandanensis	M	So	9
Halichoeres nebulosus	M	So	11
Halichoeres leucoxanthus	M	Sc	11

Maximum growth size: S = Small (4-10cm), Medium (11-20 cm), Large (21-100 cm). Behaviour: Sc = Schooling, So = Solitary.

Table 2. Capture success by species and method

Species	Size	Living behaviour	Fish population	Gill net			Scoop net			Baited hook			Speargun		
				No.	%	Catchability	No.	%	Catchability	No.	%	Catchability	No.	%	Catchability
Cirrhilabrus cyanopleura	S	Sc	70	33	47	VH	24	34	H	0	0	VL	0	0	VL
Thalassoma lunare	M	Sc	67	16	24	M	3	5	VL	0	0	VL	0	0	VL
Leptojulis cyanopleura	M	Sc	60	0	0	VL	6	10	L	0	0	VL	0	0	VL
Labrichthys unilineatus	M	Sc	40	11	28	M	2	5	VL	0	0	VL	0	0	VL
Coris batuensis	M	Sc	38	13	34	H	7	18	L	0	0	VL	0	0	VL
Halichoeres hortulanus	M	S	37	13	35	H	0	0	VL	0	0	VL	6	16	L
Oxycheilinus digrammus	L	S	34	10	29	M	0	0	VL	0	0	VL	0	0	VL
Cheilinus fasciatus	M	S	33	15	46	VH	0	0	VL	7	21	M	0	0	VL
Thalassoma jansenii	M	S	32	4	13	L	0	0	VL	0	0	VL	0	0	VL
Labroides dimidiatus	S	S	31	0	0	VL	5	16	L	0	0	VL	0	0	VL
Cheilinus chlorourus	L	S	30	11	37	H	0	0	VL	6	20	M	0	0	VL
Thalasssoma hardwicke	M	S	28	1	4	VL	0	0	VL	0	0	VL	0	0	VL
Halichoeres scapularis	M	Sc	25	6	24	M	0	0	VL	0	0	VL	1	4	VL
Hemigymnus melapterus	L	S	22	6	27	M	0	0	VL	2	9	VL	0	0	VL
Stethojulis trilineata	M	S	22	6	27	M	0	0	VL	0	0	VL	0	0	VL
Hemigymnus fasciatus	L	S	20	6	30	H	0	0	VL	3	15	L	0	0	VL
Halichoeres timorensis	M	Sc	20	2	10	L	0	0	VL	0	0	VL	0	0	VL
Halichoeres chloropterus	M	S	18	4	22	M	0	0	VL	0	0	VL	0	0	VL
Halichoeres marginatus	M	S	18	3	17	L	0	0	VL	0	0	VL	0	0	VL
Stethojulis interrupta	M	S	18	3	17	L	0	0	VL	0	0	VL	0	0	VL
Epibulus insidiator	L	S	16	8	50	VH	0	0	VL	0	0	VL	0	0	VL
Halichoeres margaritaceus	M	S	16	4	25	M	0	0	VL	0	0	VL	0	0	VL
Bodianus diana	M	S	15	9	60	VH	0	0	VL	0	0	VL	2	13	L
Halichoeres vrolikii	M	S	14	4	29	M	0	0	VL	0	0	VL	0	0	VL
Gomphosus caeruleus	M	S	12	5	42	VH	0	0	VL	0	0	VL	0	0	VL
Oxycheilinus celebicus	M	S	12	5	42	VH	0	0	VL	0	0	VL	0	0	VL
Halichoeres nigrescens	M	S	12	2	17	L	0	0	VL	0	0	VL	0	0	VL
Stethojulis strigiventer	M	S	10	7	70	VH	0	0	VL	0	0	VL	0	0	VL
Anampses caeruleopunctatus	M	S	7	2	29	M	0	0	VL	0	0	VL	0	0	VL
Stethojulis albovittata	M	S	7	0	0	VL	0	0	VL	0	0	VL	1	14	L
Anampses meleagrides	M	S	5	3	60	VH	0	0	VL	0	0	VL	0	0	VL
Pseudodax moluccanus	M	S	5	3	60	VH	0	0	VL	0	0	VL	0	0	VL
Macropharyngodon ornatus	M	S	3	3	100	VH	0	0	VL	0	0	VL	0	0	VL
Coris cuvieri	L	S	2	1	50	VH	0	0	VL	0	0	VL	0	0	VL
Hologymnosus annulatus (juvenile)	S	S	2	1	50	VH	0	0	VL	0	0	VL	0	0	VL
Total			801	220	27		47	6		18	2		10	1	

Size: S = Small (4-10cm; 8.6% of total), M = Medium (11-20 cm; 74.3% of total), L = Large (21-100 cm; 17.1% of total). **Living behaviour:** Sc = Schooling (80% of total), S = Solitary (20% of total). **Catchability:** Very low (VL) = < 10%, Low (L) = 10 - 19%, Medium (M) = 20 - 29%, High (H) = 30 - 39%, Very high >39%

Wrasses are mostly solitary or occur in pairs, but some species form small schools, in their juvenile phase (Michael & Laura 1994). The capture efficiency was strongly influenced by the size of the fish and behavioral characteristics of each species (Table 2). Captured fishes are mainly in medium size (11-20 cm.) and solitary fishes. This is also the case for the number of individuals caught (Table 3). However, more individuals per species were captured for small sized wrasses (21.0) and schooling fish (17.7) (Table 3). Table 3 concludes that the catch methods tested did select for small fish and schooling behavior.

The gill net recorded the highest capture rate of the wrasses, which collected 91% of the total captured species, and 75% of the total catch among the four capture methods. The capture rate was followed by the scoop net (17% of the captured species, 16% of the total catch), baited hook (11% of the captured species, 8% of the total catch), and spear gun (11% of the captured species, 5% of the total catch). These results indicate that the gill net is most suitable capture gear for the wrasses, irrespective of size and behavior.

Table 3. Summative statistics on the captured wrasses (species and number caught, and size and living behavior)

		Size			Living behaviour		Total
		Small	**Medium**	**Large**	**Solitary**	**Schooling**	
All							
Species caught	No. (%)	3 (9%)	26 (74%)	6 (17%)	28 (80%)	7 (20%)	35
Number caught	No. (%)	63 (21%)	179 (61%)	53 (18%)	171 (58%)	124 (42%)	295
Number/species		21.0	3.0	8.8	6.1	17.7	8.4
Gill net							
Species caught	No. (%)	2 (6%)	24 (75%)	6 (19%)	26 (81%)	6 (19%)	32
Number caught	No. (%)	34 (15%)	144 (65%)	42 (19%)	139 (63%)	81 (37%)	220
Number/species		17.0	6.0	7.0	5.3	13.5	6.9
Scoop net							
Species caught	No. (%)	2 (33%)	4 (67%)	0 (0%)	1 (17%)	5 (83%)	6
Number caught	No. (%)	29 (62%)	18 (38%)	0 (0%)	5 (11%)	42 (89%)	47
Number/species		14.5	4.5	0	5.0	8.4	7.8
Baited hook							
Species caught	No. (%)	0 (0%)	2 (50%)	2 (50%)	4 (100%)	0 (0%)	4
Number caught	No. (%)	0 (0%)	7 (39%)	11 (61%)	18 (100%)	0 (0%)	18
Number/species		0	3.5	5.5	4.5	0	4.5
Speargun							
Species caught	No. (%)	0 (0%)	4 (100%)	0 (0%)	3 (75%)	1 (25%)	4
Number caught	No. (%)	0 (0%)	10 (100%)	0 (0%)	9 (90%)	1 (10%)	10
Number/species		0	2.5	0	3.0	1.0	2.5

Species caught ----------- No. of captured species
Number caught ---------- No. of captured individuals
Number/species ---------- No. of captured individuals per species

The wrasses captured by the scoop net were occupied by only small and medium sizes of the fish (Table 3), but two of the three small species (*Labroides dimidiatus* and *Leptojulis cyanopleura*) were not captured by the gill net. The results of the captured fish with scoop net also indicate the advantage of this method to capture schooling fish (5 species and 42 individuals were captured in total). The baited hook could not capture small fish and schooling fish. The spear gun could capture only medium size of fish, and one schooling species (species names) (Table 3). However, *Stethojulis albovittata*, which is a solitary, and medium-size of the wrasse occurring sparsely was captured only by the speargun.

Clearly, the gill net was the most successful capture method in terms of the number of the collected species and individuals. Among the four different capture methods, there were significant differences between the number of captured species (fish diversity) (χ^2= 54.57, df = 3, p<0.001) and the number of captured individuals (F = 100.20, df = 3, 119, p<0.001) (Table 4). That is, the different catch methods caught different species and different numbers of specimens.

The spatial pattern from the ordination of 35 captured species showed a clear separation of the three different groups based on the results of PCA on the captured pattern with four different captured methods (Fig. 3). The first group was the gill net, which had the highest capture rates to the majority of the species captured in this study irrespective of their sizes and behaviors. The species that were captured most frequently with the gill net were *Labrichthys unilineatus*, *Anampses melanurus*, *Thalassoma lunare*, *Halichoeres hortulanus, Cheilinus fasciatus*, *Bodianus diana*, *Cheilinus chlorourus*, *Halichoeres scapularis*, *Thalassoma hardwicke*, and. The second group was the scoop net, which had moderate catch success. There were four species which were captured in moderate ratios with both of the scoop net and the gill net, but scarcely caught with the baited hook and the spear gun. They were *Cirrhilabrus cyanopleura*, *Labroides dimidiatus*, *Leptojulis cyanopleura* and *Coris batuensis*. The third group included both the baited hook and speargun and had the lowest catchability rate. These methods only caught a small number of specimens of species that tended to be abundant in the populations sampled. There was only one species commonly caught with

Table 4. Summary of ANOVA on number of fish species, specimens caught and capture methods, fish size and behaviour (ns = p>0.05, * = p<0.05, ** = p<0.01, *** = p<0.001)

Variation	**Number of fish species**	**Number of fish specimens caught**
Capture methods (df = 3, 119)	129.88***	100.20***
Fish sizes (df = 5, 119)	71.25***	61.69***
Fish behavior (df = 3, 119)	80.72***	76.26***

Variation		**F-ratio**
Capture methods	Small	4.27**
	Medium	62.52***
	Large	45.25***
Capture methods	Solitary	32.88***
	Schooling	30.65***

*Remark: All replicate data were used for ANOVA analysis.

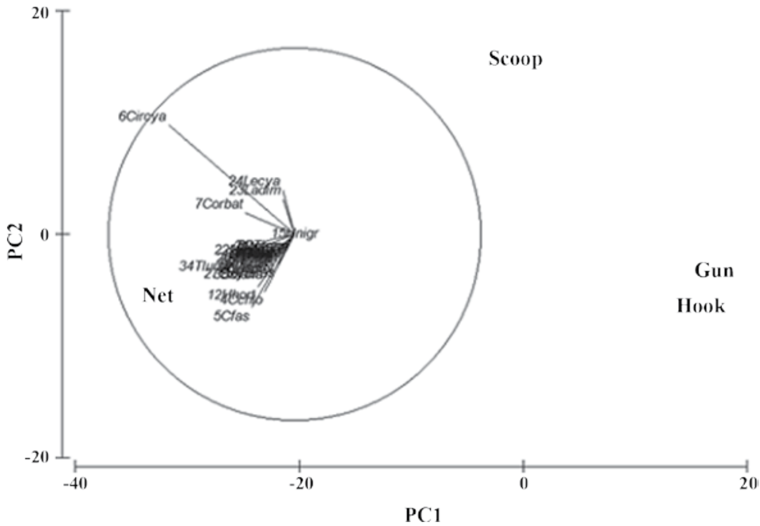

Figure 3. Ordination (Principal Component Analysis-PCA) of spatial patterns between study locations and capture techniques

this equipment, i.e. *Pteragogus cryptus*. Thus, wrasse species abundance appears only to affect catch rates for the gill net and scoop net methods, both of which have higher catch rates than the baited hook and spear gun methods.

DISCUSSION

Schooling species and fish greater than 10 cm but less than 100 cm were more likely to be caught than small and solitary fish whose cryptic behavior (hiding strategies), size (they easily avoided capture), and other behaviors, such as being too fast to catch and/or actively swam away from the operator, assisted in their ability to avoid capture. In this study, the gill net proved to be highly suited for capturing most species, irrespective of fish size and behaviour. However, there was a tendency for non-target species to be trapped on the net as by-catch (10 times). In addition, there was some minor degradation in the quality of specimens due to loss of scales around their head and operculum from struggling of the fish when caught in the fine mesh. While we did not find this significant, it may reduce the suitability of specimens for some taxonomic work.

The scoop net was appropriate for small and medium sized and schooling fish, and appears to be the only technique that can catch pelagic fishes such as *Leptojulis cyanopleura*. The speargun was only suitable for catching medium sized fish, while the baited hook was suited for capturing medium and large sized fish (Cote & Perrow 2006; Murphy & Jenkins 2010). The suitability of these methods is also limited by the need for operator experience and training. For the spear gun, training and experience is needed to achieve the desired head shot (dead point); otherwise, if the needle hits the body, the fish would escape along with the needle. This occurred 12 times in the study. For the baited hook method, there is need for the operator to master buoyancy control and breathing technique to avoid the target species swimming away from the operator.

Size of fish also affected catch rates. Small wrasses were the hardest to catch because of their cryptic behavior (hiding strategies). Small topographic elements of the benthos, such as tabulate or branching coral, cracks, caves or holes, that give wrasses protection against predators (Hixon & Beets 1993; Tuya *et al*. 2009) also protect them from being capture by taxonomists. Although smaller fish can be captured, they were frequently underrepresented in all catch methods. Medium sized wrasses were the easiest to catch, followed by the large wrasses (cf Buckmeier & Schlechte 2009).

Lunneryd *et al*. (2002) and Carassou *et al*. (2009) found that efficiency depends on mesh size as well as the size of fish. In this study, the very small mesh size (1 centimeter in diameter) enabled capture of all but the larger fish (greater than 100 cm in length). The mesh is relatively invisible so it may have had an advantage over the other equipment with the fish being less aware of its presence (see Hickford & Schiel 2008). Conversely, the efficiency of the scoop net mainly depends on the net's mouth diameter, while the catch effectiveness of the baited hook and spear gun depend on the size of the hook, or spear and its propellant force, matching the target species.

This study confirms that the gill net is the best equipment for taxonomic work and site inventories, because it captures maximum species and numbers in the shortest time, requires limited operator experience, and results in acceptable injury to specimens. While, the loss of head or opercula scales during net capture might be unavoidable in some specimens, we found this would not impede most taxonomic studies.

The principal factors to be considered in selecting a catch technique are the size range of the targeted species (Thorrold 1992; Choat *et al*. 1993; Carassou *et al*. 2009) and their behaviour (Brogan 1994; Carassou *et al*. 2009). However, researchers may need to be prepared to use multiple techniques to capture the desired range of species sizes.

Finally, the sampling efficiency of the gill net raises issues relating to moral obligations of researchers to minimize take and avoid depleting specific stocks and over-sampling. For wrasse species, our results, consistent with other studies, suggest that a defined range of wrasse sizes, behaviours and general morphological characteristics can be predetermined to target desired species and minimise by-catch. However, this requires planning and an operator with sufficient taxonomic, field and equipment experience to be selective.

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LITERATURE CITED

Brogan MW (1994) Two methods of sampling fish larvae over reefs: a comparison from the Gulf of California. **Mar Biol** 118: 33-44.

Buckmeier DL, Schlechte JW (2009) Capture efficiency and size selectivity of channel catfish and blue catfish sampling gears. **North. Am. J. Fish. Management** 29: 404-416.

Carassou L, Mellin C, Ponton D (2009) Assessing the diversity and abundances of larvae and juveniles of coral reef fish: a synthesis of six sampling techniques. **Biodiversity Conserv** 18: 355-371.

Choat JH, Bellwood DR (1998) Wrasses and Parrotfishes. In: **Encyclopedia of Animals: Fishes,** 2nd edn (eds Paxton JR, Eschmeyer WN), Weldon Owen, San Diego, California, pp. 209-213.

Choat JH, Doherty PJ, Kerrigan BA, Leis JM (1993) A comparison of towed nets, purse seine, and light-aggregation devices for sampling larvae and pelagic juveniles of coral reef fishes. **Fish Bull** 91: 195-209.

Clarke KR, Gorley RN (2006) **PRIMER v6: User Manual/Tutorial.** PRIMER-E, Plymouth, UK.

Costello MJ (1991) Review of the biology of wrasse (Labridae: Pisces) in Northern Europe. **Prog. Underwat. Sci.** 16: 29-51.

Cote IM, Perrow MR (2006) Fish. In: **Ecological Census Techniques: A Handbook** (ed Sutherland WJ), Cambridge University Press, Cambridge, pp. 250-277.

Hickford MJH, Schiel DR (2008) Experimental gill-netting of reef fish: Species-specific responses modify capture probability across mesh sizes. **J Exp Mar Biol Ecol** 358: 163-169.

Hixon MA, Beets JP (1993) Predation, prey refuges, and the structure of coral-reef fish assemblages. **Ecol Monogr** 63: 77-101.

Lunneryd SG, Westerberg H, Wahlberg M (2002) Detection of leader net by whitefish *Coregonus lavaretus* during varing environmental conditions. **Fish Res** 54: 355-362.

Michael AW, Laura W (1994) **Tropical reef fishes:** A marine awareness guideon fishes from the Indo-Pacific realm, Great Barrier Reef, Australia, Indonesia Archipelago, Bunaken Marine Park, North Sulawesi, Maldives, Malaysia, Philippines, Thailand, South Pacific Islands, Ocean grographic media, Malaysia. 126 pp.

Murphy HM, Jenkins GP (2010) Observational methods used in marine spatial monitoring of fishes and associated habitats: a review. **Mar Freshw Res** 61: 236-252.

Nelson JS (1994) **Fishes of the world.** 3rd edn, John Wiley & Sons, Inc., New York. 600 pp.

Randall JE, Allen GR, Steen RC (1990) **Fishes of the Great Barrier Reef and Coral Sea,** University of Hawii Press, Honolulu. 557 pp.

Reopanichkul P, Carter RW, Worachananant S, Crossland CJ (2010) Wastewater discharge degrades coastal waters and reef communities. **Mar Environ Res** 69: 287-296.

Reopanichkul P, Schlacher TA, Carter RW, Worachananant S (2009) Sewage impacts coral reefs at multiple levels of ecological organization. **Mar Pollut Bull** 58: 1356-1362.

RFD (2002) **Handbook of marine national park tourism: Andaman Sea.** Marine National Park Division, The Royal Forest Department (RFD), Bangkok, Thailand. (Published in Thai)

Thorrold SR (1992) Evaluating the performance of light traps for sampling small Wsh and squid in open waters of the Central Great Barrier Reef lagoon. **Mar Ecol Prog Ser** 89: 277-285.

Treasurer JW (1996) Capture techniques for wrasse in inshore waters of west Scotland. In: **Biology and use in aquaculture** (eds Sayer MDJ, Treasurer JW, Costello MJ), Blackwell Berlin, pp. 74-90.

Treasurer JW (2000) Evaluation of the relative catching power of pots for north European wrasse (Labridae). **J Appl Ichthyol** 16: 36-38.

Tuya F, Wernberg T,Thomsen MS (2009) Habitat structure affect abundances of labrid fishes across temperate reefs in south-western Australia. **Environ Biol Fishes** 86: 311-319.

Underwood AJ (1981) Techniques of analysis of variance in experimental marine biology and ecology. **Oceanogr Mar Biol Annu Rev** 19: 513-605.

Wainwright PC, Bellwood DR (2002) Ecomorphology of feeding in coral reef fishes. In: **Coral Reef Fishes. Dynamics and diversity in a complex ecosystem** (ed Sale PF), Academic Press, San Diego, pp.33-56.

Willis TR, Anderson MJ (2003) Structure of cryptic reef fish assemblages: relationships with habitat characteristics and predator densit. **Mar Ecol Prog Ser** 257: 209-221.