MINISTRY OF EDUCATION AND TRAINING
NHA TRANG UNIVERSITY

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RESEARCH ON THE SOLUTIONS TO ESCAPE THE JUVENILE SWIMMING CRAB IN ORDER TO INCREASE THE SELECTIVITY FOR THE ROUND SWIMMING CRAB TRAP IN HAI PHONG CITY

SUMMARY OF DOCTORAL THESIS
MAJOR IN: FISHING TECHNOLOGY

KHANH HOA - 2023

The dissertation submitted by Phan Dang Liem in partial fulfillment of the requirements for the completion of the Ph.D. degree in Fishing Technology in Nha Trang University.

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The thesis is presented at Doctoral Thesis Evaluation Council at Nha Trang University

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THE SUMMARY OF NEW CONTRIBUTIONS OF THE THESIS

Thesis title: Research on the solutions to escape the juvenile swimming crabs in order to increase the selectivity for the round swimming crab trap trap in Hai Phong city.

Major: Fishing Technology

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PhD Candidate: Phan Dang Liem

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Instructor: 1. Dr. Hoang Van Tinh

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Content:

1. The thesis has collected a complete set of data ensuring high reliability on the current status of fishing activities of the round crab trap in Hai Phong. Through analysis and assessments, the violation levels of fishing gear structure and fishing waters have been determined. Besides, the swimming crab resources in Hai Phong waters are also impacted by the round swimming crab trap trap.

2. The first selective model has been firstly used to determine the shape, location and size of the escape vent to release juvenile swimming crabs.

3. The escape vent with size 45 x 55 mm is proposed, installed in 03 positions located at the bottom corner of the side net to release juvenile swimming crabs.

4. The first fishing net trap with the size 2a = 50 mm (according to TCVN 10466:2021) has been successfully researched, installed in the shape of a square mesh to free juvenile swimming crabs.

Instructor		**PhD Candidate**
Dr Hoang Van Tinh	**Dr Nguyen Long**	**Phan Dang Liem**

INTRODUCTION

1. Reasons for choosing the topic

The typical seafood resources of Hai Phong waters are like the Gulf of Tonkin waters. According to a study by the Research Institute For Marine Fisheries in the period from 2016 to 2020, the reserves of marine resources in the Gulf of Tonkin waters are estimated at 627 thousand tons. In which, the Small pelagic fishes: 548,000 tons, the Demersal fishes: 51,000 tons, the cephalopods: 7,000 tons, the crustaceans: 21,000 tons and other groups: 300 kilogam. The resource reserves are divided by the sea area as follows: the coastal area is about 172,000 tons, the inshore area is about 220,000 tons and the offshore area is about 235,000 tons [20, 25]. Compared with the period from 2011 to 2015, the reserves of marine resource groups are estimated at an average of 757,000 tons (ranging from 752 to 760 tons) [17, 19]. Compared with the results of the resource survey between the two periods, the resource reserves in the Gulf of Tonkin have decreased sharply, the fishing productivity tends to decrease dramatically and the proportion of the bycatch such as juvenile squids, juvenile swimming crabs, immature fish, fish of low economic value caught more and more. Most of immature valuable species are caught by vessels, Moreover, many species are in jeopardy, and included in the Red Book of Vietnam [20, 25]. This shows the exploitation pressure on resources in Hai Phong waters in particular and the Gulf of Tonkin.

In order to reduce the impact of fishing activities on marine resources in the world, there are following solutions: installing devices to escape juvenile fish, creating the escape vent ... to increase the selectivity of fishing gears; stipulating the fishing time, suitable fishing areas and exploitation sea area; stipulating the size of species allowed to exploit... Various research methods such as fisheries surveys, fishing monitoring, image observations are based on video equipment, testing, .. the authors have made statistics of catching quantity according to the size group of the catch. Then the authors determine the selective factors: selective size, selective range, selective factors. Based on the relationship between the above factors, they will determine sizes, shapes, positions ... of the appropriate selective devices. In order to reduce juvenile fish to be caught by the round swimming crab trap trap, the countries around the world often install the fishing net trap with the square meshes, hexagonal meshes (mainly to escape fish and squids), and create the escape vent (used for crabs, swimming crabs) with different shapes, sizes and positions, ...

The round crab trap is one of the fishing activities of Hai Phong fishermen, however, this activity has tended to decline in recent years. According to statistics of Hai Phong Fisheries Sub-Department, there are 59 boats in the city by December 2020, down 47.2 % compared to 2016 [4-7]. The mesh size of the fishing net trap (2a = 30 mm) is smaller than the regulation, the juvenile crabs in the nets account for quite large proportions (about 51 %) [11], the selling price is only 50 - 60 % compared to the mature crabs (the legal size). This has significantly affected the value and sustainable development of swimming crab resources in Hai Phong waters.

In order reduce the rate of juvenile swimming crabs caught by the round crab trap in Hai Phong, it is necessary to conduct the project "Research on solutions to escape the juvenile swimming crabs so as to increase the selectivity for the round crab trap in Hai Phong city”.

2. Research objectives

2.1. General objectives

Proposing the solutions to escape immature crabs in order to increase the selectivity for the round crab trap in Hai Phong city.

2.2. *Detail objectives*

- Assessing the fishing status of the round crab trap in Hai Phong city.
- Developing the solutions to escape juvenile swimming crabs to increase the selectivity for the round crab trap.

3. Research object

The round crab trap in Hai Phong city.

4. Research scopes

4.1. Spatial scope

- The scope of the survey is concentrated in the districts where the round crab trap is developed in Hai Phong city.
- The scope of the pilot study is Hai Phong and neighboring waters.

4.2. Time scope

The duration of the project is from 2018 to 2021.

5. Research contents

Content 1: The overview of domestic and abroad researches.

Content 2: Investigating the current situations of the round crab trap in Hai Phong city.

Content 3: Assessing the current status of fishing activities of the round crab trap in Hai Phong city.

Content 4: Researching and proposing the solutions to escape immature crabs in order to increase the selectivity for the round crab trap in Hai Phong city.

6. Scientific and practical significance of the thesis topic

6.1. Scientific significance

- Adding the data sources on the current situation of the round crab trap catching juvenile swimming crabs in Hai Phong city; assessing the current status of juvenile swimming crab products caught by the round crab trap in Hai Phong city.
- Adding the calculation method, designing the shapes, location and sizes of the escape vent for the round crab trap to escape juvenile swimming crabs in order to protect and sustainably develop the marine resources in general and crab resources in particular.
- Providing a scientific basis to propose the solutions to rescue juvenile swimming crabs to increase the selectivity for the round crab trap in Hai Phong.

6.2. Practical significance

- Helping the fishermen to be aware of the impact of the round crab trap, loss of marine resources and economic value when juvenile swimming crabs are caught.
- The research results of the project contribute to providing a scientific basis to help fisheries managers develop the legal documents to rationally exploit and protect swimming crab resources in Hai Phong waters in particular and the Gulf of Tonkin in general.

CHAPTER 1 - THE OVERVIEW OF THE STUDY

1.1. Overview of international studies

1.1.1. Characteristics of resources

Several studies on common swimming crabs in the world were conducted: 1) Three spotted swimming crabs *(Portunus sanguinolentus)* inhabit the sandy and muddy bottoms in nearshore waters, about 5 - 25 m deep; they are widely distributed in the Philippine waters, China waters, Japan waters, Vietnam waters, etc,…[38]. They are reproduced around the year, the first matured size of male is 9.75 cm and female is 9.40 cm [52]; 2) Blue swimming crabs *(Portunus pelagicus)* inhabit the sandy or muddy bottoms in estuary zone to inshore, about 5 - 25 m deep; they are widely distributed in the Philippine waters, China waters, Japan waters, Vietnam waters, etc,… [31]. The main reproductive seasons are August and September with the first matured size of 118.5 mm [50]; 3) Crucifix crabs *(Charybdis feriatus)* inhabit near the rock reef, the rock sandy bottom in nearshore waters, about 5 - 35 m deep; they are widely distributed in the Philippine waters, China waters, Vietnam waters, etc,…[31]. The productive season happens around the year, the first matured size is 87.3 mm [39].

1.1.2. Swimming Crab behaviors

In the world, there have been a number of studies on the behavior of marine species as a basis for the design and operation of fishing gears, such as the author Anukorn Boutson [30] studied the behavior of swimming crabs when they start entering the entrance until being held in the trap and they crawl when exiting the trap; The author Wu (1996) [54], Winger and Walsh (2007) [53] studied the behavior of the swimming crabs when moving around the bottom of the trap and how the crabs escaped from the trap at the bottom positions; Smith and Sumpton (1989) [49] studied the behavior of crabs when trapped in the trap, protecting the bait.

1.1.3. Research on assessing the impact of the round crab trap on marine resources

In the world, There were many authors studying and assessing the impact of the round crab trap on marine resources. Morgan studied the impact of the trap fishery on marine resources and ecosystem [45]; Anukorn Boutson assessed the impact of the round crab trap on discard catch on the small-scale coastal fishing boats and commercial vessels in Thailand waters [30]; Vincent Guillory conducted a study on the effects of lost and discarded trap on the marine resources of blue swimming crabs in the Gulf of Mexico [36]; Dahri Iskandar studied the influence of the round crab trap on fishing of black damsel *(Neoglyphidodon melas)* in the Seribu archipelago - Indonesia [32].

1.1.4. Selective studies for the round swimming crab trap trap

Fishing is a selective fishing process that takes away only a defined portion of the products from the marine resources. The selectivity in fishing depends on two factors: the fishery-biological characteristics of the fishing objects and the selectivity of each type of activity [43].

The selectivity model has been applied by many authors to calculate and build the selectivity curve [30, 44, 51, 56, 57]. In order reduce the juvenile fish and swimming crab species caught in the world, there have been studies on selective fishing for the round crab trap or example, Zhang Jian conducted a study on the influence of escape vents on remaining and size selectivity of spotted swimming crabs *(Portunus trituberculatus)* in the East China Sea - China [56]; Vincent Guillory carried out a study on selectivity at different mesh sizes on round crab trap *(Callinectes sapidus)* [37]; Anukorn Boutson experimented on a device to select blue swimming crabs *(Portunus pelagicus)* of the round crab trap in Thailand [30]; Dahri Iskandar studied the effects of the trap on black damsel *(Neoglyphidodon melas)* in Seribu archipelago, Indonesia [32]; Zhang Peng conducted a study on the collapsible trap *(Carybdis japonica)* in Lizhao Bay - China [57]; La Sara conducted a study on the vent size for the round blue swimming crab trap *(Portunus pelagicus)* in the Southeast Sea of Sulawesi, Indonesia [48]; Stewart. J and Ferrell. D.J studied on mesh size selection in bottom fishing in New South Wales - Australia [41]; Estrella B.T. researched on selective equipment for lobster trap [34];...

1.2. The overview of the domestic studies

1.2.1. Characteristics of the swimming crab resources

There are several common crab species caught by the round crab trap in Hai Phong waters, such as blue swimming crab *Portunus pelagicus,* Linnaeus (1758) with the first matured size of 99.28 mm [12, 13, 29]; crucifix crab *Charybdis feriata,* Linnaeus (1758) with the first matured size of 87.3 mm (CW) [33]; three-spotted swimming crab *Portunus sanguinolentus (*Herbst, 1783) with the first matured size of 76.1 mm [25].

1.2.2. Studies on the selectivity

Nguyen Dinh Phung [14] synthesized and analyzed on some factors to assess the selectivity of fishing gears around the world; Nguyen Phi Toan [16] researched on the selectivity of the trawl with the square mesh; Vo Giang [26] studied on the selectivity of the stow net fishing in Thuan An estuary, Thua Thien Hue province; Nguyen Phong Hai [40] studied the selectivity of the set-net fishing at Tam Giang lagoon.

1.2.3. Studies on impacts of the round swimming crab trap trap on marine resources

In Vietnam, there have been a number of studies on the impacts of round crab trap on marine resources, for example, Vu Viet Ha studied and assessed trap fishing of blue swimming crab in Kien Giang waters [29]; Vu Duy Duong studied the impacts and assessment of crate fishing to marine resources in Khanh Hoa province [27]; Phan Dang Liem assessed the harmful levels of marine resources caused by fishing activities in Kien Giang province [21].

1.2.4. Studies on the proposed solutions to the round swimming crab trap trap management

In Vietnam, there have been a number of studies relating to the management of the round crab trap, for example, Tran Duc Phu studied on the improvements of the traditional traps and pots in Ninh Thuan province in order to improve fishing efficiency [24]; Hong Van Thuong studied on the status and solutions on coastal marine resources fishing with traps in Bac Lieu province [10].

1.3. The contents are inherited the overview research part of the thesis

1.3.1. National scientific research projects

- Initially, the researches mentioned the need to conduct the research on the selectivity in fishing in VietNam

- The research results of the authors show the harmful levels of fishing to marine resources in general and the harmful levels of trap to swimming crab species in particular.

The research shows that the structure of fishing gears with the unreasonable mesh sizes, so the juvenile crabs and fish are overexploited.

- There has not been any scientific researches in the country to study the selective factors (selective size, selective range, selective coefficient) for crab species fished by traps.

- The research method: the survey method according to the questionnaire form is used. This method is currently being widely used in fishery surveys in Vietnam and around the world.

- Experimental researches conducts the experiments between improved fishing gears and local fishermen’s fishing gears to draw out the superiority of the improved fishing gears. This is the common method used in the research on the improvement of fishing gears.

1.3.2. Foreign sientific research projects

- There have been a number of scientific studies on the selectivity, determining the selectivity curve for fishing industries, including traps.

- There have been some researches on swimming habits when they enter the trap, how to find baits, how to move in the trap, their reactions when finding the preys, scrambling for baits, how to find the way to get out of the trap.

- There have been some researches on escape vents of the round crab trap and how to design escape vents.

- Studying on the selectivity of the round crab trap, the authors followed the standard procedures for improving fishing gears which they have model researches and field studies after model researches are satisfactory.

- Developing the selectivity research methods for blue swimming crab (*Portunus pelagicus*), three spotted swimming crab (*Portunus trituberculatus*) ... for the trap fishery by creating escape vents for seniel crabs with different installed positions and various types of shapes such as round, square, rectangular, oval with different sizes. The author conducts the experiments in the laboratory tanks to choose the suitable designs of escape vents, then take the experiments at the fishing ground with the fishing gear is a traditional trap that fishermen has been using. The author assess the advantages and disadvantages of the improved traps by comparing the fishing efficiency and the selective efficiency of the improved fishing gear (traps) (modified gear) and the traditional fishing gears.

- The selective curve, selective size, selective range, selective coefficient for blue swimming crab (*Portunus pelagicus*), three spotted swimming crab (*Portunus trituberculatus*),... exploited by the traps in the East China Sea - China, Thai waters, New South Wales waters, ... are determined.

1.3.3. The contents are inherited from domestic and foreign research projects

- From the above analysis, PhD student inherited some contents from the domestic and foreign scientific projects to carry out the thesis as follows:

- The methods of document research are synthesizing, analyzing and evaluating information and data from thesis/projects, scientific works, articles, etc. then the author selects the approaches and research methods that are consistent with the objectives of the thesis.

- The questionnaire form survey method is applied, which is commonly used in fishery survey in Vietnam today.

- The thesis has applied the shape of the escape vents which Author Anukorn Boutson [30] studied on the blue swimming crab *(Portunus pelagicus)* fished in Thailand waters, Zhang Jian studied on the spotted seniel crabs in China [56], Vincent Guillory studied on Atlantic blue crab [37], Peter Starbatty studied on King crab [47].... However, the size of escape vents would be calculated in accordance with the crab species fished by the round crab trap in Hai Phong.

- Experiments were conducted in 2 phases, including the experimental period in the experimental tank and the experiment at the fishing ground used by Anukorn Boutson *et al.*, (2008) [30] when studying on the blue swimming crab (*Portunus pelagicus*) and Estrella B.T. and Glenn R.P (2006) [34] when studying the escape vents for lobster traps.

- The improved traps (traps with escape vents) in the tank were tested to choose the appropriate shapes, positions and sizes of escape vents.

- Experimental researches were at fishing grounds: experimental fishing with the improved traps (with the best results when tested in the tank) compared with the traps used by fishermen (control traps).

- The calculation of the selective parameters: the expressions in the study of the selectivity used by Anukorn Boutson [30] were applied to the blue swimming crab (*Portunus pelagicus*) in Thailand waters and Jian Zhang [56] studied the spotted swimming crab *(Portunus trituberculatus)* in the East China sea – China.

CHAPTER 2 - MATERIALS AND METHODOLGY

2.1. Materials

- Laboratory tanks: The experiments were conducted in a crab tank with the size tank of 1.7×1.7×1.0 m3 in Hai Phong

- Boats for research: Using boats of the round crab trap owed by Hai Phong fishermen to conduct the experimental activities at fishing grounds.

- Fishing gears: Using the fixed round crab trap owed by fishermen in Hai Phong fishermen to conduct experimental activities.

- Data collection tools: Survey forms, fishing logbooks,...

- Measurement tools: scales, rulers.

- Equipments for recording video and audio: recorders, cameras.

2.2. Methodology

2.2.1. The theoretical basis

Experimental research of escape vents to protect immature swimming crabs are based on the theory of fishing gear selectivity. The study uses a selective model to evaluate [44, 51], select each escape vent by considering the selective length [42, 46, 51]. The expression describes the selection of fishing size of the fishing objects by the trap according to the logarithmic curve as follows:

$$S(CW) = \frac{\exp(a+b.CW)}{1+\exp(a+b.CW)} \quad (2.1)$$

In which: S(CW): the probability of an object with size CW is retained; CW: the width of the carapace crab; a, b: parameters (with a < 0 and b > 0)

$CW_{50\%}$: the width of the carapace crab to be caught, 50% of the number of crabs would be kept in the trap, determined by the following formula:

$$a + b * CW50 = \ln(\frac{0,5}{1-0,5}) = \ln1=0 \quad \text{suy ra} \quad CW_{50\%} = -\frac{a}{b}$$

Lenghth range CW_{25} - CW_{75} is symmetric CW_{50} called the selective range (SR)

SR is determined by the following formular:

$$SR = CW_{75} - CW_{25} = \frac{\ln(3)-a}{b} - \frac{\ln(\frac{1}{3})-a}{b} = \frac{2\ln(3)}{b} \quad (2.2)$$

From CW_{50} value, the selective coefficient is calculated according to the escape vent size as follows:

$$S_F = \frac{CW_{50}}{a} \Leftrightarrow a = \frac{CW_{50}}{S_F} \quad (2.3)$$

In which: S_F: selective coefficient; a: size of escape vent.

2.2.2. Methods to detemine the number of surveyed samples

- Random sampling method according to FAO [35] is applied.
- The number of surveyed forms are based on the fishing boats of Hai Phong fisheries sub-department [7], the number of samplings are calculated by Yamane 's formular [55]:

$$n = \frac{N}{1 + N \times e^2} \quad (2.4)$$

2.2.3. Methods of data collection

a/ Secondary data collection: Collecting and analyzing data from the fishery management offices in Hai Phong, including the number of boats (classified by activities and locations), the number of the trap (classified by activities, length and locations); exploitation yields;…

b/ Primary data collection:

- Collecting data on the status of fishing activities and resource protection: It was carried out by the random sampling method with the number of samplings that are suitable for the thesis. The collected data included fishing boat sizes, fishing equipments, fishing gears, fishing objects, seasons, yields... The total number of surveyed forms is 65.
- Investigation of fishing gears: Directly measured from the traps, including trap sizes, mesh sizse, opening and opening angle of funnel. The total number of surveyed fishing gears was 10.
- Detailed interviews: Directly interviewing the managers and fishermen using the trap fishery in order to collect necessary information, applying the selective equipments and resource protection. The total of detailed interviews are 15.

c/ Data collection of fishing observation:

The author surveyed directly on the fishermen's fishing boats using the round crab trap in Hai Phong. The data included fishing coordinates, yields, fishing productivity, some biological characteristics of swimming crabs (species, size, weight…). The total number of fishing nets are 28.

d/ Collection of biological data in fishery at fishing ports:

Biological investigation in fishery was carried out at the main fishing ports in Hai Phong city. Swimming crabs were measured the sizes and weighed. The frequency of sampling was monthly and collected continuously in 12 months. The number of boats for biological sampling was 36.

2.2.4. Calculating and selecting the escape vents for swimming crabs to increase selectivity of the round swimming crab trap traps in Hai Phong city

Calculation of the escape vents were selected in the project based on the elements consisting of the regulations of legal documentations, the biological characteristics of the research subject, mesh size of trap following Vietnamese standards; economic effieciency of the trap fishing; inheriting the research method of the author in the world. From the above analyses, the escape vents are used in the projects as below:

+ Shapes: there are 3 types of escape vents selected and tested in the labratory tanks such as round, rectangular and square shapes.

+ Positions of vent installation: For the experimental activities, positions of escape vents installed at the bottom corner of the funnel net, the middle of the the funnel net, the top of the side net, the bottom of the side net and the top net plate.

+ Sizes of escape vent: Measuring the size and apply the calculation according to the following formula [9]:

$$a_{ct}=K_{CW}.CW \quad (2.5)$$

In which: a_{ct}: escape vent edge size; CW: width of the carapace caught objects; K_{CW}: coefficient following ratio of width and volume (K_{CW} = 0,2 x C_{max}/CW (with $C_{max:}$ the largest perimeter of crabs). According to Zhang Jian *et al.*, [56], based on the crawling behavior of the crabs, the crabs can escape from the trap, the width and height of the eascape vent should be 10-20% larger than the shell length and shell height of the crabs. In addition, during the experiments, the largest size of the juvenile crabs that need to be released will be measured as a basis for adjusting the appropriate size of the escape vent. The escape vent can be adjusted so that the selectivity of fishing gear is improved, convenient to manufacture, safe to use and does not affect the economic efficiency of fishermen.

2.2.5. Experimental method

There are 2 phases: phase 1 was conduted in the laboratory tanks and phase 2 was carried out in the fishing ground.

Phase 01: In the laboratory tanks

1) Laboratory tanks: the laboratory tanks were placed outdoor with the size of 3.0 x 2.0 x 1.0m; seawater was filtrated and aerated 24h/24h at the temperature from 28 to 30^0C, water depth of 50cm.

2) Crabs for experiments:

+ 48 individuals were selected and caught with the carapace width of 60 - 140 mm.

+ Crabs were raised in laboratory tanks for 1 day before carrying out the experiments.

3) Experimental layout:

+ The project arranged 03 crab trap traps with square, rectangular and circular escape vents into 01 tank. 48 crabs with 08 different size groups in 03 different traps (each trap with 16 individuals, with 08 groups of different sizes from 60 to 140 mm) were put in the trap, the number of repetitions was 03 times. The soak time is 3 hours.

+ Data collection: a camera was installed on the surface of tank at a suitable height for obervation 3 traps in the same tank. The crabs escaped through the vent or are remained in the trap at the different vents. The positions and sizes of the escape vent were recorded.

Phase 2: Field-experiment (fishing ground)

- Experimental traps: 4 types of trap used for tests at sea as follow: 1) the round crab trap (used by fishermen) (type I); 2) The round crab traps with the best escape vent in stage 1 (type II); 3) The round crab traps used by fishermen were changed the covering net with the mesh size of 2a = 50 mm and installed the square meshes (type III); 4) The traps with escape vent but they were modified and improved (type IV). The number of traps for each type was 30 traps.

- Fishing ground for experiments: The experiments were carried out at the traditional fishing ground by fishermen in Hai Phong waters.

- Experimental layouts:

+ The first trip: 03 types of traps were arranged alternately. The orders of traps were arranged as follows: 01 trap of type III, then 01 trap of type I and 01 trap of type II. The distance between 2 traps was 20 m.

+ The second trip: 03 types of traps were arranged alternately. The orders of traps were arranged as follows: 01 trap of type IV, then 01 trap of type I and 01 trap of type II. The distance between 2 traps was 20 m.

- Time of experimental activities: The trials were carried out in 2 sea trips within 7 days per trip and 2 fished net per day.

- Data collection: The number of crabs was collected separately following each type of trap. The crabs were counted, measured, and weighed following the types of trap and size group. All data were represented in forms.

2.2.6. Data processing methods

- Fishing productivity:

+ Fishing productivity was calculated as follow [46]: $CPUE_i = \frac{C_i}{E_i}$ (2.6)

+ Average fishing productivity [46]:

$$\overline{CPUE} = \frac{1}{n}\sum_{i=1}^{n} CPUE_i \quad (2.7)$$

In which: CPUEi: Average fishing productivity of i fishing boat [kg/day]

Ci: yields of i fishing boat [kg]

Ei: fishing effort of i fishing boat [day]

- Fishing yield: The formula of the fishing productivity is calculated as below [35]:

$$C = CPUE \times [E] = CPUE \times [F \times A \times BAC] \quad (2.8)$$

In which: C: fishing yield; CPUE: Fishing productivity; A: the number of potential day; F: total number of fishing boats; BAC: coefficient of boat activity.

$$BAC = \frac{(a_1+a_2+a_3+\cdots+a_i)}{(N_1+N_2+N_3+\cdots+N_i)} \quad (2.9)$$

In which: a_i: the number of sample boats works on the i^{th} day; N_i: the number of sample boats is selected i^{th} day.

- Calculation of economic efficiency:

+ Turnover was calculated by the formulae as below:

$$P = \sum_{i=1}^{n} P_i \quad (2.10)$$

In which: P: turnover of the sea trip; P_i: turnover of the i^{th} product; n: the number of species caught in the trip (crab in 1^{st} category, 2^{nd} category, fishes, shrimps, etc.,).

+ Costs were calculated by the formula:

$$C = \sum_{i=1}^{n} C_i \quad (2.11)$$

In which: C: Total costs of the sea trip; C_i: cost for lubricating oil, ice, food and drinks,…

+ Profits were calculated by the formula:

$$LN = P - C \quad (2.12)$$

In which: LN: Profits; P: turnover of the sea trip; C: Cost of the sea trip

+ Profitable caculation: based on the following formular [15, 28]:

$$DL_1 = \frac{LN}{CP} x100 \qquad DL_2 = \frac{LN}{V} x100 \qquad DL_3 = \frac{LN}{DT} x100 \quad (2.13)$$

In which: LN: Profits; CP: Cost of production; V: Investment capital; DT: Total turnover

- Composition of fishing yields was calculated as below:

$$Pi = \frac{\sum_{j=1}^{n} Catch_i}{\sum_{j=1}^{n} Catch} \quad (2.14)$$

In which: Pi: yield composition of the i species (%)

n: the number of fished net

$Catch_i$: yield composition of the i species at the j^{th} net [kg]

Catch: total catch of the j^{th} net [kg]

- Calculation of escape rate of crab: crabs escaped from the trap were calculated as below [56]:

$$r_L = \frac{\sum N_{NL}}{\sum(N_{NL} + N_{TrL})} \quad (2.15)$$

In which: r_L: escape rate of crab [%]; N_{TrL}: number of crab individuals was kept in the traps [individuals]; N_{NL}: number of crab individuals escapes from the traps [individuals]

- Calculation of the initial losses

The value of the initial loss when using escape vents was estimated as below [16]:

$$KT = \frac{GT_{LTT} - GT_{LCT}}{GT_{LTT}} \text{ x } 100 \quad (2.16)$$

In which: KT: Value of the initial loss; GT_{LCT}: Value of products in the trap with escape vents; GT_{LTT}: value of products in the traditional trap (fishermen's trap).

- The proposed solutions to escape juvenile crabs: Based on the regulations of legal documents and biological characteristics of the research subjects; based on the evaluation criteria to select the appropriate trap pattern to apply in practice as below [16]:

+ Criterion 1: Based on the selectivity according to yields and the number of individuals.

+ Criterion 2: Based on the initial losses of yields and turnover.

+ Summary of all evaluation criteria, the trap patterns were selected appropriately in order to suggest applying them in practice.

CHAPTER 3 - FINDING RESULTS AND DISCUSSIONS

3.1. Status of the round swimming crab trap trap in Hai Phong city

3.1.1. Structure of fishing industry

3.1.1.1. Structure of fishing industry in Hai Phong city

- Classified by fishing group: The number of fishing boats in Hai Phong by June 2020 was 2,175 boats, in which the gill net fishery was 701 boats (accounting for 32.2 %), followed by the trawl fishery with 485 boats (accounting for 22.3 %), the trap fishery was 435 boats (accounting for 20 %), the held-stick falling fishery was 245 boats (accounting for 11.3 %) and other fishery were 282 (accounting for 13 %). The group of boat length under 12m was 1.384 boats (accounting for 63.6%); the group of boat length from 12 to 15m was 392 boats (accounting for 18.0%); the group of boat length ≥15m was 399 boats (accounting for 18.4%).

- The number of fishing boats classified by the locality: The surveys showed that Thuy Nguyen district was the region having the largest number of fishing boats with 827 boats (accounting for 38.0 %); followed by Cat Hai district with 459 boats (accounting for 21.1 %); Tien Lang district with 385 boats (accounting for 17.7 %); Do Son district with 198 boats (accounting for 9.1 %); Kien Thuy district with 137 boats (accounting for 6.3 %); Duong Kinh district with 113 boats (accounting for 5.2 %) and the other districts with 56 boats (accounting for 2.58 %).

3.1.1.2. Structure of fishing boats of the trap trap in Hai Phong

The total number of the trap trap boats in Hai Phong in 2020 was 435 boats in the period of 2016 - 2020, the trap tended to declin with an average decreasing rate was about 6.6 % per year. The period when the number of boats decreased the most was the period of 2016 - 2018, with an average reduction of 12.6 % per year.

3.1.1.3. Structure of fishing boats of the round crab trap in Hai Phong

The results of surveys showed that the round crab trap in Hai Phong was 125 boats in 2016 and 59 boats in 2020, with an average reduction rate of about 10.6% per year.

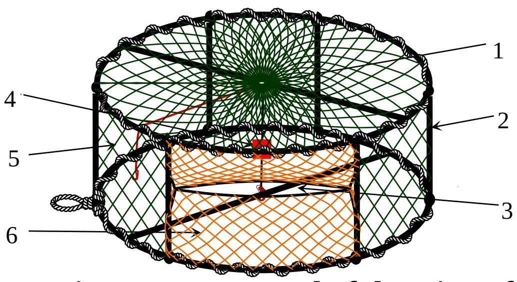
3.1.2. Characteristics of fishing boats of the round swimming crab trap in Hai Phong

The survey showed that 100 % of hull boats were made of wood, engine originated from Japan and China. The length of boat was from 9.9 m to 15.8 m,the width of boat was from 3.1 m to 4.6 m, the height of the side of the boat was from 1.4 m to 2.3 m; 100 % of the boats were equipped with winches for collecting and releasing the traps.

3.1.3. Fishing gears

3.1.3.1. General structure of fishing gear

The structure and technical parameters of fishing gear were similar, the difference was the number of traps on each boat. The structure of the trap is presented in figure 3.1.



EXPLANATION:
1. Trap entrance
2. Round trap
3. Entrance funnel
4. Bait box
5. Fishing net trap
6. Net

Figure 3.1: General of drawing of the fixed round crab trap

3.1.3.2. Basic parameters and dimensions of the round swimming crab round trap

All basic parameters were similar, consisting of diameter of trap base is 500 mm, the height of trap is 250 mm, the mesh size of fishing net trap 2a = 30 mm, the mesh size of entrance funnel: 2a = 20 mm.

3.1.3.3. Number of traps

The numbers of traps equipped on the boats were different depending on the groups of boat length. The group of length < 12 m that numbers of traps were about 320 traps per boat; the group of length from 12m to <15 m that numbers of traps were about 650 traps per boat; and the group of length ≥ 15 m that the traps were around 1,060 traps per boat.

3.1.4. Fishing ground and season

3.1.4.1. Fishing ground

Fishing ground of the fishing boats of the round crab trap in Hai Phong were mainly concentrated on around floating mounds, reefs, and sink rocks in the Gulf of Tonkin, for example: Cat Ba island area, Long Chau island area, Bach Long Vy Island area - Hai Phong, Tran Island area - Quang Ninh, Co To Island area - Quang Ninh.

3.1.4.2. Fishing season

Fishing season are mainly in 2 seasons, the main season was from May to October (Southwest monsoon) and the sub-season was from November to April next year (Northeast monsoon).

3.1.5. The immersion time for traps

The surveys showed that the average immersion time of boats with less than 12 m in length is about 3.2 hours, the average immersion time of boats with length of 12 -<15 m is about 4,1 hours, the average immersion time of boats from 15 m in length is about 4,8 hours

3.1.6. Status on labours and income of labors

3.1.6.1. The age of labours

The age of labour is mostly in the age of 30 - 41 years old, taking up 42.8 %; followed by the age group of from 41 - 50 years old, taking up 28.8 %; after that, it was the age group from 18 - 30 years old, taking up 21.1 %. The remains takes up about 0.7 - 4.3 %.

3.1.6.2. Education

The education level of labour is mainly at the primary level taking up 56.6 %; the labours finishing the econdary school take up 40.3 %; noone finishes high school, it was especially with 3.1 % of illiterate labours [18].

3.1.6.3. Professional qualifications

The number of labours who have a captain's license accounting for 8.8 % of the total workforce. The majority of sailors were trained in the "hereditary" method based on the experiences. According to the assessments of the boat owners/captains, only 33.2 % of labours could do the job well, 52.7 % completed the job at an average level and 14.1 % had poor skills. In addition, the workers on the round crab trap in Hai Phong had an average of 12.3 years of experience in fishing.

3.1.6.4. Sea handling skills of sailors

The ability of sailors to know how to handle the situations was as follows: repairing fishing gear takes up 98.1 %, operating fishing gear takes up 97.2 %, operating fishing equipment on a boat takes 89.6 %, repairing fishing equipments accounts for 50.5 %, repairing ship engine accounts for 42.8 %, rescue skill accounts for 64.6 %, survival skills accounts for 66.1 %, storm avoidance skills accounts for 88.7 %, determining fishing grounds accounts for 75.2 %, and fire protection and prevention accounts for 45.1 %.

3.1.6.5. Assessment of legal understanding level

The level of legal knowledge of the labours on the round crab trap boats was still low. In which, only 32.6% had a good understanding, 57.1% did not have much knowledge about the law in general and the law on fishery in particular, 10.3% had almost no understanding of the law.

3.1.7. Awareness of protecting the resources of the fishermen community

The awareness of protecting the swimming crab resources of the fishermen community: i) When asked if they would release the crabs in the egg-bearing stage, 100 % of the fishermen answered no; ii) When asked if they would release juvenile crabs, 62.6 % answered that they did not release them; iii) When asked about the intention to increase the mesh size to protect the swimming crab stock, 100 % of them did not; iv) When asked about banning crab fishing in the reprodution season, 86.8 % said that it should not be banned and 13.2 % thought that fishing activity should be banned for 1 - 2 months.

3.2. Assessment fishing activities of the round crab trap in Hai Phong city

3.2.1. Assessment of the status of violation

3.2.1.1. Violation of fishing gears

Through the investigation, it was found that 100 % of the mesh size of the fishing net (2a = 30 mm) was smaller than the mesh size specified in TCVN (2a = 50 mm) [1] and the size regulation for swimming crab trap traps in Circular No. 01/2022/TT-BNNPTNT dated January 18, 2022 [3].

3.2.1.2. Violation of fishing areas

Through the investigation, it was found that although there were regulations on fishing operation areas of groups of length boat, in reality, the fleets of 15 m or more in length, they still operated in coastal and inshore areas. The boats at 12 m in length to <15 m length still operated in coastal and offshore areas and the fleets of less than 12m in length still operated in inshore areas [8, 23].

3.2.1.3. Status of juvenile crab exploitation

Sampling results in 02 seasons (Northeast and Southwest monsoon seasons) showed that the rate of juvenile crabs caught in the Northeast monsoon season was 52.6%; The percentage of juvenile crabs caught in the southwest monsoon season was 57.2%. Comparing the results in the legal documents (MARD, 2008) the allowed rate was not more than 15% of the total catch. This showed that the invasive level of the Hai Phong round crab trap was at a high harmful level.

3.2.2. Fishing activity of the round swimming crab trap trap

3.2.2.1. Catch per unit effort fishing (CPUE)

CPUE had an increasing tendency following the boat length, CPUE of the boat length ≥15 m reached 80.5 kg per day; the group of boat length of 12 to <15 m reached 58.6 kg per day and the group under 12 m length reached 46.2 kg per day.

3.2.2.2. Boat activity coefficient (BAC)

BAC of the boat group under 12 m length was 0.49; the group from 12 to < 15 m length was 0.43 and the group length ≥ 15 m was 0.41.

3.2.2.3. Potential days

Potential days of the group from 12 to < 15m in length and ≥ 15 m in length were 175 days, the group under 12 m in length was 190 days. The potential days were low because the boats switch to other activity from December to March of next year.

3.2.2.4. Total fishing yields

The total fishing yields of the trap boats in Hai Phong were 272,695.9 kg per year. In which, the group length under 12 m was 89,608.8 kg per year; the group of 12 to <15 m length occupied 114,058.4 kg per year and the group ≥ 15 m took 69,028.8 kg per year.

3.2.2.5. Compositions of fishing yields

Through the investigations of the biological fishery (within 12 months with 36 boats for sampling) and data collection from 2 observation trips on fishermen's boats, it showed that swimming crab rate took up 76.3 %; mantis shrimp took up 18.1 %; fish took up 4.8 %; octopus took up 0.8 %.

3.2.3. Economic efficiency of the round crab trap in Hai Phong

3.2.3.1. Turnover

Turnover had a difference between groups of boat lengths. In which, the group of boat length ≥ 15 m had a revenue (1,065 million VND/boat/year), about 1.37 times higher than the group of boats from 12 to <15 m (775 million VND/boat/year) and the group of boat length <12 m (611 million VND/boat/year) about 1.74 times.

3.2.3.2. Costs

Costs varied between groups of boat length. In which, the group of boats ≥ 15 m had the highest cost (752 million VND/boat/year), about 1.39 times higher than the group of boats from 12 to <15 m (541 million VND/boat/year) and the group of boats <12 m (405 million VND/boat/year), about 1.86 times

3.2.3.3. Profits

The average profits were different among groups of boats. In which, the group of boat length ≥ 15 m had the highest profit (313 million VND/boat/year) about 1.34 times higher than the group of boats from 12 to < 15m (234 million VND/boat/year) and the group boat length <12 m (206 million VND/boat/year), about 1.52 times. Generally, the profit of Hai Phong's fleet of round crab traps was quite low.

3.2.3.4. Labours' income

The income of labors from the round crab trap tended to increase by boat length group. In which, the group of boats with a length of ≥ 15m reached 52.2 million VND/person/year, the group of boats with a length of 12 to <15 m reached 46.9 million VND/person/year and the group of boats with a length of <12 m reached 45.7 million VND/person/year [22].

3.2.3.5. Profit-to-revenue index

This index tended to decline depending on the group of boat length. Profit-to-revenue index by boat length group did not differ significantly; the range was 41.63 - 50.78 %. However, the ratio of profit-to-revenue index on the investment capital had a large difference, about 33.15 - 121.96 %. Although profits increased, the return on equity on investment capital was low.

3.2.4. Assesement status of fishing products

3.2.4.1. Size of swimming crabs (CW and CL)

Carapace width (CW): The width of swimming crab carapace caught by the round swimming crab trap was different between 02 wind seasons (Northeast and Southwest monsoons). The average width of swimming crab carapaces in the northeast monsoon season (92 mm) was larger than in the southwest monsoon season (88 mm).

Carapace length (CL): The average length of swimming crab carapace in the northeast monsoon season (55.3 mm) was larger than in the southwest monsoon season (54 mm).

3.2.4.2. Rate of swimming crabs with undersize and legal size for fishing

The percentage of swimming crabs reaching the exploitation size was 43.9 %. In which, the percentage of the blue swimming crab reaching the exploitation size accounted for 44.1 %, and the crucifix crabs were 43.6%. In the Northeast monsoon season, the percentage of swimming crabs that did not reach the exploiting size took 52.6 %, and the proportion of swimming crabs that did not reach the legal size took 47.4 %; In the Southwest monsoon season, the percentage of swimming crabs that did not reach the exploiting size was 57.2 %, and the proportion of swimming crabs with legal size reached 42.8 %. Thus, the proportion of swimming crabs reaching the size of exploitation in the Northeast monsoon season was 1.09 times higher than in the Southwest monsoon season [29, 39].

3.3. Research and propose the solutions to escape juvenile swimming crabs in order to increase the selectivity for the round crab trap in Hai Phong city.

3.3.1. Calculation of escape vents for the round swimming crab trap trap in Hai Phong

Based on the calculation results, the measurement of the size of 553 swimming crabs and the efficiency of the round crab trap fishing in Hai Phong, the project selected 02 types of escape vent sizes: a_{ct} = 50 mm and a_{ct} = 55 mm to conduct experimental activities.

3.3.2. Assessement of experimental results in laboratory tank

3.3.2.1. Experimental results of escape vent shapes

a) Selection of escape vent shapes:

Shapes of escape vents have various sizes as below: square shape 55 x 55 mm; rectangular shape 55 x40 mm, round shape with diameter 55 mm.

b) Frequency of crab escape through the shapes of escape vents:

Experimental results in the tank showed that: The average percentage of swimming crabs escaping from the square escape vents was 37.5 %; rectangular escape vents reached 35.4 %; circular escape vents reached 31.3 %. Comparing the frequency of swimming crabs escaping between different escape vent shapes showed that the rate of square escape vent was highest with 37.5 %; rectangular escape vents with 35.4 % and circular escape vents had the lowest rate with 31.3 %. Thus, the square escape vent was the best, followed by the rectangular escape vents and the worst was the round escape vents.

c) Analysis of swimming crab selective factors of escape vent shapes:

The results in experimental tank showed that:

The square escape vents: a = -10,4908, b = 0,1104, $CW_{50\%}$ = 95,00 mm, $CW_{25\%}$ = 85,05 mm, $CW_{75\%}$ = 104,95 mm, S_R = 19,9.

The rectangular escape vents: a = -5,7142, b = 0,0599, $CW_{50\%}$ = 95,37 mm; $CW_{25\%}$ = 77,04 mm, $CW_{75\%}$ = 113,71 mm, S_R = 36,67.

The round escape vents: a = -6,4178, b = 0,0713, $CW_{50\%}$ = 90,00 mm, $CW_{25\%}$ = 74,59 mm, $CW_{75\%}$ = 105,41 mm, S_R = 30,81.

Thus, the selective range S_R of the rectangular escape vent was the highest, followed by the circular vents and the lowest was the S_R value of the square escape vent. The width of the swimming crab carapace in which 50 % of the individuals were kept in the trap ($CW_{50\%}$) when using the square escape vent was almost equal to the minimum width allowed for exploitation of 02 species, namely the crucifix crab and the blue swimming crabs. Rectangular and square escape vents ensured for $CW_{50\%}$ but selective range was large. Therefore, the square escape vent was more effective in resource protection than the other escape vent shapes.

3.3.2.2. Experimental results of position of escape vent installation

The frequency of swimming crabs escaping through the square vent was 22 individuals, the position of the escape vents placed at the bottom of the side net was 77.8%, at the bottom corner of the side net and in the middle of the entrance funnel net were 5.5%, the remaining positions did not see the swimming crabs escape. Through the rectangular escape vents were 17 individuals, the position at the bottom of the side net was 64.7%, at the bottom corner of the entrance funnel net was 35.3%, the remaining positions did not see the swimming crabs escape. There are 15 individuals through the circular vent, the position at the bottom of the side net was 73.3%, the position of the bottom corner of the entrance funnel net was 26.7%, the remaining positions did not see the swimming crabs escape. Thus, the position at the bottom of the side net gave the highest rate of swimming crab escape.

3.3.2.3. Experimental results of sizes of escape vents

Testing with 2 types of size of the square escape vents were 50 x 50mm and 55 x 55mm and placed at bottom of the side net. The results were as follows:

a) Frequency of swimming crabs escaped from different sizes of escape vents:

Rate of swimming crab escaping from the square escape vent (55 x 55 mm) was 33.3 % and the other escape vent (50 x 50 mm) was 29.2 %.

b) Analysis of selective factors of swimming crab escaped from types of square escape vents:

Calculation results showed that the carapace width at which 50% of individuals were trapped in the trap ($CW_{50\%}$) when using the 55 x 55 mm square escape vent was a = -10,6671, b = 0.1151, $CW_{50\%}$ = 92.65 mm, $CW_{25\%}$ = 83.11 mm, $CW_{75\%}$ = 102.02 mm, coefficient S_R = 19.08. Through analysis frequency of the swimming crab size distribution with carapace width greater than 120 mm, no individual escaped from the trap, the swimming crabs with carapace width less than 70mm all escaped from the trap. Carapace width at which 50 % of individuals were kept in the trap ($CW_{50\%}$) when using a 50 x 50 mm square escape vent, a = -9.9785, b = 0.1127, $CW_{50\%}$ = 88.57 mm, $CW_{25\%}$ = 78.82 mm, $CW_{75\%}$ = 98.32, coefficient S_R = 19.5. By analyzing the frequency of the size of swimming crabs with carapace width greater than 110 mm, no individual escaped from the trap and there were some swimming crabs with carapace width less than 70 mm were still remained in the trap.

Based on the selective model, the economic effectiveness of the fishermen, the practical production, the thesis chooses a square escape vent with the size of 55 x 55 mm to conduct experiments at the fishing ground.

3.3.3. Experimental results at the fishing ground

3.3.3.1. Types of traps and numbers of tested traps

The study used 3 types of traps to test at the fishing ground, including fishermen's round swimming crab traps (Type I traps); fishermen's swimming crab traps using 55 x 55 mm square escape vents (Type II traps); Crab trap according to the mesh size of the trap's fishing net (2a = 50 mm) according to TCVN (Type III traps). The wholes were arranged alternately, 30 traps for each type.

3.3.3.2. Experimental results

a) Composition of fishing yields

Type I traps and type III traps caught 5 species consist of crucifix crab, blue swimming crab, mantis shrimp, threadfin breams and pike conger; type II traps caught 03 species which were crucifix crab, blue swimming crab, mantis shrimp.

b) Frequency of carapace width of tested traps:

Type I traps: The frequency of carapace width was found in 07 groups, group over 120mm accounts for 24.4 %; Group ≤ 70 mm accounts for 20.0 %; group from 71 - 80 mm accounts for 15.6 %; Group from 101 - 110 mm accounts for 13.3 %; group from 81 - 90 mm accounts for 11.1 %; Group from 111 - 120 mm accounts for 8.9 % and groups of 91 - 100 mm accounts for 6.7 %.

Type II traps: The frequency of carapace width of swimming crabs was found in 06 groups, groups > 120 mm accounts for 24.3 %; group from 91 - 100 mm accounts for 21.6 %; Group from 101 - 110mm accounts for 18.9 %; group from 111 - 120 mm and group 81 - 90 mm, each group accounts for 13.5 % and the group from 71 - 80 mm accounts for 8.1 %; there were swimming crabs with carapace width ≤ 70 mm.

Type III traps: The frequency of carapace width was encountered in 07 groups, group > 120mm accounts for 22.9 %; group from 91 - 100mm accounts for 20.0 %; group from 81 - 90mm accounts for 17.1 %; group from 71 - 80mm accounts for 14.3 %; group from 111 - 120mm accounts for 11.4 %; group from 101 - 110mm accounts for 8.6 % and group ≤ 70 mm accounts for 5.7 %.

c) Frequency of length of other species in tested traps:

- Mantis shrimp (*Harpiosquilla Harpax*): The frequency of length in the type I traps was distributed in 04 groups, the group < 150 mm accounts for 42.2 %, the group of 160 - 170 mm accounts for 24.5 %, the group from 150 - 160mm accounts for 22.2 % and group > 170 mm accountsfor 11.1 %; Type II traps, frequency of distribution length in 04 groups, group > 170mm accounts for 46.7 %, group of 160 - 170 mm accounts for 33.3 %, group of 150 - 160 mm accounts for 13.3 % and group < 150 mm accounts for 6.7%; Type III traps, frequency of distribution length in 04 groups, group < 150 mm accounts for 36.7 %, group of 160 - 170 mm accounts for 26.7 %, group of 150 - 160 mm accounts for 23.3 % and group > 170 mm accounts for 13.3 %.

- Threadfin breams (Nemipterae): The frequency of length in type I traps was distributed in 04 groups, group < 150 mm accounts for 44.4 %, group > 170 mm accounts for 27.4 %, group from 150 - 160 mm accounts for 16.7 % and group of 160 - 170 mm accounts for 11.1 %; Type II traps could not catch any individual; In type III traps, the frequency of distribution length in 04 groups, group of 150 - 160 mm accounts for 40.0 %, each remaining group accounts for 20.0 %.

- Pike conger (Muraenesocidae): The frequency of length in the type I trap was distributed in 04 groups, group of 400 - 500 mm and group of 500 - 600 mm, each group accounts for 36.4 %, group < 400 mm accounts for 18.1 % and group > 600 mm accounts for 9.1 %; type II traps could not catch any individual; In type III traps, the frequency of distribution length in 02 groups, group of 500 - 600 mm accounts for 60.0 %, group of 400 - 500 mm accounts for 40.0%.

d) Size of species (sub-legal and legal size):

The highest rate of the crucifix crabs in the type II traps took up 77.1 %, higher than the type III traps (accounting for 58.1 %) 1.33 times and type I traps (taking up 50.0 %) 1.54 times; 100 % of the blue swimming crabs ratio all reached the catching size; The ratio of the legal size mantis shrimp reached the highest catching size in the type II traps accounting for 86.7 %, higher than the type III traps (accounting for 56.7 %) 1.5 times and type I (accounting for 51.1 %) 1.7 times; The ratio of the threadfin breams reached the highest catching size in the type III traps taking up 60.0 %, higher than the type I traps (accounting for 38.9 %) 1.54 times, the type II traps did not catch any individuals. In addition, the percentage of other species in type II traps reached higher catching sizes than type III and type I traps.

3.3.3.3. Estimation of initial losses of crab yields and economic efficiency

a) Estimation of initial losses of swimming crab yield:

- Estimating initial losses of swimming crab yield: losses of swimming crab yield in type II traps and type III traps were higher than type I traps, taking up 10.0 % and 10.7 % respectively.

- Estimating losses for other species: mantis shrimp, threadfin breams, pike congers, groupers, etc., were sub-products or unwanted products. Through experimental researches, the loss of unwanted product yields of type II traps was 84.1 %, type III traps was 43.5 % compared to type I traps.

b) Estimation of initial loss of economic efficiency:

Type II trap: After calculation, the loss of turnover of swimming crabs was about 1.13 %. The loss of other species (mantis shrimp, fish) was quite large, so the general revenue loss of type II traps compared to type I traps was about 15.5 %.

Type III trap: After calculation, the loss of swimming crab revenue was about 11.1 % and the loss of other species (mantis shrimp, fish) from 28.7 - 72.2 %, so the overall revenue loss of the type III traps compared to type I traps was about 7.6 %.

3.3.4. Adjustment and completeness of escape vents aim at increasing the selectivity for the round crab trap in Hai Phong

3.3.4.1. Completeness of dimension for the escape vents

The test of the square escape vents showed the satisfactory results, however, when some criteria were considered such as the relationship between the length (CL) and the height (CH) in mature crabs and the size of the escape vents as well as the economic efficiency for fishermen, it is decided to choose a height of 45 mm (which was the larger height of the crabs to ensure that the crabs can get out without being entangled and 1.5$^{\lozenge}$ to facilitate to make vents). Thus, the project conducted a test of the vents of 45 x 55 mm (sign: type IV traps) for the second trip.

3.3.4.2. Results of vent completeness test

a) Composition of fishing yields:

Results from the second test showed that type I and type III traps mainly caught the species such as crucifix crabs, blue swimming crabs, mantis, threadfin breams, pike conger and grouper; type IV traps caught 03 species, including crucifix crabs, blue swimming crabs, mantis shrimp.

b) Frequency of carapace width in experimental traps:

1) The frequency of the carapace width caught by type I traps distributing in 07 groups, mainly concentrated in the group which was smaller size than the first reproductive crabs (accounting for about 46.8 %). It showed that the selectivity of this type had some limitations.

2) Carapace width frequency was found in the type IV traps distributing in 06 groups, mainly concentrated in the group which was bigger size than the first spawning crabs (accounting for 80.4 %). It showed that the selectivity of this trap model was rather good.

3) The frequency of carapace width is encountered in the type III traps concentrated in 07 groups, focusing mainly on group which was bigger than the first spawning crabs (accounting for 60.1 %). It showed the selectivity of this trap model is quite good.

c) Length frequency in experimental traps:

- Mantis shrimp (Harpiosquilla Harpax): The frequency of length caught in type I trap was distributed in 04 groups, which was concentrated in the length of 150 mm, accounting for 28.9 %; the frequency of distribution length of type IV was in 02 groups, which concentrated in the group of more than 170 mm accounting for 66.7 %; For type III traps, the frequency of length was divided into 03 groups, which was concentrated in the length group longer than 170 mm, accounts for 41.7 %.

- Threadfin breams (Nemipterae): The frequency of length caught in the type I trap was distributed in 04 groups, of which the most concentrated in groups longer than 170 mm, accounts for 41.7 %; Type IV and type III traps did not catch any individuals.

- Pike conger Muraenesocidae (Muraenesocidae): The length frequency caught in type I traps was distributed in 03 groups, of which the length of 400 - 500 mm accounts for 50.0 %; Type IV traps did not catch any individual; Type III traps caught 02 individuals belonging to the group of 500 - 600 mm.

- Grouper fish (Epinehelus spp): The frequency of length caught in the type I trap was distributed in 03 groups, which was concentrated in groups 220 mm accounting for 50.0 %; Type IV traps captured 01 individual belonging to the group of 210 - 220 mm; Length frequency of type III has 03 groups of length: shorter than 190 mm, 200 - 210 mm and longer than 220 mm.

d) Sizes of species: sub-legal and legal size:

The highest rate of legal size crucifix crabs in the type IV traps (accounting for 78.6 %) was 1.42 times higher than the type III traps (accounting for 55.3 %) and 1.63 times higher than type I traps (accounting for 48.2 %); The ratio of blue swimming crabs in the type III and type IV traps was 100 % which reached the size of exploitation; in the type I trap, 83.3 % reached the standard catching size; The legal size mantis shrimp ratio reached the highest catching size in type IV traps accounting for 100%, higher than the type III traps (accounting for 83.3%) 1.2 times and type I trap (accounting for 52.6%) 1,9 times; The percentage of threadfin breams reached the size of the type I traps accounts for 66.7 %, the type III and type IV traps did not have any individual fishes in the trap; The highest ratio of individual reached the catching size in type IV traps accounting for 100 %, higher than the type III traps (accounting for 75.0 %) 1.3 times and type I traps (accounting for 66.7 %) 1,5 times.

3.3.4.3. Estimation the initial loss in yield and economic efficiency of the experimental trap samples

a) The estimated initial loss in yield:

- The estimated initial loss in yield of crab: The loss in crab yield of the escape vents with 45 x 55 mm outlet (Type IV traps) and TCVN trap (Type III traps) compared with the traditional trap of fishermen was 15,18 % and 26,72 % respectively.

- The estimated initial loss in yield of other species: Compared with the traditional traps of fishermen (Type I traps), the initial yield loss of other species of the trap samples with escape vents (Type IV traps) was 74,5 % and the trap trap according to TCVN (Type III traps) was 38,3 %.

b) The estimated initial loss in economic efficiency:

Type IV trap: The turnover loss of crab was about 5,4 %; however, the other species such as mantis shrimp and fishes were quite big. Therefore, the overall turnover loss of the trap sample with escape vents (Type IV trap) was 16,5 % compared to the traditional trap trap.

Type III trap: The turnover loss of crab was about 24,6 %, the turnover loss of other species was quite large, therefore, the overall turnover loss of Type III trap compared with Type I trap was 26,9 %.

3.4. Proposal solutions to escape juvenile swimming crabs for the round crab trap in Hai Phong city

3.4.1. Scientific basis for proposal solutions

- Based on the legal basis and the situation of the round crab trap in Hai Phong: Regulations on the mesh size for traps in general and the round crab trap in general are exploited in the inshore and offshore regions which have been specified in Section 2, Appendix II of Circular No. 01/2022/TT-BNNPTNT [3] and at TCVN 10466:2021 [1] on determining mesh size for round crab traps

- Scientific basis to propose solutions:

+ Regarding to the size of the crabs allowed to be exploited: Previously, Circular No. 62/2008/TT-BNN [2] stipulated that the size of the crabs allowed to be exploited was CW = 100mm. Currently, there is no prohibited the crab size. However, according to the regulations of countries in the world and proposal of scientists for the exploited crab size, it must be greater than or equal to the size of crabs in the first reproductive stage (CW_{m50}). According to research by Vu Viet Ha [29] and Gyanaranjan Dash [39] size of the first breeding (CW_{m50}) of blue swimming crabs was 99.28 mm and crucifix crabs was 87.3 mm. Thus, to protect the resources of the crabs, the allowed size for exploiting must be greater than or equal to size of the first reproductive crab.

+ The criteria for selecting a model of trap to free juvenile crabs for the round crab trap in Hai Phong city were determined.

1) Criteria for the selectivity in yield and number of individuals: By marking the selectivity, the trap with escape vents (Type IV traps) and traps according to TVCN (Type III traps) were better than the traditional trap of fishermen.

2) Criteria for the initial loss of yield and turnover from experimental traps: After calculating the selectivity score, it showed that the trap samples with escape vents (Type IV trap) and traps according to TCVN (Type III traps) had higher initial loss in yield and turnover than that of the traditional traps of fishermen.

Thus, the trap samples with escape vents (Type IV traps) had the highest total score; followed by the traps according to TCVN (Type III traps); and the lowest score is the trap currently used by fishermen.

3.4.2. Proposal solutions

- Solutions' objectives: Proposing a suitable trap model to rescue juvenile in order to protect crab resources and develop sustainably the round swimming crab trap trap industry in Hai Phong city.

- Contents of solution: In order to ensure that juvenile crabs can easily escape from the round crab trap that Hai Phong fishermen are using, it is necessary to install escape vents and parameters with the position as follow:

1) Position: On each trap, there will be 03 escape vents at the bottom corner of the side net.

2) Escape vents' dimension: width of 55mm, height of 40mm

- Solution implementation:

+ Propagandizing widely in the fishermen community about the purposes, meaning, long-term benefits and necessity of installing escape vents. Then, helping them to grasp information, understanding and consensus in the fishermen community.

+ Building a pilot fishing model and installing of escape vents for the round crab traps in Hai Phong before expanding to the community.

+ Developing the relevant legal documents to guide, inspect, monitor and implement the application of the round crab traps in Hai Phong.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

1) Assessment of the status of the round swimming crab trap traps in Hai phong city: There are 59 fishing boats with the round swimming crab trap traps; the average number of trap is from 320 to 1060 traps /boat; the mesh sizes of traps are in violation of the regulations; fishing productivity is from 46.2 to 80.5 kg/day; the operating coefficient is from 0.41 to 0.49; total catch is 272,695.9 kg/year; the average profit is from 205.8 to 313.1 million

VND/boat/year and the average income of employees is from 45.7 to 52.2 million VND/person/year.

2) The research results have determined that the average swimming crab yield composition accounts for 76.7 % of the total catch. The number of swimming crabs that did not reach the standard size accounts for 54.9 % of the total number of caught crabs. In which, in the northeast monsoon season, the percentage of crabs that did not reach the standard size based on the number of individuals with 52.6 % and based on weight with 53.0 %; In the southwest monsoon season, the percentage of crabs that did not reach the standard size based on the number of individuals with 57.2 % and based on weight with 57.7 %.

3) The solutions to escape juvenile crabs for the fixed round crab trap have been proposed in Hai Phong city by installing 03 escape vents with the dimensions of height x width: 45 x 55 mm at the bottom corner of the side net or using the fishing net with the mesh size 2a = 50 mm installed in the form of a square.

2. Recommendations

- Propagating the legal regulations on exploitation and protection of marine resources to fishermen.
- Developing further research to determine the selectivity according to the objects and the mesh sizes that are suitable for the round swimming crab trap trap.
- Shifting the structure of ships and activity, shifting the invasive fishing activity into more efficient and friendly fishing activity which new scientific and technological achievements are applied.
- It is necessary to develop policies to encourage fishermen to apply 45 x 55 mm escape vents for crab traps to protect and regenerate marine resources.
- It is necessary to pilot the escape vent model with the size 45 x 55 mm for the round crab traps before expanding to the whole country.

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