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Determining the hook selectivity of bottom longline used for European hake (*Merluccius merluccius*, L. 1758) in Saros Bay (northern Aegean Sea, Turkey)

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Abstract

This study was carried out at Saros Bay, between June 2011 and July 2013 to determine hook selectivity of bottom longlines used in European hake (*Merluccius merluccius*, L. 1758) fishing. Throughout the study; thick type, 6, 7, 8 and 9 sized flat hooks were used between 150 and 400 m depth. 36 fishing operations were carried out and 222 fish were caught using 7200 hooks in total. Depending on the size of hooks; number 8 was the most efficient hook that has caught 114 fish and number 6 was the least efficient one that has caught only 14 fish. The SELECT method is used in the determination of the selectivity parameters. *Bi model* has given the best fit according to selectivity analysis of five different models. Optimum catching lengths found were 60.09 cm for 6 number hook; 51.45 cm for 7 number hook; 46.43 cm for 8 number hook; 40.11 cm for 9 number hook, in *Bi Model* model. Minimum size limit for European hake is 25 cm in Turkey. Considering the minimum size limit, use of hooks with gapes larger than number 9 hook (11.75 mm) used in this study is suggested.

Keywords: European hake, *Merluccius merluccius*, Saros Bay, Hook selectivity, Bottom longline.

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Introduction

The European hake (*Merluccius merluccius*, L. 1758) a member of the Merlucciidae family is a highly commercial fish. It exists in all coasts of Turkey (Mater *et al*., 2003) and has a wide spread range from East Atlantic to the south of Black Sea. European hake generally lives on muddy bottom structures between depths of 30 and 1075 meters. Its maximum length is 140 cm and it can live to the age of 20 years (Froese and Pauly, 2007).

Disruption of ecological balance, wrong fishing methods, use of harmful fishing gears and fishing pressure are the negative factors affecting fish stocks (Deval *et al*., 2004). Estimates of size selectivity of fishing gear give significant data for conservation and the ideal exploitation of fisheries resources (Hilborn and Walters, 1992; Beverton and Holt, 1993; Quinn and Deriso, 1999; Czerwinski *et al*., 2010; Cilbiz *et al*., 2014). Longline, is a fishing gear the selectivity of which can easily be arranged. It allows to catch target species and length by hook design and bait size (Løkkeborg ve Bjordal, 1992). In the hook selectivity studies, when possible, the selectivity parameters of higher catch rated species are determined (Cortez-Zaragoza *et al*., 1989; Erzini *et al*., 1998; Otway and Craig, 1993; Peixer and Petrere, 2007; Yamashita *et al*., 2009).

The European hake *M. merluccius*is, is a targeted species in a number of European countries, such as Portugal, Spain, France, England, Italy and Greece (Cardénas *et al*., 1987; Aldebert *et al*., 1993; Martos and Peralta, 1995; Papaconstantinou and Stergiou, 1995; Santos *et al*., 2003). Also, European hake has an important place in Turkey's fishing industry. The catch amount of European hake was 1256 tons in 2010 but the amount decreased to 676 tons in 2013 (TÜİK, 2013). The numbers reveal that the European hake stocks are falling to a decay due to fishing pressure and other reasons. In Turkey's legal regulations, only length is limited and no other limitation is stated on fishing gear.

Trawling is prohibited in Saros Bay during the whole season for European hake and the other highly commercial demersal fish, caught by using gill nets and bottom longlines. On the other hand there is no study to contribute to fisheries management to regulate the limitations for this fish. Selective fishing gear that catches economic fish and lets the little ones escape, must be in place in good fisheries management (Annstrong *et al*., 1990). For this reason determining the hook selectivity of bottom longlines used in the region has significant importance. In this study, suggestions on the ideal hook size in bottom longlines for European hake considering the minimum legal catch length was aimed by determining the selectivity parameters of size 6, 7, 8 and 9 hooks in Saros Bay.

Materials and methods

This study was carried out at Saros Bay, between June 2011 and July 2013 to determine hook selectivity of bottom longlines used in European hake (*Merluccius merluccius*, L. 1758) fishing in Saros Bay. Field studies took place in commercial fishing areas which varie between 150 and 400 meter depths (Fig. 1).

Longline tackles are equipped on 1000 meter long and 1, 2 mm diameter

mainlines. Branchlines which are 1.5 m long and 0.80 mm diameter fish line were knotted to mainlines interspaced 4 meters from each other. VMC brand 9747 PS model size 6,7,8 and 9 hooks were used in longline tackles (Fig. 2).

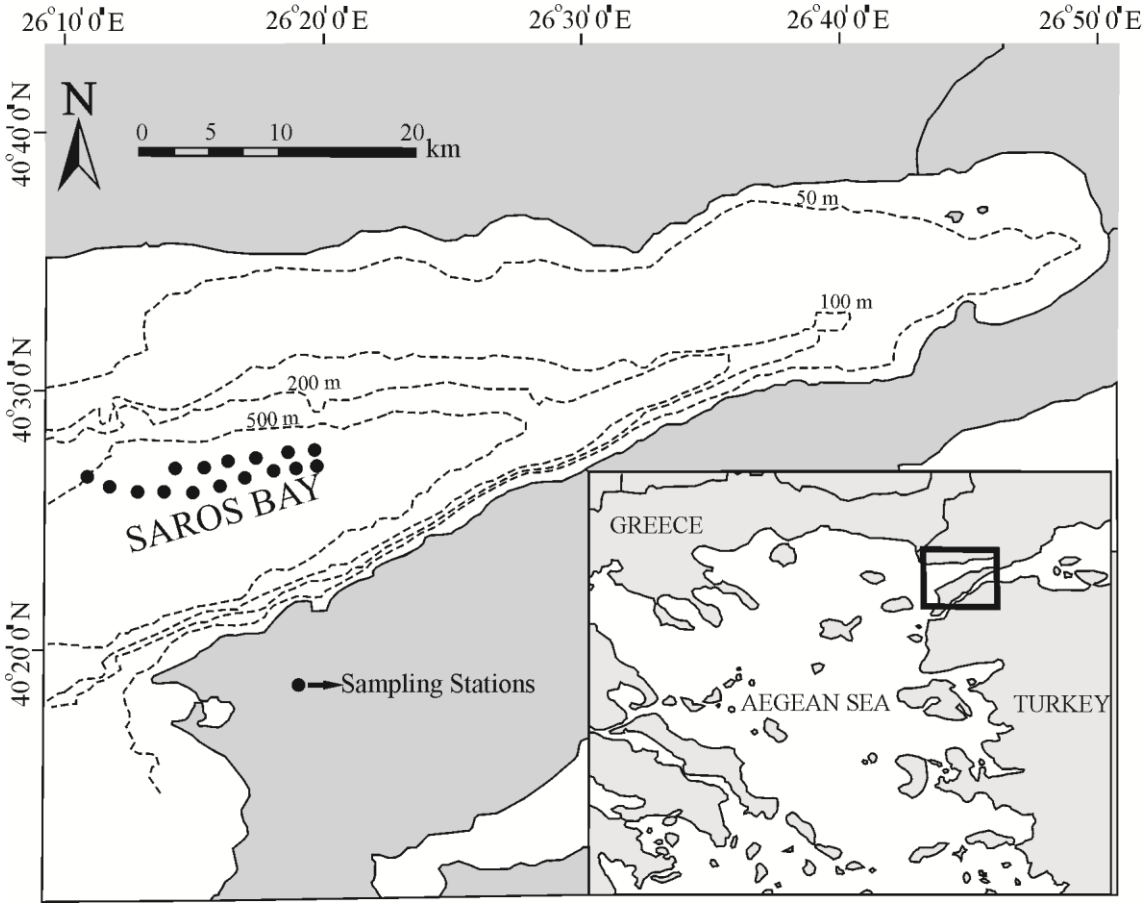

Figure 1: Map of Saros Bay.

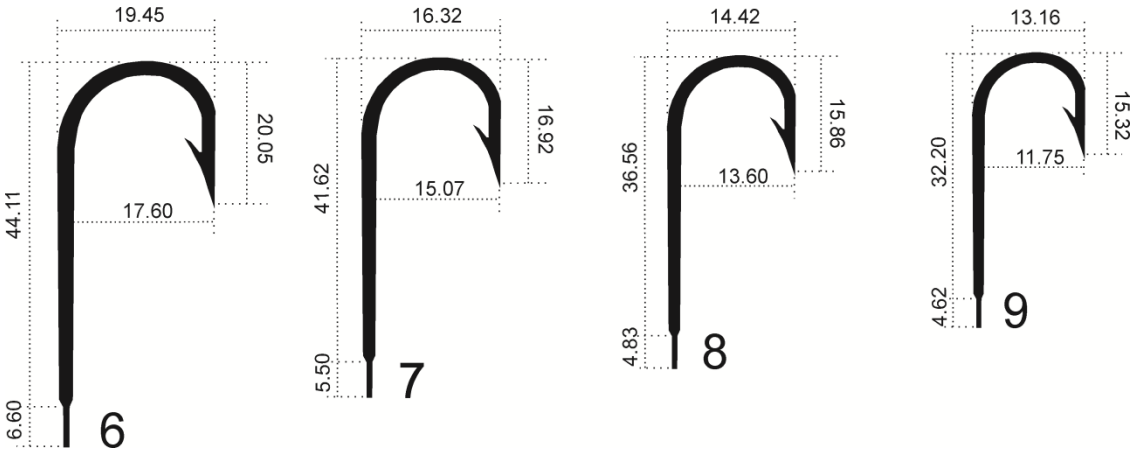

Figure 2: VMC brand's 9747 PS model size 6,7,8 and 9 hooks.

Choosing the most convenient bait is the first condition of longline fishing (Ferno and Olsen, 1994). Sardine and allis shad were used as baits in longlines because of easy and cheap supply conditions.It was stated in a study that using sardines as bait for hake (*M. merluccius*,L. 1758) in longlines is a traditional method (Franco *et al*., 1987).

The baits used were salted 4 - 6 hours before fishing operations to easily attach the hook and extend the soak time. Same size baits were used on hooks to prevent the effect on the aim of fishing (one sardine was attached to one hook). After baiting, the longline tackle is deployed in the direction of the current and wind, and then sinkers and floaters are tied to front and endline. It is very important to estimate the seabed while choosing the fishing ground. Sinkers are tied to mainlines to ensure high fishing performance of the tackle and its proper deployment. Another reason is to prevent the loss of branchline due to currents. Also floaters are tied to mainline to prevent tangling. Bottom longlines were deployed as flatline and left in water between 1 and 12 hours from early morning to sunset or from afternoon to the next day.Fish that are caught during field studies were classified according to hook size. All fish total length and fork length were measured with 1 mm precision measuring board and weighed with 0.01 g precision electronic scale.

SELECT (share each length class's catch total) method was used to evaluate the data belonging to fish hooks (Millar and Holst, 1997; Millar and Fryer, 1999). The SELECT method is generally described as, number of l_j (j= 1, 2, 3, ..., n) long fish caught with m_i (I= 1,2,3,……,k) hooks which has independent Poisson distribution called:

Y_{lj}. Y_{lj}~Po (pj·λ_l)

This distribution gives the amount of *l* length fish that encounter with fishing gear (λ_l). (p_j) representing proportional fishing intensity. *j* is used to represent *l* length fish that interact with combined fishing gear and selectivity curve of *j* hook either.

N_{lj}~P_0 (Pj·λ_l·r_l (j))

Modelling the efficiency of *j* hook is proportioned to hook gap.

Pj=c · lj

In equation l j is size of j hook. Thus log likelihood function is as can be seen in the equation below:

$L = \sum l.j\ n_{lj} \cdot \log(v_{lj}) - v_{lj} = \sum n_{lj} \cdot [\log(p_j) + \log(\lambda_l) + \log(r_j(l))] - p_j \cdot \lambda_l \cdot rj(l)$

With select method; selectivity curves can be fit into five different models called normal location, normal scale, lognormal, gamma and binormal (Millar, 1992):

Normal scale: $\exp[-(l-k_1 \cdot m_j)^2/2k_2^2 \cdot mj^2]$

Normal location: $\exp[-(l-k \cdot m)^2/2\sigma^2]$

Log-normal: $m_j/(l \cdot m_l)\ \exp[\mu-\sigma^2/2-((\log(l)-\mu-\log(m_j/m_l))^2/2\sigma^2]$

Gamma: $[l/(\propto-1) \cdot k \cdot m_j)]^{(\propto-1)}\ \exp[\propto-1-l/(k \cdot m_j)]$

Bio-normal: $\exp[-((l-a_1 \cdot m_j)^2/2(b_1 \cdot m_j))] + w \cdot \exp[-((l-a_2 \cdot m_j)^2/2(b_2 \cdot mj)^2]$.

In the model equations shown above; m_j represents hook size, k is constant, α and β represent regression coefficient of gamma distribution, w is for second curve's peak point of bi-normal model. σ and μ are parameters of selectivity curve and specify the curve's width and form.

Two different assumptions were used in models to estimate the selectivity of hooks. The first assumption is equal fishing effort and the second one is fishing effort to α hook gap size. While determining the best fit for selectivity curve, we took notice of two criteria. The first criteria is the lowest deviation / degree of freedom proportion. The second criteria is checking the P-values of models but this is used in case

the first criteria results are equal. Data were analyzed with two way Kolmogorov-Smirnov test to ensure whether length frequency proportion of fish caught with each hook differ significantly or not (Siegel and Castellan, 1988).

Results

Size 6, 7, 8 and 9 hooks were used in field studies between 150 and 400 meter depths. A total of 36 field studies were carried out and 7200 hooks were used in total during these field studies. In total, 222 fish were caught in these field studies. The number of fish caught by size 8 hook caught was the greatest at 114, while size 6 hook caught the least number of fish at 14. The length and weight of each fish were measured. Length frequency Table is displayed in Fig. 3. Maximum-minimum length and weight vary between max 83.1 cm-3381.50 g and min 26.8 cm-73 g, respectively (Table 1).

Selectivity curve parameters of European hake that were caught in field studies were calculated with SELECT method using the length frequency according to each hook size separately (Tables 2 and 3).

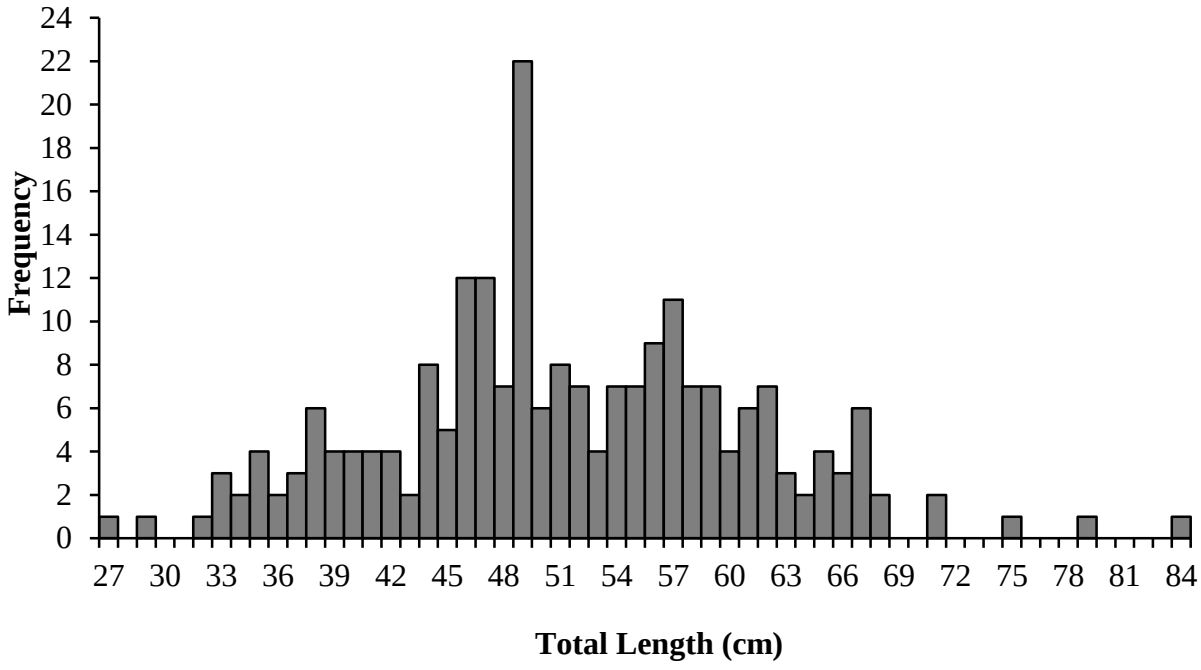

Figure 3: Length frequency distribution of European hake (*Merluccius merluccius,* L. 1758).

Table 1: Length-Mouth gap relation table of European hake (*Merluccius merluccius,* L. 1758).

Hook Number	G* (mm)	N	N%	Total length (cm)		
				Minimum	Maximum	Mean ± S.E.
DK6	17.6	14	6.3	26.8	64.8	39.7 ± 2.41
DK7	15.07	57	25.7	28.2	63	45.02 ± 1.04
DK8	13.61	114	51.4	34.6	83.1	52.58 ± 0.73
DK9	11.75	37	16.7	40.1	78.9	58.60 ± 1.39

*Hook Gape, S.E = Standart Error

Table 2: Selectivity parameters of European hake (*Merluccius merluccius,* L. 1758).

Model	Parameters	Modal Deviance	*p* -value	Degree of Freedom(d.f.)
Normal location	(k;σ)=(3.409; 8.641)	104.905	0.000008	56
Normal skala	(k_1;k_2)=(3.446; 0.607)	106.024	0.000006	56
Lognormal	(μ_1;σ)=(3.698; 0.171)	105.218	0.000007	56
Gamma	(k;α)=(0.101; 34.545)	104.853	0.000008	56
Bimodal	(k_1;k_2;k_3;k_4;w) (3.414; 0.528; 4.837; 0.649; 0.499)	102.141	0.000005	53

Table 3: Optimum length and spread values of European hake (*Merluccius merluccius,* L. 1758) according to *Bi modal* method.

Hook number	G (mm)	Total Length (mm)	Max Size (mm)	Model Length (cm)	Spread value (cm)
9	11.75	36.82	432.635	40.11	6.20
8	13.61	41.39	562.904	46.43	7.18
7	15.07	48.12	725.168	51.45	7.96
6	17.6	50.71	892.496	60.09	9.29

Discussion

Bi-modal gave the best fit according to selectivity calculations of findings and increase in model length depending on the hook size was determined (Woll *et al*., 2001). Fish which have a mouth gap smaller than the hook gap had low possibility of getting angled. Also fish which have a larger mouth gap than hook gap had the chance to vomit the hook and avoid being angled. This situation was similar to that of our study.

Increase in fish length, weight and selectivity curve width were observed for selectivity curves of European hake when the hook gap increases. According to a formal research result based on European whiting (*Gadus merlangus euxinus* Nordmann, 1840), optimum selectivity lengths for size 20, 16, 12 and 8 hooks were estimated as 13.7, 16.3 / 18.6, 22.4/ 22.5, 32.4, respectively in the method described in Baranov (1948). The same parameters were estimated as 10.3, 13.9, 19.2 and 27.8, respectively in the Holt

(1963) method. A linear relation between mean fish length and hook size was found (Kalaycı, 2001). This linear relation is in agreement with our results that fish length increases as the hook gap increases. The result of the Kolmogorov-Smirnov supported this condition (Table 4). However, small fish can also be caught with large sized hooks due to big mouth gap and large upper jaw of European hake. For this reason hooks should be picked for the intended European hake length. Researchers stated the number of fish caught by longlines decrease as the hook sizes used in tackles increase. On the other hand small size hooks catch more fish than larger hooks (Bjordal, 1981; Erzini *et al*., 1995; Akamca, 2004). There was no significant difference between the catching efficiency of the hooks used in our study. The reason for this fact is European hake's migrant character, not the hook size or type. Optimum catch length according to *bi modal* model was estimated as 60.09 cm for number 6 hook, 51.45 cm for number 7 hook, 46.43 cm for number 8 hook and 40.11 cm for number 9 hook. Legal minimum catch length for the species is 25 cm. According to results, hooks used in this study are selective and have no pressure on this species. However, the European hake stocks are being overexploited and are under high fishing pressure (Çiçek and Avşar, 2010). Because of this fact using number 9 or bigger hooks should be recommended in legal regulations.

Table 4: Kolmogorov-Smirnov test result for comparing total legth frequency distributions between different hook types. Hook 1 and Hook 2 represent the different hook configuration of hook number.

Hook 1		Hook 2		Kolmogrov - Smirnov Test		
Hook No	**N**	**Hook No**	**N**	**D_{max}**	**Critical Values (α=0.05)**	**Decision**
6	37	7	113	0.479	0.257	H_0 recejected
6	37	8	56	0.613	0.288	H_0 recejected
6	37	9	14	0.803	0.426	H_0 recejected
7	113	8	56	0.377	0.222	H_0 recejected
7	113	9	14	0.75	0.385	H_0 recejected
8	56	9	14	0.464	0.406	H_0 recejected

Using innovative and type-specific fishing methods is highly important in maintaining sustainable fishing and also in preventing seabirds, sea turtles, endangered fish and sea mammals; declared by CITES (Convention of International Trade In Endangered Species of Wild Fauna and Flora); getting caught accidentally by fishing gear. Therefore using type-specific hooks and hook sizes in long lines is very important to increase the catch efficiency and selectivity of tackles.

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