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Contribution to the Symposium: '*Fishery-Dependent Information*'

Original Article

Comparing different survey methods to estimate European sea bass recreational catches in the Basque Country

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This is the first study that estimates sea bass recreational catches in the Basque Country including fishers from shore, boat, and spearfishing. Three different offsite survey methods were used (e-mail, phone, and post) and their performance was compared. Estimates were different depending on the survey method used. Total catch estimates for shore fishing were 129, 156, and 351 tonnes for e-mail, phone, and post surveys, respectively. For boat fishing, estimates varied from 5 tonnes (phone) to 13 tonnes (e-mail and post). For spearfishing, only e-mail surveys were performed and total catch was estimated in 13 tonnes. Potential representation and measurement bias of each survey method were analysed. It was concluded that post surveys assured a full coverage of the target population, but showed very low response rates. Telephone surveys presented the highest response rates, but lower coverage of the target population. E-mail surveys had a low coverage and a low response rate, but it was the cheapest method, and allowed the largest sample size. All surveys methods were affected by recall bias. Recommendations are made about how to improve the surveys (increasing coverage, reducing non-response, and recall bias) to set up a routine cost-effective monitoring programme for Basque recreational fisheries. Results show that estimated sea bass recreational catches are comparable to commercial catches, which emphasize the relevance of sampling recreational fishing on a routine basis and including this information into the stock assessment and management processes.

Keywords: Basque Country, offsite survey method, recreational fishing, sea bass.

Introduction

Recreational fishing is an important social and economic activity in coastal zones worldwide (Cowx, 2002; Pitcher and Hollingworth, 2002). Although it involves a large number of participants and consequently high levels of fishing effort, little attention has been paid historically to the implication of recreational fisheries on fish populations (McPhee *et al.*, 2002). Only when concerns about overfishing have grown, attention has turned towards the impact of marine recreational fishing (Coleman *et al.*, 2004). Several studies have evidenced that the impacts made by recreational fisheries might be comparable with those made by commercial fisheries (McPhee *et al.*, 2002; Coleman *et al.*, 2004; Lloret *et al.*, 2008). These results suggest that management based only on data analysis of commercial fishing may be insufficient to assure the sustainability of the fisheries, and that there is a need to include information on recreational fisheries in stock assessment and management processes (Lewin *et al.*, 2006).

In the European Union, fisheries management heavily relies on scientific advice, and therefore depends on accurate, relevant, and up-to-date data. The collection, management, and use of these data have been regulated since 2001 by the Data Collection Regulation (DCR; EC, 2001) and the Data Collection Framework (DCF; EC, 2008a, b). The DCR determines the obligation of sampling recreational catches of Atlantic salmon (*Salmo salar*) in the Baltic Sea and North Sea, and bluefin tuna (*Thunnus thynnus*) in all areas (EC, 2001). The Commission Decision 2008/949/EU describes in detail the Multiannual EU Programme to support the DCF, and extends the obligation of sampling recreational catches to a number of species depending on the area (EC, 2008c). For the North Atlantic, these species are Atlantic salmon, European sea bass (*Dicentrarchus labrax*), sharks, and European eel (*Anguilla anguilla*). Both regulations make provisions for carrying out pilot surveys to estimate the importance of the recreational fisheries, where relevant. In addition to the obligations set by the DCF, since 2011, Member States should also collect catch data of recreational fisheries for stocks under a recovery plan (EC, 2011).

Recreational fisheries have thus been present in European data collection legislation since its beginnings, but they have not been monitored with the same rigor as commercial fisheries. Since scientific assessments of marine fish stocks in Europe have been focused on the impacts caused by commercial fisheries, these have become the main target for data collection. Additionally, recreational fishers are not required to register their catches, and estimates of recreational catches are difficult and expensive to obtain, requiring methodological approaches that are different from the ones commonly used in European commercial fisheries (ICES, 2010, 2013).

The main difficulties in recreational surveys are due to the large number and diversity of recreational fishers, and to the fact that they do not land their catches at specific points. There are many techniques of fishing (e.g. anglers who surface fish from shore or from private or charter boats or fishers who spearfish while diving). Many anglers release their catch. Some fishers travel far to fish, whereas others fish near their home. Some fish only a few times each year, and others fish almost every day. Additionally, surveys depend on anglers' recall and willingness to volunteer valid information (NRC, 2006).

A large variety of methods is available for surveying recreational fisheries. Different approaches have their own strengths and weaknesses, and are more or less appropriate according to the scale and objectives of each particular survey (Pollock *et al.*, 1994; ICES, 2010). In general, we can distinguish between off-site methods, in which fishers are surveyed after fishing activity has occurred (i.e. phone, mail, and diaries), and on-site methods, in which fishers are interviewed during or immediately after fishing, at locations near the fishing activity (i.e. aerial, access point, and roving surveys). Off-site surveys can be more cost-effective and accessible, and they are used to collect information on recreational effort and harvest in many European member states (ICES, 2010). Their main drawback is that they are known to be associated with several biases, of which coverage, non-response, and recall biases are the most dominant (Tarrant *et al.*, 1993; Connelly and Brown, 1995; Lyle *et al.*, 2002; Vaske *et al.*, 2003).

Effort done in Europe during the last decade to sample recreational fisheries is allowing the integration of recreational fisheries information in the assessment process (ICES, 2013). In 2013 and for the first time, the assessment of western Baltic cod stock included information of both commercial and recreational fisheries (Strehlow *et al.*, 2012; ICES, 2013). In 2014, an estimate of recreational fishing mortality was accommodated in the assessment of sea bass in ICES Divisions IVbc and VIIa, d–h (ICES, 2015).

In the Basque Country, only one attempt has been done before this work to describe boat recreational fisheries (Zarauz *et al.*, 2013), but a more comprehensive approach taking into account all fishing techniques was lacking. This study presents the results of a study conducted in 2012 to estimate sea bass recreational catches in the Basque Country, including fishers from shore, boat, and spearfishing. Additionally, the performance of three different off-site survey methods (e-mail, phone, and post) was compared to determine a routine cost-effective monitoring programme of Basque sea bass recreational fisheries.

Material and methods

Data collection

The Basque coastline extends 176 km. It is situated in northern Spain, and borders with France in the east and the Bay of Biscay in the north (Figure 1). Recreational fishing in the Basque Country has historically been a popular activity, quite related to the cultural roots of this country. The management of recreational fishing depends on the Basque Government, who issues recreational fishing licenses that are mandatory for angling and spearfishing. There are two types of licenses: one for surface fishing (shore and boat fishing) and one for spearfishing. The first one is renewed every 5 years, and the second one, annually. Additionally, for boat fishing, boat owners should register their boats in a specific census.

Data collection was done during the first quarter of year 2012. Three different off-site methods were used to estimate catches made by shore and boat fishers: e-mail, phone, and post. Spear fishers were only contacted by e-mail. A company was subcontracted to carry out the telephone and the post surveys. The e-mail surveys were directly done by AZTI using SurveyMonkey (www.surveymonkey.com).

Contact information for the boat census was not available. Sampling frames were then constructed with the contact information found in the corresponding license census. The surface licence census was used to interview shore and boat fishers. The sampling frames for the surveys were constructed with the available contact information in the census, which was complete for postal address, but incomplete for telephone (19% of total licenses) and e-mail (15% of total licenses). The spearfishing license census was used to build the sampling frame for spearfish. Only e-mail information, which covered a 33% of the total licenses, was used. For post and phone sampling, 500 fishers owning a surface license were randomly selected. When no phone answer was obtained in a household, at least four attempts were done at different times of the day before considering that sample as a non-response. In post surveys, no follow-up contacts were performed. All available e-mails were used to send the e-mail questionnaire, and like in post surveys, no follow-up was carried out.

Table 1 summarizes the available contact information, the sampling coverage, and the response rate for each type of license and sampling method. The gross sample refers to the number of samples selected from the sampling frame. The net sampling is the number of available samples after accounting for sample loss (e.g. invalid contact information and returned mails). A response rate was calculated as the number of fully responding questionnaires divided by the gross sample.

All surveys fall in the category of recall surveys, in which interviewers are asked about an event performed in the past. To minimize the non-response during the survey, €300 were raffled among all participants. Questionnaires were exactly the same among survey methods (e-mail, phone, and post) and fishing techniques (fishers from shore, boat, and spearfishing). Information about the age of fishers, their experience (in number of years), fishing effort (in days), and total sea bass catches in 2011 were asked. Fishing effort refers to total fishing days, although it is know that sea bass catches are very dependent on the gear used. Total catches were collected both in number and weight, without taking into account the

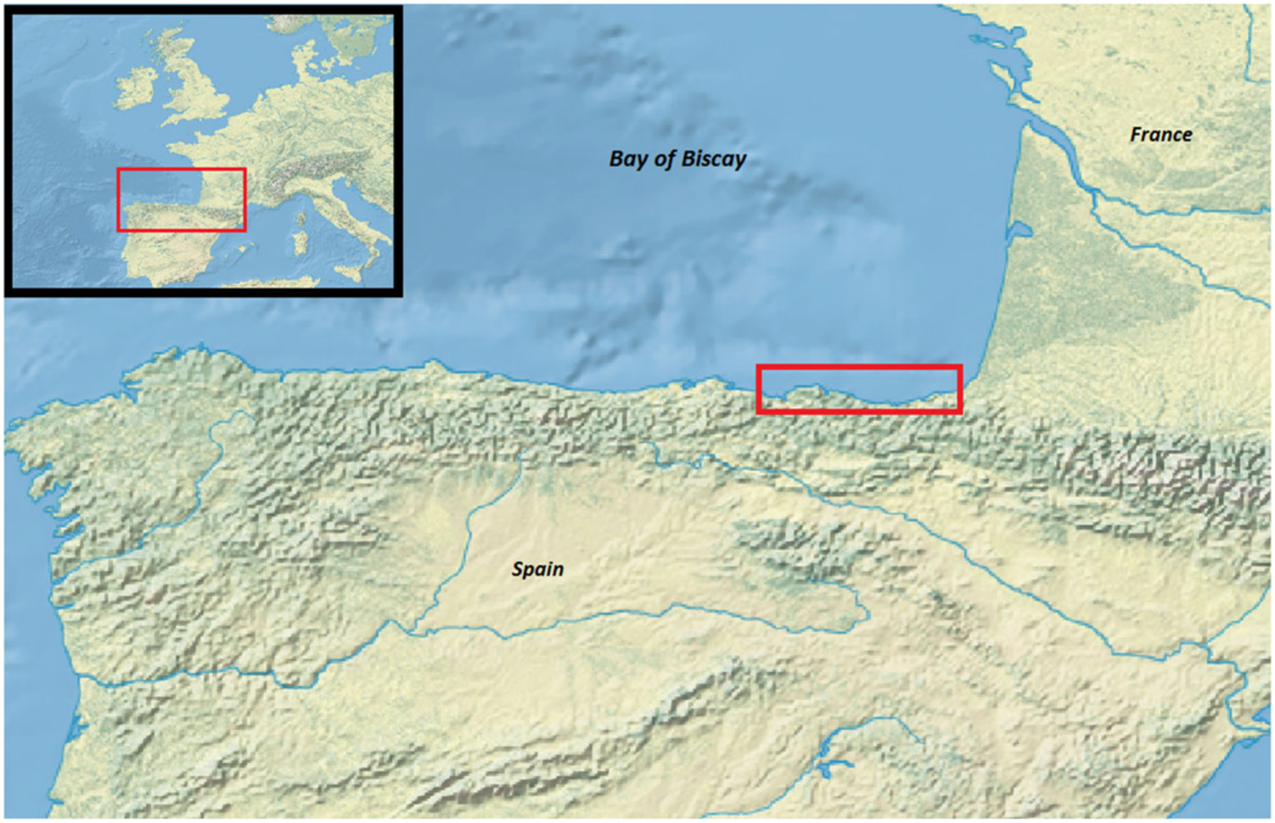

Figure 1. Location of the Basque Country autonomous community in northern Spain.

Table 1. Number of fishers holding a license for surface and spearfishing, contact information available by sampling method, number of samples randomly selected from the sampling frame (gross sample), number of available samples after removing invalid contact information (net sample), number for fully responding fishers and response rate.

License type	Total license holders	Sampling method	Contact information available	Gross sample	Net sample	Fully responding	Response rate (%)
Surface	60 636	E-mail	8877	8877	7283	850	10
		Phone	11 713	500	430	383	77
		Post	60 636	500	487	37	7
Spear	1823	E-mail	599	599	491	117	20

Response rate was calculated as the number of fully responding questionnaires divided by the gross sample.

catch and release. For surface fishers, respondents were first asked if they owned a boat registered for recreational fishing; and if so, two separate questionnaires were filled out: one for shore fishing and another one for boat fishing. Those who did not own a recreational fishing boat were only asked about shore fishing.

Estimation of total catches

The objective was to estimate the total sea bass recreational catches by a fishing technique (shore, boat, and spearfishing), and to identify the effect of the different survey methods on catch estimates.

Total catches were estimated by raising the mean sampled non-zero catch to the estimated total population with non-zero catches. Effort and catch rate estimates, together with their standard error (SE), were also calculated to better understand the results and allow comparisons with other studies.

$$\hat{C} = p_{c\neq 0} \times \bar{C} \times N;$$

where

$$\bar{C} = \frac{\sum_{i=1}^{n} c_i}{n_{c\neq 0}}, \quad p_{c\neq 0} = \frac{n_{c\neq 0}}{n},$$

$$\hat{E} = p_{c\neq 0} \times \bar{E} \times N;$$

where

$$\bar{E} = \frac{\sum_{i=1}^{n} e_i}{n_{c\neq 0}}, \quad p_{c\neq 0} = \frac{n_{c\neq 0}}{n},$$

$$\hat{R} = \frac{\sum_{i=1}^{n} c_i/e_i}{n_{c\neq 0}},$$

where $\hat{C}$ is the estimated total catch of sea bass, $\bar{C}$ is the mean sampled non-zero catch per fisher, and c_i are the non-zero catches reported by fisher. $\hat{E}$ is the estimated total effort (number of days fishing); $\bar{E}$ is the mean effort considering only answers with non-zero catches; e_i is the effort with non-zero catches reported by fisher. $\hat{R}$ is the mean catch rate considering only answers with non-zero catches. N is the total population, that is, the number of individuals with fishing license for shore fishing (60 636) and spearfishing (1823); and the number of boats allowed for recreational fishing for boat fishing (4609; Table 1). n is the number of answers, $n_{c\neq0}$ is the number of answers with non-zero catch, and $p_{c\neq0}$ is the proportion of answers with non-zero catches. Variance and the 95% of confidence intervals of the estimated total catch were calculated following Pollock *et al.* (1994).

For shore and boat fishing, estimates were calculated for the different survey methods independently.

Analysis of bias

Non-response bias was examined (i) by using Wilcoxon Mann–Whitney test to compare the estimates of catches, effort, and catch rates for each survey method, and (ii) by analysing the experience of fully responding fishers and the percentage of answers reporting non-zero catches. Three different classes of experience were defined: low (<10 years), medium (10–20 years), and high (>20 years).

Results

Performance of the surveys

A gross sample of 8877 e-mail, 500 phone, and 500 post questionnaires was sent to shore and boat fishers. A total of 599 e-mail questionnaires was sent to spear fishers (Table 1). Some of these surveys were not valid due to incorrect contact information (i.e. non-existing telephone numbers and returned mails). The net sample of shore and boat fishing surveys conducted by e-mail was 7283, by telephone 430, and by post 487. For spearfishing, 491 valid e-mail surveys were made.

The response rate was highly variable between survey methods. Telephone surveys showed the highest response rate (77%). E-mail surveys presented a response rate of 10% among surface fishers, and 20% among spear fishers. Post surveys showed the lowest response rate (7%).

The three survey methods were also different in terms of costs. It summed €1239 for the telephone survey and €733 for the post survey. The e-mail surveys were sent from AZTI computers, and the total cost of the working time spent by AZTI's staff to perform the surveys is estimated in 700€. These numbers include only the work needed to collect the data. They do not reflect the work time spent designing the survey and managing the data.

Catch, effort, and catch rate estimates

Catch, effort, and catch rate estimates were calculated for each fishing technique (fisher from shore, boat, and spearfishing) and survey method (e-mail, phone, and post). It was observed that for the same fishing technique, the various survey methods gave different estimates.

Shore fishing

The total catch calculated using e-mail, phone, and post surveys was 129, 156, and 351 tonnes, respectively. Mean catch per individual fisher varied from 7 kg in e-mail surveys to 11 kg in post surveys (Table 2a). Mean effort associated with this fishing technique in 2011 ranged from 40 (e-mail surveys) to 47 d (post surveys). The mean catch rate based on e-mail and phone surveys was 0.23 kg d^{-1}, and the mean catch rate based on post surveys 0.22 kg d^{-1} (Table 2a).

Wilcoxon Mann–Whitney test results showed that with 95% of confidence interval, effort and catch distribution data were significantly different between the three survey methods ($p < 0.01$), except for the comparison between catches based on e-mail and post surveys ($p = 0.052$). Differences in catch rates were not significant (Figure 2 and Table 3a).

The experience of respondent fishers was significantly different between e-mail and post ($p < 0.05$), showing that people answering the post survey were more experienced (Figure 2a and Table 3a). Results also show that there were significant differences in effort and catches between people of low and high experience, and low and medium experience (Figure 3 and Table 3b).

The percentage of answers with catches different from zero was similar for e-mail and phone surveys (31 and 29%), but was higher for the post survey (54%; Figure 2a and Table 2a).

Boat fishing

Total catch estimates for boat fishing also varied depending on the survey method used, being 13 tonnes for e-mail and post surveys, and 5 tonnes for phone surveys. Post-based estimates showed the widest confidence interval. Mean catch per individual fisher varied from 7 (e-mail surveys) to 15 kg (post surveys). Mean effort ranged from 36 (phone surveys) to 53 d (post surveys); and mean catch rate from 1 (post) to 7 kg d^{-1} (phone; Table 2b).

Catches estimated using phone surveys were significantly different from those estimated using e-mail and post surveys ($p < 0.01$). Effort estimated using post surveys was significantly different from

Table 2. For shore fishing (a), boat fishing (b), and spearfishing (c); and for each survey method (e-mail, phone, and post): number of answers (n), percentage of answers with non-zero catches ($p \neq 0$), total catch of sea bass (TC), mean catches per fisher (mean C), mean effort per fisher (mean E), and mean catch rate per fisher (mean R), with their standard error (in brackets), and the 95% of confidence intervals of the estimated total catches of sea bass (c_i 0.025 and c_i 0.975).

Survey	n	$p \neq 0$	TC (tonnes)	Mean C (kg)	Mean E (d)	Mean R (kg d^{-1})	c_i 0.025	c_i 0.975
(a) Shore fishing								
E-mail	850	0.31 (0.02)	128.64 (12.09)	6.9 (0.5)	40.4 (2.07)	0.23 (0.02)	127.83	129.44
Phone	383	0.29 (0.03)	155.76 (27.61)	8.9 (1.4)	44.65 (4.46)	0.23 (0.02)	152.67	158.86
Post	37	0.54 (0.08)	351.36 (125.17)	10.7 (3.4)	46.7 (7.4)	0.22 (0.05)	311.04	391.68
(b) Boat fishing								
E-mail	212	0.41 (0.03)	13.47 (2.51)	7.2 (1.2)	41.24 (3.66)	0.2 (0.03)	13.14	13.79
Phone	93	0.08 (0.03)	5.2 (2.53)	15.0 (4.6)	36.71 (9.58)	0.67 (0.35)	4.7	5.71
Post	13	0.38 (0.13)	13.47 (11.56)	7.6 (5.6)	52.6 (19.21)	0.13 (0.06)	7.2	19.75
(c) Spearfishing								
E-mail	117	0.66 (0.04)	12.73 (1.88)	10.6 (1.4)	42.74 (3.84)	0.32 (0.08)	12.41	13.06

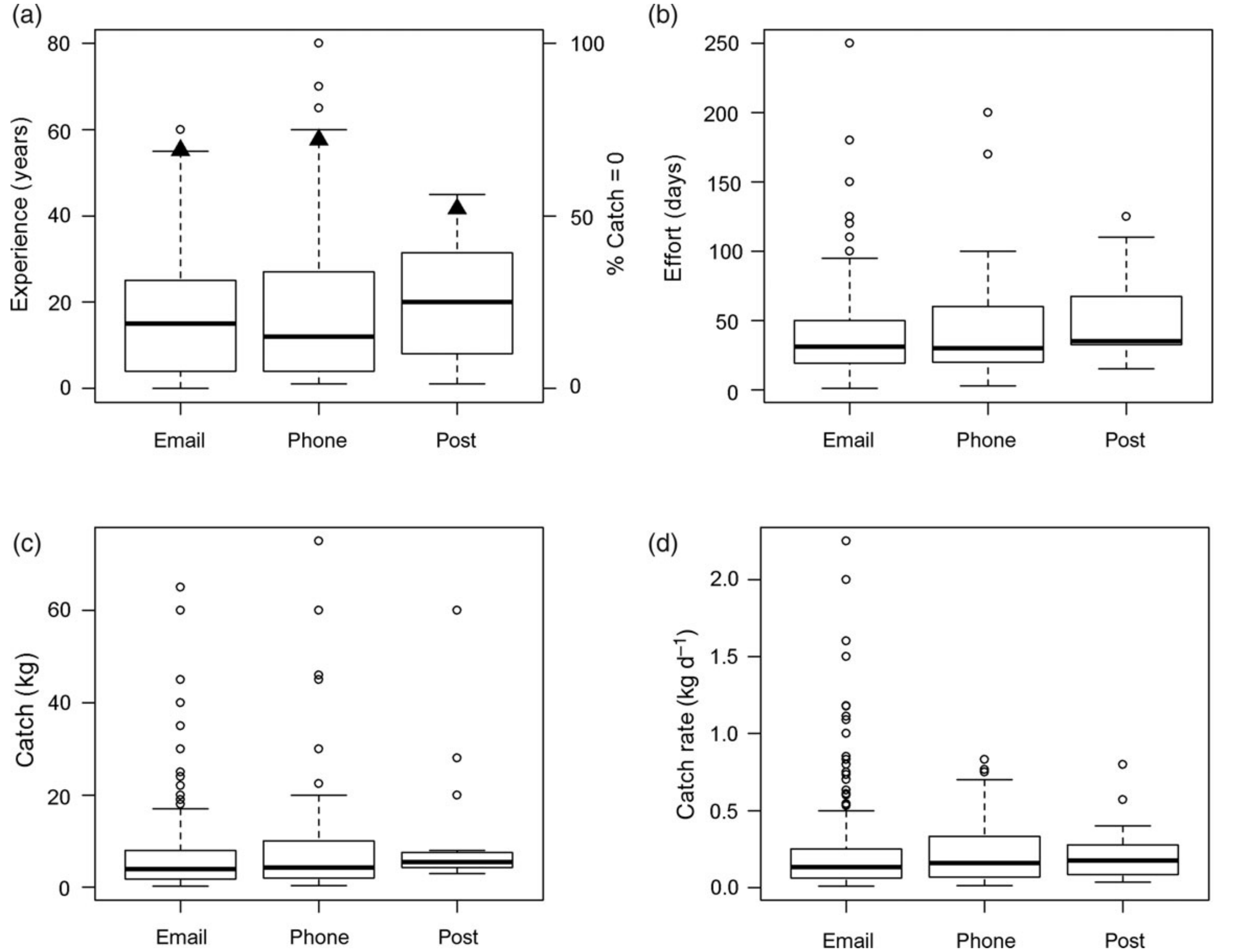

Figure 2. For shore fishing: (a) boxplot showing the experience (in years) of the people interviewed with the three survey methods: e-mail, phone, and post. The triangles show the percentage of the people interviewed with zero catches (secondary axis); (b) boxplot of the effort (in days) reported by people answering the three different survey methods; (c) boxplot of the catches of sea bass (in kg) fished by people answering the three different survey methods; and (d) boxplot of the catch rates (in kg d^{-1}) estimated for people answering the three different survey methods.

Table 3. For shore fishing: (a) Wilcoxon Mann–Whitney test results comparing catches (kg), effort (days), catch rates (kg d^{-1}), and experience (years), estimated using the three survey methods: e-mail, phone, and post. (b) Wilcoxon Mann–Whitney test results comparing effort (days), catches (kg), and catch rates (kg d^{-1}) among people of different experience classes: low (<10 years), medium (10–20 years), and high (>20 years).

	E-mail–phone		**E-mail–post**		**Phone–post**	
(a) Wilcoxon Mann–Whitney test results comparing						
Catches	$W =$ **109 977**	$p <$ **0.01****	$W =$ 10 024	$p =$ 0.052	$W =$ **7129**	$p <$ **0.01****
Effort	$W =$ **116 199**	$p <$ **0.001*****	$W =$ **8901**	$p <$ **0.01****	$W =$ **7704**	$p <$ **0.001*****
Catch rates	$W =$ 10 519	$p =$ 0.201	$W =$ 2515	$p =$ 0.747	$W =$ 834	$p =$ 0.722
Experience	$W =$ 98 235	$p =$ 0.764	$W =$ **9600**	$p <$ **0.05***	$W =$ 6708	$p =$ 0.060
	Low–med		Low–high		Med–high	
(b) Wilcoxon Mann–Whitney test results comparing						
Catches	$W =$ **32 303**	$p <$ **0.001*****	$W =$ **57 944**	$p <$ **0.001*****	$W =$ 37 193	$p =$ 0.082
Effort	$W =$ **35 035**	$p <$ **0.05***	$W =$ **64 341**	$p <$ **0.001*****	$W =$ 37 912	$p =$ 0.216
Catch rates	$W =$ 7013	$p =$ 0.063	$W =$ 11 578	$p =$ 0.106	$W =$ 5465	$p =$ 0.552

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Significant differences (p 0.05) are highlighted in bold.

the other two ($p < 0.001$). There were no significant differences between the experience of people that fully responded to the interview (Table 4 and Figure 4).

The percentage of non-zero catches related to e-mail surveys was 41%. For phone surveys, this percentage was the lowest (8%), and resulted in only seven answers with non-zero catch (Table 2b). In

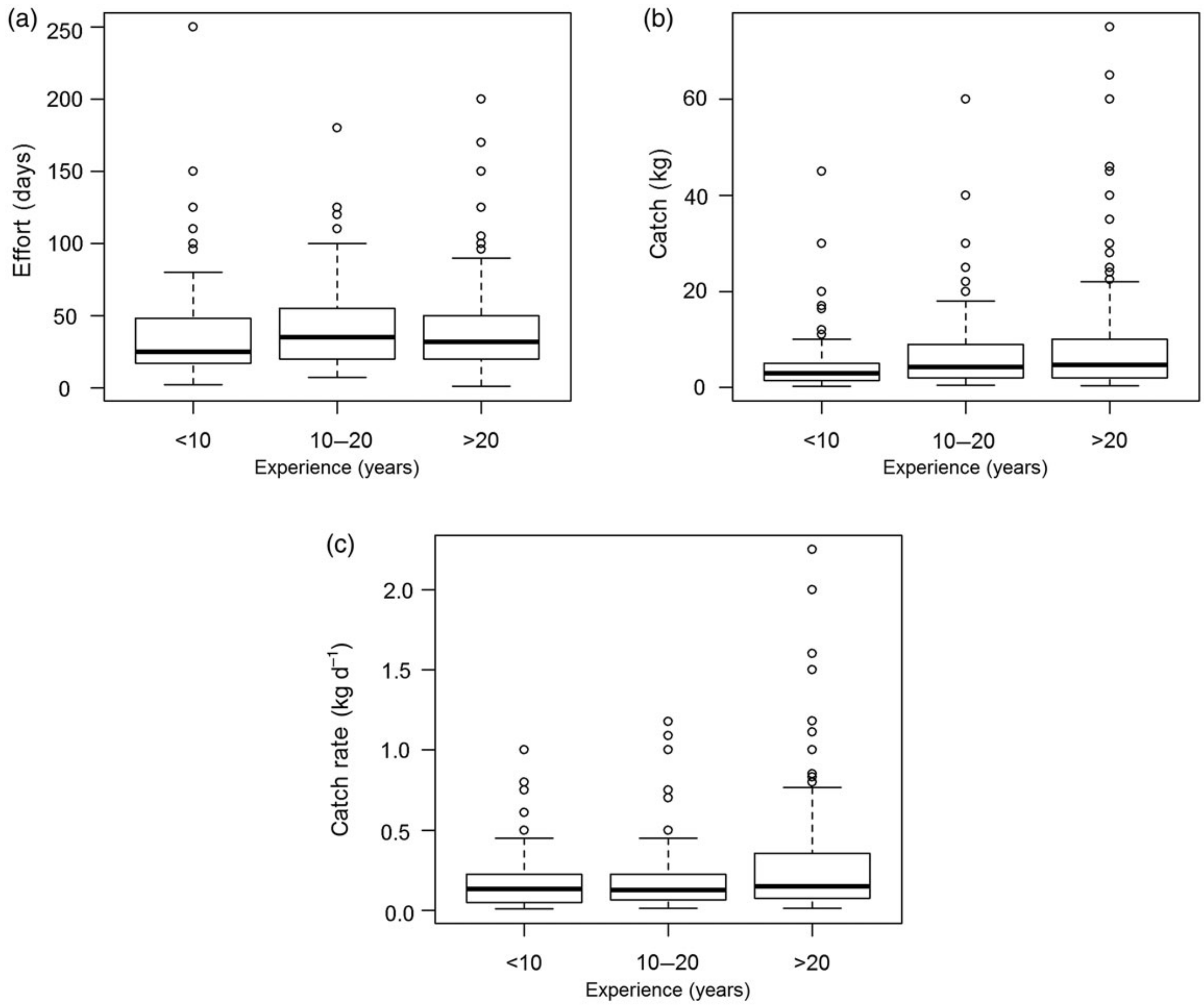

Figure 3. For shore fishing: boxplot of the (a) effort, (b) catches of sea bass; and (c) catch rates, estimated for people showing different experience in recreational fishing. Experience in recreational fishing is divided into three categories: <10 years, between 10 and 20 years, and >20 years.

the post survey, the percentage of answers with non-zero catches was 38%, but the number of fully responding questionnaires was 13, which resulted in only 4 answers with non-zero catch available to calculate the estimates.

Spearfishing

Only e-mail surveys were performed to assess the activity of spearfishers. Total catch was estimated 13 tonnes, mean catch per individual fisher 11 kg, and mean effort 43 d. The mean catch rate was estimated 0.32 kg d^{-1}. The percentage of answers with non-zero catches was 66% (Table 2c).

Potential differences between people with different experience were compared to understand the profile of spearfishers. Significant differences were found between the catches reported by people with low and high experience with 95% confidence intervals, but there were no significant differences on effort or catch rates (Table 5 and Figure 5).

Total recreational catch

The total catch of sea bass made by recreational fishers, considering all fishing techniques, summed 155 tonnes (when using e-mail surveys), 174 tonnes (phone surveys), and 378 tonnes (post surveys). Spearfishing estimates used in these totals are always based in e-mail surveys.

Discussion

Our study is the first to estimate marine recreational fishing catches of European sea bass in the Basque Country, taking into account all types of fishing targeting this species (fishing from shore, boat, and spearfishing). Catch estimates are different depending on the survey method used. Total catch estimates for shore fishing were 129, 156, and 351 tonnes for e-mail, phone, and post surveys, respectively. For boat fishing, estimates varied from 5 (phone) to 13 tonnes (e-mail and post). For spearfishing, only e-mail surveys were performed and total catch was estimated in 13 tonnes.

This study shows that shore-based fishing is the most important type of fishing technique used to target sea bass in the Basque Country, which was found to be one order of magnitude higher than the estimates for boat fishing and spearfishing. The mean catch rate estimated for shore-based fishers was homogenous for

Table 4. For boat fishing: (a) Wilcoxon Mann–Whitney test results comparing effort (d), catches (kg), catch rates (kg d^{-1}), and experience (years) estimated using the three survey methods: e-mail, phone, and post. (b) Wilcoxon Mann–Whitney test results comparing effort (d), catches (kg), and catch rates (kg d^{-1}) among people of different experience classes: low (<10 years), medium (10–20 years), and high (>20 years).

	E-mail–phone		E-mail–post		Phone–post	
(a) Wilcoxon Mann–Whitney test results comparing						
Catches	$W =$ **12 990**	$p <$ **0.001****	$W = 1449$	$p = 0.7256$	$W =$ **784**	$p <$ **0.01****
Effort	$W = 1354$	$p = 0.919$	$W =$ **17 432**	$p <$ **0.001*****	$W =$ **1102**	$p <$ **0.001*****
Catch rates	$W =$ **154**	$p <$ **0.05***	$W = 264$	$p = 0.393$	$W = 10$	$p = 0.254$
Experience	$W = 1271$	$p = 0.641$	$W = 571$	$p = 0.754$	$W = 8550$	$p = 0.065$
	Low–medium		Low–high		Medium–high	
(b) Wilcoxon Mann–Whitney test results comparing						
Catches	$W = 2196$	$p = 0.150$	$W =$ **6504**	$p <$ **0.05***	$W = 4715$	$p = 0.670$
Effort	$W = 2197$	$p = 0.269$	$W = 6675$	$p = 0.086$	$W = 4941$	$p = 0.872$
Catch rates	$W =$ **184**	$p <$ **0.05***	$W =$ **503**	$p <$ **0.05***	$W = 465$	$p = 0.686$

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Significant differences (p 0.05) are highlighted in bold.

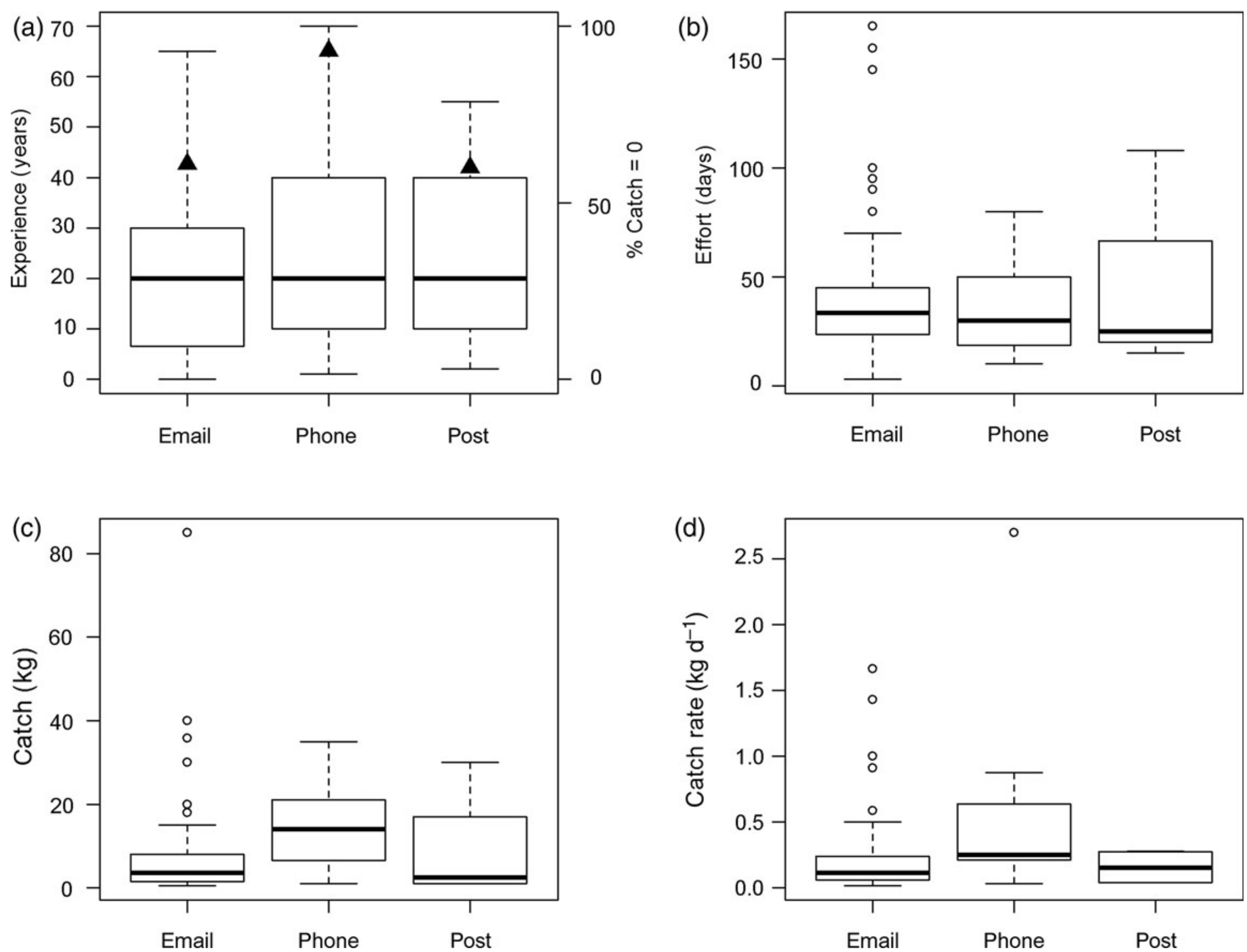

Figure 4. For boat fishing: (a) boxplot showing the experience (in years) of the people interviewed with the three survey methods: e-mail, phone, and post. The triangles show the percentage of the people interviewed with zero catches (secondary axis); (b) boxplot of the effort (in days) reported by people answering the three different survey methods; (c) boxplot of the catches of sea bass (in kg) fished by people answering the three different survey methods and (d) boxplot of the catch rates (in kg d^{-1}) estimated for people answering the three different survey methods.

all survey methods used (0.22–0.23 kg d^{-1}), which is lower than the 0.45 kg of sea bass kept per trip from the shore estimated by Rocklin *et al*. (2014), and 0.8 kg estimated by Pickett and Pawson (1994). This may be explained because we are using total fishing effort, which includes fishing days targeting sea bass and also fishing days where sea bass catches will be zero due to the chosen gear. The catch rate would increase if it was calculated using fishing days targeting sea bass.

Table 5. For spearfishing: Wilcoxon Mann–Whitney test results comparing effort (d), catches (kg), and catch rates (kg d^{-1}) among people of different experience classes: low (<10 years), medium (10–20 years), and high (>20 years).

	Low–medium		Low–high		Medium–high	
Catches	$W = 419$	$p = 0.099$	$W = \mathbf{14}$	$p < \mathbf{0.001}$***	$W = 484$	$p = 0.086$
Effort	$W = 568$	$p = 0.786$	$W = 810$	$p = 0.082$	$W = 484$	$p = 0.089$
Catch rates	$W = 302$	$p = 0.928$	$W = 357$	$p = 0.736$	$W = 283$	$p = 0.632$

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Significant differences ($p < 0.05$) are highlighted in bold.

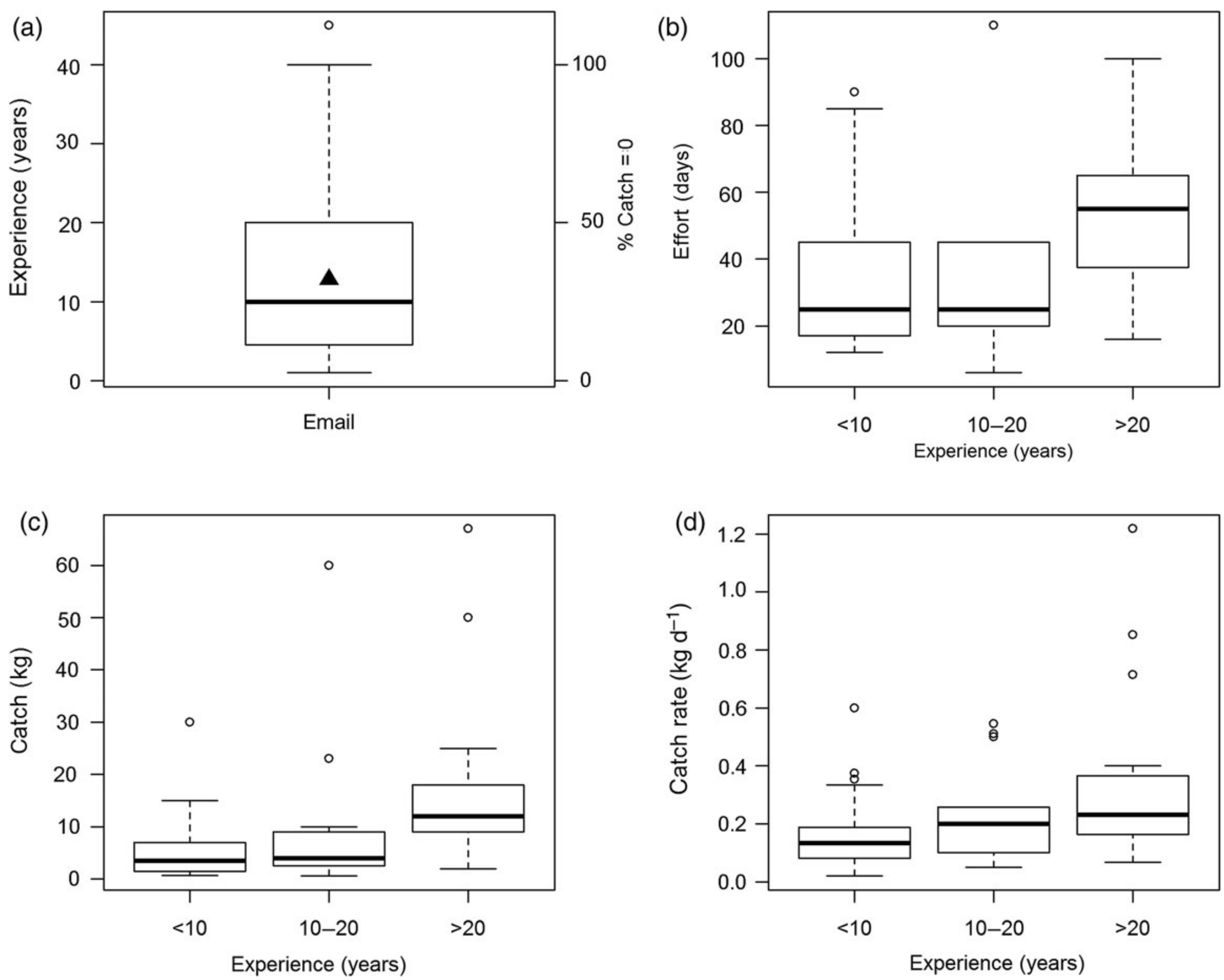

Figure 5. For spearfishing: (a) boxplot showing the experience (in years) of the people interviewed with the e-mail survey. The triangles show the percentage of the people interviewed with zero catches (secondary axis); (b) boxplot of the effort (in days) reported by people showing different experience in recreational fishing; (c) boxplot of the catches of sea bass (in kg) fished by people showing different experience in recreational fishing; and (d) boxplot of the catch rates (in kg d^{-1}) estimated for people showing different experience in recreational fishing. Experience in recreational fishing is divided into three categories: <10 years, between 10 and 20 years, and >20 years.

The percentage of licensed shore-based anglers who fished at least one sea bass during 2011 ranged from 31 to 54% depending on the survey method used (Table 2), and mean catch varied from 6.9 to 10.7 kg of sea bass per individual and per year. The percentage of spearfishers who fished at least one sea bass during 2011 was higher (66%), with a mean catch rate of 0.32 kg d^{-1} per fisher, and a mean catch of 10.6 kg per fisher and per year. Spearfishing is generally seen as a relatively homogenous group of avid fishers, using specialized fishing gears (ICES, 2010) and targeting larger fish (Lloret *et al.*, 2008). Anglers, however, are a much more heterogeneous group, including avid and non-avid fishers. Given the low price of the license, there are even people who have never gone fishing. These results are comparable with the work done by Herfaut *et al.* (2013), who estimated that in France 55% of the fishers interviewed (all fishing techniques considered) caught at least one fish and that the mean retained catch per year was 10 kg per year, with the sea bass the most important species. Rocklin *et al.* (2014) focused on the French sea bass fishery and estimated an average of 8.6 kg of sea bass per fisher per year.

Differences were found between the estimates obtained with the three different sampling methods. The catch estimated for shore-based fishing using data from post surveys was double the estimates from e-mail and phone surveys. Total catch estimates from e-mail and phone surveys were not so distant, but significant differences are observed regarding their distributions of mean catch and effort data (Tables 3 and 4). These differences raise concerns about the reliability of the estimates, suggesting that they could be biased. In fact, errors can arise in every step of the survey process. Inadequate precision can be addressed by increasing the sample size, but biases are more difficult to identify and reduce. Groves *et al*. (2004) classify bias as either representation errors or measurement errors. We will follow this approach to identify the potential bias of our study.

Errors of representation

Errors of representation are those that arise due to problems that prevent the sample from representing the population accurately. These errors can lead to bias in the estimates if the excluded population units differ from the included ones. In fisheries surveys, these errors include the coverage error and non-response error (NRC, 2006).

The coverage of the sampling frame for the post survey was complete, as the address is a compulsory field when buying a fishing license. However, this was not the case for e-mail and phone surveys, which covered <20% of the total surface license holders, and 33% of spearfishing license holders. This means that a large fraction of the population had no chance of being selected in e-mail and phone surveys, and therefore these surveys are more susceptible to under-coverage bias. This is especially relevant if the license holders who provided accurate telephone or e-mail contact information fished differently than those who did not. Another important issue regarding coverage is that we are not taking into account non-licensed fishers in our sampling frames.

Non-response error occurs when some sampled units do not provide data, either because they are not located (e.g. not at home in telephone survey), or because they refuse to participate. This error can lead to bias in the responses; if for example avid fishers are more likely to answer than people with zero catches (Tarrant and Manfredo, 1993). In our study, the phone survey was the less likely to be influenced by this bias, as it reached response rates of 77%. Response rates of e-mail and post surveys ranged from 7 to 20%, meaning that most of the people contacted refused to give an answer.

Results show that the main drawback of e-mail and phone surveys was the low coverage. Improving coverage is a difficult issue, as the management of recreational fishing depends on the administration, and thus we have limited field of action (e.g. to make telephone and/or e-mail fields compulsory when buying the fishing license). It is worth to note that although presenting the lowest coverage of the shore fishing sampling frame, mail surveys allowed the highest sample size of fully responding fishers (14 times higher than phone and post surveys). This is because performing e-mail surveys is cheaper, with a cost which is almost independent to the number of samples. The cost of subcontracting a company to carry out phone and post survey, however, increases with every survey performed (the higher the time needed to finalize the surveys, the higher the cost).

The main drawback of e-mail and post surveys was the low response rate. This is traditionally a common problem of mail surveys, which explain the poor image they have among researchers. However, significant progress has been done to reduce this error, and Dillman (1991) concluded that there is no longer any reason to accept the low response rates to e-mail and post surveys. Some of the proposed approaches are to make the questionnaire appear easier and less time consuming to complete (e.g. care for the ordering of the questions and the graphical design); to offer monetary rewards; to increase trust (e.g. by use of official stationery and sponsorship); to use well-designed follow-ups; and to perform a "variety of contacts", which may include different survey methods and also different intensities (e.g. a first soft contact mentioning that a survey will be coming).

It must be noted that a critical problem when trying to assess the relevance of representation bias is that we do not know which distributions (e-mail, phone, or post surveys) are more representative of the target population. Differences could be due to either differences in frame coverage, differences in non-response, or some combination of both. An attempt to investigate these biases was done, by comparing experience and percentage of zero catches among survey methods. Data obtained revealed that shore-based fishers that responded to the post survey had higher experience and lower percentage of zero catches. E-mail and phone exhibited similar results in terms of experience and percentage of zero catches (Figure 2). These results suggest that people with low experience or without catches were less likely to answer post surveys. Thus, post surveys performed in this study may be biased because of non-respondents, overrepresenting a fraction of the population more experienced and with higher catches. On the other hand, the lack of differences in the experience of respondents to telephone and e-mail surveys question the idea that only younger fishers will respond to e-mail surveys, showing that the Internet has become a familiar tool for people of a wide age range (Zickuhr and Madden, 2012). But these conclusions should be interpreted with care. To better assess the effect of non-response bias, we need some information about the non-respondents. The best way do so is to obtain some demographic information of the whole population frame (Dillman *et al*., 2009). If this is not possible, we can use respondents within the survey sample who are in some way similar to non-respondents. For example, by comparing early respondents with late respondents (Lindner *et al*., 2001); or by comparing the results of mixed-mode surveys, where two or more survey methods are combined in different stages of the survey process: to contact people, in the initial response phase, and also in following up on respondents (De Leeuw, 2005).

In addition to the mentioned sources of bias, we have observed a major representation problem regarding the survey design for boat fishing estimates. The sampling frame for surface fishing includes two fishing techniques (shore and boat), which can be practised by the same fisher. But the number of registered recreational boats (4609), as well as the greater investment needed, suggests that the number of fishers from boats is much lower than those fishing from shore, which can lead to the boat fishing being underrepresented. Additionally, the survey was designed in a way that respondents were asked if they owned a boat registered for recreational fishing; and if so, they were requested to fill out two separate questionnaires: one for each fishing technique. This lead to the questionnaire being longer, which could have increased the non-response. Although estimated catch results are comparable to those estimated by Zarauz *et al*. (2013), other studies show that the impact of boat fishing may be much higher (Herfaut *et al*., 2013; Rocklin *et al*., 2014). In our study, few answers were obtained for boat fishing (Table 2), especially for the phone and post surveys, with only 7 and 5 answers with non-zero catches. When comparing experience and percentage of zero catches among survey methods (Figure 4), it was not possible to make clear conclusions, and we believe that boat fishing was not well represented in our sampling. This problem can be addressed by using the census of recreational boat owners as a separate sampling frame to determine boat-based estimates. The census was not available by the time of this study, but may be available in the future.

Errors of measurements

Errors of measurement are those which explain the difference between the value provided by the respondent and the true (but unknown). Main error of this type is *recall bias*, which is related to the difficulty of the fisher to remember past events. It is a complex issue influenced by the length of the recall period and the frequency of participation, such that the longer the recall period the greater the bias, and the greater the activity level (avidity) the greater the bias. Other contributing factors are the simple exaggeration (inadvertent or deliberate) of activity within the recall period; and the phenomenon of telescoping, that is, the inclusion of activities that occurred outside of the recall period (ICES, 2010). Digit preference is also dependent on recall bias and typically increases with an increasing recalling period (Huttenlocher *et al.*, 1990; Tarrant and Manfredo, 1993). Recall bias can also vary depending on the survey method used. This may be explained by the different time given to answer (which is longer in e-mail or post surveys), assuming that the longer the time, the lower the bias would be. Significant differences have also been found in the answers that people give to aural (telephone) and visual (e-mail and post) surveys (Tarnai and Dillman, 1992; Christian *et al.*, 2008; Dillman *et al.*, 2009). Recall bias is usually associated with overestimations of catches (ICES, 2010, 2013), although some studies show that over- or underestimation may occur depending on the type of species reported (Herfaut *et al.*, 2013).

It was not possible to assess recall bias with the data collected in our study, but it could be done if some modifications in the survey design are considered in the future. One way to quantify measurement bias and improve our estimates is to compare different recalls periods, as for example, 3, 6, and 12 months (Tarrant and Manfredo, 1993). Another way is to support recall surveys by either diaries or on-site surveys (ICES, 2010). As on-site surveys are expensive and difficult to implement on a routine basis (Herfaut *et al.*, 2013), alternatives such as fishing diaries (in paper or on-line) or the use of a reference fleet may be a more cost-effective approach.

Conclusions

Despite its limitations, this work confirms that, while each individual fisher harvests a small number of fish, collectively recreational fishing can represent a significant fraction of the total catch. Commercial sea bass catches landed in Basque ports during 2011 were around 180 tonnes (source: AZTI). Therefore, estimated recreational catches, which ranged from 155 to 378 tonnes, may represent between 48 and 68% of total catch. These percentages are higher than the proportion of recreational removals estimated by ICES (2015) for France, England, Netherlands, and Belgium, which ranged from 25 to 29%. The difference can be explained by the fact that for the Basque Country, commercial fisheries sea bass is mainly a bycatch. Another important point to consider is that commercial catches included several fishing grounds, while recreational fisheries impact exclusively on populations close to the Basque coast. Results show that recreational catches are comparable to those made by commercial fleets, and emphasize the relevance of estimating catches from recreational fishing on a routine basis, to estimate the total fishing mortality for stock assessment and management processes.

This work also reflects the difficulties of carrying out statistically sound surveys for recreational fishing. Among the methods used, post surveys were the only ones assuring a full coverage of the sampled population; however, the response rate was very low (7%), and consequently the sample size was small, and the risk of non-response bias was high. Telephone surveys were the less influenced by non-response bias (77% of response rate), but the list of available telephones only covered a 19% of the total population. E-mail allowed the largest sample size at the cheapest price, with a cost which was almost independent to the number of surveys performed, but the e-mail sampling frame for surface fishing covered a 15% of the total population and response rate was only 10%. For spearfishing, e-mail surveys presented a coverage of 33% and a response rate of 20%. All surveys are prone to recall bias, as questionnaires asked about the catches obtained during the previous year, and it is difficult to remember this information accurately.

Many measures have been proposed in this study to improve the surveys, by increasing coverage, reducing non-response, and reducing recall bias. Among them, we will summarize the most appropriate to be implemented in a routine sampling scheme in the Basque Country, knowing that limited resources may not allow us to execute all of them. Post survey has the clear advantage of having full coverage, so efforts can be done to increase response rate by improving the graphical design of the survey, using follow-ups, etc. If the response rate is increased, post surveys could be used in a two-phase approach, where a general post survey is sent to a large sample asking if the respondent is willing to participate, and a more detailed questionnaire is sent to respondents using other methods (e-mail, phone, or post). An alternative approach would be to increase the coverage of phone and e-mail surveys, which have shown a higher response rate (phone) and allows for the large sample sizes (e-mail). In any case, a strategy is needed to collect information about the non-respondents. Recall errors should also be addressed. An option would be to use supplementary diaries (in paper or on-line) or select a reference fleet. A shorter period between surveys will also help reduce recall bias. At last, to achieve more accurate recreational sea bass catch estimates, further analysis will be needed related with relevant issues that have not been addressed in this study: non-licensed fishing, catch and release, and survival rate of sea bass (Ferter *et al.*, 2013).

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