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Trotline hook selectivity for the Atlantic Bonito (*Sarda sarda* Bloch, 1793) fishery in the Çanakkale Strait (northern Aegean Sea, Turkey)

by

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Abstract

This study was conducted to determine the selectivity of hooks (galvanized, tin, carbon, nickel) used for Atlantic bonito (*Sarda sarda* Bloch, 1793) in the Gallipoli Peninsula and the Dardanelles during the 2015 and 2018 fishing seasons (spring and autumn). The Atlantic bonito was fished with hooks of size 1/0, 2/0, 3/0, and 4/0. A total of 604 bonitos were caught, including 201 individuals using a galvanized hook, 194 individuals using a tin hook, 158 individuals using a nickel hook and 51 individuals using a carbon hook. A lower catch was obtained with hooks of size 4/0 (42 in total). The highest catch (100 total) was obtained with hooks of size 1/0 and a lower catch (19 in total) was obtained with hooks of size 4/0 in the case of tin hooks. In the case of nickel hooks, the highest catch (63 in total) was obtained with hooks of size 1/0 and a lower catch (eight in total) was obtained with hooks of size 4/0. The optimum catch length and curve width were calculated in relation to the size of hooks. It was determined that all hooks used in the experiments catch below the length allowed for fishing. It was therefore concluded that the use of the largest hooks would be preferable, with size 4/0 being the most suitable for maintaining the continuity of the species.

Key words: Çanakkale Strait, SELECT, hook size, selectivity parameters, hook material

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Introduction

The Çanakkale Strait and the Bosphorus system are important transit points for pelagic fish populations (horse mackerel, mackerel, chub mackerel, bonito and bluefish) migrating from the Black Sea to the Aegean Sea and from the Aegean Sea to the Black Sea for feeding and breeding purposes (Devedjıan 1926; Nümann 1955; Slastenenko 1956). Bonitos are the number one aquaculture producer in Turkey, with a short and intensive fishing season. Bonitos from the Scombridae family are mostly known as marine and mesohaline fishes that perform pelagic, neritic and oceanic migration (Riede 2004). They can be found in all Turkish seas. Bonitos are epipelagic species and can also form larger shoals (Collette & Nauen 1983; Froese & Pauly 2009). In general, they live between 80 and 200 m below sea level (Maigret & Ly 1986). Bonitos can be found in the Eastern Atlantic from Norway to Southern Africa. At the same time, they can be found in the Mediterranean and the Black Sea. Each year, the catch rate for bonitos in Turkey is decreasing. Between 1998 to 2001, Turkey accounted for 50% of the total world bonito catch, which dropped to 25% between 2002 to 2003 (FAO 2005). It increased again between 2011 to 2014, but decreased to 4573 tons in 2015 (TUIK 2015). In 2016, the bonito ranked first with a total of 2.034 kg of catch (Çanakkale Provincial Directorate of Agriculture and Forestry, 2016).

The bonito was listed by the IUCN as a least concern species on the list of endangered species. Worldwide research focuses on fish biology, catch, swimming performance, blood parameters and DNA structure (Rey & Ramos 1986; Oray & Karakulak 1997; Zengin et al. 2005; Campo et al. 2006; Di Natale et al. 2006; Zaboukas & Megalofonou 2007; Valeiras 2008; Ates et al. 2008; Kahraman et al. 2014; Akyasan 2016; Oztekin 2018). However, no studies have been found in the reviewed literature on the selectivity of hooks used to catch bonito with trotlines.

The major predators of this species are dolphin species (Massuti et al. 1998) and larger individuals of *Sarda sarda* due to cannibalism. The bonito is caught with purse seines and trammel nets. It is the most important commercial fish species after anchovy and horse mackerel for purse seiners.

The bonito generally lives in shallow waters of warm seas and always migrates toward the surface for feeding. For this reason, it is usually caught near surface waters (1–30 m) rather than in deep waters.

Çanakkale is the second province with the longest coastline in Turkey – 671 km, hence it is very important for seafood production. There are 9971 fishermen and 835 licensed boats in the province (Çanakkale Provincial Directorate of Agriculture and Forestry, 2016). The study area is also an important fishing area in terms of angling, with 67.6% of the boats registered in the Çanakkale region being 7 m long or smaller. These boats are used in line fishing (Özekinci et al. 2005). In addition, bonitos are also caught with trotlines by small-scale fishermen who are engaged in coastal fishing, which is an environmentally friendly way involving low fuel consumption. Technical features of trotlines vary. Feathers of different colors and hooks made of different materials (galvanized, tin, carbon, nickel) are used. Highly selective fishing gear must be used to ensure sustainable stocks. In this connection, FAO (2000) published a handbook describing selection methods for trammel nets and fishing lines. Recently, research on hook selectivity has been increasing worldwide (Bertrand 1988; Otway & Craig 1993; Erzini et al. 1998; Clarke et al. 2001; Kaykac et al. 2003; Bacheler et al. 2004; Oztekin et al. 2012; Ferrari & Kotas 2013; Brulé et al. 2015; Garner et al. 2016; Gezen 2017).

The selectivity of fishing gear may vary for each species of fish, and even for different populations of the same species in different habitats. In order to achieve maximum efficiency in preserving sustainable stocks, the selection criteria for target species must be known. This study provides the necessary scientific support to determine the selectivity characteristics of trotlines used to catch the bonito – the most fished species in the Çanakkale region, and contributes to the implementation of legal sanctions for the protection of stocks. The study will contribute to future similar studies by assessing the Common Fisheries Policy in the European Union harmonization process, which is necessary for fisheries management, modernization of fishing gear, dissemination of species-specific fishing gear and increasing selectivity characteristics.

Materials and methods

Study Area

The Çanakkale Strait is a special area that connects the Aegean Sea and the Sea of Marmara. Due to this specific location, the Çanakkale Strait is a migration route for some fish, especially migrating pelagic fish, i.e. *Sarda sarda*, *Scomber japonicus*, *Scomber scombrus*. In addition, the catch records show that this region is one of the most important areas for *Sarda sarda* in the Turkish seas. The seasonal migration pattern of *Sarda sarda* indicates that the species migrates from the Black Sea to the Aegean Sea in spring for feeding and returns from the Aegean Sea to the Black Sea in autumn for spawning. As a result of this special pattern, *Sarda sarda* can only be found in spring and autumn around the Çanakkale Strait.

The sampling strategy was designed so as to take account of the duration of the season during which *Sarda sarda* is present in the study area. Samples of the Atlantic bonito (*Sarda sarda* Bloch, 1793) were collected in the spring and autumn seasons between 2015 and 2018 at depths ranging from 1 m to 30 m (Fig. 1).

Figure 1

Study area (northern Aegean Sea, Turkey)

Atlantic bonito (*Sarda sarda* Bloch, 1793) trotlines

Hooks in four different sizes were used (1/0, 2/0, 3/0 and 4/0) in the survey, all of which were straight shank hooks (Fig. 2). White, pink, red, orange and green feathers were used on the hooks. The hooks were made of steel, tin, nickel and carbon. Trotlines and hook sizes used in the present study were selected in accordance with those used by fishermen. Trotlines were used in the study to catch bonitos and all lines had the same features except for hook sizes. A fishing line with a diameter of 0.40 mm was used for snoods

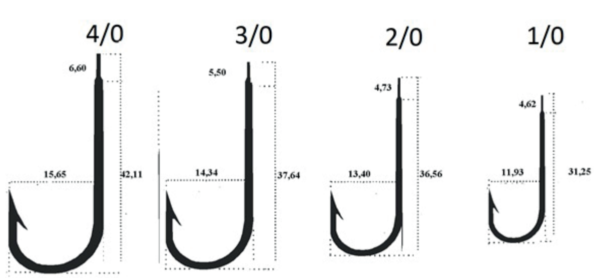

Figure 2

Hooks used for fishing Atlantic bonito and gap measures (mm; hook gaps were determined by calculating the mean value of the gap between 60 hooks in each box)

and 0.60 mm for the mainline. The trotlines were equipped with 60 cm long snoods and the interval between snoods was 150 cm. Depending on the currents and winds, sinkers from 60 and 100 g were used (Fig. 3).

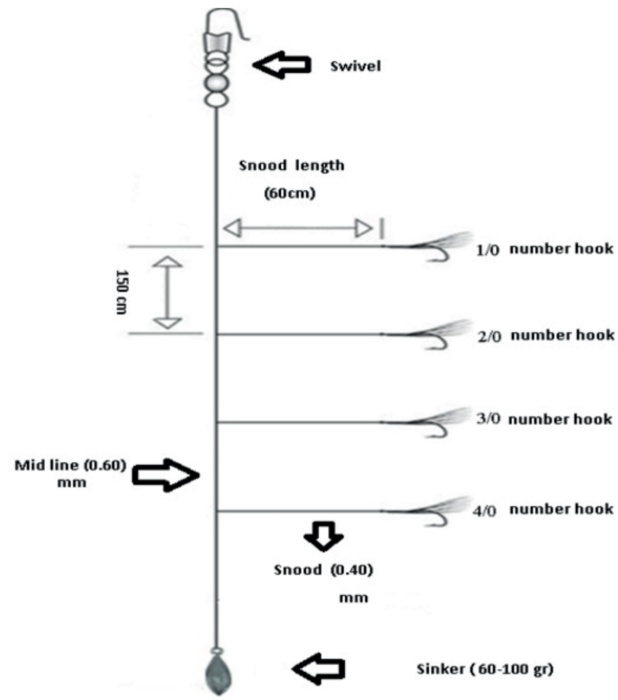

Figure 3

Trotlines used for fishing Atlantic bonito (*Sarda sarda* Bloch, 1793)

In this study, four different trotlines were prepared with five different feather colors and four different hook sizes for each material (galvanized steel, tin, nickel and carbon). Each trotline tackle contained 20 hooks (Fig. 4).

Data Analysis

The SELECT (Share Each Length Class's Catch Total) method was used to evaluate data related to fish hooks (Millar & Holst 1997). This method assumes that the number of fish with a length of *l* and caught with a hook of size *j* has a n_{lj} Poisson distribution, and is defined by Equation 1:

$$n_{lj} \approx n_{lj} \approx Pois\left[p_j \lambda_l r_j(l)\right] \quad (1)$$

where λ_l is the abundance of fish of size *l* caught on a hook; and p_j (l) is the relative fishing intensity (relative abundance of fish of size *l* that can be caught with a hook of size *j*). The Poisson distribution of the number

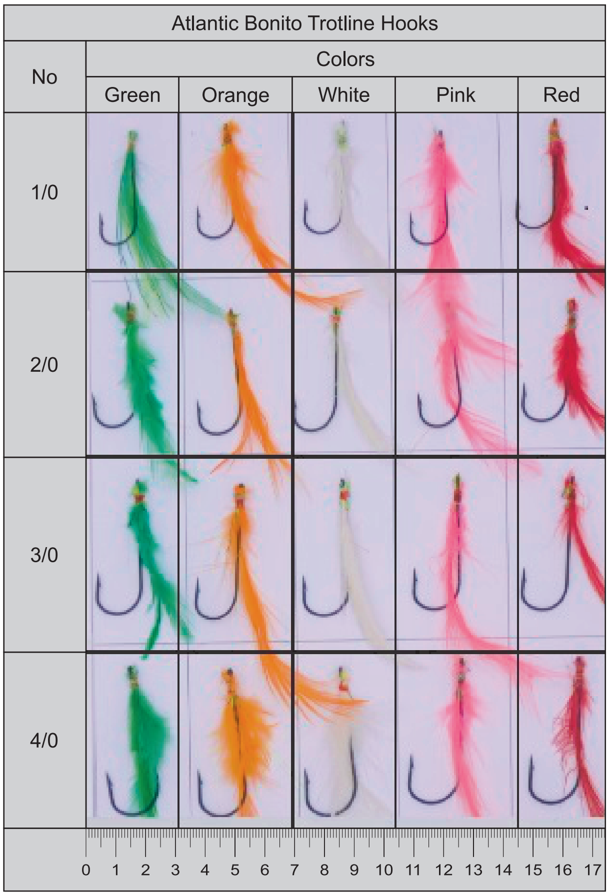

Figure 4

Trotline hooks used for fishing Atlantic bonito (*Sarda sarda* Bloch, 1793) consisting of steel, tin, nickel, and carbon

of fish of size l caught by fishing gear with a hook size j is defined as $p_{j(l)}\lambda_l \cdot r_{j(l)}$, which is a selectivity curve for a hook of size j.

The log-likelihood of n l_j is expressed by Equation 2:

$$\sum_l \sum_j \left\{ n_l log\left[p_j \lambda_l r_j(l)\right] - p_j \lambda_l r_j(l) \right\} \qquad (2)$$

The GILLNET (Generalized Including Log-Linear N Estimation Technique) program (Constant 1998) was used for the analysis of the obtained data. The program calculates the selectivity parameters of five different models (normal location, normal scale, log-normal, gamma and bi-normal) based on the SELECT method and by comparing the model deviances; the lowest one is selected for the best model (Millar & Holst 1997; Millar & Fryer 1999).

The Kolmogorov–Smirnov (K–S) test was used to determine differences in the size frequency distributions of fish caught by hooks of different sizes (Sigeal & Castellan 1989; Karakulak & Erk 2008).

Results

The study has shown that the highest catch for each type of hook material was observed for the smallest hook and the lowest catch – for the largest hook.

For tin hooks, the highest catch was observed for 1/0 hooks (100 ind.) and the smallest catch for 4/0 hooks (19 ind.). Similarly for nickel hooks, the highest catch was obtained for 1/0 hooks (63 ind.) and the lowest one for 4/0 hooks (8 ind.).

Fishing was carried out in spring and autumn, i.e. in the migration season, when the highest fishing activity is observed. A total of 26 operations were performed with four different trotlines; 14 of them were carried out in autumn and 12 in spring. Each operation was performed during 2 h. A total of 604 individuals (167 kg) were caught. The great majority of catch was obtained in autumn with hook size 1/0 and orange feather. The higher catch rate in autumn observed in the study area may be a result of the migration pattern that occurs from the Sea of Marmara to the Aegean Sea. The number of bonitos caught by each differently sized hook, as well as the minimum, maximum, mean lengths and standard errors are presented in Table 1.

The catch size frequency distributions for each hook size used for fishing the Atlantic bonito are shown in Figure 5. Larger hook sizes had a greater mean length of fish caught. As shown in Table 1, an individual with a minimum size of 27.5 cm was caught with steel hook 1/0, while an individual with

Table 1

The number and length values of Atlantic bonito (*Sarda sarda* Bloch, 1793) in relation to hook sizes

Material	Hook size	N	Total length (cm)		
			Minimum	Maximum	Mean ± SE
Steel	1/0	73	27.5	39.5	30.42 ± 0.16
	2/0	51	30	38.6	31.34 ± 0.18
	3/0	35	30	38.7	31.80 ± 0.20
	4/0	42	30.4	44.6	37.86 ± 0.22
Tin	1/0	100	25.6	33.9	30.21 ± 0.14
	2/0	44	28.8	33.9	30.88 ± 0.19
	3/0	31	30.3	34.4	31.56 ± 0.24
	4/0	19	30.9	37	32.79 ± 0.16
Nickel	1/0	63	28.4	31	29.96 ± 0.17
	2/0	50	29.7	38.5	31.30 ± 0.28
	3/0	37	30.1	40	33.42 ± 0.21
	4/0	8	30.3	33.5	31.25 ± 0.24
Carbon	1/0	19	28.7	31.6	29.90 ± 0.13
	2/0	20	30	33.2	30.52 ± 0.19
	3/0	6	30.3	33.4	31.33 ± 0.33
	4/0	6	30.3	32.3	30.95 ± 0.20

*SE standard error

a maximum length of 44.6 cm was caught with steel hook 4/0 (Fig. 5). Individuals with a minimum length of 25.6 cm were caught with tin hook 1/0, while individuals with a maximum length of 37 cm were caught with tin hook 4/0 (Fig. 6). In the case of nickel hooks, an individual with a minimum length of 28.4 cm was caught with hook 1/0, whereas an individual with a maximum length of 40 cm was caught with hook 3/0 (Fig. 7). The best SELECT models were estimated for each hook material. For steel hooks, a bi-modal model was selected with a *p* value of 0.001257. Lognormal modal was selected for tin material with a *p* value of 0.00003, whereas normal scale modal was selected for nickel material with a *p* value of 0.00091 (Table 2).

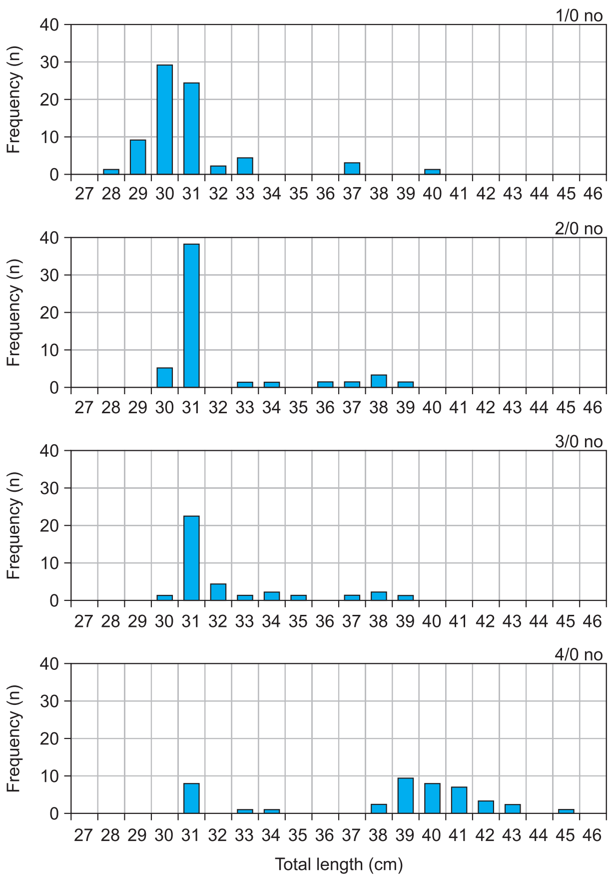

Figure 5

Length frequency distribution of Atlantic bonito (*Sarda sarda* Bloch, 1793) for steel hooks

Modal lengths and distribution values for Atlantic bonito (*Sarda sarda* Bloch, 1793) per each hook size are presented in Table 3 based on bi-modal (steel), log-normal (tin), and normal scale (nickel) models. The modal length increases accurately as the hook size increases. The differences in selectivity between the size of fish for different sizes of hooks were compared

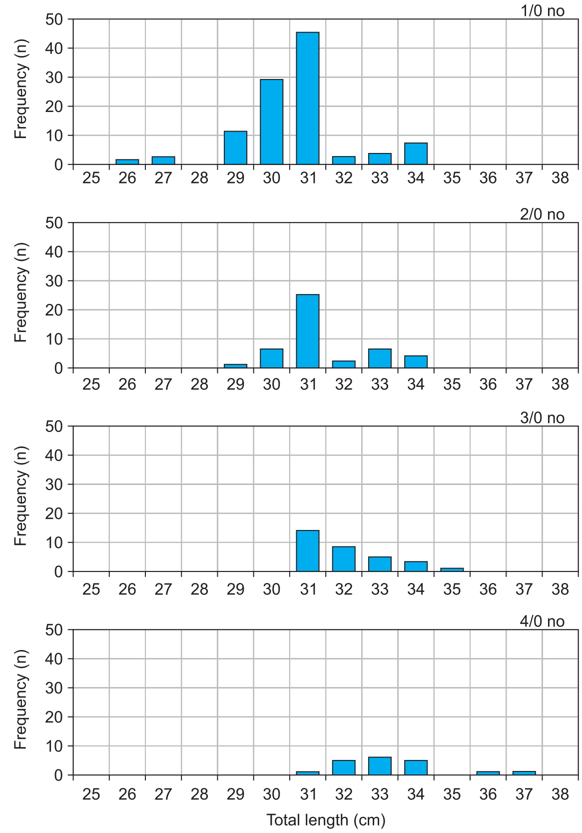

Figure 6

Length frequency distribution of Atlantic bonito (*Sarda sarda* Bloch, 1793) for tin hooks

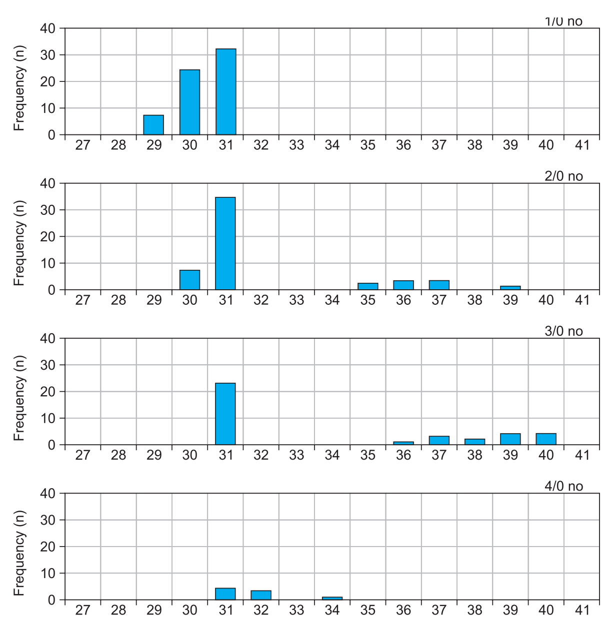

Figure 7

Length frequency distribution of Atlantic bonito (*Sarda sarda* Bloch, 1793) for nickel hooks

Table 2

Estimates of the SELECT model parameters for hook selectivity for Atlantic bonito (*Sarda sarda* Bloch, 1793)

Material	Model	Parameters	Modal deviance	*p*-value	Degree of freedom (df)
Steel	Normal location	(k; σ) = (25.911; 3.364)	69.018	0.000239	33
	Normal scale	(k_1; k_2) = (26.374; 2.772)	75.938	0.000031	33
	Lognormal	(μ_1; σ) = (3.391; 0.102)	69.764	0.000193	33
	Gamma	(k; α) = (0.277; 95.37)	71.709	0.00011	33
	Bi-modal	(k_1, k_2, k_3, k_4, w) = (25.726; 2.082; 33.776; 1.046; 0.248)	58.875	0.001257	30
Tin	Normal location	(k; σ) = (27.487; 4.344)	65.077	0.000007	23
	Normal scale	(k_1; k_2) = (27.784; 3.081)	60.864	0.000029	23
	Lognormal	(μ_1; σ) = (3.435; 0.123)	60.705	0.00003	23
	Gamma	(k; α) = (0.392; 71.688)	60.739	0.00003	23
	Bi-modal	-	-	-	-
Nickel	Normal location	-	-	-	-
	Normal scale	(k_1; k_2) = (25.535; 2.816)	39.536	0.00091	16
	Lognormal	(μ_1; σ) = (3.489; 0.124)	40.48	0.000662	16
	Gamma	(k; α) = (0.359; 71.877)	40.123	0.000747	16
	Bi-modal	-	-	-	-

Table 3

Modal lengths and distribution values for Atlantic bonito (*Sarda sarda* Bloch, 1793) for each hook size

Material	Hook size	Gap (mean) (cm)	Model length (cm)	Distribution value (cm)	Model
Steel	1/0	1.13	29.14	2.35	Bi-modal
	2/0	1.34	34.42	2.78	
	3/0	1.43	36.74	2.97	
	4/0	1.47	37.90	3.06	
Tin	1/0	1.10	19.08	2.11	Lognormal
	2/0	1.22	23.10	2.56	
	3/0	1.38	23.92	2.65	
	4/0	1.49	30.46	3.37	
Nickel	1/0	1.27	13.64	1.53	Normal scale
	2/0	1.36	16.51	1.86	
	3/0	1.45	17.10	1.92	
	4/0	1.66	21.77	2.45	

using the Kolmogorov–Smirnov test. The analysis showed that the statistical difference between the size distributions of galvanized hooks of different sizes is significant.

As the size of hooks increases, the size of fish caught increases too ($p < 0.05$). The same results were obtained for hooks made of tin and nickel and the selectivity was significant ($p < 0.05$). As fewer fish were caught with hook 4/0 containing only nickel material, this type of hook was not taken into account when comparing the length of fish caught using other hooks made of the same material.

Atlantic bonito selectivity curves for each hook size are presented in Figure 8 based on bi-modal (steel), log-normal (tin), and normal scale (nickel) models.

Discussion

In this study, the selectivity parameters were calculated for hooks made of galvanized, tin and nickel material. When the calculated optimum catch length was analyzed (Tables 1, 2 and 3), different model lengths and distribution values were calculated for each material. The largest optimum catch size was calculated for the galvanized (steel) hook. This is thought to be caused by the difference in the size distribution of hooks made of different materials. In another study, the optimum catch size for hooks 1/0, 2/0, 3/0 and 4/0 was calculated as 20.98–29.85 cm (Oztekin et al. 2015). In our study, the results obtained for nickel material showed similarity with the results of Oztekin et al (2015).

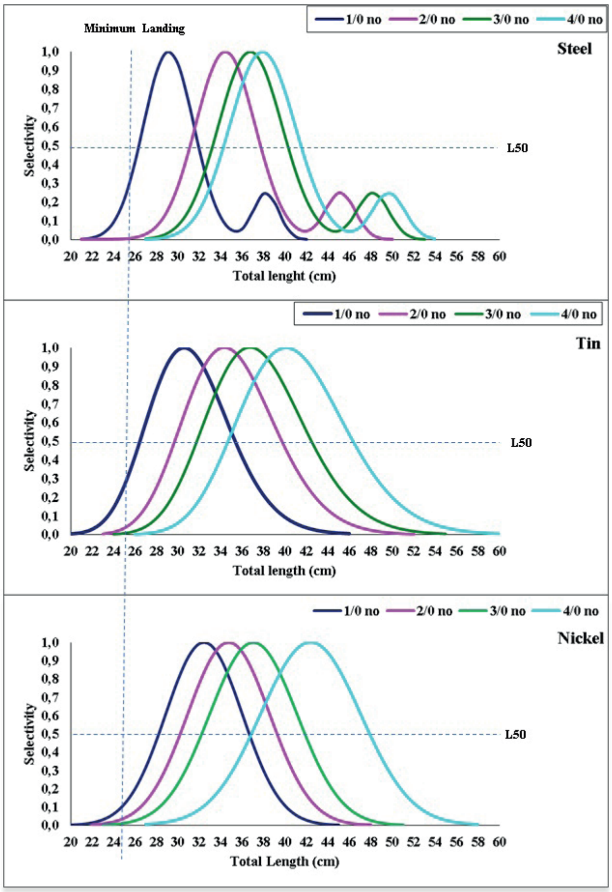

Figure 8

Selectivity curves of Atlantic bonito for each hook size in relation to the bi-modal (steel) model, the log normal (tin) model, and the normal scale (nickel) model

The fisheries regulations in Turkey define the legal catch size for bonito as 25 cm. In the study conducted in the Black Sea and the Sea of Marmara, the first maturity length was calculated as a total length of 45 cm for female individuals and 39 cm for male individuals (Kahraman et al. 2014). The first maturity length was determined as 35.8 cm for males and 41.9 cm for female individuals around the Gallipoli Peninsula and the Dardanelles (Çanakkale Strait; Cengiz 2013). The calculated modal lengths for hooks 1/0, 2/0 and 3/0 showed that they are not suitable for *Sarda sarda* in terms of the first maturity lengths. Specimens from the lower class of length were most often caught with these hooks. In this respect, only hooks 4/0 could be accepted as sustainable fishing gear. On the other hand, it was observed that the type of hook also affects the desired catch length. Steel hooks could be accepted as the most suitable types of hooks, whereas nickel hooks are the worst. Tin hooks were sustainable only in size 4/0.

It was determined that all hooks used in the tests caught fish under the first maturity length except for steel hooks. The same pattern was determined in the study conducted for *Sarda sarda* in the same area (Özekinci et al., 2012). In that study, the authors calculated lower modal lengths for hooks size 3, 2, 1, 1/0, 2/0, 3/0, 4/0, 5/0 and 6/0.

It is crucial to determine the selectivity of fishing gear to be used in the design and development of fisheries management plans and to ensure their sustainability. To prevent undesired lengths and fish species being caught, it is necessary to increase the selectivity of fishing gear in order to contribute to the conservation of natural stocks. Research on hook selectivity has generally focused on the effects of different hook sizes on the length distribution of individuals caught (Zaragoza et al. 1989; Souso et al. 1999; Çekiç & Başusta 2004; Erzini et al. 2006; Öztekin 2012). On the other hand, there are studies related to different shapes of hooks, especially J-hooks and circle fishing hooks (Cooke et al. 2003; Akamca 2004; Woll et al. 2001; Kaykaç et al. 2003; Kara 2008; Ward et al. 2009; Patterson et al. 2012; Brulé et al. 2015).

Most fishermen prefer hooks that provide high catch rates and do not cause much damage when retrieving fish. The catch results for steel material that was used in our study show that it can be a useful type of material in trotline fisheries. Mouth dimensions of fish should be considered when fishing with trotlines, as the size and mouth openings of pelagic fish species vary.

For this reason, a hook that has been assessed as suitable for a given species in terms of selectivity may show low or extreme selectivity for other species. In order to design a more efficient hook in terms of selectivity, the species behavior with respect to mouth openings and the hook material to be used should first be determined (Oztekin et al. 2014).

Based on the data analyzed in our study, it was determined that the use of 4/0 and/or larger hooks would be recommended in terms of stock sustainability. The study also shows that as the size of hooks used on the trotline decreases, the total catch rate increases as the hook mouth width becomes smaller. The first maturity lengths of bonito in our region were determined as greater than 35.8 cm TL (Cengiz, 2013). On the other hand, the number of mature fish (> 35.8 cm TL) caught increased with increasing hook size. The results of this study showed that the catch number varies with hook material. Steel hooks should be used for trotlines due to their greater catch capacity. Therefore, care should be taken to select a special type of hook and hook size in order to avoid non-target length catch on trotlines.

Finally, if the minimum catch length remains unchanged, some legal regulations, such as length selectivity and control of fishing pressure, could not be introduced and the stock sustainability would be even more compromised. Alternative fishing methods, such as trotlines and fishing rods, should therefore be encouraged and studies should be carried out to determine the selectivity of these types of fishing gear.

In order to establish a standard for fishing gear, emphasis should be placed on the selection and use of materials for the production of fishing gear. In this way, better fisheries management policies can be implemented using fishing gear that is less harmful to the environment and provides greater yields.

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