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ARTICLE

Assessment of the Relative Catch Performance of a Surrounding Net without the Purse Line as an Alternative to a Traditional Boat Seine in Small-Scale Fisheries

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Abstract
The catch performance of a traditional Ligurian boat seine, which is not in line with the European Union regulation, was compared with an experimental surrounding net without the purse line as a potential legal alternative. The relative catch performance between the two gear types was assessed using a new catch comparison method requiring neither paired data collection nor equal number of hauls with the two gears. The comparison was based on the catches of the three species that comprise the bulk of the catch in traditional Ligurian boat seine fisheries: Bogue *Boops boops*, Saddle Bream *Oblada melanura*, and Blotched Picarel *Spicara maena*. The experimental gear exhibited poor catch efficiency for all three species, since it was estimated that the catches would only be 2, 64, and 6%, respectively, of those with the boat seine. For both Bogue and Blotched Picarel these reductions in catch performance were found to be highly significant proving that the experimental surrounding net is not a viable solution to replace the traditional boat seine.

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The Council Regulation (European Council 2006) which introduced provisions to promote the sustainable exploitation of fishery resources, including technical prescriptions regarding the fishing gear design and use, had profound impact on many small-scale coastal fisheries (Sala et al. 2009, 2011, 2015; Sala and Lucchetti 2010, 2011; Santiago et al. 2015). The boat seine is among the gears affected by the new provisions. This fishery is typical of restricted geographical areas and has traditionally been used along Italy's Ligurian coast in the north-central Mediterranean Sea. Moreover, the fishery has long played an important role in this area, since it not only provided landings and income, but also was closely interwoven into the social and economic fabric: its part-time nature, organization as a family business, and direct relationship with end-users have made it a "traditional" fishery (Repetto et al. 1998; Lucchetti et al. 2014).

The boat seine fleet consisted of fishing vessels having a tonnage up to 10 gross tons (GT), an average length overall of 6.5 m, and 25 kW of engine power (Eigaard et al. 2011). It was a seasonal fishery—typically carried out from November to March depending on fish availability and on its profitability compared with other fisheries—as well as a typical multispecies fishery, with annual landings that in some areas reached 200 metric tons per year. (Repetto et al. 1998). Some target species had a high commercial value, but their landings were limited, e.g., Gilthead Seabream *Sparus aurata*, European Seabass *Dicentrarchus labrax*, other seabreams *Diplodus* spp., and European squid *Loligo vulgaris*. Other, less-prized species like Picarel *Spicara smaris*, Blotched Picarel *Spicara maena*, Bogue *Boops boops*, European Pilchard *Sardina pilchardus*, and Saddle Bream *Oblada melanura* were very abundant. However, catches mostly consisted of small-sized fish such as Transparent Goby *Aphia minuta* and Mediterranean Sand Eel *Gymnammodytes cicerelus*.

Until June 2010, yearly ministerial decrees authorized Ligurian boat seines with 5-mm-mesh opening in derogation to current provisions regarding towed nets (European Council 1994). Then the enactment of European Council (EC) Regulation 1967/2006, which superseded Regulation 1626/1994, involved its adoption without exception of the restrictions applying to bottom trawls, i.e., those having a 40-mm-square-mesh or 50-mm-diamond-mesh cod end, and the prohibition to use these gears within 5.56 km (3 nautical miles) of the coast or within the 50-m isobath where such depth is reached at a distance < 5.56 km from the coast. These provisions have effectively abolished the boat seine fishery, whose catch efficiency relied on small-mesh nets operated in shallow waters at a short distance from the coast.

The present study tested an experimental surrounding net without a purse line that was conceived as a possible replacement to the boat seine and addressed how a change from the traditional boat seine to the surrounding net could affect fisher's catches. The technical features of the experimental surrounding net are particularly well suited for this fishery primarily because, according to the European Union legislation, the minimum mesh size that fishers are allowed to use with this gear is 14 mm, allowing them to catch target species that are usually small in size. Furthermore, the surrounding net without the purse line does not touch the sea bottom (Fonteyne and Polet 2002), which makes it much more "environmentally friendly" compared with the boat seine. Introducing a new fishing method in a fishery requires taking into consideration the fishery's characteristic features (Lucchetti and Sala 2012; Lucchetti et al. 2015), such as vessel design, size, power, and on board technology, gear design and size, fishing practices, and target species and their market value (Sala et al. 2008). Surrounding nets without a purse line are extensively used by small vessels to catch surface-schooling pelagic fish in the Mediterranean Sea. Small surrounding nets are used to catch Dolphinfish *Coriphaena hippurus*, Greater Amberjack *Seriola dumerili*, and Blackspot Seabream *Pagellus bogaraveo* clustering around fish-aggregating devices (Massutì et al. 1999; B. Morales-Nin, L. Cannizzaro, E. Massutì, A. Potoschi, and F. Andaloro, paper presented at the Pêche Thonière et Dispositifs de Concentration de Poissons conference, 1999).

To assess the ability of an experimentally designed net to replace a traditional one, a new methodological approach based on catch comparison analysis was applied to assess the relative catch efficiency between the two gear types.

METHODS

Technical specifications of the traditional Ligurian boat seine.—A typical Ligurian boat seine is depicted in Figure 1.

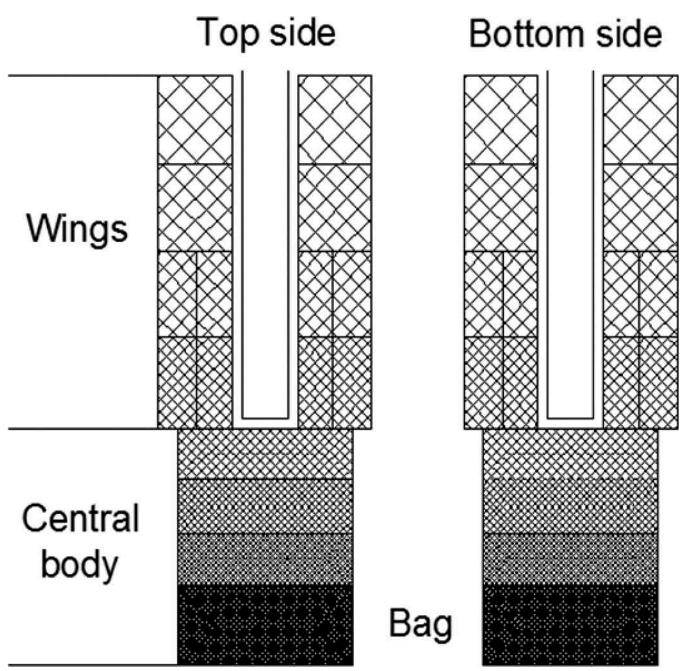

FIGURE 1. Design of a typical Ligurian boat seine. The net has a top and a bottom side (two-face net). It is composed of two lateral portions, or wings, and a central body. Mesh size decreases from the wings to the central body, which is similar to the cod end of a bottom-trawl net.

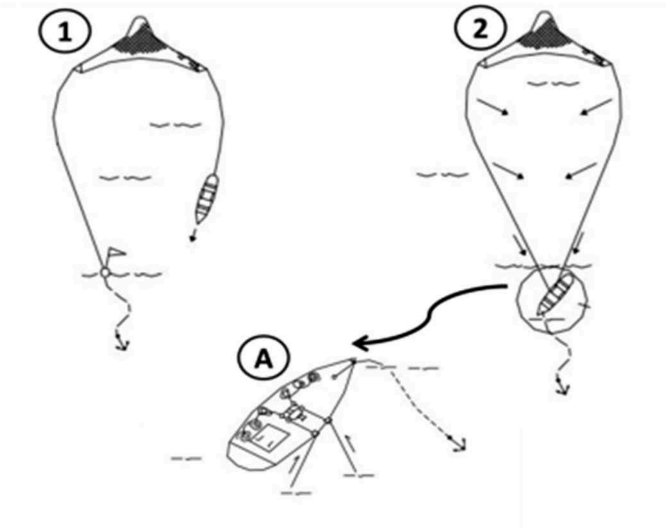

FIGURE 2. Shooting and hauling pattern for a Ligurian boat seine. The boat (A) (1) casts anchor, drops the rope into the sea on the outer side of a fish school; one end has a floater, the other end is attached to the wing; (2) after shooting one wing and the body, the other wing is dropped followed by the second rope, and the boat returns to the site where it cast anchor. The net is then hauled by the ropes attached to the wings.

It is a symmetric net consisting of a central body with a bag and two long wings. Its shooting and hauling phases (Figure 2) involve: (1) casting the anchor, dropping the rope into the sea on the outer side of a fish school; one end has a float, and the other end is attached to the wing; (2) after one wing and the body of the net have been shot, the other wing is dropped followed by the second rope, and the boat returns to the site where the anchor was cast. Finally the net is hauled by the ropes attached to the wings. Hauling speed is controlled relative to the technical specifications of the hydraulic winch.

A number of different Ligurian boat seines were analyzed and measured to gather information that would aid in designing the experimental surrounding net. The seines varied widely depending on vessel characteristics and size. Headrope length ranged from 100 to 300 m and had floats every 5 m; the footrope was slightly longer than the headrope and was rigged with cylindrical lead weights (leads; total weight, 200–500 g/m); wing length ranged from 80 to 160 m; mesh size increased from 18 to 50 mm from the central to lateral portion of the wing; and the cod end was 18–20 m in length and had a very small mesh size (5 mm). The sweeps used during hauling operations ranged from 200 to 300 m, depending on depth. The mesh color of the panels ranged from ochre to garnet, while the cod end was usually dark red. The commercial boat seine net used in the present sea trials had the following features: headrope and leadrope length: 270 and 250 m, respectively; length of wings, body, and cod end: 130, 145, and 15 m, respectively; and sweep length, 200 m.

Characteristics of the experimental surrounding net.—Our intention was to develop a gear comparable in performance and specification to the traditional Ligurian boat seine but that was permissible under EC regulations. The experimental surrounding net was made of black polyamide plastic and had a garnet-colored central cod end. The headrope floats had the same size and buoyancy as the boat seine, but were more numerous, and were placed at 0.25-m intervals to provide greater buoyancy. The leadrope weighed 200 g/m, i.e., less than half that of the traditional boat seine (500 g/m); it had no external leads, and was shorter than the headrope. The main body of the gear consisted of two wings of identical length (178 m) made up of four rectangular panels having different heights, lengths, and mesh size. The cod end (17 m high and 4 m wide; mesh size, 14 mm) formed a scoop during hauling. Unlike common surrounding nets, the experimental net had no sweeps because it was hauled directly from the two lateral bands by short bridles. The experimental surrounding net is depicted in Figure 3.

Sea trials.—Overall, eight valid hauls were performed with the boat seine and six with the experimental surrounding net (Table 1). Seven hauls performed with the surrounding net were discarded due to the malfunctioning of the gear. The hauls were performed on board a commercial fishing vessel having an overall length of 9.36 m, a tonnage of 4.9 GT, and 81 kW of engine power. A hydraulic winch was used to haul the net. Sea trials were carried out in four periods from June to December 2012 along the Ligurian coast in areas traditionally exploited by local fishers (Figure 4). Both gear types were deployed during each of the four periods and in the same area. The fishing gears were fished by local professional fishers. All hauls were conducted with the same fishing vessel, skipper, and fishing crew. The gears were fished one at the time because they applied two different fishing methods that could not be conducted simultaneously with one vessel. This resulted in unpaired catch data for the two gear types. But the type of gear was alternated once in a day or once in 2 d (Table 1). Factors that potentially could have affected the catch performance, such as fishing depth, distance from the shore, and fishing area, were kept as constant as possible, regardless which of the two gear types was fished in a haul. However, the average haul duration differed between the two gear types, but it represented typical deployment times for the gears (39 ± 6.7 min [mean ± SD] for the boat seine and 29 ± 3.7 min for the surrounding net). Therefore a relevant assessment of the relative catch performance between the two gear types can be made based on the catches from the conducted hauls.

Catch comparison analysis.—The study compared the catch efficiency of the traditional boat seine (gear type *a*) with that of the experimental surrounding net (gear type *b*). The study applied a catch comparison methodology proposed by Krag et al. (2014b), but the methodology was further

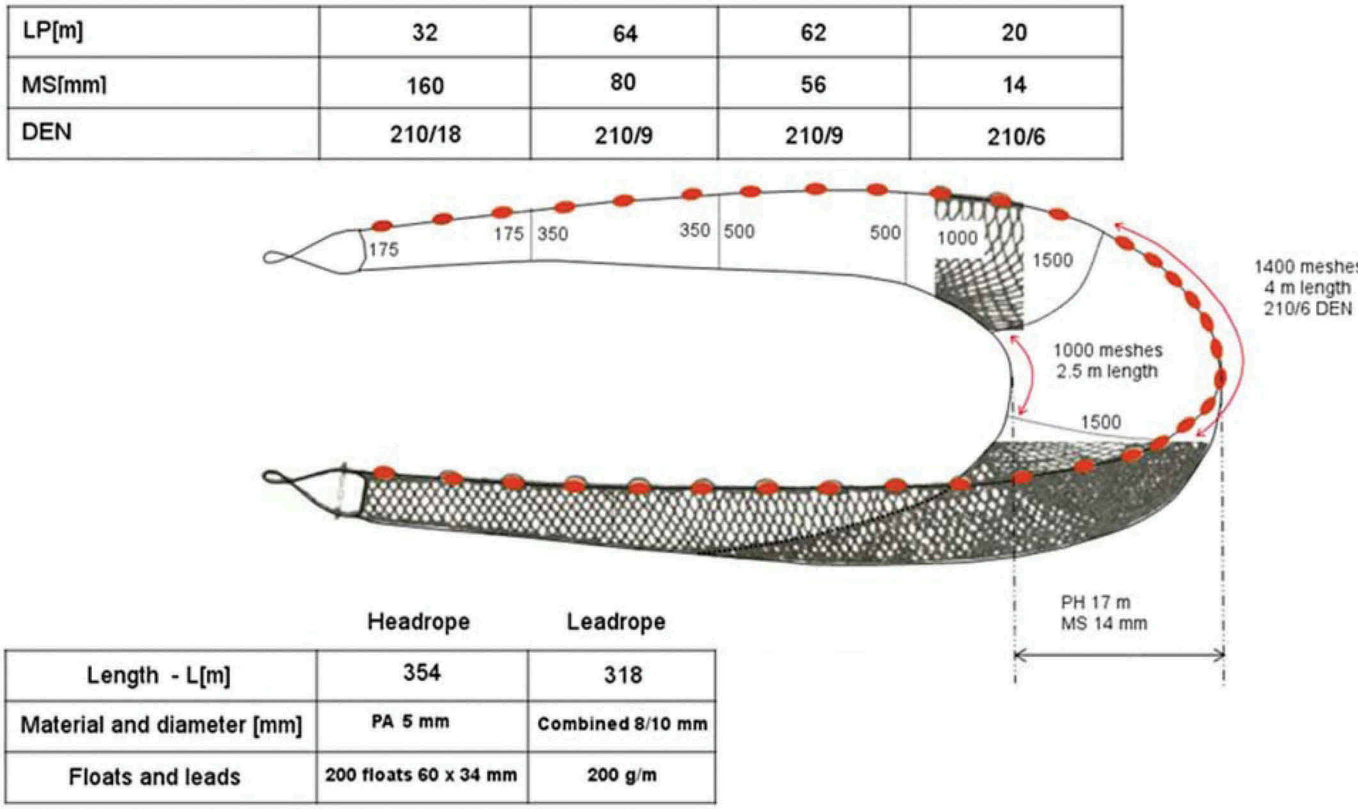

FIGURE 3. Schematic representation of the experimental surrounding net designed to replace the traditional Ligurian boat seine. LP[m]: length of the panels; MS[mm]: stretched mesh size; DEN: material density; L[m]: length of headrope and leadrope; PA: polyamide; PH: panel height.

TABLE 1. Details of the hauls conducted during the sea trials in 2012 to compare efficiency of the surrounding net and the boat seine. BS: boat seine; SN: experimental surrounding net.

Cruise	Date	Gear	Duration (min)
1	Jun 20	BS	43
1	Jun 20	SN	28
1	Jun 21	BS	37
1	Jun 21	SN	34
2	Jul 30	BS	32
2	Jul 30	BS	32
2	Jul 31	BS	47
2	Jul 31	SN	25
2	Aug 1	SN	32
2	Aug 2	BS	33
3	Oct 3	SN	25
3	Oct 4	BS	47
4	Dec 6	BS	45
4	Dec 6	SN	30

developed not to require paired experimental data nor equal number of hauls with the two gears. This enabled the analysis based on the unpaired experimental data collected during the sea trials. Besides gear type, the number and size of fish available may affect catch efficiency at the time of the haul and by haul site. Because of how the sea trials were conducted, we expected that, on average, the same number and size of fish would be available for hauls conducted with each of the two fishing gear tested. We therefore assumed that it would be valid to interpret the catch comparison rate pooled over hauls for the two different gears as a measure of how the two gears performed relative to each other even though the data for the comparison were not collected in pairs.

The following describes the analysis that was conducted individually for each species. The experimental summed catch comparison rate, cc_l, where l stands for fish length, is given by:

$$cc_l = \frac{\sum_{j=1}^{bq} nb_{lj}/qb_j}{\sum_{i=1}^{aq} na_{li}/qa_i + \sum_{j=1}^{bq} nb_{lj}/qb_j}, \tag{1}$$

where na_{li} and nb_{lj} are the number of fish measured in each length class l caught by gears a and b in respective haul i for gear a and haul j for gear b. The terms qa_i and qb_j are the length-independent sampling ratios (the fraction of the catch

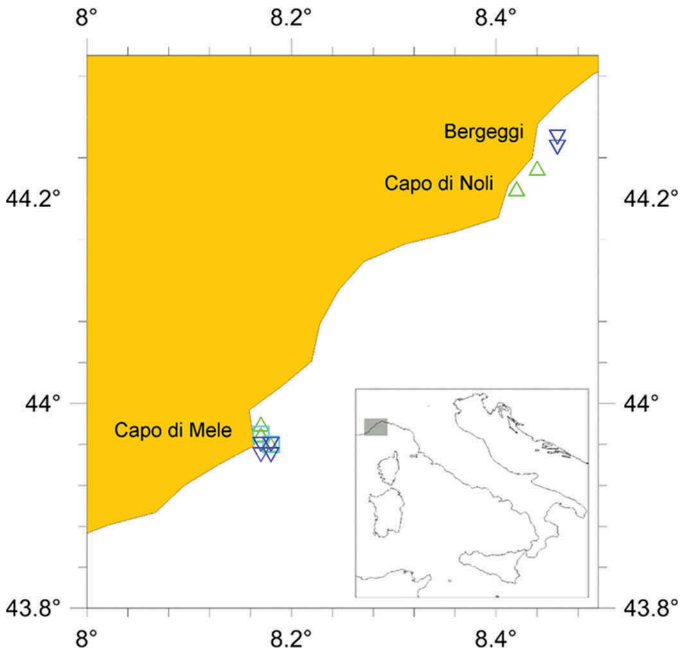

FIGURE 4. Ligurian coast in northern Italy where the sea trials were conducted. Green triangles: hauls with the boat seine; blue triangles: hauls with the experimental surrounding net. *x*- and *y*-axes represent longitude (E) and latitude (N), respectively.

being length measured) for gear *a* in haul *i* and gear *b* in haul *j*. The terms *aq* and *bq* are the number of hauls conducted with gears *a* and *b*, respectively.

If the catch efficiency of gear *a* (Ligurian boat seine) and gear *b* (experimental surrounding net) are equal, and the number of hauls conducted are the same ($aq = bq$), then the expected value of the summed catch comparison rate is 0.5. In case of unequal numbers of hauls, the baseline for no difference in catch performance between the two gear types is $bq/(aq+bq)$.

The experimental cc_l is often modeled by the function $cc(l,v)$, which has the following form (Krag et al. 2014b):

$$\frac{cc(l, v) = \exp(f(l, v_0, \ldots, v_k))}{1 + \exp(f(l, v_0, \ldots, v_k)),} \tag{2}$$

where *f* is a polynomial of order *k* with coefficients v_0 to v_k. Thus, $cc(l,v)$ is the probability of finding a fish of length *l* in the catch of one of the hauls of gear *b*, given that it is found in the catch of one of the hauls of gears *a* or *b*. The values of *v*, describing $cc(l,v)$, are estimated by minimizing equation (3):

$$-\sum_{l}\left\{\sum_{i=1}^{aq}\frac{na_{li}}{qa_i}\times\ln(1-cc(l,v))+\sum_{j=1}^{bq}\frac{nb_{lj}}{qb_j}\times\ln(cc(l,v))\right\}. \tag{3}$$

The inner summations in equation (3) are the summations over hauls conducted respectively with gears *a* and *b*. The outer summation in equation (3) is the summation over length classes *l*. Minimizing equation (3) is equivalent to maximizing the likelihood of the data obtained from the hauls (see Herrmann et al. 2013a for additional information). In equation (2) we considered *f* up to an order of four with parameters v_0, v_1, v_2, v_3, and v_4. Leaving out one or more of the parameters $v_0 \ldots v_4$ provided 31 additional models that were considered as the potential models to describe $cc(l,v)$. Based on these models, multimodel inference was applied to describe $cc(l,v)$ according to how likely the individual models were compared with each other (Burnham and Anderson 2002). We called the resulting model the combined model. In the combined model the individual models were ranked and weighted according to their Akaike information criterion (AIC) values corrected for finite sample sizes (AIC_c) (Akaike 1974; Burnham and Anderson 2002). Models yielding AIC_c values within +10 of the value of the model with the lowest AIC_c were considered to contribute to $cc(l,v)$ based on the procedure described by Katsanevakis (2006) and Herrmann et al. (2015). The ability of the combined model to describe the experimental data were assessed based on the *P*-value, which expresses the likelihood to obtain at least as big a discrepancy as observed between the fitted model and the experimental data by coincidence. Therefore, for the combined model to be a candidate model, the *P*-value should not be below 0.05 (Wileman et al. 1996). In case of poor-fit statistics (P-value < 0.05; deviance $\gg$ df), the deviations between the experimental catch comparison points and the fitted curve were examined to determine whether this was due to structural problems in describing the experimental data with the combined model or due to data overdispersion.

Confidence intervals for the catch comparison curve were estimated using a double bootstrap method. The procedure accounted for uncertainty due to between-haul variation in catch efficiency and in the availability of fish of different sizes by selecting *aq* hauls with replacement from the pool of gear *a*, and *bq* hauls with replacement from the pool of gear *b* hauls during each bootstrap repetition. Within-haul uncertainty in the size structure of the catch data were accounted for by randomly selecting fish with replacement from each of the selected hauls separately. The number of fish selected from each haul was the number of fish length measured in that haul. These data were then combined as described above, and the catch comparison curve was estimated. A total of 1,000 bootstrap repetitions were performed and Efron 95% CIs (Efron 1982) were calculated for the catch comparison curve. By incorporating the above described combined model approach in each bootstrap repetition, additional uncertainty in the catch comparison curve due to the uncertainty in model selection was accounted for.

To determine whether there was a significant difference in catch efficiency between the two gears, we examined for length classes with the lack of overlap between the 95% CI and of the baseline for no difference in catch performance between the two gear types, $bq/(aq+bq)$.

Catch ratio analysis.—The catch comparison rate $cc(l,v)$ cannot be used to quantify directly the ratio between the catch efficiency of gear a versus gear b for a fish of length l. Instead, we used the catch ratio $cr(l,v)$. For the experimental data, the average catch ratio for a length class l was expressed as follows:

$$cr_l = \frac{\frac{1}{bq}\sum_{j=1}^{bq} {nb_{lj}}/{qb_j}}{\frac{1}{aq}\sum_{i=1}^{aq} {na_{li}}/{qa_i}}. \quad (4)$$

Simple mathematical manipulation based on equations (1) and (4) yields the following general relationship between the catch ratio and the catch comparison rate:

$$cr_l = \frac{aq \times cc_l}{bq \times (1 - cc_l)}. \quad (5)$$

This entails that the same relationship exists for the functional forms:

$$cr(l,v) = \frac{aq \times cc(l,v)}{bq \times (1 - cc(l,v))}. \quad (6)$$

An advantage of using the catch ratio, as it is defined by equations (4) and (6), is that unlike the catch comparison rate it provides a direct relative value of the catch efficiency of gear b compared with gear a. Moreover, the way the catch ratio is defined by equations (4) and (6) provides a value that is independent of the number of hauls carried out with each gear. Thus, if the catch efficiency of the two gears is equal, $cr(l,v)$ should always be 1.0 (when we do not consider the difference in the haul duration between the two gear types). For example, $cr(l,v) = 1.25$ would mean that gear b catches, on average, 25% more fish of length l than does gear a, whereas $cr(l,v) = 0.75$ would mean that gear b catches only 75% of the fish with length l compared with gear a. If we take into account that the duration of the hauls with the surrounding net was, on average, 73.42% of that with the boat seine, the catch efficiency of the two gears can be considered equal when $cr(l,v)$ is not 1 but 0.7342. The CI for the catch ratio was estimated using equation (6) and incorporated the calculation of $cr(l,v)$ for each relevant length class into the double bootstrap procedure described for the catch comparison rate. Catch ratio analysis was used to estimate the length-dependent effect of a change from gear a to gear b on catch efficiency.

An average catch ratio value, cr_{avr}, summed over the length classes that were available during the sea trials was estimated using the equation:

$$cr_{avr} = \frac{\frac{1}{bq}\sum_l \sum_{j=1}^{bq} {nb_{lj}}/{qb_j}}{\frac{1}{aq}\sum_l \sum_{i=1}^{aq} {na_{li}}/{qa_i}}. \quad (7)$$

The uncertainty regarding the cr_{avr} value was estimated by incorporating equation (7) into each of the bootstrap iterations described in the previous section. The cr_{avr} value was used to quantify the change in average catch efficiency related to a switch from gear a to gear b. The value is specific for the population size structure that was available to the gear during the trials.

The sequence of analysis described above was implemented in the SELNET software tool (Herrmann et al. 2012), which was used for all analyses. SELNET has previously been applied to analyze size-selectivity data (Sistiaga et al. 2010; Frandsen et al. 2011; Wienbeck et al. 2011, 2014; Eigaard et al. 2012; Herrmann et al. 2012, 2013a, 2013b, 2013c, 2013d, 2015; Madsen et al. 2012; Krag et al. 2014a; Tokac et al. 2014; Sala et al. 2015) and catch comparison data (Krag et al. 2014b) collected with trawls. This is the first time this method was used to analyze catch data of fishing gears such as boat seines and surrounding nets.

RESULTS

The catches of the most abundant species divided by fishing gear and the respective catch rates are reported in Table 2. The traditional gear caught considerably more fish compared with the experimental gear. Bogue, Saddle Bream) and Blotched Picarel were selected for catch comparison analysis because they were the most abundant species in the catches of both gears. Their catch data, disaggregated by gear, are reported in Table 3.

The length-dependent catch comparison rate of Bogue, Saddle Bream, and Blotched Picarel between the two gears was then estimated and plotted (Figure 5). In the catch comparison curves, $cc(l,v)$, the horizontal line is the level representing no effect of the surrounding net compared with the boat seine (thick stippled line in Figure 5).

In Figure 5 the black dots represent the rates obtained experimentally according to equation (2), whereas the thick black curves represent the estimated $cc(l,v)$. From Figure 5 it is evident that for all three species the combined catch comparison curves seem to reflect the trends in the experimental data well. However, the P-values obtained for the model fits for Bogue and Saddle Bream were below 0.05 (Table 4), which could indicate problems in describing the experimental data with the model. Given the lack of systematic patterns in the deviation between experimental points and model curves this was considered to be a case of overdispersion in the data

TABLE 2. Total catch weight and percent of total catch of the main fish species caught by each gear type. BS: boat seine; SN: experimental surrounding net. Data are summed in the Total column. The three species selected for catch comparison analysis (Bogue, Saddle Bream, Blotched Picarel) are indicated in bold text.

	BS		SN		Total	
Species	(kg)	(%)	(kg)	(%)	(kg)	(%)
Silversides *Atherina* spp.	74.41	2.49			74.41	2.2
Bogue *Boops boops*	**1,559.53**	**52.17**	**104.03**	**25.97**	**1,663.55**	**49.07**
Damselfish *Chromis chromis*	10.86	0.36	5.91	1.47	16.77	0.49
Seabream *Diplodus* sp.	3.6	0.12	0.46	0.11	4.06	0.12
Surmullet *Mullus surmuletus*	21.82	0.73	0.06	0.01	21.88	0.65
Saddle Bream *Oblada melanura*	**322.81**	**10.8**	**272.56**	**68.03**	**595.37**	**17.56**
Red Porgy *Pagrus pagrus*	5.37	0.18			5.37	0.16
Salpa *Sarpa salpa*	146.68	4.91	0.64	0.16	147.32	4.35
Gilthead Seabream *Sparus aurata*	4.5	0.15			4.5	0.13
European Barracuda *Sphyraena sphyraena*	21.7	0.73			21.7	0.64
Blotched Picarel *Spicara maena*	**202.58**	**6.78**	**9.83**	**2.45**	**212.41**	**6.27**
Picarel *Spicara smaris*	450.1	15.06	0.1	0.02	450.2	13.28
Black Seabream *Spondylisoma cantharus*	23.7	0.79	0.14	0.03	23.84	0.7
Mediterranean Horse Mackerel *Trachurus mediterraneus*	141.82	4.74	6.9	1.72	148.72	4.39
Total	**2,989.46**		**400.62**		**3,390.08**	

TABLE 3. Catch data for the three selected species (Bogue, Saddle Bream, Blotched Picarel) summed over all hauls. The expected number represents summed and raised values. BOG: Bogue; SBS: Saddle Bream; BPI: Blotched Picarel; BS: boat seine; SN: experimental surrounding net; SD.

	BOG		SBS		BPI	
Data variable	BS	SN	BS	SN	BS	SN
Number of individuals						
Measured	2,566	110	162	223	151	29
Expected	11,431	110	468	223	626	29
Fish length (cm)						
Minimum	4	12	10.5	6.5	11.5	12
Maximum	30	25	32	26.5	21	21
Mean	16.00	18.27	18.71	16.17	16.41	16.57
SD	4.92	3.13	4.81	4.15	2.44	2.37

(Wileman et al. 1996). This overdispersion is further indicated by the considerable amount of binominal noise in the experimental data points (Figure 5).

Therefore, we are confident in making further assessment regarding the difference in catch efficiency between gear types for all three species based on the obtained combined catch comparison curves. For Bogue and Blotched Picarel we found length-class ranges where the CIs for the catch comparison curves were outside the baseline for the equal catch efficiency, unlike what we found for Saddle Bream. These results demonstrate the difference in catch efficiency between the surrounding net and the traditional boat seine. The quantitative difference in catch efficiency between the two gear types is evident from the catch ratio curves (Figure 6).

A horizontal line in Figure 6 at $cr(l,v) = 1.0$ defines the no-effect baseline of the surrounding net compared with the boat seine in the catch ratio curves $cr(l,v)$ (when the difference in deployment time is not taken into account). Because haul duration differed between gears, a dot–dashed horizontal line indicating $cr(l,v) = 0.7342$ was also added to Figure 6 to define the baseline for no difference in the catch efficiency between the two gears (in the case of accounting for the difference in deployment time). The catch ratio curves in Figure 6 for Bogue and Blotched Picarel indicate a generally and markedly lower catch efficiency of the surrounding net, because the catch ratio curves (solid black line) are far below the horizontal lines for $cr = 1.0$ and $cr = 0.7342$ (Table 5). For Bogue the catch ratio was significantly lower than the baselines for length classes up to ~24 cm, while for Blotched Picarel significance was only observed for length classes from ~14–16.5 cm and from ~18.5–20 cm, based on $cr(l,v) = 1$ baseline, or from ~14–16 cm based on $cr(l,v) = 0.7342$ baseline. Contrary to the species mentioned above, the baseline of no effect on catch ratio for Saddle Bream was inside the 95% CI for all length classes and therefore did not show any evidence of difference in catch efficiency between the two gear types for this species. The results

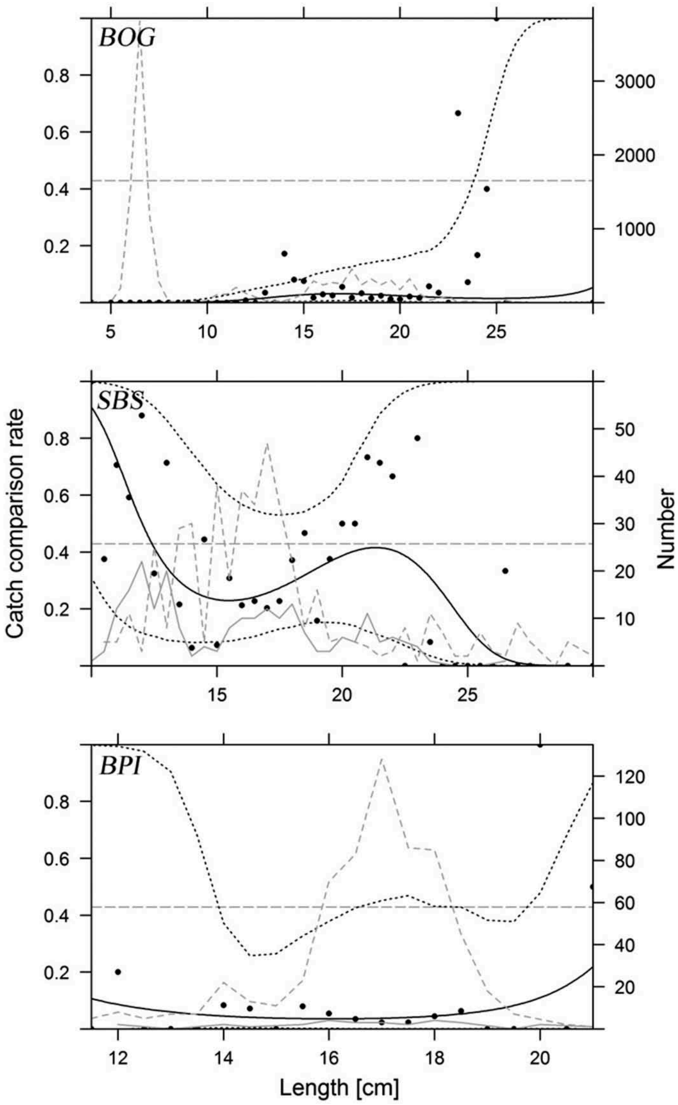

FIGURE 5. Catch comparison rate for the experimental surrounding net versus the boat seine (solid black curves). Dots represent experimental rates. Thin black dotted curves represent the 95% CI for the catch comparison curves. Dark gray solid curves represent summed and raised catch populations for hauls with the experimental surrounding net. Dark gray dashed curves represent summed and raised catch population for hauls with the boat seine. Horizontal dark gray lines represent baselines for no effect of gear type on the catch performance. BOG: Bogue; SBS: Saddle Bream; BPI: Blotched Picarel.

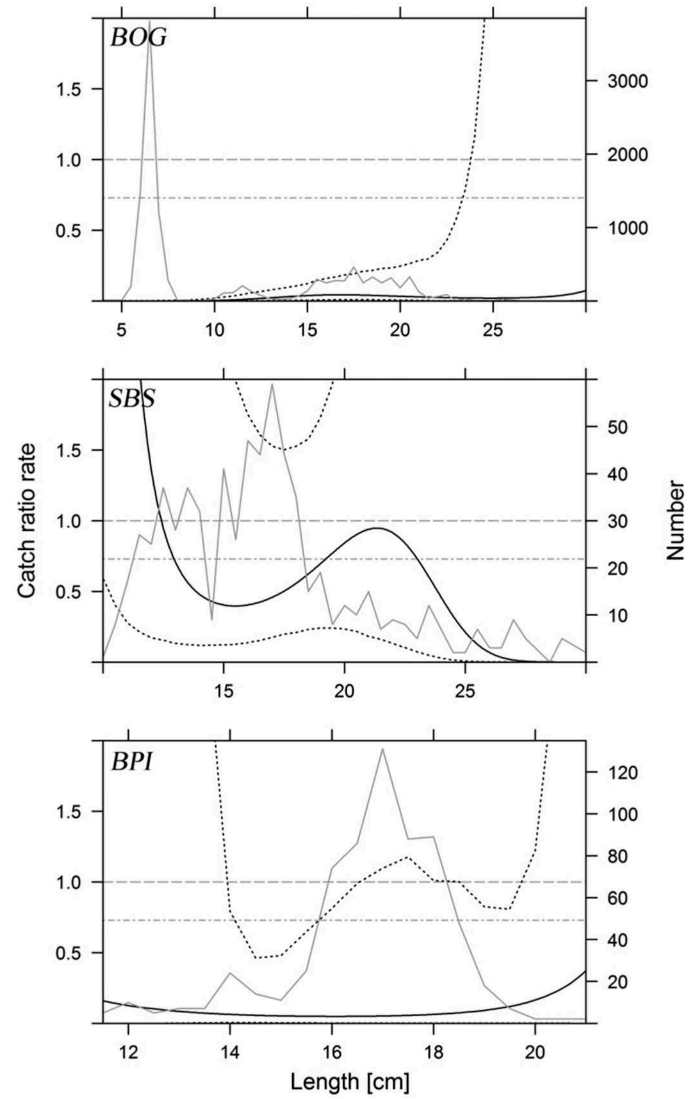

FIGURE 6. Catch ratio curves for the experimental surrounding net versus the boat seine (solid black curves). Thin black dotted curves represent the 95% CI for the catch ratio curves. Dark gray solid curves represent total summed and raised catch populations for both gears. The horizontal dashed dark gray lines define the baseline for no effect on catch performance by changing gear type. The horizontal dot–dashed lines at $cr(l,v) = 0.7342$ defines the baseline for no effect on catch performance by changing gear type when accounting for the difference in average haul duration. BOG: Bogue; SBS: Saddle Bream; BPI: Blotched Picarel.

TABLE 4. Fit statistics for the combined catch comparison curve. BOG: Bogue; SBS: Saddle Bream; BPI: Blotched Picarel.

Statistic	BOG	SBS	BPI
P-value	<0.001	<0.001	0.072
Deviance	96.89	107.80	23.62
df	39	38	15

presented in the Table 5 quantify the relative catch efficiency of the surrounding net compared with the boat seine in terms of the catch ratio. The average catch ratio values for Bogue, Saddle Bream, and Blotched Picarel were 2.37, 63.50, and 6.18%, respectively (Table 5). For Bogue and Blotched Picarel the values were significantly below both the 73.42% and 100% baselines. The difference in average catch efficiency between the two gears is further illustrated in Figure 7.

TABLE 5. Estimated catch ratios values for different length classes of fish species obtained with the combined model with the boat seine used as the baseline. BOG: Bogue; SBS: Saddle Bream; BPI: Blotched Picarel. The values for cr_{avr} are calculated based on equation (7); values in parentheses represent the 95% CI.

Catch ratio	BOG	SBS	BPI
$cr(5,v)$ (%)	3.00×10^{-4} (3.00×10^{-8}–0.12)		
$cr(7,v)$ (%)	0.01 (2.07×10^{-5}–0.27)		
$cr(9,v)$ (%)	0.12 (3.47×10^{-5}–0.96)		
$cr(11,v)$ (%)	0.72 (0.06–3.54)		
$cr(13,v)$ (%)	2.18 (0.25–7.68)	70.7 (13.17–842.16)	8.45 (0.17–1,264.42)
$cr(15,v)$ (%)	3.75 (0.58–12.25)	40.39 (12.12–235.86)	5.25 (0.34–47.85)
$cr(17,v)$ (%)	4.28 (0.92–18.41)	45.77 (17.53–152.64)	5.18 (0.13–109.73)
$cr(19,v)$ (%)	3.71 (0.76–22.93)	69.56 (24.05–172.89)	9.16 (0.11–82.53)
$cr(21,v)$ (%)	2.84 (0.33–28.58)	93.97 (18.22–563.28)	37.24 (0.01–868.01)
$cr(23,v)$ (%)	2.2 (0.11–57.07)	73.38 (7.33–7,127.77)	
$cr(25,v)$ (%)	1.98 (0.05–334.06)	21.16 (0.7–1.89×10^5)	
cr_{avr} (%)	2.37 (0.27–8.78)	63.53 (29.65–184.97)	6.18 (0.96–44.44)
Δcr_{avr} (%)	−97.63 (−99.73–−91.22)	−36.47 (−70.35–84.97)	−93.82 (−99.04–−55.56)

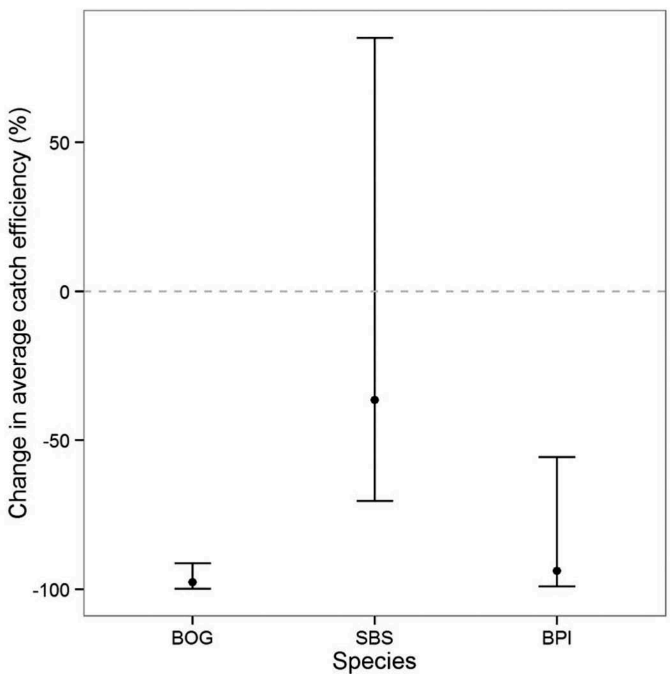

FIGURE 7. Percentage changes in length-averaged catch ratios for Bogue (BOG), Saddle Bream (SBS), and Blotched Picarel (BPI) using the boat seine as the baseline. Vertical bars represent the 95% CI.

DISCUSSION

Each fishery is characterized by a number of distinctive features. When a new fishing method or practice is adopted in a fishery these characteristics need to be taken into consideration, since its effectiveness may be affected by several different factors. The surrounding net without the purse line is used in several Mediterranean countries and fisheries (El-Haweet 2001); therefore, this potentially could have been a suitable alternative to the traditional boat seine, which is no longer legal for use in the Ligurian fishery. The successful introduction of new technology rests on a few simple requirements (Catchpole et al. 2008): the gear should be practical (e.g., it should be easy to use and not expensive to maintain), be acceptable to managers (e.g., enabling achievement of management and biological targets), have low impact (e.g., on the sea bed), and be easily enforceable (e.g., it should be easy to control by inspection agencies). Potentially the surrounding net without the purse line could meet all of those requirements for replacement of the traditional boat seine. The experimental gear exhibited poor catch efficiency for all three species considered (Bogue, Saddle Bream, Blotched Picarel), since it was estimated that the catches would only be 2, 64, and 6%, respectively, of those with the boat seine. For both Bogue and Blotched Picarel this reduction in catch performance was found to be highly significant, proving that the experimental surrounding net it is not a viable solution to replace the traditional boat seine. In contrast, the results obtained for Saddle Bream did not provide any evidence of a difference in catch efficiency between the gears.

The new method tested herein has a broad scope for application, since it can be used to assess the effect of design changes to passive or active fishing gears on catch efficiency, as well as compare the catch efficiency of different types of gears where paired data collection is not possible or too impractical to use.

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