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Investigation of the Interaction Between Bottom Gillnet Fishery (Sinop, Black Sea) and Bottlenose Dolphins (*Tursiops truncatus*) in Terms of Economy

Sedat Gönener[1,*], Süleyman Özdemir[1]

[1] Sinop Üniversitesi, Su Ürünleri Fakültesi Avlama ve İşleme Teknolojisi Bölümü, 57000, Akliman, Sinop.

* Corresponding Author: Tel.: +90.368 2876265/246 ; Fax: +90.368 2876255;
E-mail: sedatgonener@hotmail.com

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Abstract

The present study was carried out in the Sinop Bay between April 2007 and February 2008 where intensive red mullet (*Mullus barbatus*) fishing activities were conducted by use of commercial bottom gill nets. For the purpose of the study, dual-core (black and white) two signal system SaveWave® acoustic devices and 2 pieces of multifilament bottom gill nets, each with a length of 1500 m and mesh size of 17 mm, were used. One of the experimental nets is a non-equipped control net and the other was a net bearing acoustic devices (active net). According to the results of the study, catch per unit effort (CPUE) was 0.96±0.10 kg/km.h with active nets whereas it was 0.50±0.06 kg/km.h with control nets (P<0.05). Moreover, the damage occurred on control nets was 69.8% higher than active nets. On the contrary, the biomass of control nets was determined to be 34.4%. Usage of acoustic devices for commercial fishing was demonstrated to bring a profit of 3.30TL/km.s otherwise each fishing boat to make an average loss of 2191.72 TL throughout the season.

Keywords: Pinger, Fisheries, Gillnets, Dolphins, Black Sea.

Dip Solungaç Ağı Balıkçılığı (Sinop, Karadeniz) ve Şişe Burun Yunuslar (*Tursiops truncatus*) Arasındaki Etkileşimin Ekonomik Açıdan İncelenmesi

Özet

Bu çalışma, Nisan 2007 ve Şubat 2008 tarihleri arasında ticari dip solungaç ağları ile barbunya (*Mullus barbatus*) avcılığının yoğun olarak yapıldığı Sinop iç liman bölgesinde gerçekleştirilmiştir. Araştırmada, siyah ve beyaz çekirdekli, çift sinyal sistemine sahip SaveWave®marka akustik cihazlar ve ağ göz açıklığı 17 mm olan 2 adet 1500 m uzunluğunda multifilament, dip solungaç ağları kullanılmıştır. Deneme ağlarından biri cihazsız (kontrol) ağ olup, diğeri akustik cihazlar ile donatılmış (aktif) durumdadır. Araştırmada elde edilen bulgulara göre birim çabada av miktarları cihazlı ağlarla 0.96±0.10 kg/km.s, kontrol ağlarla 0.50±0.06 kg/km.s olarak gerçekleşmiştir (p<0.05). Ayrıca denizde kaldığı birim zamanda cihazsız-kontrol ağlarda oluşan hasarların, cihazlı ağlardan %69.8 daha fazladır. Buna karşılık kontrol ağ grubundaki biyomasın %34.4 olduğu belirlenmiştir (p<0.05). Bölgede yapılan ticari balıkçılıkta akustik cihazların kullanılması durumunda 3.30 TL/km.s kar edileceği, aksi halde sezon boyunca her bir teknenin ortalama 2191.72 TL zarar edeceği belirlenmiştir.

Anahtar Kelimeler: Akustik cihaz (pinger), Yunuslar, Balıkçılık, Karadeniz, Solungaç ağı.

Introduction

It is reported from many parts of the world that some marine mammals feed on fish caught by fishing gears (Lauriano *et al*. 2004). Killer whales (*Orcinus orca* L. 1758) at the coasts of New Zealand and south of Brazil that prey on tunny (*Thunnus thynnus* L., 1758) or swordfish (*Xiphias gladius* L.1758) setlines (Visser, 2000), killer whales (*O. orca*) and sperm whales (*Physeter macrocephalus* L. 1758) that prey on seabass (*Dissostichus eleginoides* Smitt, 1898) setlines (Nolan *et al*, 2000) in Southern Atlantic and bottlenose dolphins (*Tursiops truncatus* (Montagu, 1821) that prey on set nets and bottom gill nets that are used to catch mullet and mackerel at Mediterranean basin and USA-Atlantic coasts are some examples to this phenomenon (Bearzi *et al*. 2003, Read *et al*. 2004, Cox *et al*. 2003). The bottlenose dolphins inhabiting all over the continental shelves of the Mediterranean basin often cause these interactions because of their extreme opportunistic feeding behaviors (Couperus, 1997; López *et al*. 2005, Lauriano *et al*. 2004). Therefore, the distribution of bottlenose dolphins is closely related to the distribution and abundance of fish which is the target of commercial coastal fishing. Some studies have been carried out concerning these competitive interactions in Greece (Casale *et al*. 1999), Spain (Alonso *et al*. 2000, Lopez *et al*. 2000, Gazo *et al*. 2002) Tunisia (Naceur Lofti, 2000), Italy (Quero *et al*. 2000). This competition between fishermen and dolphins can be examined under two categories. Operational (direct) competition is the interaction between dolphins and the nets used for fishing whereas the ecologic (indirect) competition is the combat for the same nutritional sources and fish stocks (CIESM, 2004, Lauriano *et al*. 2004). Here, in the former situation, various negative results may emerge in the name of fishery economics and protection of dolphins. Dolphins steal the fish entangled in nets and cause a reduction in total catch, give damage to nets and also themselves (Lauriano *et al*. 2004, Cox *et al*. 2003, CIESM, 2004).

It is asserted that a rivalry and a conflict exist between humans and dolphins. They die by drowning in nets or killed immediately after caught alive in the Black Sea that offers significant possibilities to almost each country at the region in terms of fishery sector (Birkun, 2002, Birkun *et al*. 2006, Notarbartolo di Sciara, 2002). Topaloğlu *et al*. (1990), Öztürk (1999), Öztürk *et al*. (1999), Dede (2001), Birkun (2002) and Tonay and Öztürk (2003) conducted several studies in the Black Sea where the dolphins and porpoise, are accused for the reduction in fish stocks, their large population sizes, the damage they give to nets and entangled fish.

As in many parts of the world (Goodson *et al*. 2001, Gazo *et al*. 2002, STECF 2002, Northridge *et al*. 2003, Vernicos *et al*. 2003, Northridge *et al*. 2004), also in Black Sea, some descriptive studies have been executed concurrent with EU council regulation no 812/2004 and with arguments and persisting demands on the interaction of fishermen with dolphins (Gönener and Bilgin 2007, Gönener and Bilgin, 2009). The studies held in Mediterranean, Black Sea and Atlantic demonstrate that the single signal devices are successful in preventing porpoises, (*Phocoena phocoena*) from attaching to the bottom gill nets (Gazo *et al*. 2001, Gönener and Bilgin 2009, Cox *et al*. 2003). However, these single signal devices are reported to be insufficient in sending bottlenose dolphins (*T. truncatus*) away from bottom gill nets since they have an opportunistic and active feeding behavior (Burke, 2004; Lauriano *et al*. 2004). Therefore, in the present study, double signal devices have been used and the effectiveness of these acoustic devices has been investigated in discouraging bottlenose dolphins from approaching bottom gill nets. Since fishing by bottom gill nets has been common for long periods in the region (Anon, 2004; Anon, 2011), determination of quantitative product losses because of bottlenose dolphins that is said to be enormous make up the economic aspect of the study. Thus, the information obtained during the study will fill an important gap as a research aiming to prevent the ecologic and operational competition between dolphins and men in circumstances of Black Sea.

Materials and Methods

The cove area of Sinop peninsula ($42^0 00^{'} 54''$N-$35^0 11^{'} 10''$E) where the present study was conducted is a fishery area mainly covered by sea grasses ((*Zostera* spp) and has a substratum structure quite suitable to fisheries by bottom gill nets. The study was carried out in areas of commercial fishing by bottom gill nets at depths between 15 and 35 m between April 2007 and February 2008 (Figure 1).

The research was executed by a 9 meter long commercial fishing boat equipped with a 85 HP engine and the data on depth and substratum structure of the area was obtained by a fish finder device

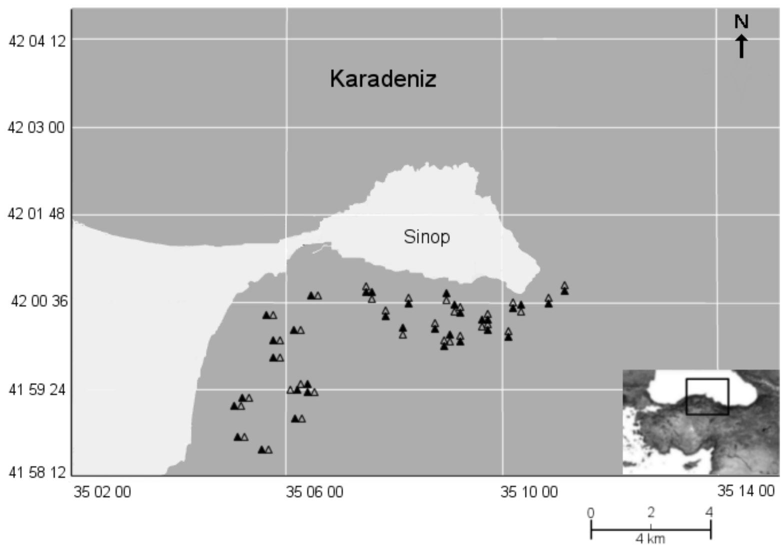


Figure 1. Research area.

"Nakano-Fuso Fec-609N®" available on boat. In the scope of the study, several factors that may affect the fishing course such as depth, bottom structure, wind, daily set-up and haul-out times were taken into consideration. The study period planned to include whole fishing season consisted of 11 months.

Each net set, comprised of those equipped with devices (active or pinger nets) and without devices (control), were set and hauled out on three days of a month coinciding approximately the beginning, middle and end of the month. This process was performed for a total of 33 times for each net set.

Fishnet Features

Each net set was comprised of 11 pieces each with a length of 137 m building up a total length of approximately 1500 m and width (height) of 1.3-1.5 m with 73 meshes. Both net sets were trammel nets. The rope thickness of the multifilament inner net was 23 tex 2 no (PA) with a mesh size of 17 mm whereas the rope thickness of the wide-meshed part of fishnet was 23 tex 4 no (PA) with a mesh size of 110 mm.

Device Features

The SaveWave acoustic deterrent devices (pingers), that are used to keep the dolphins away from bottom gill nets, broadcast sound waves at different frequencies, possess double signal system and have white (5-90 kHz) and black (30-160 kHz) battery cores. They produce randomized and varying signals for 0.2-0.9 seconds with have randomized 4-16 seconds interpulse intervals. The energy of these sound waves (sound intensity) is below 155 dB at 1 µP/m (Fortuna and Northridge 2005).

Supporting foam is available under the outer covering for buoyancy of the device offering a dimension of 202x67x42 mm and weight of nearly 400 gr. Thus, the catch potential of the fishnet is maintained by preventing the cork line to lay down and sink because of the weight of device. Water enters into the device through the openings under the covering where the white or black cores can be seen and enables it to operate (in water) or to stop (out of water). Prior to each operation, the devices were submerged in water and checked whether they gave signal or not.

Each device has an operating time of 2000 hours, a maximum operating depth of 200 m and produce sound waves effective at a horizontal distance of 200m (Fortune and Northridge 2005). A total of 10 acoustic devices (5 with black and 5 with white core) were attached to the floatline of the active fishnet. Two of these devices were positioned 75 meters from the first and the last floaters of the active fishnet and the other eight were located alternately as white and black cores with a spacing of 150 m between them (Figure 2).

Nets were set parallel to coastline as in commercial fisheries but to prevent them to influence the area of the control nets the effective distances of the devices on the active fishnets were also taken into consideration. During the research, the setting and hauling of the nets were executed in daytime as in commercial fishing activities. At the samplings carried out 3 times a month, the beginning and end of the sampling periods, in other words the net setting and hauling times were recorded in order to determine the soak duration. Although it changes depending on months, setting operations were done at sunrise and hauling started at sunset hours. For instance, during the second sampling period at the beginning of the study in April, the nets were usually set at about 06:45 and hauling started at about 16:55. At the end of the study in February, the second sampling was carried out between 08:15 and 15:00 hrs. During each fishing period, dolphins which appear at the vicinity of fishnets were observed via mobile or stationary boats and the number and species of the dolphins were recorded. In order for the soak time (average 9.95±0.19 hrs; minimum 7.05 hrs; maximum 12.00 hrs) of both testing nets to be equalized for the catch operation conducted on the same day the nets which

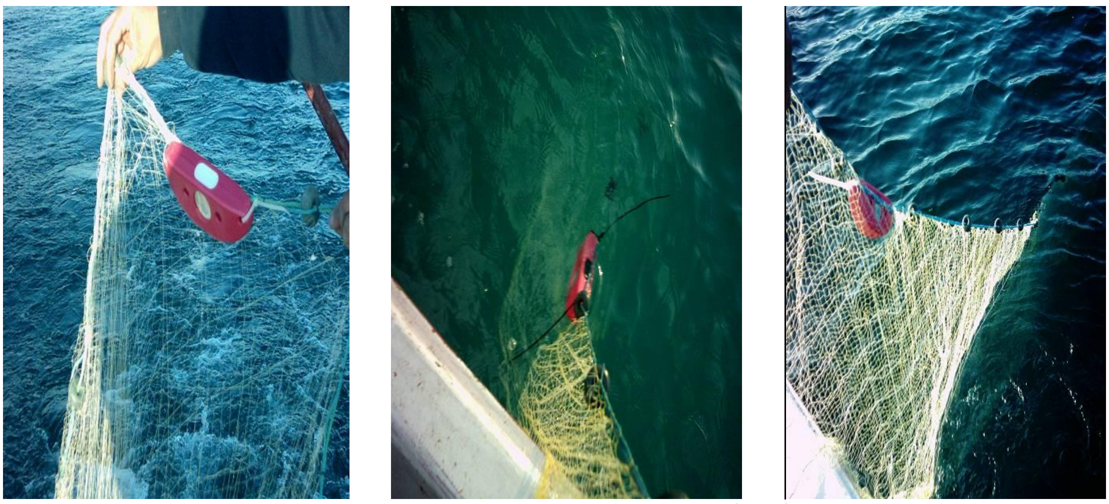


Figure 2. The white and black cored acoustic devices attached to the cork line of the fish net.

were set before were hauled first.

The linear relationship between the occurrence of bottlenose dolphins and characteristic noises because of several fishing activities such as sound of low action engines, hydrolic net reals or cranes was demonstrated (Lauriano *et al*. 2004). Therefore, neither engines nor hydrolic net reals were operated at the time of hauling (Figure 3). The damage caused by dolphins is prominent on nets, fish or fish discards as reported in several studies (Read *et al*. 2004, Lauriano *et al*. 2004). For example, when the thornback rays feed on entangled prey, the fish become exhausted and reveal several fine scars on their body as if they were scratched (Figure 4). The holes and damages observed just on inner net and occurrence of fibrous mesh edges of inner net as if they were cut support this phenomenon. Especially the presence of fish heads or other body parts on nets, bites on these parts and the recentness and texture of these bites are some characteristic signs which provide proof for us to attribute this damage to dolphins (Figure 5). The differentiation of these damages caused by bottlenose dolphins were realized by considering the aforementioned features. Following the hauling of both net sets used in the study, due to the fact that it is not practical to measure all damages one by one on a net of 3000 m (1500x2), three parts of the net, each with a length of 137 m (410 m in total), randomly

Figure 3. Hauling of nets.

Figure 4. The damage caused by thornback rays to entangled fish

Figure 5. Characteristic features suggesting the depredation of dolphins on nets.

chosen from the beginning, middle and end of the whole net were inspected and all holes and tears were recorded. All the ripped parts and holes were cut and repaired by fishermen in order for the net to be re-used for the next sampling.

In both net sets used in the study, exclusively the weight of fish species with a marketing quality was taken into consideration. The formulas below by Burke 2004 (Formula 1), Lifelinda, 2007, Buscaino *et al*. 2009 (Formula 2), Lauriano *et al*. 2004, Gazo *et al*. 2008 (Formula 3) were applied in order to conduct economic analyzes and to determine the CPUE of fish species in both net sets.

$CPUE = C / ST.NL$ [1]

where CPUE is the catch per unit effort (kg/km.s), C is the catch (kg), ST is the soak time (hours), NL is the length of the net (km).

$X = cpue.kgp$, $Y = cpue.kgp$, $Z = (cpue_x.kgp_x - cpue_y.kgp_y)$ [2]

where X is the income (TL) obtained per unit effort via device equipped nets, kgp is the sale price of the fish species (kg/TL), Y is the income (TL) obtained per unit effort via control nets, Z is the profit (TL) per unit effort

$ED = L . l . f . d . p$ [3]

where *ED* is economic loss (TL) of each boat, *L* is the average catch loss of net (kg/km), *l* is the daily average net length (km) used by fishermen (in the area, the daily length of net used by fishermen is comprised of 20 pieces each 137m with a total length of 2740 m ≈2,74 km and *l* was assumed as 2.74 in calculations), *f* is the frequency of interactions with dolphins, *d* is the average time period of catch (days) and *p* is the marketing price (TL/kg) of the catch species.

For the calculations, the market price (*kgp*, *p*)of the catch species was taken as 11 TL/kg for red mullet, 6 TL/kg for whiting fish, 3.5 TL/kg for horse mackerel, 9 TL/kg for scorpionfish, 3 TL/kg for picarel, 10 TL/kg for medium sized bluefish and bluefish.

Assuming that the qualitative and quantitative damage by living organisms other than dolphins are at a negligible level in the study, the catch compositions obtained by use of both fishnets, catch per unit effort and damages observed at fishnets such as ruptures and holes were examined by means of t-test, non-parametric Mann-Whitney U test and sign test, respectively. The Microsoft Excel and Minitab 15 were used for calculations.

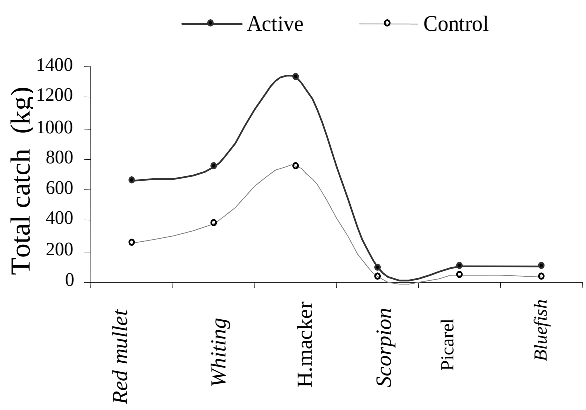
Results

The Effect of Devices on Catch Composition

A large amount of (67.0 %) the total catch of 4554.2 kg achieved during the study was composed of fish caught by means of active nets. Weight of fish caught by means of control nets was 1506.4 kg whereas it was 3047.8 kg for active nets. 72.2% of total red mullet catch of 914.3 kg and approximately 75.0% of total bluefish catch of 139.3 kg were obtained by active nets (Figure 6). For the remaining part of the catch composition, the share of scorpionfish and picarel was approximately 71.0% whereas it was 66.3% and 63.9% for whiting fish and horse mackerel, respectively (Table 1 and Table 2). Significant differences were found for several months between experimental nets in catch of red mullet, which is the target species for bottom gillnets, and for catch of bluefish and scorpionfish offering high market prices (t test $p<0.05$). For example, a catch of 24.2±10.3 kg was obtained by control nets in June whereas this amount increased to 42.67±7.45 kg by using active nets. These increases were observed in August for scorpionfish and in November for bluefish for which catch amounts by active and control nets rising from 1.77±0,66 kg to 7.33±1.59 and from 2.43±0.82 kg to 9.50±3.23 kg, respectively.

The Effect of Devices on Net Damage and Catch Yield

In fishing operations, total fish caught per unit length of active nets per hour was found to be 189.52 kg whereas approximately half of this amount (99.56 kg) was able to be obtained by control nets. Total amount of red mullet caught per unit time (h) was



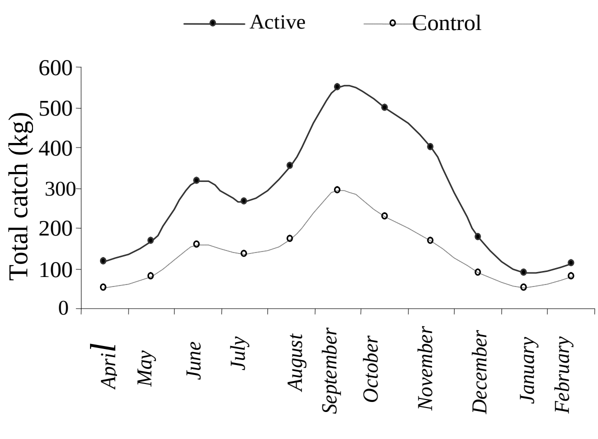


Figure 6. Catch compositions of active and control net sets

Table 1. Catch amount fished by active nets with pingers

	Opr. no	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Total
Red mullet	1	4.6	18.0	32.0	25.0	0.9	1.4	32.0	29.2	19.5	1.5	18.5	
	2	33.0	41.0	57.0	0.8	21.0	22.0	47.0	38.0	4.4	7.0	5.3	660.3
	3	10.0	42.0	39.0	3.0	30.0	21.0	24.0	23.0	3.4	0.3	5.5	
		15.87±8.71	33.67±7.84	42.67±7.45	9.60±7.73	17.30±8.60	14.80±6.71	34.33±6.74	30.07±4.35	9.10±5.21	2.93±2.06	9.77±4.37	
Whiting	1	19.0	22.0	26.0	41.5	36.0	47.0	39.5	11.5	18.5	4.0	23.4	
	2	7.0	13.0	25.5	58.5	55.5	30.5	10.5	2.2	24.0	12.0	4.5	748.9
	3	16.0	0.3	39.0	23.0	49.0	49.0	4.0	10.1	0.9	15.0	11.0	
		14.00±3.61	11.77±6.29	30.17±4.42	41.0±10.3	46.83±5.73	42.17±5.86	28.0±12.0	7.93±2.90	14.47±6.97	10.33±3.28	12.97±5.54	
H. mackerel	1	1.7	11.0	4.5	23.3	38.5	134	90.0	71.5	10.0	30.0	7.0	
	2	4.0	0.0	9.5	4.8	48.0	140.0	127.0	85.0	11.0	8.0	8.5	1329.3
	3	10.0	1.0	40.5	50.0	31.5	60.0	77.0	92.5	75.0	5.0	19.5	
		5.23±2.47	4.00±3.51	18.2±11.3	26.0±13.1	39.33±4.78	111.3±25.7	98.00±15.0	83.00±6.14	32.00±21.5	14.33±7.88	11.67±3.94	
Scorpion fish	1	2.5	3.2	9.3	6.5	7.5	10.5	2.5	0.5	1.5	1.0	5.7	
	2	4.0	2.2	3.0	6.5	4.5	0.5	2.0	0.0	0.0	0.0	1.8	98.2
	3	0.0	1.3	4.2	3.2	10.0	1.2	2.0	0.3	0.0	0.3	0.5	
		2.17±1.17	2.23±0.54	5.50±1.93	5.40±1.10	7.33±1.59	4.07±3.22	2.17±0.16	0.27±0.14	0.50±0.50	0.43±0.29	2.67±1.56	
Picarel	1	1.3	0.7	7.0	11.0	8.3	4.0	3.5	1.6	1.4	0.2	0.2	
	2	3.3	2.6	5.5	4.5	0.2	9.5	8.7	1.4	0.4	0.0	0.0	106.7
	3	0.5	4.3	4.8	4.5	4.4	4.3	1.7	4.5	0.5	1.3	0.6	
		1.70±0.83	2.53±1.04	5.77±0.64	6.67±2.17	4.30±2.34	5.93±1.79	4.63±2.10	2.50±1.00	0.77±0.31	0.50±0.40	0.27±0.16	
Bluefish	1	2.3	2.5	3.6	0.8	2.2	3.9	6.8	14.2	5.2	0.3	0.0	
	2	1.9	0.0	2.1	0.3	1.8	6.5	9.4	11.0	0.2	0.9	0.7	104.4
	3	0.6	0.4	2.2	0.0	3.4	5.8	10.0	3.3	1.4	0.6	0.1	
		1.60±0.51	0.97±0.77	2.63±0.48	0.37±0.23	2.47±0.48	5.40±0.77	8.73±0.98	9.50±3.23	2.27±1.51	0.60±0.17	0.27±0.20	
	Total	121.7	165.5	314.7	267.2	352.7	551.1	497.6	399.8	177.3	87.4	112.8	3047.8

Table 2. Catch amount fished by control nets without pingers

	Opr no	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Total
Red mullet	1	2.1	7.2	44.6	10.3	13.2	0.3	2.0	1.9	8.5	0.7	3.4	
	2	7.7	27.3	11.5	0.3	9.1	2.5	7.0	4.5	2.4	3.6	7.7	254.0
	3	9.4	11.8	16.5	1.6	0.4	5.0	7.4	11.3	1.6	0.0	11.2	
		6.40±2.21	15.43±6.08	24.2±10.3	4.07±3.14	7.57±3.77	2.60±1.36	5.47±1.74	5.90±2.80	4.17±2.18	1.43±1.10	7.43±2.26	
Whiting	1	6.0	7.3	14.2	27.5	29.5	25.4	6.6	2.5	8.2	2.2	18.0	
	2	3.4	7.0	21.0	19.4	26.5	17.5	21.3	1.0	5.3	6.6	2.5	381.3
	3	8.8	0.3	10.5	12.2	18.2	30.0	1.4	6.2	0.3	9.5	5.0	
		6.07±1.56	4.87±2.28	15.23±3.07	19.7±4.42	24.73±3.38	24.30±3.65	9.77±5.96	3.23±1.55	4.60±2.31	6.10±2.12	8.50±4.80	
H. mackerel	1	0.8	2.2	15.8	32.0	22.0	77.5	48.6	54.5	48.0	5.3	9.8	
	2	0.2	6.9	5.0	2.7	18.0	35.5	44.7	36.5	6.6	18.9	13.4	751.7
	3	5.7	0.6	2.5	14.2	26.4	81.3	71.2	38.0	4.2	2.4	0.3	
		2.23±1.74	3.23±1.89	7.77±4.08	16.30±8.52	22.13±2.43	64.8±14.7	54.83±8.26	43.00±5.77	19.6±14.2	8.87±5.09	7.83±3.91	
Scorpion fish	1	0.2	1.5	3.7	0.2	0.5	3.5	2.4	0.7	0.0	0.4	0.2	
	2	1.2	0.0	4.0	3.3	0.5	0.0	1.3	0.3	0.2	0.6	0.7	40.2
	3	1.1	1.5	1.0	1.5	2.5	0.8	1.4	0.4	0.2	0.4	4.0	
		0.83±0.31	1.00±0.50	2.90±0.95	1.67±0.80	1.17±0.66	1.43±1.06	1.70±0.35	0.47±0.12	0.13±0.06	0.47±0.06	1.63±1.19	
Picarel	1	0.4	2.2	1.5	4.5	1.8	2.5	0.7	0.0	0.7	0.5	2.5	
	2	1.5	0.8	2.2	0.8	0.0	2.8	1.9	1.8	0.3	0.2	1.2	44.3
	3	0.2	0.7	1.4	1.2	0.0	4.0	2.5	2.3	0.7	0.3	0.2	
		0.70±0.40	1.23±0.48	1.70±0.25	2.17±1.17	0.60±0.60	3.10±0.45	1.70±0.52	1.34±0.69	0.57±0.13	0.33±0.08	1.3±0.6	
Bluefish	1	0.2	0.2	0.5	1.0	1.3	1.3	1.8	3.0	2.2	0.5	0.3	
	2	0.2	0.5	0.7	0.3	0.5	2.3	2.3	3.5	1.2	0.5	0.1	34.9
	3	0.4	0.7	1.0	1.5	1.5	1.5	2.5	0.8	0.0	0.0	0.6	
		0.27±0.06	0.47±0.14	0.73±0.14	0.93±0.34	1.10±0.30	1.70±0.20	2.20±0.20	2.43±0.82	1.13±0.63	0.33±0.16	0.33±0.14	
	Total	49.5	78.7	157.6	134.5	171.9	293.7	227.0	169.2	90.6	52.6	81.1	1506.4

40.96 kg by active nets and 16.7 kg by control nets. In the study, catch amount of economic fish species such as whiting fish, horse mackerel, scorpionfish, picarel and bluefish was respectively 47.74 kg, 81.14 kg, 6.5kg, 6.78 kg and 6.74 kg by active nets whereas 25.69 kg, 49.21 kg, 2.73 kg, 2.96 kg and 2.27 kg by control nets (Figure 7). Average fish amount caught per unit effort (kg/km.h) varies depending on experimental nets and fish species (Table 3). Catch per average unit effort of particularly red mullet, whiting fish, scorpionfish and picarel caught by use of active nets were generally found to be relatively higher. The difference between average catch amounts is statistically significant (U test $p<0.05$). 84.9% of torn parts and holes per soak time (h) were determined to be on control nets. In another words, 69.8% less damage was reported from active nets. Despite the fact that the damage observed on nets without devices (0.59±0.09 n/h) were more than those with devices (0.11±0.02 n/h), the biomass at the former net set (4.53±0.48 kg/h) was found to be significantly lower than those equipped with acoustic devices (8.62±0.99 kg/h) revealing a percentage of 34.4% (Sing test Z=0.0596 P=0.0199).

It is noted during reparation of all experimental nets that holes and tears smaller than 50 cm constituted 79.5% of control nets and 85.3% of active nets (Table 4). In the scope of the results of the study, the price of fish caught per hour per unit active nets was calculated as 6.82 TL. This amount is approximately 2 times of the cost (3.55 TL/km.h) by use of control nets (Table 5). The price of red mullet caught per unit by active nets is 13.64 TL/km.h whereas it is 5.61 TL/km.h by control nets. The difference as 8.03 TL/km.h implies the economic rantability obtained per unit effort (km/h). In the study period of 33 days bottlenose dolphin occurrence was recorded totally 6 times in the area (*f:0.18*) on the 3rd

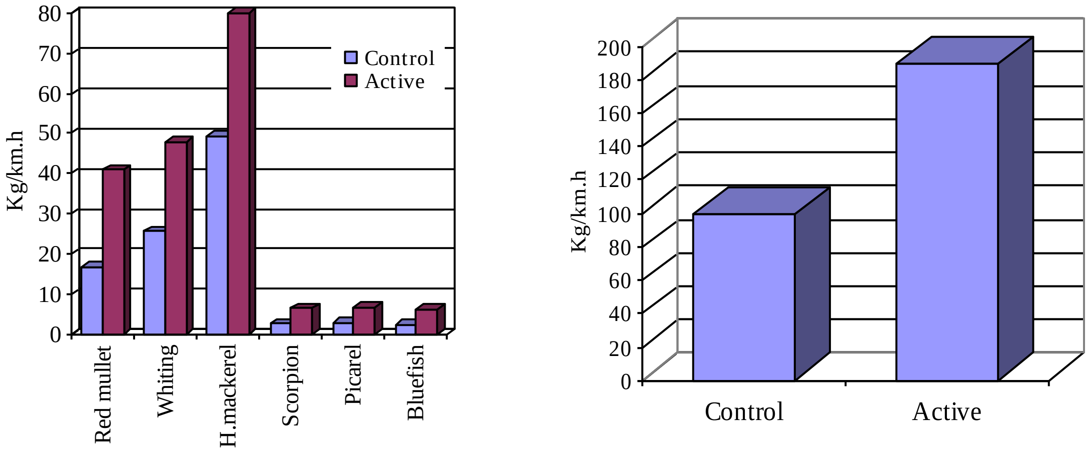


Figure 7. Catch per unit effort of active and control net sets.

Table 3. Catch per unit effort in net sets (kg/km.h)

Species	Active net	Control net	
	Mean.±SE		*P*
Mullus barbatus ponticus	1.24±0.19	0.51±0.09	0.016
Gadus merlangus euxinus	1.45±0.20	0.78±0.11	0.021
Trachurus mediterraneus	2.46±0.46	1.49±0.26	0.275
Scorpaena porcus	0.20±0.03	0.08±0.02	0.044
Spicara smaris	0.21±0.03	0.10±0.01	0.044
Pomatomus saltatrix	0.19±0.04	0.07±0.01	0.058
Total	0.96±0.10	0.50±0.06	0.001

Table 4. Number and size of damages observed on experimental nets

Size(cm)	Control net Mean±SE	*n*	Active net Mean±SE	*n*
<20	13.73±0.49	77	13.51±1.09	21
20-49	36.95±1.02	78	37.00±2.10	8
50-99	74.62±4.23	24	71.50±16.6	3
>100	143.96±8.22	16	130.10±6.60	2

day of April, 12th day of July, 13th day of August and 19th day of October via nets without devices and on 8th June and 21th October via nets equipped with devices. One of these two encounters occurred at hauling of control nets during the III. operation in April (18:30, 3rd day) and the other during hauling of active nets with devices at the III. operation in October (19:10, 21st day). It was observed that catch season continued for 5 months and generally 20 pieces of bottom gill nets (1:2.74 km) were installed on fishing boats in the area where the study was conducted (Table 6). The calculations performed for all economic fish species caught by use of bottom gill nets revealed that total loss per boat in the area was 13150.30 TL and the average loss was 2191.72 TL/boat (Table 7).

Discussion

It was reported in previous studies that acoustic devices directly discourage dolphins or prevent them

Table 5. Short term economic evaluation

Species	Active net (TL/km.h)	Control net (TL/km.h)	Rantability (TL/km.h)
Mullus barbatus	13.64	5.61	8.03
Gadus merlangus euxinus	8.70	4.68	4.02
Trachurus mediterraneus	8.61	5.22	3.40
Scorpaena porcus	1.80	0.72	1.10
Spicara smaris	0.63	0.30	0.33
Pomatomus saltatrix	1.90	0.70	1.20
Total	6.82	3.55	3.30

Table 6. Biomass of control nets, the number of damages (recently observed holes-tears) and dolphin occurrence

Months	Opr	Day.	*Dolphin	Control net Biomass (kg/h)	Control net n holes /h	Active net Biomass (kg/h)	Active net n holes /h
April	I.	1	-	1.10	0.44	5.39	0.11
	II.	2	-	1.40	0.00	2.08	0.00
	III.	3	+	2.51	0.78	2.95	0.10
May	I.	4	-	1.85	0.63	5.15	0.00
	II.	5	-	4.20	0.99	5.82	0.00
	III.	6	-	1.35	0.17	4.27	0.09
June	I.	7	-	7.11	0.09	7.30	0.00
	II.	8	+	5.07	1.49	11.73	0.23
	III.	9	-	3.18	0.39	12.59	0.00
July	I.	10	-	7.46	0.10	10.65	0.00
	II.	11	-	2.81	0.42	7.85	0.21
	III.	12	+	3.17	1.08	8.21	0.10
August	I.	13	+	6.20	1.18	8.45	0.00
	II.	14	-	5.28	0.00	12.66	0.19
	III.	15	-	4.79	0.68	12.52	0.49
September	I.	16	-	11.00	0.40	19.98	0.00
	II.	17	-	5.37	0.80	18.49	0.00
	III.	18	-	11.75	0.86	13.52	0.19
October	I.	19	+	6.18	2.29	17.34	0.10
	II.	20	-	7.89	0.10	20.56	0.00
	III.	21	+	7.22	0.50	9.89	0.17
November	I.	22	-	6.87	1.32	14.12	0.11
	II.	23	-	4.28	0.27	12.32	0.18
	III.	24	-	5.85	0.10	13.24	0.00
December	I.	25	-	6.59	0.88	0.81	0.49
	II.	26	-	1.71	0.43	0.70	0.00
	III.	27	-	0.74	0.32	1.42	0.11
January	I.	28	-	0.96	0.69	3.66	0.00
	II.	29	-	3.32	0.55	3.05	0.33
	III.	30	-	1.35	0.11	2.43	0.00
February	I.	31	-	4.86	1.28	7.77	0.14
	II.	32	-	3.53	0.00	2.87	0.14
	III.	33	-	2.57	0.12	4.48	0.00
Mean biomass per hour (±SE)				4.53±0.48		8.62±0.99	
Mean holes per hour (±SE)					0.59±0.09		0.11±0.02

*(+) presence of dolphins;(-) absence of dolphins

Table 7. Seasonal economic loss of a boat using bottom gill nets

Species	*f*	*d(day)*	*l (km)*	*L(kg/km)*	*p (TL/ kg)*	*ED(TL)*
Mullus barbatus	0.18	150	2.74	8.21	11.0	6,681.13
Gadus merlangus euxinus				7.71	6.0	3,422.31
Trachurus mediterraneus				11.67	3.5	1,813.03
Scorpaena porcus				1.17	9.0	571.27
Spicara smaris				1.32	3.0	175.78
Pomatomus saltatrix				1.41	10.0	486.79
Economic damage(TL)						2,191.72

to come closer to nets and reduce bycatch of dolphins by the help of sound waves they broadcast (Gearin *et al*. 2000, Culik *et al*. 2001, Kastelein *et al*. 1995, Kraus *et al*. 1997, Larsen 1999, Cox *et al*. 2001, Barlow and Cameron 2003, Gönener and Bilgin 2009). Lifelinda (2007), Lauriano *et al*. (2004) and Read *et al*. (2004) asserted that dolphins stole the fish entangled to set nets and they might give serious damage to nets and especially to fish leaving only head or some other parts and making it impossible to market them.

The present study carried out considering the mounting evidence about the subject and the persistent arguments of the fishermen in the area represents the preliminary attempt with an aim to investigate the bottlenose dolphin-fishermen interaction in terms of economy. In this context, the efficiency of effective acoustic devices (SaveWave®) was examined and economic losses occurring as a result of ecological competence with bottlenose dolphins were determined. A large amount of fish (67%) caught in the study is composed of those obtained by nets equipped with acoustic devices. 72% of red mullets, 75% of bluefishes, and 71% of scorpionfishes were caught by means of active nets. This is of importance because of high marketing prices of these fish species rendering them as target species of bottom gill nets. Significant differences are observed between monthly catch of fish by use of experimental nets. For example in June, catch amount of red mullet by active nets was found to be 42.67±7.45 kg being 1.76 times more than those caught by control nets. Similarly, catch of scorpionfish by active nets was 4.1 times more (7.33±1.59 kg) in August and catch of bluefish was 3.9 times more in November. Total fish catch per unit effort by active nets was 189.56 kg/km.h and the share of the target species, the red mullet, was %71. Burke (2004) used the same acoustic devices (SaveWave®) on a gill net comprised of 118 pieces, 63 of which were active and 55 were control, for catch of Spanish mackerel (*Scomberomus maculatus*) in North Carolina-Hatteras.

In the study carried out considering catch per unit effort for experimental nets, it was found that acoustic devices were not able to discourage the bottlenose dolphins which prey on nets although catch per unit effort of active nets were 1.27 times higher than the others. In the aforementioned study, similar to the research conducted by Buscaino *et al* (2009) in Mediterranean-Sicily, numbers of tears, holes and damages were considered as a comparing factor other than catch amount. Accordingly, 84.9% (0.59±0.09 *n*/h) of such damages per unit soak time was found to be on control nets. However, biomass in the control nets was only 34.4% (4.53±0.48 kg/h). In both experimental nets, much of the damage was comprised of holes or tears smaller than 50cm. Contrary to Buscaino *et al*. (2009), significant differences were found in this study between active and control nets in terms of damage and biomass.

Table 5 demonstrates the profit by active nets at an average level of 3.30 TL/km.h according to the assessment of net per unit length /unit time. However, when the target species, red mullet is regarded, economic profitability of acoustic device use is high (8.03 TL/km.h) because of the average soaking time of nets (9.95±0.19 h) and the marketing prices. Considering several contributing factors such as frequency of dolphin encounters, length of nets generally used in the area, sale price of target species (TL), and average loss of catch per unit net (km) the economic evaluation of the catch season of the area reveals that loss of each boat using control nets is 2191.72 TL (Table 7). This cost, estimated considering all the species caught, is quite similar to the results (0.48 € = 1TL) obtained in studies carried out in central and northwestern Mediterranean. In the aforementioned studies at Sardinia-Asinara islands in 1999-2001 and at Majorca-Balearic islands in 2001-2003, the economic loss of each fishing boat because of bottlenose dolphins was estimated to be 1.168 € and 1.100 €, respectively (Lauriano *et al*.2004, Gazo *et al*. 2008).

Brotons *et al* (2008a) reported that bottlenose dolphins modestly reduced the total catch revenue of small scaled fishermen to 12.3% and total catch amount (as weight) to 6.5% in Balearic Islands. On the other hand, according to Bearzi *et al*. (2008), the damage given to gears by dolphins during their feeding activity causes loss of time and catch. All the fishermen come up against with economic loss in the areas where seasonal or perennial fishing is carried out and the prices vary depending on the duration of fishing period. For example, fishing season of the target species "red mullet" lasts for 75 days in Balearic islands and approximately 33 days in Asinara islands (Lauriano *et al*. 2004, Gazo *et al*. 2008) making up just 50 and 20% of the fishing period in Sinop. On the contrary, while the market price of red mullet in these islands is 9.8 ≈ 10 €/kg, it is 11 TL/kg in average in Sinop area where the present study was conducted. In this area, economic loss per fishing boat for one season may raise up to 6681.13 TL if red mullet is taken into consideration (Table 7).

As mentioned before by Bearzi *et al.* (2008) the economic loss of fishermen is not just the financial loss because of the reduction in catch of that fishing season but instead it should be considered as the sum of the following:

-damage given to soaked nets during depredation make them impossible to properly operate again in the next fishing seasons and shortens their total expected life.

- Reparation of nets causes labor and time loss.

In many studies, acoustic devices fixed on set nets were reported not to have an effect on the catch composition of nets and not to produce a negative side effect on the fishery of target species (Culik *et al.* (2001), Trippel *et al.* (1999), Kraus *et al.* (1997), Barlow and Cameron, (2003), Carlström *et al.* (2002)). Even in experimental studies by Gazo and Aguilar (2002), acoustic devices were reported to significantly reduce the damages caused by dolphins and to provide an increase in amount of catch. Despite the red lists of several countries such as Balearic Islands and Spain and agreements of Bonn, Barcelona and Bern concerning conservation of dolphins, use of acoustic deterrent devices is legal and also recommended in Western Mediterranean (Jefferson and Curry 1996, Scott, 2007, Gazo *et al.* 2008, Buscaino *et al.* 2009, Additionally, in accordance with the article 812 prepared in the direction of results obtained in the related studies, installation of acoustic devices on bottom gill nets have been made mandatory since 2004-2005 in EU member countries (EUCR 2004). On the contrary, in a study by Zahri *et al* (2004) carried out in three fishing areas with intensive sweep net activities at Morocco-Mediterranean coasts, the annual damage caused by dolphins was determined to reach to 2.1 million Euros and the economical loss per boat approximately to 19.0 %. The fishermen of the area succeeded in reducing their loss initially to 50% and in the next months to 20% by using the 300 kHz acoustic device called "dolphin tube" which is effective in an area with a diameter of 1km. The relative decrease in the efficiency of the device is attributed to the adaptation of bottlenose dolphins to the device and it was notably emphasized that other solutions should be produced instead of using these hand made devices within the framework of respect to international treaties concerning conservation of marine mammals. In the present study conducted at Black Sea-Sinop region, although observed just in one operation (III. sampling in October), depredation of acoustic-active nets by dolphins during hauling is suggestive of most known side effects such as "dinner-bell effect" reported by Bearzi *et al.* (2008) and Brotons *et al.* (2008b) or by habituation and adaptation reported by Dawson *et al.* (1998) and Zahri *et al.* (2004). In our study, the controls made during setting of nets revealed that devices (SaveWave®) should be changed more often. However, this is a negative factor for small scale fishermen using bottom gill nets in the area since it results in multiplication of the already high device costs. On the other hand, it shouldn't be ruled out that common and unregulated use of such deterrent devices can contribute to acoustic pollution sources which are able to cause negative by-effects such as loss of hearing and communication conflicting with main targets of conservation of biodiversity by dissociating dolphins from their habitats (Zollet, 2004; Morton and Symonds 2002; Scott 2007).

As a conclusion, in the present study, significant differences were recorded between the active and control nets in terms of catch per unit or total effort and damage of nets. The differences that occur during depredation of bottlenose dolphins were investigated from the point of short or long term economic results as "profit" or "loss" of fishermen. These results, in concordance with several leading studies carried out in Mediterranean by Lauriano *et al* (2004), Gazo *et al* (2008), and Buscaino *et al* (2009), demonstrate that equipment of acoustic devices on bottom gill nets may have a positive effect providing that the entire risk factors are taken into consideration concerning the conservation of dolphins.

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