ACTA ZOOLOGICA BULGARICA

Applied Zoology
Research Article

Acta Zool. Bulg., 74 (4), December 2022: 597-603

Published online 14 November 2022
http://www.acta-zoologica-bulgarica.eu/2022/002604

Selectivity of Spiral Sieve in the Striped Venus Clam Fishery

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Abstract: Striped Venus clam (*Chamelea gallina*) fishery is intensively carried out on the Black sea coast of Turkey using a hydraulic dredge. For this reason, this study aimed to determine the selectivity of the spiral sieves used in this fishery and the factors affecting the selectivity depending on the structure of the sieve. Samplings were carried out on the coast of the South Black sea onboard a commercial clam vessel from 3 to 15 December 2019. The covered codend method was applied, and the between haul variations were taken into account by using CC2000 and ECmodel software. Thus, the L_{50} results of the Standard Sieving Process (SSP), Cycle per minute (CPM), and Flow rate (FR) were determined as 15.17 mm, 15.49 mm, and 17.06 mm, respectively. Besides, only one factor (FR) affects selectivity. The SR values were found to be quite high for all sieving processes. The proportion of individuals below the minimum legal size in landed catches was determined as quite high. Therefore, the design of a new different sorting sieve system would be more appropriate for striped Venus clam fishery.

Key words: Black sea, selectivity, sieve, Striped Venus clam

Introduction

Striped Venus clam *Chamelea gallina* (Linnaeus, 1758) (Bivalvia: Veneridae) is found from Norway to the coast of North Africa including the Mediterranean, Marmara and Black Seas; it is distributed widely in sandy and sandy-muddy areas at a depth of 5–25 m (Gaspar et al. 2003). Turkey was the only country on the Black sea coast that conducted clam fishery but recently other countries, including Bulgaria, have developed an interest in other non-fish resources such as *C. gallina* (FAO 2021a). The annual production of *C. gallina* in Turkey (34941 tons) was more than that of Europe (14142 tons) in 2017, though the product is not consumed by Turkey and is exported to the European Union (Dalgiç & Ceylan 2012, FAO 2021b, TUİK 2019). Thus, sustainable exploitation of clam stock in the Black sea is very important. Dredges were imported from Italy in the 1990s but the fishing method differs. While the boats are towing the dredge backwards with the help of an anchor in the Adriatic, in the Black Sea the dredge is operated from the stern of the boat and is towed forward (Dalgiç 2006, Petetta et al. 2021). The hydraulic dredges are said to have poor selectivity characteristics while towing due to the spaces between the bars getting clogged by the sediments and small clam jams during the operation (Kim et al. 2005). Since the selection process is made using the sieves on the deck, smaller clams and the discards should be thrown alive into the sea during this process. Double-layer spiral sieves are used in almost all Black Sea boats. The first layer sorts and throws larger species such as *Rapana venosa*, *Anadara kagoshimensis* back to the sea, but Venus clam is not supposed to be thrown out of the sieve in this layer. The second layer sorts the landed catch and rejects the smaller size individuals. There is no regulation for the spiral sieves in the Turkish fishery legislation, except that the distance between the bars cannot be less than 8.5 mm (Anonymous 2016). It is not known which scientific study was taken into account when this arrangement of the regulation was put into effect and its relationship with the minimum landing size (MLS) (> 17 mm).

In a previous study, the ratio of small size clam was reported to exceed the legal limits with the rate of discard being 36 % in the landed catch (Dalgiç & Ceylan 2012). Recently, fishermen have complained that the size of the *C. gallina* in the exploited stocks is smaller and the sieves cannot discard the small size individuals (personal communication). Therefore, an obvious selection problem exists in the *C. gallina* fishery. Besides, the effects of hydraulic dredges on target and non-target species differ in the short and long term. Though the effect was less on the non-target species, the recovery of the target species was taking a long time as well (Ragnarsson et al. 2015), revealing the importance of capturing the appropriate size individuals for sustainable fishing. It is very important to determine the selectivity characteristics of the spiral sieves to understand whether we need sieves that are more selective. The purpose of this study was to determine the selectivity of spiral sieves used in *C. gallina* fishery.

Materials and Methods

Study area and samplings

Totally, 20 hauls were carried out on the Karasu and Düzce coast of the South Black sea from 3 December to 15 December 2019 (Fig. 1). Researchers participated in the commercial activities of a fishing boat (Sinyor Paşa; LOA: 15 m, 380 HP main engine, 130 HP secondary engine for water pump). The cylindrical spiral sieve consisted of two layers, where the first layer had a grid with a bar spacing of 14 mm. The whole catch to be sieved was sent from the collection box to this part in the centre of the cylinder by water flow. Only large-sized species or materials were retained in the first layer. As the sieve cycle progressed, the material retained in the layer moved to the exit at the end of the sieve and was thrown by the water flow into the sea. However, striped Venus clams passed directly to the second layer. The second layer consisted of a grid with a bar spacing of 8.5 mm. Individuals below the minimum landing size fell out while the marketable product moved forward, toward the exit of the second layer for packaging. The length and the diameter of the cylindrical sieve were 200 cm and 80 cm, respectively (Fig. 2), and the sieving process was performed at 45 Cycles Per Minute (CPM).

The experiment was conducted in two steps. The effects of some changeable or intervenable properties of sieve on the selectivity were determined by selecting two parameters, except for the constructional properties. Firstly, the Standard Sieve Process (SSP) was carried out by the crew for 10 sieving processes. The first parameter was the amount of product entering the sieve (Flow Rate – FR) and the second one was the number of cycles per minute (CPM). These parameters were easily changeable by the crew during the process and were considered a means for increasing the amount of the marketable product. For this reason, these parameters were analysed by considering on-board observations and the opinions of experienced fishermen.

Five sieving processes were carried out to assess the effect of each parameter, through reducing either the CPM of the sieve or the FR of the material into the sieve by 25%. Once the sieving process was started, marketable and discarded clams were collected and the samples were tagged and stored on-board. The commercial and discarded catches were weighed,

Fig. 1. Study area.

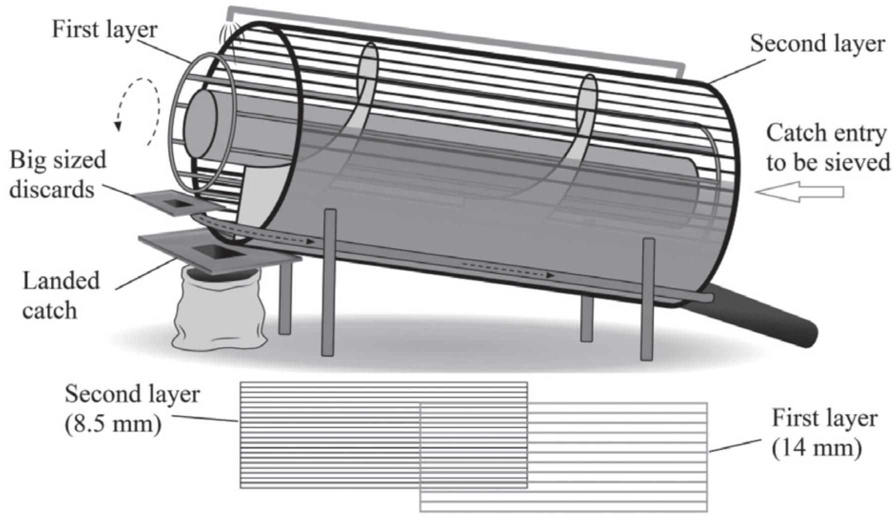

Fig. 2. Spiral sieve the selectivity characteristic of which determined.

subsampled and the length of clams was measured to the nearest mm accuracy with digital calliper (Sylvac, S Cal EVO Smart). Thickness measurements were performed to determine the relationship between the length and thickness of the clams. Furthermore, the amount of wastage (small size organisms and striped Venus clam shells that cannot be discarded) in the landed catch was determined.

Samplings with the SSP were carried out at the depths of 8–16 m and the hauling speed between 3.2–3.4 knots. In the sampled CPM hauls, the depth and the hauling speed ranged from 11–14 m and 3.2–3.4 knots, respectively. The haul speed was recorded as 3.5 knots in only one haul and the depth in FR sampling varied between 11–15 m. The duration was recorded as 8 min in all the operations.

Data analysis

The size selectivity for the spiral sieve processes was assessed using the covered codend method (Wileman et al. 1996). The length frequency of eliminated and retained catch should be known in this method. During the operation of the sieve, the rejected small-size individuals were collected. Thus, the same principle of a covered codend method was adopted and applied in this work.

The L_{50} selectivity parameters for each sieving process were estimated by fitting a logistic function:

$$r(l) = \exp\left(v_{1+v_2} l\right) / [1 + \exp(v_1 + v_2 l)]$$

$$L_{50} = \frac{-v_1}{v_2}$$

where $r(l)$ is the retained material in layer 2 (selectivity takes place in this layer), which is proportional to the length class, and v is the parameter to be estimated (Wileman et al. 1996).

Another important parameter in terms of selectivity is the selection range (SR) that is the difference in total length of fish having 75 and 25% probability of being retained, respectively. This is a parameter related to the sharpness of the selection curve. SR for each sieving process was estimated using the formula below.

$$SR = L_{75}\text{-}L_{25}$$

Selectivity parameters for individual hauls were estimated using the residual maximum-likelihood method. The mean 50% retention length (L_{50}) was calculated using the between-haul variation method developed by Fryer (1991). All possible linear expressions of the selectivity parameters as functions of the explanatory Flow Rate (FR) and Cycles Per Minute (CPM) were tested as a two-level factor. The model that best describes the data was selected according to the lowest value for Akaike's Information Criterion (Akaike 1974, Fryer & Shepherd 1996). Estimations of the selectivity parameters and models were performed using CC2000 and ECModel software.

Results

During the study, a total of 20 randomly selected hauls were sampled in 10 SSP with 5 CPM, and the FR was 5. The details of the 10 standard procedure and 10 experimental hauls performed during the study are summarised in Table 1 The wastage ratio of the SSP ranged from 9.7 % to 15.4 %, and the

Table 1. The details of hauls. Legend: D: duration, Wastage: Weighted components except for the clam in the landed catch.

Type	Date	Speed (Knot)	Depth (m)	Time			Location	Wastage (%)
				Start	End	D. (min)		
SSP								
1	03.12.2019	3.2	8	06:55	07:03	8	Düzce	10.9
2	03.12.2019	3.3	8	07:35	07:43	8	Düzce	9.9
3	03.12.2019	3.4	11	09:30	09:38	8	Karasu	15.4
4	03.12.2019	3.3	11	11:50	11:58	8	Karasu	15.1
5	04.12.2019	3.2	14	06:00	06:08	8	Karasu	12.3
6	04.12.2019	3.2	16	08:00	08:08	8	Karasu	12.3
7	04.12.2019	3.2	9	09:36	09:44	8	Karasu	13.8
8	05.12.2019	3.2	9	07:41	07:49	8	Düzce	
9	05.12.2019	3.2	8	12:34	12:42	8	Düzce	10.6
10	05.12.2019	3.2	10	12:55	13:03	8	Düzce	9.7
CPM								
1	04.12.2019	3.3	11	06:54	07:02	8	Karasu	24.3
2	05.12.2019	3.2	12	08:04	08:12	8	Karasu	12.6
3	05.12.2019	3.3	14	09:00	09:08	8	Düzce	11.6
4	05.12.2019	3.4	13	10:32	10:40	8	Düzce	9.6
5	05.12.2019	3.3	11	11:57	12:05	8	Düzce	15.8
FR								
1	03.12.2019	3.5	11	07:15	07:23	8	Düzce	12.9
2	03.12.2019	3.3	12	08:02	08:10	8	Düzce	9.8
3	03.12.2019	3.3	11	08:40	08:48	8	Düzce	7.9
4	06.12.2019	3.5	9	09:45	09:53	8	Karasu	11.6
5	06.12.2019	3.2	15	10:17	10:25	8	Karasu	8.5

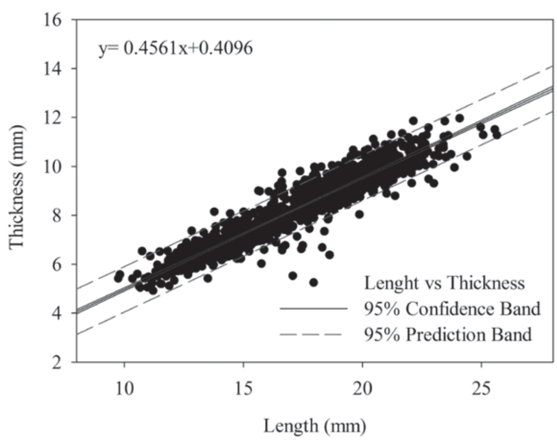

Fig. 3. The length-thickness relationship of striped Venus clam.

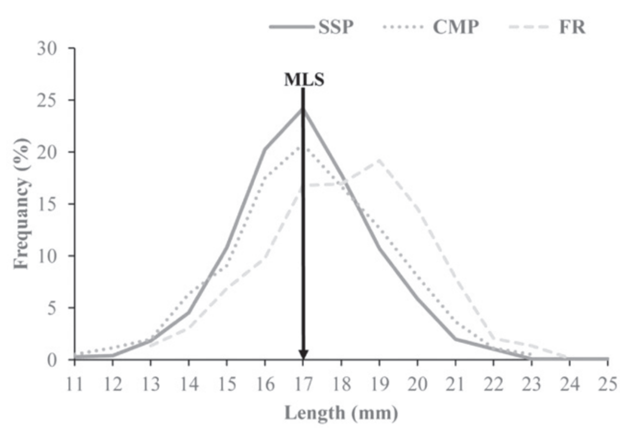

Fig. 4. Length frequency of *C. gallina* in the landed catch.

mean value was determined to be 12.24 ± 2.01 % (Table 1). The linear regression between length and thickness is given in Fig. 3. The clam thickness for 17 mm length was calculated as 8.16 mm.

The selectivity parameters of SSP were calculated for each sample (Table 2). Sample number 8 was not taken into account due to an error during the sampling. The L_{50} and SR (Selection range) values varied between 14.56–15.61 mm and 2.70–5.18 mm, respectively. The calculated mean L_{50} value was 15.17 mm, and the SR value was 3.67 mm. The length-frequency distribution of the landed *C. gallina* caught in the SSP samples is given in Fig. 4. The average length of the landed clams was 17.05 ± 0.23 mm. 38.10% of the landed biomass was found to be smaller than the minimum landing size (MLS: 17 mm).

The wastage ratio of CPM ranged from 9.6 % to 24.3 %, and the mean value of wastage was determined as 14.74 ± 5.8 % (Table 1). The selectivity parameters of CPM hauls are given in Table 2. The L_{50} and SR values varied between 14.78–15.86 mm and 2.47–5.60 mm, respectively. The calculated mean values of L_{50} and SR were 15.44 mm and 4.23 mm, respectively. The length-frequency distribution of the landed *C. gallina* caught in the CPM samples is given in Fig. 4. The average length of the

Table 2. Selectivity parameter for samples. Legend: L_{50} (%50 retention), SR (Selection range), SE (Standard error) are the selectivity Parameters. V_1 and V_2: maximum likelihood estimators of the selectivity parameters, R_i. are values in the covariance matrix, d.f.: degrees of freedom.

Process	ID	L_{50}	(SE)	SR	(SE)	V_1	V_2	R_{i11}	R_{i12}	R_{i22}	Deviance	d.f.	p-value
SSP	1	15.18	(0.21)	4.02	(0.48)	-8.283	0.545	0.0448	-0.0446	0.2350	231.65	11	0.00
	2	15.61	0.15	2.70	0.29	-12.696	0.813	0.0245	-0.0076	0.0838	245.16	13	0.00
	3	15.14	0.30	4.03	0.70	-8.242	0.544	0.0949	-0.1145	0.4994	305.79	11	0.00
	4	15.48	0.33	4.38	0.77	-7.756	0.501	0.1148	-0.1394	0.6017	344.37	9	0.00
	5	14.78	0.18	4.03	0.39	-8.045	0.544	0.0339	-0.0398	0.1592	154.61	12	0.00
	6	15.01	0.27	4.73	0.68	-6.966	0.464	0.0774	-0.1150	0.4661	122.32	10	0.00
	7	14.56	0.21	3.98	0.41	-8.036	0.552	0.0448	-0.0519	0.1707	249.98	11	0.00
	9	15.41	0.42	5.18	1.01	-6.531	0.424	0.1807	-0.2418	1.0121	489.69	12	0.00
	10	15.54	0.22	3.27	0.47	-10.417	0.670	0.0506	0.0283	0.2278	453.95	13	0.00
	Mean (Fryer)	15.17	0.13	3.67	0.24	-8.345	0.550						
CMP	1	14.78	0.50	5.60	1.28	-5.792	0.392	0.2516	-0.3286	1.6543	582.37	10	0.00
	2	15.67	0.13	2.47	0.23	-13.925	0.888	0.0194	-0.0087	0.0552	226.12	12	0.00
	3	14.98	0.52	5.04	1.25	-6.533	0.436	0.2783	-0.3946	1.5854	840.06	10	0.00
	4	15.86	0.37	5.42	1.10	-6.425	0.405	0.1407	-0.0890	1.2276	647.73	10	0.00
	5	15.37	0.40	4.95	1.01	-6.821	0.444	0.1672	-0.1977	1.0307	656.26	10	0.00
	Mean (Fryer)	15.49	0.14	4.23	0.69	-7.92	0.511						
FR	1	16.07	0.18	3.40	0.37	-10.365	0.645	0.0358	-0.0058	0.1426	239.67	11	0.00
	2	16.98	0.16	2.83	0.28	-13.189	0.776	0.0287	0.0043	0.0792	173.71	11	0.00
	3	17.30	0.22	2.58	0.39	-14.714	0.851	0.0505	0.0069	0.1539	393.72	12	0.00
	4	17.70	0.18	2.43	0.29	-16.007	0.904	0.0347	0.0054	0.0884	251.88	13	0.00
	5	17.03	0.28	3.44	0.58	-10.853	0.637	0.0825	0.0314	0.3422	317.01	10	0.00
	Mean (Fryer)	17.06	0.27	2.86	0.24	-12.924	0.7576						

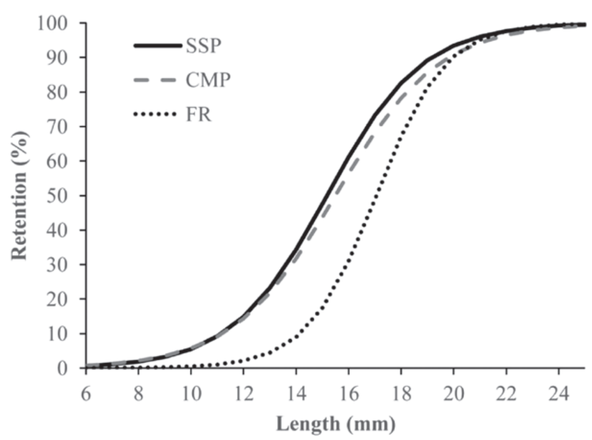

Fig. 5. Mean selectivity curves of Standard Sieve Process (SSP), Cycles Per Minute (CPM), Flow Rate (FR).

Table 3. Determining the direction and magnitude of the influence of the explanatory variable on selectivity parameter. Legend: α_1: alpha parameter estimates, SD: standard deviation, d.f.: degrees of freedom, f_i: FR.

Parameter		Estimate	S.D.	*t*-Value	d.f.	*p*-Value
α_1	(L_{50}, constant)	18.123	0.382	47.476	32	0.000
α_2	(SR, constant)	3.433	0.192	17.868	32	0.000
α_3	(L_{50}, f_i)	-0.028	0.004	-6.539	32	0.000

landed clams was calculated as 17.17 ± 0.25 mm. Also, 36.55 % of the landed biomass was found to be smaller than the MLS.

The wastage ratio of the FR ranged from 7.9 % to 12.9 %; the mean value was determined as 10.14 ± 2.09 % (Table 1). The selectivity parameters of the FR hauls are given in Table 2. The L_{50} and SR values varied between 16.07–17.7 mm and 2.43–3.44 mm, respectively. The calculated mean L_{50} value was 17.06 mm while the SR values were 2.86 mm. The size frequencies of the landed *Chamelea gallina* in the FR samples are given in Fig. 4. The average length of the sampled clams was calculated as 18.12 ± 0.34 mm and 21.06 % of the landed biomass was found to be numerically smaller than 17 mm. Selectivity curves for all the sieving processes are shown in Fig. 5.

The reduction of FR (one of the external variables) was found to have an effect on the L_{50} value and inversely proportional to L_{50}, while it had no effect on SR (Log-Likelihood: –35.06, AIC: 76.12) (t =-6.539, p<0,01) (Table 3). The model selected according to the lowest value of Akaike's Information Criterion-AIC (Fryer and Shepherd, 1996), was:

$$E\begin{pmatrix} L_{50} \\ SR \end{pmatrix} = \begin{matrix} \alpha_1 + \alpha_3 f_i \\ \alpha_2 \end{matrix}$$

There was no statistically significant effect of CPM on either L_{50} or SR.

Discussion

The fishery of *Chamelea gallina* has been carried out in the Black sea for a long time (Dalgiç 2006). However, there is a need for increased regulations and standards to manage this fishery. Our results show that the selectivity of spiral sieves is not satisfactory. The primary aim of the fishermen is to eliminate the product accumulated in the collection box within 8 min and process the product for the next haul. Therefore, they are not concerned about better selectivity or smaller individuals but only try to reduce the waste in the landed catch. That is because they do not encounter any problems while marketing the smaller individuals. The L_{50} (15.2 mm) and SR (3.7 mm) values obtained from the SSP were not within the acceptable limits. Additionally, the wastage (12.2 %) and small individual (38.9%) ratios in the landed catch were not at all profitable for a fishery with a quota. The same bad results were encountered even in the CPM results, where the L_{50} value was approximately the same as that of the SSP along with the bad wastage (14.74 %) and small individual (61.18 %) ratios. Furthermore, the SR value obtained was very wide. Only in the FR samples, a valid L_{50} value was obtained but the other parameters were still unacceptable (SR, wastage, and small individual).

Considering the selectivity of spiral sieves, it is clear that sufficient selectivity characteristics were not achieved as seen from the low L_{50} value and wide SR range, although it has sufficient spaces between bars in terms of clam thickness. Even if the value of L_{50} reached 17 mm by reducing FR, the high proportion of smaller individuals in the landed catch indicated that this L_{50} value was also not sufficient. Moreover, the flow rate is under the control of the fishermen, hence it is not possible to standardize it logically. Again, the wide range of SR leads to the mixing of small individuals in the landed catch, which in turn results in commercial losses within the discarded catch. Better results can be achieved by a controlled mechanical sieve process on the deck.

A study conducted in 2009–2010 reported the rate of discard and small individuals in the landed catch to be 36% and 19%, respectively (Dalgiç & Ceylan 2012). It was reported in 2012 that spiral sieves were insufficient in terms of the rate of the discard and small individuals; thus, they were not suitable for our selectivity study. It is necessary to consider new sieve alternatives that may provide better results. Clams must be in contact with the grids in a vertical position to get a good selectivity. The rotational movement of the spiral sieve is not considered sufficient for this vertical contact because clams move forward as a pile at the bottom of the spiral sieve. A similar problem (all captured clam individuals do not come into contact with the metal bar of the dredge) was reported in a study on dredge selectivity, the contact of all individuals with escape space between the metal bars is very important for the full realisation of size selectivity (Petetta et al. 2021). To improve contact of all individuals, a flat and vibrating area that allows clams to fall out of the gaps in the grids may be needed rather than spiral sieve. One study reported success in reducing the retention of small-sized individuals up to 5 % using vibrating sieves while increasing the number of individuals up to 67 %, which is above the legal limit (Sala et al. 2017). Thus, it is necessary to develop urgently a vibrating sieve for the clam fishery in the Black Sea. It can ensure that both large-size discards and small-size clams that cannot be sieved are thrown into the sea quickly with a vibrating sieve, which should consist of several layers. The newly designed vibrating sieve may positively affect the commercial income of fishermen, which are currently discarding a large part of their daily catch.

It was reported that the growth rate of striped Venus clams was lower in the Black Sea compared to other seas; that it reaches reproductive maturity after the first year of age (Dalgiç et al. 2009). The MLS applied in the Adriatic Sea is 25 mm and striped Venus clam individuals at this length are three years old (Bargione et al. 2020). While the average length of striped Venus clam at the age of three was 17.6 mm in the areas closed to hydraulic dredging fisheries in the Black Sea, it was reported as 14.8 mm in the fishing areas. Reproduction in the Black Sea occurs in smaller individuals than in the Adriatic Sea. It is very important to investigate the contribution of the number of eggs and recruitment provided from these small-sized individuals to the sustainability of the stocks and fisheries of *C. gallina* in the Black Sea.

The high rate of small individuals in the commercial catch is a threat for sustainable striped Venus clam stocks because many striped Venus calms are caught before they reach breeding size. Moreover, the stocks should be exploited at a lower rate for sustainability (Worm et al. 2009). However, the most important strategy for achieving the desired patterns in exploitation is the selectivity regulations of many fisheries (Macher et al. 2008). Therefore, modifications are needed to reduce the SR and obtain a steeper S-shaped selectivity curve.

Conclusion

The present results did not show sufficient selectivity in either SSP or CPM samples. Although a valid L_{50} value was reached by reducing the flow rate, it is understood that appropriate results were not obtained due to the high SR value and the high proportion of smaller individuals in the landed catch. The technical character of the sieve varies depending on the choice of the boat owner and FR is under the control of the crew. Many technical components affect the CPM of the sieve. Hence, it is very difficult to standardize this type of sieve and put it under the control of authorities. Even if sufficient sieves in terms of selectivity are developed, the crew can easily change the character of a sieve to gain more product. In this context, it is more appropriate not to use spiral sieves in the clam fishery. A new standardised sieve needs to be developed that provides adequate selectivity with fishermen compulsorily using the sieve.

Acknowledgments: I would like to thank the owner and crews of the SİNYOR PAŞA fishing vessel for their help. This study was supported by the Research Fund of the Recep Tayyip Erdogan University. Project Number: FBA-2019-1055.

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Received: 19.01.2022
Accepted: 08.11.2022