RESEARCH ON THE FITNESS BETWEEN THE MESH SIZE AND THE LENGTH OF THREADFIN BREAM (*Nemipterus sp.*) IN STOW NET FISHERY

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ABSTRACT

The study has used 4 different mesh sizes and mesh shapes in codends, catching 40 trial hauls in Nai lagoon to collect data. The fishing process has collected 2,041 individual threadfin bream (Nemipterus sp.) for analysis of fish weight and length, and using Wileman's method of assessing the selective ability to determine selective parameters for threadfin bream.

The research results show that the fish length with the probability of 50% retained in the codends (L50) of the samples M1, M2, M3 and M4 is respectively 5.02cm, 6.40cm, 6.49cm and 7.80cm. The selection factor (SF) of the diamond mesh is 3.56 and the square mesh is 7.21. The appropriate the mesh size for fishing with L_{50} is 21mm for both diamnond mesh and square mesh.

Key words: Nemipterus sp., stow net fishery, mesh size, fishing gear selectivity.

I. INTRODUCTION

For the stow net activity in Nai lagoon, Ninh Thuan province, the economic value and the yield of Nemipterus sp. are high. Among 14 common species, nemepterus account for 10.5% of the total exploited species. However, the yield of this species tends to decline sharply, from 24.8 tons (in 2012) to 14.0 tons (in 2016), the average decreased by 8.7% per year [4,5].

The stow net activitiy in Nai lagoon is not large, the number of households participating in this activity are small [6]. However, the stow net is fixed at Tri Thuy bridge area - is the circulation gate from Nai lagoon to Phan Rang bay, the mesh size at the codend is small, 2a = 12mm, the mesh size is diamond and made by nylon, therefore, under the effect of flow, meshes are deformed and closed, which reduces the the escape ability of the small fish [6]. Therefore, the stow net can catch all species flowing the water into the mouth of the stow net, including little shrimps and fish, immature shrimps and fish.

The main reason leading to the output decline is that the immature fish are over-exploited; the size of the exploited fish cannot be controlled; the mesh size in the fish trap has not been managed and the need to use small fish to feed the species in the rafts and cages in the area has increased, which makes fishermen over-exploit [4]. Therefore, the reality of the caught young fish tends to increase, which reduces the reserve of the aquatic resources in general and the quantity of nemipterus in particular.

Therefore, the research and selection of the mesh size which are suitable for the exploited fish size limit the little fish kept in the codend, which contributes to protecting and developing nemipterus resources in particular and the aquatic resources in Nai lagoon in general.

II. MATERIALS AND RESEARCH METHODS

1. Theoretical basis and selection of research models

1.1. Selective theoretical basis in fishing

Fishing is a selection process, only the species that have enough size can be exploited and the species with small sizes are removed. This is an important theoretical basis to determine the mesh size which are suitable for the size of the fish in which the mature fish can participate in reproduction to supplement resources.

In order to limit the little fish are caught, scientists studied and evaluated in many aspects and stages of the exploitation

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process and they base on six factors such as: mechanics, geometry, biology, mechanics - biology, physics - biology and the combination of the above elements together [16]. In fact, it is not always possible to separate the selection by specific factors, but they are closely related. Accordingly, selection by mechanical factors is the most important, mainly based on the selective characteristics of the fishing gear structure, size and the mesh type [13].

The principle of selection by mechanical factors for each type of gear is shown by adjusting the size and type of mesh. At that time, the selective ability depends on the yield, size, types of fish in the output; the transformation of the mesh during the operation under the effect of flow and yield in the codend; roughness and the mesh stretch, movement speed of fishing gear or flow, fish shape etc. [3,7,11]. When assessing the selectivity of fishing gears with the certain mesh sizes and shapes for an aquatic species with the assumption of the external factors don't affect the escape ability of fish from the fishing gears [13].

The process accessing the selectivity in the fishing process is expressed through the selective curve and the probability of the exploited species according to different sizes in the yield [3,7]. The selective curve is expressed as the logarithmic equation (1) [17].

$$r(L) = \frac{\exp(a+bxL)}{1 + \exp(a+bxL)} \qquad (1)$$

In which, L is the classification of the length of the study object (cm); a and b: Constants which are determined through the experimental data and r(L) is selective ratio.

The selective ratio r(L) is the ratio of the number of fish and the length L retained in the condend, calculated by formula (2) [15,17].

$$r(L) = \frac{N_{cod}}{(N_{cod} + N_{cov})} \qquad (2)$$

In particular, N_{cod}: the total number of fish kept in the codend and N_{cov}: the total number of fish escaping from the condend but being retained in the external codend.

From the equation (1) the algorithm is done, we will have an equation (3).

$$a+bxL = \ln\left(\frac{r(L)}{1 - r(L)}\right) \qquad (3)$$

The equation (3) is a linear with a, b are intercept and slope. The number of fish kept in the codend will increase when the length of the fish increases, therefore b will be greater than 0 and the percentage of fish are kept in the codend when the length L = 0 is 0% [11,15,17].

Fish with the length (L) being stuck into the codend will have a certain probability of being retained in the codend, having a value of 0 (probability of holding 0%) to 1 (probability of holding 100%). This probability is calculated by observing the number of retained fish and the number of fish having the same length escaping from the net. The correlation between fish length (L) and r(L) is shown in the form of logarithms or logarithms curve (1) [17]. The two important parameters of the selective process are L_{50} (length of the fish with a probability of 50% is retained) and the selective interval (SR), which is the difference between L_{75} (fish length with a probability of 75% is retained) and L_{25} (fish length with a probability of 25% is retained). Thus, the selective curve is distributed around the value L_{50} and the L_{75}-L_{50} = L_{50}-L_{25}. The relationship between L50 and used mesh size is called the selective factor (SF) [11,15,17].

Thus, in order to select mesh sizes of the codend which are suitable for size of fish, the research team experimented the codend with the diamond mesh and the filter with the square mesh installed on the codend (with the diamond mesh).

1.2. Select a calculation model

The stow net belongs to fixed fishing gear group, water leads fish into the net with flow, then water is filtered through nets and fish are kept. Considering the correlation of movement between water and fishing gears, the operation principle of the stow net is to filter water to keep fish, fishing gears don't move and fish move.

Until now, there have been many scientists applying the selective model of the trawl net to determine the selective parameters for the stow net [8-10,12,14,18]. Thus, in order to evaluate the selectivity of the stow net, the research team used the calculation method guided by Wileman [17] as the equation (1).

2. Research materials

2.1. Test instruments

4 stow nets of fishermen are simultaneously used with the same specifications. On the 4 mouths of the stow net, the codend and different filters are simultaneously installed in order to collect the data.

- The codend with the diamond mesh, there are 2 samples: M1 sample has 2a = 12mm – the bar size that fishermen are using and M2 sample has 2a = 18mm - according to state regulations.

- The square mesh filter, there are 2 samples, M3 sample has a = 9mm (the mesh size is the same as M2 but the mesh shape is different) and M4 sample has a = 11mm. The dimensions of M3 and M4 filters are shown in the figure 1.

The codends are fitted with the cover nets to capture the species escaping from the internal codend (M1, M2, M3 and M4), shown in Figure 2.

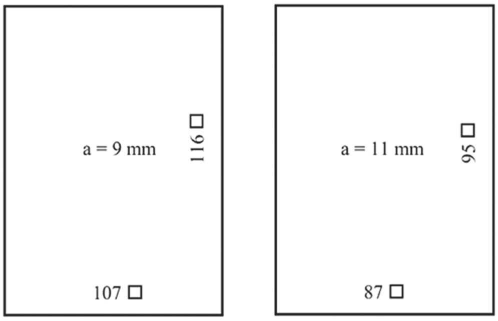
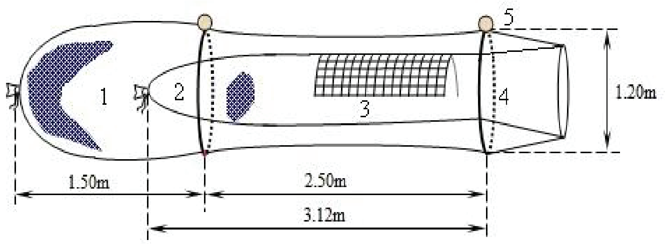


Figure 1. Square mesh filter



1. Cover codend, 2. Codend, 3. Filter, 4. Wooden ring, 5. Buoys

Figure 2. Assembling the codend, cover codend and filter

2.2. Boats for research

Fishing boats of fishermen are used to operate the stow net activity in Nai lagoon, the registration number: NT00360TS; the main machine capacity 15CV; the length of 8.50m and the width of 2.55m.

3. Test layout method and data collection

3.1. Test layout

- Test site: Fishing gears are fixed at the area near Tri Thuy bridge, Nai lagoon, Ninh Thuan province from 4/8/2016 to 20/8/2016.

- The nets are done at the same time, in the same fishing ground, same fishermen and same boats to limit the externalities affecting the test results.

- The test process carried out 40 hauls, 10 hauls for each stow net and 2,041 individuals of the Nemipterus sp. were colected.

3.2. Test data collection

- The exploitated products are separated by the internal and the external codend, then they are washed and weighed the total output of each net.

- Nemipterus are separated from other exploited species and collect 100% of the output to determine the size and the volume of each.

+ The size of fish is measured from the mouth to the caudal fin with the table ruler and rounded to the nearest 0.5cm, according to Sparre guidelines [15] and MARD [1,2].

+ The weight is determined by Ohaus electronic scale, error of 0.001g.

4. Calculation method

4.1. Determine the selective length

- The selective length of fish with a probability of 25% (L_{25}), 50% (L_{50}), and 75% (L_{75}) of fish retained in the codend is calculated according to the formular (4), (5) and (6) as follows:

$$L_{25} = \frac{\text{Ln}(1/3)\text{-a}}{\text{b}} \quad (4)$$

$$L_{50} = -\frac{a}{b} \quad (5)$$

$$L_{75} = \frac{\ln(3)\text{-a}}{\text{b}} \quad (6)$$

4.2. Determine the selective interval

The selective coefficient (SR) is determined by the formular (7) as follows:

$$SR = L_{75} – L_{25} \quad (7)$$

4.3. Determine the selection factor

The selection factor (SF) is determined by the formular (8) as follows:

$$SF = \frac{L_{50}}{KTML} \quad (8)$$

In particular, KTML is the mesh size at the fish trap.

4.4. Determine the mesh size

If there is an SF factor, the mesh size of the filter or the fish trap will be determined. There is 50% of minimum length (L) can be allowed to catch, as the following formular (9).

$$KTML = \frac{L_{50}}{SF} \quad (9)$$

III. RESEARCH RESULTS AND DISCUSSIONS

1. The ability to escape small fish of the samples

The statistical results of the yield and the escape rate of the little fish in the 40 test samples are shown in table 1.

Table 1. The output of nemipterus escaping by each sample

Survey index	M1		M2		M3		M4	
	Cod	Cov	Cod	Cov	Cod	Cov	Cod	Cov
The yield in each codend (kg)	2.18	0.25	1.82	0.48	2.13	0.52	1.79	1.09
The yield rate in each codend (%)	89.71	10.29	79.48	20.52	80.38	19.62	62.15	37.85
The total yield (kg)	2.43		2.30		2.65		2.88	

From the table 1 shows that the higher the output of escape fish is, the larger the mesh size is. The highest escape fish rate is M4 sample of 37.85%; followed by the M2 sample of 20.52%; M3 sample of 19.62% and M1 sample of 10.29%.

Thus, when using M2, M3 and M4 samples, there are 10.24%; 9.33% and 27.56% respectively of the small fish escape from the M1 sample.

The number of fish and the escape small fish rate of 40 test samples in each sample are shown in table 2.

Table 2. Number of nemipterus escaping from the samples

Survey index	M1		M2		M3		M4	
	Cod	Cov	Cod	Cov	Cod	Cov	Cod	Cov
The number of fish in each codend (fish)	377	128	276	196	296	197	248	323
The rate of fish in each codend (%)	74.65	25.35	58.47	41.53	59.88	40.12	43.43	56.57
The total of fish (fish)	505		472		493		571	

The table 2 shows that many fish can escape if the mesh size is large. The highest escape rate is M4 sample, with 56.57%; followed by the M2 sample with 41.53%; M3 sample with 40.12% and the lowest M1 with 25.35% of the quanties of fish.

Thus, when M1 codend is replaced by M2, M3 and M4 codend, we can protect 16.18%; 14.77% and 31.22% of the number of fish with smaller than the permitted length of exploitation.

When the same bar size is used but the mesh shape is different, the output rate and the number of the qescape fish are negligible. The percentage of small fish escaping from the codend M2 is 1.05 times higher than M3 in terms of the yield (Table 1) and 1.03 times higher in terms of the number of fish (Table 2). This shows the compatibility between the mesh shape during the process of working with the cross-section of the fish body, Nemipterus with oval shape are easy to escape from the diamond-shaped mesh. The test results shows that the mesh size plays a more important role than the mesh shape because small fish can escape from the gears depending on the mesh size. However, the square meshes are less likely to be deformed during operation under the effect of the flow and the output, so the selectivity will be more stable than that of diamond.

2. Distribution of length of nemipterus

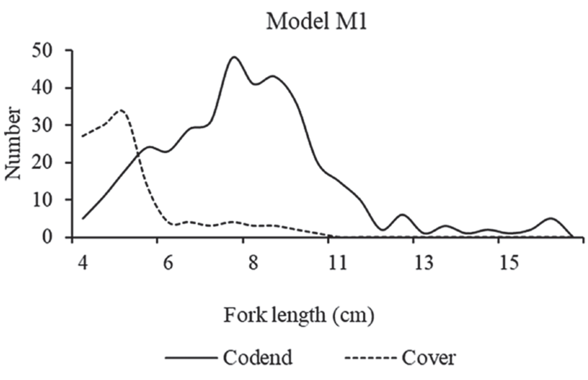
The number of nemipterus according to classification of length in the internal codend and the external codend in the test process are shown in the table 3.

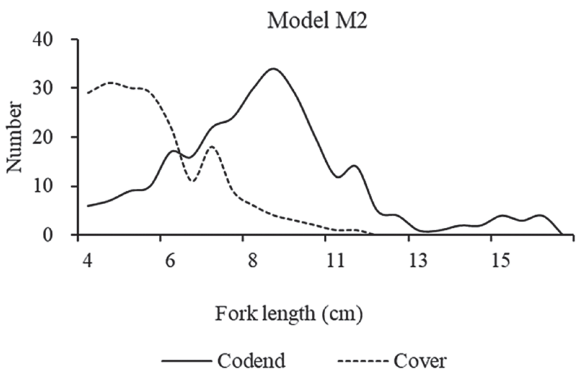
Table 3. The number of nemipterus according to classification of length in the samples

L (cm)	M1		M2		M3		M4	
	Cod (fish)	Cov (fish)	Cod (fish)	Cov (fish)	Cod (fish)	Cov (fish)	Cod (fish)	Cov (fish)
4.0	5	27	6	29	8	30	5	31
4.5	11	30	7	31	9	28	6	30
5.0	18	33	9	30	6	28	7	24
5.5	24	14	10	29	10	24	8	24
6.0	23	4	17	22	11	19	7	35
6.5	29	4	16	11	12	15	13	40
7.0	31	3	22	18	22	17	12	38
7.5	48	4	24	9	26	18	16	39
8.0	41	3	30	6	30	5	23	24
8.5	43	3	34	4	33	4	19	15
9.5	36	2	29	3	31	3	30	12
10.0	20	1	20	2	27	3	23	3
10.5	15	0	12	1	23	2	24	4
11.0	10	0	14	1	12	1	20	2
11.5	2	0	5	0	5	0	13	1
12.0	6	0	4	0	5	0	8	1
12.5	1	0	1	0	1	0	3	0
13.0	3	0	1	0	3	0	2	0
13.5	1	0	2	0	3	0	2	0
14.0	2	0	2	0	1	0	2	0
14.5	1	0	4	0	4	0	2	0
15.0	2	0	3	0	3	0	1	0
16.0	5	0	4	0	9	0	2	0
16.5	0	0	0	0	2	0	0	0
	377	128	276	196	296	197	248	323

The number of fish (table 3) show that the length of exploited nemipterus in the samples is from 4.0 ÷ 16.5cm. In particular, nemipterus have a common length of about 4.0÷11.0cm (accounting for 94%); Nemipterus reaching the permitted size (15cm) is very small, 31/2,041 individuals, accounting for 1.5% of the caught fish. Thus, the percentage of nemipiterus having the permitted size to exploit in the experimental net is very low. This represents that the fishermen have overexploited, which greatly affects the fertility and supplements resources.

The distribution of length and the number





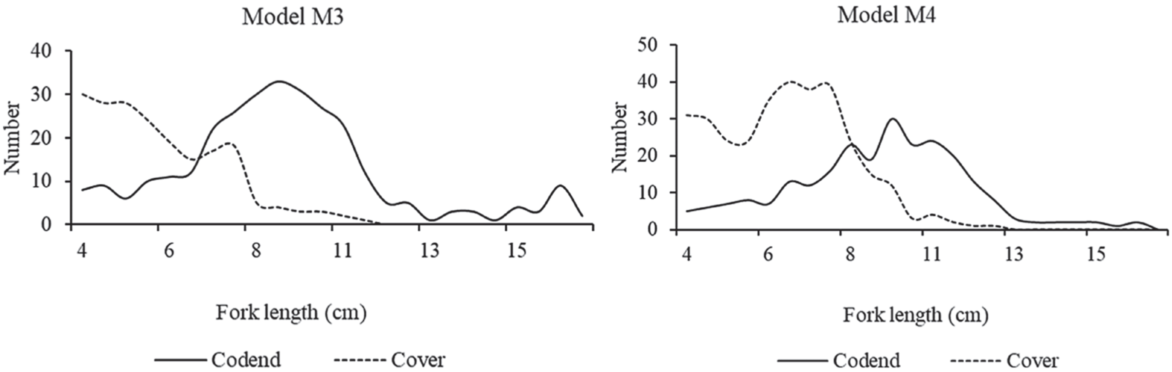


Figure 3. Distribution of length and the number of nemipterus in the samples

of nemipterus in the internal codend and the external codend are shown in Figure 3.

From the figure 3 shows that:

- All 4 samples M1, M2, M3 and M4 are capable of keeping fish with a length of 4.0cm or more in the internal codend.

- The bigger the mesh size is, the smaller the percentage of small fish kept in the internal codend is low. In which, the largest length of fish that can escape out of the codends M1, M2, M3 and M4 is 10.0cm, 11.5cm and 12.0cm respectively. For the sample M4, the largest length that fish can escape is similar (11.5cm).

Thus, when the bar size is increased, fish can easily escape and the small fish can be removed from the gear, which protects the little fish.

3. Selection parameters of nemipterus

3.1. Selective length and selective range (SR)

From the test caught data (table 3), the constants a, b and coefficient R^2 are determined, as a basis for determining the parameters L_{25}, L_{50}, L_{75} and SR. The results are shown in the table 4.

Table 4. Selective parameters of the stow nets in exploiting nemipterus

Samples	Constant (a)	Constant (b)	R^2	L_{25}	L_{50}	L_{75}	SR
M1	- 3.91891	0.78030	0.8241	3.61	5.02	6.43	2.82
M2	- 4.35574	0.68011	0.9496	4.79	6.40	8.02	3.23
M3	- 4.28611	0.66039	0.9259	4.83	6.49	8.15	3.33
M4	-4.65076	0.59651	0.9216	5.95	7.80	9.64	3.68

From the table 4:

- The coefficient R^2 shows the correlation between the length (L) and r(L), in which samples M2, M3 and M4 have the $R^2 > 0.9$, which shows that the relationship between the coefficients is very tight. Therefore, the proportion of the retained fish ensures high reliability.

- The probability of 50% of nemipterus is retained in the net (L_{50}) of the samples M1, M2, M3 and M4 is respectively 5.02cm; 6.40cm; 6.49cm and 7.80cm. This shows that the bigger the mesh size is, the greater the length of the fish kept in the net is, the small fish escapes a lot, the selectivity is high and the resources are well protected.

- The selective range (SR) is obtained from the test process is relatively small.

+ The sample M1 has the smallest selectivity with 2.82cm; the sample M4 has the largest selectivity with 3.68cm; samples M2 and M3 range from 3.23cm to 3.33cm.

+ The smaller the SR is, the better the efficiency of exploitation and the protection of the resources are, however, if the SR is large, the number of fish whose length is greater than L_{50} is able to escape much from the net, causing loss of production for fishermen and the number of fish whose length is smaller than L_{50} are retained in the codend will reduce the efficiency of resource protection.

3.2. Selection factor (SF)

In the four test samples, M1 sample was used to collect the control data to compare with the caught results of M2, M3 and M4 samples. Therefore, the team only determined the SF of the design samples having the same bar size (M2 and M3) as a basis for selecting the mesh type and size. The results of the selectivity of samples M2 and M3 are shown in the table 5.

The table 5 shows that:

Table 5: Selective factor (SF) of the test samples

Mesh type	The bar size (mm)	SF
Diamond mesh	9	3.56
Square mesh	9	7.21

+ SF of Nemipterus is determined for each type of mesh, the diamond mesh is 3.56 and the square mesh is 7.21.

+ SF depends on the type of mesh. The square mesh has SF larger than the diamond one.

Besides the mesh size, the escape ability of Nemipterus is also dependent on the opportunity to meet the mesh at which they can escape. When fish are caught in the net, they often tend to swim to the back of the codend to find the exit, where the mesh has an openness and better stability in the codend.

3.3. Selective curves

After the constants a and b are determined (table 4), these values are replaced in the equation (1) [17], the selective curve equations will be set corresponding to samples M1, M2, M3 and M4 of Nemipterus as follows:

Model M1 $$r(L)=\frac{\exp(0.7803\times L-3.91891)}{1+\exp(0.7803\times L-3.91891)}$$

Model M2 $$r(L)=\frac{\exp(0.68011\times L-4.35574)}{1+\exp(0.68011\times L-4.35574)}$$

Model M3 $$r(L)=\frac{\exp(0.66039\times L-4.28611)}{1+\exp(0.66039\times L-4.28611)}$$

Model M4 $$r(L)=\frac{\exp(0.59651\times L-4.65076)}{1+\exp(0.59651\times L-4.65076)}$$

From the above equations, we have the values of the selective curves according to the samples M1, M2, M3, M4 of Nemipterus, then the selective graph is shown in figure 4.

The figure shows that:

- Under the same test conditions in terms of the flow speed, the operating time and the fishing gears, the selectivity is considered not to be affected by the external factors. Therefore, the selectivity of nemipterus depends entirely

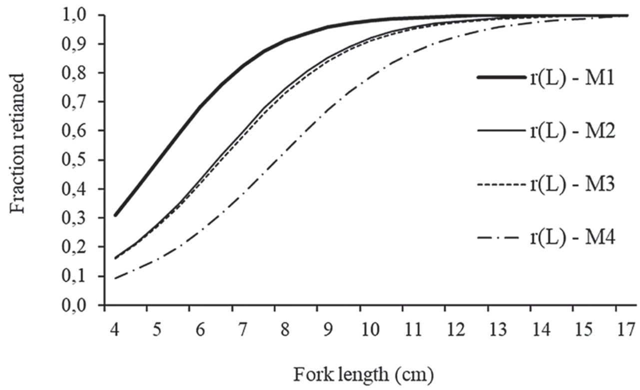


Figure 4. Nemipterus selective curve of the samples

on the size and type of mesh.

- The larger the mesh size is, the biased to the right of the graph the L50 on the curve is (the length at which there are 50% of fish are retained) that means the length of the exploited fish in the codend is larger or vice versa. At that time, the small-sized fish can escape from the codend.

- The selectivity of the samples which the fishermen are using is low. Nemipterus with L_{50} is only 5.02cm, equivalent 1/3 of the minimum size which are allowed to exploit (L≥150mm).

Thus, in this test, when the bar size is similar, the selectivity is not significantly different between the square mesh and the diamond one.

4. The mesh size is suitable for nemipterus

The selection factor (Table 5) obtained from the test process. It is different in different mesh types, so the calculation of the mesh size at the fish keeping section is calculated separately for each mesh type. The research team used the length of nemipterus that is allowed to exploit in accordance with the government's regulations 150mm [1].

The bar size corresponds to the probability of 50% of fish with the L = 150mm that can escape out:

The diamond mesh:

$$\text{KTML} = \frac{L_{50}}{\text{SF}} = \frac{150}{2 \text{ x } 3.56} = 21.07\text{mm}$$

The square mesh:

$$\text{KTML} = \frac{L_{50}}{\text{SF}} = \frac{150}{7\ 21} = 20.80\text{mm}$$

The calculation results show that the dimond bar size and the square one are similar. However, the stability of the square mesh size is higher than the diamond one, the selectivity will be more stable.

Thus, in order to exploit the nemipterus resources in Nai lagoon sustainably, it is necessary to specify the bar size at the codend of 21mm for the diamond mesh and 21mm for the square mesh.

From the calculation results, the research team conducted 40 test samples, 2 filters are installed on the back of the stow net.

In particular, one net used the diamond mesh with the bar size of 21mm (T21) and another used the square mesh with the bar size of 21mm (V21). The test results shows that the sample T21 had 51.06% of the quantity of nemipterus with the length of 150mm was retained in the codend and 48.94% of the quantity of nemipterus escaped and were retained in the cover codend. In the sample V21, 53.49% of fish were retained in the codend and 46.51% were retained in the cover codend. This shows that the calculation and selection of mesh sizes are not significantly different from the theory.

Thus, the research results can be applied to the production practices to protect and develop the aquatic resources. Besides, it can be used as a scientific basis to define the mesh size for each species or a group of exploited species.

IV. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

- The size of nemipterus caught by the stow net in Nai lagoon is small, ranging from 4.0cm to 16.5cm. In particular, 98.5% of the caught fish are not big enough according to the regulation.

- The larger the bar size in the codend and the filter is, the greater the length of escape fish is, the M1 sample is 10.0cm; M2 sample and M3 sample are 11.5cm and M4 sample is 12.0cm.

- The study has identified the selective parameters of the stow net (selective length, selective interval, selection factor and selective curve). Besides, the bar size in the codend that is suitable for nemipterus is 21mm for the diamond mesh and 21mm for square mesh.

2. Recommendations

- Fishermen and local authorities should increase the mesh size in the codend in order to rationally exploit and protect nemipterus resources.

- Besides improving the selectivity of fishing gears, the size of exploited species should be controlled well.

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