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Mesh size selectivity of surface and mid-water gillnet for catching freshwater sardines "*Sardinella tawilis*" (Herre, 1927) in Taal Lake, Philippines

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ABSTRACT

Technical information on the mesh size selectivity for *tawilis* fishery in Taal Lake is presently unknown or undocumented and different mesh sizes of gillnets are employed to exploit the species at various sizes. The study investigated the mesh size selectivity involving gillnet fishery for *Sardinella tawilis* using four different mesh sizes: 3.39 cm (10k), 3.05 cm (11k), 2.77 cm (12k), and 2.65 cm (12.5k). Fishing trials were conducted in Taal Lake, Philippines from October 2014 to September 2015. A total of 4,456 pieces of *S. tawilis* were caught with the length ranges from 8.5 cm to 14.5 cm mid-length. The seasonal changes in the gonadosomatic index (GSI) showed that *S. tawilis* spawns between March-May and August. Length at 50% maturity (L50) was estimated at 11.66 cm and used as the criterion for selecting the appropriate mesh size. The optimal length for each mesh size was estimated employing the Baranov-Holt method. The estimated optimal lengths of *S. tawilis* were estimated at 10.6 cm, 11.08 cm, 13.07 cm, and 14.53 cm for the mesh sizes of 12.5k, 12k, 11k, and 10k, respectively. Hence, the appropriate gillnet mesh size for *S. tawilis* corresponding to length at 50% maturity was 3.05 cm (11k).

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1. INTRODUCTION

The existing open access policy of the government provided in Presidential Decree 704 allows no limit on the number of fishing units and types of gears to be used in municipal waters including lakes. Open access resources to fishermen allow for the unregulated entry of fishing practices like the use of fine-meshed nets.

Local fishery ordinance concerning mesh size regulation for *Sardinella tawilis* fishery has been adapted from the prescribed legal mesh size of 12.5k (2.65 cm) recommended by the Taal Volcano Protected Landscape (TVPL) Management Plan (Sec. 4 of PAMB-TVPL NO. 20 S. 2013), provided that it can be amended when there is an appropriate result from a research study regarding fish net size. It is important for fishery managers and researchers to find ways to improve assessment, to determine desirable exploitation level, and to recommend precautionary management guidelines for this critical species. Without the safeguard of resource monitoring and constant assessment, overexploitation may lead to the extinction of species (Dulvy et al., 2003) and species loss (Lavides et al., 2010).

S. tawilis, locally known as *tawilis*, is the only freshwater sardine belonging to the family Clupeidae in the world and is endemic to Taal Lake, Philippines (Whitehead 1985). The highest recorded production of *tawilis* was in 1984 with 29,000 MT (Bleher 1996; Hargrove 1991) trailed by 8,798 MT in 1998 (PCTT 1994) and 6,858 MT in 1992 (PCTT 1994). However, the catch of *S. tawilis* has been dwindling in the past years from 8,789 MT in 1998 to 68.9 MT in 2011 (DA-BFAR 2012). It is now reported to be heavily exploited at the rate of 62% from the optimum range of 30-50% and caught using various fishing gears such as motorized push nets (*suro*), "intense" light attractant, a very strong artificial illumination used to attract the fish at night (Castillo, 2005) and practices that make use of fine-meshed nets.

The recent study of Mutia et al. (2004) reported that tawilis is mainly caught by gill net (*pante*), beach seine (*pukot-tabi*), motorized push net (*suro*), and ring net (*kubkuban*). Among these, gillnet is the dominant gear used with 14,784 units or 92.7%

of the total number of fishing gear units (15,947 units) and beach seine with 38 units contributing for the majority of *tawilis* catch. The mesh sizes used were 12k (2.77 cm) for gillnet and 17k (1.9 cm) and 22k (1.45 cm) for beach seine. Mutia et al. (2004) suggested a need to strictly regulate mesh size for *tawilis* fishery from 12k (2.77 cm) to 11k (3.05 cm). Castillo (2005) on separate studies, however, recommended the reduction of fishing pressure to the optimal level by using 2.5 cm mesh size for gillnets and catch size limit of 10 cm length for the *tawilis*.

Although the problem of overfishing and declining production of *tawilis* has already been recognized and several approaches has been done by the local government units and other concerned government agencies to address the declining *tawilis* catch in the lake, including banning of active gears (e.g. motorized push net), declaration of reserve area for *tawilis*, restriction on the use of small-sized mesh net, and recommendation for possible closed season, still it is left uncontrolled or unregulated. To bridge this gap, an attempt is made to provide the technical information on the mesh size for *tawilis* fishery to determine the best mesh size of the net for selective catching of matured tawilis.

Various studies on gillnet selectivity and mesh size regulation for sardine fishery in other countries are conducted to protect extreme depletion of sardine stocks. In Bali Strait, the recommended minimum mesh size of gillnet to catch mature fish (Lm ≥ 17.1 cm) was 2.94 cm and size of fish landed must be higher than 17.3 cm (Setyohad et al. 2013). Studies of Chindah and Tawari (2001) in Brass River Nigeria using three (3) mesh size of gillnets (35 mm, 60 mm, and 70 mm) were used for Bonga and *Sardinella eba* fishing. The results indicated that large size classes of fish were obtained with the increase in mesh sizes of nets. High selection for larger fish sizes in the catch was favored by the bigger mesh sizes (70 mm).

The present study aimed to evaluate four (4) different mesh sizes using surface and midwater gillnets fishing gear for harvesting freshwater sardines *Sardinella tawilis*. Information gathered could be used as a management benchmark for the formulation or revision of policies involving fishery regulatory measures and strategies for ensuring sustainability.

2. MATERIALS AND METHODS

2.1. Research design

This study used an experimental fishing method of research, where the comparative effect of meshes using various sizes was investigated directed to the general condition of catch, i.e., species composition, weight and size of the catch, catch rate, and the relative abundance of target species or species concerned from other catches. Method of operations and test-fishing conditions were treated similarly at random for each independent variable, i.e., net mesh size. A length-based model assessment was primarily used as a tool to relate mesh size to fish length (total length in cm of unsexed samples) of susceptible target species. The length-frequency distribution data were used to generate population parameters and to estimate the selection curve of the different meshes. The resulting length parameters in association with the selective parameters of mesh sizes at fifty (50) percent length, i.e., the length of fish at which 50% are retained and 50% released, was used as the basis for determining the best mesh size.

2.2. Study area

The study was conducted in Taal Lake, Philippines from October 2014 to September 2015 on a monthly basis. The lake has an area of about 24,356 hectares, with a circumference of 120 kilometers and a maximum depth of 172 meters, situated inland of Batangas Province. Fishing operations were conducted around the areas of the lake, encircled by 11 coastal municipalities, namely Talisay, San Nicolas, Lipa City, Laurel, Tanauan City, Santa Teresita, Mataas na Kahoy, Balete, Cuenca, Alitagtag, and Agoncillo. Fishing positions were situated at latitude 13.9847° N and longitude 121.0158° E (Figure 1). Table 1 shows the coordinates of the 56 fishing areas covered in Taal Lake.

2.3. Experimental gear and mesh sizes

Gillnet was the test gear used in the study. It consists of a single netting wall kept vertical by a float

ACTUAL FISHING POSITIONS					
Station	Longitude (⁰)	Latitude (⁰)	Station	Longitude (⁰)	Latitude (⁰)
1	120.97875	13.93453	29	121.	13.
2	120.97875	13.94103	30	121.	13.
3	120.98000	13.93559	31	121.	13.
4	120.97686	13.93372	32	121.	13.
5	120.99953	13.93897	33	121.	13.
6	120.96828	13.94592	34	121.	13.
7	120.96942	13.94922	35	121.	13.
8	120.97111	13.93642	36	121.	13.
9	120.97081	13.95001	37	121.	13.
10	120.96703	13.94650	38	121.	13.
11	120.98900	13.93914	39	121.	13.
12	120.99011	13.93247	40	121.	13.
13	120.99553	13.92861	41	121.	14.
14	120.99725	13.90489	42	121.	14.
15	120.98364	13.92458	43	121.	14.
16	120.96803	13.97869	44		14.
17	120.96692	13.96858	45		14.
18	120.98561	13.97944	46		14.
19	120.98361	13.97922	47	121.	14.
20	120.98200	13.97961	48	121.	14.
21	120.98053	13.97819	49		14.
22	120.97950	13.97433	50	121.	14.
23	121.01828	13.97042	51		14.
24	121.02189	13.96939	52	121.	14.
25	121.02204	13.97503	53		14.
26	121.04256	13.98003	54	121.	14.
27	121.03794	13.97837	55		14.
28	121.04718	13.95375	56	121.	14.

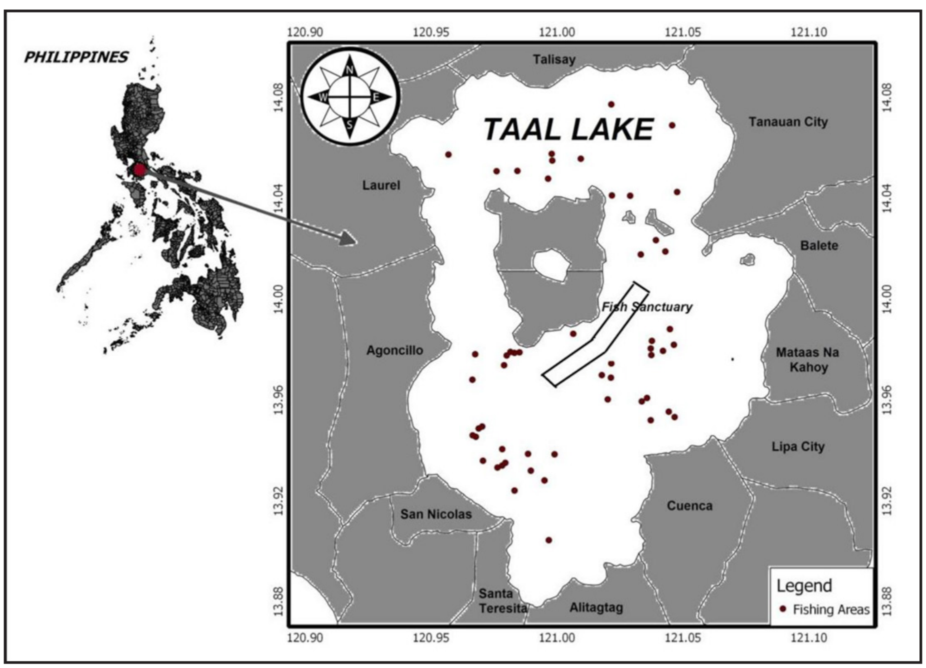


Figure 1: Map of the study area.

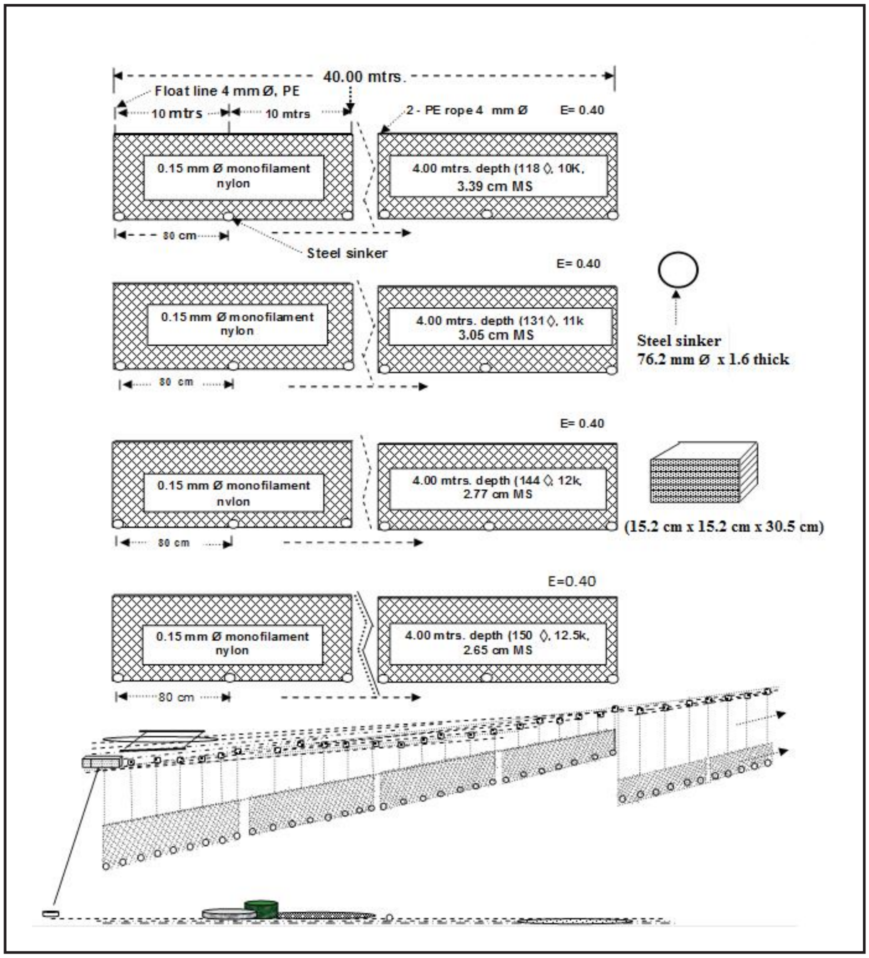


Figure 2. Structural design and gear dimension of gillnet.

line (upper line/head rope) and a weighted ground line (lower line/footrope). Fishing deployment includes near surface (depth range of 0-9 m) and mid-water operations (depth range beyond 9.1-18 m) as adopted from observed traditional practices of local gillnetters (Figure 2).

For each deployment, four (4) sets of replicate were constructed to represent the experimental net mesh sizes (MS). The nettings comprised of monofilament nylon nettings (0.15 mm Ø) with a finished length of 40 m and 4 m net depth, with corresponding mesh sizes as follows: 3.38 cm (10k), 3.05 cm (11k), 2.77 cm (12k), and 2.65 cm (12.5k). All strips of nettings had a uniform hanging rate of 40% at the head rope and no sinker line.

The sinker was circular steel ring (76.2 mm Ø x 1.6 mm thickness) and joined with the rubber hose (1.6 mm Ø). The steel sinker is inserted to the second lower mesh of the net at a distance of 80 cm. Styrofoam was used as floats with a measurement of 15.2 cm x 15.2 cm x 30.5 cm.

2.4. Fishing operations and collection of data

Full-scale test fishing operations were conducted for twelve (12) months duration for each fishing deployment with a sampling frequency of five (5) nights per month and at an average of 12 hours soaking time per night. For each operation, data and information gathered includes the date of fishing, fishing position (Latitude and Longitude) obtained from the global positioning system (GPS), and individual setting and hauling time. Other observations include the prevailing lake and weather condition at the time of operation.

Gillnet operations used an outrigger boat powered by 10-12 horsepower (HP) engine. The experiment was conducted during night time at the designated fishing grid. Four (4) mesh sizes were used, i.e., 10k; 11k; 12k; and 12.5k for test comparison. These were operated through simultaneous fishing by attaching each net strip at random sequence representing mesh size being tested with four net panels per set. The sets of netting were released instantaneously in a straight direction and go with the water current from the rear of the boat while other fisherman paddled the boat in the direction of the wind. A buoy or styrofoam is attached at either end of the net so that the fisherman can easily locate it when left during the night. After twelve (12) hours of soaking time, the fisherman retrieved the nets through manual hauling and finally detaching the fish caught from the nets by segregating the catch to corresponding mesh sizes.

Dealing with the catch included sorting, identifying, weighing, dissecting, and recording using catch data form. For small-catches, the number and weight of all species from the entire catch were measured and recorded. For large catches, sub-sampling of the catch was applied. The total length, girth, and body depth of fish were measured to the nearest centimeter (cm) while the individual weights were recorded in grams (g) to the nearest hundredths using a digital weighing scale. The mode of catching, i.e., gilled, enmeshed and entangled, was also determined.

Fish samples were dissected and gonads were examined to determine maturity stage and sex ratio. The eight-point scale classification of maturity stages of eggs by Buckman (1929) and Laevastu (1965) was modified into five (5) parts classification scale (Aypa et al. 1991), namely Stage 1 (immature), Stage II (maturing), Stage III (mature), Stage IV (gravid) and Stage V (spent). The spawning season was determined using the gonadosomatic index (GSI) method by Bal and Rao (1984). The formula is as follows:

$$GSI = \frac{\text{gonad weight}}{\text{body weight}} \times 100$$

At the end of the collection period, information taken from fishing and catch data forms were encoded, analyzed, and recorded in an excel spreadsheet. The length frequency distribution data of selected target species were also prepared and encoded separately in an excel spreadsheet and re-sorted according to size class and the resulting middle length class for length-based parameter model estimation using FiSAT II Program.

2.5. Estimation of length at 50% maturity

Length at 50% maturity (L50) was employed as the principal criterion to investigate the desirable mesh size (Amarasinghe and Pushpalatha 1997; Amarasinghe 1988). Thus, the optimum length caught by the desirable mesh size should be above L50. The logistic function between the proportions of mature to immature fish (PL) in each length class at 1 cm interval was applied to estimate L50 as shown in Equation 2 (Sparre and Venema 1998):

$$P_L = \frac{1}{1+e^{(s_1 - S_2 L)}} \times 100$$

where S_1 and S_2 are the equation coefficients. This equation was further used to estimate L50 by setting P_L at 0.5.

2.6. Estimation of gillnet selection

For gillnet of different mesh sizes, Sparre and Venema's (1998) model for various mesh sizes was used. Estimate of an overall selection factor and a common standard deviation can be obtained from the results of an analysis of each pair of successive mesh sizes as in Baranov-Holt method (Holt 1963) by relating the catches in terms of logarithmic ratios of two contiguous mesh sizes to fish length using linear regression. The regression coefficients were estimated to calculate the common selection factor (SF) as shown in Equation 3 (Sparre and Venema 1998). If the number of the slightly different mesh sizes used is n, then there will be n-1 pairs of estimations.

$$SF = \frac{-2^{*}\sum_{i=1}^{n-1}(m_i + m_{i+1})^{*}\left(\frac{a_i}{b_i}\right)}{\sum_{i=1}^{n=1}(m_i + m_{1+1})^{*}}$$

A_i and b_i are the intercept and slope, respectively, of the regression derived from two successive mesh sizes m_1 and m_1+1. The common standard deviation (SDcommon) was estimated as the mean value of the individual estimates for each consecutive pair of mesh sizes.

$$SD_{common} = \sqrt{\frac{1}{n-1} * \sum_{i=1}^{n-1} \frac{-2*a_i*(m_{i+1} - m_i)}{b_i^2 * (m_i + m_{i+1})}}$$

The optimum length for mesh size i (L_{mi}) was then estimated.

$$L_{mi} = SF * m_i$$

3. RESULTS AND DISCUSSIONS

3.1. Species selectivity and catch efficiency

Surface gillnet. The surface fishing deployment was designed to simulate fishing practices of fisherfolk in the area. One hundred forty-eight (148) hauls were obtained for surface gillnet from twelve (12) month sampling time covering the months of October 2014 to September 2015. The total volume of the catch was 73.42 kg and the average catch rate for all meshes was placed at 0.11 kg/hr. Figure 3 shows the catch composition of surface gillnet composed of twelve (12) finfish taxa. Freshwater sardines *Sardinella tawilis,* an endemic commercial fish species in the lake, had the highest production with 36 kg or a relative abundance of 49% from the total catch. Milkfish *Chanos chanos* ranked 2nd with 35 kg or 47% whereas the remaining 4% were dispersed among the other species in minor proportion.

By mesh size, the catch rate (CPUE) varied based on different mesh sizes used and that capture

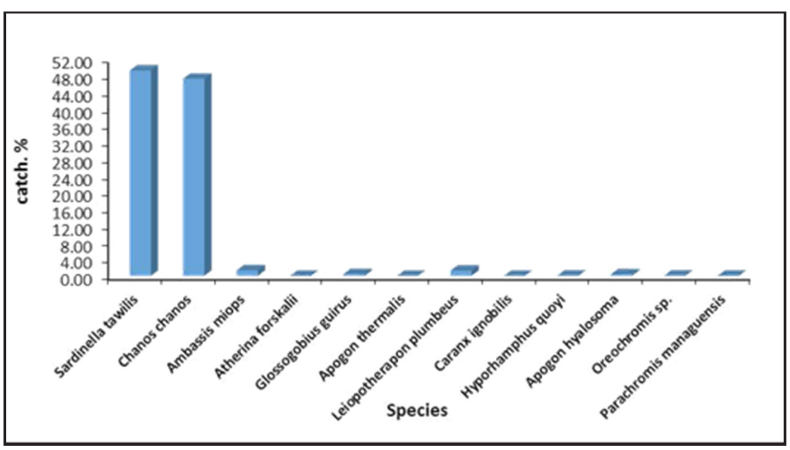


Figure 3. Catch composition and catch percentage of surface gillnet.

Table 2. Catch, CPUE, and portion of sardines using surface gillnet.

Mesh size	10K	11K	12K	12.5K	Total
Catch (kg)	12.39	14.98	20.32	25.73	73.42
CPUE (kg/hr)	0.02	0.02	0.03	0.04	0.11
Sardinella tawilis (%)	1.67	7.5	18.04	29.51	56.72

of fish species was higher (20.32 kg and 25.73 kg) at smaller mesh sizes (12.5k and 12k) particularly for freshwater sardines (18.04% and 29.51%), respectively (Table 2). These mesh sizes also increased the number of immature to maturing *S. tawilis* individuals. The study also shows that retention of freshwater sardines may vary, being higher in smaller mesh sizes (12.5k and 12k) versus larger mesh sizes (11k and 10k), highest catch proportion of sardines was collected in the mesh size 12.5k. Thus, the use of smaller mesh sizes than 11k proved to be more effective in capturing individuals in contrast with the bigger meshes.

Mid-water gillnet. A total of one hundred fifty-three (153) hauls were completed using mid-water gillnet. The total catch was 72.49 kg with an average catch rate (CPUE) for all meshes at 0.11 kg/hr. Nine (9) taxa of fishes were identified from mid-water gillnet catches. Majority of the catches were milkfish *Chanos chanos* with 44.82 kg or 61.82% relative abundance trailed by freshwater sardines S*ardinella tawilis* with a share of 42.45 kg or 58.55 % (Figure 4).

Among mesh sizes used, the catch rate (CPUE) varied based on the different mesh sizes used and that gives a high efficiency of collecting organisms at smaller mesh sizes (12.5k and 12k), especially for freshwater sardines (34.34% and 18.55%), respectively (Table 3). However, using 11k and 10k mesh size leads to low catch efficiency. These mesh sizes also increased the number of matured and gravid individuals. The study shows that catch efficiency of gillnet by mesh size demonstrated greater sieving or filtering effect of smallest sized mesh used and, in contrast, greater escapement chance for small fishes to pass through the net with the use of larger mesh sizes.

Table 3. Catch, CPUE, and portion of sardines using mid-water gillnet.

Mesh size	10K	11K	12K	12.5K	Total
Catch (kg)	13.25	14.12	21.89	23.23	72.49
CPUE (kg/hr)	0.02	0.02	0.03	0.03	0.11
Sardinella tawilis (%)	1.76	7.86	18.55	34.34	62.51

Based from catch composition analysis and abundance of the two fishing deployments, gillnet exhibited a high-selection level for *S. tawilis* and *C. chanos*, thus, it was recognized as a very selective type of fishing gear for a given mesh size and expected to use the gillnet that catches most of the available sizes that do not undermine the sustainability of the species in the area.

In a survey conducted from 2008 to 2009 in Taal Lake, 31% of the total fish production consisted of *S. tawilis* from gillnet catches, described as the most dominant fish in the open waters (Mutia et al. 2010). Herein, the abundance of *S. tawilis* was validated in gillnet catches. Also, the occurrence of migratory species *C. chanos* was observed as this species was ranked as 2nd among the occurring fish resources of the bay.

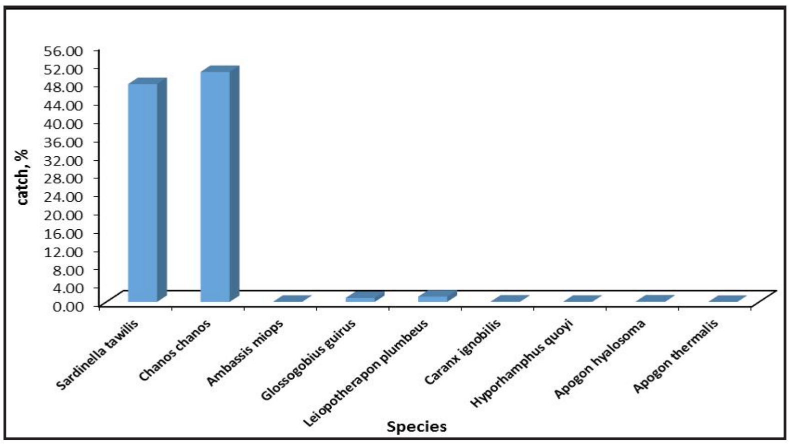
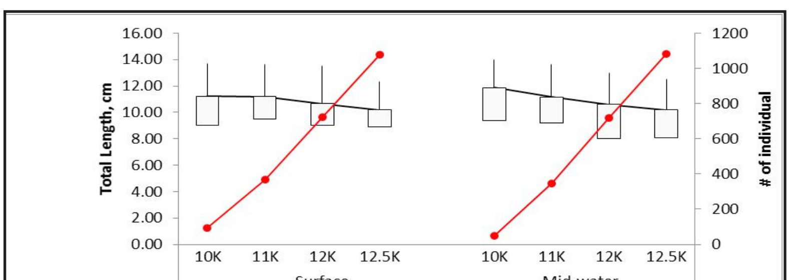


Figure 4. Catch composition and catch percentage of mid-water gillnet.



	10K	11K	12K	12.5K	10K	11K	12K	12.5K
	Surface				Mid-water			
min	9.00	9.50	9.00	8.90	9.40	9.20	8.00	8.10
max	13.70	13.60	13.50	12.30	14.00	13.60	13.00	12.50
mean	11.23	11.20	10.66	10.19	11.88	11.17	10.61	10.20
# of individual	95	367	724	1077	50	347	720	1081

Figure 5. Length sizes of *Sardinella tawilis* by mesh size from surface and mid-water gillnet catches.

3.2. Population length structure by mesh size

Population length structure of *S. tawilis* was available to fishery from 8.9 cm to 13.7 cm by surface gillnet fishing deployment and from 8.0 cm to 14.0 cm by mid-water gillnet. *S. tawilis* population in both gillnet fishing deployments showed a varied size range of fish encountered by the gear from smallest to largest as presented in Figure 5. The plot distribution of surface gillnet operations by meshes registered a larger sized concentration of individuals at mesh size 11k with minimum size harvested of 9.5 cm and a maximum of 13.7 cm at 10k mesh size. Mid-water gillnet operations illustrated larger sizes of *S. tawilis* at mesh size 10k with a mean length of 11.08 cm. Hence, comparative mean total length pattern by mesh size was apparent. Thus, the probability of retaining a large proportion of juvenile or immature catches was high at 12.5k mesh size while using of larger mesh size could retain larger mature fish.

In terms of gillnet type (fishing deployment), it seems that both surface and mid-water gillnet are efficient in catching different sizes and appreciable quantities of species. It may be possible that the swimming layer of *S. tawilis* is set both to mid-water and close to the surface layer. In addition, local gillnetters developed proficiency in harvesting and accessing *S. tawilis* populations from determined locations and timing of fishing along shallow and near coastal areas, where the concentration of nursery grounds are located. They made use of fine-meshed nettings to sieve or collect as

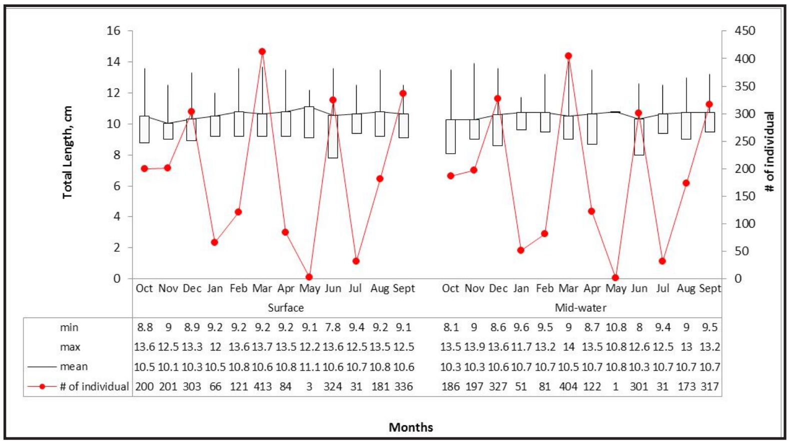


Figure 6. Length sizes of *Sardinella tawilis* by month from surface and mid-water gillnet catches.

many resources as possible since all species taken has economic value for human consumption.

3.3. Population length structure by month

Monthly plot distribution of total fish lengths caught by two sampling deployments of gillnet gear was presented in Figure 6. For surface gillnet, the concentration of young *S. tawilis* recruits was observed in months of September to January and larger sized individuals registered in other months with the largest from summer (May). Mid-water deployment depicted the same size structural pattern with the smallest size registering high during northeast monsoon months and increasing towards summer until the end of southwest monsoon months. More *tawilis* were caught during the onset of summer months with a peak in March. A fewer catch was observed towards the end of summer with the least occurrence in May and start to increase again from June to December during the onset of southwest monsoon towards the end of the season (June to December). Least occurrence of *S. tawilis* in a certain month, i.e., May, may possibly be explained by its certain biological characteristics and/or environmental condition, i.e., offshore spawning which spares the eggs and juveniles from the uncertainties of fluctuating water levels.

3.4. Length Frequency Data

The recorded mid-length size range of *S. tawilis* from a twelve-month (12) sampling period was 8.5 cm to 14.5 cm caught by the four mesh sizes used. The observed mature length (Stage IV-gravid) of this species was 13.6 cm total length (TL) in the month of May which was smaller from the stated maximum size of 15.2 cm TL in FishBase (Froese and Pauly 2010). However, the observed smallest mature of this species was at 8.6 cm (mostly caught from October to December) which was smaller from the reported size of 10.4 cm TL in the study of Mutia et al. (2015). The result showed that the mature size (Stage IV – gravid) of *S. tawilis* was becoming smaller from 10.4 cm (Mutia et al. 2015) to 8.6 cm (Figure 7.0). Hence, frequencies of *S. tawilis* were most abundant at approximately 53% in the mid-length size of 10.5 cm. It demonstrates clearly that more than 50% of spawning (Stage IV – gravid) *tawilis* were caught by gillnet during peak months of spawning season. Data on monthly frequency revealed four (4) peaks in a year (March, June, September, and December), while the lean period was observed from other months with the least occurrence in May.

Figure 7.1 shows that the catch of mesh size (MS) 12.5k ranges from 8.5 cm-14.5 cm mid-length; MS 12k, 9.5 cm-12.5 cm; MS 11k, 9.5cm-13.5cm; and

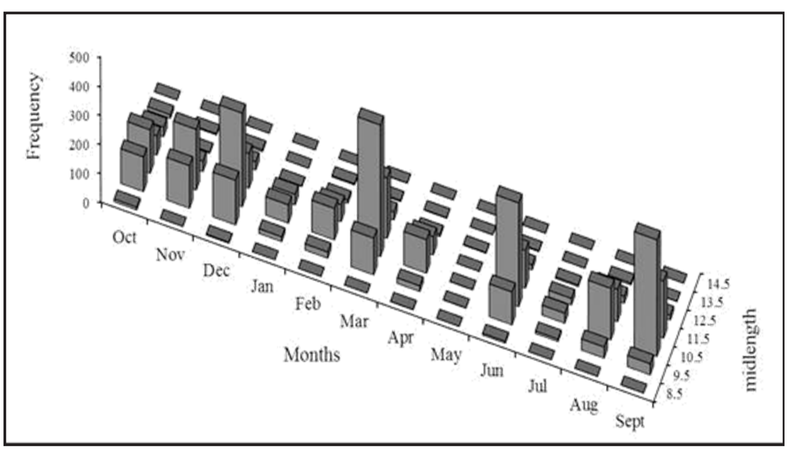


Figure 7.0. Length frequency distribution of *S. tawilis* by month from surface and mid-water gillnet catches.

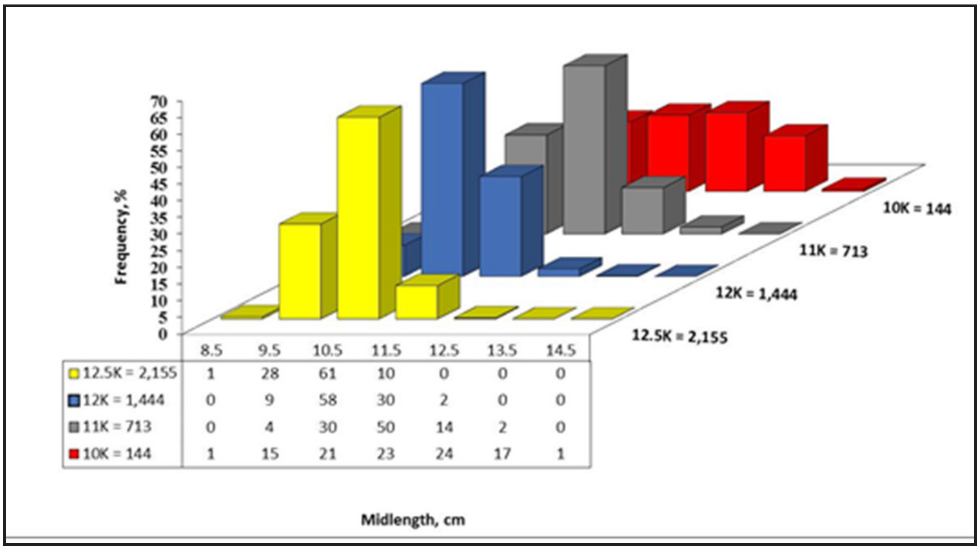


Figure 7.1. Length frequency distributions of *S. tawilis* by 4 mesh sizes.

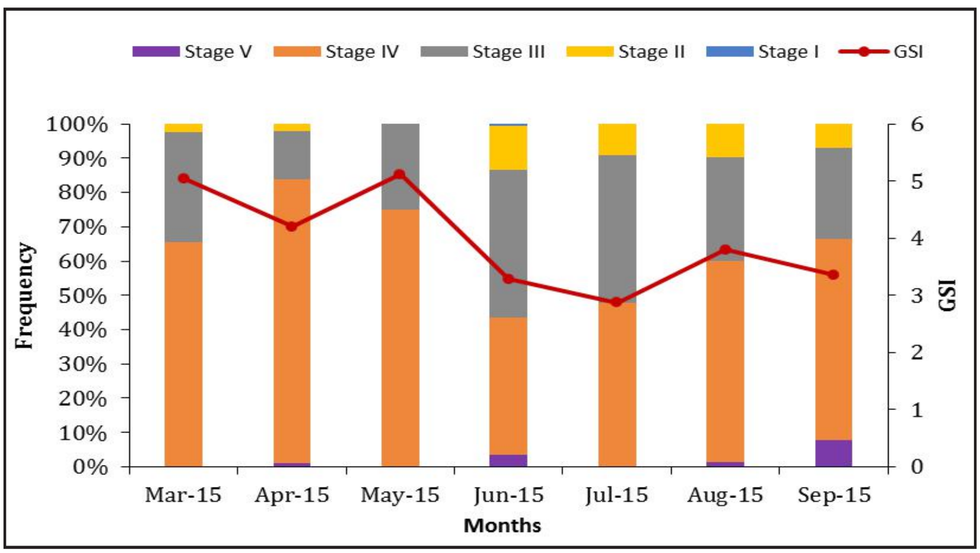


Figure 8. Monthly gonadosomatic index (GSI) and distribution of various stages of gonad maturity.

MS 10k, 8.5 cm-14.5 cm. It shows that the length frequency distribution caught by the four (4) mesh sizes is unimodal distribution and the probability of capture of the large individual increased with mesh size from 12.5k to 10k. Catches in the two large mesh nets were considerably low and there is skewness in data distribution. This particular observation may be further explained by its behavioral patterns, i.e., the reaction of the fish to nets and/or greater capacity of body compression to ease passage through the nettings and body shape, i.e., intrinsic body shape with more prominent body depth during early stage and body becomes fairly slender as it grows. Generally, large fish were caught in all mesh sizes but the average catch overall was lowest in the 10k mesh size.

3.5. Spawning Season

Gonadosomatic index (GSI) and distribution of various stages of gonad maturity for freshwater sardines *S. tawilis* was done from the catches of surface and mid-water gillnet in Taal Lake (Fig. 8). Gonadal

Table 4. Length distribution of *Sardinella tawilis* by maturity stages caught by 4 mesh sizes.

MidLength (cm)	Frequency (%)						Total %
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Spent	
12.5k							
8.5	0	25	50	25	0	0	0.3
9.5	1	15	51	31	0	3	21.1
10.5	0	10	39	47	1	2	66.7
11.5	0	5	37	55	2	1	11.7
12.5	0	0	67	33	0	0	0.2
Total %	0.5	10.2	41.6	44.5	1.0	2.1	100
11k							
7.5	0	0	0	0	0	0	0
9.5	0	10	45	45	0	0	3.5
10.5	1	6	37	49	0	6	30.1
11.5	0	5	25	67	0	3	51.6
12.5	0	4	21	74	0	1	13.5
13.5	0	0	13	88	0	0	1.4
Total %	0	5	29	62	0	3	100
12k							
8.5	0	33	33	33	0	0	0.4
9.5	0	15	42	38	0	6	6.6
10.5	0	9	36	52	0	3	59.2
11.5	0	7	41	51	0	1	32.5
12.5	0	0	36	55	9	0	1.4
Total %	0	8.5	38.1	50.6	0.5	1.9	100
10k							
7.5	100	0	0	0	0	0	1.2
9.5	17	17	67	0	0	0	7.1
10.5	0	20	47	20	0	13	17.9
11.5	0	8	23	62	0	8	31.0
12.5	0	9	30	57	4	0	27.4
13.5	0	0	8	85	0	8	15.5
Total %	2.4	9.5	29.8	51.2	1.2	6.0	100

stages were classified into five stages, namely Stage I (immature), Stage II (maturing), Stage III (matured), Stage IV (gravid), and Stage V (spent).

Monthly percentage in the gonad maturity stages of *S. tawilis* revealed that matured and gravid, immature and maturing individuals existing in seven (7) months of gonad dissection (spent fish, however, was recorded at size range of 9.7-11.5 cm), with highest gravid samples from March to May when surface temperature is at high and August. These months were marked as spawning period due to the frequent presence of Stage IV (gravid) with generally larger size commonly caught in bigger mesh size, i.e., 11k & 10k, and Stage I (immature) contributing 2.94% of the total samples (Figure 8). Present study coincided with spawning months noted on three (3) separate studies conducted. Accordingly, it spawns intermittently throughout the year with peak months from March to May and November to December (Mutia et al. 2004; Joson-Pagulayan 1999; Aypa et al. 1991). This information could possibly be used for prescribing fishing season or period when to protect young fishes from a high level of capture.

The observed smallest mature length (Stage III) caught by mesh sizes 12.5k and 12k was at mid-length 8.5 cm and the biggest mature length was at mid-length 12.5 cm. Mesh sizes 11k and 10k caught mid-length size of spawners which range from 9.5 cm to 13.5 cm, respectively. The mid-length size range of the samples with gonads considered juvenile (Stage I) was 7.75 cm 10.5cm (Table 4). The highest catch caught by mesh sizes 12.5k (66.7%) and 12k (59.2%)

Table 5. Population parameters of unsexed *Sardinella tawilis* from length frequency distribution analysis

Parameters	S. tawilis
Asymptotic length (L∞)	16.06 cm
Growth coefficient (K)	0.63 year-1
Exploitation Rate (E)	0.76

was observed at mid-length 10.5 cm, and mesh sizes 11k (51.6%) and 10k (31%) was recorded at mid-length 11.5 cm.

3.6. Population Parameters

Population parameters from the length frequency distribution of freshwater sardine *S. tawilis* were generated from processed clustered length class of samples using FiSAT II Program (Table 5). The asymptotic length (length infinity,) and growth constant (K) were estimated at 16.06 cm and 0.63 year-1. The derived L∞ from this study corresponds with the result of Mutia et al. (2015) in Taal Lake and K value is higher than the reported value of 0.44 year-1. However, imposing extremely high levels of exploitation is harmful to the stock. An E-value above 0.5 limit reference point of *S. tawilis* suggested that there were unsustainable fishing practices in the lake.

3.7. Estimation of length at 50% maturity

Length population distribution of *S. tawilis* was examined through various meshes. The selectivity measurement of gill net toward stock sustainability is based on the value of length at 50% maturity (L_{50}). Hence, the optimum length caught by the desirable mesh size should be above L_{50} so that fishing activity had to let 50% of mature fish back to the fishing ground in order to give chance to reproduce. The stock sustainability can be kept for future generation and continuation of fishing activity by fishermen will be ensured. Based on the proportion of mature fish at each length class, the length at 50% maturity (L_{50}) of the samples was estimated at 11.66 cm (Figure 9). The result of this study is higher than the value obtained in the study conducted by Catedral (2002), where first sexual maturity of *S. tawilis* was observed at size class of 96-100 mm or 9.6-10.0 cm FL. The recent study of Mutia et al. (2015) revealed combined sexes length at first sexual maturity of 10.4 cm with a maximum length of 15.6 cm.

3.7. Estimation of gillnet selection

Length population distribution of *S. tawilis* was analyzed across various meshes fished. The selectivity of gillnet was obtained from plots of 4,456 individual length samples of freshwater sardine, which ranged between 8.0 and 14 cm.

Based on the value of selection factor (SF = 4.30), it is obtained that the size of optimum length (L_{mi}) of *S. tawilis* caught by 12.5k, 12k, 11k, and 10k were 10.6 cm, 11.91 cm, 13.07 cm, and 14.53 cm, respectively (Table 6). The higher the mesh size of the net used, the longer the optimum length of the fish caught will be (Gulland 1983). In addition, the probability of retaining a large proportion of immature catches was high at 2.65 cm (12.5k) while the use of greater mesh size could retain larger mature fish.

Using the estimated length at 50% maturity (L_{50}) of 11.6 as the criterion for considering the desirable mesh size corresponding the results of the optimum length (L_{mi}), the appropriate gillnet mesh size recommended for *S. tawilis* was determined to be 11k (3.05 cm) mesh size for sustainability of the fishing resource of sardines and local gillnet fishery. The percentage of individuals caught under the minimum catchable size of 11.6 cm were 11.7%, 32.5%, 51.6%, and 31% for 12.5k, 12k, 11k, and 10k mesh sizes, respectively. Results will provide the opportunity for smaller fish among the species to avoid and escape capture, thus demonstrating effectiveness and table size fish catch efficiency.

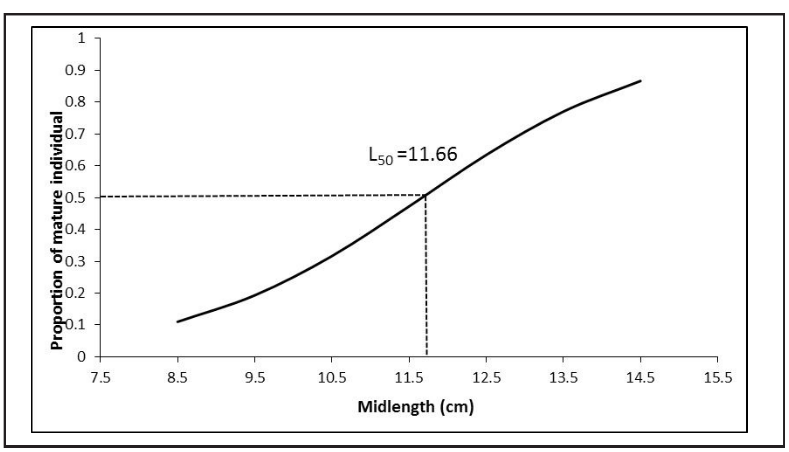


Figure 9. The proportion of mature unsexed *S. tawilis* in each middle class.

Table 6. Selection Factor, standard deviation and the optimum length at each mesh size of gillnet.

	Mesh size (cm)			
Selection Parameters	**12.5K**	**12K**	**11K**	**10K**
Selection factor (SFcommon)	4.30	4.30	4.30	4.30
Common standard deviation (sdcommon)	1.52	1.52	1.52	1.52
Optimum length (Lmi;cm)	10.60	11.08	13.07	14.53

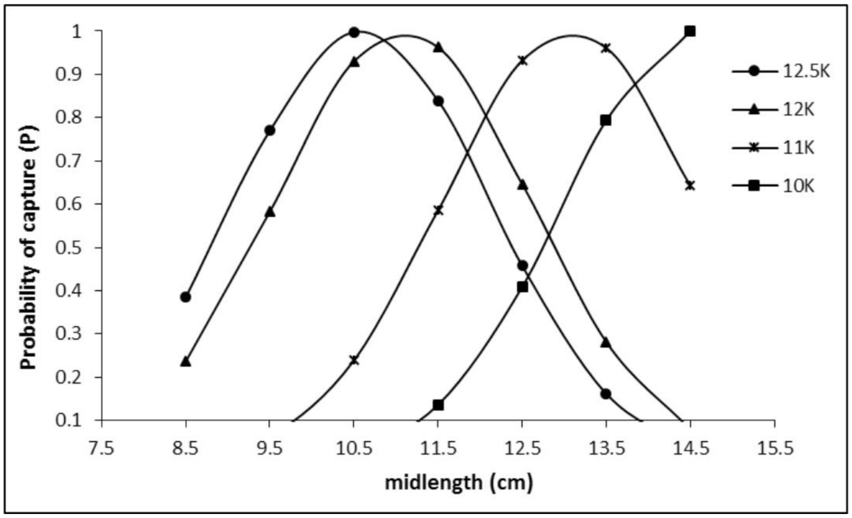


Figure 10. Selection curves of S. tawilis using the multi-mesh model.

The relative selection curves of the different meshes for *S. tawilis* were plotted and shown in Figure 10. From the figure, capture probability of bell-shaped curve of mesh sizes provided an overview of the differences in capture size of meshes used. Comparative efficiencies related to mesh dynamics has been explicitly demonstrated using the results generated from the fish length-based model assessment. Thus, the obtained estimated optimum length (L_{mi}) could be used as an important length size standard for ideal harvestable landing size of freshwater sardines in coherence with the use of optimum mesh size, i.e., 11k. For sustainable development, larger gillnet mesh sizes are recommended by appropriate governmental agencies through legislation and education on the need to employ and deploy proper gear and utilizing the recommended net sizes as capacity building to the local artisanal fishermen. Other relevant technical descriptions of the gillnet fishing activities could provide assistance to the TVPL Management Plan in relation to mesh regulation for selective catching of *S. tawilis* resources and succeeding fishery programs.

4. CONCLUSION

Population length at 50% maturity and the selectivity of mesh sizes could be used as reference materials and management standards for policy formulation and/or revision. Based on the results of the study, the estimated optimal length at maximum yield was 13 cm, thus, the desirable gillnet mesh size recommended for *S. tawilis* corresponding to estimated length at 50% maturity (L_{50}) was determined to be 11k (3.05 cm) mesh size.

Based on the analysis of population length sizes, spawning period of *S. tawilis* occurs from March to May and August, showing larger sized individuals. In terms of fishing deployments (surface and mid-water gillnet), both are effective in catching different sizes of species and appreciable quantities of *S. tawilis*. Possibly, the swimming layer of the species is located both in mid-water and close to the surface layer.

The most common way the *S. tawilis* to be caught was through enmeshing 60% of the total samples with the highest catch in mesh sizes 12k and 12.5k (20% and 28%, respectively) while being gilled or entangled in mesh sizes 10k and 11k at 3%. Each entangled catch usually occurred in bigger species such as *Chanos chanos* of 9%.

The mid-length size range of the samples with gonads considered juvenile (Stage I) was 7.5 cm 10.5cm. The highest catch caught by mesh sizes 12.5k (66.7%) and 12k (59.2%) was observed at mid-length 10.5 cm while mesh sizes 11k (51.6%) and 10k (31%) was recorded at mid-length 11.5 cm.

By mesh size, the catch rate (CPUE) of both surface and mid-water gillnet fishing deployments varied on the different mesh sizes used and that capture of fish species was higher at smaller mesh sizes (12.5k and 12k), particularly for freshwater sardines. These mesh sizes also increased the number of immature to maturing *S. tawilis* individuals. Hence, the use of smaller mesh sizes than 11k proved to be more effective in capturing individuals in contrast with the bigger meshes.

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