Chinese Red Swimming Crab (*Portunus haanii*) Fishery Improvement Project (FIP) in Dongshan, China (August-December 2018)

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1. Introduction

Chinese red swimming crab *Portunus haanii* 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). The species 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). *Portunus haanii* is characterized with a flattened hind pair of legs with red-purple in the tips (Fig. 1).

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 trawl fishery (Zhang 1997). *Portunus haanii* in Minnan-Taiwan Bank fishing grounds was reported to have two breeding seasons, February-April and 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. Based on a previous study, the abundance and average size of *P. haanii* have

shown a decline compared 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) launched the first phase of a fisheries improvement project (FIP) in August 2018. A priority component of the FIP's initial 5-year work plan was identified as fishery monitoring efforts to understand: the fishery's catch and effort, status of *P. haanii*, the fishery's ecosystem impact and relevant management recommendations to meet international sustainability standards.

These initial fishery monitoring efforts were contracted to Dr. Liu Min and her team at Xiamen University, and this report presents the results of the project under Phase I of the FIP, conducted in Dongshan County in August-December 2018. The objectives were defined as follows:

(1) to document the species composition in the fishery's catch for both trawl and trap gears;

(2) to describe the size range of main species (species group) caught;

(3) to characterize the sex of crabs landed and egg bearing status of females;

(4) to evaluate catch data collection approaches; and

(5) to provide recommendations needed to monitor, manage and ensure regulatory compliance to achieve improved sustainability.

2. Materials and Methods

2.1. Study site and survey frequency

This study was conducted in Dongshan County, and four major landing ports throughout the county, Dawo, Donggu, Aojiao and Gongqian, were surveyed (Fig.2).

During August-December 2018, eight field trips were conducted; twice per month in August, September and October, and once per month in November and December (Table 1).

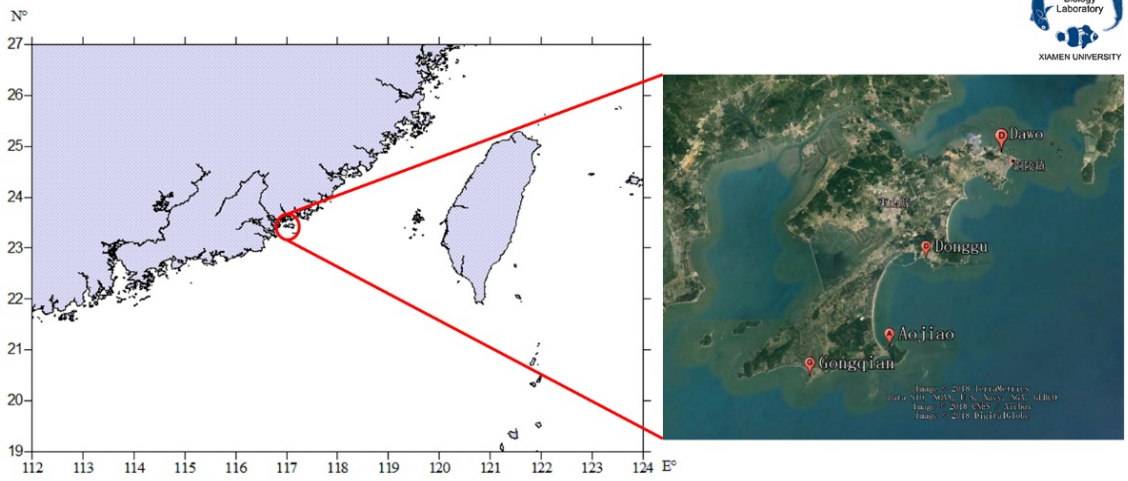


Fig. 2. Study sites in Dongshan County

Table 1. Eight field trips of the present study

No.	Date	No.	Date
1	August 14-16, 2018	5	October 11-13, 2018
2	August 25-27, 2018	6	October 25-27, 2018
3	September 06-08, 2018	7	November 15-17, 2018
4	September 26-28, 2018	8	December 05-11, 2018

2.2. Sample collection

In Dongshan County, about 1,015 trawl vessels and 100 trap vessels registered; for trap vessels, only 10% still go fishing (Mr. Fang, personal communication). For the mid-August trip, only trap vessels were available because of the summer fishing moratorium for trawl vessels was still in place. For the remaining seven monitoring visits, only trawl vessels were surveyed because the difficulties of finding trap vessels landings during the same sampling periods.

For each field trip (Table 1), approximate ten fishing vessels were randomly selected for detailed investigation (Fig. 3).

Fig. 3. Two fishing gears surveyed, trawl (left) and trap (right)

In Dongshan County, we noticed that four crab species were usually separated in catch landings: Chinese red swimming crab *Portunus haanii*, three-spot swimming crab *P. sanguinolentus*, ridged swimming crab *Charybdis nataor* and bread crab *Calappa philargius* (Table 2). Although the project primarily focused on the *P. haanii* fishery, we extended our data and sample collection to *P. sanguinolentus*, *C. nataor* and *C. philargius* to better understand the overall crab fishery in Dongshan County.

For each fishing vessel selected, approximately 30 individuals of each of the four crab species were collected randomly for further measurement and examination (Fig. 4). In addition, samples of other captured fishes, crustaceans and cephalopods were also collected for understanding the species diversity of Dongshan capture fisheries.

During sample collection, fishing vessel captains and crews were interviewed (Fig. 4). Information on fishing vessel registration number, fishing gear type, fishing areas, number of days at sea, total capture volume, crab capture volume and capture volume of main species groups were collected.

Table 2. Target four major crab species in the present study

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*

Fig. 4. Crab sampling (left) and captain interview (right) at the landing ports.

2.3. Species identification

Fishes, crustaceans and cephalopods collected at the landing ports were transferred to the laboratory of Dongshan Swire Marine Station (D-SMART), Xiamen University. Species identification was conducted to species or genus level (Fig. 5).

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).

Fig. 5. Species sorting and identification in the laboratory

2.4. Sample measurement

Sample measurements were conducted in the laboratory of D-SMART, Xiamen University.

For crab individuals sampled, the carapace length (cm) and body weight (g) were measured. 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. 6). The sex was determined based on the variation of abdomen (Fig. 7).

The spawning season of crabs is determined by the appearance of females bearing eggs (Fig. 8). 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. During embryo development, the color of the carried eggs changes from orange-red (full of yolk) to brown and further to black (eyes of larvae can be easily seen) prior to larvae release. We assigned the carried eggs to black, brown, orange-red, for further

understanding the spawning season of females.

For fishes, other crustaceans and cephalopods collected for species diversity study, measurements were also conducted for length and body weight.

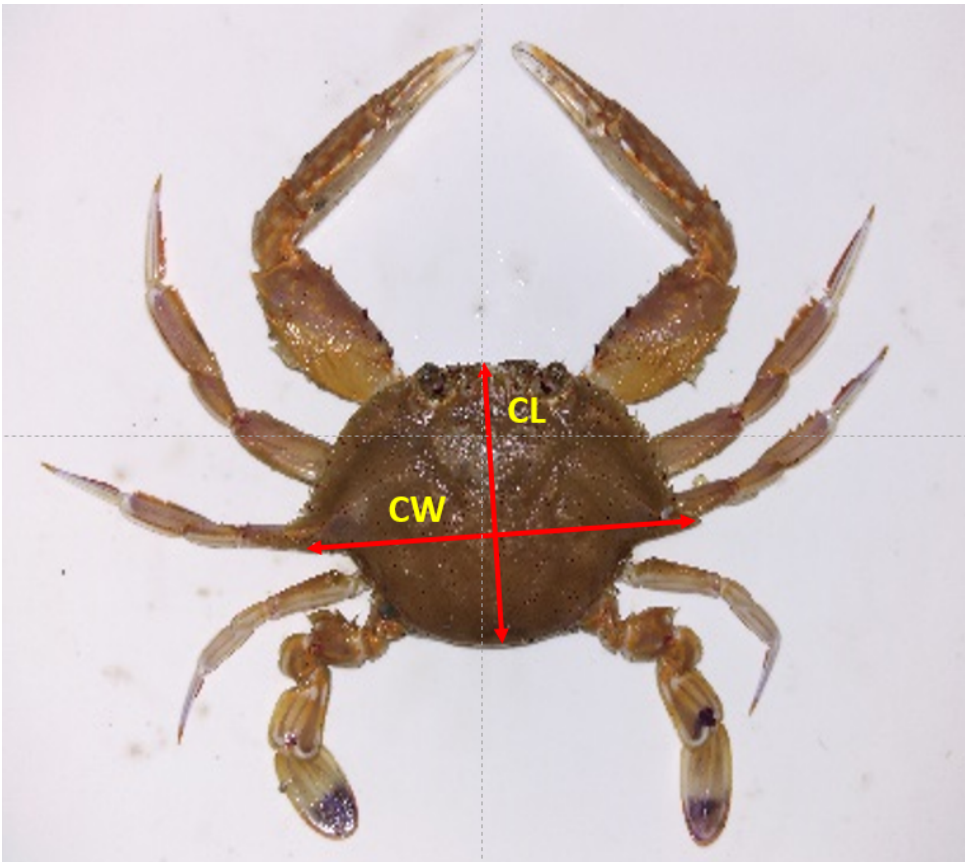


Fig. 6. Crab measurement for length in laboratory

(CW: carapace width; CL: carapace length)

Fig. 7. Sex determination for crabs

Fig. 8. Female crab (*Charybdis nataor*) bearing, orange-red, eggs

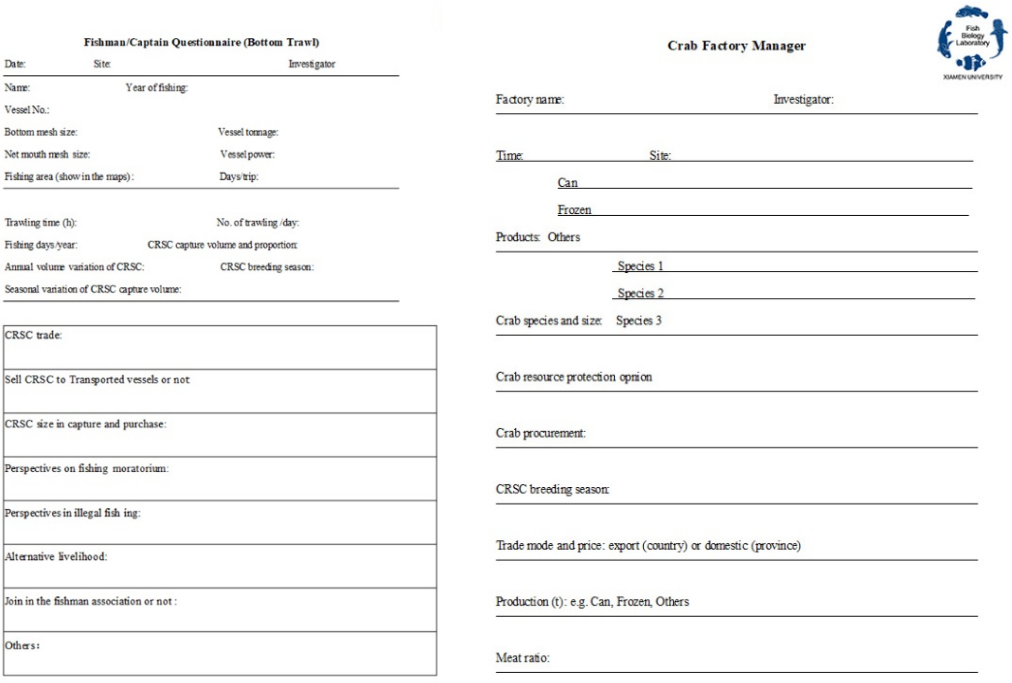
2.5. Interviews

Four crab species, *P. haanii*, *P. sanguinolentus*, *C. nataor* and *C. philargius*, are important in Dongshan crab fishery; among these, *P. haanii* is the most important and, according to processors, the exclusive species for crab meat can products and for export, though yet not verified by processing plant observations. Therefore, to further understand *P. haanii* fishery pattern in Dongshan County, additional interviews were conducted with fishing vessel (both trawl and trap gears) captains, at homes or fishery society offices (Fig. 9). For captain interviews, information such as fishing area (map of the Taiwan Strait and northern South China Sea was provided so that the captains could draw on it to obtain more accurate fishing areas) and season, *P. haanii* capture volume with its proportion to total capture volume, seasonal and year variation in crab size, and spawning season were collected (Fig. 10). Information on their opinions on the current fishing moratorium period, alternative livelihoods for the crews, and trade patterns for their landings were also collected.

To further understand *P. haanii* trade pattern in Dongshan County, interviews were conducted with crab processing factory owners at their factory offices (Fig. 9). For these

interviews, information such as the supply sources of *P. haanii*, proportion of *P. haanii* in crab species processed, size preference, processing volume, crab meat can product volume for export, and the months with female crabs bearing eggs, were collected (Fig. 10). Opinions on the current fishing moratorium period were also collected and questions about crab meat productivity (crab meat weight/the whole crab weight) were asked.

Fig. 9. Fishing vessel captain (left) and crab processing factory owner (right) interviews



Fishman/Captain Questionnaire (Bottom Trawl)

Date: Site: Investigator

Name: Year of fishing:

Vessel No.:

Bottom mesh size: Vessel tonnage:

Net mouth mesh size: Vessel power:

Fishing area (show in the maps): Days/trip:

Trawling time (h): No. of trawling /day:

Fishing days/year: CRSC capture volume and proportion:

Annual volume variation of CRSC: CRSC breeding season:

Seasonal variation of CRSC capture volume:

CRSC trade:
Sell CRSC to Transported vessels or not:
CRSC size in capture and purchase:
Perspectives on fishing moratorium:
Perspectives in illegal fish ing:
Alternative livelihood:
Join in the fishman association or not :
Others:

Crab Factory Manager

Factory name: Investigator:

Time: Site:

Products: Can

Frozen

Others

Crab species and size: Species 1

Species 2

Species 3

Crab resource protection option

Crab procurement:

CRSC breeding season:

Trade mode and price: export (country) or domestic (province)

Production (t): e.g. Can, Frozen, Others

Meat ratio:

Fig. 10. Questionnaires designed for

fishing vessel captain and crab processing factory owner interviews

2.6. Estimation of annual capture volume of *Portunus haanii*

Fishing vessel surveys at the landing ports (see 2.2. section) and interviews with fishing vessel captains (see 2.5. section) were used to estimate the total capture volume or landing volume of *P. haanii* in Dongshan County. The estimation of *P. haanii* capture volume can be conducted based on the data collected, such as the average capture volume of *P. haanii* per vessel, the total number of registered trawl and trap vessels, and the average operation days at sea.

It is also important to estimate the volume of *P. haanii* used in canned crab meat product processing in Dongshan County for evaluating the sustainability of *P. haanii* fishery. However, during the interviews conducted with crab processing factory owners (see 2.5. section), we realized that it was not possible to obtain annual processing volume of *P. haanii* and the export volume of crab meat can products from them. Alternatively, we obtained canned crab meat product volume for export of Fujian Province in 2008-2018 (only from January to September in 2018) from Chinese Customs service. Based on the proportion of crab meat to whole crab weights (i.e. crab meat productivity) obtained above through interviews with crab processing factory owners (see 2.5. section), the total annual crab volumes used for processing in Fujian Province can be calculated, with the proportion of *P. haanii* in canned crab meat product providing an estimate of the volume of *P. haanii*.

3. Results

3.1. Species diversity

3.1.1. Species composition

In total 148 species were identified from the trawl fishery in Dongshan County, including 115 fishes (77.70%), 26 crustaceans (17.57%) and seven cephalopods (4.73%) (Table 3). Fishes come from two classes (Chondrichthyes and Actinopterygii), 14 orders and 60 families, with half of the fish species from Perciformes. Crustaceans come from two orders and five families, and cephalopods from two orders and two families.

In the trap fishery, 17 fish species and 7 crustaceans were recorded; all found in trawl fishery (Table 3).

Table 3. Species recoded in

trawl fishery (N=148) and trap fishery (*, N=23) in Dongshan County

Order	Family	Species	No.
Fishes			
Carcharhiniformes	Carcharhinidae	Spadenose shark *Scoliodon macrorhynchos*	1
		Spot-tail shark *Carcharhinus sorrah*	2
		Tiger shark *Galeocerdo cuvier*	3
	Shpyrnidae	Scalloped hammerhead *Sphyrna lewini*	4
	Triakidae	Spotless smooth-hound *Mustelus griseus*	5
Torpediniformes	Narcinidae	Chinese numbfish *Narcine lingula*	6
Rajiformes	Rhynchobatidae	Giant guitarfish *Rhynchobatus djiddensis*	7
	Rhinobatidae	Ringstreaked guitarfish *Rhinobatos hynnicephalus*	8
	Rajidae	Boeseman's skate *Okamejei boesemani*	9
Myliobattiformes	Platyrhinidae	Fan ray *Platyrhina sinensis*	10
	Dasyatidae	Red stingray *Dasyatis akajei*	11

		Pale-edged stingray *D. zugei*	12
	Gymnuridae	Japanese butterfly ray *Gymnura japonica*	13
Anguiliformes	Muraenidae	Dusky-banded moray *Gymnothorax reticularis*	14
		Sieve-patterned moray eel *G. cribroris*	15
	Ophichthidea	Snake eel *Xyrias chioui*	16
		Longfin snake-eel *Pisodonophis cancrivorus*	17
		Finny snake eel *Caecula pterygera*	18
	Congridae	White spotted conger *Conger japonicus*	19
		Conger eel *Gnathophis heterognathos*	20
	Muraenesocidae	Daggertooth pike conger *Muraenesox cinereus*	21
		Slender conger *Uroconger lepturus*	22
		Shorttail pike conger *Oxyconger leptognathus*	23
Clupeiformes	Clupeidae	Bloch's gizzard shad *Nematalosa nasus*	24
		Round sardinella *Sardinella aurita*	25
Siluriformes	Ariidae	Threadfin sea catfish	26

		Arius arius	
		Spotted sea catfish *A. maculatus*	27
	Plotosidae	Striped eel catfish *Plotosus lineatus*	28
Aulopiformes	Synodontidae	Slender lizardfish *Saurida elongata*	29*
		Greater lizardfish *S. tumbil*	30*
		Blunt-nose lizardfish *Trachinocephalus myops*	31
Mugiliformes	Mugilidae	Flathead grey mullet *Mugil cephalus*	32
Gasterosteiformes	Syngnathidae	Longnose seahorse *Hippocampus trimaculatus*	33
		Gray's pipefish *Halicampus grayi*	34
	Fistulariidae	Bluespotted cornetfish *Fistularia commersonii*	35
		Red cornetfish *F. petimba*	36
Scorpaeniformes	Scorpaenidae	Ocellated waspfish *Apistus carinatus*	37
		Sea ruffe *Sebastiscus marmoratus*	38*
		Flasher scorpionfish *Scorpaenopsis macrochir*	39
		Weedy stingfish *S. cirrosa*	40

	Dactylopteridae	Oriental flying gurnard *Dactyloptena orientalis*	41
	Triglidae	Red gurnard fillets *Lepidotrigla microptera*	42
	Platycephalidae	Rough flathead *Grammoplites scaber*	43
		Bartail flathead *Platycephalus indicus*	44*
		Crocodile flathead *Cociella crocodila*	45
Perciformes	Mornidae	Japanese sea bass *Lateolabrax japonicus*	46
	Epinephelidae	Chocolate hind *Cephalopholis boenak*	47
		Banded grouper *Epinephelus awoara*	48*
		Orange-spotted grouper *E. coioides*	49
		Red spotted grouper *E. akaara*	50
		Oval grouper *Triso dermopterus*	51
	Priacanthidae	Purple-spotted bigeye *Priacanthus tayenus*	52
		Red bigeye *P. macracanthus*	53
	Apogonidae	Half-lined cardinal *Apogon semilineatus*	54
		Cardinalfish	55

		A. cathetogramma	
	Sillaginidae	Silver sillago *Sillago sihama*	56*
		Japanese whiting *S. japonica*	57*
	Coryphaenidae	Common dolphinfish *Coryphaena hippurus*	58
	Rachycentridae	Cobia *Rachycentron canadum*	59
	Carangidae	Japanese scad *Decapterus maruadsi*	60
		Japanese jack mackerel *Trachurus japonicus*	61
		Black pomfret *Parastromateus niger*	62
		Yellowstripe scad *Selaroides leptolepis*	63
		Yellowtail amberjack *Seriola aureovittata*	64
		Blackbanded trevally *S. nigrofasciata*	65
	Leiognathidae	Ponyfish *Equulites rivulatus*	66
		Deep pugnose ponyfish *Secutor ruconius*	67
	Lutjanidae	Russell's snapper *Lutjanus russellii*	68
		Crimson snapper *L. erythopterus*	69

	Haemulidae	Broadbanded velvetchin *Hapalogenys analis*	70
		Chicken grunt *Parapristipoma trilineatum*	71
		Trout sweetlips *Plectorhinchus pictus*	72
	Lethrinidae	Pacific yellowtail emperor *Lethrinus atkinsoni*	73
	Sparidae	Yellowfin seabream *Acanthopagrus latus*	74*
		Threadfin porgy *Evynnis cardinalis*	75*
		Goldlined seabream *Rhabdosargus sarba*	76*
	Polynemidae	Fourfinger threadfin *Eleutheronema tetradactylum*	77
	Sciaenidae	Croaker *Johnius distinctus*	78
		Trewavas croaker *J. trewavasae*	79
		Belanger's croaker *J. belangerii*	80
		Croaker *J. taiwanensis*	81
		Yellow drum *Nibea albiflora*	82
		Big-head pennah croaker *Pennahia macrocephalus*	83
		Donkey croaker	84

		P. anea	
	Mullidae	Japanese goatfish *Upeneus japonicus*	85*
		Blackspot goatfish *Parupeneus spilurus*	86
	Glaucosomatidae	Deepsea jewfish *Glaucosoma buergeri*	87
	Terapontidae	Jarbua terapon *Terapon jarbua*	88
	Pomacanthidae	Bluestriped angelfish *Chaetodontoplus septentrionalis*	89
	Labridae	Azurio tuskfin *Choerodon azurio*	90*
		Wrasse *Parajulis poecilepterus*	91*
		Blackspot razorfish *Xyrichtys dea*	92*
		Red naped wrasse *Pseudolabrus eoethinus*	93
	Pinguipedidae	Harlequin sandsmelt *Parapercis puplchella*	94
		Grub fish *P. sexfasciata*	95
	Callionymidae	Izu ruddertail dragonet *Callionymus curvispinis*	96
	Trichonotidae	Spotted sand-diver *Trichonotus setiger*	97
	Ammodytidae	Mitsukuri's Sandlance	98

		Bleekeria mitsukurii	
	Uranoscopidae	Marbled stargazer *Uranoscopus bicinctus*	99
	Siganidae	Mottled spinefoot *Siganus fuscescens*	100
	Sphyraenidae	Yellowtail barracuda *Sphyraena flavicauda*	101
		Japanese barracuda *Sphyraena japonica*	102
	Trichiuridae	Largehead hairtail *Trichiurus japonicus*	103
	Scombridae	Japanese Spanish mackerel *Scomberomorus niphonius*	104
Pleuronectiformes	Paralichthyidae	Cinnamon flounder *Pseudorhombus cinnamoneus*	105
	Bothidae	Blue flounder *Crossorhombus azureus*	106
	Pleuronectidae	Ovate sole *Solea ovata*	107
		Ridged-eye flounder *Pleuronichthys cornutus*	108
	Cynoglossidae	Speckled tonguesole *Cynoglossus puncticeps*	109
Tetraodontiformes	Monacanthidae	Unicorn leatherjacket filefish *Aluterus monoceros*	110
		Threadsail filefish *Stephanolepis cirrhifer*	111*
		Faintstripe filefish *Paramonacanthus pusillus*	112*
	Tetraodontidae	Blowfish	113*

		Lagocephalus wheeleri	
		Lattice blaasop *Takifugu oblogus*	114
		Pufferfish *T. poecilonotus*	115
Crustaceans			
Stomatopoda	Squillidae	Orange & white mantis shrimp *Lysiosquilla sulcirostris*	116
		Japanese mantis shrimp *Oratosquilla oratoria*	117
		Peacock mantis shrimp *Odontodactylus japonicus*	118
		Mantis shrimp *Harpiosquilla harpax*	119
Decapoda	Solenoceridae	Shrimp *Solenocera carssicornis*	120
	Penaeidae	King prawn *Melicertus canaliculatus*	121
		Kuruma prawn *Marsupenaeus japonicus*	122
		King prawn *Panaeus monodon*	123
		Spear shrimp *Parapenaeopsis hardwickii*	124
		Coral shrimp *P. cornuta*	125
		Shrimp *Trachypenaeus curvirostris*	126
		Velvet shrimp *Metapenaeopsis barbata*	127
		Elvet shrimp *M. lamellata*	128
	Calappidae	Spotted box crab	129*

		Calappa philargius	
		Reef box crab *C. lophos*	130
	Portunidae	Soldier swimming crab *Charybdis miles*	131
		Swimming crab *C. sagamiensis*	132
		Swimming crab *C. amboinensis*	133
		Mud crab *C. hellerii*	134
		Swimming crab *C. acuta*	135
		Crucifix crab *C. feriatus*	136*
		Rock crab *C. nataor*	137*
		Flower swimming crab *Portunus pelagicus*	138*
		Japanese blue swimming crab *P. trituberculatus*	139*
		Chinese red swimming crab *P. haanii*	140*
		Three-spot swimming crab *P. sanguinolentus*	141*
Cephalopods			
Teuthoidea	Loliginidae	Mitre squid *Loligo chinensis*	142
		Squid *Loligo* sp.	143
Sepioidea	Sepiidae	Spineless cuttlefish *Sepiella maindroni*	144
		Needle cuttlefish *Sepia aculeata*	145
		Small octopus *Octopus variabilis*	146
		Webfoot octopus *O. ocellatus*	147

		Marbled octopus *O. aegina*	148

3.1.2. ETP species

Among 148 species identified, two were ETP (endangered, threatened and protected) species, i.e. Scalloped hammerhead shark *Sphyrna lewini* and Longnose seahorse *Hippocampus trimaculatus* (Table 3).

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. 11); only six individuals from two fishing vessels were found, all in October 2018 surveys, and sold to the local markets for food.

Fig. 11. Scalloped hammerhead shark *Sphyrna lewini* in Dongshan County trawl fishery

Hippocampus trimaculatus was listed in CITES Appendix II in 2002, as "Vulnerable" in IUCN Red List in 2012, and listed as National Protected Species Class II of China in 2018. In Dongshan County, *H. trimaculatus* is the absolutely dominant landing species in seahorse catches from bottom trawl fishing vessels (Fig. 12). The seahorse price of wet weight is approximately 1600 RMB/kg (220 USD/kg) at landing ports, the highest unit price of all capture species. Up to 20% of bottom trawl fishing vessels had *H. trimaculatus* catches during landing port surveys; seahorse catches were approximate 1-50 kg wet weight/vessel/trip.

Fig. 12. Longnose seahorse *Hippocampus trimaculatus* in Dongshan County trawl fishery

3.2. Fishing vessels surveyed at the landing ports

During August-December 2018, 79 vessels were surveyed at the landing ports of Dongshan County, including 68 trawl fishing vessels, nine trap fishing vessels and two transshipment vessels (Table 4). Trap fishing vessel surveys were only conducted in August because of the low occurrence during surveys.

Based on the captain interviews of fishing vessels surveyed at the landing ports, we found that the main fishing grounds for trawl and trap vessels from Dongshan County are within 117º-119º E and 22º-24º N in the southwest Taiwan Strait and northern South China Sea, including Minnan Fishing Ground, Taiwan Bank Fishing Ground and Yuedong Fishing Ground. The captains and crews were busy landing catches and did not have much time to talk with us. The area of 117º30′-118º30′ E and 22º-23º N is reported to be the main fishing grounds for crabs. The habitat of the main fishing grounds for *P. haanii* is dominant by sandy bottom with a depth of less than 50 m.

For more accurate fishing grounds, we also obtained additional information from captain interviews at home or at fishery society offices (see 3.8. section below).

3.2.1 Fishing gears registered often changed without permit

Based on the registered number of the fishing vessels surveys at the landing ports, we checked the types of fishing gears they were registered in the fishing vessel administration department. We found that the fishing gears of many fishing vessels surveyed differ from those originally registered (Table 4). Among the 68 trawl vessels surveyed, only 35 were registered as trawlers (51.47%), 19 vessels were modified from trap, gill net and hook (27.94%), and 13 vessels no longer exist in Dongshan County Fishing Vessel Administration Division under Dongshan County Ocean and Fishery Bureau records (19.12%). Among the nine trap vessels surveyed, only one registered as trap (11.11%), and the remaining eight were modified from gill net, seine net and hook (88.89%).

Thirteen trawl vessels are not found in the official record of Dongshan County Fishing Vessel Administration Division. There are at least two possibilities. One is that their vessel licenses had been bought back by government, however, the vessels have not yet been destroyed and are still operating illegally. The other is that the captains provided wrong vessel number to us; because of low tide, some trawl vessels used small engine boats to transfer catches to landing ports.

The fishers are not requested to report their capture volumes to local fishery societies or to Dongshan County Ocean and Fishery Bureau. The registered fishing vessels are required to install GPS instrument so that the routines of fishing vessels can be monitored by Dongshan County Ocean and Fishery Bureau.

Table 4. Fishing vessels surveyed and their fishing gears registered

(*Data from Dongshan County Fishing Vessel Administration Division)

Fishing gear operated	Fishing gear registered*	Number	Total
Trawl	Trawl	35	68
	Trap	1	
	Gill net	16	
	Hook	2	
	Others	1	

	Vessels not recorded	13	
Trap	Trap	1	9
	Gill net	5	
	Seine net	1	
	Hook	2	

3.2.2 Function of transshipment vessels

Transshipment vessels in Dongshan County play an important role in transferring catches from trap fishing vessels to landing ports, both live and iced crabs.

Based on the surveys at the landing ports, these transshipment vessels made landings every 2-3 days, with those landings usually collected from 6-20 trap fishing vessels. The catches of different trap fishing vessels were separated, and at landing port the catches were collected by the representatives of the trap fishing vessels. Transfer vessels also play a role in supplying food and ice for the trap fishing vessels so that they can operate at sea longer as long as the weather is suitable for fishing.

Live crab species included *Portunus sanguinolentus*, *P. pelagicus*, *P. trituberculatus*, *Charybdis nataor* and *Charybdis feriatus* (Table 3). Live crabs are popular in domestic markets and have higher price (about twice) than those of dead ones.

Iced crab species were *P. haanii*, *C. nataor*, *P. sanguinolentus* and *Calappa philargius* (Table 3). For *P. haanii*, cooked crabs were occasionally found, with bodies and claws stored separated. For *C. philargius*, only claws were kept.

3.3. Crab capture proportion and volume

3.3.1. Four main crab species in catches and their utilization

Four crab species, Chinese red swimming crab *Portunus haanii*, three-spot swimming crab *P. sanguinolentus*, ridged swimming crab *Charybdis nataor* and bread crab *Calappa philargius*, were usually separated in catch landings. The trade modes of

the four crab species are different (Table 5). Occasionally, a few other crab species were mixed with the four crab species (Table 5).

Table 5. Trade modes of four main crab species

No.	Species	Trade	Mixed species
1	*Portunus haanii*	Mainly to processing factories; A few to domestic markets.	*Charybdis miles* *C. sagamiensis*
2	*Portunus sanguinolentus*	To processing factories; To domestic markets; Proportion is unknown.	*P. pelagicus* *P. trituberculatus* *Charybdis feriatus*
3	*Charybdis nataor*	To processing factories; To domestic markets; Proportion is unknown.	*C. amboinensis* *C. acuta*
4	*Calappa philargius*	Only claws sold to domestic markets; Body discarded.	*Calappa lophos*

3.3.2. Crab capture proportion in total capture volume

Based on the trawl fishing vessels surveyed at the landing ports, they spent 2~13 days (mean 7.67 days, N=61) operating at sea per trip (Table 6). The fishing days per trip highly depends on weather. Although fishing days at sea varied highly, most of trawl fishing vessels surveyed at the landing ports spent 7 or 8 days at sea per trip when the weather is fine.

The estimated average crab capture volume per trip (1,603 kg/bottom trawl vessel/trip) represented 20.41% of the estimated all species capture volume (7,855 kg/bottom trawl vessel/trip) (Table 6). Of the total crab capture volume per trip, *P. haanii* was 1,075 kg, *P. sanguinolentus* was 379 kg, *C. nataor* was 127 kg and *C.*

philargius was 22 kg, representing 13.69%, 4.82%, 1.62% and 0.28% of the total all species capture volume, respectively (Table 6).

For the trap fishing vessels surveyed at the landing ports (August 2018 only), they spent 9~15 days (mean 12.75 days, N=9) at sea per trip (Table 6).

The estimated average crab capture volume per trip (6,143 kg/trap vessel/trip) represented 81.26% of the estimated all species capture volume (7,560 kg/trap vessel/trip) (Table 6). Among the crab capture volume per trap trip, *P. haanii* was 3,324 kg (260.71 kg/vessel/day) and *P. sanguinolentus* was 2,819 kg, representing 43.97% and 37.29% of the all species capture volume, respectively (Table 6).

Table 6. Crab capture volume proportion from fishing vessels surveyed at the landing ports of Dongshan County

	Trawl (Range, mean, N=sample size)	**Trap** (Range, mean, N=sample size)
Fishing days per trip	2~13 days, N=61 (mean 7.67 days)	9~15 days, N=9 (mean 12.75 days)
Average all species total capture volume per trip (kg/vessel/trip)	7855	7560
Average total crab capture volume per trip (kg/vessel/trip)	1603	6143
Total crab volume/all species total capture volume (%)	20.41%, N=64	81.26%, N=9
Portunus haanii volume/all species total capture volume (%)	13.69%, N=59	43.97%, N=9
Portunus sanguinolentus volume/all species total capture volume (%)	4.82%, N=53	37.29%, N=9
Charybdis nataor volume/all species total capture volume (%)	1.62%, N=32	-

Calappa philargius volume/all species total capture volume (%)	0.28%, N=29	-

There are two main differences between trawl fishing and trap fishing in the Dongshan County fishery (Table 6). First, days spent at sea for trap fishing trips are longer than trawl fishing trips. Second, trap fishing trips had significantly higher crab catches than trawl trips.

In order to confirm the fishing days at sea per trip for different fishing gears, additional interviews were conducted with captains, from both trawl and trap vessels, at homes or at fishery society offices. The fishing days at sea per trip were usually 7~14 days for trawl vessels and from 10~20 days up to one month for trap vessels.

3.3.3. Crab capture proportion variation by month

Trap vessels were only surveyed in August, therefore, the analysis on crab capture proportion by month was only conducted for trawl vessels.

The crab proportion in all specie total capture volume for trawl fishing vessels showed monthly variation (Fig. 13). Crab proportion was high (23.38%) in late-August, almost the first trip after the fishing moratorium (which for trawl ended at noon on 16 August). Crab proportion declined and remained low in September through early-October (around 15%), and increased to more than 25% in late-October-December.

Portunus haanii was the dominant specie in August-December 2018 crab landings (Fig. 13). The *P. haanii* proportion of all species total capture volume was high in late-August (19.74%) and late-October (22.88%), around 10% in September and early-October, and remained around 15% in November and December.

Proportion of *Portunus sanguinolentus* in all species total capture volume increased from late-October to December, and reached to nearly 10% in November and December. Proportions of *Charybdis nataor* and *Calappa philargius* in all species total capture volume were low and usually did not exceed 5% (Fig. 13).

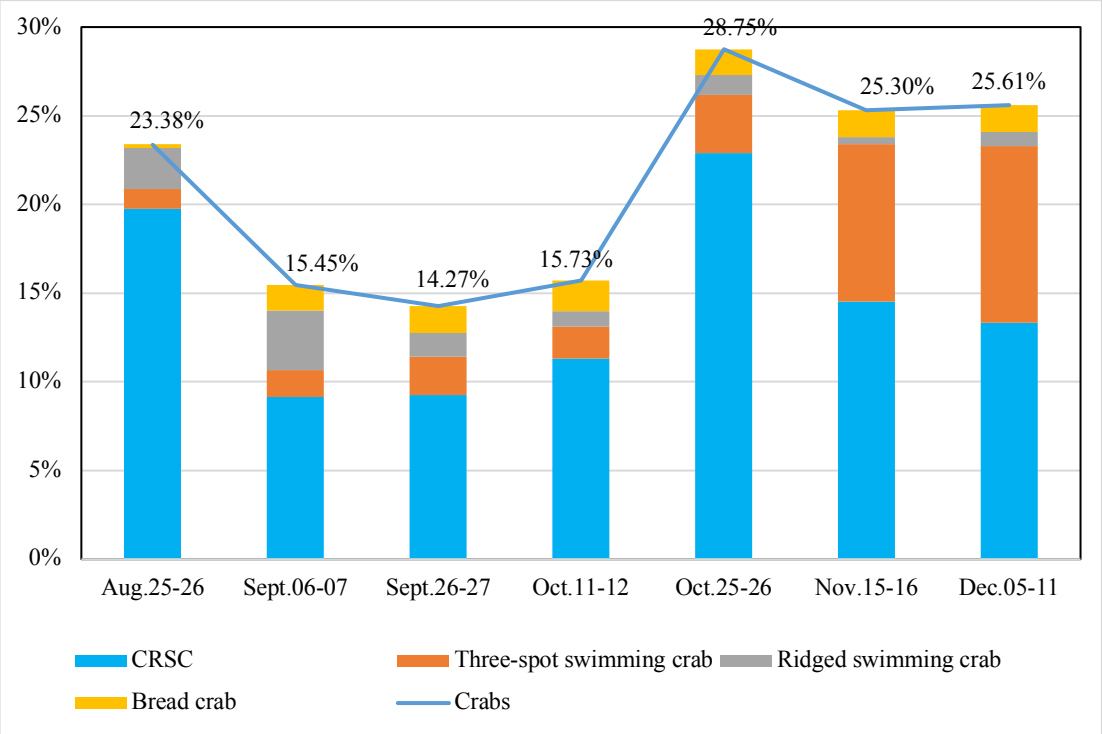


Fig. 13. Crab capture proportion (value shown at the top of the bar, and the blue line shows the trend) of all species total capture volume from bottom trawl vessels surveyed at the landing ports of Dongshan County by month

(CRSC: *Portunus haanii*; Three-spot swimming crab: *P. sanguinolentus*; Ridged swimming crab: *Charybdis nataor*; Bread crab: *Calappa philargius*)

3.3.4. *Portunus haanii* capture volume variation by month

Portunus haanii capture volume was further analyzed and showed a variation by month.

The average monthly capture volume of *Portunus haanii* ranged from 721.47 to 1511.25 kg/vessel/trip (mean 1024.92 kg/vessel/trip), the highest in late-August and the lowest in early-October (Fig. 14).

Based on the fishing days that the vessel surveyed spent at sea (determined through interviews at the landing ports), the average capture volume of *Portunus haanii* ranged from 105.14 to 182.50 kg/vessel/day (mean 140.16 kg/vessel/day), the highest in late-October and the lowest in December (Fig. 14).

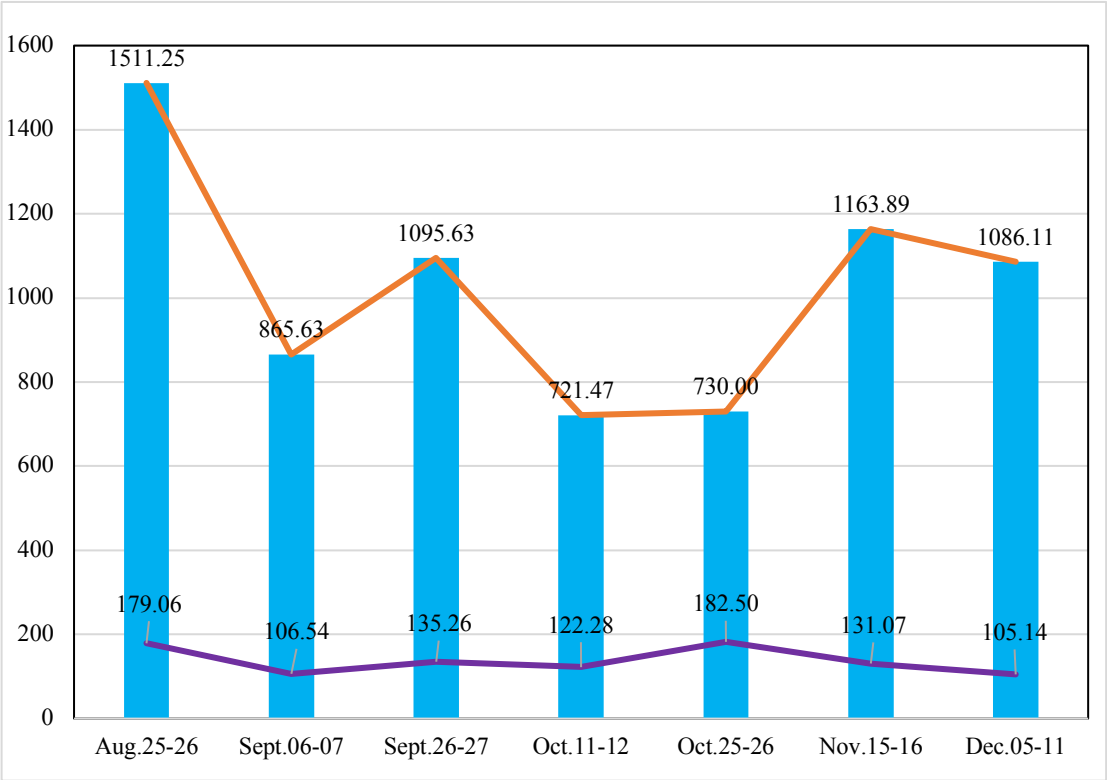


Fig. 14. Average capture volume of *Portunus haanii* (kg/vessel/trip) (value shown at the top of bar) from trawlers surveyed at the ports of Dongshan County by month (Orange line shows the trend of the average capture volume of *P. haanii* in kg/vessel/trip; purple line shows the trend of the average capture volume of *P. haanii* in kg/vessel/day)

3.3.5. Capture proportion of other species groups in total capture volume

Based on the 30 bottom trawl vessels surveyed at the landing ports in late-October, November and December, the average capture proportion of crabs was 26.55% (ranged of 25.30~28.75%) (see 3.3.3. section). Capture proportions of other taxonomic species groups were also estimated as below (Table 7):

Average of 38.3% (ranged of 16.4~60.1%) for fish group of all species total catch volume;

Average of 15.7% (ranged of 5.9~28.6%) for cephalopod group of all specie total catch volume;

Average of 7.0% (ranged of 2.2~19.8%) for shrimp group of all species total

catch volume;

Average of 32.7% (ranged of 21.6~50.5%) for feed fish group of all species total catch volume.

Table 7. Capture proportions of species groups in all species total capture volumes

Species group	Proportion (mean, range)	Dominant species
Fish	38.3% (16.4-60.1%)	*Trachurus japonicas* *Decapterus maruadsi* *Sillago sihama* *S. japonica* *Trachinocephalus myops* *Saurida* spp. *Upeneus japonicus* *Evynnis cardinalis*
Cephalopod	15.7% (5.9-28.6%)	*Sepiella* maindroni *Octopus* spp. *Loligo* spp.
Shrimp	7.0% (2.2-19.8%)	*Parapenaeopsis hardwickii* *Panaeus* spp.
Feed fish	32.7% (21.6-50.5%)	Unknown

For fish group, the dominant species were *Trachurus japonicus*, *Decapterus maruadsi*, *Sillago sihama*, *Sillago japonica*, *Trachinocephalus myops*, *Saurida* spp., *Upeneus japonicus* and *Evynnis cardinalis*. Among these species, *Trachurus japonicus* and *Decapterus maruadsi* were usually mixed in catches and contributed to 0.69%-34% of total catch volume (average of 10%). *Sillago sihama* and *Sillago japonica* were usually mixed in catches and contributed to 0.96%-10.00% of total catch volume (average of 4%), *Trachinocephalus myops* and *Saurida* spp. were usually mixed in catches and contributed to 1.46%-9.78% of total catch volume

(average of 4%). *Upeneus japonicus* contributed to 0.59%-7.65% of total catch volume (average of 3%), and *Evynnis cardinalis* contributed to 0.99%-20% of total catch volume (average of 10%).

For cephalopod group, the main species were from cuttlefish, squid and octopus species.

For shrimp group, the main species were *Parapenaeopsis hardwickii* and *Panaeus* spp..

The "feed fish group" in this report represents those small-sized, low-valued, poorly preserved, fishes, with their destination to aquaculture farms, mentioned by the captains of the fishing vessels surveyed. The "feed fish group" may also include crustaceans and cephalopods. Species in "feed fish group" are unknown and merit further investigation.

Overall, in all species total catches, fish group and feed fish group were dominant, followed by crab group (see 3.3.3. section), cephalopod group and shrimp group.

3.4. Size variation in crab catches

3.4.1. Size variation of *Portunus haanii* between fishing gears

Size (carapace width, CW) variation of *P. haanii* was compared from the samples collected from both trawl vessels and crab trap vessels in August 2018, the only month with both fishing gear samples available.

The minimum and maximum sizes of *P. haanii* caught by trawl and trap were similar, 4.8~10.6 cm CW and 4.1~10.6 cm CW, respectively. However, individuals caught by trap were generally larger than those by trawler (Fig. 15); the average size from trap vessels was 8.6 cm CW, and was 7.6 cm CW for trawl vessels. The dominant size class showed a large difference between the two fishing gears: 9.0-9.9 cm size class (43.55%) dominant in trap fishing and 6.0-6.9 cm size class (30.77%) dominant in trawl fishing (Fig. 15). In trap fishing, more than 80% of individuals were larger than 8.0 cm CW, while about 77% of individuals were within 6.0-8.9 cm CW size classes in bottom

trawl fishing.

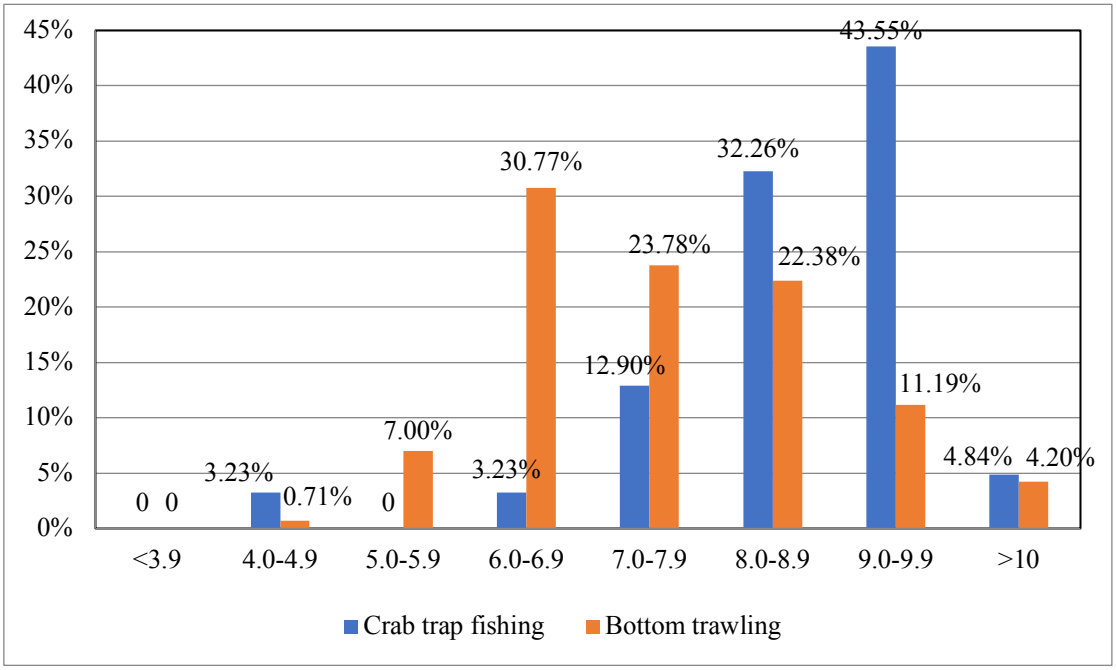


Fig. 15. Proportions of different size classes (cm in carapace width) of *Portunus haanii* caught by trap and bottom trawl

3.4.2. Size variation of *Portunus haanii* by month

In total 1,832 individuals of *Portunus haanii* were collected from bottom trawl vessels in August-December 2018. Sizes ranged from 3.7 to 13.1 cm CW. Monthly average size ranged from 7.9 to 8.6 cm CW, showing a monthly fluctuation (Fig. 16).

More than 90% of individuals were larger than 6.0 cm CW every month from August to December, with only low proportions (1.48-8.99%) of individuals smaller than 6.0 cm (Fig. 16). The dominant size classes (defined as the proportion >20%) in mid-August, late-August, early-September, late-September and early-October were 8.0-9.9 cm (50.91%), 6.0-9.9 cm (89.28%), 6.0-8.9 cm (71.07%), 7.0-9.9 cm (76.26%) and 7.0-8.9 cm CW (61.45%), respectively (Fig. 16). Proportions of larger size (>10.0 cm CW) were low, mainly less than 10%. From late-October, the proportion of larger size (>10.0 cm CW) increased significantly, and reached nearly 33% in December. Sizes smaller than 6 cm CW can be found in August-December, mainly in late-October-December (Fig. 16).

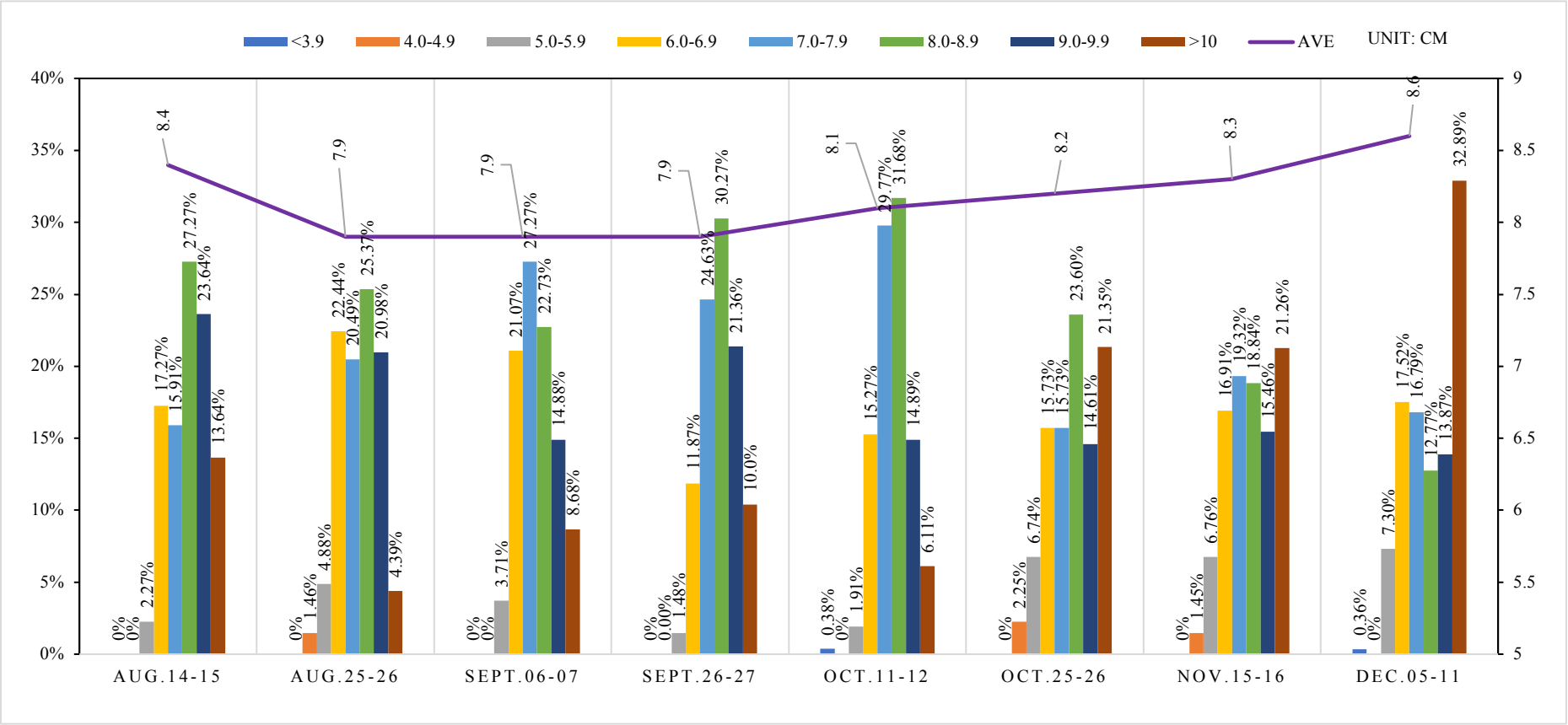


Fig. 16. Proportions of different size classes (cm in carapace width) of *Portunus haanii* by month (left Y-axis) and the trend of the monthly average sizes of *P. haanii* (right Y-axis, purple line shows the trend)

3.4.3. Size variation of *Portunus sanguinolentus* by month

In total 539 individuals of *Portunus sanguinolentus* were collected from bottom trawl vessels in August-December 2018, except late-October because no *P. sanguinolentus* specimens were available. Sizes ranged from 3.9 to 19.1 cm CW. Monthly average size ranged from 9.5 to 14.3 cm CW, showing a monthly fluctuation, high in August and September and low in November (Fig. 17).

In August and September, the dominant sizes were larger than 12 cm CW. In October and November, the proportions of small size classes (<10 cm CW) increased significantly; in particular more than 70% of individuals were smaller than 10 cm CW in November (Fig. 17).

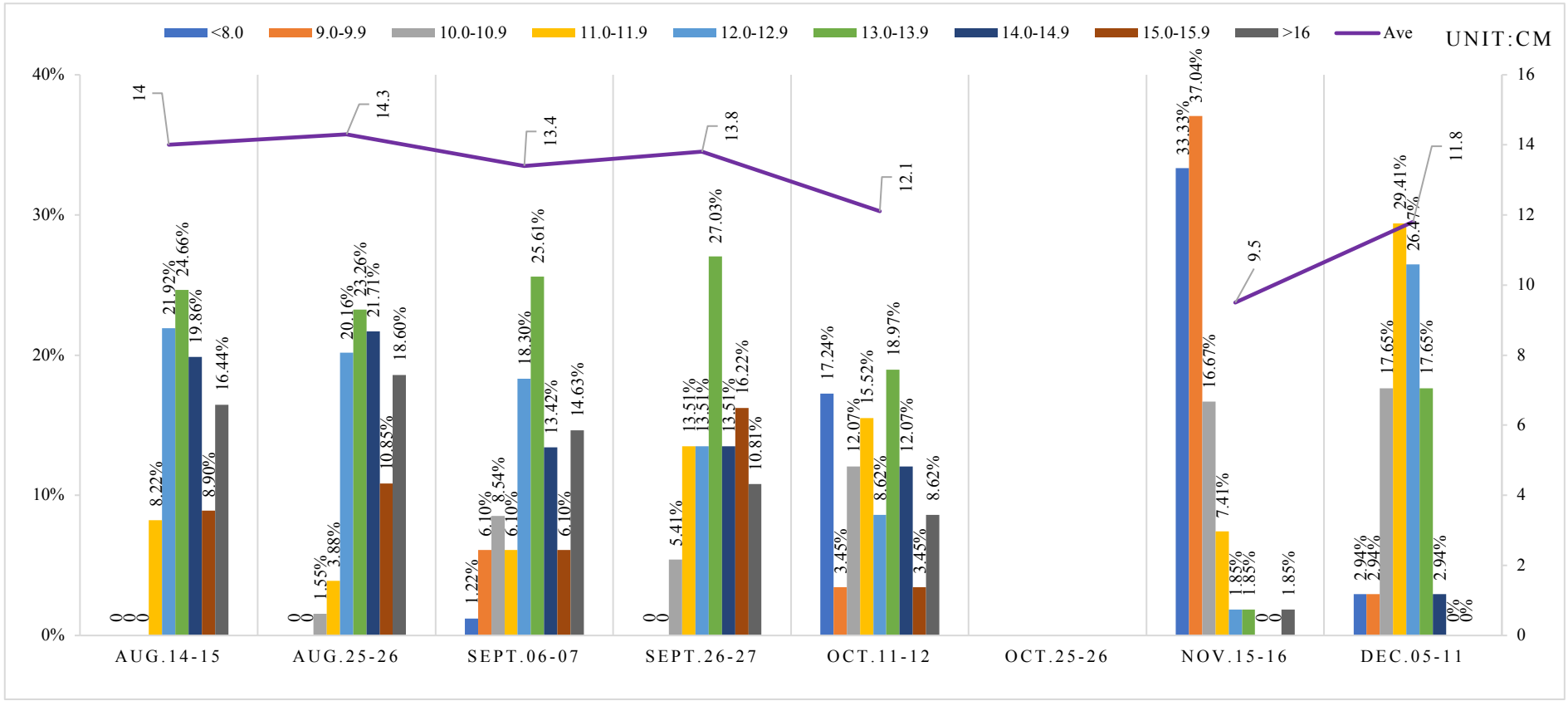


Fig. 17. Proportions of different size classes (cm in carapace width) of *Portunus sanguinolentus* by month (left Y-axis) and the trend of the monthly average sizes of *P. sanguinolentus* (right Y-axis, purple line shows the trend)

3.4.4. Size variation of *Charybdis nataor* by month

In total 720 individuals of *Charybdis nataor* were collected from bottom trawl vessels in August-December 2018. Sizes ranged from 3.3 to 12.5 cm CW. Monthly average size ranged from 6.6 to 8.5 cm CW, showing a monthly fluctuation (Fig. 18).

The dominant size classes were generally on 6.0-8.9 cm CW in August-October (proportions >75%), and on 7.0-9.9 cm CW (proportions >80%) in November and December. Proportions of larger size classes (>9.0 cm CW) were high in November and December, more than 25% (Fig. 18).

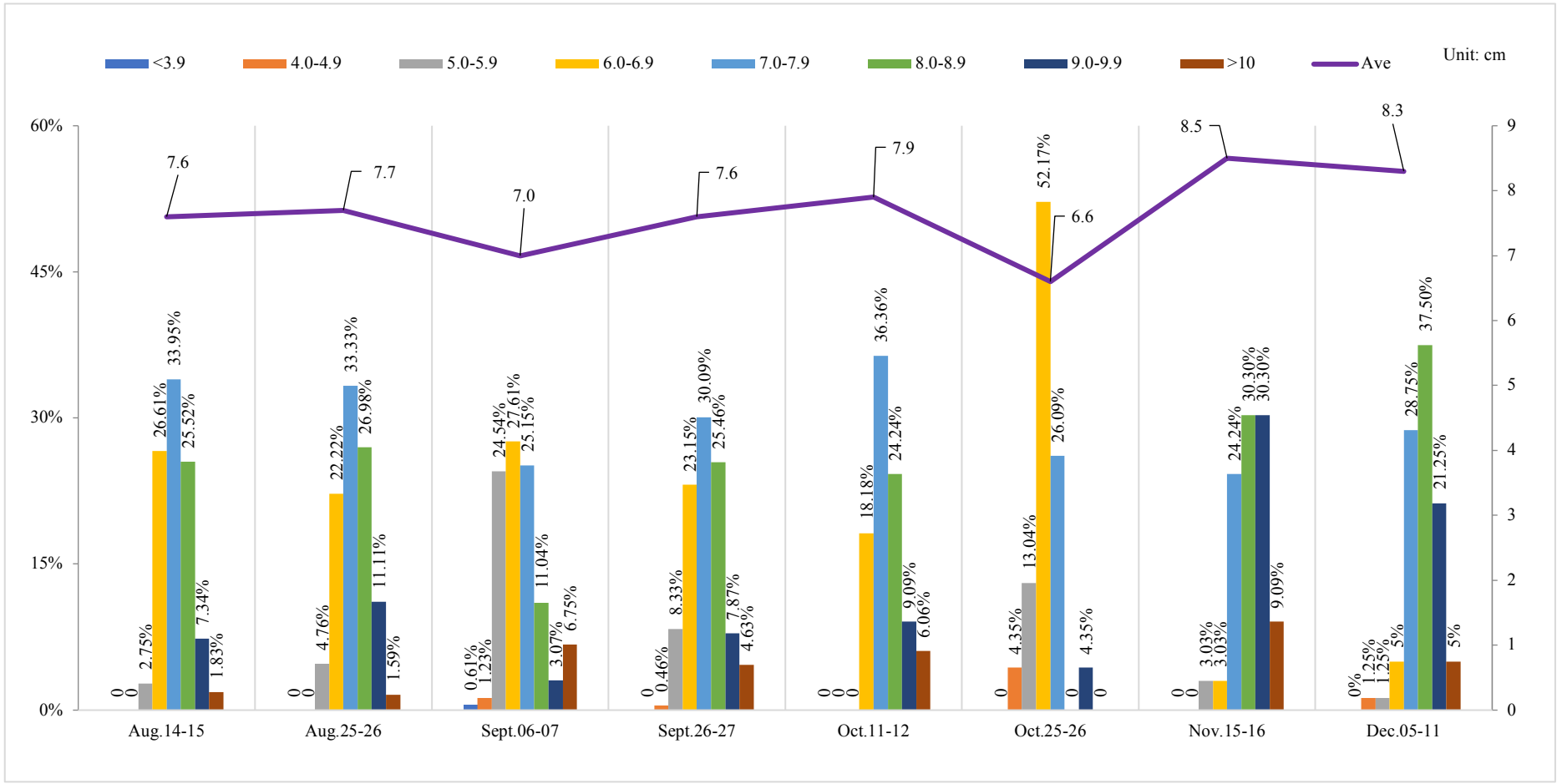


Fig. 18. Proportions of different size classes (cm in carapace width) of *Charybdis nataor* by month (left Y-axis) and the trend of the monthly average sizes of *C. nataor* (right Y-axis, purple line shows the trend)

3.4.5. Size variation of *Calappa philargius* by month

In total 322 individuals of *Calappa philargius* were collected from bottom trawl vessels in August-December 2018. Sizes ranged from 4.3 to 14.2 cm CW. Monthly average size ranged from 10.8 to12.9 cm CW, showing a monthly fluctuation (Fig. 19).

The dominant size classes were generally larger than 10 cm CW in all months (Fig. 19). Smaller size classes <9 cm CW were found in September and early-October.

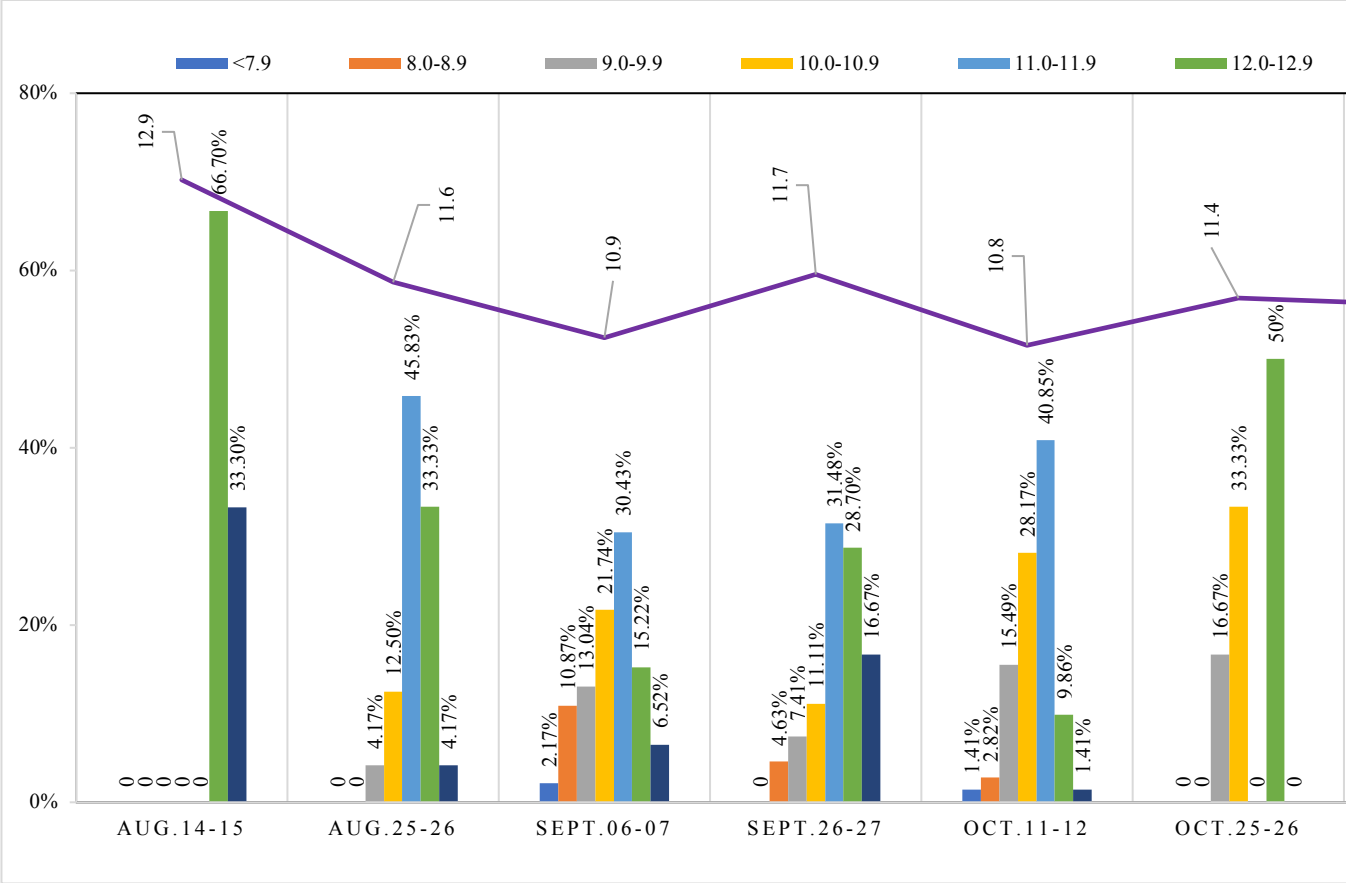


Fig. 19. Proportions of different size classes (cm in carapace width) of *Calappa philargius* by month (left Y-axis) and the trend of the monthly average sizes of *C. philargius* (right Y-axis, purple line shows the trend)

3.5. Length-weight relationships

Length-weight relationships of four target crabs were determined and showed the expression of $BW=a*CW^b$:

$BW = 0.1536*CW^{2.8046}$ (R^2=0.8136; N=1,832) for *Portunus haanii* (Fig. 20);

$BW = 0.0546*CW^{3.0281}$ (R^2=0.8426; N=539) for *Portunus sanguinolentus* (Fig. 21);

$BW = 0.2876*CW^{2.8139}$ (R^2=0.8527; N=720) for *Charybdis nataor* (Fig. 22);

$BW = 0.3253*CW^{2.6412}$ (R^2=0.6338; N=322) for *Calappa philargius* (Fig. 23);

where BW is the body weight (g), and CW is the carapace width (cm).

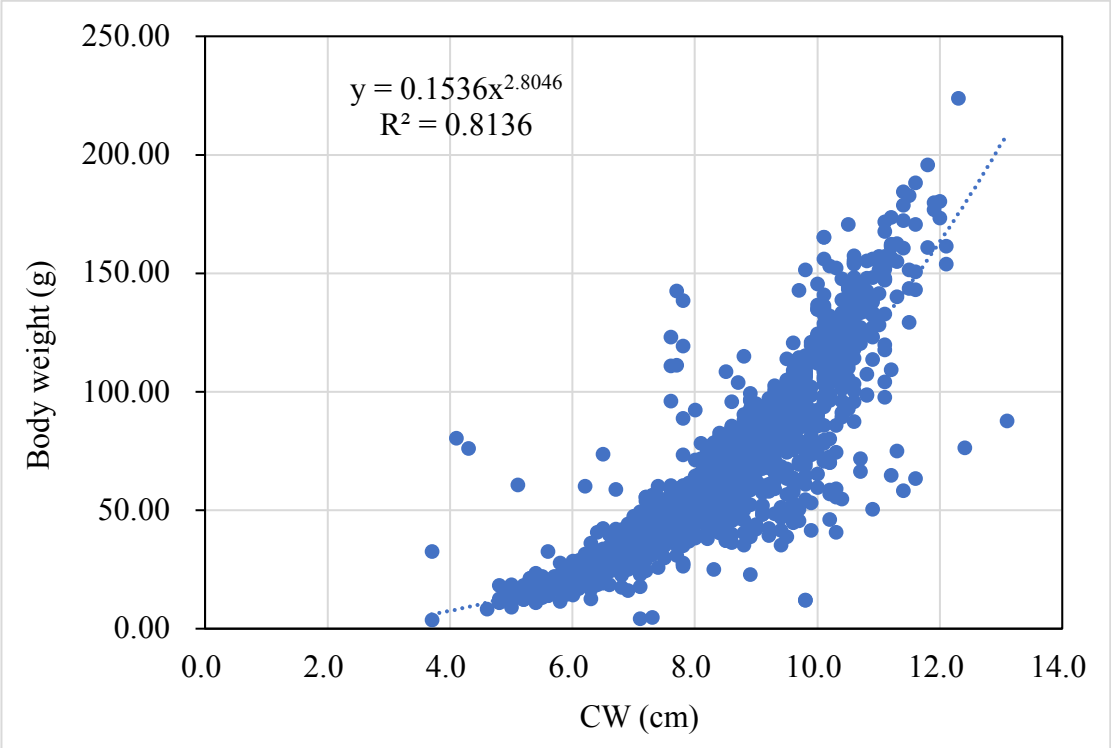


Fig. 20. Length-weight relationship of *Portunus haanii* (N=1,832)

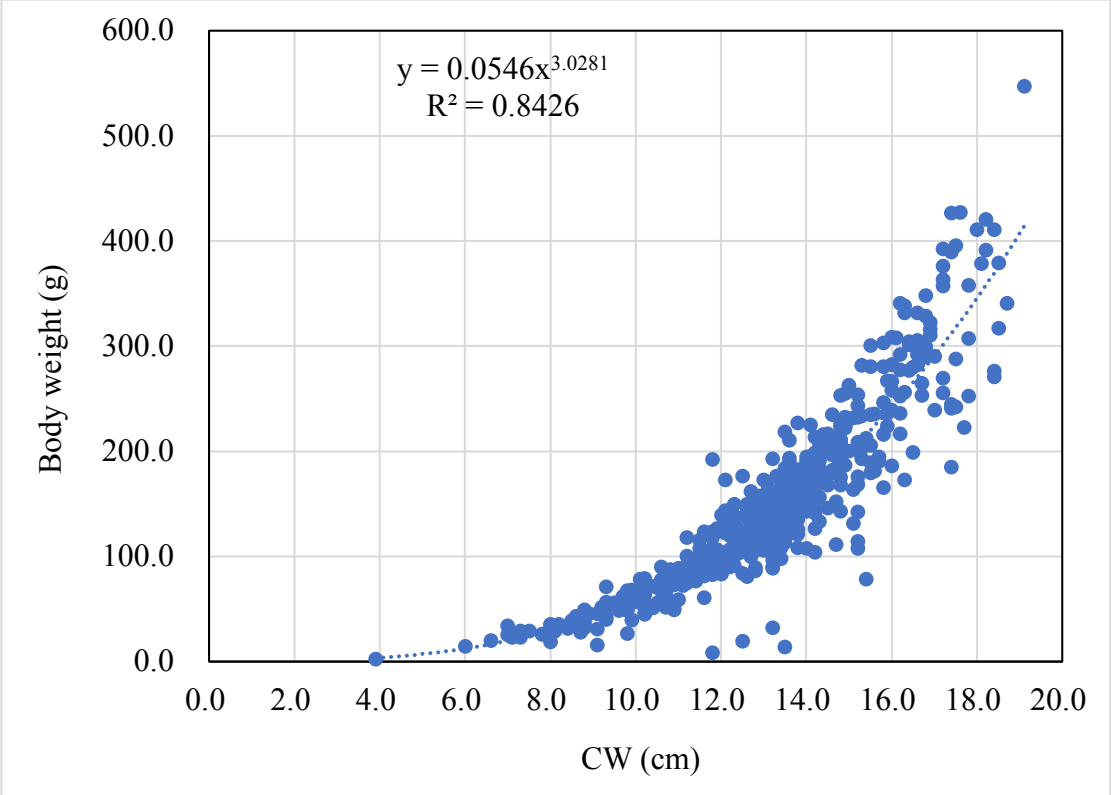


Fig. 21. Length-weight relationship of *Portunus sanguinolentus* (N=539)

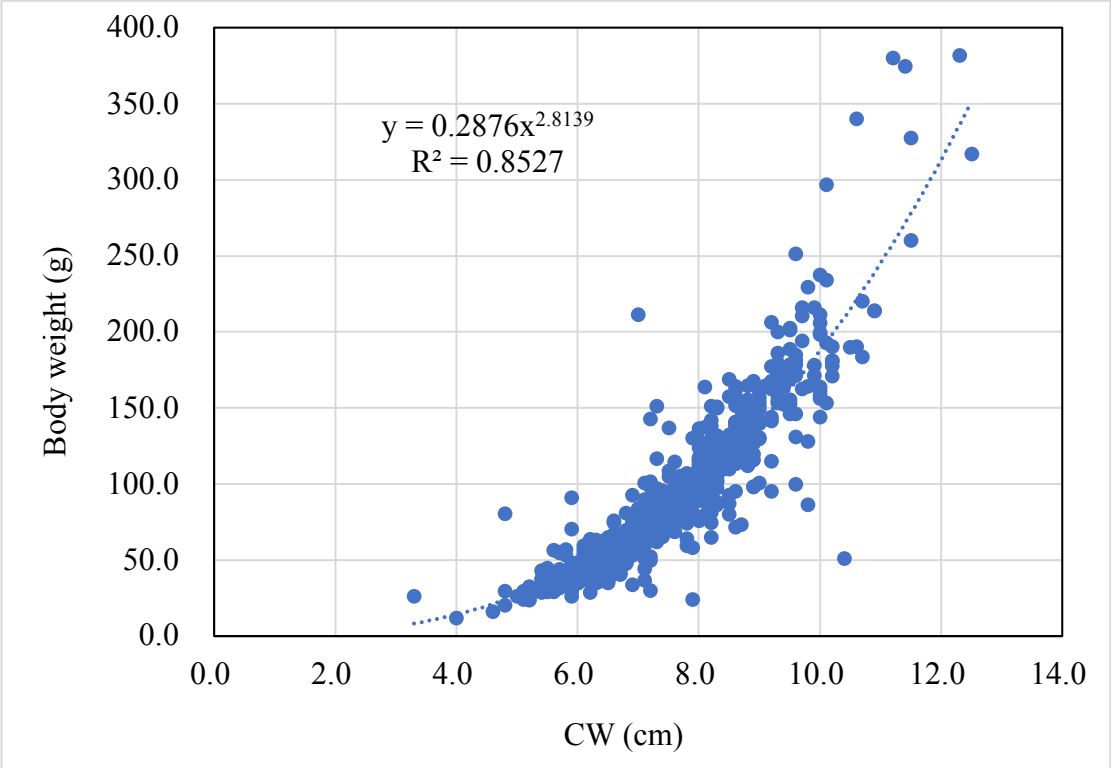


Fig. 22. Length-weight relationship of *Charybdis nataor* (N=720)

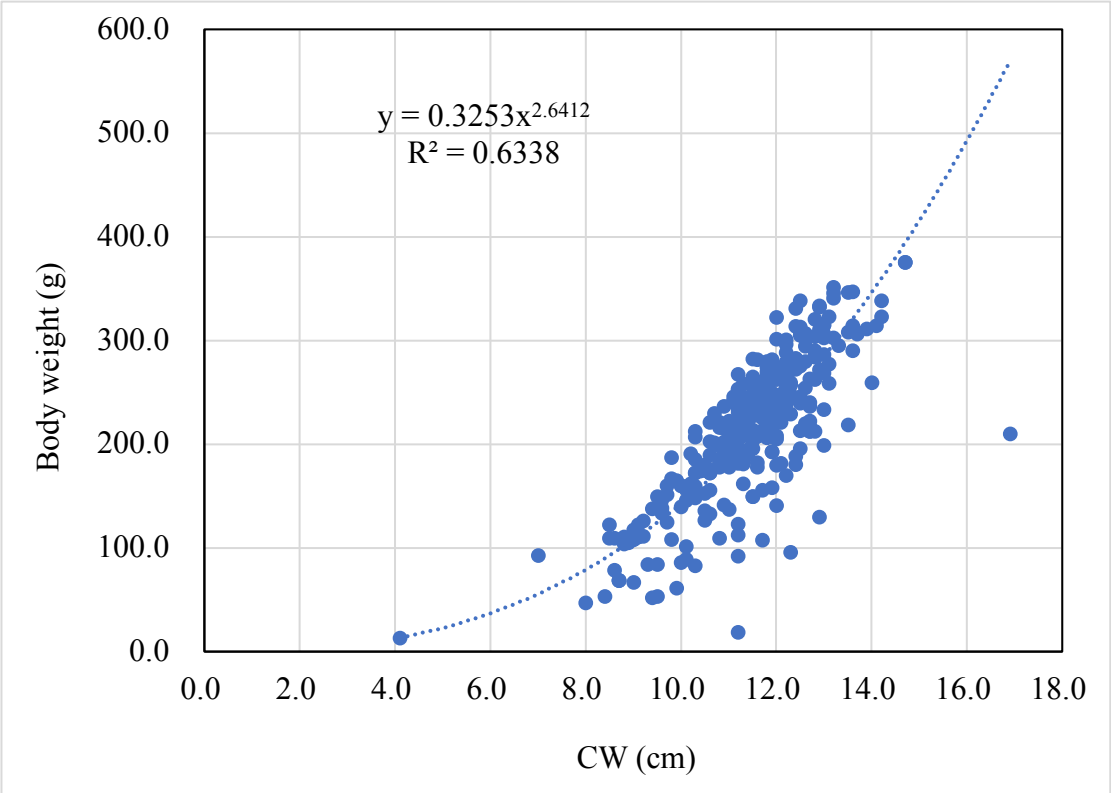


Fig. 23. Length-weight relationship of *Calappa philargius* (N=322)

3.6. Sex ratios of crabs

Sex ratios showed monthly variation in all four main crabs:

For *Portunus haanii*, the overall male: female sex ratio was 1.86: 1, showing a strong male-dominance in August, September and December (Fig. 24);

For *P. sanguinolentus*, the overall male: female sex ratio was 1: 1.27, showing a female-dominance in August-November (Fig. 25);

For *Charybdis nataor*, the overall male: female sex ratio was 1.03: 1, however, monthly fluctuation was large (Fig. 26);

For *Calappa philargius*, the overall male: female sex ratio was 1.42: 1, showing a strong male-dominance in August-early September. The proportions of males declined from 100% in August to 9.09% in December (Fig. 27).

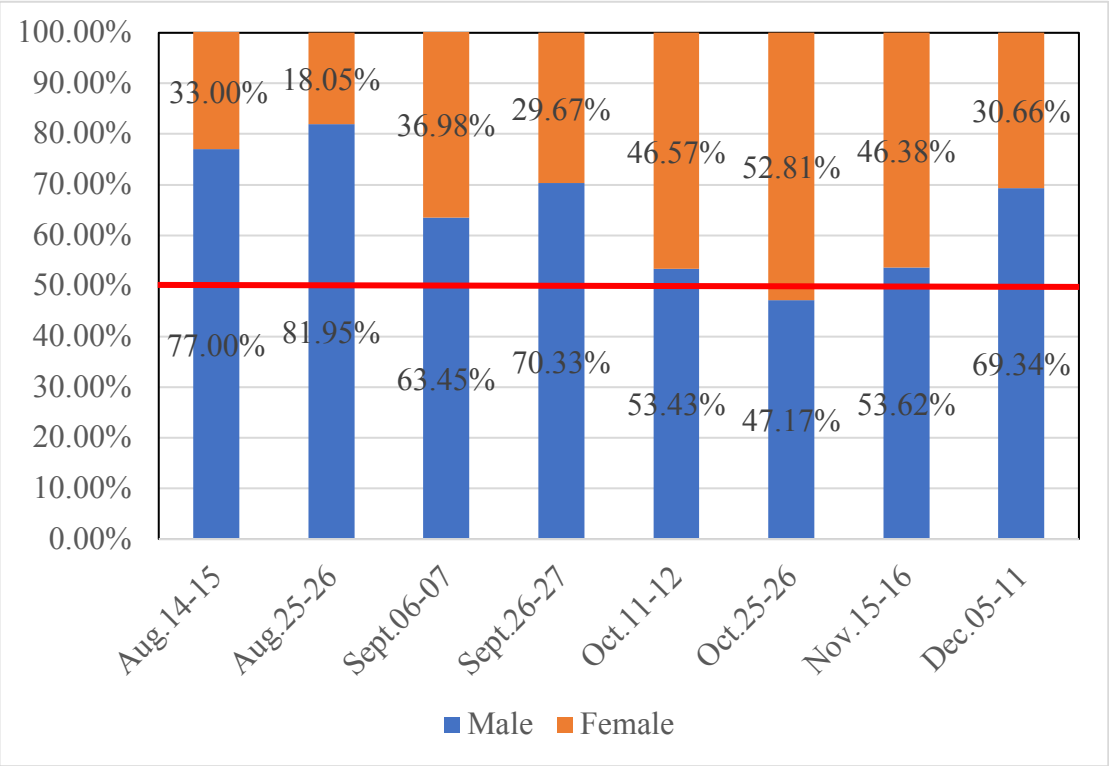


Fig. 24. Sex ratios of *Portunus haanii* by month

(Horizontal red line presents the male and female sex ratio of 1:1)

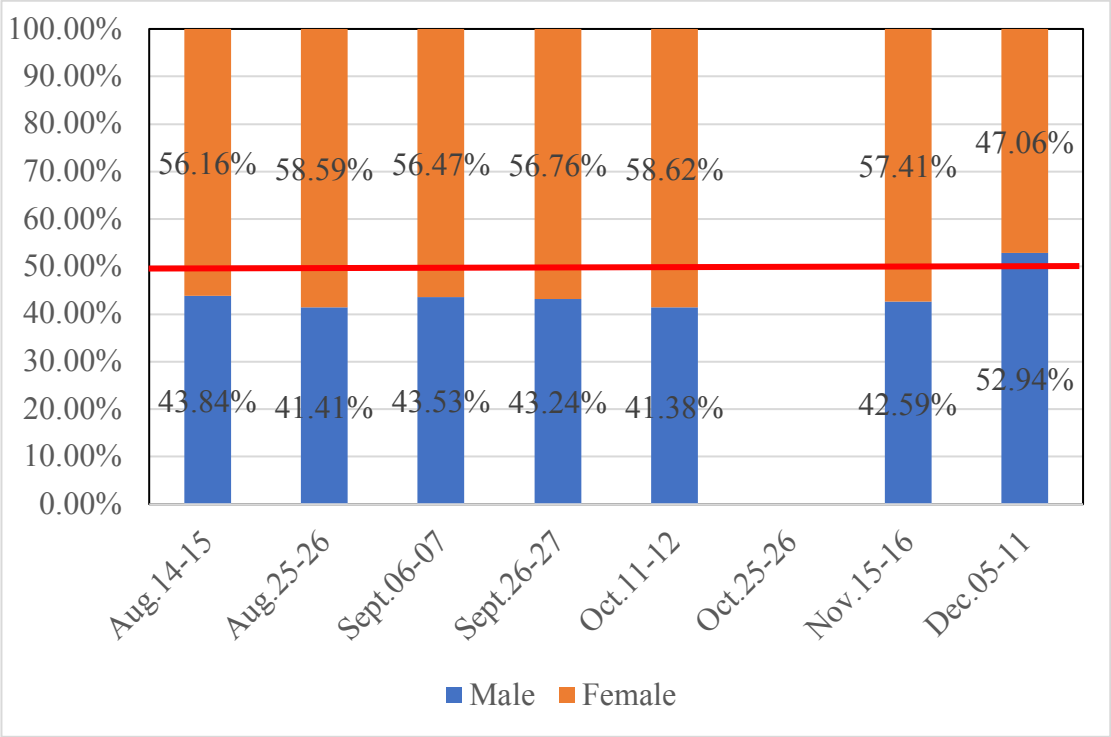


Fig. 25. Sex ratios of *Portunus sanguinolentus* by month

(Horizontal red line presents the male and female sex ratio of 1:1)

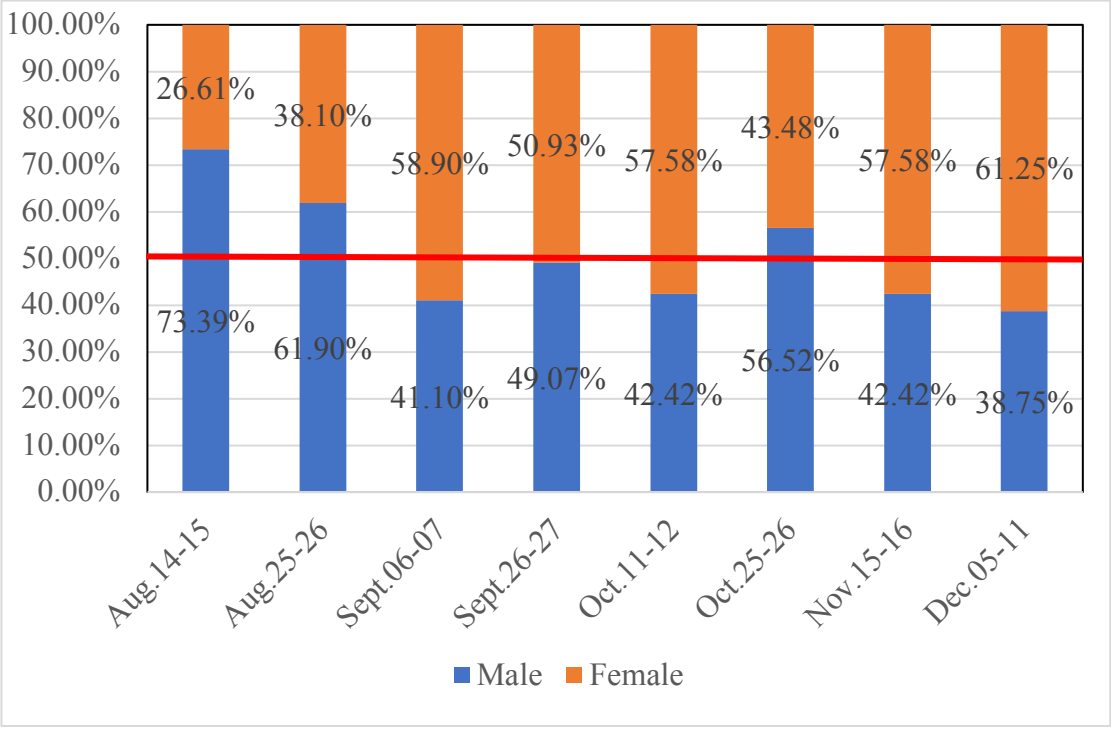


Fig. 26. Sex ratios of *Charybdis nataor* by month

(Horizontal red line presents the male and female sex ratio of 1:1)

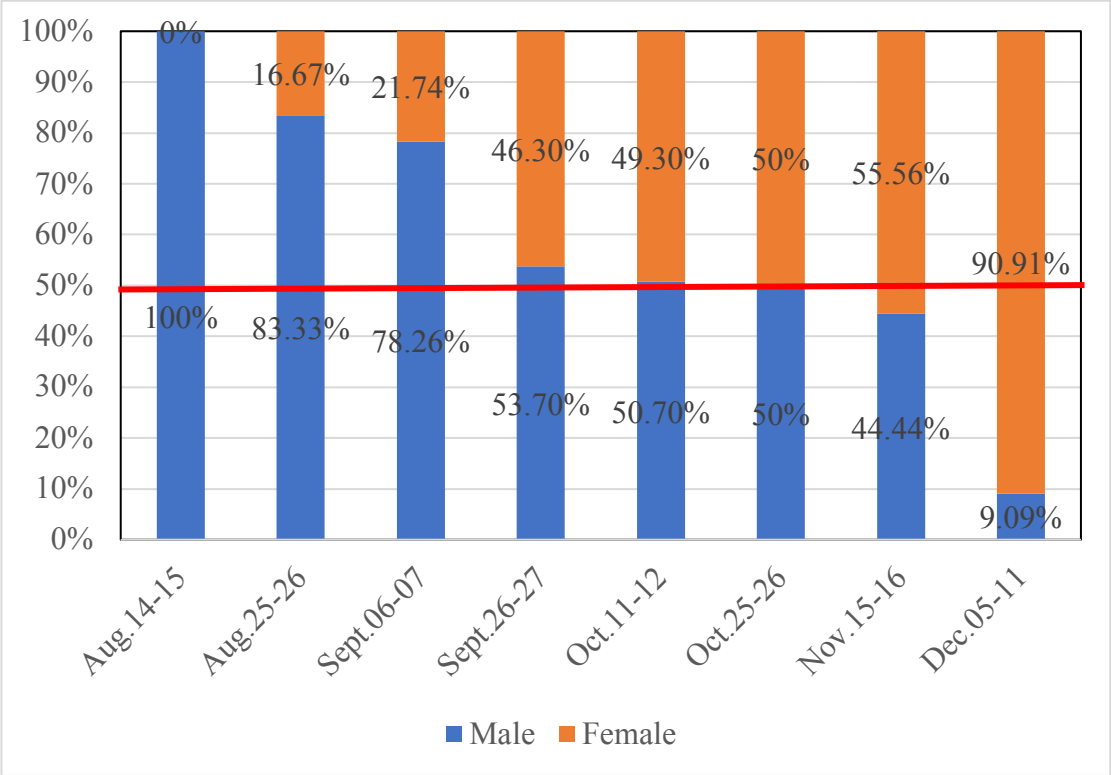


Fig. 27. Sex ratios of *Calappa philargiu* by month

(Horizontal red line presents the male and female sex ratio of 1:1)

3.7. Spawning seasons of crabs

3.7.1. Minimum sizes for females bearing eggs

Based on literature, the minimum sizes for females bearing eggs were 8.0 cm CW in *Portunus sanguinolentus* and 6.9 cm CW in *Charybdis nataor* (Ye 1998; Ye 1999) (Table 8).

In the present study, the minimum sizes for females bearing eggs for the four target crab were also determined based on the samples collected at the landing ports: 5.5 cm CW for *Portunus haanii*, 11.8 cm CW for *P. sanguinolentus*, 6.2 cm CW for *Charybdis nataor*, and 9.0 cm CW for *Calappa philargius* (Table 8). For the first time, the minimum sizes for females bearing eggs in *P. haanii* and *C. philargius* were recorded.

The present study was only conducted in August-December 2018, a period of less than half a year. Therefore, the variations of the minimum sizes for females bearing eggs between references and the present study for the same species merit further assessment.

Table 8. Minimum sizes (cm, CW) for females bearing eggs in four crab species

Crab species	Minimum size (cm, CW)	
	From reference	The present study
Portunus haanii	-	5.5 (Found in late-August)
P. sanguinolentus	8.0	11.6 (Found in mid-August)
Charybdis nataor	6.9	6.2 (Found in early-September)
Calappa philargius	-	9.0 (Found in late-September)

3.7.2. Spawning seasons determined

The present study was only conducted in August-December 2018, therefore, the spawning seasons of the four crabs studied cannot be fully understood, and it is unknown if the four crabs studied have more than one spawning season.

Proportions of females bearing eggs/total number of females showed monthly variations in the four crabs based on the samples collected at the landing ports:.

For *Portunus haanii*, proportions of females bearing eggs declined from mid-August (65.22%) to less than 5% in October-December, indicating a peak spawning season in August (Fig. 28).

For *P. sanguinolentus*, proportions of females bearing eggs remained at level of 18.75-42.86% in August and September and declined to less than 5% in October-December, indicating a peak spawning season in late-September (Fig. 29).

For *Charybdis nataor*, proportions of females bearing eggs remained low (<10%), and increased to nearly 25% in December, indicating a peak spawning season possibly in January or February of the coming year (Fig. 30).

For *Calappa philargius*, there were two peaks for high proportions of females bearing eggs; 40% in late-September, and 48% in mid-December, the second peak may extend to January of the coming year (Fig. 31).

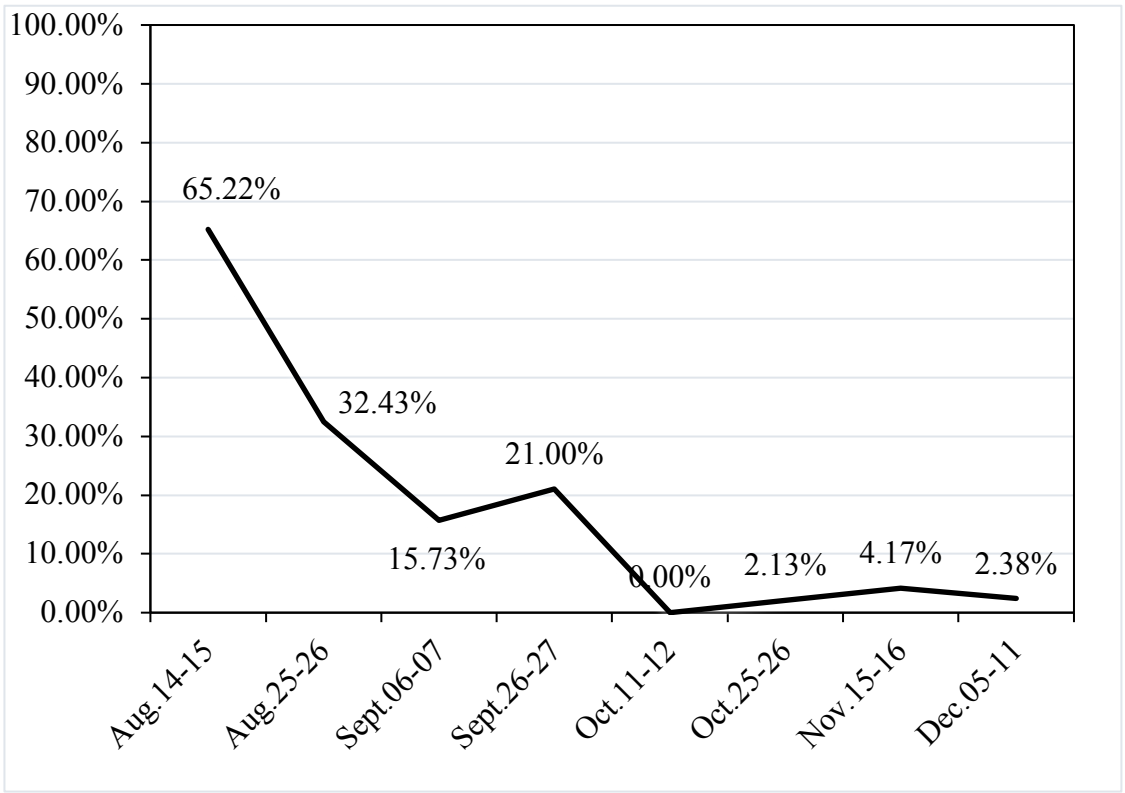


Fig. 28. Proportions of *Portunus haanii* females bearing eggs by month

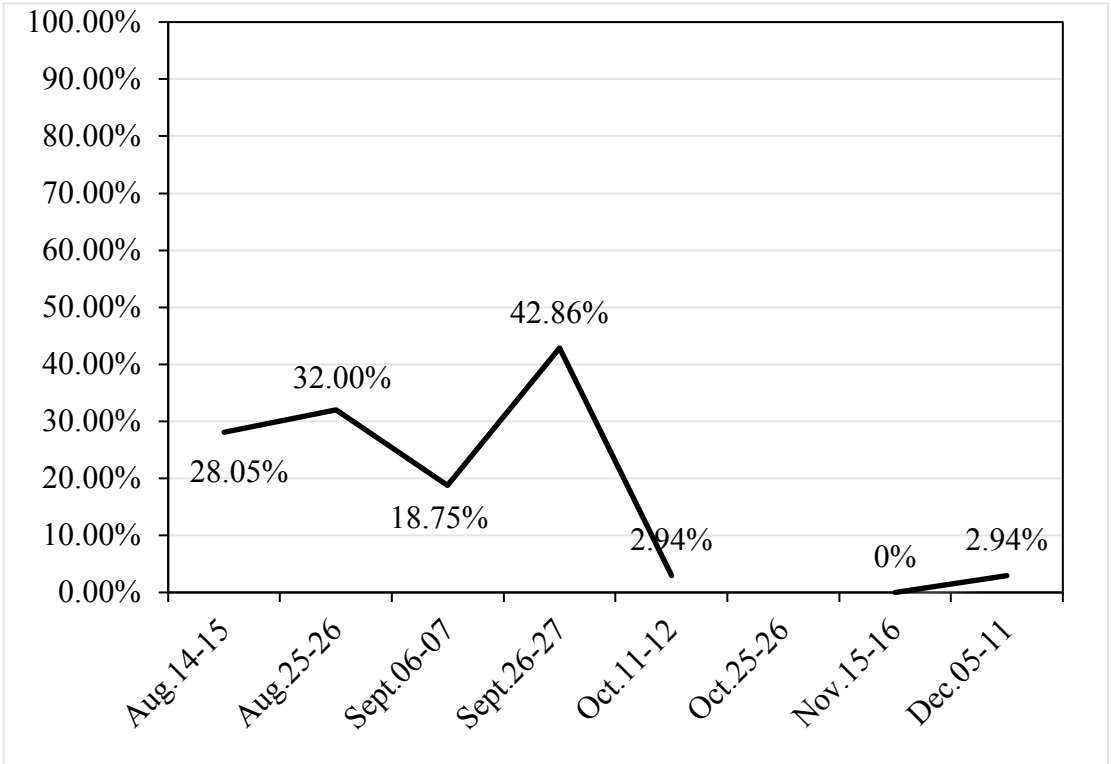


Fig. 29. Proportions of *Portunus sanguinolentus* females bearing eggs by month

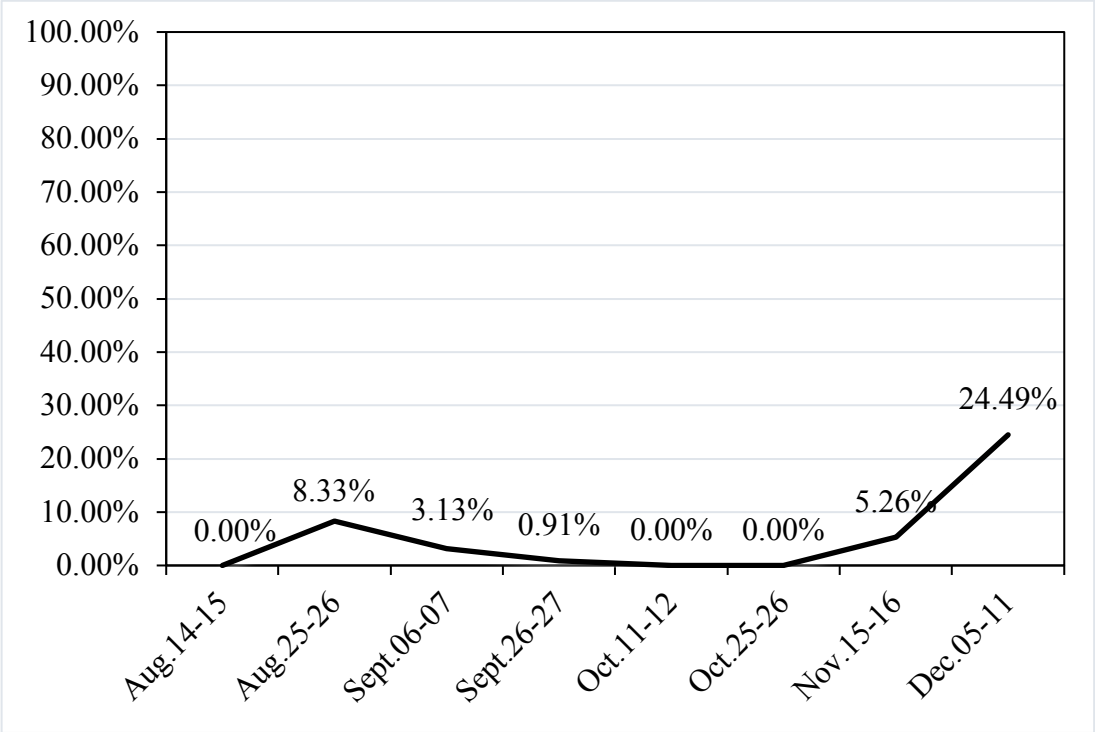


Fig. 30. Proportions of *Charybdis nataor* females bearing eggs by month

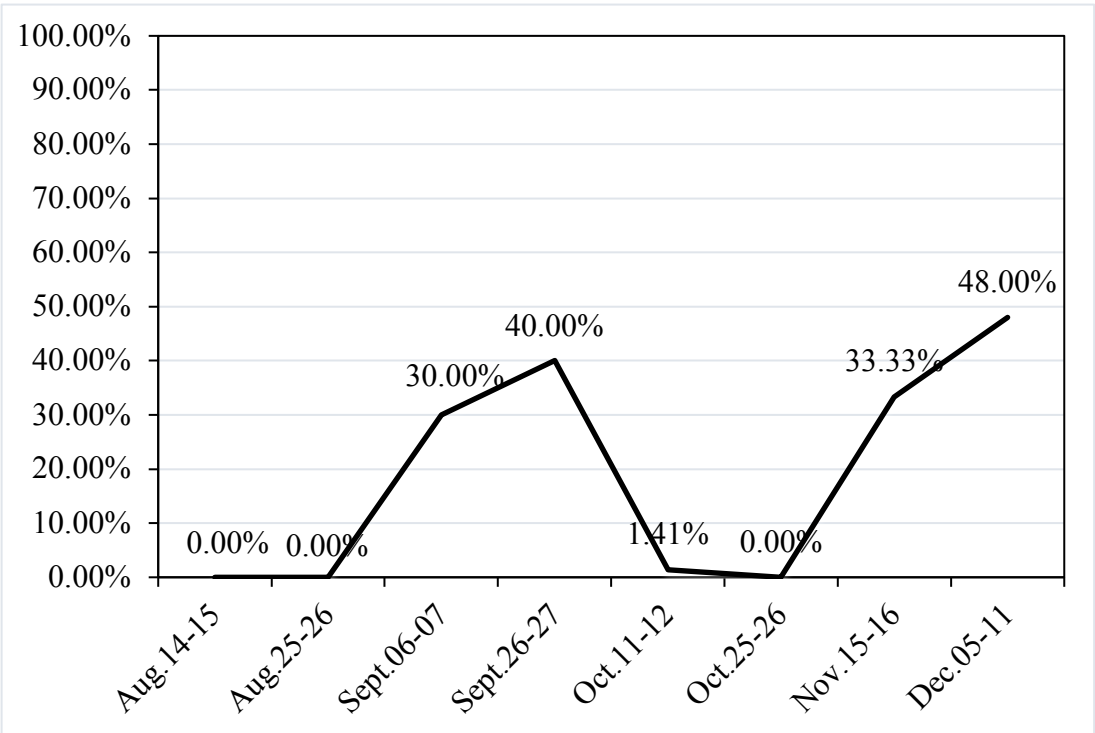


Fig. 31. Proportions of *Calappa philargius* females bearing eggs by month

3.8. Interview findings Besides the surveys conducted at the landing ports of Dongshan County in August-December 2018, an additional 13 bottom trawl captains,

five trap vessel captains and eight processing factory owners were interviewed in Dongshan County. This section summarizes supplemental information to better understand the crab fishery and trade in Dongshan County.

3.8.1. Annual fishing days for trawl and trap vessels

The national annual fishing moratorium periods are from 1 May to 16 August (3.5 months) for the trawl fishery and from 1 May to 1 August (3 months) for the trap fishery. Taking into consideration bad weather and holidays, the captains interviewed estimated that their suitable fishing days total about 4 months (120 days) and 4.5 months (135 days) per year for the trawl fishery and trap fishery, respectively.

3.8.2. Fishing operation patterns

For the trawl fishery, the fishing days per trip are usually less than 10 days. The operation pattern was about 5.3 net tows per day at sea (range of 3-8 net tows), with an average of 4 hours/net tow.

For the trap fishery, the fishing days per trip are usually 10-20 days. Each vessel carries about 3,000-4,000 traps; about 1,000 traps were connected by a line and operated as a unit. About 200 g bait (usually sardines) are used per trap. During day time, traps were collected every 5-6 hours. At night time, traps were collected after about 10 hour sets. The captains mentioned that *Portunus haanii* mainly feed in day time and *P. sanguinolentus* and *Charybdis* feed in night time.

Some trap vessels prefer to operate in rocky bottom, particularly for *Charybdis nataor*, which can avoid the conflict of the sandy bottom fishing habitats that bottom trawl vessels prefer.

For the trap fishery, cold weather and rough condition at sea give good crab catches compared to good, calm weather because of the crab behavior, more active in the rough sea condition; therefore, trap fishing has higher risk compared to bottom trawl fishing.

3.8.3. Spawning seasons of *Portunus haanii*

Based on the interviews with captains and processing factory owners, two spawning seasons (females bearing eggs) were identified for *Portunus haanii*; November to February, and February to April.

The information obtained from interviews were different from the results

concluded from the samples collected in August-December, in which the spawning season was determined to be in August (see 3.7.2. section).

3.8.4. Fishing grounds of *Portunus haanii*

Portunus haanii usually inhabits flat sandy-muddy bottoms within 50 m depth in Minnan, Taiwan Bank, Yuedong, Dongsha and southern Taiwan fishing grounds.

Based on the interviews with captains, fishing grounds between trawl and trap fisheries are found to largely overlap (Figs. 32 & 33).

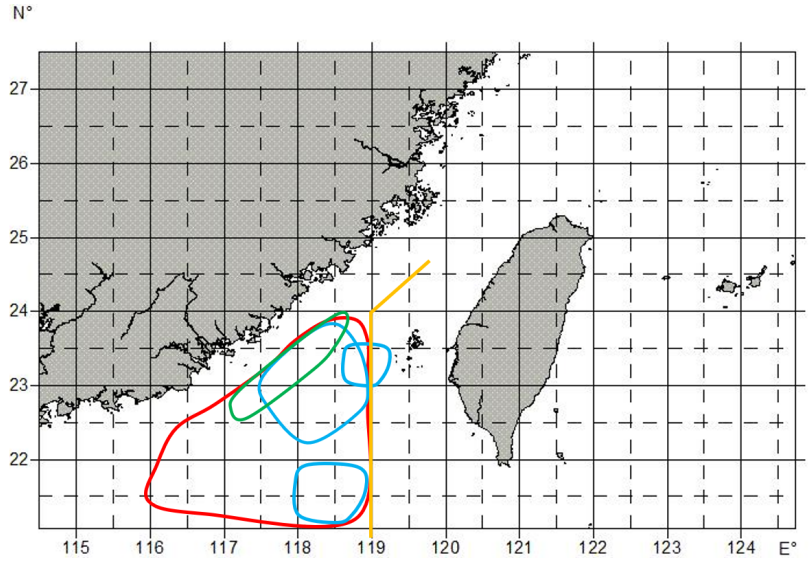


Fig. 32. Fishing grounds of bottom trawler vessels from Dongshan County (Yellow line shows the boundary between mainland China and Taiwan at sea, and no fishing vessels from mainland China are allowed to cross the line. Red line circle is the main fishing grounds for bottom trawl vessels operation. Blue line circles are the main fishing areas for *Portunus haanii*. Green line circle is the main feeding grounds for *P. haanii* juveniles in February-April.)

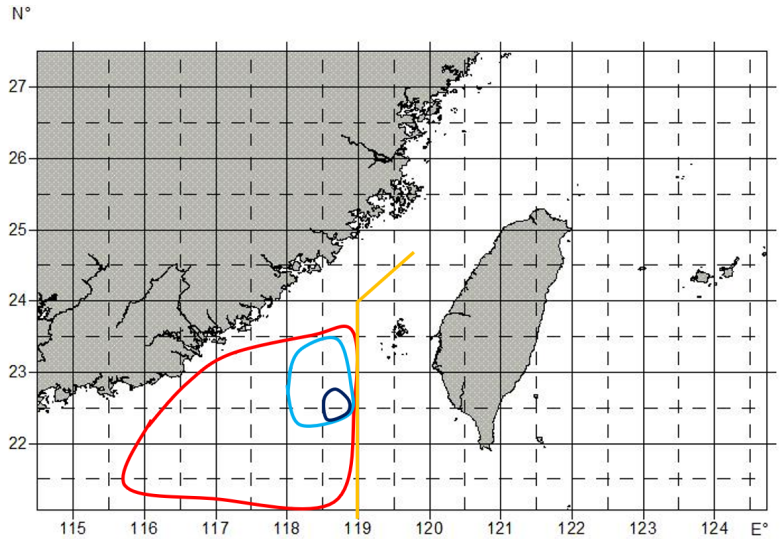


Fig. 33. Fishing grounds of trap vessels from Dongshan County (Yellow line shows the boundary between mainland China and Taiwan at sea, and no fishing vessels from mainland China are allowed to cross the line. Red line circle is the main fishing grounds for trap vessels. Blue line circle is the main fishing areas for *Portunus haanii*; dark blue line circle has the highest capture of *Portunus haanii*.)

3.8.5. *Portunus haanii* catch trend

The catches of *P. haanii* have shown a significant decline over the past decade in Dongshan County.

Captains of the trawl vessels reported that the highest capture volumes for *P. haanii* were in 2011-2014; nearly 500 kg/net tow, contributing to 60-70% of the total catches of all species per net tow. However, based on interviews with processing factory owners, the supply of *P. haanii* was the highest in 2008-2009.

In the present study, *P. haanii* capture volume contributed to approximately 10-23% of total catches (average of 13.69%), based on the surveys at the landing ports (see 3.3.2. and 3.3.3. sections).

For trap vessels, the capture volumes of *P. haanii* are high in August and September, right after the end of fishing moratorium; the catches decline gradually until next February, and small individuals of *P. haanii* are mainly caught in March and April.

3.8.6. *Portunus haanii* trade mode

Trawl vessels usually do not sell their catches to transshipment vessels, with all catches brought back to landing ports. Catches of *P. haanii* are sometimes sorted by size

on board before storage, and individuals less than 3 cm CW are usually discarded or pooled into low-valued, small-sized “feed fishes”.

For trap vessels, crabs caught are usually kept alive on board for higher prices. Sizes of *P. haanii* larger than 6 cm CW are kept for trade; smaller ones are usually discarded even alive, based on the information of the captains interviewed. Sometimes, *P. haanii* are cooked at sea and the bodies and claws are stored separately for trade (also see 3.2.2. section).

Portunus haanii is the only dominant crab species sold to crab processing factories for meat products and export. The meat products have usually three types: claw meat, canned meat from the fifth pairs of legs, and canned meat from the other parts of the body. Based on the interviews with the processing factory owners, it is estimated that nearly 50% of the annual total capture volume of *P. haanii* in China is processed in Zhangzhou City, particularly in Dongshan County, Longhai County and Zhaoan County; Dongshan County contributed to 35% of total nationwide *P. haanii* processing volumes.

For *P. haanii*, the carapace width >6 cm CW is considered to be the suitable size for processing based on the experience of the processing factory owners; the larger the better. In recent years, smaller size individuals (<6 cm CW) are also processed as “one bite crab” and sold in domestic markets, indicating the utilization of smaller size crabs.

Because of the increase of domestic consumer market demand (usually give higher price than wholesale or retail price and required larger size), and the decline of *P. haanii* catches recent years, the supply of *P. haanii* to crab processing factories has shown a shortage, mentioned as the crab processing factory owners interviewed. Imported *P. haanii* is also reported from Vietnam, and also purchased from other domestic fisheries such as Quanzhou City, Longhai County, Zhao’an County, Guangdong Province, and Guangxi Province, inferring the shortage of *P. haanii* supply in Dongshan County. However, details on volume and transport approach are unknown. The most recent competition of the crab processing factories is from ‘Wechat businessmen’ who buy crabs at the landing ports with higher price. The operation of *P. haanii* supply chain relies on personal relationship and trust; the factories and supply dealers do not sign any contracts.

The Chinese sand crab *Ovalipes punctatus*, mainly caught in Zhejiang Province, is another species for canned crab meat product in Dongshan County, particularly when during a shortage of *P. haanii* supply. However, the proportion of *O. punctatus* in

canned crab meat product is unknown, but generally is low, based on the crab processing factory owners interviewed.

Another three crabs, the Gazami crab *Portunus trituberculatus*, *Portunus sanguinolentus* and *Charybdis nataor*, are also simply processed (i.e. with shells or half cut) and kept frozen for trade, mainly for domestic markets and some for export.

3.8.7. Opinions on fishing moratorium and IUU fishing

Different recommendations on fishing moratorium period are provided by fishers and crab processing factory owners.

All captains interviewed suggested an adjustment of the fishing moratorium period in the Taiwan Strait, i.e. earlier start and earlier end. Captains gave the adjustment from 1 February to 1 May or from 1 March to 1 July, to allow the growth of crab juveniles. However, crab processing factory owners interviewed suggested the extension of fishing moratorium period for at least another half or one month, i.e. from 1 May to 31 August or 15 September, to allow crabs to grow larger.

Captains interviewed mentioned that almost no enforcement is in place. Illegal fishing during the fishing moratorium period happens all the time, based on the interviews with captains. Beyond the fishing moratorium period, illegal fishing such as the fishing vessels without a license (also confirmed by the present study, see 3.2.1. section) and using tickler electricity to stun fishes and crabs still operate at sea. The status of illegal fishing is more serious in Guangdong Province.

3.8.8. Fishers' alternative livelihoods

During the fishing moratorium period, most of captains and crews stay at home; some have alternative livelihoods, e.g. invest in aquaculture sector or go for hook-and-line fishing in coastal waters (mainly for fishes) or provide transportation for recreational fishing.

3.9. Crab export trade

In the present study, no detailed data on *P. haanii* supply volume for processing and the crab meat product volume for trade were obtained, because the processing factories consider that it is the business secret.

3.9.1. Crab meat productivity

Based on the factory owners' experience, the average crab meat productivity (proportion of crab meat extracted compared to total body weight) was about 11.75% (ranged from 11-12.5%), i.e. 1 kg of *P. haanii* can produce 117.5 g meat. Meanwhile, only 95% of crab supply volume can be used for processing; approximate 5% of small sized and poor quality crabs are discarded.

3.9.2. Crab export volume in Fujian Province

From 2008 to 2018 (only January-September in 2018), more than 279,000 t of crab products, including lives crabs, frozen crabs and crab processing products, were exported from Fujian Province to 18 countries (Lithuania, Netherlands, Belgium, UK, Italy, USA, Canada, New Zealand, Australia, South Korea, Japan, Malaysia, Singapore, Indonesia, Thailand, Vietnam, India and U.A.E) and 2 areas (Taiwan and Hong Kong) (Fig. 34). USA, Hong Kong and Taiwan were the three main export destinations with more than 78% of total export volume.

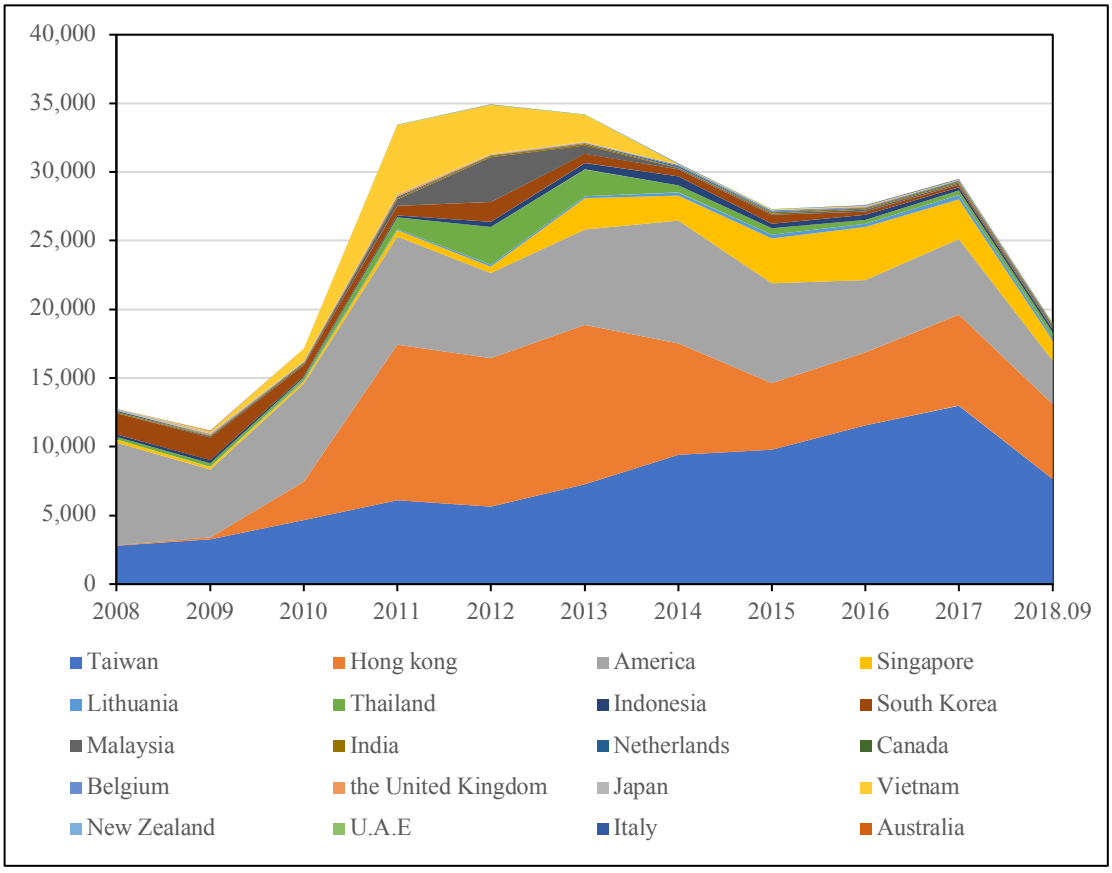


Fig. 34. Crab export volume (t) and destinations from Fujian Province, China (Data source: Chinese Customs data)

3.9.3. *Portunus haanii* export volume in Fujian Province

The code 16051000 in Chinese Customs represents the crab product for export volume. The recorded annual crab product for export volume in Fujian Province varied from 6,641 t to 28,822 t in 2008-2018 (only January-September in 2018) (Fig. 35).

In China, *P. haanii* processing factories are mainly located in Fujian Province, and the crab product volume in Fujian Province contributes to 75-80% (average of 77.5%) of the total national crab products. Therefore, the *P. haanii* product export volumes from Fujian Province ranged from 5,146 t to 22,337 t in 2008-2018; in 2018, the volume of the whole year was estimated rather than 9 months (Fig. 36).

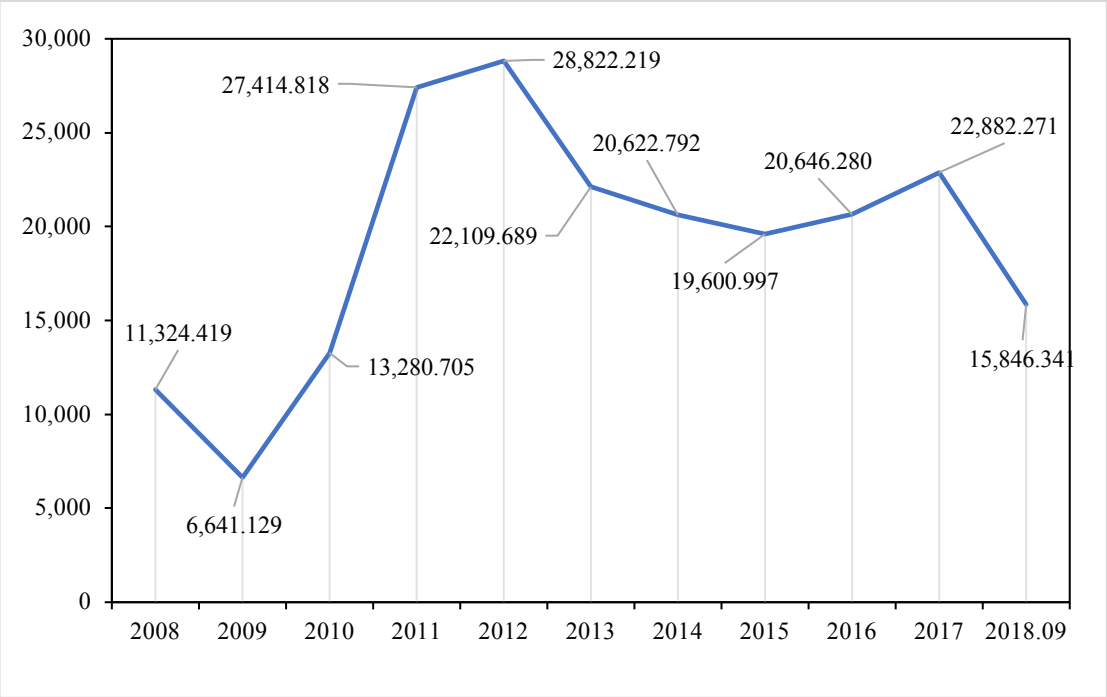


Fig. 35. Crab product export volume (t) in 2008-2018 (only January-September in 2018) in Fujian Province (data source: Chinese Customs data)

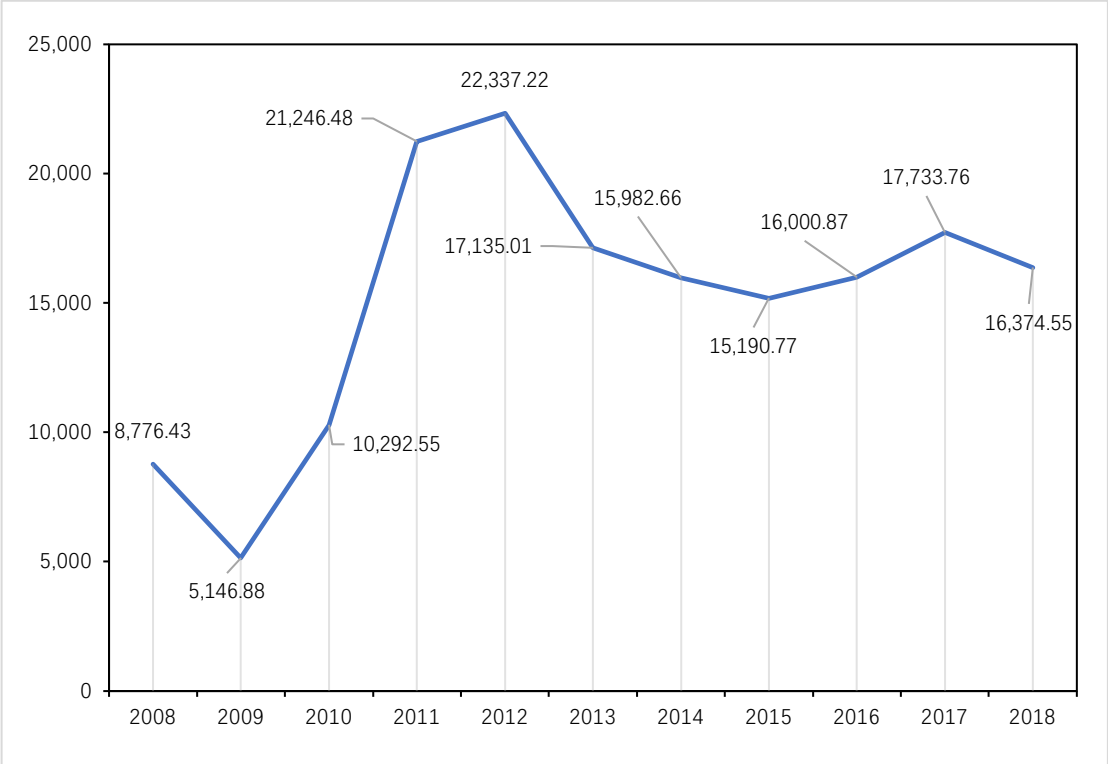


Fig. 36. *Portunus haanii* product export volume (t) in 2008-2018 in Fujian Province (Data source: Chinese Customs data)

4. Conclusions and recommendations

4.1. Seahorse bycatch

All *Hippocampus* species in China (about 10 species recorded) were assigned as the National Protected Species Class II in 2018 by simply applying the CITES Appendix II to the National Protected Species Class II.

Hippocampus trimaculatus has a high price among trawl catches in Dongshan County, and its capture volumes are high (see 3.1.2. section).

There is an urgent need to collect seahorse fishery data and to more understand their biology, e.g. seahorse habitats.

4.2. *Portunus haanii* spawning seasons

There are different findings in spawning seasons of *P. haanii*.

From literature, *P. haanii* has two spawning seasons, February-April and October in south Fujian-Taiwan Bank fishing ground (Zhang 1997).

Based on *P. haanii* collection and examination from the present study, the spawning season is August (see 3.7.2. section). Based on the interviews with captains and

processing factory owners, two spawning seasons were identified for *Portunus haanii*; November to February, and February to April.

Sample collection and examination year-round are needed to understand the spawning seasons of *P. haanii* in Minnan-Taiwan Bank fishing ground, southern Fujian, and to evaluate the variation of its spawning seasons over years.

4.3. *Portunus haanii* fishing grounds

Based on the interviews at the landing ports, and with captains at home or fishery society office (see 3.8.4. section), the main fishing grounds for *P. haanii* are determined to be in the area of 117º-119 º N and 22º10-24º E within in the Minnan-Taiwan Bank fishing grounds (Fig. 37).

Fishing grounds for *P. haanii* determined in the present study provide valuable information that can be used in the designation for long-term monitoring in the future; e.g. for the area surveyed, the number of stations and their locations, and the fishing gears selected.

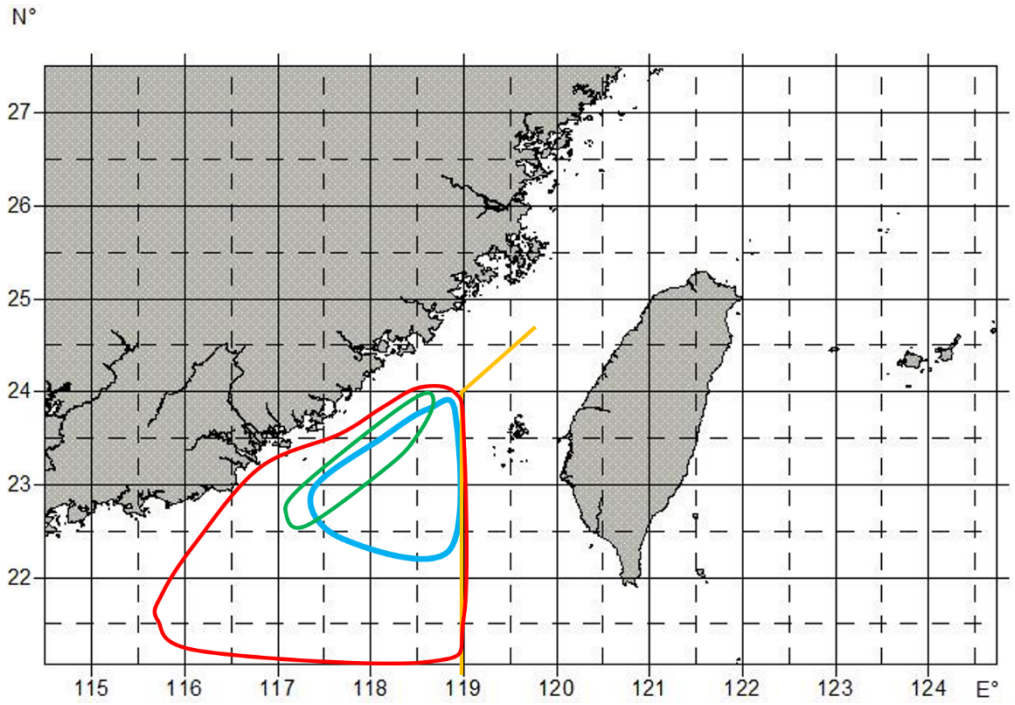


Fig. 37. Main fishing grounds for *Portunus haanii*

(Yellow line shows the boundary between mainland China and Taiwan at sea. Red line circle is the main fishing grounds of Dongshan County fishing vessels. Blue line circle is the fishing areas for *Portunus haanii*. Green line circle is the main feeding grounds for *P. haanii* juveniles in February-April.)

4.4. CPUE for *Portunus haanii* over years

Based on the average capture volume for *P. haanii* (kg/vessel/day) (see 3.3.4. section) and the average of 5.3 net tows per day for bottom trawl fishing (see 3.8.2. section), a preliminary comparison of *P. haanii* capture per unit effort (CPUE) in Minnan-Taiwan Bank fishing grounds over years was conducted over 20 years. The significant declines of CPUE were found in August-November between 1993-1995 and 2018 (Fig. 38).

Long-term monitoring is needed to assess the CPUE of *P. haanii* for understanding the sustainability of *P. haanii* fishery.

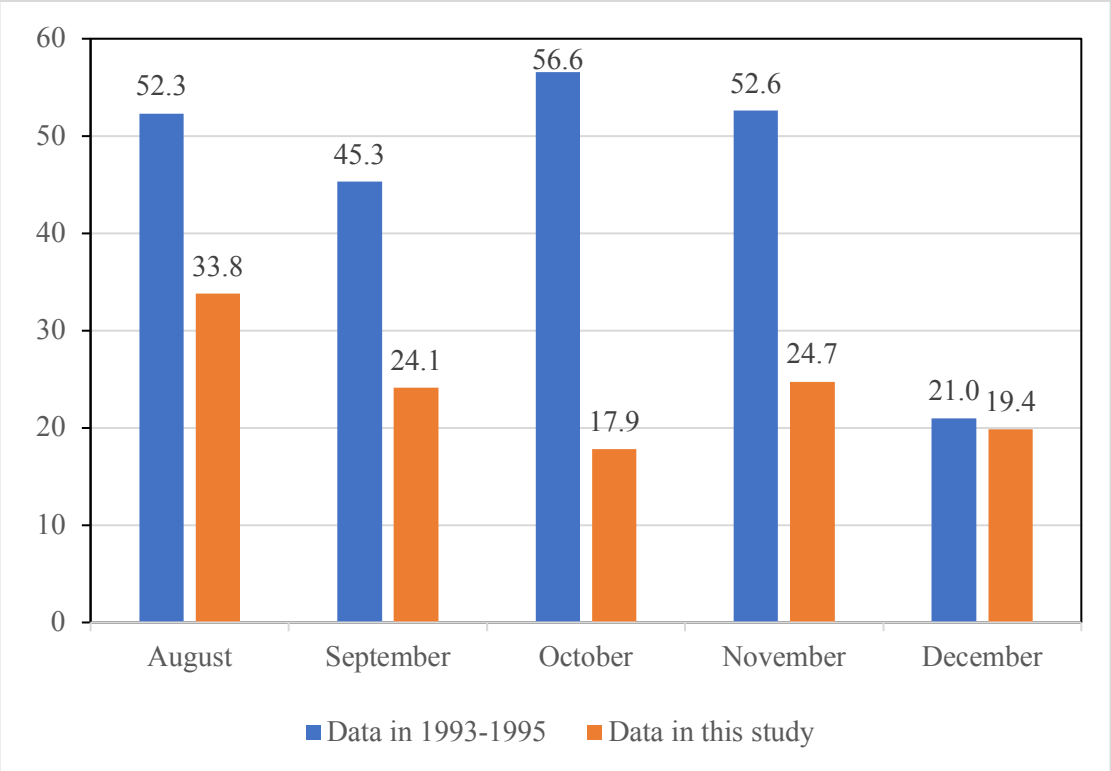


Fig. 38. Comparison of CPUE for *Portunus haanii* (kg/net tow) (value on the top of the bar) in 1993-1995 (Zhang 1997) and 2018 (the present study)

4.5. Estimation of *Portunus haanii* capture volume in Dongshan County

In 1993-1995, the annual capture volume for *P. haanii* was estimated to be 30,000-35,000 t from Minnan-Taiwan Bank fishing ground, the same area as the present study (Zhang 1997).

Based on the data obtained in the present study, an estimation of the annual capture

volume of *P. haanii* in Dongshan County was conducted:

(1) 1,015 trawl vessels and 100 trap vessels registered in Dongshan County (data from Dongshan County Ocean and Fishery Bureau);

(2) The average of 120 fishing days for trawl fishing and 135 days for trap fishing (see 3.8.1. section); and

(3) The average capture volumes for *P. haanii* (140.16 kg/vessel/day for trawl and 260.71 kg/vessel/day for trap) (see 3.3.2. and 3.3.4. sections).

Therefore, the estimated annual capture volume for *P. haanii* was 20,592 t in Dongshan County, including 17,072 t by bottom trawl and 3,520 t by trap.

4.6. Estimation of *Portunus haanii* capture volume from export data

An estimation on the annual capture volume of *P. haanii* was also conducted based on the crab export data. The estimated *P. haanii* product export volume was about 16,375 t in Fujian Province in 2018 (see 3.9.3. section). An estimation of 35% of the total *P. haanii* product export volume was from Dongshan County, i.e. 5,731 t (see 3.8.6. section).

The average crab meat productivity and the discard rate in the processing factories were estimated to be 11.75% and 5%, respectively (see 3.9. section). Therefore, the estimated *P. haanii* volume for processing in 2018 in Dongshan County was about 51,342 t.

Based on the estimations, there is a large shortage on *P. haanii* supply (about 30,750 t) in 2018. Due to the large shortage on *P. haanii* supply, *P. haanii* catches from other places (e.g. Quanzhou City, Longhai County, Zhaoan County, Guangdong Province, Guangxi Province, Vietnam) were reported as being used to meet Dongshan crab processing demands.

4.7. Minimum size for *Portunus haanii* fishery

Recently, Fujian Province Ocean and Fishery Administration Department released a regulation on 35 commercial important fishery species for their minimum catch sizes (http://hyyyt.fujian.gov.cn/zfxxgkzl/zfxxgkml/ywgz/yzygjdaqsc/201806/t20180608_3161670.htm). In the regulation, the minimum catch size for *P. haanii* is 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 in the coming years: <30% juveniles in 2019, and <20% in 2020 and afterward.

There are several challenges for applying the regulation of the minimum catch size to *P. haanii* in trawl fishery. *Portunus haanii* is mainly caught by trawl vessels in Dongshan County. In the present study, the proportions of *P. haanii* <8 cm CW were about 35.45-52.05%, varied by month in August-December, 2018 (see 3.4.2. section). 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 (see 3.8.4. section) could potentially be considered. Because of the large proportion of smaller crabs (<6 cm CW) in catches, and the market exploration of "one bite crab" product in domestic markets, the crab processing factories found an opportunity to utilize the smaller crabs. However, the scale of "one bite crab" product market is still unknown.

In the present study, the proportion of *P. haanii* <8 cm CW was nearly 20% using trap fishing (see 3.4.1. section). The result reveals that the trap fishing is a good practice for the crab fishery, with high selectivity for crabs and low proportion of small sized crabs.

4.8. Recommendations

Based on the present study, several recommendations are provided below:

(1) **Initiating monitoring programs on ETP species in China is needed.**

Currently, *Sphyrna lewini* and *Hippocampus trimaculatus* were found in landed catches; the former recorded from Zhejiang Province to Hainan Province, and the latter commonly found in Dongshan County. The Minnan-Taiwan Bank fishing grounds are likely to be the suitable habitat for seahorses. Data on fishing site, habitat, stock density and capture volume should be collected for *H. trimaculatus* to further understand its fishery.

(2) **The adjustment of 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. In the present study, 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. For *P. haanii*, more studies are needed to understand its spawning seasons, the spawning grounds, the habitat for juvenile growth, the stock size and the CPUE before proposing any recommendation on fishing moratorium adjustment.

(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*. Without any further academic advice, additional management measures and enforcement, the captains and crews are not able to reduce the proportions of small size crabs in practices.

(4) **Fishing vessel registration for fishing gear and horsepower should be checked randomly.**

In the present study, we found that 49.53% of trawl vessels and 88.89% of trap vessels surveyed changed their original, registered, fishing gears, and even some vessels operate without license. The administration offices should conduct monitoring randomly at the landing ports or on board.

(5) **Trap fishery may not be promoted by government for safety consideration.**

Although the trap fishery is a good practice with high species selectivity and low proportions of small size crabs, the fishing gear may not be promoted by government due to safety considerations. The trap fishing vessels have too many traps on board, which easily makes the vessel unstable and vulnerable to capsize. To avoid the gear conflicts with trawl vessels fishing in the same areas, trap vessels usually go fishing in high wind and rough sea conditions when trawl vessels are on the way back for shelter, which raised safety issues. In 2018, two trap vessels in Dongshan County sank, resulting more than 20 human deaths.

(6) **The efficiency of the current fisheries management and regulation at provincial and national levels should be examined**.

It is a comprehensive subject which should include the considerations of environmental, economic and social issues, and should be evaluated at the levels of the regulatory system, fishery regulatory measures, and the reformation on the fishery system. Individual fishery management approaches, such as relying on fishing license, total allowable catch, fishing moratorium, control vessel number and total engine power, minimum mesh size requirement, minimum fishable standard, fishing vessel buyback

and fishers relocation, each have their own problems and limitations, which highlights the need for comprehensive review.

(7) **Challenges on catch data collection in the present study.**

On one hand, catch data collection methodology from trawl vessels is practical. Because the catches from trawl vessels are landed at the landing ports; the catches are usually sorted by main species groups and can be estimated by following the entire procedure of landing. On the other hand, we faced challenges for collecting catch data from trap vessels. The trap vessels usually brought their catches using transshipment vessels every 2-3 days so that they can operate at sea longer. Therefore, the landings of the trap vessels at the landing ports are usually not their total catches for the entire trip. Meanwhile, we had difficulties collecting the catch data on trap vessels, because of the low occurrence of trap vessels at the landing ports of Dongshan County. Therefore, the comparisons of the two fishing gears on catch volumes of crabs, proportions of crab volumes in total catches, and sizes and sex ratios of crabs caught cannot be conducted.

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