Chinese Red Swimming Crab (*Portunus haanii*) Fishery Improvement Project (FIP) in Zhangzhou City, Fujian Province, China

(August 2018–April 2019)

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1. Introduction

Chinese red swimming crab (*Portunus haanii*, Portunidae) is widely distributed in the Indo-Pacific, and in China it is commonly found in the East China Sea and South China Sea (Dai et al. 1986). *Portunus haanii* is characterized with a flattened hind pair of legs with red-purple in the tips (Fig. 1). *Portunus haanii* lives in sandy and gravelly bottom within 100 m (Dai et al. 1986) and feeds on crustaceans and demersal fishes with Macrura and Brachyura species dominant (Huang 2004).

Fig. 1. Chinese red swimming crab *Portunus haanii*.

Portunus haanii fishery has become to be important in Minnan-Taiwan Bank fishing grounds since the 1990s, and it can be caught year-round (Zhang 1997). The estimated annual capture volume of *P. haanii* in the 1990s was 30,000-35,000 t in Minnan-Taiwan Bank fishing grounds, and the capture volume of *P. haanii* contributed to 16-23% of the total capture volume in bottom trawl fishery (Zhang 1997). *Portunus haanii* in Minnan-Taiwan Bank fishing grounds was reported to have two spawning seasons, in February-April and in October (Zhang 1997).

Portunus haanii is currently the most commercially important crab processed in Dongshan County (Zhangzhou City, Fujian Province, China) with the majority for export as crab meat. Based on a previous study, the abundance and average size of *P. haanii* have shown a decline after its resource be explored from comparted to results of research in the 1990s. In an effort to

ensure the fishery's sustainability, the China Aquatic Products Processing and Marketing Alliance (CAPPMA), its local affiliate the Zhangzhou Aquatic Products Processing and Marketing Alliance (ZAPPMA), the US based national Fisheries Institute (NFI) and Ocean Outcomes (O2) has launched the Phase I of a fisheries improvement project (FIP) in August-December 2018, conducted in Dongshan County with a focus on understanding the trawl and trap fisheries. However, the trap vessels surveys in Dongshan County in Phase I were not very success.

In January-April 2019, Qingdao Marine Conservation Society (QMCS) launched the Phase II of the FIP. In the Phase II, we continued our focus on trawl and trap fisheries in Dongshan County with another extension to trap fishery in Longhai County. The operation patterns of trap fishery in Dongshan County and Longhai County are different; offshore in Dongshan County and nearshore in Longhai County.

The initial fishery monitoring efforts of the Phase I and Phase II were contracted to Dr. Min Liu at Xiamen University. In order to better understand the patterns and trends of the crab fishery, this report represents the results from the Phases I and II of the FIP if data available, i.e. representing data as a continuous 9-month period (August 2018-April 2019). The objectives are defined as follows:

(1) to document the species composition in catches from trawl and trap gears, including those from the "feed fishes";

(2) to measure the size ranges and/or weight ranges of the main species (including crustaceans, fishes and cephalopods) in the catches to understand the fishery status;

(3) to estimate the proportion of main species or species groups caught;

(4) to determine the sex of crabs sampled and the status of females carried eggs; and

(5) to evaluate the efficiency of the current fishery management system, and to provide the suggestions for relevant improvement and the designation based on a balance of cost and profit achievement and on the evaluation plan better than traditional fishery resource monitoring (Note: this section will be prepared as an independent report).

2. Materials and Methods

2.1. Sampling sites and dates

This study was conducted in Dongshan County and Longhai County. Two major landing ports (Dawo and Gongqian) from Dongshan County and one major landing port (Doumei) in Longhai County were surveyed monthly from January to April, 2019 (Table 1; Fig. 2).

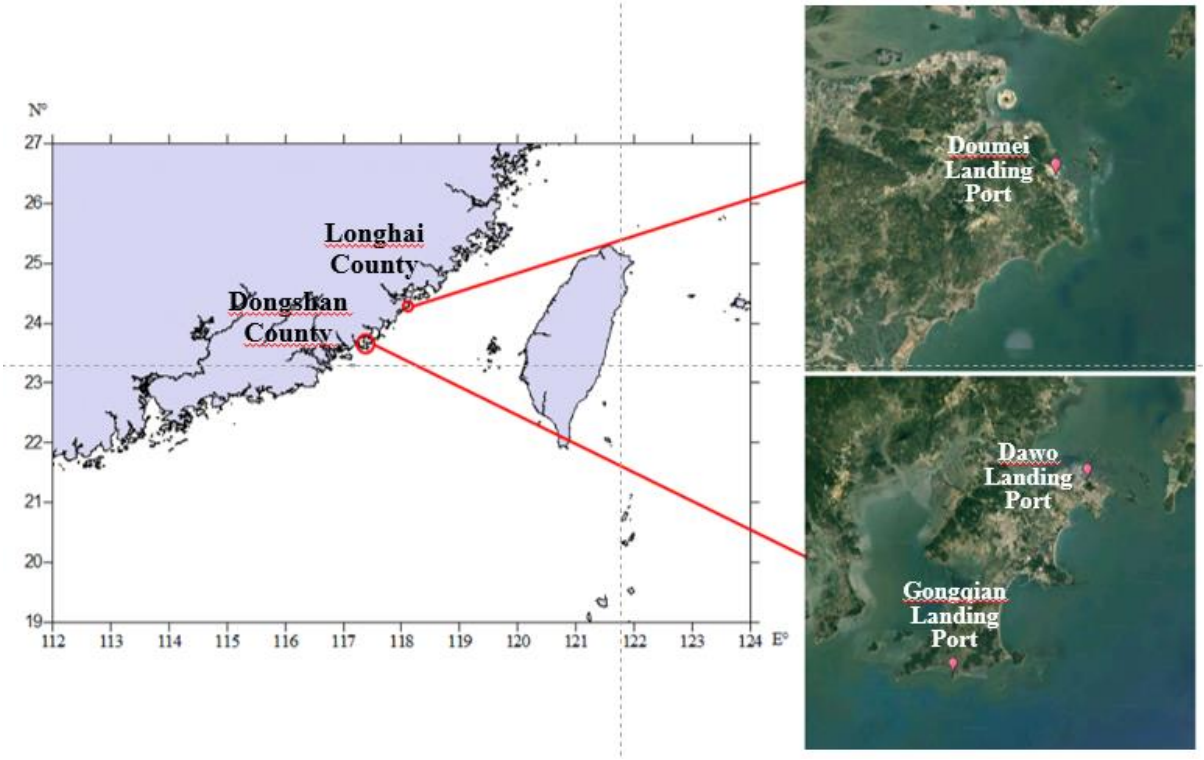

Fig. 2. Sampling sites in January-April 2019 in Dongshan County and Longhai County of Zhangzhou City, Fujian Province, China.

Table 1. Sampling dates in January-April 2019 in Dongshan County and Longhai County of Zhangzhou City, Fujian Province, China.

No.	Dongshan County	Longhai County
1	January 06-12, 2019	January 07-08 & 18-19, 2019
2	February 16-19, 2019	February 26-28, 2019
3	March 05-11 & 30-31, 2019	March 30-31, 2019
4	April 11-16, 2019	April 15-16, 2019

2.2. Types of fishing gears surveyed—trawl and trap

In Dongshan County, about 1,015 trawl vessels and 100 trap vessels registered. For trap vessels, only 10% operate at sea and this figure would be lower than 10% in March and April (after Chinese Spring Festival), prior to the start of the national fishing moratorium in May due to the low catches of crabs (Mr. Fang & Mr. Xie, personal communications). In January-April 2019, two types of fishing gears were surveyed, trawl and trap (Fig. 3).

In Longhai County, around 30 trap vessels are registered and operate nearshore waters,

mainly for live crab fishery (Fig. 4). Most captains refused collaborating with us. Only one captain allowed us to do sampling in his trap vessel; therefore, each month in January-April, five trips' catch data were obtained from the only trap vessel surveyed and crab samples were collected monthly in January-April 2019.

Fig. 3. Two types of fishing gears (left, trawl; right, trap) surveyed in January-April 2019 in Dongshan County.

Fig. 4. Trap fishing gear surveyed in January-April 2019 in Longhai County.

2.3. Crab species sampled

In Dongshan County, four crab species, the Chinese red swimming crab *Portunus haanii*, the three-spot swimming crab *P. sanguinolentus*, the ridged swimming crab *Charybdis nataor* and the bread crab *Calappa philargius*, were dominant in crab catches and usually separated in catch landings in both trawl and trap fisheries.

In Longhai County, eight crab species, the Chinese red swimming crab *Portunus haanii*, Japanese blue crab *P. trituberculatus*, Flower crab *P. pelagicus*, the three-spot swimming crab *P. sanguinolentus*, the ridged swimming crab *Charybdis nataor*, Crucifix crab *C. feriatus*, the Japanese crab *C. japonica* and the bread crab *Calappa philargius*, were found in trap catches and landed as live crabs.

Although the project focused on *P. haanii* fishery only, we extended our sample collection to *P. sanguinolentus*, *C. nataor* and *C. philargius* for better understanding the overall crab fishery in Dongshan County and Longhai County (Table 2).

In Dongshan County, at least 200 individuals of each of the four crab species (Table 2) were sampled randomly monthly for further measurement and examination in January-April 2019. In Longhai County, all individuals of the four crab species (Table 2) were sampled from each trip for 5 trips per month for further measurement and examination in January-April 2019.

Table 2. Four crab species sampled.

No.	Photo	Species name
1		Chinese red swimming carb *Portunus haanii*
2		Three-spot swimming crab *Portunus sanguinolentus*

		
3		Ridged swimming crab *Charybdis nataor*
4		Bread crab *Calappa philargius*

2.4. Feed fish sampled

About 1-2 kg feed fishes were randomly collected each month in January-April 2019 from trawl vessels in Dongshan County for further size measurement and species identification. This will explore our understanding on species diversity and size range in feed fishes in trawl fishery of Dongshan County.

2.5. Fishing vessel information collection

For those trawl and trap vessels where crab and feed fish sampled, information on vessel registration number, fishing areas and number of days at sea were collected.

2.6. Capture volume data collection

For those trawl and trap vessels where crab and feed fish sampled, information on total

capture volume, crab capture volume, and capture volume of main species or species groups, and capture volume of feed fishes were estimated at the landing ports based on observation and interview.

2.7. Species identification

To understand the species diversity in Dongshan County fishery, common species of fishes, crustaceans and cephalopods were noted and photos were taken at the landing ports for taxonomic use. If necessary, specimens were purchased for further identification in the laboratory.

Species diversity from trap fishery in Longhai County was evaluated by checking the captain's fishing logbook because he sold catches alive on the sea. The logbook noted catches as taxonomic groups (e.g. groupers, manta shrimps or octopus), except the crabs those were noted at the species level.

For feed fishes, species were identified to species, genus or family levels, due to most specimens were small juveniles or sometimes under bad conditions.

Fish identification was based on *Fishes of The World* (Nelson 2006), *Marine Fishes of Southern Fujian, China (Volume 1)* (Liu et al. 2013), *Marine Fishes of Southern Fujian, China (Volume 2)* (Liu et al. 2014), www.fishbase.org and fishdb.sinica.edu.tw.

Crustacean identification followed *Marine Crabs of China* (Dai et al. 1986), *A Catalog of The Mantis Shrimps (Stomatopoda) of Taiwan* (Ahyong et al. 2008) and *Penaeidae Shrimps of The South China Sea* (Liu et al. 1988).

Cephalopod identification followed *Fauna Sinica Vol. 4: Phylum Mollusca Class Cephalopode* (Dong 1988).

2.8. Sample measurement

Sample measurements were conducted in the laboratory or at the landing ports.

2.8.1. Crabs

For the four target crabs sampled, the carapace length (cm) and body weight (g) of specimens were measured in the laboratory. The carapace width (CW) was measured as the line distance between the two tips of the most lateral carapace spines, while the carapace length (CL) was measured dorsally along the midline between the frontal notch and the posterior margin of the carapace (Fig. 5). The sex was determined based on the variation of abdomen (Fig. 6).

The spawning season of crabs is determined by the appearance of the females bearing eggs

(Fig. 7). Gonads develop within the carapaces of female and male crabs. When ovaries mature, the eggs are released and attached to the belly of the females; meanwhile the eggs are fertilized then further develop until the larvae hatch and enter sea.

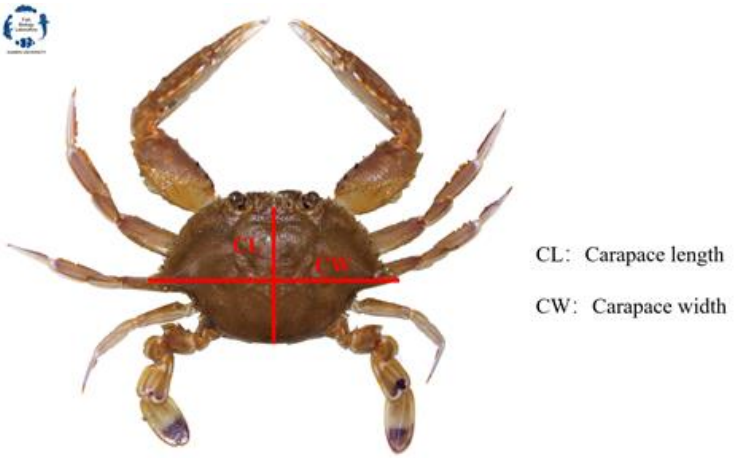

Fig. 5. Crab measurement for carapace length in laboratory.

Fig. 6. Sex determination for crabs.

Fig. 7. Female crab bearing eggs.

2.8.2. Dominant species in catches

For dominant species in catches, sizes were estimated directly at the landing ports by deploying a ruler on the top of catches and subsequently by taking photos. Size estimation was conducted by displaying photos in the computer screen for measurement.

2.8.3. Feed fishes

For fishes, crustaceans and cephalopods in feed fishes, measurements were also conducted individually for length (in cm) and body weight (in g), maximum 30 individuals each species per batch.

3. Results

3.1. Species diversity

3.1.1. Species composition

In Dongshan County, totally 265 species were identified from trawl and trap fisheries between August 2018 and April 2019, including 204 fishes (76.98%), 43 crustaceans (16.23%) and 18 cephalopods (6.79%) (Table 3). Fishes come from two classes (Chondrichthyes and Actinopterygii), 16 orders and 76 families, with more than half of the fish species from Perciformes. Crustaceans come from two orders and nine families, and cephalopods from two orders and four families.

Among 265 species, 238 species were found in trawl fishery including 177 fishes, 43 crustaceans and 18 cephalopods, while 89 species were found in trap fishery including 75 fish species, 8 crustaceans and 6 cephalopods (Table 3). There are 61 species, including 47 fishes, 8 crustaceans and 6 cephalopods, were found in both trawl and trap fisheries (Table 3).

In Longhai County, totally 15 species (2 fishes, 11 crustaceans, 2 cephalopods) were identified from trap fishery in January-April 2019, with additional three species groups, including groupers (fishes), mantis shrimps (crustaceans) and snails (gastropods) (Table 4).

Table 3. Species recoded (N=265) in trawl and trap fisheries in August 2018-April 2019 in Dongshan County.

(Note: the table combined the results of the Phase I report)

Order	Family	Species	Common Name	No.	Trawl	Trap
Fishes						
Carcharhiniformes	Carcharhinidae	*Scoliodon macrorhynchos*	Spadenose shark	1	+	
		Carcharhinus sorrah	Spot-tail shark	2	+	
		Galeocerdo cuvier	Tiger shark	3	+	
	Shpyrnidae	*Sphyrna lewini*	Scalloped hammerhead	4	+	
	Scyliorhinidae	*Halaelurus buergeri*	Blackspotted catshark	5	+	
	Triakidae	Mustelus griseus	Spotless smooth-hound	6	+	
Torpediniformes	Narcinidae	Narcine lingula	Chinese numbfish	7	+	
Rajiformes	Rhinobatidae	*Rhynchobatus djiddensis*	Giant guitarfish	8	+	
	Rhinobatidae	*Rhinobatos hynnicephalus*	Angel fish	9	+	
	Rajidae	*Okamejei boesemani*	Boeseman's skate	10	+	
Myliobattiformes	Platyrhinidae	*Platyrhina sinensis*	Chinese fanray	11	+	+
	Dasyatidae	*Dasyatis akajei*	Red stingray	12	+	
		Taeniura meyeni	Round ribbontail ray	13	+	
	Gymnuridae	*Gymnura japonica*	Japanese butterflyray	14	+	
Anguiliformes	Muraenidae	*Gymnothorax reticularis*	Moray eel	15	+	+

		Gymnothorax niphostigmus	Snowflake-patched moray	16		+
		Gymnothorax flavimarginatus	Yellow-edged moray	17		+
		Gymnothorax cribroris	Sieve-patterned moray	18	+	+
		Gymnothorax albimarginatus	Whitemargin moray	19		+
		Gymnpthorax prionodon	Australian mottled moray	20		+
	Ophichthidea	*Xyrias chioui*	Snake eel	21	+	
		Apterichtus hatookai	Orange blotched eel	22	+	
		Callechelys kuro	Black ridge-fin eel	23	+	
		Pisodonophis cancrivorus	Longfin snake-eel	24	+	
		Caecula pterygera	Finny snake eel	25	+	
	Congridae	*Conger japonicus*	Beach conger	26	+	+
		Gnathophis heterognathos	Shorttail pike conger	27	+	
		Conger myriaster	Whitespotted conger	28		+
	Muraenesocidae	*Muraenesox cinereus*	Daggertooth pike conger	29	+	+
		Uroconger lepturus	Slender conger	30	+	
		Oxyconger leptognathus	Shorttail pike conger	31	+	
Clupeiformes	Clupeidae	*Nematalosa nasus*	Bloch's gizzard shad	32	+	
		Sardinella aurita	Round sardinella	33	+	+
	Engraulidae	*Engraulis japonicus*	Japanese anchovy	34	+	

Siluriformes	Ariidae	*Arius arius*	Threadfin sea catfish	35	+	
		Arius maculatus	Spotted catfish	36	+	
		Plotosus lineatus	Striped eel catfish	37	+	
Aulopiformes	Synodontidae	*Saurida elongata*	Slender lizardfish	38	+	+
		Saurida tumbil	Greater lizardfish	39	+	+
		Trachinocephalus myops	Snakefish	40	+	+
Gadiformes	Bregmacerotidae	*Bregmaceros* sp.	Codlet	41	+	
Ophidiiformes	Ophidiiae	*Brotula multibarbata*	Goatsbeard brotula	42		+
Mugiliformes	Mugilidae	*Mugil cephalus*	Flathead grey mullet	43	+	
		Moolgarda cunnesius	Longarm mullet	44	+	
Gasterosteiformes	Pegasidae	*Pegasus laternarius*	Brick seamoth	45	+	
	Syngnathidae	*Halicampus grayi*	Gray's pipefish	46	+	
		Hippocampus kuda	Spotted seahorse	47	+	
		Hippocampus trimaculatus	Longnose seahorse	48	+	
		Trachyrhamphus serratus	Rough pipefish	49	+	
		Fistularia commersonii	Bluespotted cornetfish	50	+	
		Fistularia petimba	Red cornetfish	51	+	
		Halicampus grayi	Gray's pipefish	52	+	
Scorpaeniformes	Scorpaenidae	*Apistus carinatus*	Ocellated waspfish	53	+	

		Dendrochirus bellus	Bricked firefish	54	+	
		Minous monodactylus	Grey stingfish	55	+	
		Sebastiscus marmoratus	False kelpfish	56	+	+
		Scorpaenopsis macrochir	Flasher scorpionfish	57	+	+
		Scorpaena miostoma	Scorpionfish	58		+
		Scorpaenopsis cirrosa	Weedy stingfish	59	+	+
	Aploactinidae	*Aploactis aspera*	Dusky velvetfish	60	+	
	Triglidae	*Dactyloptena orientalis*	Oriental flying gurnard	61	+	
		Chelidonichthys spinosus	Spiny red gurnard	62	+	
		Lepidotrigla alata	Forksnout searobin	63	+	
		Lepidotrigla microptera	Redwing searobin	64	+	
	Platycephalidae	*Grammoplites scaber*	Rough flathead	65	+	+
		Platycephalus indicus	Bartail flathead	66	+	+
		Cociella crocodila	Crocodile flathead	67	+	
		Inegocia japonica	Japanese flathead	68	+	+
		Inegocia guttata	Crocodile flathead	69	+	
		Sorsogona tuberculata	Tuberculated flathead	70	+	
Perciformes	Mornidae	*Lateolabrax japonicus*	Japanese seabass	71	+	
	Serranidae	*Diploprion bifasciatum*	Barred soapfish	72	+	

	Epinephelidae	*Cephalopholis boenak*	Chocolate hind	73	+	+
		Cephalopholis sonnerati	Tomato grouper	74		+
		Epinephelus akaara	Hong Kong grouper	75	+	+
		Epinephelus areolatus	Areolate grouper	76	+	
		Epinephelus awoara	Yellow grouper	77	+	+
		Epinephelus bleekeri	Duskytail grouper	78	+	+
		Epinephelus bruneus	Longtooth grouper	79	+	
		Epinephelus coioides	Orange-spotted grouper	80	+	+
		Epinephelus quoyanus	Longfin grouper	81	+	+
		Triso dermopterus	Oval grouper	82	+	+
	Priacanthidae	*Priacanthus tayenus*	Purple-spotted bigeye	83	+	+
		Priacanthus macracanthus	Red bigeye	84	+	+
		Pristigenys niphonia	Japanese bigeye	85	+	+
	Apogonidae	*Apogon semilineatus*	Half-lined cardinal	86	+	
		Apogon cathetogramma	Cardinalfish	87	+	+
		Apogon lineatus	Indian perch	88	+	
		Apogon niger	Cardinalfish	89	+	
		Ostorhinchus fasciatus	Broadbanded cardinalfish	90	+	
	Sillaginidae	*Sillago sihama*	Silver sillago	91	+	+

		Sillago japonica	Japanese sillago	92	+	+
	Coryphaenidae	*Coryphaena hippurus*	Common dolphinfish	93	+	
	Rachycentridae	*Rachycentron canadum*	Cobia	94	+	
	Echeneidae	*Remora remora*	Shark sucker	95	+	
	Carangoides	*Parastromateus niger*	Black pomfret	96	+	
		Selaroides leptolepis	Yellowstripe scad	97	+	
		Decapterus maruadsi	Japanese scad	98	+	
		Trachurus japonicus	Japanese jack mackerel	99	+	+
		Seriola aureovittata	Yellowtail amberjack	100	+	+
		Seriola nigrofasciata	Blackbanded trevally	101	+	
		Alectis ciliaris	African pompano	102	+	
	Menidae	*Mene maculata*	Moonfish	103	+	
	Leiognathidae	*Equulites rivulatus*	Ponyfish	104	+	
		Secutor ruconius	Deep pugnose ponyfish	105	+	
	Lutjanidae	*Lutjanus russellii*	Russell's snapper	106	+	
		Lutjanus vitta	Brownstripe red snapper	107		+
		Lutjanus erythopterus	Crimson snapper	108	+	
		Lutjanus ophuysenii	Spotstripe snapper	109		+
	Haemulidae	*Hapalogenys analis*	Broadbanded velvetchin	110	+	+

		Parapristipoma trilineatum	Chicken grunt	111	+	+
		Plectorhinchus pictus	Trout sweetlips	112	+	
		Plectorhinchus cinctus	Crescent sweetlips	113	+	
	Nemipteridae	*Nemipterus japonicus*	Japanese threadfin bream	114		+
		Scolopsis vosmeri	Whitecheek monocle bream	115		+
		Parascolopsis inermis	Unarmed dwarf monocle bream	116		+
	Lethrinidae	*Lethrinus atkinsoni*	Pacific yellowtail emperor	117	+	
		Lethrinus nebulosus	Spangled emperor	118		+
	Sparidae	*Acanthopagrus latus*	Yellowfin seabream	119	+	
		Evynnis cardinalis	Threadfin porgy	120	+	+
		Rhabdosargus sarba	Goldlined seabream	121	+	+
	Polynemidae	*Eleutheronema tetradactylum*	Fourfinger threadfin	122	+	
	Sciaenidae	*Argyrosomus japonicus*	Japanese meagre	123	+	
		Johnius distinctus	Croaker	124	+	
		Johnius trewavasae	Trewavas croaker	125	+	
		Nibea albiflora	Yellow drum	126	+	
		Pennahia macrocephalus	Big-head pennah croaker	127	+	
		Pennahia anea	Truncate-tail croaker	128	+	

		Chrysochir aureus	Reeve's croaker	129	+	
	Mullidae	*Upeneus japonicus*	Japanese goatfish	130	+	+
		Parupeneus spilurus	Blackspot goatfish	131	+	+
		Parupeneus chrysopleuron	Yellow striped goatfish	132		+
	Glaucosomatidae	*Glaucosoma buergeri*	Deepsea jewfish	133	+	
	Kyphosidae	*Microcanthus strigatus*	Stripey	134		+
	Terapontidae	*Terapon jarbua*	Jarbua terapon	135	+	
		Pelates quadrilineatus	Fourlined terapon	136		+
	Drepaneidae	*Drepane punctata*	Spotted sicklefish	137	+	
	Chaetodontidae	*Heniochus acuminatus*	Pennant coralfish	138	+	
	Pomacanthidae	*Chaetodontoplus septentrionalis*	Bluestriped angelfish	139	+	
	Oplegnathidae	*Oplegnathus fasciatus*	Barred knifejaw	140	+	
	Pomacentridae	*Teixeirichthys jordani*	Jordan's damsel	141	+	
		Pomacentrus sp.1	Damsel fish	142	+	
		Pomacentrus sp.2	Damsel fish	143	+	
	Labridae	*Bodianus masudai*	Pacific Redstripe Hogfish	144	+	+
		Choerodon azurio	Scarbreast tuskfin	145		+
		Coris musume	Japanischer kammjunker	146		+
		Parajulis poecilepterus	Multicolorfin rainbowfish	147	+	+

		Pseudolabrus eoethinus	Red naped wrasse	148		+
		Pseudolabrus eoethinus	Red naped wrasse	149		+
		Scarus ghobban	Blue-barred parrotfish	150	+	+
		Suezichthys gracilis	Slender wrasse	151	+	
		Xyrichtys dea	Blackspot razorfish	152	+	
		Xyrichtys twistii	Twistii Razorfish	153	+	
		Xyrichtys verrens	Rosed razorfish	154	+	+
	Pinguipedidae	*Parapercis ommatura*	Sandperch	155	+	
		Parapercis puplchella	Harlequin sandsmelt	156	+	
		Parapercis sexfasciata	Grub fish	157	+	+
	Callionymidae	*Bathycallionymus kaianus*	Kai Island deepwater dragonet	158	+	
		Callionymus curvispinis	Izu ruddertail dragonet	159	+	
		Calliurichthys japonicus	Japanese dragonet	160	+	
	Trichonotidae	*Trichonotus setiger*	Spotted sand-diver	161	+	
		Trichonotus filamentosus	Black-spot sand diver	162	+	
	Percophidae	*Acanthaphritis barbata*	Duckbill	163	+	
	Ammodytidae	*Bleekeria mitsukurii*	Sand lance	164	+	
		Bleekeria viridianguilla	Sand lance	165	+	
	Uranoscopidae	*Uranoscopus bicinctus*	Marbled stargazer	166	+	

		Uranoscopus chinensis	Chinese stargazer	167	+	
	Gobiidae	*Amblychaeturichthys hexanema*	Goby	168	+	
	Siganidae	*Siganus fuscescens*	Mottled spinefoot	169	+	+
	Sphyraenidae	*Sphyraena flavicauda*	Yellowtail barracuda	170	+	
		Sphyraena japonica	Japanese barracuda	171	+	
	Trichiuridae	*Trichiurus japonicus*	Largehead hairtail	172	+	
		Trichiurus sp.	Hairtail fish	173	+	
	Scombridae	*Scomber japonicus*	Chub mackerel	174	+	+
		Scomberomorus niphonius	Japanese Spanish mackerel	175	+	
		Sarda orientalis	Striped bonito	176	+	
Pleuronectiformes	Paralichthyidae	*Pseudorchombus arsius*	Largetooth flounder	177	+	
		Pseudorhombus cinnamoneus	Cinnamon flounder	178	+	
		Pseudorhombus oligodon	Roughscale flounder	179	+	
	Bothidae	*Bothus myriaster*	Indo-pacific oval flounder	180	+	
		Engyprosopon grandisquama	Largescale flounder	181	+	
		Engyprosopon filipennis	Flatfishes	182	+	
		Engyprosopon multisquama	Flatfishes	183	+	
		Crossorhombus azureus	Blue flounder	184	+	
	Soleidae	*Liachirus melanospilus*	Blackspotted sole	185	+	

		Solea ovata	Ovate sole	186	+	
		Zebrias crossolepis	Sole	187	+	
		Zebrias zebra	Zebra sole	188	+	
	Pleuronectidae	*Pleuronichthys cornutus*	Ridged-eye flounder	189	+	
	Cynoglossidae	*Cynoglossus abbreviatus*	Three-lined tongue sole	190	+	
		Cynoglossus puncticeps	Speckled touguesole	191	+	
		Cynoglossus oligolepis	Touguesole	192	+	
		Cynoglossus sp.	Touguesole	193	+	
		Paraplagusia japonica	Black cow-tongue	194	+	
Tetraodontiformes	Monacanthidae	*Aluterus monoceros*	Unicorn leatherjacket filefish	195	+	+
		Chaetodermis penicilligerus	Prickly leatherjacket	196	+	+
		Stephanolepis cirrhifer	Threadsail filefish	197	+	+
	Tetraodontidae	*Paramonacanthus pusillus*	Japanese leatherjacket	198	+	+
		Lagocephalus wheeleri	Blowfish	199	+	+
		Takifugu oblogus	Lattice blaasop	200	+	+
		Takifugu xanthopterus	Yellowfin puffer	201		+
		Takifugu poecilonotus	Pufferfish	202	+	+
	Balistidae	*Abalistes stellaris*	Starry triggerfish	203		+
		Sufflamen fraenatum	Masked triggerfish	204		+

Crustaceans						
Stomatopoda	Squillidae	*Lysiosquilla sulcirostris*	Orange & White mantis shrimp	205	+	
		Oratosquilla oratoria	Japanese squillid mantis shrimp	206	+	
		Oratosquilla kempi	Mantis Shrimp	207	+	
		Odontodactylus japonicus	Mantis Shrimp	208	+	
		Harpiosquilla harpax	Mantis Shrimp	209	+	
		Lophosquilla costata	Mantis Shrimp	210	+	
		Lophosquilla sp.	Mantis Shrimp	211	+	
Decapoda	Solenocerdae	*Solenocera carssicornis*	Udang merah	212	+	
	Penaeidae	*Panaeus canaliculatus*	King prawn	213	+	
		Panaeus latisulcatus	Western king prawn	214	+	
		Panaeus longistylus	King prawn	215	+	
		Panaeus japonicus	Kuruma shrimp	216	+	
		Panaeus monodon	Giant tiger prawn	217	+	
		Parapenaeopsis hardwickii	Spear shrimp	218	+	
		Parapenaeopsis cornuta	Coral shrimp	219	+	
		Trachypenaeus curvirostris	Southern rough shrimp	220	+	
		Metapenaeopsis barbata	Velvet shrimp	221	+	
		Metapenaeopsis palmensis	Velvet shrimp	222	+	

		Metapenaeopsis lamellata	Elvet shrimp	223	+	+
	Caridae	*Leptochela gracilis*	Lesser glass shrimp	224	+	
		Birulia kishinouyei	Glass shrimp	225	+	
	Porcellanidae	*Porcellana* sp.	Porcelain crab	226	+	
	Raninidae	*Ranina ranina*	The red frog crab	227	+	
	Leucosiidae	*Leucosia* sp.	Crab	228	+	
	Calappidae	*Cycloes granulosa*	Bread crab	229	+	
		Calappa philargius	Bread crab	230	+	
		Calappa lophos	Bread crab	231	+	
		Matuta lunaris	Yellow moon crab	232	+	
	Portunidae	*Charybdis miles*	Soldier swimming crab	233	+	
		Charybdis variegata	Swimming crab	234	+	
		Charybdis bimaculata	Swimming crab	235	+	
		Charybdis sagamiensis	Swimming crab	236	+	
		Charybdis amboinensis	Swimming crab	237	+	
		Charybdis hellerii	Mud crab	238	+	
		Charybdis acuta	Swimming crab	239	+	
		Charybdis feriatus	Crucifix crab	240	+	
		Charybdis nataor	Rock crab	241	+	

		Portunus sanguinolentus	Three-spot swimming crab	242	+	
		Portunus pelagicus	Flower crab	243	+	
		Portunus trituberculatus	Japanese blue crab	244	+	
		Portunus hastatoides	Swimming crab	245	+	
		Portunus haanii	Chinese swimming crab	246	+	
		Portunus gracilimanus	Swimming crab	247	+	
Cepholopods						
Teuthoidea	Loliginidae	*Loligo chinensis*	Southern dumpling squid	248	+	
		Loligo oshimai	Squid	249	+	
		Loligo japonicus	Squid	250	+	
		Loligo duvaucelii	Indian squid	251	+	
		Loligo sp.	Squid	252	+	
		Heterololigo bleekeri	Loliginid squid	253	+	
		Sepioteuthis lessoniana	Bigfin reef squid	254	+	
Sepioidea	Sepiolidae	*Sepiola* sp.	Bobtail Squid	255	+	
		Euprymna berryi	Bobtail Squid	256	+	
	Sepiidae	*Sepiella maindroni*	Spineless cuttlefish	257	+	+
		Sepia aculeata	Needle cuttlefish	258	+	
		Sepia Lycidas	Kisslip cuttlefish	259	+	+

		Sepia pharaonic	Pharaoh cuttlefish	260	+	+
	Octopodinae	*Octopus variabilis*	Whiparm octopus	261	+	+
		Octopus ocellatus	Webfoot octopus	262	+	+
		Octopus aegina	Octopus	263	+	+
		Octopus dolliusi	Marbled octopus	264	+	
		Hapalochlaena lunulata	Greater blue-ringed octopus	265	+	

Table 4. Species (N = 15) and species groups (N = 3) recoded in trap fishery in January-April 2019 in Longhai County.

Order	Family	Species/Species group	No.
Fishes			
Scorpaeniformes	Scorpaenidae	*Sebastiscus marmoratus*	1
		Inimicus sp.	2
Perciformes	Epinephelidae	Groupers	3
Crustaceans			
Stomatopoda	Squillidae	Mantis shrimps	4
Decapoda	Calappidae	*Calappa lophos*	5
	Portunidae	*Portunus sanguinolentus*	6
		Portunus trituberculatus	7
		Portunus haanii	8
		Portunus pelagicus	9
		Charybdis variegata	10
		Charybdis bimaculata	11
		Charybdis japonica	12
		Charybdis feriatus	13
		Charybdis nataor	14
		Charybdis sp.	15
Cephalopods			
Sepioidea	Octopodinae	*Octopus ocellatus*	16
		Octopus sp.	17
Gastropods			
		Snails	18

3.1.2. ETP species

Three ETP (endangered, threatened and protected) species were observed, all from trawl fishery in Dongshan County, including the Scalloped hammerhead shark *Sphyrna lewini*, the Longnose seahorse *Hippocampus trimaculatus* and the spotted seahorse *Hippocampus kuda* (Table 3; Fig. 8; Fig. 9).

Sphyrna lewini was listed in CITES Appendix II in 2014, and as “Endangered” in the International Union for Conservation of Nature (IUCN) Red List in 2007. As a by-

catch species, *S. lewini* had a low occurrence at the landing ports of Dongshan County (Fig. 8); only six individuals from two trawl vessels were found, all observed in October 2018 surveys, and sold to the local markets for food.

Fig. 8. Scalloped hammerhead shark *Sphyrna lewini* found in Dongshan County trawl fishery in October 2018.

Hippocampus trimaculatus and *H. kuda* were listed in CITES Appendix II in 2002, and as "Vulnerable" in IUCN Red List in 2012. In Dongshan County, *H. trimaculatus* is the absolutely dominant landing species in seahorse catches from trawl fishery throughout the entire survey period in August 2018-April 2019 (Fig. 9), and *H. kuda* mixed with *H. trimaculatus* in seahorse catches, only found in April 2019 (Fig. 9).

The seahorse whole prices of wet weight are approximately 1,600-2,000 RMB/kg (220-280 USD/kg) at landing ports, revealing its unit price is the highest among all capture species. Up to 20% of trawl vessels had *H. trimaculatus* catches during landing port surveys in August-December 2018, and the proportions increased to nearly 47% in January-April 2019. Seahorse catch volumes were between 1 and 50 kg wet weight/vessel/trip in August-December 2018, while in January-April 2019, the average seahorse catch volumes were about 5.32 kg wet weight/vessel/trip (1-30 kg wet weight/vessel/trip).

Fig. 9. Longnose seahorse *Hippocampus trimaculatus* (left) and spotted seahorse *H. kuda* (right) found in Dongshan County trawl fishery.

3.2. Number of fishing vessels surveyed at the landing ports

In January-April 2019, totally 48 vessels were surveyed at the landing ports of Dongshan County, including 30 trawl vessels and 18 trap vessels. Only three trap vessels were surveyed in April because of the low occurrence.

In Longhai County, only one trap vessel was surveyed for continuous four months in January-April 2019, i.e. 5 trips/month.

3.3. Fishing areas—offshore and nearshore

Based on the captain and crew interviews, trawl and trap vessels from Dongshan County surveyed mainly operate in offshore fishing grounds, including Minnan Fishing Ground, Taiwan Bank Fishing Ground and Yuedong Fishing Ground within 117º-119º E and 22º-24º N or more extended (see the Phase I report for the fishing area details) (Fig. 10).

Based on the interviews, trap vessels in Longhai County usually operate nearshore within 24°00'-24°30'N and 118°00-119°00'E (Fig. 10).

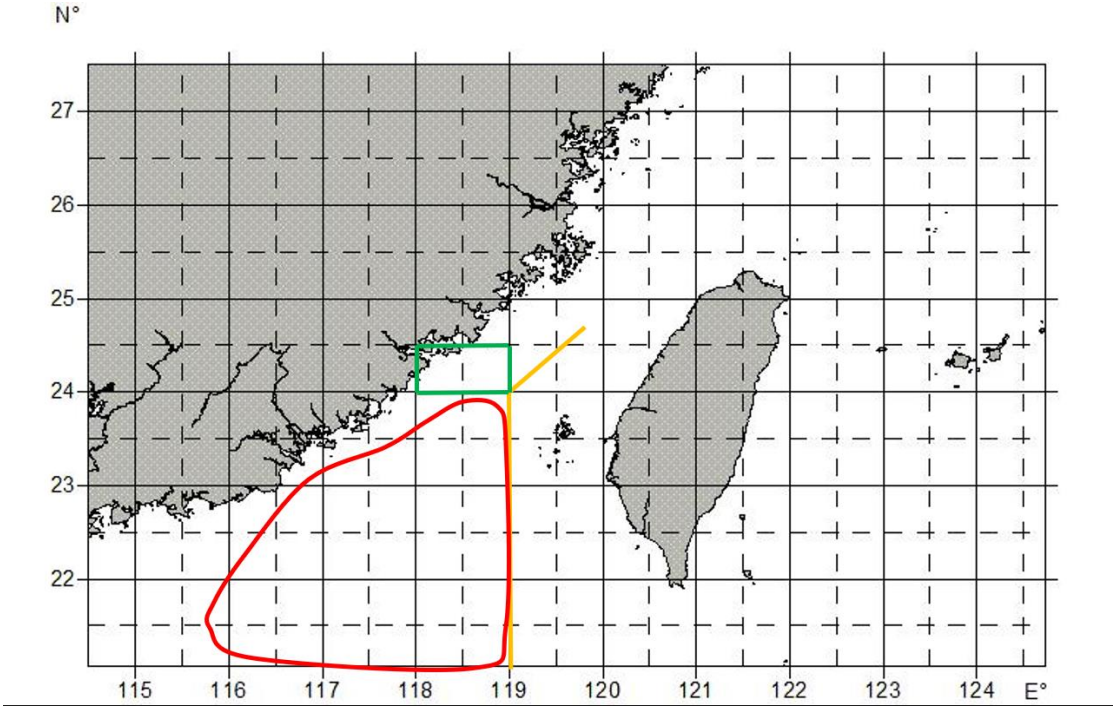

Fig. 10. Nearshore trap fishery in Longhai County (green line) and offshore trawl and trap fisheries in Dongshan County (red line). Yellow line shows the boundary between mainland China and Taiwan at sea, and no fishing vessels from mainland China are allowed to crossed it.

3.4. Crab trade modes

In Dongshan County, crab trade modes of the main four crab species, *Portunus haanii*, *P. sanguinolentus*, *Charybdis nataor* and *Calappa philargius*, are different, and have been documented in details in Phase I report and further confirmed in the present study (Table 5). Occasionally, a few other crab species were mixed with the four crab species (Table 5).

In Longhai County, all catches from trap vessels were kept alive and sold to the middle men at sea near the landing ports for domestic markets (Table 5). Eight crab species, *Portunus haanii*, *P. trituberculatus*, *P. pelagicus*, *P. sanguinolentus*, *Charybdis nataor*, *C. feriatus*, *C. japonica* and *Calappa philargius*, were separated and prices were different in terms of size and gonad maturity. Other catches, like fishes, manta shrimps, shrimps, cephalopods and snails were also sold alive to the middle men.

Table 5. Trade modes of four main crab species.

No.	Species	Dongshan County			Longhai County
		Trawl	Trap	Mixed species	Trap
1	*Portunus haanii*	Mainly to processing factories for canned food; A few to domestic markets.	Mainly to processing factories; A few to domestic markets.	*Charybdis miles* *C. sagamiensis*	To domestic markets and usually sold alive
2	*P. sanguinolentus*	To processing factories and iced for domestic markets;	To processing factories and iced for domestic markets;	*P. pelagicus* *P. trituberculatus* *Charybdis feriatus*	
3	*Charybdis nataor*	To processing factories and iced for domestic markets;	To domestic markets (sold at sea in live crab).	*Charybdis acuta* *C. amboinensis*	
4	*Calappa philargius*	Only claws sold to domestic markets; Body discarded sometimes.	Only claws landing and sold to domestic markets; Body discarded at sea.	*Calappa lophos*	

3.5. Operation patterns from different fishing areas and gears

Based on trawl vessels surveyed at the landing ports in Dongshan County in January-April 2019, they spent 3-9 days/trip at sea (mean = 6.37, N = 30) (Table 6). The variation of fishing days at sea highly depends on weather condition; however, most of trawl vessels surveyed spent 7-8 days/trip at sea when the weather is fine. The results are similar with the finding in the Phase I report (August-December 2019).

Based on trap vessels surveyed at the landing ports in Dongshan County in January-April 2019, the catches from trap vessels were delivered by transfer vessels every 1-10 days (mean = 4.17, N = 18), so that the trap vessels can operate at sea longer, up to 30 days/trip (Table 6).

Based on the fishing logbook of the only trap vessel surveyed in Longhai County in January-April 2019, they collected the catches every 1-3 days/trip (mean = 1.75, N = 20) (Table 6). The catches per trip were from 3,000 traps and operated at the depth of 15-25 m in the nearshore fishing grounds (see Fig. 10 above). All catches were kept alive for sale.

3.6. Capture volumes and proportions by trawl and trap in Dongshan County and Longhai County

3.6.1. Overall capture volumes and proportions of different taxonomic groups

Based on the trawl vessels surveyed in Dongshan County in January-April 2019 (Table 6):

(1) The most dominant capture taxonomic group was the fishes, contributed to 23.9~95.1% (mean 67.8%, average of 4,006.52 kg/trawl vessel/trip) of the estimated total capture volume.

(2) About one third of the fish capture were the feed fishes (average of 1,471.00 kg/trawl vessel/trip), contributed to 23.6% of the total capture volume.

(3) The average total crustacean capture volume (868.38 kg/trawl vessel/trip) contributed to 18.8% of the estimated average total capture volume (average of 5,369.57 kg/trawl vessel/trip), with the estimated average 403.22 kg/trawl vessel/trip (8.3%) for crab capture volume and 438.17 kg/trawl vessel/trip (10.2%) for shrimp capture volume.

(4) The average total cephalopod capture volume was 441.67 kg/trawl vessel/trip, which contributed to 10.8% of the estimated total capture volume.

Based on the trap vessels surveyed in Dongshan County in January-April 2019 (Table 6):

(1) The total fish capture volume contributed to 22.0%~98.2% (mean 53.0%, average of

682.50 kg/trap vessel/trip) of the estimated total capture volume, the highest among taxonomic groups.

(2) The estimated average total crustaceans (only crabs) capture volume (762.78 kg/trap vessel/trip) contributed to 39.4% of the estimated average total capture volume (1,755.5 kg/trap vessel/trip) in trap fishery.

(3) Average total cephalopod capture volume (77.19 kg/trap vessel/trip) contributed to 6.6% of the estimated total capture volume.

Based on the only trap vessel surveyed in Longhai County in January-April 2019 (Table 6):

(1) Up to 86.2% of the estimated average total capture (114.21 kg/trap vessel/trip) were crustaceans, with 83.3% were crabs (average of 98.57 kg/trap vessel/trip) and 2.9% were mantis shrimps (average of 2.54 kg/trap vessel/trip).

(2) The rest catches were the fishes, cephalopods and snails, contributed to 2.4%, 0.5% and 8.6% of the estimated average total capture volume, respectively.

Table 6. Operation patterns, capture volumes and proportions from trawl and trap vessels surveyed in January-April 2019 at the landing ports of Dongshan County and Longhai County.

	Dongshan County (Range, mean, N=sample size)			**Longhai County** (Range, mean, N=sample size)	
	Trawl		**Trap**	**Trap**	
Fishing days per trip	3~9 (Mean=6.37, N=30)		1~10 (Mean=4.17, N=18)	1~3 (Mean=1.75, N=20)	
Average total capture volume per trip (kg/vessel/trip)	5369.57 (N=30)		1526.64 (N=18)	114.21 (N=20)	
Average total crustacean capture volume per trip (kg/vessel/trip)	Shrimps	Crabs	Crabs	Mantis shrimps	Crabs
	438.17 (N=30)	403.22 (N=30)	762.78 (N=18)	2.54 (N=20)	98.55 (N=20)
	868.38 (N=30)			101.09 (N=20)	
Total crustacean volume/total capture volume (%)	Shrimps	Crabs	Crab	Mantis shrimps	Crab
	10.2% (N=30)	8.3% (N=30)	39.4% (N=18)	2.9% (N=20)	83.3% (N=20)
	18.8% (N=30)			86.2% (N=20)	
Average total fish capture volume per trip (kg/vessel/trip)	4006.52 (N=30)		682.50 (N=18)	2.25 (N=20)	
Total fish volume/total capture volume (%)	23.9~95.1% (Mean=67.8%, N=30)		22.0~98.2% (Mean=53.0%, N=18)	2.4% (N=20)	
Average total feed fish capture volume	1471.00 (N=30)		-	-	

per trip (kg/vessel/trip)			
Total feed fish volume/total capture volume (%)	23.6% (N=30)	-	-
Average total cephalopod capture volume per trip (kg/vessel/trip)	441.67 (N=30)	77.19 (N=18)	0.25 (N=20)
Total cephalopod volume/total capture volume (%)	10.8% (N=30)	6.6% (N=18)	0.4% (N=20)
Average total snail capture volume per trip (kg/vessel/trip)	-	-	7.89 (N=20)
Total snail volume/total capture volume (%)	-	-	8.6% (N=20)

3.6.2. Crabs

3.6.2.1. Overall

The crab capture volume proportions in total capture volumes of trawl and trap fisheries in Dongshan County in August 2018-April 2019 and of trap fishery in Longhai County in January-April 2019 were analyzed and showed monthly variation (Fig. 11):

(1) Crab proportions in total capture volumes of trawl fishery in Dongshan County were about 14.5-25.6% in August 2018-January 2019 with the highest in December 2018 (25.6%). Subsequently, crab proportions declined largely from January 2019 (15.5%) to April 2019 (3.3%).

(2) The differences on crab capture proportions between trawl and trap fishing gears in Dongshan County were significant. Trap provided significantly higher proportions on crab catches (46.2-62.8%) than those of trawl (3.3-15.5%) in January-April 2019, except in March.

(3) The differences on crab capture proportions in trap fishery between different fishing grounds (see Section 3.3) were significant in January-April 2019. Nearshore (Longhai County) crab capture proportions (78.2-87.3%) were significant higher than those of offshore (Dongshan County in Taiwan Bank fishing grounds) (7.1-62.8%).

3.6.2.2. *Portunus haanii*

Portunus haanii capture volumes and proportions in total capture volumes were further analyzed, and showed monthly variation between two fishing gears (i.e. trawl and trap) in Dongshan County, and showed variation between different fishing grounds (nearshore and offshore) using the same type of fishing gear—trap (Table 7; Fig. 11; Fig. 12; Fig. 13):

(1) The *P. haanii* proportions in total capture volumes for trawl fishery in Dongshan County were about 9.2-19.7% in August 2018-January 2019 with the highest in August 2018 (19.7%). Subsequently, *P. haanii* proportions declined gradually from January 2019 (13.2%) to April 2019 (2.3%). The *P. haanii* proportions in total capture volumes in trap fishery in Dongshan County remained high (28.1-43.7%) in January-April 2019, except in March (4.5%).

(2) *Portunus haanii* was the dominant species in crab catches of trawl and trap fisheries in Dongshan County. Among the estimated average total crab capture volume of 403.22 kg/trawl vessel/trip in trawl fishery, *P. haanii* was 327.00 kg/trawl vessel/trip, *P. sanguinolentus* was 47.67 kg/trawl vessel/trip, *C. nataor* was 13.88 kg/trawl

vessel/trip and *C. philargius* was 14.67 kg/trawl vessel/trip, contributed to 6.7%, 1.0%, 0.3% and 0.4% of the total capture volume, respectively. Among the estimated average total crab capture volume of 762.78 kg/trap vessel/trip in trap fishery, *P. haanii* was 513.06 kg/trap vessel/trip, *P. sanguinolentus* was 105.00 kg/trap vessel/trip and *C. philargius* was 144.72 kg/trap vessel/trip, which contributed to 28.4%, 4.2% and 6.8% of the total capture volume, respectively. No *C. nataor* was found in trap vessels.

(3) *Portunus haanii* was not the dominant specie in trap fishery in Longhai County. The estimated average total crab capture volume was 98.55 kg/trap vessel/trip in January-April 2019, with 1.59 kg/trap vessel/trip *P. haanii*, 1.68 kg/trap vessel/trip *P. sanguinolentus*, 0.69 kg/trap vessel/trip *C. nataor* and 2.76 kg/trap vessel/trip *C. philargius*, which contributed to low proportions in Longhai's trap fishery, 2.0%, 2.1%, 0.8% and 3.1% of the total capture volume, respectively. Three crabs, *Charybdis japonica* (62.3%), *Portunus pelagicus* (7.0%) and *P. trituberculatus* (6.2%) were the dominant crab species in Longhai's trap fishery, contributed to 75.5% of the total capture volume.

(4) The capture volumes of *P. haanii* showed monthly variation in Dongshan County in trawl fishery in August 2018-April 2019. The capture volumes of *P. haanii* ranged from 109.50 to 1511.25 kg/vessel/trip (mean 761.81 kg/vessel/trip), declined gradually from the highest in August 2018 to the lowest in April 2019. Based on the average fishing days that the vessels surveyed through interviews at the landing ports, the average CPUE of *Portunus haanii* ranged from 102.76 to 179.06 kg/vessel/day (mean 102.76 kg/vessel/day), with the highest in August 2018 and the lowest in April 2019, and with a decline from January to April 2019.

(5) The capture volumes of *P. haanii* also showed monthly variation in Dongshan County in trap fishery in January-April 2019. The capture volume of *P. haanii* ranged from 17.00 to 818.75 kg/vessel/trip (mean 510.72 kg/vessel/trip), the highest in January and the lowest in March). The CPUE of *P. haanii* ranged from 5.67 to 192.65 kg/vessel/day (mean 116.37 kg/vessel/day), the highest in January and the lowest in March.

(6) The capture volumes of *P. haanii* was one of the few common crab species in Longhai County in trap fishery in January-April 2019. The capture volume of *P. haanii* ranged from 0.95 to 2.80 kg/vessel/trip (mean 1.61 kg/vessel/trip), the highest in January and the lowest in February). The CPUE of *P. haanii* ranged from 0.41 to 2.8 kg/vessel/day (mean 1.18 kg/vessel/day), the highest in January and the lowest in February.

(7) Trap fishery provided higher CPUE for *P. haanii* than that of trawl fishery in Dongshan

County.

(8) Trap fishery in Dongshan County provided much higher capture volume and CPUE for *P. haanii* than the trap fishery in Longhai County in January-April 2019.

Table 7. Four crab species capture volumes (kg) and proportions (%) in total capture volumes from different fishing areas and fishing gears in January-April 2019 (red bold: the dominant species or species group).

	Dongshan County				Longhai County	
Crab species	Trawl (N=30)		Trap (N=18)		Trap (N=20)	
	Volume (kg)	Proportion (%)	Volume (kg)	Proportion (%)	Volume (kg)	Proportion (%)
Portunus haanii	327.00	**6.7%**	513.06	**28.4%**	1.59	2.0%
P. sanguinolentus	47.67	1.0%	105.00	4.2%	1.68	2.1%
Charybdis nataor	13.88	0.3%	0.00	0.0%	0.69	0.8%
Calappa philargius	14.67	0.4%	144.72	6.8%	2.76	3.1%
Other crabs	0.00	0.0%	0.00	0.0%	91.85	**75.5%**
Total	403.22	8.3%	762.78	39.4%	98.57	83.3%

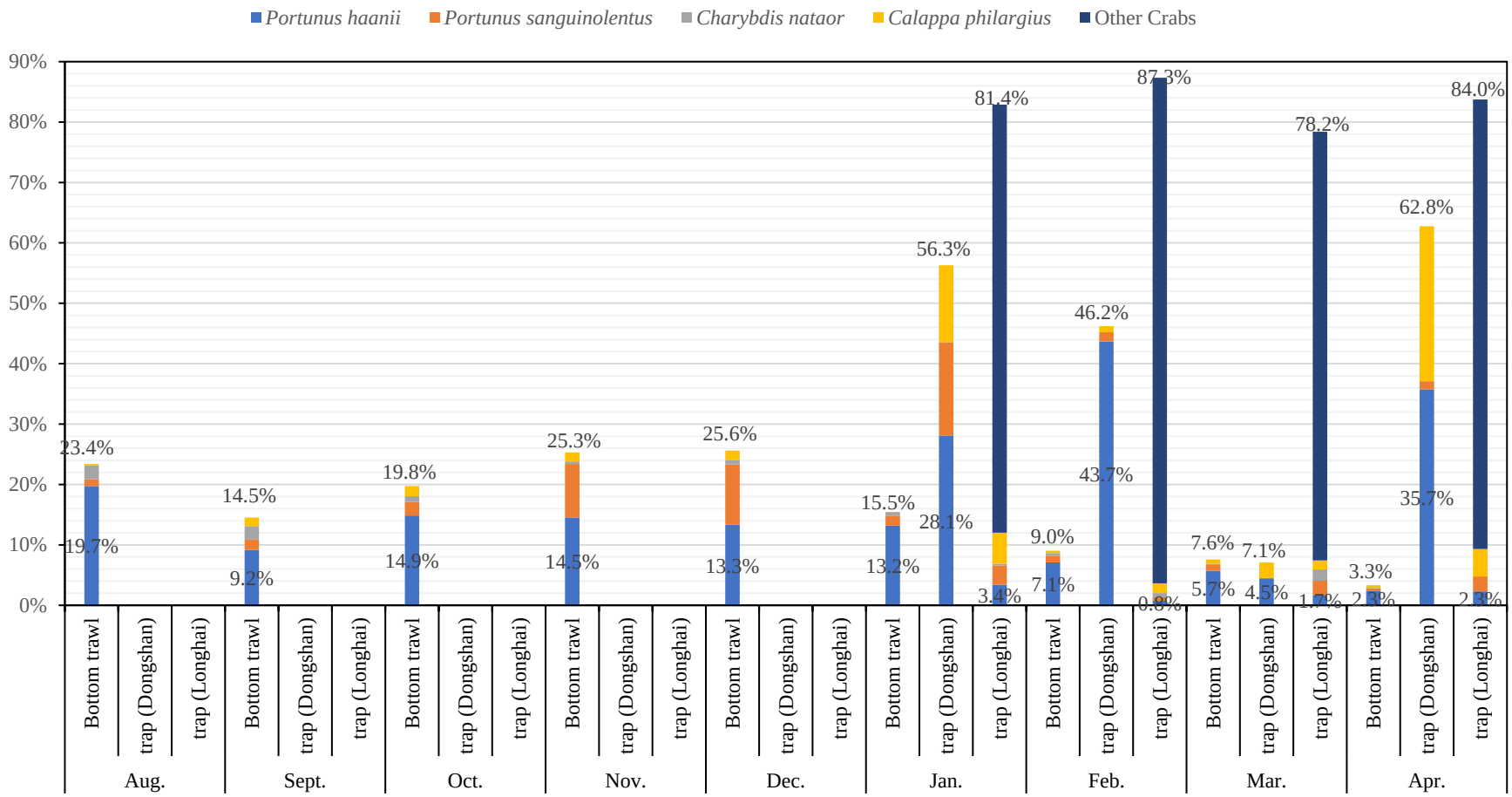

Fig. 11. Crab capture proportions (% shown at the tops of bars) in total capture volume from trawl and trap vessels surveyed at the landing ports of Dongshan County and Longhai County monthly in August 2018-April 2019. *Portunus haanii* capture proportions shown at the middle of blue bars.

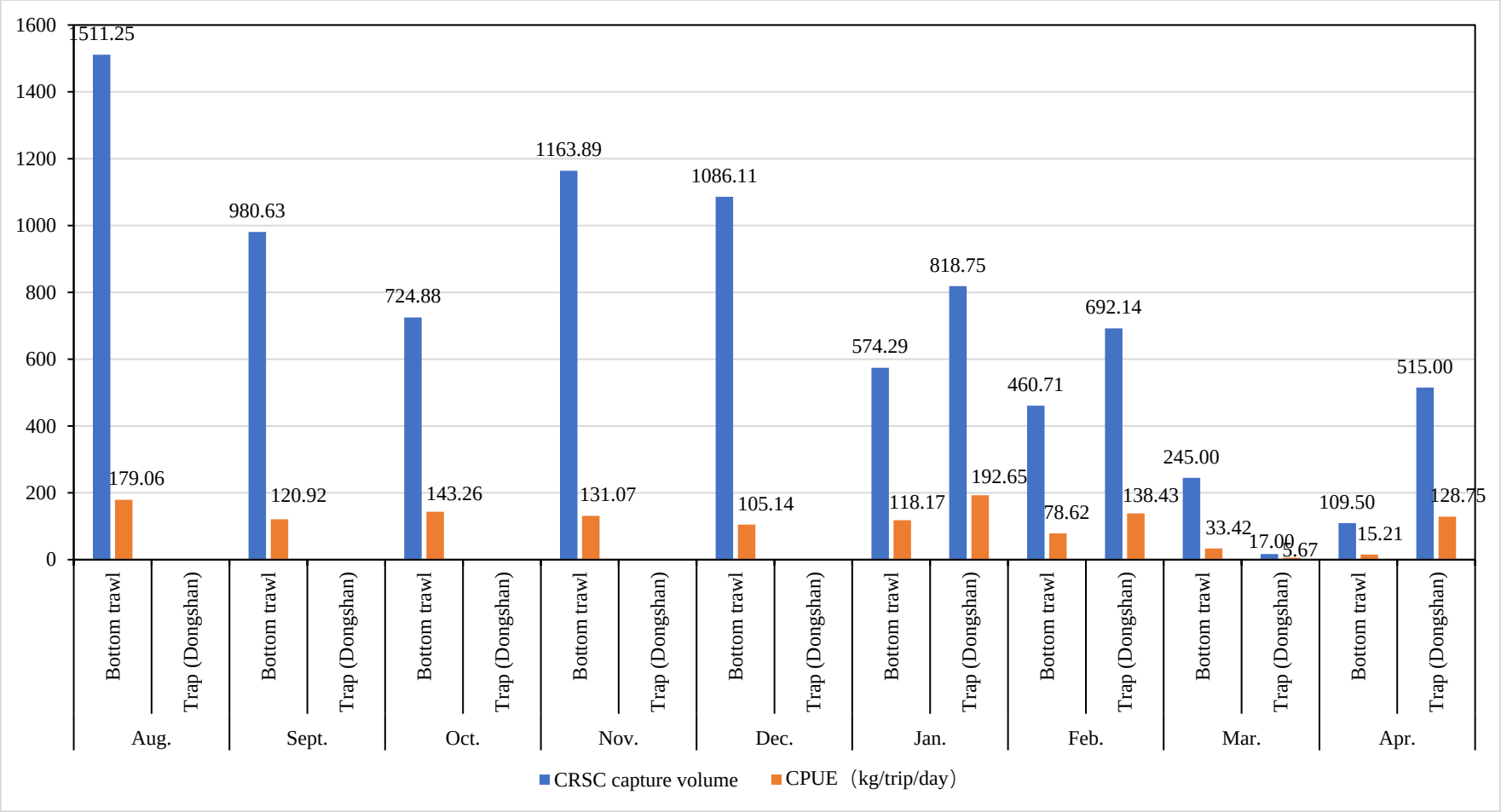

Fig. 12. Mouthly CPUE of *Portunus haanii* (kg/vessel/trip) (value shown at the tops of the blue bars) surveyed at the landing ports of Dongshan County in August 2018-April 2019 from trawl and trap fisheries (orange bars showed monthly CPUE of *P. haanii* in kg/vessel/day).

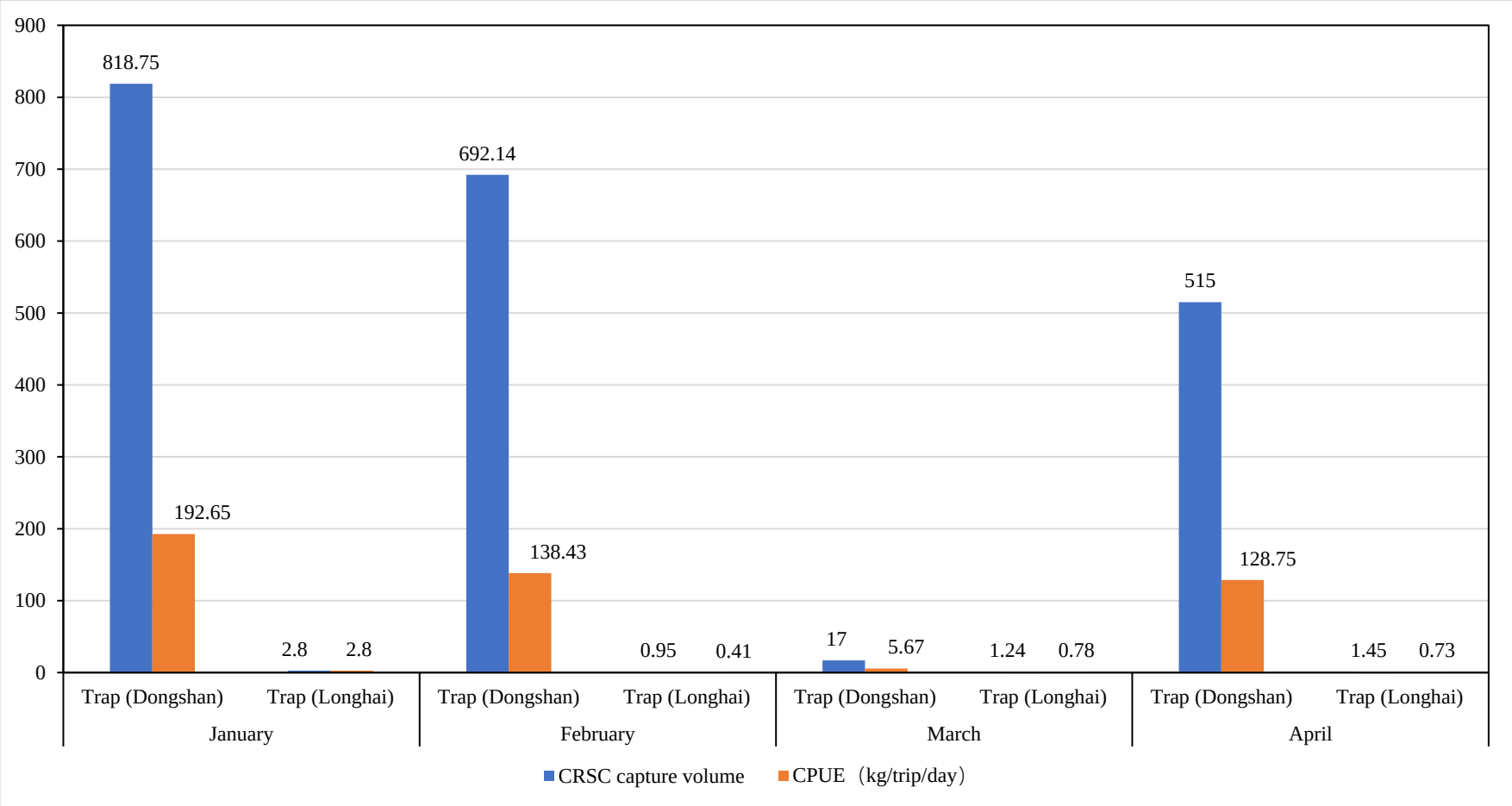

Fig. 13. Mouthly CPUE of *Portunus haanii* (kg/vessel/trip) (value shown at the tops of the blue bars) surveyed at the landing ports of Dongshan County and Longhai County in August 2018-April 2019 from trap fishery (orange bars showed monthly CPUE of *P. haanii* in kg/vessel/day).

3.6.3. Food fishes

The dominant food fish species or species groups in trawl fishery in Dongshan County were *Trachinocephalus myops*, *Saurida* spp., *Sillago sihama*, *Sillago japonica*, *Upeneus japonicus*, *Evynnis cardinalis*, *Trichonotus setiger*, *Acanthaphritis barbata* and *Bleekeria mitsukurii* (Table 8). Among these fish species, *Trachinocephalus myops* and *Saurida* spp., *Sillago sihama* and *Sillago japonica*, *Trichonotus setiger*, *Acanthaphritis barbata* and *Bleekeria mitsukurii* were usually mixed in catches. Dominant food fish species, capture proportions in the total capture volumes and their size ranges (SL in cm) showed monthly variation by different fishing gears (trawl and trap) in Dongshan County in January-April 2019 (Table 8).

Table 8. Dominant fish species or species groups in capture proportions of total capture volumes and their size ranges (SL, standard length in cm) in trawl and trap fisheries in Dongshan County in January-April 2019.
(Red bold: the dominant species or species group)

	January		February		March		April	
Fish species	Trawl (%, cm)	Trap (%, cm)	Trawl (%, cm)	Trap (%, cm)	Trawl (%, cm)	Trap (%, cm)	Trawl (%, cm)	Trap (%, cm)
Total fish%	56.6%	41.5%	79.5%	48.1%	59.2%	78.0%	72.5%	30.6%
Gymnothorax spp.						**18.0%** (30.6-80.9)		
Trachinocephalus myops & *Saurida* spp.	5.3% (13.3-25.2)		4.7% (8.3-26.8)		7.9% (2.2-34.2)			
Epinephelus awoara						**35.4%** (16.1-28.3)		
Sillago sihama & *S. japonica*	**12.7%** (8.0-14.2)				3.8% (8.5-12.4)		3.6% (12.3-15.2)	
Scolopsis				5.9%				

vosmeri				(10.5-15.5)				
Upeneus japonicus		1.1% (6.7-13.5)	2.4% (6.8-11.2)				3.6% (8.6-12.8)	4.1% (7.3-14.8)
Evynnis cardinalis	2.1% (7.5-12.5)	**35.8%** (7.3-15.7)		11.7% (10.5-15.5)				**11.4%** (10.2-16.3)
Choerodon azurio						8.5% (10.9-19.4)		
Trichonotus setiger, *Acanthaphritis barbata*, *Bleekeria mitsukurii*			**28.7%** (7.5-9.7)		**18.6%** (7.8-11.4)		**44.8%** (6.2-11.4)	
Takifugu poecilonotus		2.2% (11.4-25.4)						
Takifugu oblogus				6.3% (17.0-21.0)				9.2% (16.8-22.4)

3.6.4. Feed fishes

3.6.4.1. Proportions and species diversity of feed fishes

The “feed fishes” in this report were those small-sized, low-valued, poorly preserved, fishes (also including crustaceans and cephalopods), with their destination to aquaculture farms, mentioned by the captains of the trawl vessels surveyed. Based on the 30 trawl vessels surveyed at the landing ports of Dongshan County in January-April 2019, feed fishes contributed to 11.4~37.0% of the total fish catches (Fig. 14). In January, more than 50% of the fish catches were feed fishes.

Based on the random samplings (mean 1.67 kg/month, range of 0.87-2.25 kg) of

feed fishes at the landing ports of Dongshan County in January-April 2019, 91 species with 65 fishes, 20 crustaceans and 6 cephalopods were identified (Table 9). Among these, 49 species with 32 fishes, 13 crustaceans and 4 cephalopods were only found in feed fishes.

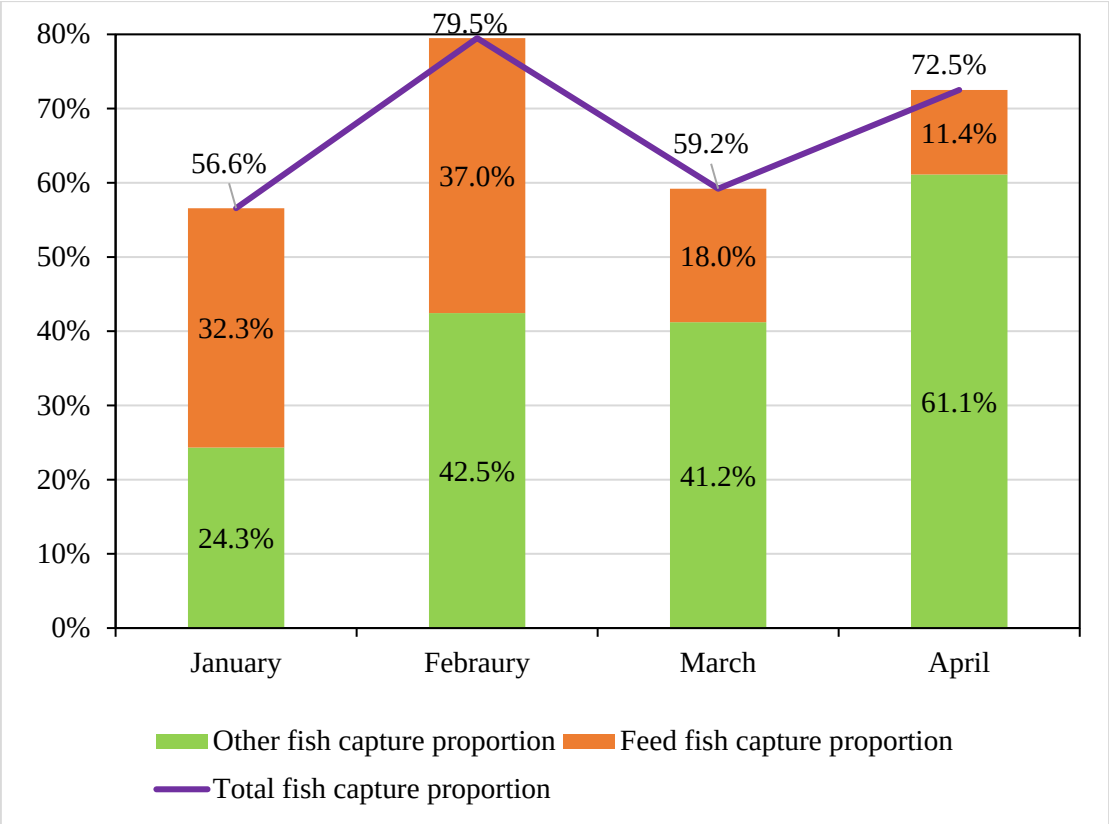

Fig.14. Fish capture proportions (values on the tops of the bars) and feed fish capture proportions in total capture volumes in trawl fishery in Dongshan County in January-April 2019.

3.6.4.2. *Portunus haanii* in feed fishes

Portunus haanii was one of the few common species found in feed fishes in trawl fishery in Dongshan County, contributed to 4.42%, 3.45%, 0.52% and 8.77% of the total feed fish volumes from January to April 2019, respectively (Table 9).

Based on the minimum size for maturity (female bearing eggs) determined in the present study (carapace width = 4.6 cm) for *P. haanii*, up to 78.57%, 100%, 100% and 100% of *P. haanii* individuals in feed fishes were juveniles from January to April 2019, respectively (Table 9).

Table 9. Species diversity and their size (standard length for fish, carapace width for crab) and proportion in feed fishes in trawl fishery in Dongshan County in January-April 2019.

(*: species only found in feed fishes) (Red bold: the dominant species or species group)

No.	Species name	January		February		March		April	
		Size (cm)	%	Size (cm)	%	Size (cm)	%	Size (cm)	%
1	*Platyrhina sinensis*					8.2	1.21%		
2	**Apterichtus hatookai*							25.5	3.63%
3	**Callechelys kuro*	23.2	0.30%	31.8	0.70%			21.2-30.4	1.66%
4	*Pisodonophis cancrivorus*							30.5	1.63%
5	*Oxyconger leptognathus*			24.6	0.89%				
6	*Gnathophis heterognathos*			23.8	1.27%			11.2	0.24%
7	*Saurida tumbil*	4.2-11.0	0.86%	12.2	0.73%				
8	*Saurida elongata*								
9	*Trachinocephalus myops*			7.8-11.8	1.48%			5.9-10.1	2.16%
10	**Bregmaceros* sp.	5.6-6.6	0.32%	5.6-5.8	0.11%			4.5-6.5	0.77%
11	*Mugil cephalus*					12.0-15.8	4.39%		
12	**Engraulis japonicus*								
13	*Pegasus laternarius*							6.8	0.59%
14	*Apistus carinatus*	6.3	0.33%	4.8	0.12%	2.1	0.02%	3.4-7.2	0.21%

15	**Minous monodactylus*			5.4-6.2	0.56%	3.3-5.8	0.65%		
16	**Aploactis aspera*			6.9	0.27%				
17	*Sebastiscus marmoratus*	5.3-7.1	0.95%					3.7	4.83%
18	**Lepidotrigla alata*			10.2	1.28%	11.5	1.79%		
19	*Cociella crocodila*	5.2-9.6	2.20%	6.1-11.3	2.13%	15.8	2.68%		
20	**Inegocia guttata*							6.6	0.70%
21	**Sorsogona tuberculata*							5.4-6.9	0.15%
22	*Epinephelus areolatus*			11.5	1.55%				
23	*Epinephelus awoara*			12.4	2.72%				
24	*Sillago sihama*	5.1-10.3	2.70%						
25	*Apogon cathetogramma*	5.8	0.44%						
26	**Apogon lineatus*			6.1	0.40%				
27	**Apogon niger*			4.7-5.9	0.84%			5.6-6.5	2.18%
28	**Ostorhinchus fasciatus*					6.5	0.48%		
29	*Equulites rivulatus*	3.5-4.5	0.21%					3.1-4.9	0.71%
30	*Decapterus maruadsi*	3.1-4.9	3.04%			3.9-8.3	3.16%		
31	*Trachurus japonicus*	3.3-4.8	2.26%			5.0-9.4	**12.63%**		
32	*Evynnis cardinalis*	2.9-11.2	**22.04%**			2.8-4.3	**16.97%**		
33	*Upeneus japonicus*	5.3-10.4	2.12%	8.2-8.9	2.38%			3.0-4.9	0.56%

34	**Teixeirichthys jordani*							2.6-9.0	**11.46%**
35	**Pomacentrus* sp.1	4.2-4.7	0.41%						
36	**Pomacentrus* sp.2			9.0	1.15%				
37	*Xyrichtys verrens*			11.3	1.44%				
38	**Suezichthys gracilis*	6.4	0.22%	10.5	0.75%				
39	**Parapercis ommatura*								
40	**Bathycallionymus kaianus*							4.1-6.6	0.93%
41	**Calliurichthys japonicus*								
42	*Callionymus curvispinis*	4.0-12.0	**9.75%**	4.1-9.7	**5.01%**	5.8-7.6	0.81%	6.1-7.1	1.07%
43	*Parapercis ommatura*	5.7-5.9	0.38%						
44	*Trichonotus setiger*	6.7-16.6	**32.87%**	5.3-12.2	**5.63%**	5.1-9.8	0.98%	5.3-11.8	1.35%
45	**Trichonotus filamentosus*							5.1-7.6	**5.89%**
46	**Bleekeria viridianguilla*	1.2-12.3	**26.78%**	8.7-11.8	4.68%	8.8-11.8	1.74%	6.6-10.6	2.11%
47	*Bleekeria mitsukurii*	10.1-10.2	1.62%	7.0-11.1	**7.91%**			9.1-10.6	**5.83%**
48	*Trichiurus* sp.					1.2-2.6	0.33%		
49	*Scomber japonicus*			3.9-10.0	**8.28%**	4.4-13.3	**42.83%**		
50	**Uranoscopus chinensis*					7.4	0.77%	3.6-7.2	3.56%
51	**Amblychaeturichthys hexanema*					8.4	0.38%		
52	*Pseudorhombus oligodon*	5.1-8.2	1.94%						

53	**Pseudorchombus arsius*			5.4-10.1	1.53%	2.8-5.9	0.25%		
54	*Crossorhombus azureus*							5.9	0.20%
55	**Bothus myriaster*							6.9	0.07%
56	**Engyprosopon grandisquama*							4.3-8.5	3.75%
57	** Engyprosopon multisquama*			6.1-9.8	1.77%				
58	**Engyprosopon filipennis*							3.7-8.8	**5.99%**
59	**Liachirus melanospilus*	6.1-8.2	0.81%					6.3-10.4	3.40%
60	**Zebrias crossolepis*					9.3	0.81%	3.8	0.56%
61	*Pleuronichthys cornutus*								
62	*Cynoglossus puncticeps*			6.0-12.6	2.12%	9.1	0.29%		
63	**Cynoglossus oligolepis*			6.5-8.6	0.46%	2.4-4.6	0.38%		
64	**Cynoglossus* sp.							6.0-10.8	**15.15%**
65	*Stephanolepis cirrhifer*	7.3-7.8	1.89%						
66	*Odontodactylus japonicus*			10.8	0.96%			13.3	0.41%
67	**Oratosquilla kempi*	1.2	0.25%						
68	**Lophosquilla costata*							7.7	0.39%
69	**Lophosquilla* sp.	1.0-1.5	1.10%			1.2-1.5	0.31%		
70	*Parapenaeopsis cornuta*	1.3-2.0	0.45%	1.4-2.6	0.36%				
71	*Metapenaeopsis palmensis*	1.1-2.7	1.61%					2.2-6.1	3.35%

72	*Metapenaeopsis barbata*	0.9-1.4	1.55%	1.1-3.2	1.40%	1.0-3.3	2.78%		
73	*Metapenaeopsis lamellata*							6.5	0.13%
74	*Trachypenaeus curvirostris*			2.8	0.23%				
75	**Leptochela gracilis*					0.3-0.4	0.06%		
76	* *Birulia kishinouyei*							2.2-2.5	1.15%
77	**Porcellana* sp.	0.6	0.02%						
78	**Leucosia* sp.					0.8	0.02%		
79	**Matuta lunaris*	1.8-3.0	0.77%	2.6-2.9	0.80%	2.6-2.8	0.69%		
80	**Cycloes granulosa*							1.1-2.0	1.09%
81	**Charybdis variegata*	1.7-2.0	0.07%	2.0-3.3	0.56%	1.7-1.8	0.15%	0.8-1.2	0.27%
82	**Charybdis bimaculata*			3.0-3.9	0.64%				
83	**Portunus hastatoides*					3.7	0.14%		
84	**Portunus gracilimanus*	2.4	0.07%						
85	*Portunus haanii*	2.1-5.8	4.42%	1.3-3.2	3.45%	3.1-3.8	0.52%	1.2-3.8	**8.77%**
86	*Octopus ocellatus*	4.4	0.64%	5.0	1.85%			15.7-18.4	1.83%
87	**Octopus dolliusi*			5.0	1.03%				
88	**Hapalochlaena lunulata*							3.1	0.37%
89	**Loligo* sp.	2.3-5.1	1.02%	3.6-6.2	1.04%		0.29%		
90	**Sepiola* sp.	2.6	0.14%	5.0	1.03%			1.2-1.6	0.90%

91	*Euprymna berryi*	2.2-3.8	0.79%	2.0-2.8	2.17%		1.48%		

3.7. Biological variation of *Portunus haanii* between trawl and trap fisheries in Dongshan County

The Chinese national fishing moratorium periods are from the 1st May to the 1st August for trap fishery and from the 1st May to the 16th August for trawl fishery. Surveys were conducted in August 2018-April 2019 (covered all official fishing months) in Dongshan County with two fishing gears (trawl and trap). Totally 4,233 individuals were collected and measured; 3,118 from trawl fishery and 1,115 from trap fishery.

3.7.1. Size variation

Irrespective of fishing gears, sizes (carapace width, CW in cm) of *P. haanii* ranged from 2.9 to 13.1 cm CW, and monthly average sizes ranged from 6.5 to 9.5 cm CW, showing a monthly fluctuation (Table 10; Fig. 15):

(1) The average sizes (carapace width, CW in cm) of *P. haanii* caught by trap were larger than those caught by trawl in the same period of August 2018 and of January-April 2019.

(2) The average sizes of *P. haanii* caught by trawl showed a decline with time, large in average sizes in August-December (right after the fishing moratorium), small in average sizes in January-April (after several month exploration).

(3) The size ranges of *P. haanii* caught by trawl and trap overlapped largely during the same fishing season of January-April 2019, within the same fishing grounds; however, trawl fishery could catch smaller juveniles < 5 cm CW.

Table 10. Size range and average size (carapace width, cm) of *Portunus haanii* between trawl and trap fisheries in Dongshan County in August 2018-April 2019

	August		September		October		November		December
	Trawl	Trap	Trawl		Trawl		Trawl		Trawl
Range	4.8-10.6	4.1-11.1	5.0-11.5		3.7-11.8		4.8-12.1		3.7-13.1
Average	7.6	8.5	8.2		8.1		8.3		8.6
	January		February		March		April		
	Trawl	Trap	Trawl	Trap	Trawl	Trap	Trawl	Trap	
Range	2.9-	5.3-	4.4-	5.8-	4.9-	5.1-	4.2-	5.5-	

	11.4	11.3	12.1	11.5	11.9	12.0	12.2	10.1	
Average	6.5	8.2	7.3	8.4	7.4	9.5	7.0	8.0	

The dominant size classes (defined as the proportion >20%) of *P. haanii* caught by trawl in August 2018-April 2019 showed monthly variation (Fig. 15):

(1) More than 90% of individuals were larger than 6.0 cm CW in August-December 2018, and March 2019, and in January, February and April, around 42.41%, 10.84% and 24.82% individuals smaller than 6.0 cm.

(2) The dominant size classes were 6.0-8.9 cm (76.93%) in August 2018, 7.0-8.9 cm (53.21%) in September 2018, 7.0-8.9 cm (55.84%) in October 2018, >10.0 cm (21.26%) in November 2018, >10.0 cm CW (32.89%) in December 2018, 5.0-6.9 cm (60.54%) in January 2019, 6.0-7.9 cm (65.08%) in February 2019, 6.0-7.9 cm (68.50%) in March 2019 and 5.0-7.9 (75.93%) in April 2019.

(3) Proportions of larger sizes (>10.0 cm CW) were high in November and December 2018, around 21.26% and 32.89%, respectively, and were low in the rest of months, mainly less than 10%.

(4) Sizes smaller than 6 cm CW were found in all months of between August 2018 and April 2019, and mainly found in January 2019 and April 2019.

The dominant size classes of *P. haanii* caught by trap were larger than those caught by trawl in January-April 2019, both gears operate in the same fishing grounds offshore (see Section 3.3) (Fig. 16):

(1) In January, the dominant size classes were 7.0-8.9 cm CW (70.51%) for trap fishery and 5.0-6.9 cm CW (60.54%) for trawl fishery. More than 90% of individuals in trap fishery were larger than 7.0 cm CW, while about 73.25% of individuals were smaller than 7.0 cm CW in trawl fishery.

(2) In February, the dominant size classes were 7.0-8.9 cm CW and >10.0 cm CW (79.24%) for trap fishery and 6.0-7.9 cm CW (65.08%) for trawl fishery. Nearly 90% of individuals were larger than 7.0 cm CW for trap fishery, while less than 45.5% of individuals were smaller than 7.0 cm CW for trawl fishery.

(3) In March, the dominant size classes were larger than 9.0 cm CW (72.22%) for trap fishery and 6.0-7.9 cm CW (68.50%) for trawl fishery. Nearly 80% of individuals were larger than 8.0 cm CW for trap fishery, while about 75% of

individuals were smaller than 8.0 cm CW for trawl fishery.

(4) In April, the dominant size classes were 7.0-8.9 cm CW (70.45%) for trap fishery and 5.0-7.9 cm CW (75.93%) for trawl fishery. Nearly 85% of individuals were larger than 7.0 cm CW for trap fishery, while about 55.34% of individuals were smaller than 7.0 cm CW for trawl fishery.

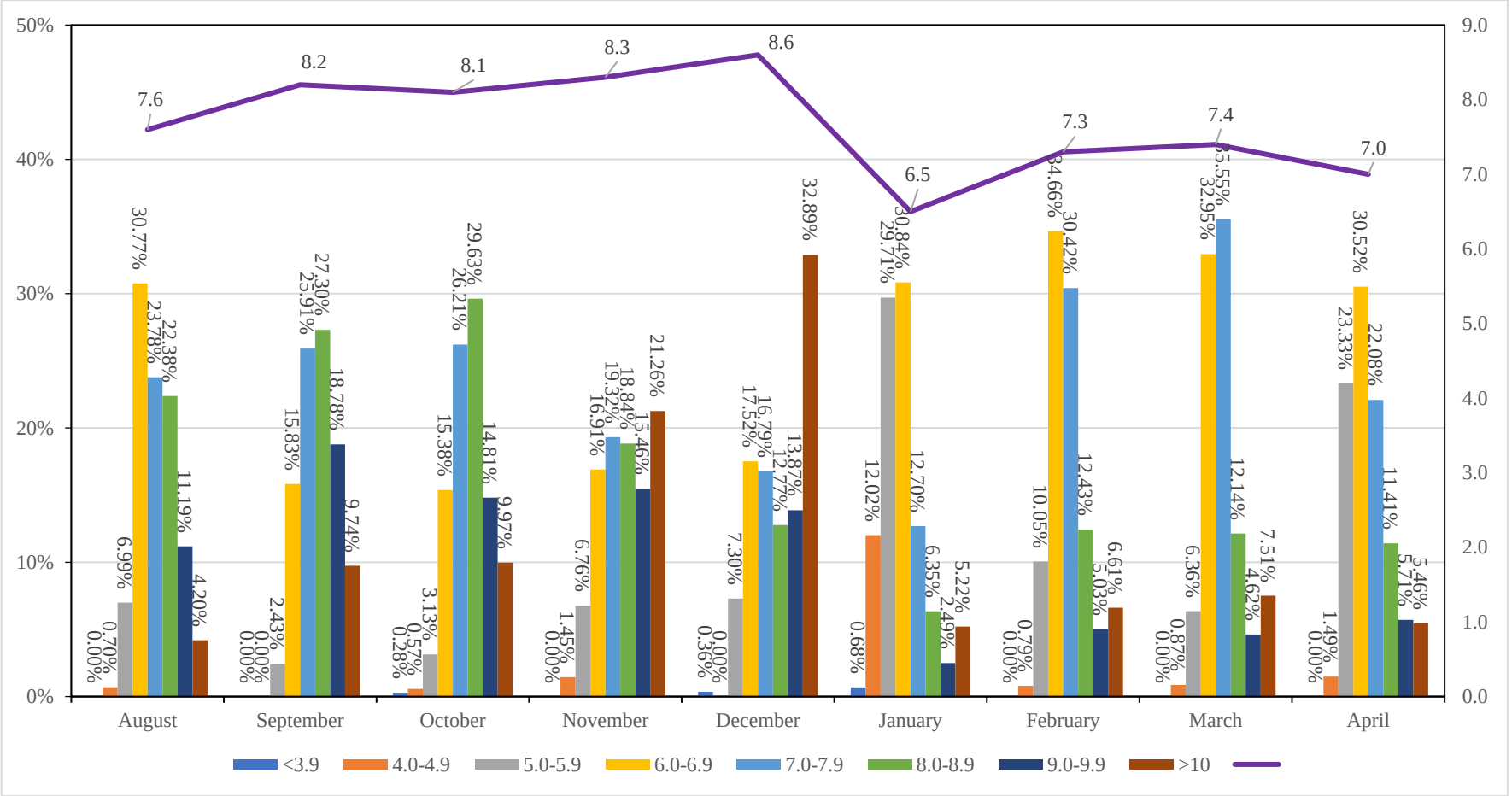

Fig. 15. Proportions of different size classes (cm in carapace width) of *Portunus haanii* (left Y-axis) and the trend (purple line) of the monthly average sizes (right Y-axis) by trawl in Dongshan County in August 2018-April 2019.

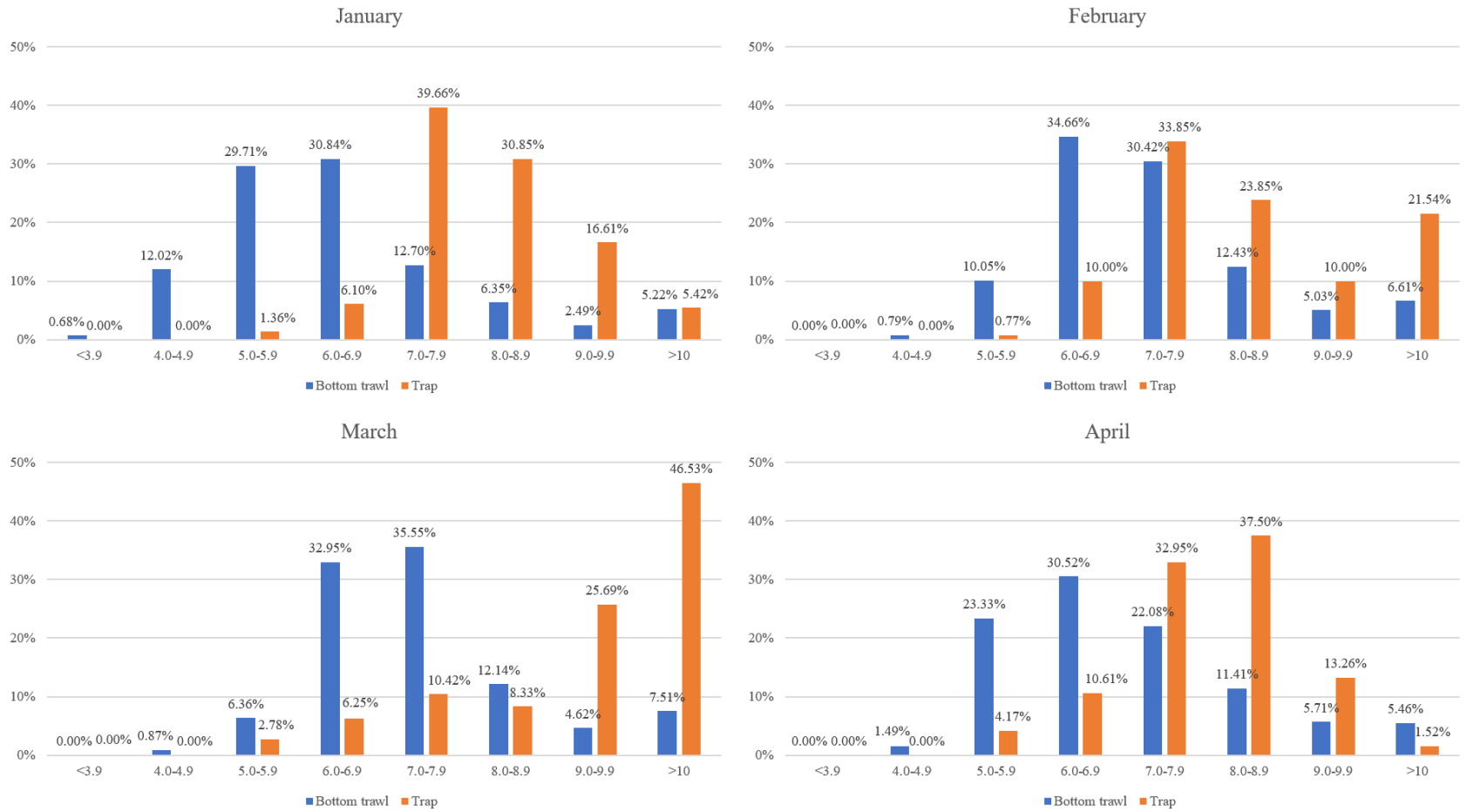

Fig. 16. Proportions of different size classes (cm in carapace width) of *Portunus haanii* caught by trawl and trap in Dongshan County in January-April 2019.

3.7.2. Sex ratio variation

Sex ratios of *P. haanii* showed monthly variation in Dongshan County in August 2018-April 2019 between trawl and trap fisheries, with their fishing grounds overlapped largely (see Section 3.3) (Fig. 17; Fig. 18):

(1) In trawl fishery in August 2018-April 2019, the overall sex ratio was 0.91:1 (male: female) (N = 3,118), showing the change from a strong male-bias in August, September and December 2018 to a strong female-bias in February and March 2019.

(2) In trap fishery, the overall sex ratio in trap fishery was 1.56:1 (male: female) (N = 1,115), showing a strong male-bias in August 2018, March and April 2019, and a strong female-bias in January 2019.

(3) Irrespective of different fishing gears, the overall sex ratio of *P. haanii* was 1.05:1 (male: female) (N = 4,233), showing a male-bias in August, September and December 2018 and April 2019, and a female-bias in January-March 2019.

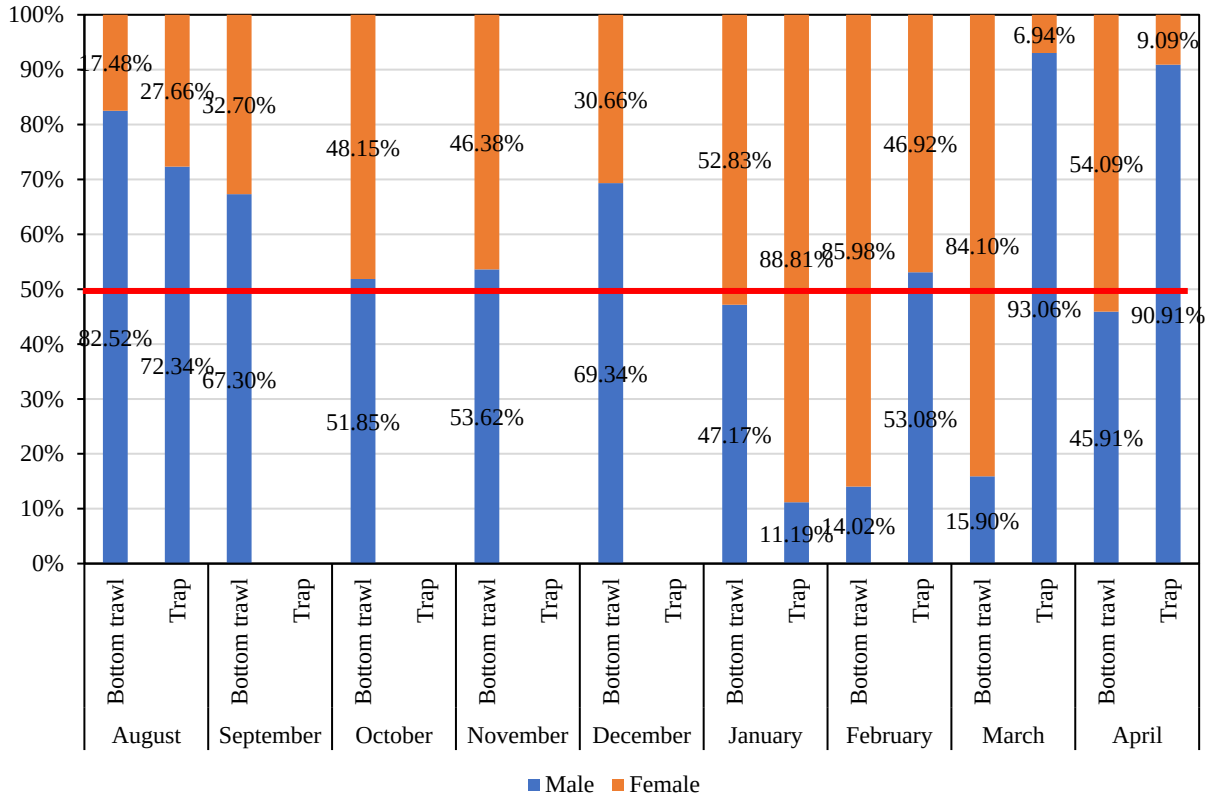

Fig. 17. Sex ratios of *Portunus haanii* in trawl and trap fisheries in Dongshan County in August 2018-April 2019. Red line showed the sex ratio of 1:1.

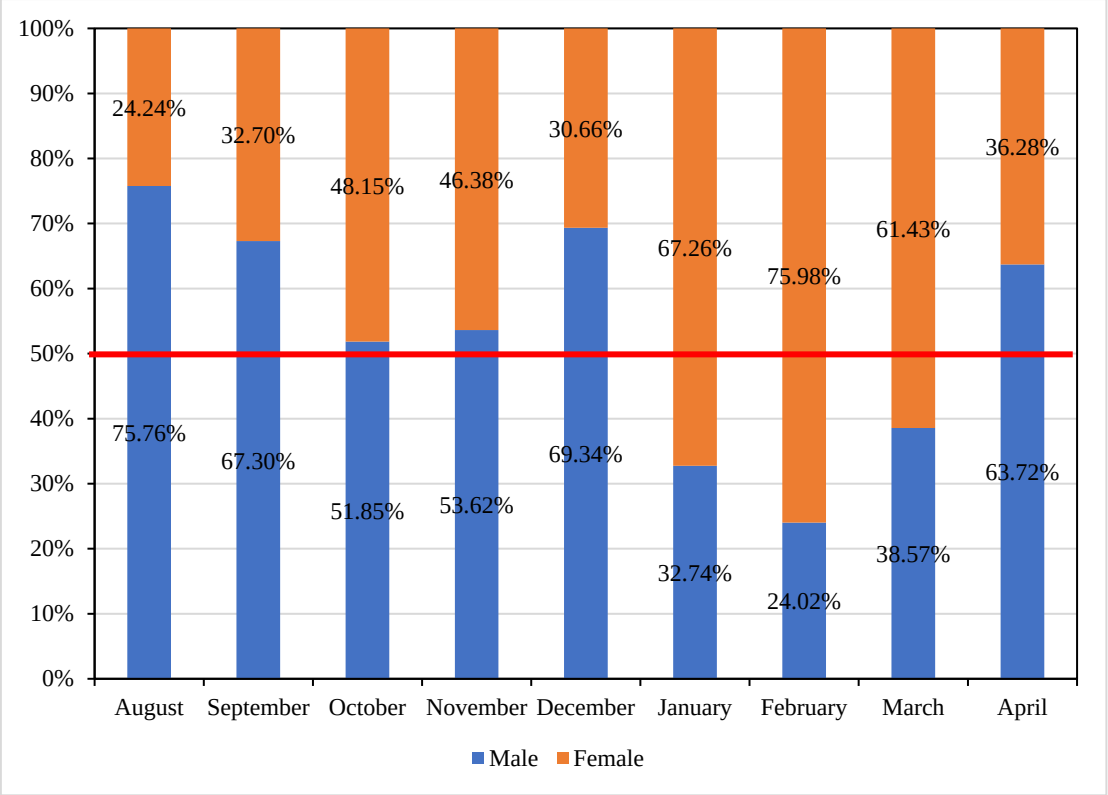

Fig. 18. Sex ratios of *Portunus haanii* in Dongshan County in August 2018-April 2019. Red line showed the sex ratio of 1:1.

3.7.3. Spawning season and the minimum size for female bearing eggs

Proportions of *P. haanii* females bearing eggs (number of females bearing eggs/number of females) were different between trawl and trap fishery in Dongshan County, operated in the same fishing grounds (Fig. 19) (see Section 3.3):

(1) In trawl fishery in Dongshan County in August 2018-April 2019, the proportions of *P. haanii* females bearing eggs showed two peaks, one in August 2018 and one in February-April 2019.

(2) In trap fishery in Dongshan County in August in 2018 and January-April 2019, the proportions of *P. haanii* females bearing eggs also showed two peaks, one in August and one in January-March 2019.

Therefore, there are two spawning seasons determined for *P. haanii*; one in August, and one in January-April.

The minimum size for females bearing eggs was 4.6 cm CW for *P. haanii*, caught in April 2019.

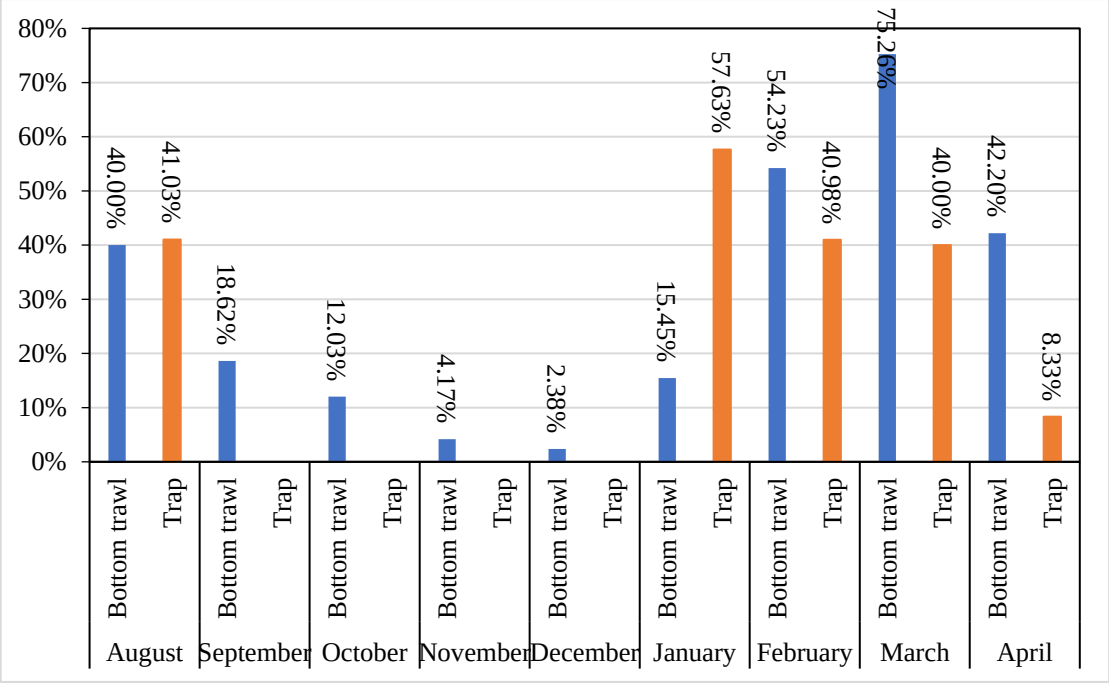

Fig. 19. Proportions of *Portunus haanii* females bearing eggs between trawl and trap fisheries in Dongshan County in August 2018-April 2019.

3.7.4. Size-weight relationship

The relationship of size (carapace width, CW) and weight (whole body weight, BW) for *P. haanii* was: $BW = 0.1242*CW^{2.9248}$ (R^2=0.8877; N=4,233) (Fig. 20).

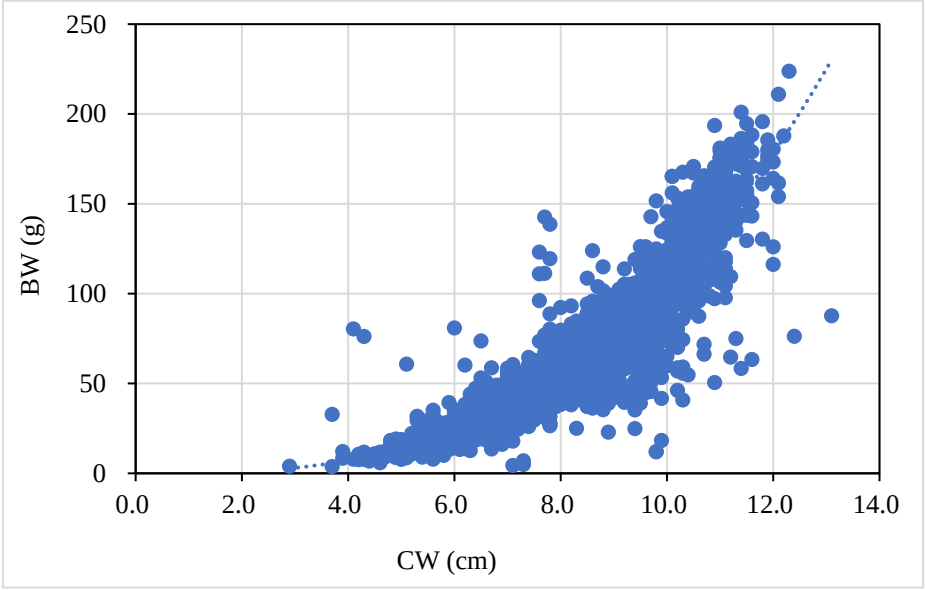

Fig. 20. Size (carapace width, CW)-weight (whole body weight, BW) relationship of *Portunus haanii* (N=4,233).

3.7.5. Carapace length-carapace width relationship

Carapace length (CL)-carapace width (CW) relationship for *Portunus haanii* was: CL = 0.5487*CW + 0.186 (R^2 = 0.9228; N=4,233) (Fig. 21).

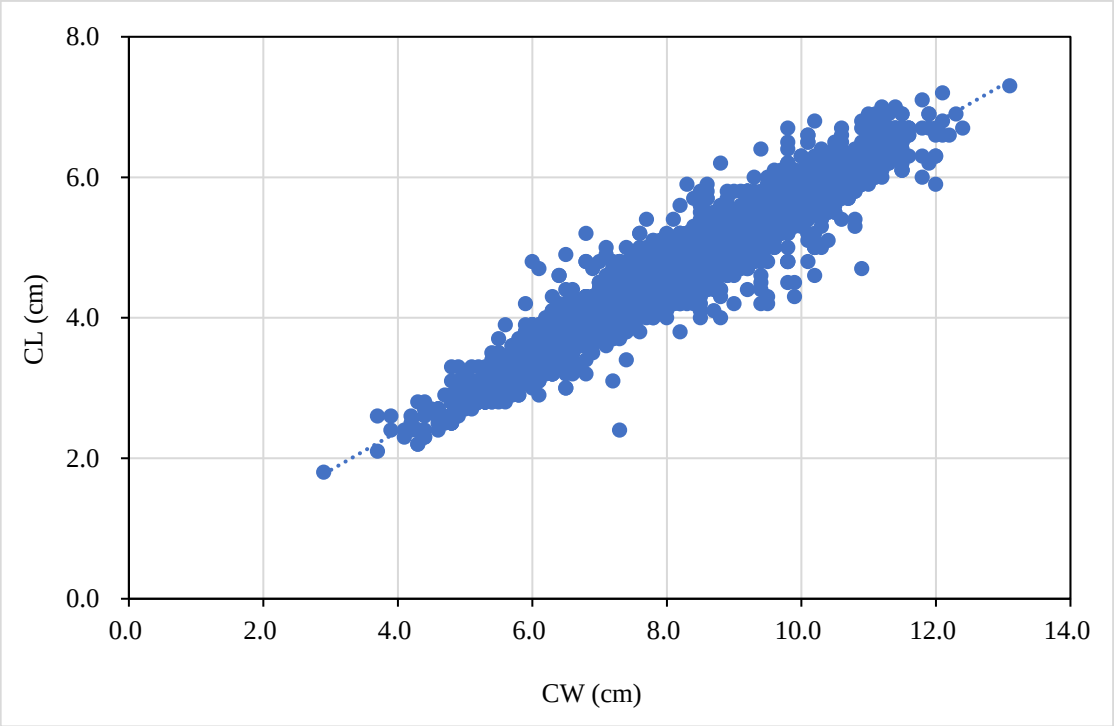

Fig. 21. Carapace length (CL)-carapace width (CW) relationship of *Portunus haanii* (N=4,233).

3.8. Biological variation of Portunus haanii in trap fishery between Dongshan County and Longhai County

The comparisons were conducted between Dongshan County and Longhai County in January-April 2019 by the same type of fishing gear--trap, indicated different fishing grounds, offshore and nearshore waters, respectively (see Section 3.3).

3.8.1. Size variation

Sizes of *P. haanii* caught by trap in Dongshan County and Longhai County overlapped largely, ranged from 5.1 to 12.0 cm CW (Table 11).

The average sizes of *P. haanii* caught by trap in Dongshan County and Longhai County were similar in January-April 2019, with a trend of larger individuals caught from offshore (Table 11).

Table 11. Size range and average size (carapace width, cm) of *Portunus haanii* in trap fishery between Dongshan County and Longhai County in January-April 2019

	January		February	
	Dongshan	Longhai	Dongshan	Longhai
Range	5.3-11.3	5.6-10.8	5.8-11.5	7.0-11.4
Average	8.2	8.1	8.4	9.0
	March		April	
	Dongshan	Longhai	Dongshan	Longhai
Range	5.1-12.0	5.4-9.8	5.5-10.1	6.2-10.6
Average	9.5	7.1	8.0	7.6

The dominant size classes of *P. haanii* caught by trap between Dongshan County and Longhai County showed monthly variation in January-April 2019 (Fig. 22):

(1) In January, the dominant size classes were the same; 7.0-8.9 cm CW in Dongshan County and Longhai County, with proportions of 70.51% and 61.70%, respectively.

(2) In February, the dominant size classes were all larger than 7.0 cm CW, nearly 90% in Dongshan County and 100% in Longhai County.

(3) In March, the dominant size classes showed a large difference between Dongshan County and Longhai County; 6.0-7.9 cm CW (80.62%) in Dongshan County, and >9.0 cm CW (72.22%) in Longhai County.

(4) In April, the dominant size classes were the similar; 7.0-8.9 cm CW in Dongshan County (70.45%) and 6.0-8.9 cm CW in Longhai County (98.82%).

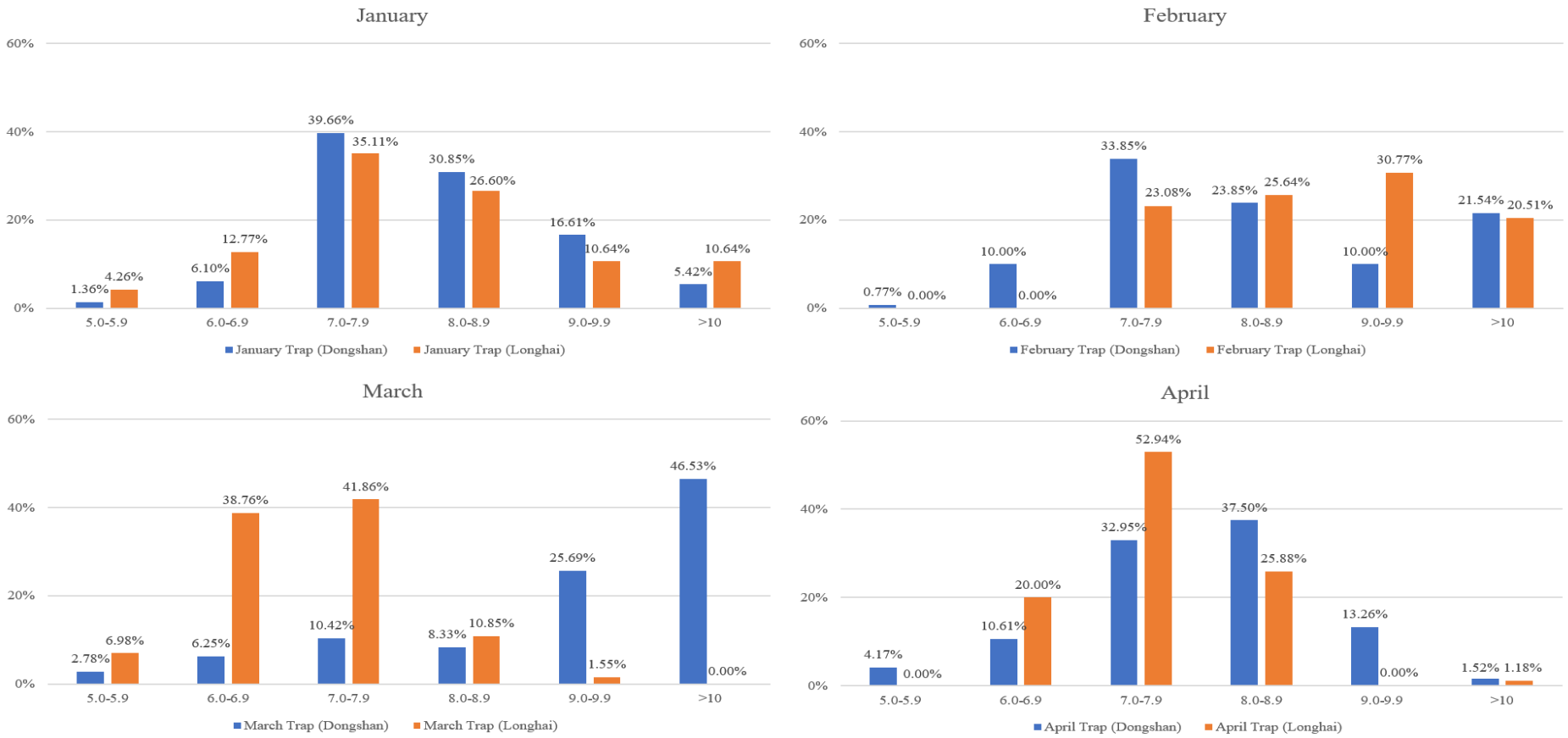

Fig. 22. Proportions of different size classes (cm in carapace width) of *Portunus haanii* caught by trap in Dongshan County and Longhai County in January-April 2019.

3.8.2. Sex ratio variation

Sex ratios of *P. haanii* showed monthly variation in trap fishery in Dongshan County and Longhai County in January-April 2019, operated nearshore and offshore fishing grounds, respectively (see Section 3.3) (Fig. 23):

(1) In Dongshan County, the overall sex ratio was 1.33: 1 (male: female), showing a strong female-bias in January to a strong male-bias in March and April.

(2) In Longhai County, the overall sex ratio was 3.96: 1 (male: female), showing a strong male-bias in all four months.

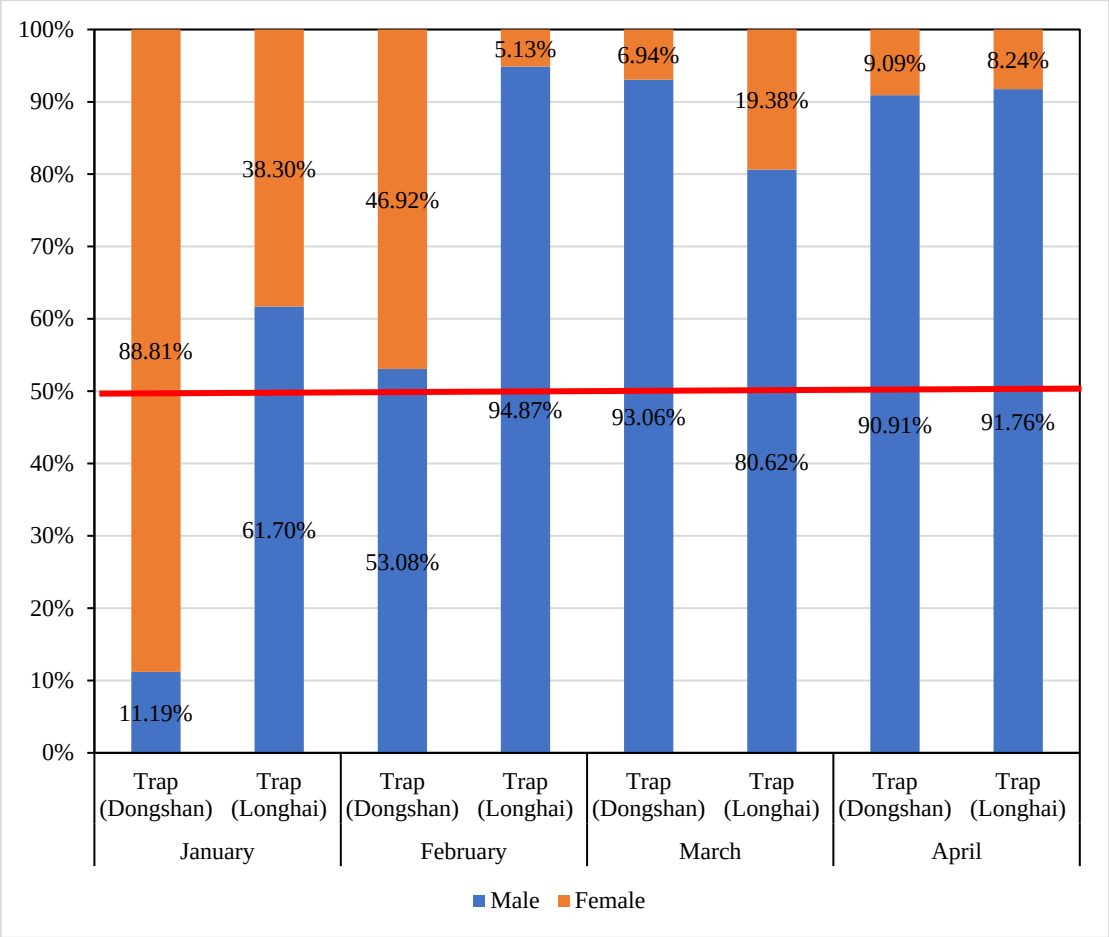

Fig. 23. Sex ratios of *Portunus haanii* in trap fishery in Dongshan County and Longhai County in January-April 2019. Red line showed the sex ratio of 1:1.

3.8.3. Spawning season

Proportions of *P. haanii* females bearing eggs showed the similarity in trap fishery in Dongshan County and Longhai County, operated in offshore and nearshore

fishing grounds, respectively; one peak in January-March 2019 in Dongshan County, and one peak in February-March 2019 (Fig. 24).

Therefore, irrespective of fishing grounds, one spawning season for *P. haanii* was determined in January-March.

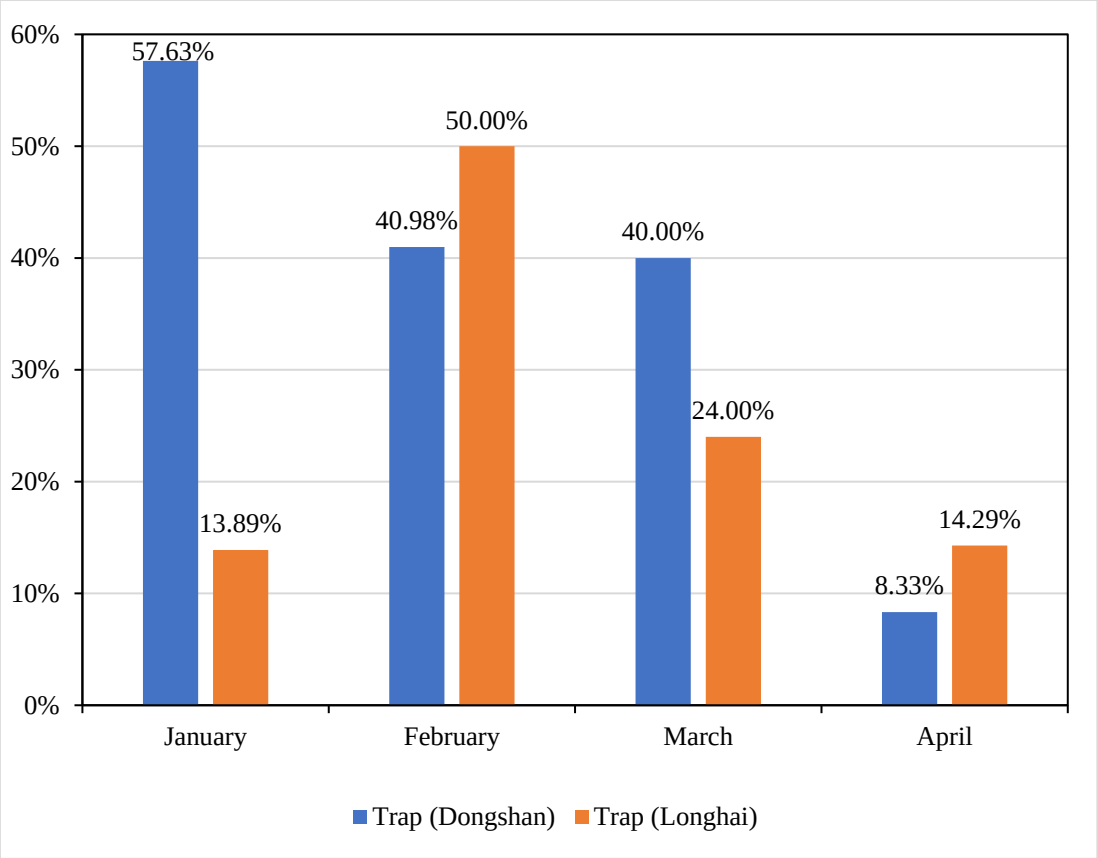

Fig. 24. Proportions of *Portunus haanii* females bearing eggs in trap fishery between Dongshan County and Longhai County in January-April 2019

3.9. Biological variation of other crabs in Dongshan County in August 2018-April 2019

In Dongshan County, the trawl and trap vessels operated in the different habitats of the same fishing grounds (see Section 3.3, and more details in Phase I report). For *P. haanii*, the size, sex ratio and proportion of females bearing eggs were different between trawl and trap fisheries (see Section 3.7). For the other three targeted species, *Portunus sanguinolentus*, *Charybdis nataor and Calappa philargius*, however, we analyzed their biological data, irrespective of different fishing gears.

3.9.1. *Portunus sanguinolentus*

3.9.1.1. Size variation

Totally 1,141 individuals of *P. sanguinolentus* were collected; 721 from trawl vessels and 420 from trap vessels in August 2018-April 2019 in Dongshan County (Fig. 25):

(1) Sizes ranged from 3.9 to 19.1 cm CW.

(2) Monthly average size ranged from 9.5 to 14.3 cm CW, showing a monthly fluctuation, high in August 2018 and April 2019, and low in November 2018.

(3) In August and September 2018, the dominant sizes were larger than 12.0 cm CW.

(4) In October and November 2018, the proportions of small size classes (<10.0 cm CW) were high; particularly more than 70% of individuals were smaller than 10.0 cm CW in November.

(5) From December 2018 to April 2019, the dominant sizes were larger than 11.0 cm CW.

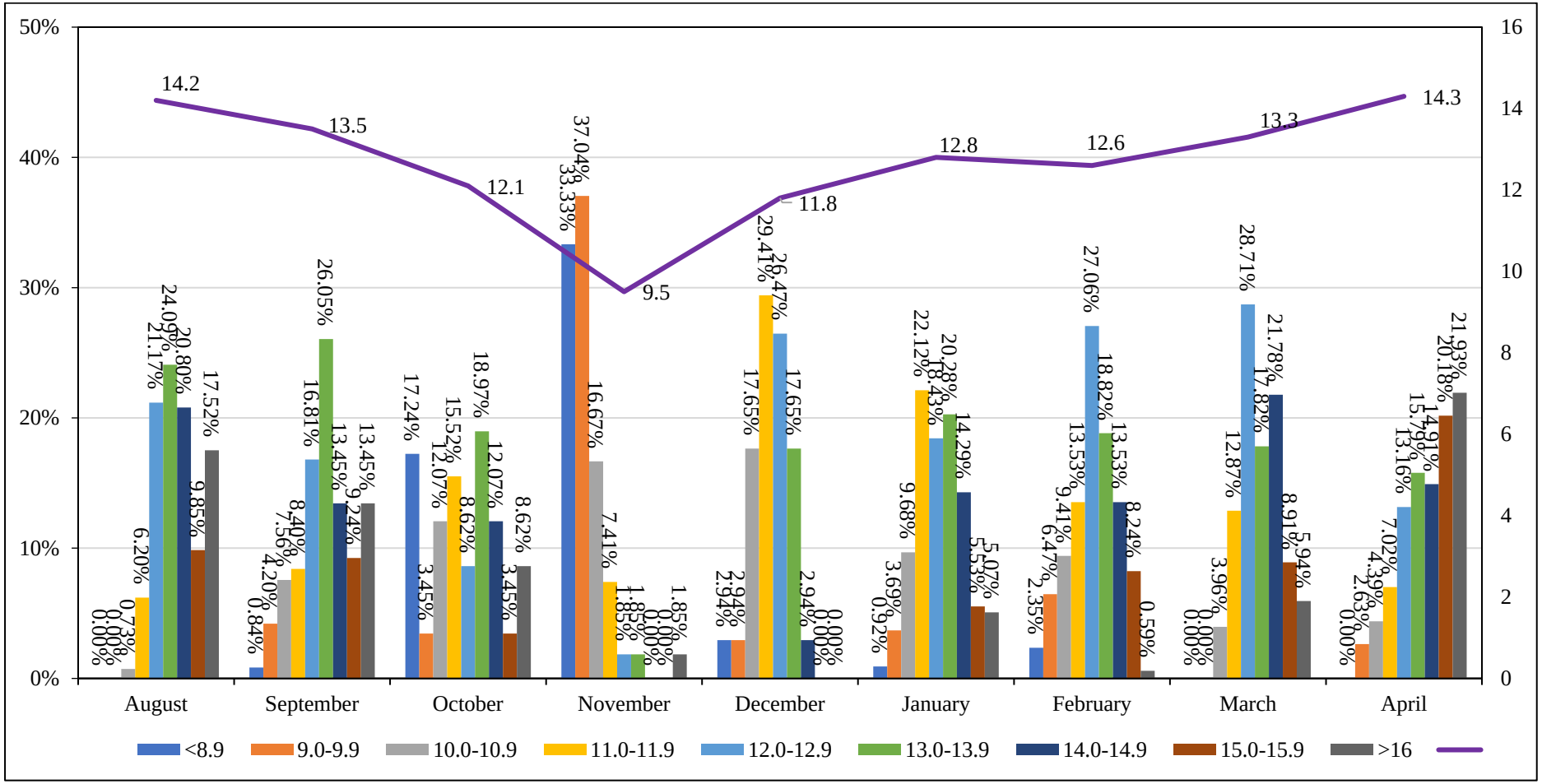

Fig. 25. Proportions of different size classes (cm in carapace width) of all *Portunus sanguinolentus* individuals (left Y-axis) and the trend (purple line) of the monthly average sizes (right Y-axis) by both trawl and trap in Dongshan County in August 2018-April 2019

3.9.1.2. Sex ratio variation

Overall sex ratio of *P. sanguinolentus* was 1: 1.51 (male: female), showing a female-bias in August 2018-April 2019, except in December 2018 (Fig. 26).

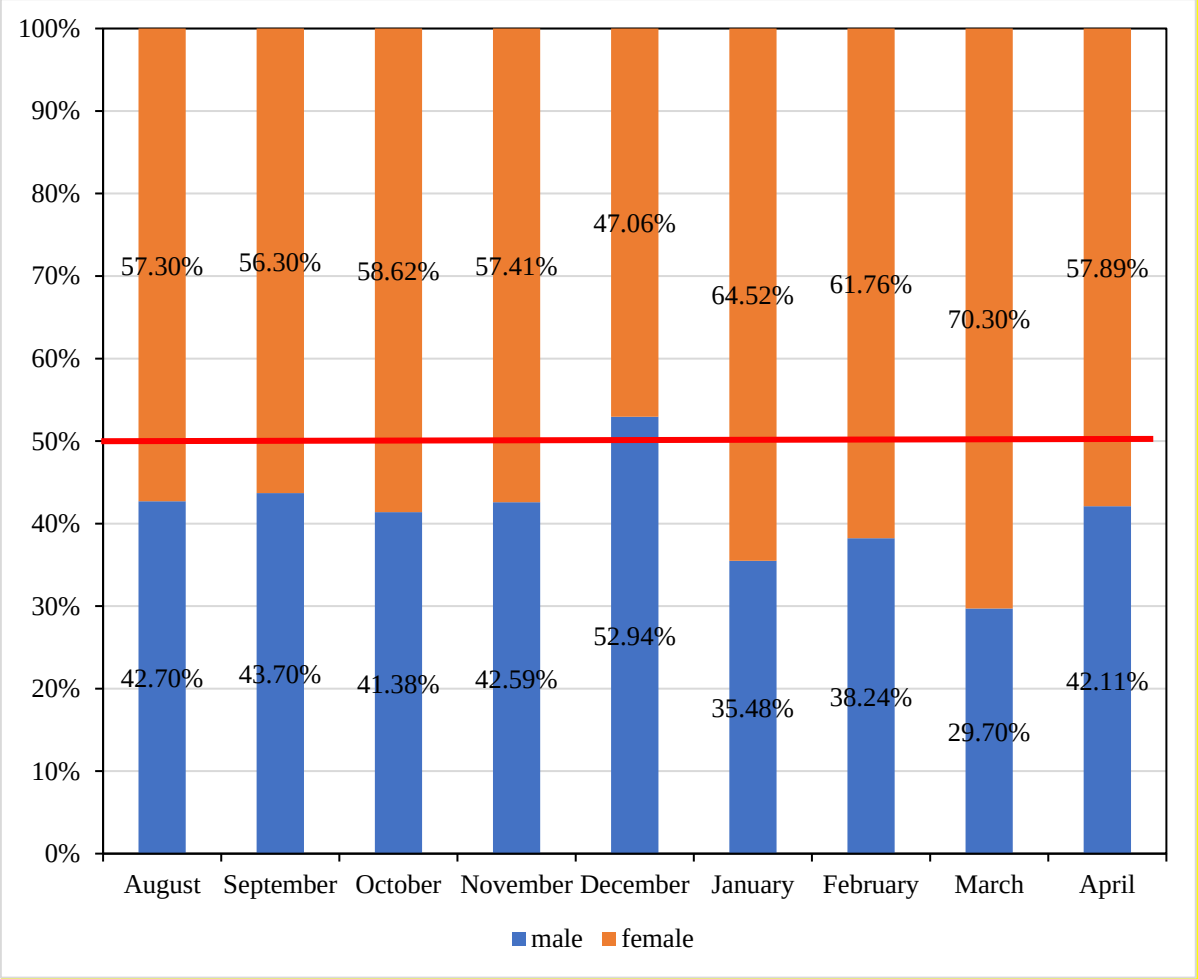

Fig. 26. Sex ratios of *Portunus sanguinolentus* in Dongshan County in August 2018-April 2019. Red line showed the sex ratio of 1:1.

3.9.1.3. Size-weight relationship

The relationship of size (carapace width, CW) and weight (whole body weight, BW) for *P. sanguinolentus* was: $BW = 0.0655*CW^{2.9607}$ (R^2=0.8231; N=1,141) (Fig. 27).

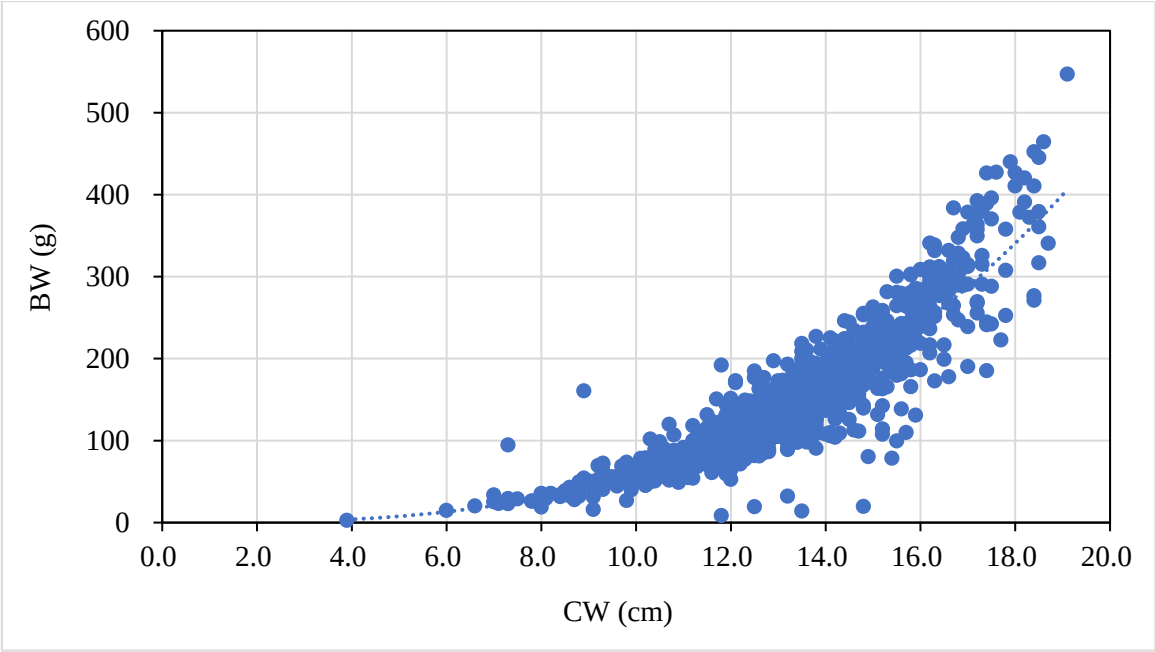

Fig. 27. Size (carapace width, CW)-weight (whole body weight, BW) of *Portunus sanguinolentus* (N=1,141).

3.9.1.4. Carapace length-carapace width relationship

Carapace length (CL)-carapace width (CW) relationship for *P. sanguinolentus* was CW=0.4187*CL + 0.4394 (R^2 = 0.8825; N=1,141) (Fig. 28).

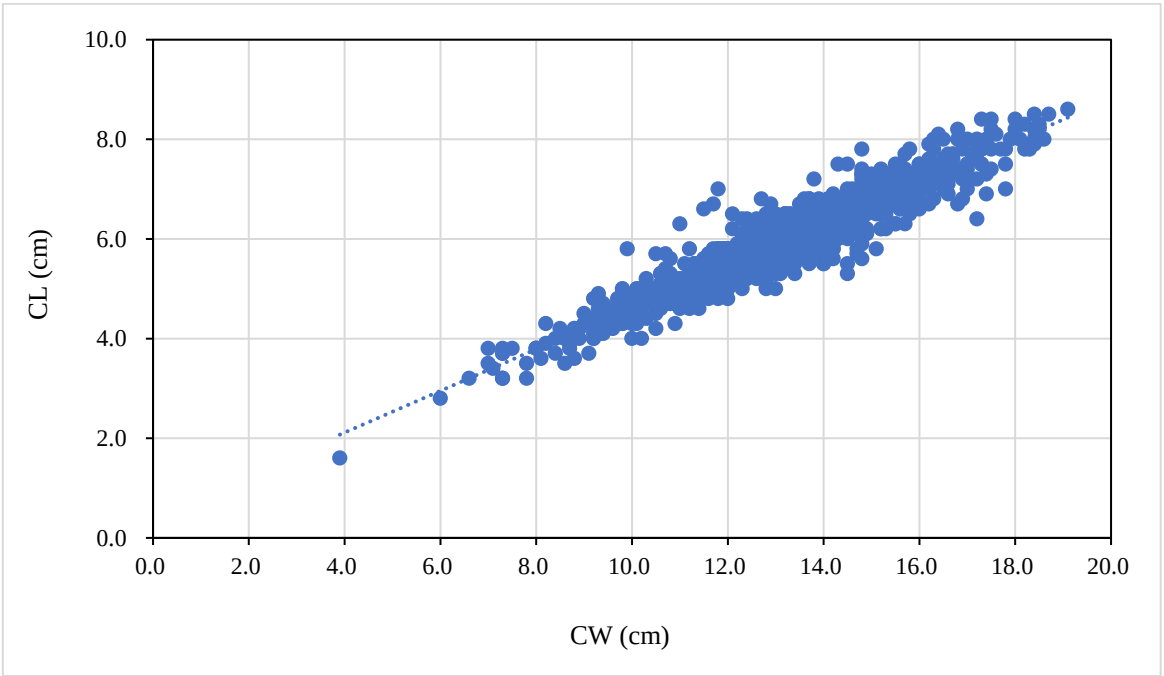

Fig. 28. Carapace length (CL)-carapace width (CW) relationship of *Portunus sanguinolentus* (N=1,141)

3.9.1.5. Spawning seasons and the minimum size for female bearing eggs

The proportions of females bearing eggs remained high (>20%) in August and September and in February-April, indicating the two spawning seasons in August and September and in February-April (Fig. 29).

The minimum size for female bearing eggs was 9.7 cm CW for *P. sanguinolentus*, caught in February 2019.

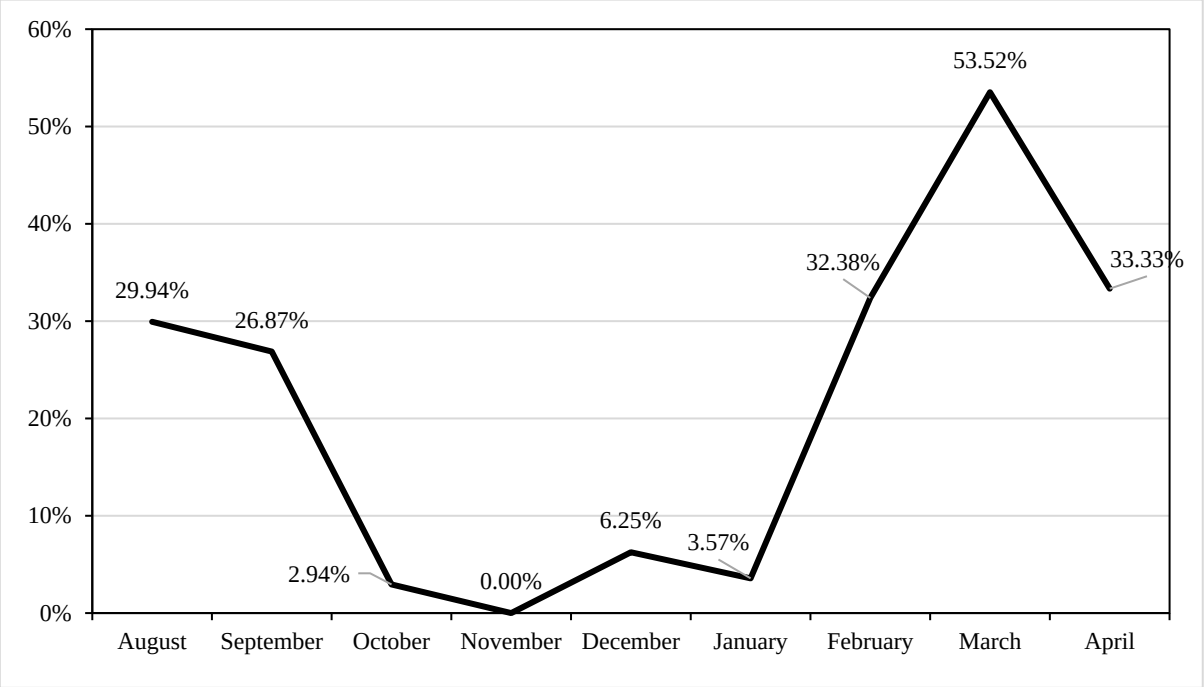

Fig. 29. Proportions of *Portunus sanguinolentus* females bearing eggs in Dongshan County in August 2018-April 2019.

3.9.2. *Charybdis nataor*

3.9.2.1. Size variation

Totally 1,193 individuals of *C. nataor* were collected; 1,084 from trawl vessels and 109 from trap vessels in August 2018-April 2019 in Dongshan County (Fig. 30):

(1) Sizes ranged from 3.3 to 13.4 cm CW.

(2) Monthly average size ranged from 7.3 to 9.0 cm CW, showing a monthly fluctuation, high in February 2019, and low in September 2018.

(3) The dominant size classes were generally on 6.0-8.9 cm CW in August-October 2018, and January and March 2019 (proportions >75%), and on 7.0-9.9 cm CW (proportions >80%) in November-December 2018 and April 2019, and larger than 8.0 cm in February 2019.

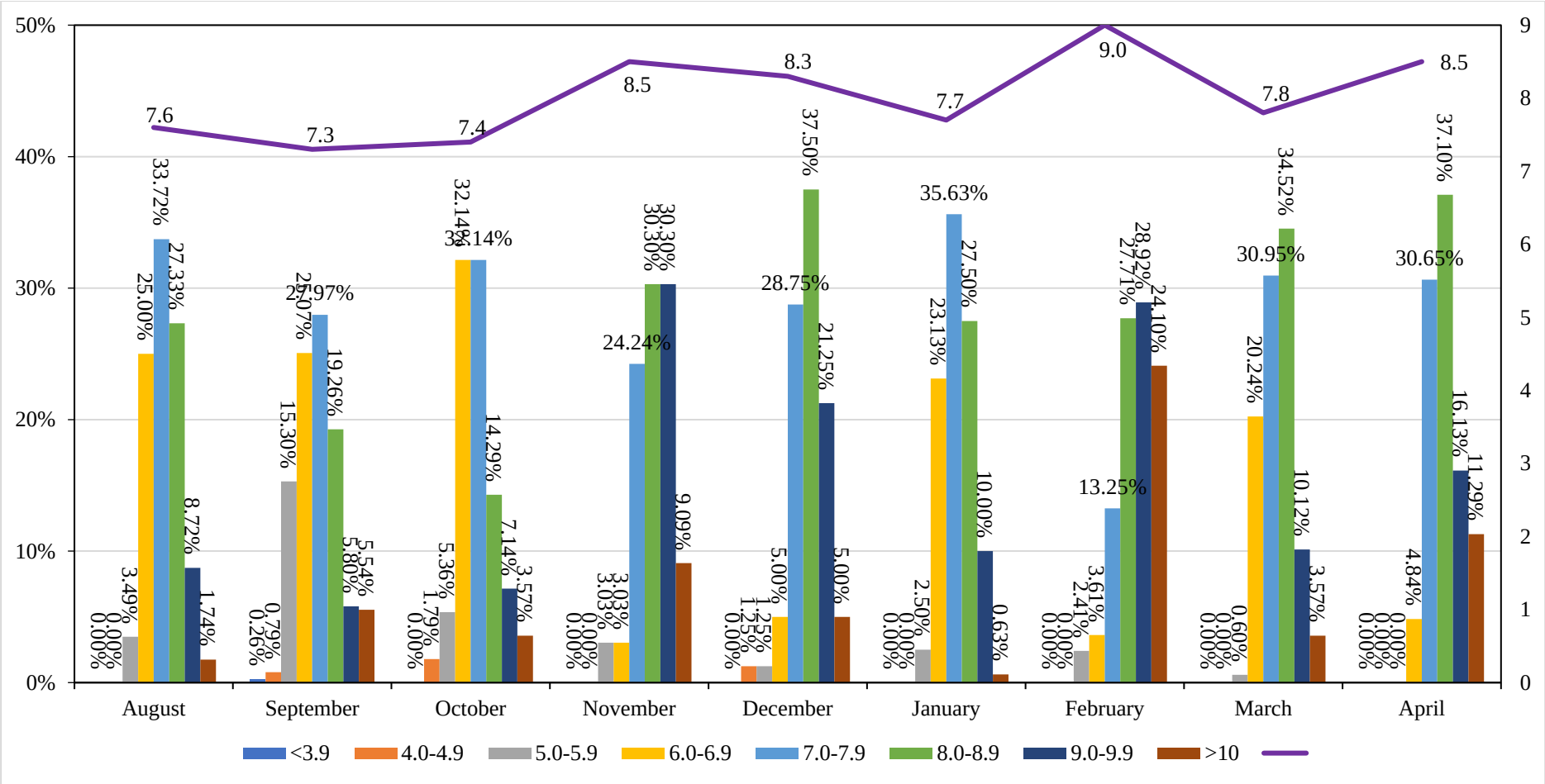

Fig. 30. Proportions of different size classes (cm in carapace width) of all *Charybdis nataor* individuals (left Y-axis) and the trend (purple line) of the monthly average sizes (right Y-axis) by both trawl and trap in Dongshan County in August 2018-April 2019.

3.9.2.2. Sex ratio variation

Overall sex ratio of *C. nataor* was 1: 1.21 (male: female), showing a male-bias in August 2018, and a female-bias in September-December 2018 and in February-April 2019 (Fig. 31).

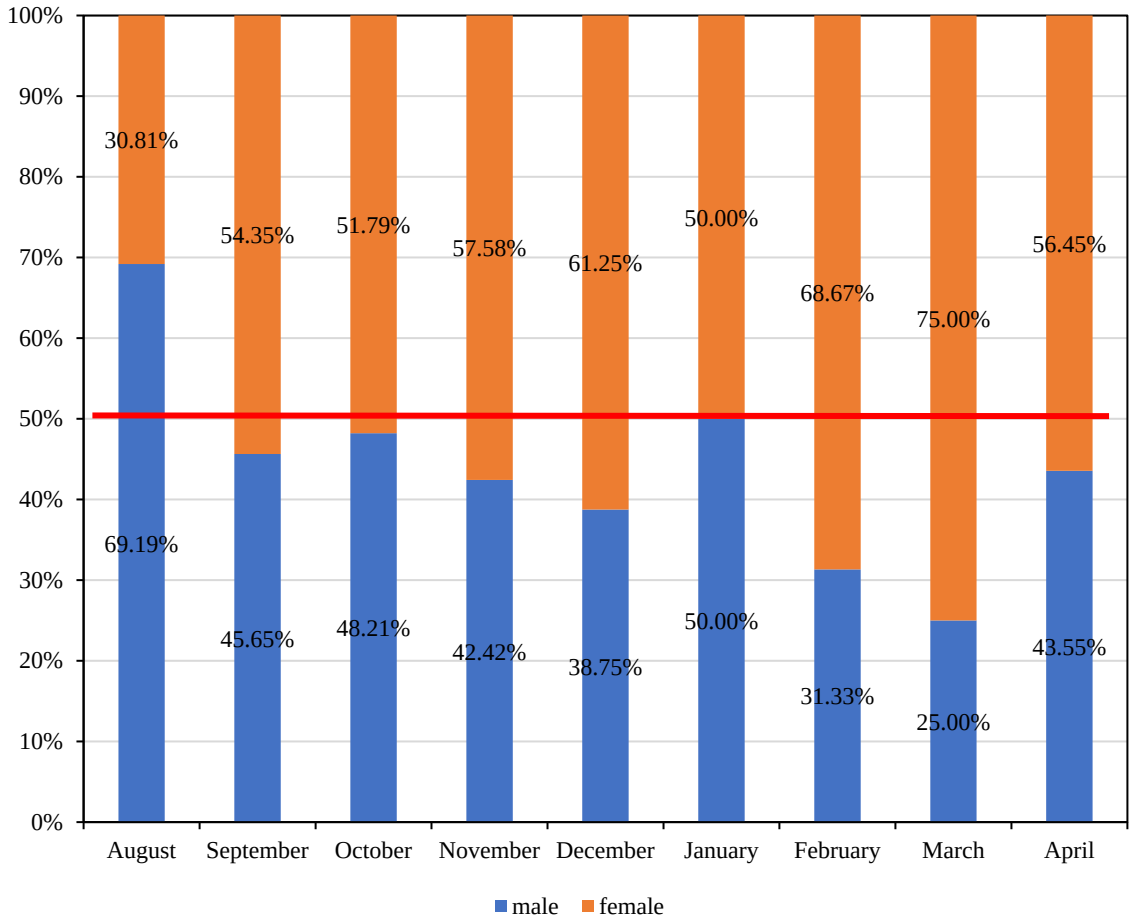

Fig. 31. Sex ratios of *Charybdis nataor* in Dongshan County in August 2018-April 2019. Red line showed the sex ratio of 1:1.

3.9.2.3. Size-weight relationship

The relationship of size (carapace width, CW) and weight (whole body weight, BW) for *C. nataor* was: $BW = 0.2376*CW^{2.9222}$ (R^2=0.8705; N=1,193) (Fig. 32).

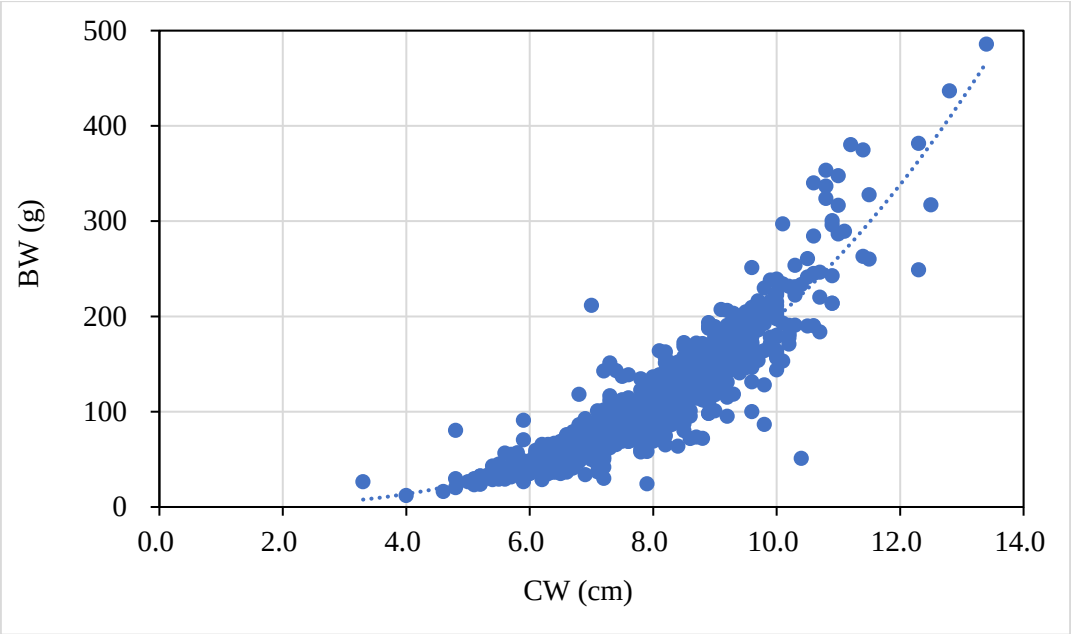

Fig. 32. Size (carapace width, CW)-weight (whole body weight, BW) of *Charybdis nataor* (N=1,193).

3.9.2.4. Carapace length-carapace width relationship

Carapace length (CL)-carapace width (CW) relationship for *C. nataor* was CW=0.6424*CL + 0.3639 (R^2 = 0.9172; N=1,193) (Fig. 33).

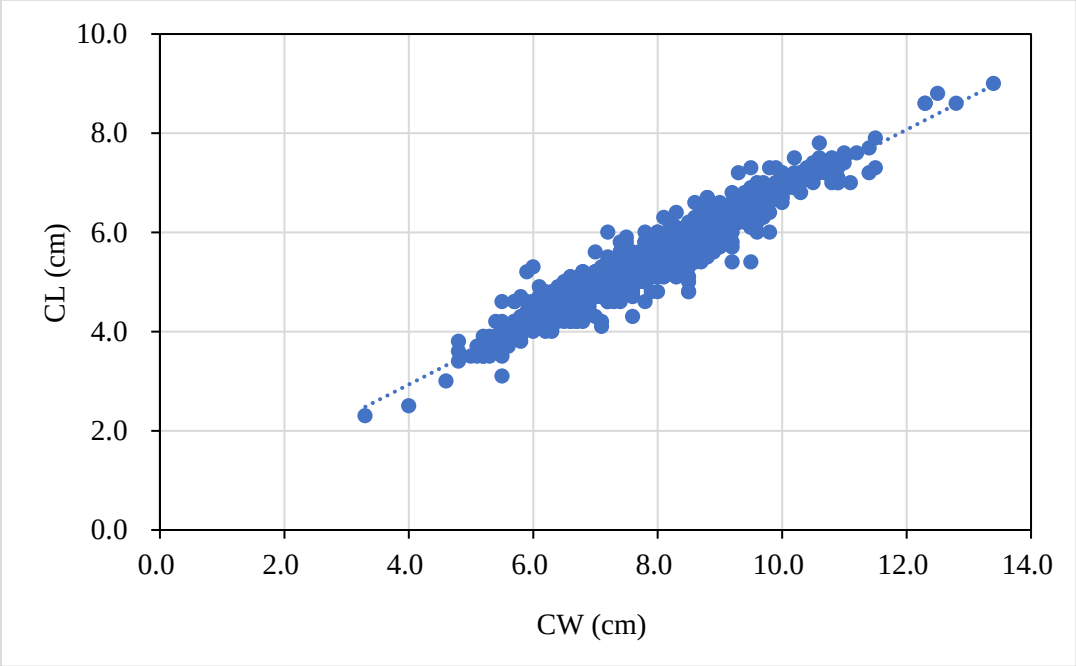

Fig. 33. Carapace length (CL)-carapace width (CW) relationship of *Charybdis nataor* (N=1,193).

3.9.2.5. Spawning seasons and the minimum size for female bearing eggs

The proportions of females bearing eggs remained low (<10%) in August-November and January, with a high peak (>55%) in February-April 2019 and another peak in December 2018 (>20%), indicating two spawning seasons in December and February-April (Fig. 34).

The minimum size for females bearing eggs was 6.1 cm CW for *C. nataor*, caught in March 2019.

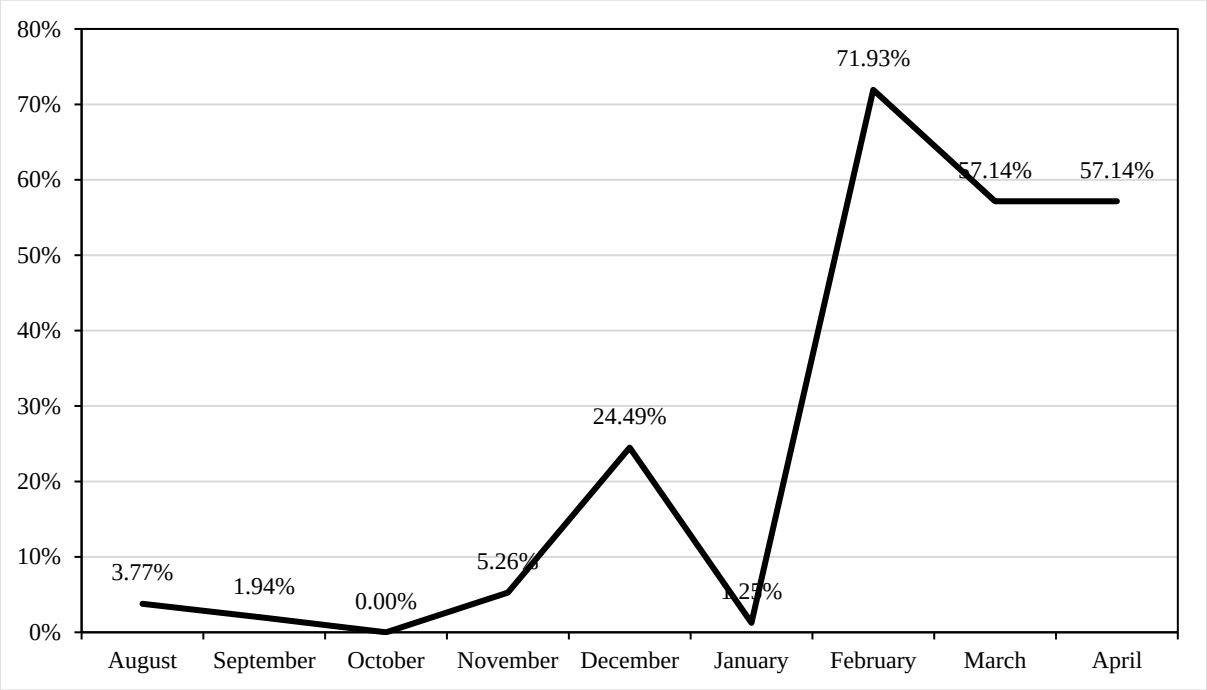

Fig. 34. Proportions of *Charybdis nataor* females bearing eggs in Dongshan County in August 2018-April 2019.

3.9.3. *Calappa philargius*

3.9.3.1. Size variation

Totally 617 individuals of *Calappa philargius* were collected; 614 from trawl vessels and 3 from trap vessels in August 2018-April 2019 in Dongshan County (Fig. 35):

(1) Sizes ranged from 4.1 to 16.9 cm CW.

(2) Monthly average size ranged from 10.9 to12.2 cm CW, showing a monthly fluctuation.

(3) The dominant size classes were generally larger than 10.0 cm CW in all months. Smaller size classes <9.0 cm CW were dominant in October 2018 (15.58%) and March 2019 (20.51%).

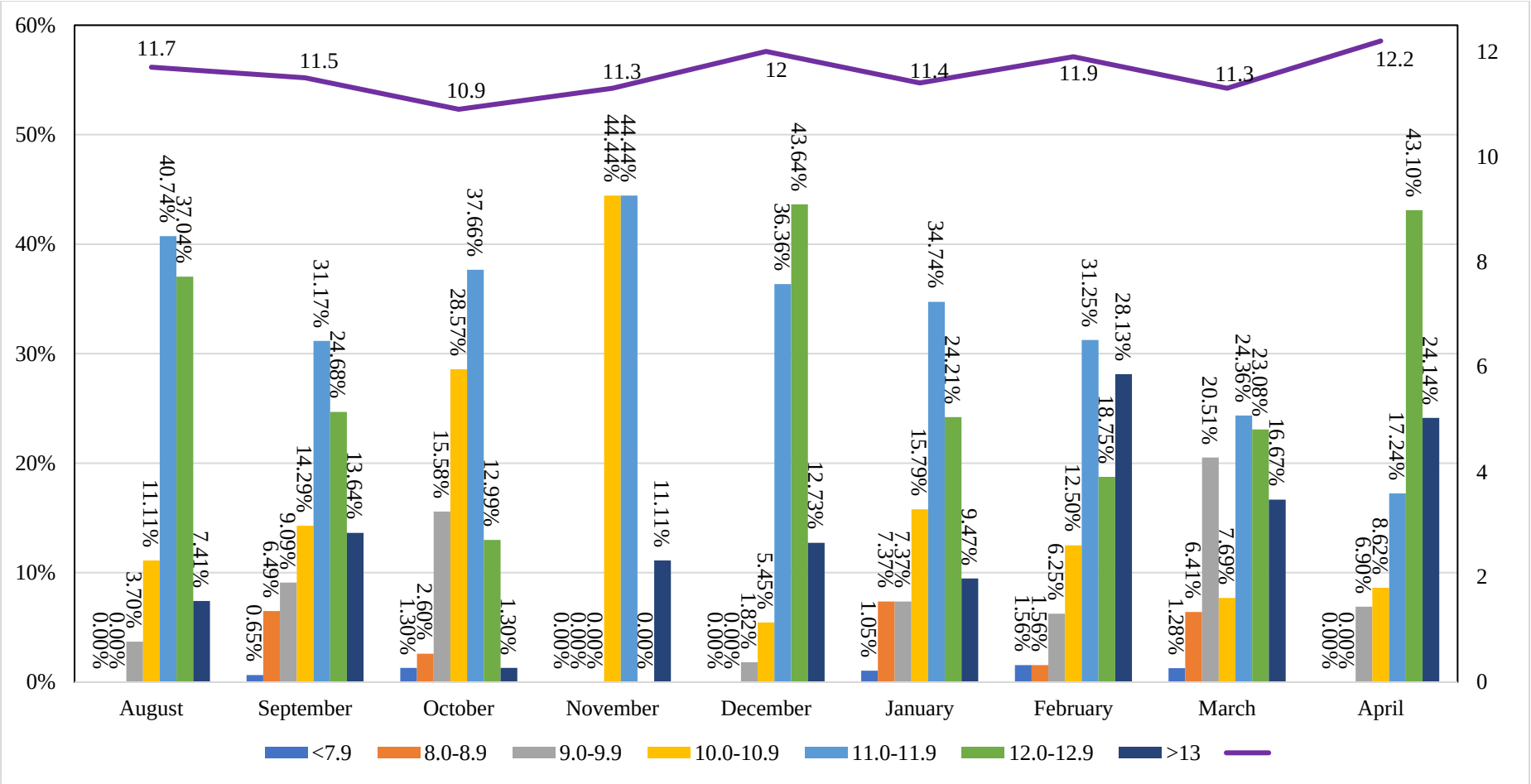

Fig. 35. Proportions of different size classes (cm in carapace width) of all *Calappa philargius* individuals (left Y-axis) and the trend (purple line) of the monthly average sizes (right Y-axis) by both trawl and trap in Dongshan County in August 2018-April 2019.

3.9.3.2. Sex ratio variation

Overall sex ratio of *C. philargius* was 1: 1.46 (male: female), showing a strong male-bias in August and September 2018, and a strong female-bias in November 2018-April 2019 (Fig. 36).

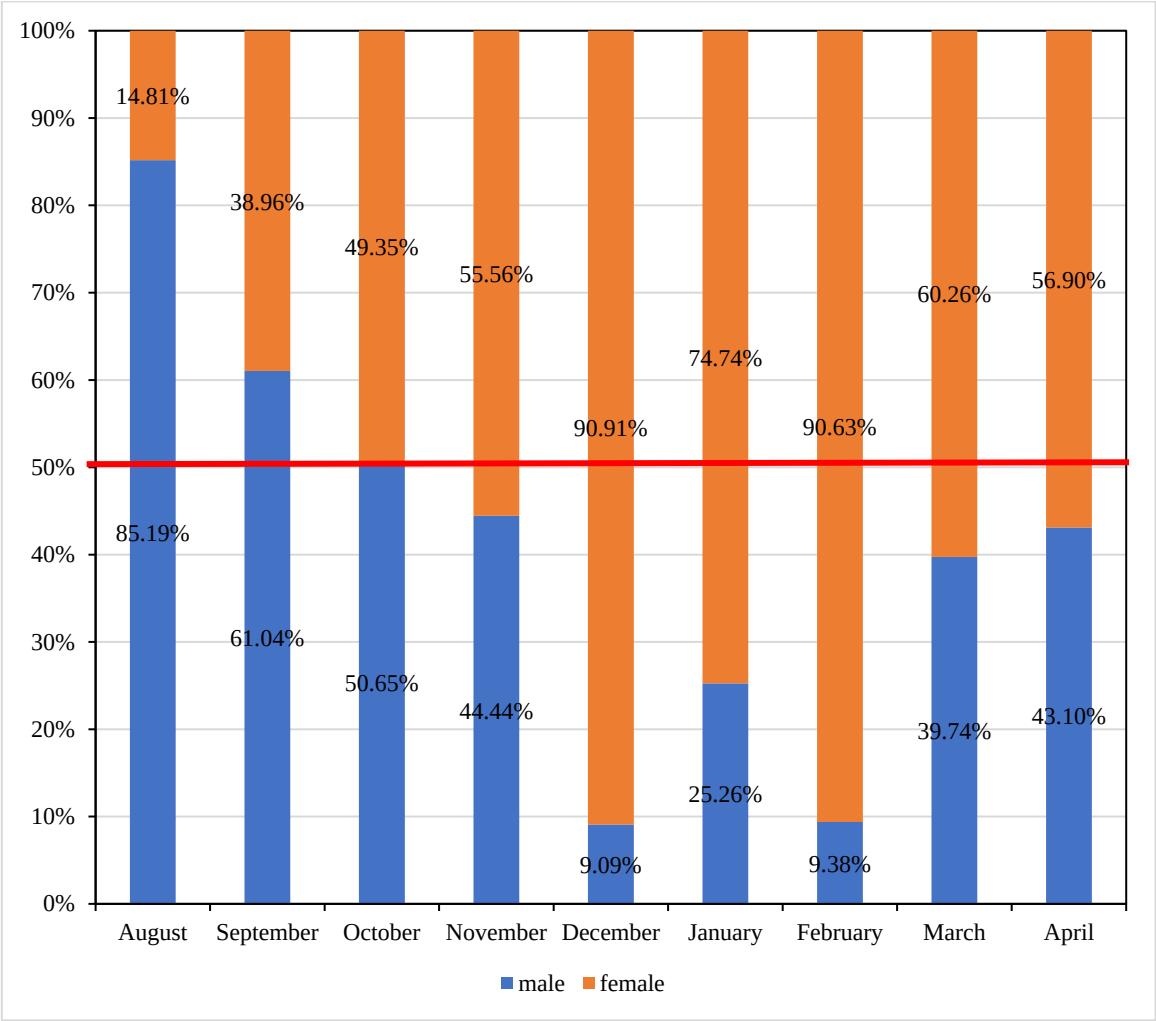

Fig. 36. Sex ratios of *Calappa philargius* in Dongshan County in August 2018-April 2019. Red line showed the sex ratio of 1:1.

3.9.3.3. Size-weight relationship

The relationship of size (carapace width, CW) and weight (whole body weight, BW) for *C. philargius* was: $BW = 0.3086*CW^{2.6711}$ ($R^2 = 0.7272$; N = 617) (Fig. 37).

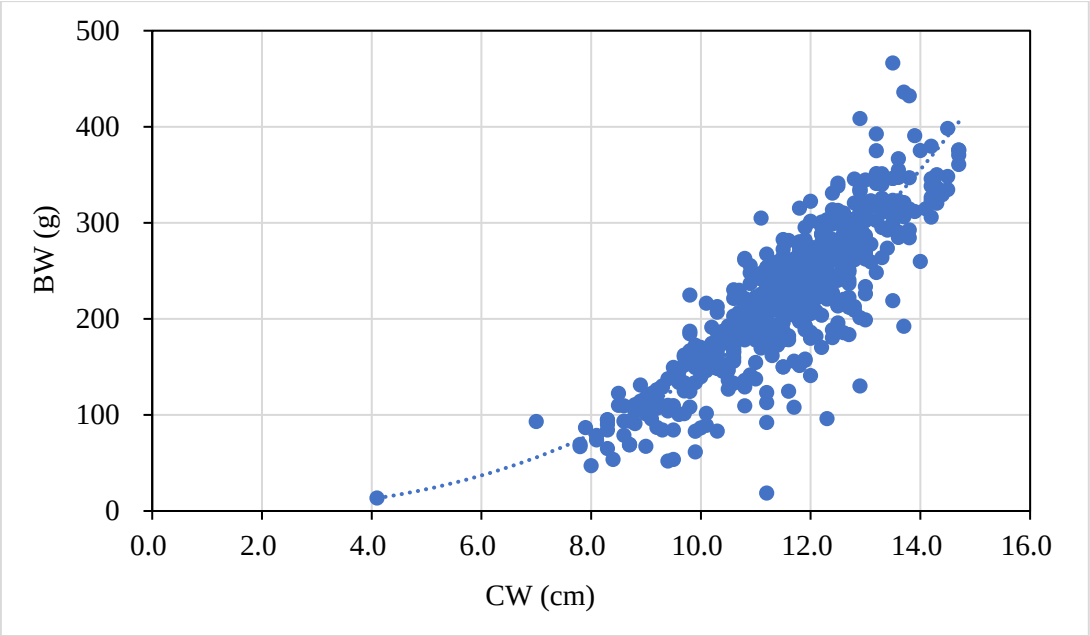

Fig. 37. Size (carapace width, CW)-weight (whole body weight, BW) of *Calappa philargius* (N=617).

3.9.3.4. Carapace length-carapace width relationship

Carapace length (CL)-carapace width (CW) relationship for *C. philargius* was CW=0.6154*CL + 1.0067 (R^2 =0.6486; N=617) (Fig. 38).

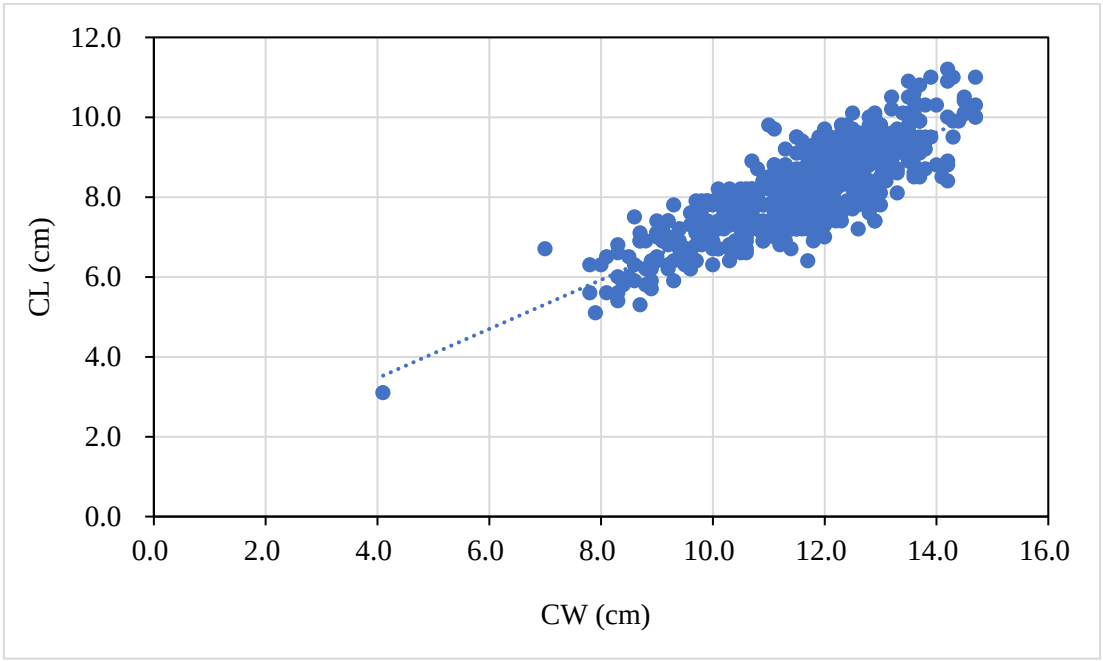

Fig. 38. Carapace length (CL)-carapace width (CW) relationship of *Calappa philargius* (N=617).

3.9.3.5. Spawning seasons and the minimum size for female bearing eggs

The proportions of females bearing eggs showed significantly fluctuation with four peaks; one in September (38.33%), one in November and December (>45%), one in February (63.79%) and one in April (38.39%), indicating three spawning seasons, in September, November-December, and February (Fig. 39).

The minimum size recorded was 9.0 cm CW for *C. philargius*, caught in September 2018.

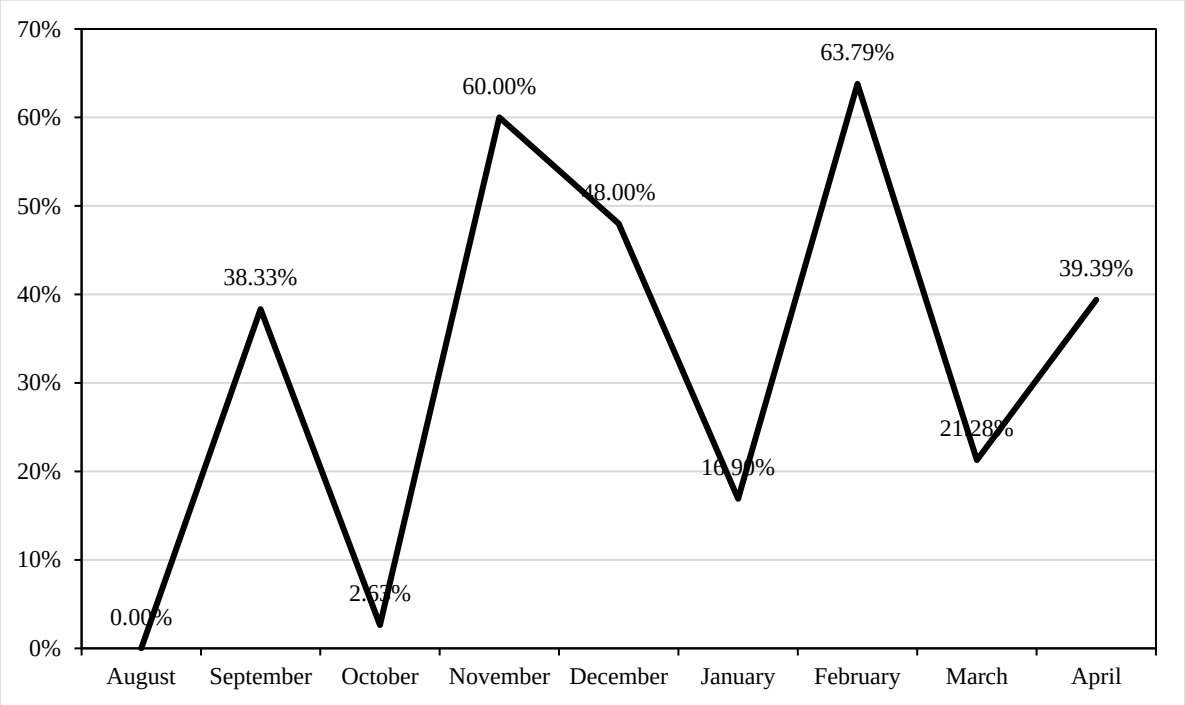

Fig. 39. Proportions of *Calappa philargius* females bearing eggs in Dongshan County in August 2018-April 2019.

3.10. Baits in trap fisheries

In trap fisheries, the sardines (*Sardinella* spp.), Pacific saury (*Cololabis saira*) and Bombay-duck (*Harpadon nehereus*) were commonly used as baits. About 200 g baits were usually in one trap.

In Dongshan County, sardines were commonly used, and in Longhai County, the Pacific saury and Bombay-duck were commonly used.

Sardines and Pacific saury were bought from deep-sea fishery companies, while Bombay-duck were bought from local markets.

3.11. Ecology impacts of different fishing gears

Based on the interviews of captains and crews at the landing ports, an estimation of 7,000-10,000 traps/vessel/year were lost or damaged in Dongshan County. The main reasons for the trap loss were by trawl fishing vessels operated in the same areas and the rocky seabed. For trawl vessels, net loss was not a big issue, however, nets broken was common.

4. Significant findings

(1) Totally 265 species were identified in August 2018-April 2019, including 204 fishes (76.98%), 43 crustaceans (16.23%) and 18 cephalopods (6.79%). Trawl fishery had higher species diversity than trap fishery. There were 60 species, including 46 fishes, 8 crustaceans and 6 cephalopods, found in both trawl and trap fisheries.

(2) Totally 91 species with 65 fishes, 20 crustaceans and 6 cephalopods were identified in feed fishes. Among these, 49 species with 32 fishes, 13 crustaceans and 4 cephalopods were only found in feed fishes.

(3) Confirmed that seahorse bycatch by trawl fishery is significant and common in Dongshan County. The species include *H. trimaculatus* and *H. kuda*.

(4) Obtained the size range information for the main species (including crustaceans, fishes and cephalopods) in trawl fishery in Dongshan County. The majority of the size ranges was less than 30 cm in length.

(5) The main species or species groups in catches were different among different fishing grounds and different fishing gears. In trawl fishery offshore, the main species groups were food fishes, feed fishes and crustaceans. In trap fishery offshore, the main species groups were fishes and crustaceans. In trap fishery nearshore, the main species group was crabs.

(6) Based on the monthly sampling in August 2018-April 2019, the spawning seasons for the four targeted species (*P. haanii*, *P. sanguinolentus*, *C. nataor* and *C. philargius*) were determined. All four species exist one spawning season in February-April. However, another spawning season was also determined, in August-September, or in November-December.

(7) Contributed significantly to crab biology in Chinese waters (Table 12).

Table 12. Minimum sizes (cm, CW) for females bearing eggs (-: no data)

Crab species	**Minimum size (cm, CW)**	
	From reference	**Present study**
Portunus haanii	-	4.6

		(Found in April 2019)
P. sanguinolentus	8.0	9.7 (Found in February 2019)
Charybdis nataor	6.9	6.1 (Found in March 2019)
Calappa philargius	-	9.0 (Found in late-September 2018)

(8) Trap fishery has significant impact on ecosystem. First, there is a significant use of baits for volume. Based on the information on the weight of bait per trap (200 g), the number of traps per vessel (3000 traps) and the number of collection per day (3 collections) in Dongshan trap fishery, the amount of bait weight was estimated, i.e. 1,800 kg bait weight/vessel/day (= 200*3000*3/1000). Second, the loss of traps at sea is significant, about 7,000-10,000 traps/vessel/year.

(9) There is a significant catch of smaller juveniles (<4 cm CW) of *P. haanii* in trawl fishery and mixed in feed fishes.

(10) The CPUE for *P. haanii* in trawl fishery in Dongshan County showed a significant decline over 20 years (Fig. 40).

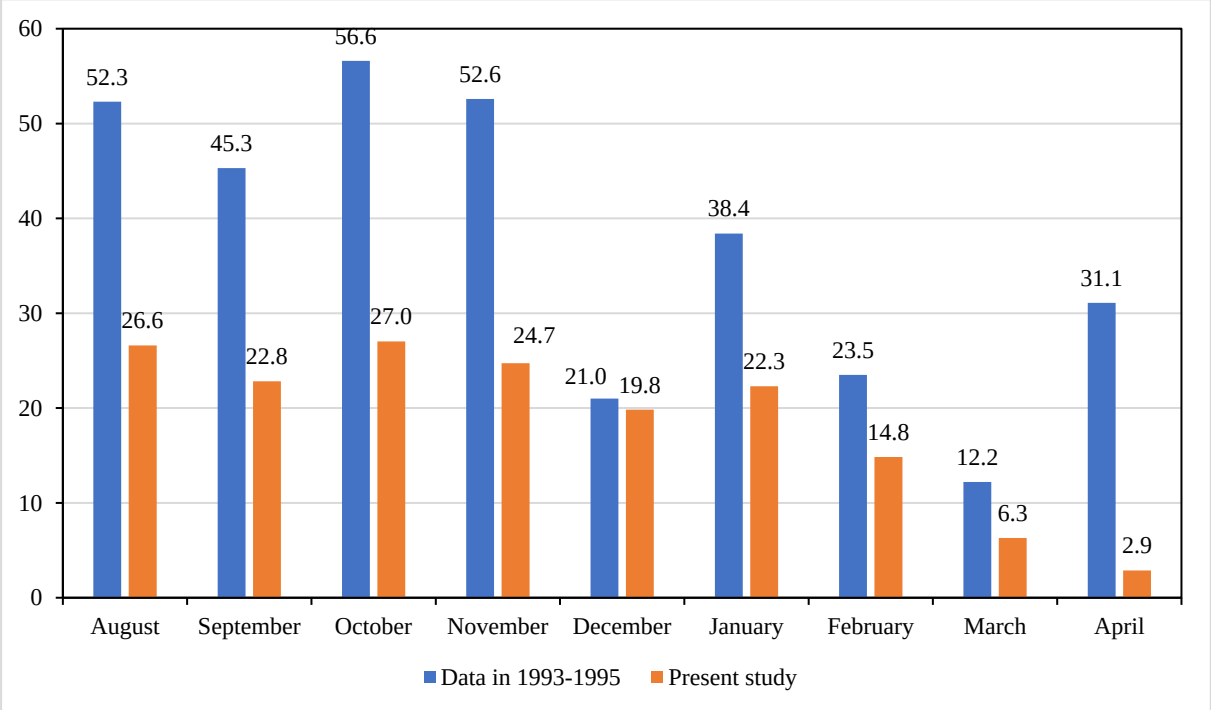

Fig. 40. *Portunus haanii* capture volumes (kg/net) (value on the top of the bar) in 1993-1995 (Zhang 1997) and 2018-2019 (the present study)

5. Recommendations

Based on the Phase II and the previous Phase I findings, several recommendations are provided as below:

(1) **Initiating the monitoring programs on seahorses in Chinese waters are needed.** Currently, *Hippocampus trimaculatus* and *H. kuda* were commonly found in landing catches in Dongshan County. The Minnan-Taiwan Bank fishing grounds are likely to be the suitable habitats for seahorses. Data on fishing site, habitat, stock density and capture volume should be collected, particularly for *H. trimaculatus* to further understand its biology and fishery status.

(2) **The adjustment on the fishing moratorium period should be considered seriously and supported by various academic studies on different species.** A relatively uniform fishing moratorium period is set in the four Chinese Seas for easy management and monitoring, with some adjustments for different fishing gears. There is a strong voice for adjusting fishing moratorium period; earlier start and earlier end from fishers' societies, and the extension of fishing moratorium from crab processing factory industries. Based on the surveys in August 2018-April 2019, two spawning seasons were found for *P. haanii*, in August and in January-April. More studies are needed to understand its spawning grounds, the habitat for juvenile growth, the stock size and the CPUE.

(3) **Regulation on the minimum catch size should not be a paper regulation.** A regulation on the minimum catch size of 35 commercial important specie was released in Fujian Province in 2018, including *P. haanii*. In the regulation, the minimum catch size for *P. haanii* is set at 8.0 cm CW. The details of the regulation for *P. haanii* include the proportions of juveniles in the all species total catches per vessel per trip were <30% juveniles in 2019, and <20% in 2020 and afterward. Without any further academic advices and enforcements, the captains and crews are not able to reduce the proportions of small size crabs in practices. The proportions of *P. haanii* <8 cm CW were about 44.17-64.24% in bottom trawl in August-December 2018, and about 75.93-85.94% in bottom trawl in January-April 2019, and 19.44-47.73% in trap vessels in Dongshan County with the individuals (<8 cm) of *P. haanii* in March <30%. Without change in management measures, fishing practices, and enforcement, it is impossible for trawl vessels to meet the juvenile proportion requirement in 2019 (i.e. <30%). The practices, such as the increase of mesh size in the trawl vessels and the closure of juvenile feeding grounds of *P. haanii* in certain months could potentially be considered.

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