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Participation, catches and economic impact of sea anglers resident in the UK in 2016 & 2017

Annex 4. Estimating catches by sea anglers resident in the UK in 2016 and 2017

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Executive Summary

A UK programme was implemented in 2016 and 2017 to estimate the annual catches of sea anglers resident in the UK. The programme used a national face-to-face omnibus survey to estimate number of sea anglers and recruited a nationwide panel of sea anglers to record their catches during the year in diaries. The data from the panel were combined with estimates of total numbers of sea anglers from the Watersports Participation Survey (WPS) to estimate total UK sea angling catches. This report describes the analysis methods used to estimate catches by UK sea anglers in 2016-17 which are then compared with catches from previous surveys. To utilise the data efficiently and produce robust estimates of catches, the impact of data selection, weight conversion, imputation of missing data, trimming of outliers, and stratification were assessed and used to develop an appropriate estimation method for numbers and tonnages of fish kept and released.

Diarists that provided less than six months of data each year were excluded from the analysis, leaving 292 diarists from 432 entering data in 2016 and 639 from the 1216 entering data in 2017. Any species with less than 4 diarists or 15 records were simply highlighted as caught, but no further analysis was done. Where analysis was possible, diarists that had the three highest and lowest catches for each the species were trimmed from the database to reduce the impact of single large catches on the estimates. Tonnages were calculated for species for which at least five people recorded 50 individual fish lengths or more, and if below this threshold then only numbers were presented. The numbers and / or tonnages were raised using a combination of three avidity and two platform strata in 2016 and three avidity and two age strata in 2017. Sampling error was estimated by combining errors in the numbers of anglers from the WPS data with errors in annual catches between diarists in the panel. The estimates and associated errors for the kept and released components of the catch by UK resident sea anglers were presented.

In total 100 fish species were reported as being caught by sea anglers fishing in the UK, with numbers calculated for 68 species and tonnages for 32 of these over the two-year period. The total number of fish kept and released was 49.7 million in 2016 and 54.5 million in 2017, with a release rate of around 80%. The majority of catches were by English sea anglers, due to the high proportion of UK sea anglers resident in England. Catches and releases were similar in 2016 and 2017, but were higher than in 2012 especially for the released component. Catch composition was similar in 2012, 2016 and 2017 with some difference in the order of species. For species required under the Data Collection Framework (DCF), catches were minimal for diadromous species, but higher for cod, bass, and pollack. The distribution of catches was as expected with most sea bass caught in the south west of England and a more even spatial distribution for cod. Released fish were generally smaller than kept fish and large amounts of voluntary catch and release of fish above the Minimum Conservation Reference Size (MCRS) was recorded.

All approaches for collecting data on sea angling are subject to error, due to the varied and dispersed nature of the activity. There will be uncertainty in the UK estimates of participation, effort, and expenditure. The issues with the 2016-17 approach and analysis were related to errors associated with the small numbers of respondents in the WPS, self-selected nature of the diary panel, missing data, and analysis methods. Post-stratification was used to reweight the diary panel to reflect the

population in terms of avidity, age, or sea angling method. However, this does not fully remove bias, which must be taken into consideration when the data are used.

Catches estimated in England were consistently higher in 2016-17 than in 2012, particularly for released fish despite the overall composition of catches being similar. It is unlikely for this to be only a result of random sampling error in estimates of catch rates obtained from the on-site and diary surveys, as the differences were observed over many species. Three potential reasons for these differences are: 1) the true total catches of many species increased substantially between 2012 and 2016; 2) annual fishing effort or numbers of anglers (needed for raising catch rate estimates of all species to total annual catches), were under- or overestimated due to random sampling error in the nationwide population surveys; and 3) there were different types and extent of bias associated with the design and implementation of the on-site surveys in 2012 and the diary surveys in later years. As the 2012 data are for only one year and used different survey methods, it has not been possible to determine the extent to which the increased catch estimates are due to survey bias, random sampling error or changes in fish abundance. It is likely that a combination of these factors generated the differences. Suggestions for future improvements included a small regional validation survey (currently underway in 2019), improving the user experience to increase completion rates, assessing the importance of bias related to centrality to lifestyle and experience, and testing modelling approaches for analysis.

Table of Contents

Table of Tables

Table of Figures

1 Introduction

There are many different approaches that can be used to estimate catches from marine recreational fisheries (MRF), with the most appropriate methods dependent on many characteristics including: availability of a list of anglers to sample, participation rates, characteristics of the fishery, responses to survey instruments, and budgets. As a result, methods vary between countries with a bespoke mix of aerial, household, mail, phone, logbook, and on-site surveys used to quantify the catches. This variation in methods can lead to different sources of bias and error in the catch estimates provided. For example, a telephone-based panel survey is implemented where fishers are contacted every week and asked if they went fishing and, if they did, what they caught in New Zealand (Wynne-Jones et al., 2014). Alternatively, the USA samples the catches of recreational fishers using a household fishing effort survey (FES) as well as an access point interception survey (APIS), where fishers encountered at beach/harbour access points are sampled (Andrews et al., 2014; NOAA, 2014). As part of the FES, fishers are also asked to report their catches via a logbook. The catch data collected during the FES and APIS are matched to the fishing trips reported by the FES and the total trips is calculated based on the total reported trips and the ratio of trips matched. An aerial survey was used in Portugal to estimate MRF participation and effort (Veiga et al., 2010). In the UK, sea angling is the most common method of marine recreational fishing in the UK. There are no complete lists of marine recreational fishers nor licensing schemes in the UK, so an independent study is required to estimate participation, effort, and catches (see ICES, 2010; Jones and Pollack, 2013; Pollack et al. 1994).

In 2012, a survey to quantify sea angling catch, effort, and participation in England was conducted (Armstrong et al., 2013). Due to the large sample area and lack of sea angling licence in England, a household survey conducted by the UK Office of National Statistics (ONS) was chosen to screen the population for recreational fishers and estimate the fishing effort of anglers fishing from the shore and private boats. Estimates of catch per unit of effort of these types of fishing trips were obtained using a roving creel survey of shore anglers interviewed whilst fishing, and an access point survey of private boat anglers returning from trips, with both surveys taking place at randomly selected sites. A separate charter boat survey developed a list frame of boats and skippers of randomly selected boats collected catch data. Armstrong et al. (2013) found that 2% of the population (884000 people) fish recreationally in the sea each year, which is similar to the average participation rate of 1.6% in Europe (Hyder et al., 2018). Furthermore, the removals of fish by English recreational sea fishers was significant compared to commercial fisheries for many fish stocks (e.g. 25% of the total catch of sea bass in England was by sea angling- Armstrong et al., 2013), a trend also observed across throughout Europe (Radford et al., 2018).

A new survey that expanded the findings of Armstrong et al. (2013) to the whole of the UK was implemented using a different methodology. Two surveys were carried out to estimate the total catch of recreational sea angling in the UK in 2016 and 2017. Firstly, questions were added to the UK-wide Waterports Participation Survey to ask if respondents had been sea angling in the past year from different platforms (shore, private boat, kayak, charter boat) and the number of days that an individual had been sea angling. The data were collected from face-to-face interviews at 12,000 randomly selected households within survey strata across the UK and raised to the population using social and demographic information (Annex 1). Mean annual catch per angler from logbook data (Annex 2) recorded by a panel of sea anglers recruited throughout the UK following publicising of the survey and incentives through social media, angling media and events, tackle shops and contacts with anglers who participated in previous surveys. Catches and releases of all species, and sizes of fish caught, were recorded monthly by the individual panel members throughout the year[1]. These two surveys were used to estimate catches by sea anglers resident in the UK. The numbers of sea anglers by region, platform, avidity, and social groups was used to reweight catch data from the second survey. In this annex, estimates of catches and releases by sea anglers in 2016 and 2017 are presented. Methods for raising catches from the diary survey to the whole population are outlined and a post-stratification and reweighting approach is identified to correct for differences between the panel composition and the sea angling population. Then catches and releases by sea anglers are presented and a comparison made between the two years and catches obtained in 2012.

[1] https://www.seaangling.org/

2 Methods

The methods for raising are complex so have been split into three sections. Firstly, the general approach for raising the data is described for both numbers and tonnage including calculating precision. Then the approach for developing the estimation method is outlined including data selection, dealing with the catch diary and post-stratification and reweighting. Finally, the methods for assessing catches and comparisons with previous surveys are described.

Two datasets formed the basis of the analysis:

- Watersports Participation Survey (WPS): a face-to-face omnibus survey of 12,000 randomly selected households within strata across the UK that provides a population level estimate of the numbers, profile, and activity of sea anglers in the UK (see Annex 1 for a full description).
- Sea angling diary: the year-long online catch diary tool that provides a record of the catches from a self-selecting panel of sea anglers (see Annex 2 for a full description).

2.1 Raising procedure

The overall aim of the analysis was to estimate the numbers and tonnages of fish kept and released by adult sea anglers resident in the UK by species, along with the associated estimates of precision. To achieve this, estimates of the number of anglers (effort) from the WPS (Annex 1) were combined with catches by individual anglers (catch per unit effort) from the sea angling diary survey (Annex 2). This type of two-stage survey is done for most sea angling surveys (see Jones and Pollock, 2013; Pollock et al., 1994 for a general review) to account for differences in the composition of the sample and population. The diarist panel was self-selecting rather than random, so has potential for significant bias due to under- or over-representation of anglers in terms of avidity, fishing methods, age, region, or other factors that affect catches. The randomised WPS interviews should provide less biased estimates of the composition of the sea angling population in terms of such characteristics, as well as provide auxiliary data that can be used to re-weight the diarist panel. The weighting factors were themselves imprecise because the WPS is based on a small sample of the UK population and is therefore subject to sampling error which contributes to the inter-annual variations in WPS estimates of participation and composition. The general raising approach and estimation of the errors is described in this section.

2.1.1 Total catch

Raised estimates of sea angling catches were found using the Horvitz-Thompson estimator:

$$X = \sum_{i=1}^{n} c_i X_i \qquad (1)$$

where X is the catch or release of an individual species, X_i is a an estimate of catch by sea angler i reported in the diary, n is the number of sea anglers in the diary, and c_i is the sampling weight. The sampling weight denotes how many sea anglers in the population each diarist represents and is calculated as $c_i = 1/\omega_i$.

Post-stratification of the data sets was used to reduce the effect of bias in the diary panel due to self-selection (non-probabilistic sampling). Strata were defined using characteristics of anglers that were likely to be related to their annual catches, such as avidity, fishing methods, and region. The WPS was treated as a benchmark survey with a less biased description of the profile of the target population of adult sea anglers resident in the UK than is given by the diarist panel. The panel and the WPS sample were split into identical strata, and in each stratum k the weight, c_k given to all diarists is chosen such that:

$$c_k = \frac{N_k}{n_k} \tag{2}$$

where n_k is the number of adult diarists in stratum k and N_k is the number of adult sea anglers in the UK in stratum k estimated from the Watersports Participation Survey. This method assigned the same weight to all diarists in a stratum.

The WPS data were derived from a survey of households across the UK, in which all individuals in the target population have similar probability of being sampled. However, to reduce the effects of random sampling error, it included a procedure to reweight the interviewees to make the achieved total sample data set more representative of the total population in terms of age group, region, gender and social grade, using Office of National Statistics (ONS) survey data to provide the population breakdown. For this analysis, it resulted in weighting factors for respondent (i) in the WPS that was related to each stratum for the diary panel (k) and defined as w_{ik}. The number of sea anglers in stratum k in the population, N_k was then given as:

$$N_k = \sum_{i=1}^{n} Y\, w_{ik} \tag{3}$$

where Y is total population size for the target population (from ONS) divided by the total unweighted sample size of the WPS survey. The product Yw_{ik} is the number of people in the population represented by each WPS participant i in stratum k.

As the weights for each angler in a stratum were identical, the total catch X_{sk} of species s in stratum k was given by:

$$X_{sk} = \frac{N_k}{n_k} \sum_{i=1}^{n} X_{ski} \tag{4}$$

which is the total numbers of anglers in stratum k multiplied by the mean annual catch per angler in that stratum. Thus, the total catch across all strata (m) was:

$$X_s = \sum_{k=1}^{m} X_{sk}. \tag{5}$$

2.1.2 Precision of estimates

Equations 1-5 gave the best estimate of the catches, but it was important to know the level of precision associated with the estimate. The level of precision was related to two sources of error in the analysis: 1. uncertainty in the population of anglers from the WPS; and 2. the variation in catches between diarists within each stratum. The estimate for the total catches in numbers in strata k can be rewritten:

$$X_k = \sum_{i=1}^{n} c_{ik}\, x_{ik} \tag{6}$$

where x_{ik} is the total catch in numbers of diarist i in stratum k, and c_{ik} is the sampling weight. As all sampling weights in a stratum were the same and related to ratio of the number of anglers in the population to number in the sample (N_k/n_k), this can be rewritten as:

$$X_k = c_k \sum_{i=1}^{n} x_{ik} = \frac{N_k}{n_k} \sum_{i=1}^{n} x_{ik}. \quad (7)$$

and mean diarist catch in stratum k as:

$$\bar{x}_k = \frac{1}{n_k} \sum_{i=1}^{n} x_{ik}. \quad (8)$$

To combine the errors, it was assumed that the WPS and sea angling diary were independent. It was likely that the two measures were not independent, but this approach did not require assumptions to be made about the covariance structure and represented a worst-case scenario. Assuming no covariances between WPS estimates of anglers and panel estimates of mean catch per angler, the variance of the estimate of total catch X_k in stratum k was:

$$V(X_k) = V(N_k)\bar{x}_k^2 + V(\bar{x}_k)N_k^2, \quad (9)$$

the total variance for catches of an individual species was:

$$V(X) = \sum_{k=1}^{m} V(X_k), \quad (10)$$

and

$$CV = \sqrt{V(X)}/X. \quad (11)$$

The design effect is used in surveys to account for correlation within groups that reduces the variance in parameter estimates. The overall size of this effect is related to the design of the survey and was estimated as:

$$n_{eff} = \frac{(\sum w_i)^2}{\sum w_i^2} \quad (12)$$

where n_{eff} is the effective sample size.

2.1.3 Estimating tonnage

To estimate tonnages rather than numbers of fish caught an additional step was needed. Diarists provided information on the length and / or weight of all the fish that they catch. Where lengths were provided, these were converted into weights using length-weight relationships for each species (Silva et al., 2013). These were used to estimate the mean catches in tonnes, rather than numbers, per angler within each stratum. The equations were the same, but the units change with X_{ski} the weight in tonnes of species s caught by diarist i in stratum k. The error in the length-weight conversion was not accounted for the estimates of precision.

2.2 Developing the estimation method

The WPS (Annex 1) and diary panel (Annex 2) are covered in detail in other annexes, but it is useful to provide a summary of the data and how that impacts the estimation approach. The WPS obtained data from 181 (2016) and 194 (2017) UK residents of 16 years or over that had been sea angling. Only diarists of 18 years or over were used in the analysis, so 158 (2016) and 166 (2017) of the respondents to the WPS could be included. A total of 432 and 1216 diarists provided data in 2016 and 2017 respectively, but many did not provide data for the whole year, some were under 18, some had incomplete records, or reported fishing outside the UK. Selecting individuals that were over 18 and provided data for at least six months of the year left 292 diarists in 2016 and 639 in 2017 to raise from. The members of the panel were generally more avid and older than the general sea angling population. In 2016, 50986 fish were recorded and 94288 in 2017, although individual length or weight were not provided in all cases. Diarists that provided at least six months of data reported a total of 9209 kept and 36665 released fish in 2016 and 16156 kept and 60354 released in 2017 that were available to be analysed. A total of 100 fish species were recorded over the two years by sea anglers fishing in the UK, with some species caught very rarely.

The challenges with the data lead to a number of key issues that needed to be resolved in developing the analysis approach. Firstly, a minimum number of observations (numbers, weights) needed to be set to ensure that raising resulted in robust estimates. Secondly, the individual fish sizes needed to be converted into weights from lengths, including imputation for missing length data. Thirdly, the impact of missing data on fishing trips and catches in individual diaries needed to be assessed and methods tested. Finally, an approach was needed for identifying the most appropriate post-stratification of the diary and WPS data for reweighting of the diary panel to represent the population. These are discussed in detail below.

2.2.1 Data selection

No estimates were provided where there were fewer than 15 records for an individual species as these were considered too uncertain to provide robust estimates. In addition, tonnages were not calculated for species that had fewer than 50 individual lengths recorded or these lengths were provided by less than five different diarists.

Fish lengths recorded by diarists needed to be expressed as weights in order to estimate tonnages. Outlying lengths that were not biologically feasible were checked and corrected or removed from the database. For each species, all lengths were converted to weights using length-weight relationships, with fish weights (W_s) in grams estimated for an individual species (s) from length using the equation:

$$W_s = a_s L^{b_s} \tag{13}$$

where L is the total length (cm) and a_s, b_s are parameters defined for each species. The parameters for most species were taken from length-weight relationships derived from survey data (Silva et al., 2013). Where parameters were not available, the most closely related species with a similar body shape was used. Sea bass parameters were taken from the ICES assessment where $a_s = 0.01296$ and $b_s = 2.969$ (ICES, 2018). For some species, individual fish may be outside the ranges used to generate the relationships, so there may be some bias in catch weights. Fish with missing lengths were assigned the average weight of all records of the same species and fate with known length from the same year.

2.2.2 Catch diary data

It is difficult to ensure that diarists provide data for all months in the year despite significant effort put into contacting individual sea anglers (see Annex 2). As a result, there were some diarists missing one or more months of catches, but it was not known if these represented no fishing or non-provision of data. Previous studies have used hotdecking to account for missing months by substituting at random with data from similar diarists (van der Hammen et al., 2016). Following van der Hammen et al. (2016), the effectiveness of filling missing months using hotdecking was tested for 2016 using stratification method “strata 12” and for 2017 using “strata 15” (see Table 1). Here, catches were assigned to a missing month by “borrowing” the catch of an angler selected at random from the same month and stratum (including zero catch if no fishing took place). Catch estimations were produced for diarists with six or more months, eight or more months, and full year both with and without hotdecking to assess the impact of missing data. These results were reviewed and used to generate a cut-off for the number of months of data provided by diarists to be included in the catch estimates.

It was possible that a limited number of very avid diarists with large catches might significantly impact the raised estimates. To assess this, the effect of ‘trimming’ was tested by excluding a number of high and low entries for each species and category (kept or released). The effect of different levels of trimming (0, 1, 2, 3, 5, 7 and 10 individuals) on catches and releases of sea bass and cod was tested. This was used to decide if trimming should be used to reduce the impact of very avid diarists.

2.2.3 Post-stratification

Post-stratification involved a trade-off between the number of strata and the number of respondents in the WPS and diarists reporting catch within each stratum. Increasing the number of strata resulted in fewer diarists and respondents to the WPS, generating large uncertainty in the estimates. As there were limited number of diarists and respondents to the WPS, the choice of stratification was very important for the final estimates as it results in different weights and errors for the individual stratum. Thus, different approaches for post-stratification were tested to assess the impact and generate an appropriate method. Many different combinations of post-stratification by age, avidity, platform type, and region were tested, as these factors were thought to influence catches by individual anglers.

Three metrics were generated to test the performance of individual post-stratification approaches: 1. bias discount (unidirectional change); 2. average absolute difference (distance between different stratifications); and 3. volatility (difference in estimates). Supposing it is desired that the effect of a stratification A on q weight estimates is to be tested. Let B be the base stratification with equal weighting of all anglers in the panel. For species i the weight estimates by stratification A and B is denoted as a_i and b_i respectively.

Bias discount is a measure of the level of unidirectional change created by a new stratification. It is the average percentage that each estimate in the base stratification changes under another stratification. The bias discount ($\mathrm{BD}(A)$) of a stratification is defined as:

$$\mathrm{BD}(A) = \frac{1}{q}\sum_{i=1}^{q}\frac{a_i - b_i}{b_i} \quad (12)$$

A bias discount of -5% means that, on average, each estimate is decreased by 5% when the stratification is introduced. A negative bias discount means that the stratification reduced estimates by addressing positive bias.

Average absolute difference measures the average distance between each estimate from stratification A and B. The average absolute difference ($\mathrm{AAD}(A)$) of stratification A is:

$$\text{AAD}(A) = \frac{1}{q}\sum_{i=1}^{q}\frac{|a_i - b_i|}{b_i} \quad (13)$$

An average absolute difference of 10% means that introducing stratification A makes each estimate move, on average, by 10% in direction. The important difference is that unlike bias discount, it does not say which way they are moving on average.

Volatility measures changes in estimates of individual species, even if there is no overall bias. This metric picks up changes that may be due to fish appearing in different geographical regions or a species that is primarily caught from a boat rather than the shore. It measures bidirectional changes, unlike bias discount which is purely for unidirectional changes. The volatility of stratification A is defined as:

$$\text{Volatility}(A) = \text{AAD}(A) - \text{BD}(A) \quad (14)$$

This is always non-negative as $\text{AAD} \geq \text{BD}$.

Thirty-one different post-stratification approaches were tested and compared with the baseline of no stratification (Table 1). This resulted in between one and forty individual strata with different levels for a combination of avidity (two to four strata), platform (two to three strata), region (four to six strata), and age (two to five strata). These variables were chosen due to their potential to influence catches by diarists. The choice of the final stratification was based on the number of individuals in the diary and WPS and the metrics (bias discount, average absolute differences, volatility). The choice was made to achieve the minimum sufficient stratification to allow a robust reweighting based on avidity, region, age, or angling method that maintains a sufficient number of anglers per stratum in both the WPS and the diary panel, but also provide a reasonably high bias discount, high average absolute difference, and low volatility. The number and profile of survey participants was different in 2016 and 2017, so the final choice of stratification categories for the years was also different.

2.2.4 Analysis approach

The impact of data selection, weight conversion, hotdecking, trimming, and stratification were assessed and used to develop an appropriate estimation method for numbers and tonnages kept and released. The approach was developed to utilise the data efficiently and produce robust estimates of catches. The full approach was described as a flow diagram to ensure transparency.

2.3 Assessing catches

Once the approach for analysis had been determined, the numbers and tonnages of fish kept and released were estimated for 2016 and 2017 for each species. The numbers of fish kept and released (total and catch per angler), release rates, and catch composition were compared for 2016 and 2017. Numbers caught, released and composition were compared for England only between 2012 and 2016-17 as the 2012 survey only covered England. The DCF relevant species were plotted and sea bass and cod catches partitioned between country within the UK and ICES sea area. Finally, the length-frequency of fish kept and released was provided for the DCF species.

Table 1. Stratification approaches tested for each category (e.g. avidity, platform, location, age). Levels are the boundaries for the individual stratum and number is the number of strata.

		Levels				Number				
Strata	Description	Avidity	Platform	Location	Age	Avidity	Platform	Location	Age	Total
0	No stratification									1
1	Avidity	<4, 4-8, 9-19, 20+				4				4
1.4	Avidity	<9, 9+				2				2
1.5	Avidity	<5, 5-19, 20-34, 35+				4				4
1.6	Avidity	<20, 20+				2				2
1.7	Avidity	<5, 5-19, 20+				3				3
2	Platform		Boat only, Shore only, Both				3			3
2.1	Platform		Shore only, boat only & both				2			2
2.2	Platform		Boat only, shore only & both				2			2
3	Regions			"South East, London and East", "South West", "Midlands and North", "Northern Ireland and Wales", "Scotland",				5		5
3.1	Regions			"South East, London and East", "South West", "Midlands and North", "Northern Ireland", "Wales", "Scotland"				6		6
3.2	Regions			"South East, London and East", "South West", "Midlands and North", "Northern Ireland, Wales and Scotland"				4		4
4	Age				<55, 55+				2	2
4.1	Age				18-34, 35-44, 45-54, 55-64, 65+				5	5
4.2	Age				18-34, 35-54, 55-64, 65+				4	4
5	Avidity & region	<4, 4-8, 9-19, 20+		5 regions		4		5		20
6	Avidity, region, & age	<4, 4-8, 9-19, 20+		5 regions	<55, 55+	4		5	2	40
7	Avidity, region, & age	<9, 9+		4 regions	<55, 55+	2		4	2	16
8	Avidity, region, & age	<5, 5-19, 20-34, 35+		4 regions	<55, 55+	4		4	2	32
9	Avidity & age	<5, 5-19, 20-34, 35+		4 regions		4		4		16
10	Avidity & age	<20, 20+		5 regions		2		5		10
10.5	Avidity & age	<9, 9+		5 regions		2		5		10
11	Avidity & platform	<5, 5-19, 20-34, 35+	Boat only, Shore only, Both			4	3			12
12	Avidity & platform	<5, 5-19, 20+	Shore only, boat only & both			3	2			6
13	Avidity, platform & region	<5, 5-19, 20+	Shore only, boat only & both	4 regions		3	2	4		24
14	Avidity, platform & age	<5, 5-19, 20+	Shore only, boat only & both		<55, 55+	3	2		2	12
15	Avidity & age	<5, 5-19, 20+			<55, 55+	3			2	6

Strata	Description	Levels Avidity	Platform	Location	Age	Number Avidity	Platform	Location	Age	Total
16	Avidity, platform & age	<20, 20+	Boat only, shore only & both		<55, 55+	2	2		2	8
17	Avidity & platform	<5, 5-19, 20+	Boat only, shore only & both			3	2			6
18	Avidity & age	<4, 4-8, 9-19, 20+			<55, 55+	4			2	8
19	Avidity, platform & age	<9, 9+	Boat only, shore only & both		<55, 55+	2	2		2	8
20	Avidity & age	<5, 5-19, 20-34, 35+			<55, 55+	4			2	8

3 Results

3.1 Developing the estimation method

3.1.1 Data selection

Sea anglers fishing in the UK caught 100 fish species over the two years, with raising to numbers possible for 68 and tonnages for 32. Numbers could not be estimated 20 from 82 species in 2016 and 27 from 95 species in 2017 excluded due to insufficient diarists or records to provide robust estimates (Table 2). As tonnages were not calculated for species with lengths provided by fewer than five diarists, or with less than 50 individual lengths, tonnages were estimated for 20 and 32 species and 4 groups (all fish, elasmobranchs, sharks, skates and rays) in 2016 and 2017, respectively (Table 3).

Table 2. Species recorded that were excluded from the analysis in 2016 and 2017 because there were fewer than 15 recorded entries or they were caught by less than 4 unique diarists.

2016	2017
Anchovy	Black-mouthed Dogfish
Black-mouthed Dogfish	Blue Whiting
Bull Rout (short spined sea scorpion)	Bull Rout (short spined sea scorpion)
Common Skate	Four-bearded Rockling
Connemera Sucker (Clingfish)	Giant Goby
Greater Weever Fish	Greater Pipefish
Lemon Sole	John Dory
Leopard-spotted Goby	Lemon Sole
Lesser Sandeel	Leopard-spotted Goby
Monkfish (Anglerfish)	Long Rough Dab (American Plaice)
Porbeagle Shark	Megrim (Cornish Sole, Whiffy)
Red Mullet (Striped Mullet)	Norway Pout
Red Sea Bream	Pandora Sea Bream
Rock cook Wrasse	Pilchard
Rock Goby	Red Mullet (Striped Mullet)
Sand Goby	Red Sea Bream
Shad (twaite)	Salmon (North Atlantic Salmon)
Smelt (Small-scaled)	Sand Sole
Sprat (skipper)	Shad (twaite)
Vivaporous Blenny (eelpout)	Smelt (Small-scaled)
	Spanish Mackerel
	Starry Ray (Thorny Skate)
	Stingray (Common Stingray)
	Topknot
	Triggerfish
	Vivaporous Blenny (eelpout)
	White Sea Bream

Table 3. Number of individual length measurements (lth) and diarists reporting lengths (ppl) for fish kept (K) and released (R) in 2016 and 2017. Thresholds of 50 lengths and 5 diarists were used for estimation of tonnages with 'Yes' and 'No' indicating numbers above and below these thresholds, respectively. NR were not raised in 2016.

	Data								Tonnage			
	2016				2017				2016		2017	
Species	Klth	Rlth	Kppl	Rppl	Klth	Rlth	Kppl	Rppl	K	R	K	R
All fish	3241	14961	454	1495	5827	25602	906	2824	Yes	Yes	Yes	Yes
Elasmobranchs	38	3252	18	319	96	4098	46	592	No	Yes	Yes	Yes
Sharks	31	2936	12	220	51	3572	26	416	No	Yes	Yes	Yes
Skates rays	7	316	6	99	45	526	20	176	No	Yes	No	Yes
Baillon's Wrasse	0	3	0	3	0	4	0	2	No	No	No	No
Ballan Wrasse	1	530	1	50	5	554	4	87	No	Yes	No	Yes
Bass	61	1819	39	117	136	2970	70	257	Yes	Yes	Yes	Yes
Bib	60	586	15	69	139	1394	34	146	Yes	Yes	Yes	Yes
Black Goby	0	3	0	2	0	10	0	2	No	No	No	No
Black Sea Bream	77	270	18	24	217	527	45	63	Yes	Yes	Yes	Yes
Blonde Ray	0	43	0	14	0	54	0	13	No	No	No	Yes
Blue Shark	0	2	0	1	0	10	0	6	No	No	No	No
Brill	0	1	0	1	4	0	4	0	No	No	No	No
Bull Huss	2	114	2	31	7	159	5	44	No	Yes	No	Yes
Coalfish	15	327	7	39	6	661	5	57	No	Yes	No	Yes
Cod	234	744	58	82	478	1470	108	136	Yes	Yes	Yes	Yes
Common Goby	0	0	0	0	0	11	0	5	No	No	No	No
Common Skate	NR	NR	NR	NR	0	1	0	1	No	No	No	No
Conger eel	0	175	0	38	0	389	0	90	No	Yes	No	Yes
Corkwing Wrasse	0	44	0	8	0	141	0	30	No	No	No	Yes
Couch's Sea Bream	0	0	0	0	0	7	0	3	No	No	No	No
Cuckoo Wrasse	0	29	0	11	0	28	0	15	No	No	No	No
Dab	31	448	14	63	72	1134	29	131	No	Yes	Yes	Yes
Dover Sole	3	10	3	5	26	42	17	27	No	No	No	No
Dragonet	0	3	0	2	0	5	0	5	No	No	No	No
Five bearded Rockling	0	19	0	10	0	46	0	22	No	No	No	No
Flounder	26	632	11	73	57	979	30	133	No	Yes	Yes	Yes
Freshwater Eel	0	42	0	15	0	194	0	53	No	No	No	Yes
Garfish	6	42	4	14	36	53	13	25	No	No	No	Yes
Gilthead Sea Bream	0	4	0	3	10	19	5	11	No	No	No	No
Golden Grey Mullet	0	4	0	4	0	2	0	1	No	No	No	No
Goldsinney Wrasse	0	8	0	3	0	24	0	7	No	No	No	No
Greater Weever Fish	NR	NR	NR	NR	1	1	1	1	No	No	No	No
Grey Gurnard	0	40	0	19	1	22	1	12	No	No	No	No
Haddock	8	31	4	7	14	35	5	6	No	No	No	No
Herring	27	23	8	6	14	12	4	7	No	No	No	No
Lesser Sandeel	NR	NR	NR	NR	0	0	0	0	No	No	No	No
Lesser Spotted Dogfish	29	2400	10	95	43	2655	20	197	No	Yes	No	Yes
Lesser Weever	0	18	0	15	0	32	0	13	No	No	No	No
Ling	29	21	14	8	40	46	19	20	No	No	No	No
Mackerel	1826	1209	87	67	2595	1392	152	94	Yes	Yes	Yes	Yes
Plaice	181	316	36	44	193	480	59	99	Yes	Yes	Yes	Yes
Pollack	178	835	51	86	529	1285	100	133	Yes	Yes	Yes	Yes
Poor Cod	2	27	2	14	0	59	0	23	No	No	No	Yes
Red Band Fish	0	0	0	0	0	0	0	0	No	No	No	No
Red Gurnard	0	46	0	27	11	61	10	34	No	No	No	Yes
Rock cook Wrasse	NR	NR	NR	NR	0	0	0	0	No	No	No	No
Rock Goby	NR	NR	NR	NR	0	17	0	6	No	No	No	No
Sand Goby	NR	NR	NR	NR	0	5	0	5	No	No	No	No
Sandeel	6	8	2	4	27	28	10	11	No	No	No	No
Scad	13	79	5	21	20	115	4	19	No	Yes	No	Yes
Sea Scorpion	0	16	0	11	0	16	0	13	No	No	No	No
Sea Trout	0	9	0	7	0	10	0	8	No	No	No	No
Shad	0	0	0	0	0	0	0	0	No	No	No	No
Shanny	0	8	0	6	0	39	0	10	No	No	No	No
Shore Rockling	0	27	0	12	0	72	0	30	No	No	No	Yes
Small Eyed Ray	0	30	0	17	2	47	2	23	No	No	No	No
Smelt	0	5	0	3	0	23	0	9	No	No	No	No
Smoothhound	0	154	0	42	1	230	1	70	No	Yes	No	Yes
Spotted Ray	0	30	0	13	0	38	0	22	No	No	No	No

Species	Data 2016 Klth	Rlth	Kppl	Rppl	2017 Klth	Rlth	Kppl	Rppl	Tonnage 2016 K	R	2017 K	R
Spurdog	0	62	0	9	0	153	0	13	No	Yes	No	Yes
Starry Smoothound	0	176	0	32	0	299	0	61	No	Yes	No	Yes
Thick Lipped Grey Mullet	0	13	0	9	1	29	1	17	No	No	No	No
Thin Lipped Grey Mullet	0	3	0	2	0	12	0	6	No	No	No	No
Thornback Ray	7	172	6	41	43	330	18	89	No	Yes	No	Yes
Three bearded Rockling	0	32	0	17	0	67	0	35	No	No	No	Yes
Tompot Blenny	0	9	0	4	0	30	0	11	No	No	No	No
Tope	0	28	0	10	0	66	0	25	No	No	No	Yes
Tub Gurnard	1	35	1	14	4	52	3	27	No	No	No	Yes
Turbot	8	42	6	19	22	57	15	22	No	No	No	Yes
Undulate Ray	0	41	0	14	0	56	0	28	No	No	No	Yes
Whiting	410	3114	50	118	1073	6843	112	253	Yes	Yes	Yes	Yes

3.1.2 Catch diary data

There were missing months data for many catch diarists with fewer less avid diarist providing full data and lower completion rates in 2016 than 2017 (Figure 1). There was little impact on the estimates of tonnages of cod and bass kept or released with either filling of data using hotdecking (van der Hammen et al., 2016), or using six, eight, or 12 months of data (Figure 2). Hence, hotdecking was not used in the final estimation to minimise complexity and the numbers of diarists was maximised by selecting any respondent with six or more months of data. This assumed that non-reporting was due to individuals not fishing within that month. Increasing the numbers of individuals trimmed reduced the tonnages kept and released, but was limited after the three individual largest and smallest catches had been removed (Figure 3). Thus, trimming three individuals with the largest and smallest catches was used to reduce the impact of a small number of anglers on the estimates of the total catch. This approach can lead to less variance and resultant interannual variation in estimates caused by chance occurrence of anglers with very high catches, but at the expense of some bias in estimates for each year.

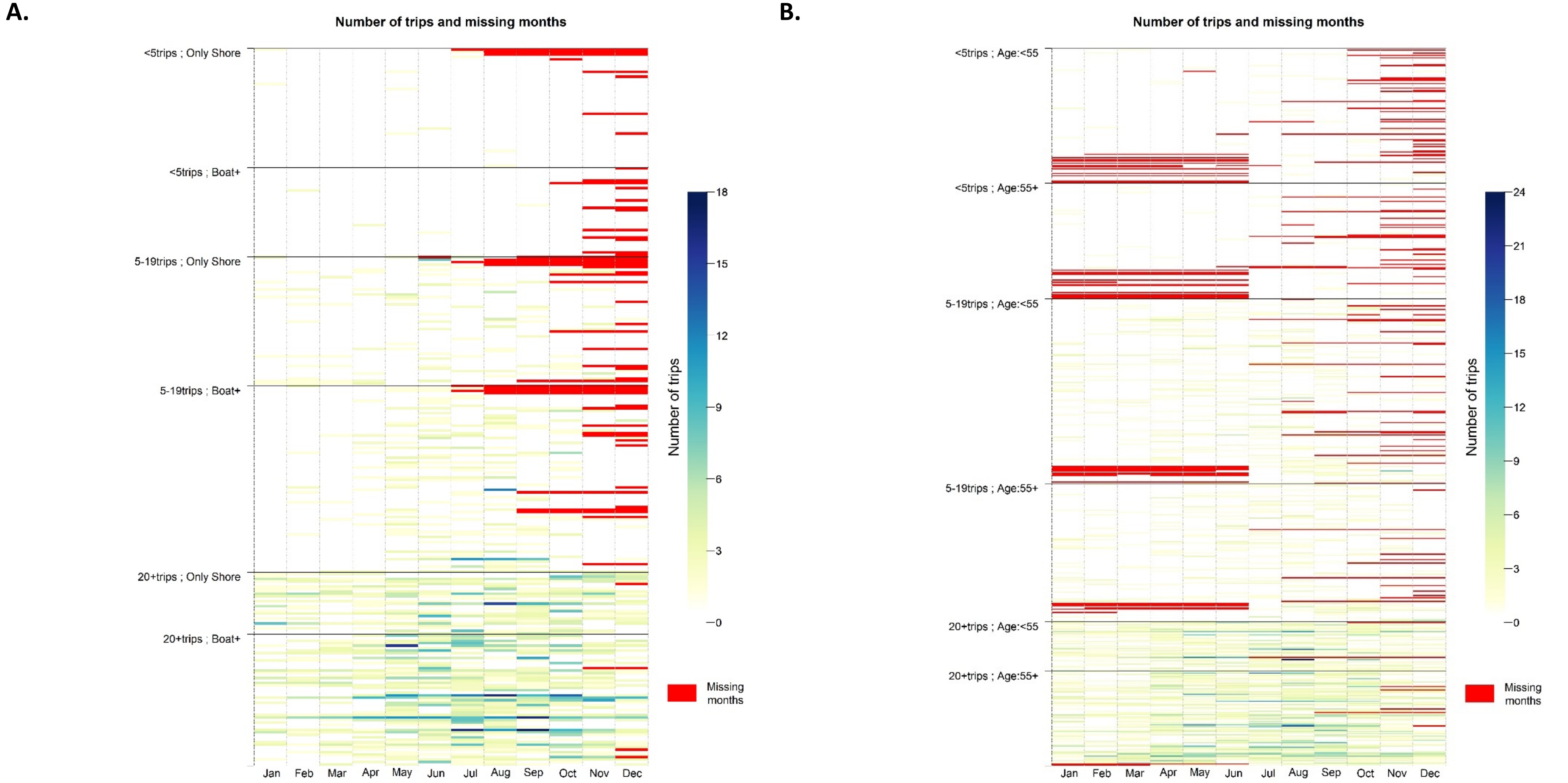


Figure 1. Number of trips reported per month for all diarists arranged by stratum. This uses three avidity and two platform strata (Strata 12 – Table 1) in 2016 (A) and three avidity and two age strata (Strata 15 – Table 1) in 2017 (B). Months for which no data was entered are shown in red.

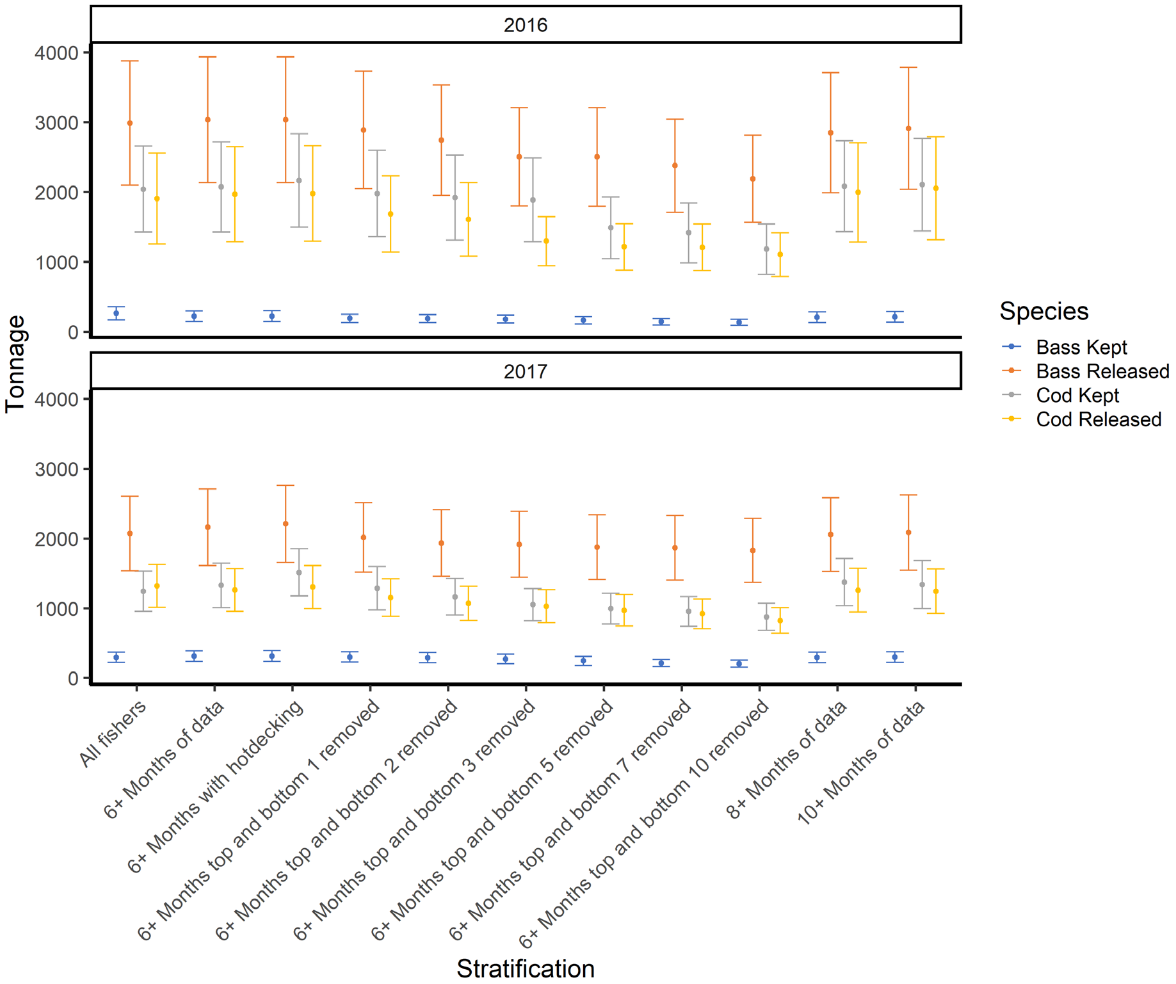


Figure 2. (A) Comparison of the total tonnage for cod and sea bass in 2016 raised to the total population obtained, from left to right, from all diarists, for those with at least 6 or 8 months of data, using stratification method strata 12 (Table 1). For each of these, there are results obtained both with and without filling in missing months by hotdecking; (B) Estimates for 2017 using stratification method strata 15 for all diarists and those with minimum 6, 8, 10 or 12 months of data in 2017. Error bars represent the standard error.

3.1.3 Post-stratification

Thirty-one different approaches for post-stratification were tested and compared to no stratification to assess the impact and generate an appropriate approach for post-stratification (Table 4; Table 5). The total number of strata ranged from one (no stratification) to 40 (4 avidity, 5 regions, 2 ages) which led to a minimum of 0-158 people in the WPS and 1-292 in the diary in 2016 (Table 4) and 0-166 in the WPS and 0-639 in the diary in 2017 (Table 5). Metrics used to assess the different approaches showed a wide range of bias discount, volatility, and average absolute difference (Table 4; Table 5). Balancing the numbers of respondents (WPS and diary) and metrics led to selection of strata 12 for 2016 (3 avidity and 2 platform - Table 4) and strata 15 for 2017 (3 avidity and 2 age - Table 5).

3.1.4 Analysis approach

It was then possible to define an estimation method for 2016 and 2017 catches by UK sea anglers (Figure 3). For each species recorded, this involved compiling and cleaning both the WPS and diary data, converting lengths to weights and filling missing weights. Once clean any species with less than four diarists or 15 records in the data sets were simply highlighted as caught, but no further analysis was done. If analysis was possible, diarists that had provided data for six months or more were selected and those with the three highest and lowest catches trimmed from the database to reduce the impact of single very large catches on the estimates. Then the potential to estimate tonnages was assessed by checking if five or more people recorded at least 50 individual fish lengths, and if below this threshold then only numbers were presented. The numbers and / or tonnages were then raised using the formulae and approach described in Section 2.1, using a combination of three avidity and two platform strata (strata 12 - Table 4) in 2016, and three avidity and two age strata (strata 15 - Table 5) in 2017. Finally, the estimates were presented with associated errors for the kept and released components of the catch by UK resident sea anglers in 2016 and 2017 (Figure 3). This approach was used to generate the estimates provided in Section 3.2.

Table 4. Testing the effect of different post-stratification approaches for 2016 on the minimum number of people in each stratum in the Watersports Participation Survey (WPS) and Diary survey. % refer to the % of respondents that could not be classified. Metrics shown are the bias discount (Bias_Discount) volatility and average absolute difference (Ave_Abs_Diff). Approach highlighted in grey was selected for full analysis.

		Number of divisions					Minimum number of people				Selection criteria		
Strata	**Description**	**Avidity**	**Platform**	**Region**	**Age**	**# Strata**	**WPS**	**Diary**	**WPS (%)**	**Diary (%)**	**Bias_Discount (%)**	**Volatility (%)**	**Avg_Abs_Diff (%)**
0	No stratification					1	158	292	0	0	#N/A	#N/A	#N/A
1	N. of Trips: <4, 4-8, 9-19, 20+	4				4	22	65	0	0	42.38	1	43.78
1.4	N. of Trips: <9, 9+	2				2	46	141	0	0	37.59	1	39.06
1.5	N. of Trips: <5, 5-19, 20-34, 35+	4				4	11	39	0	0	40.46	1	41.3
1.6	N. of Trips: <20, 20+	2				2	24	79	0	0	25.86	3	29.29
1.7	N. of Trips: <5, 5-19, 20+	3				3	24	79	0	0	39.74	1	40.57
2	Platform: Only Boat, Only Shore, Both Shore and Boat		3			3	26	71	0	0.7	17.05	5	21.77
2.1	Platform: Only Shore, Boat+		2			2	67	125	0	0.7	16.28	5	21.27
2.2	Platform: Only Boat, Shore+		2			2	41	71	0	0.7	-0.42	1	0.76
3	5 regions			5		5	15	28	0	0	4.88	10	14.87
3.1	6 regions			6		6	15	18	0	0	4.98	10	14.72
3.2	4 regions			4		4	21	66	0	0	6.19	8	14.65
4	Age: <55, 55+				2	2	48	128	0	0	-4.39	36	31.24
4.1	Age: 18-34, 35-44, 45-54, 55-64, 65+				5	5	19	14	0	0	-21.91	86	64.12
4.2	Age: 18-34, 35-54, 55-64, 65+				4	4	19	14	0	0	-21.48	79	57.2
Combined Categories:		0	0	0	0								
5	1 and 3	4		5		20	0	3	0	0	NA	NA	NA
6	1, 3 and 4	4		5	2	40	0	1	0	0	NA	NA	NA
7	1.4, 3.2 and 4	2		4	2	16	2	8	0	0	41.84	6	47.72
8	1.5, 3.2 and 4	4		4	2	32	0	1	0	0	NA	NA	NA
9	1.5 and 3.2	4		4		16	1	5	0	0	35.29	4	39.2
10	1.6 and 3	2		5		10	3	3	0	0	25.94	9	35.26
10.5	1.4 and 3	2		5		10	5	7	0	0	39.81	5	44.93
11	1.5 and 2	4	3			12	1	4	0	0.7	51.05	1	51.66
12	1.7, 2.1	3	2			6	10	25	0	0.7	49.03	0	49.47
13	1.7, 2.1 and 3.2	3	2	4		24	1	3	0	0.7	50.29	4	54.11
14	1.7, 2.1, and 4	3	2		2	12	3	10	0	0.7	48.42	4	52.03
15	1.7 and 4	3			2	6	11	30	0	0	41.11	2	43.19
16	1.6, 2.2 and 4	2	2		2	8	0	4	0	0.7	NA	NA	NA
17	1.7 and 2.2	3	2			6	2	11	0	0.7	45.5	1	46.26
18	1 and 4	4			2	8	8	23	0	0	42.74	2	45.09
19	1.4, 2.2 and 4	2	2		2	8	1	9	0	0.7	37.13	5	42.36
20	1.5 and 4	4			2	8	4	14	0	0	38.01	2	40.47

Table 5. Testing the effect of different post-stratification approaches for 2017 on the minimum number of people in each stratum in the Watersports Participation Survey (WPS) and Diary survey. % refer to the % of respondents that could not be classified. Metrics shown are the bias discount (Bias_Discount) volatility and average absolute difference (Ave_Abs_Diff). Approach highlighted in grey was selected for full analysis.

		Number of divisions					Minimum number of people				Selection criteria		
Strata	**Description**	**Avidity**	**Platform**	**Region**	**Age**	**# Strata**	**WPS**	**Diary**	**WPS (%)**	**Diary (%)**	**Bias_Discount (%)**	**Volatility (%)**	**Avg_Abs_Diff (%)**
0	No stratification					1	166	639	0	0	#N/A	#N/A	#N/A
1	N. of Trips: <4, 4-8, 9-19, 20+	4				4	17	129	0	0	25.46	0	25.46
1.4	N. of Trips: <9, 9+	2				2	46	287	0	0	29.26	0	29.61
1.5	N. of Trips: <5, 5-19, 20-34, 35+	4				4	11	61	0	0	24	0	24.34
1.6	N. of Trips: <20, 20+	2				2	29	129	0	0	9.97	1	10.55
1.7	N. of Trips: <5, 5-19, 20+	3				3	29	129	0	0	21.99	0	22.33
2	Platform: Only Boat, Only Shore, Both Shore and Boa		3			3	25	107	0	0.2	2.34	21	23.36
2.1	Platform: Only Shore, Boat+		2			2	81	302	0	0.2	-4.62	10	5.8
2.2	Platform: Only Boat, Shore+		2			2	56	107	0	0.2	-5.68	28	22.56
3	5 regions			5		5	16	52	0	0	3.38	13	15.91
3.1	6 regions			6		6	13	20	0	0	4.7	16	20.68
3.2	4 regions			4		4	33	125	0	0	3.46	13	16.08
4	Age: <55, 55+				2	2	66	311	0	0	7.13	7	14.58
4.1	Age: 18-34, 35-44, 45-54, 55-64, 65+				5	5	27	0	0	41.8	#N/A	#N/A	#N/A
4.2	Age: 18-34, 35-54, 55-64, 65+				4	4	33	61	0	0	11.65	4	16.12
Combined Categories:													
5	1 and 3	4		5		20	2	8	0	0	26.25	9	35.58
6	1, 3 and 4	4		5	2	40	0	2	0	0	#N/A	#N/A	#N/A
7	1.4, 3.2 and 4	2		4	2	16	1	20	0	0	31.5	10	41.51
8	1.5, 3.2 and 4	4		4	2	32	0	1	0	0	#N/A	#N/A	#N/A
9	1.5 and 3.2	4		4		16	1	6	0	0	20.96	19	39.59
10	1.6 and 3	2		5		10	3	8	0	0	11.34	14	25.76
10.5	1.4 and 3	2		5		10	6	20	0	0	28.72	9	37.88
11	1.5 and 2	4	3			12	2	4	0	0.2	17.22	15	31.8
12	1.7 and 2.1	3	2			6	13	61	0	0.2	18.79	2	20.42
13	1.7, 2.1 and 3.2	3	2	4		24	1	8	0	0.2	19.92	13	32.45
14	1.7, 2.1, and 4	3	2		2	12	5	21	0	0.2	23.34	8	30.95
15	1.7 and 4	3			2	6	14	44	0	0	24.34	4	28.17
16	1.6, 2.2 and 4	2	2		2	8	3	2	0	0.2	1.9	27	28.47
17	1.7 and 2.2	3	2			6	8	11	0	0.2	12.19	16	28.61
18	1 and 4	4			2	8	4	44	0	0	28.03	3	30.97
19	1.4, 2.2 and 4	2	2		2	8	6	8	0	0.2	25.52	11	37
20	1.5 and 4	4			2	8	4	16	0	0	25.99	4	30.33

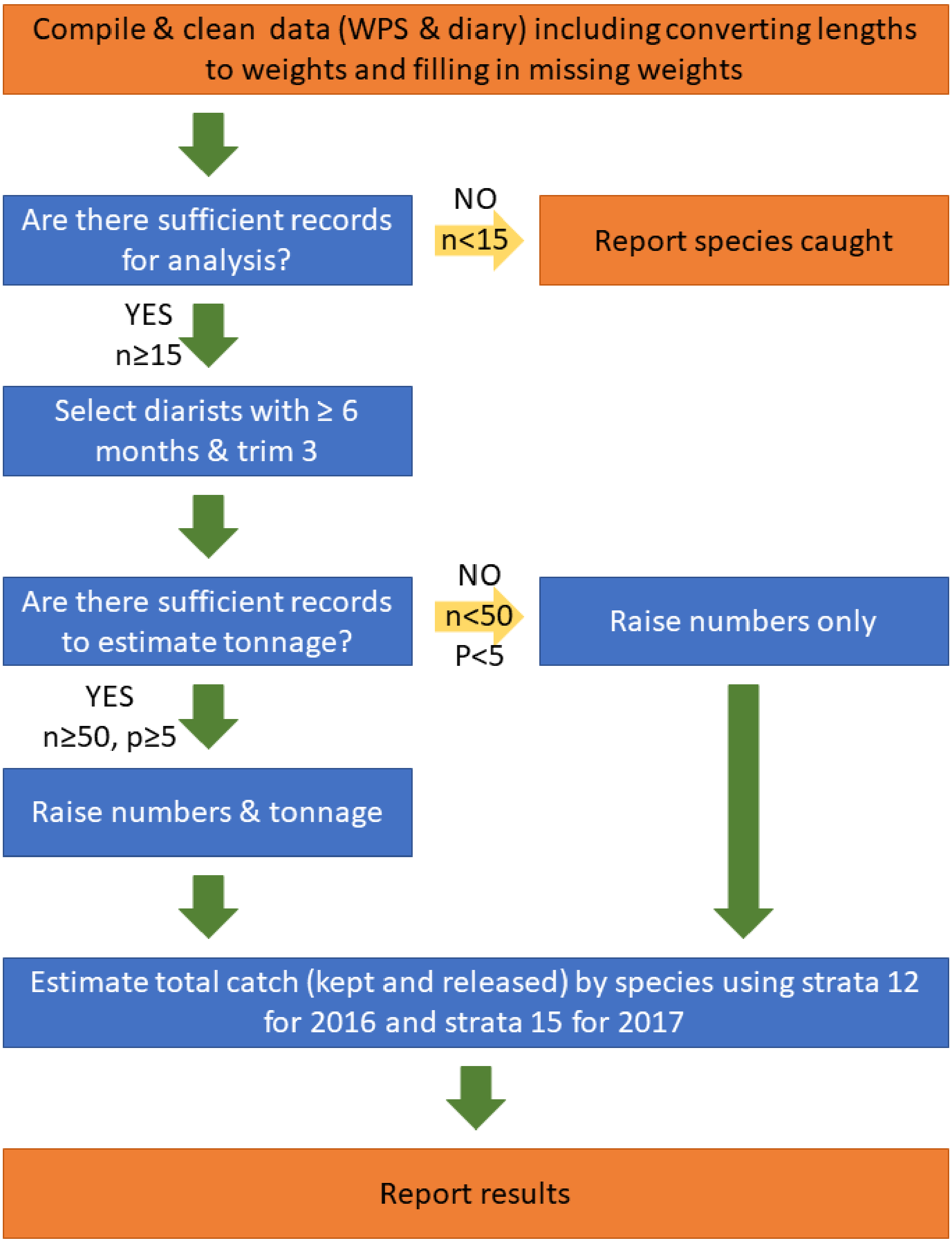


Figure 3. Schematic demonstrating the final estimation procedure for each species and/or group. Stratification method strata 12 in 2016 and strata 15 in 2017 are described in Table 1.

3.2 Assessing catches

3.2.1 Numbers & tonnages

The total number of fish caught was similar in both the 2016 (49.7 million) and 2017 (54.5 million) surveys. For the limited numbers of species where tonnage was estimated, a total of 25559 t and 28856 t thousand tonnes of fish were caught in 2016 and 2017, respectively. Further, the quantity of fish retained and released were similar in terms of both number (2016: retained 9.6 million, released 40.1 million; 2017: retained 11.9 million, released 42.6 million) (Figure 4A) and tonnage (2016 retained: 5866t, released: 19693t; 2017 retained: 6784t, released: 22073t). The percentage of fish that were released ranged between 81% in 2016 and 78% in 2017 (Figure 4B).

The total number of fish kept and released were similar in 2016 (34.6 million) and 2017 (40.5 million) with release rates in the region of 80%. English sea anglers kept (Figure 4C) and released (Figure 4D) the largest numbers of fish, mainly due to the higher number of anglers resident in England. Catches per angler were similar in 2016 and 2017 (Figure 5A), but total numbers of kept and released varied for Wales and Northern Ireland (Figure 5B&C) probably due to the small number of diarists. A similar picture is seen for individual species, where the numbers and tonnages were similar in 2016 and 2017 (Figure 6; Figure 7). Differences in tonnages kept and released between the years were largely explained by differences in the average fish weights (Figure 8).

For England, catches of kept fish were similar in 2012 to 2016 and 2017 (Figure 4C), but the number of fish released was much higher in 2016 and 2017 than 2012 (Figure 4D). This corresponded to higher release rates in 2016 (81%) and 2017 (78%) than 2012 (61%). The catches by individual anglers were higher across the whole year (Figure 5A) and for each trip (Figure 5B) in 2016 and 2017 than 2012. This difference was much larger for the released (Figure 5E&F) than kept (Figure 5C&D) component of the catch both per angler and trip. This was true for most individual species with catches higher, but the difference was greatest in the released component of the catch (Figure 9; Figure 10).

3.2.2 Catch composition

In total, 100 fish species were recorded as being caught by sea anglers in the UK in 2016 and 2017 varying from small unusual species (e.g. tompot blenny) through common angling species (e.g. cod, bass, dab, whiting and mackerel) to large pelagic fish (e.g. blue shark). The composition of species in the catch was similar in 2016 and 2017 with the same top four most common species in terms of numbers of fish caught being whiting, mackerel, dogfish and bass (Figure 11). The next four most common species were cod, pollack, dab and bib, but these appeared in a different in order in the two years (Figure 11). The only difference at number 20 was ling in 2016 replaced by corkwing wrasse in 2017 (Figure 11), suggesting that numbers caught at this level should be interpreted with caution. The composition of catches was similar for England in 2012 and 2016 although there were differences in the order and the two most common species, whiting and mackerel, which were reversed in the two years (Figure 12).

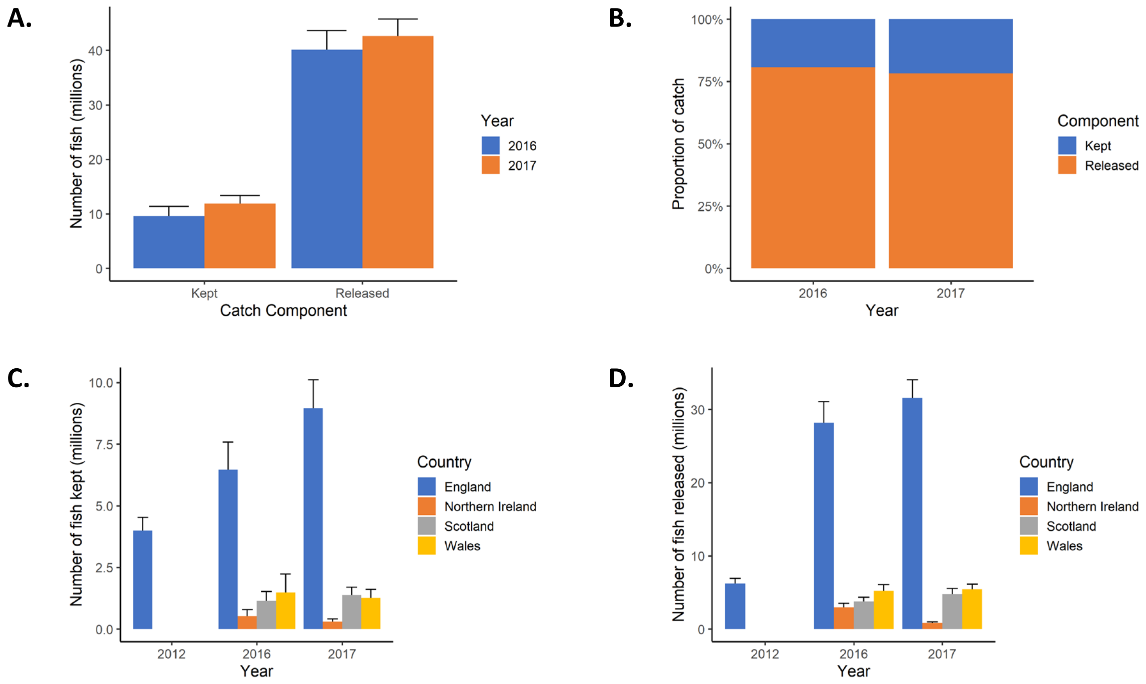


Figure 4. Numbers of fish kept and released (A) and release proportions (B) for the whole UK in 2016 and 2017 (A&B); and numbers of fish kept (C) and released (D) for individual countries within the UK in 2012, 2016 and 2017. The error bars represent standard errors.

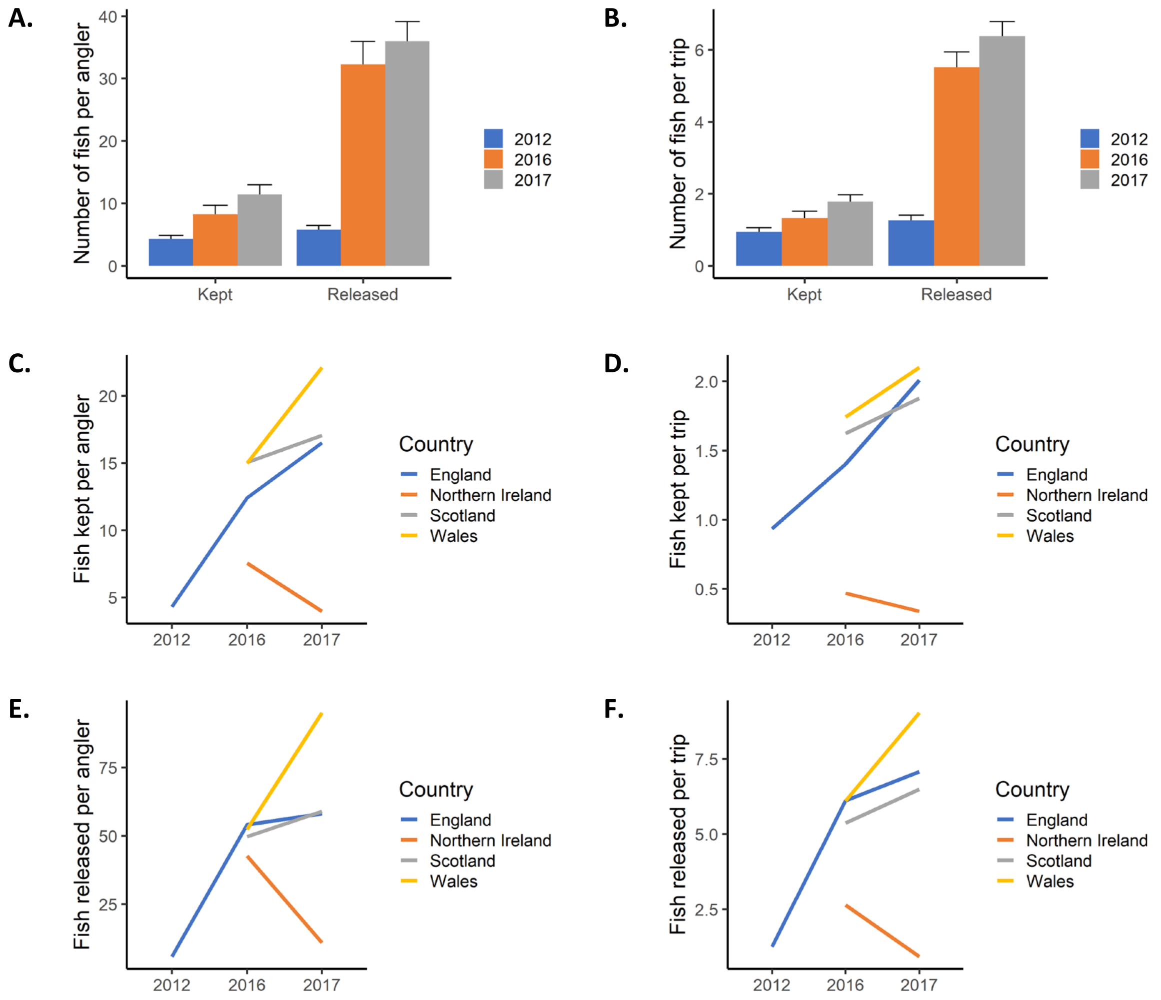


Figure 5. Catch per angler (A, C, E) and per day (B, D, F) by individual sea anglers resident the UK. Comparison of fish kept and released by angler (A) and trip (B) in England in 2012 with the UK in 2016 and 2017. Numbers of fish kept and released by anglers each year (C&D) and each trip (E&F) by country within the UK.

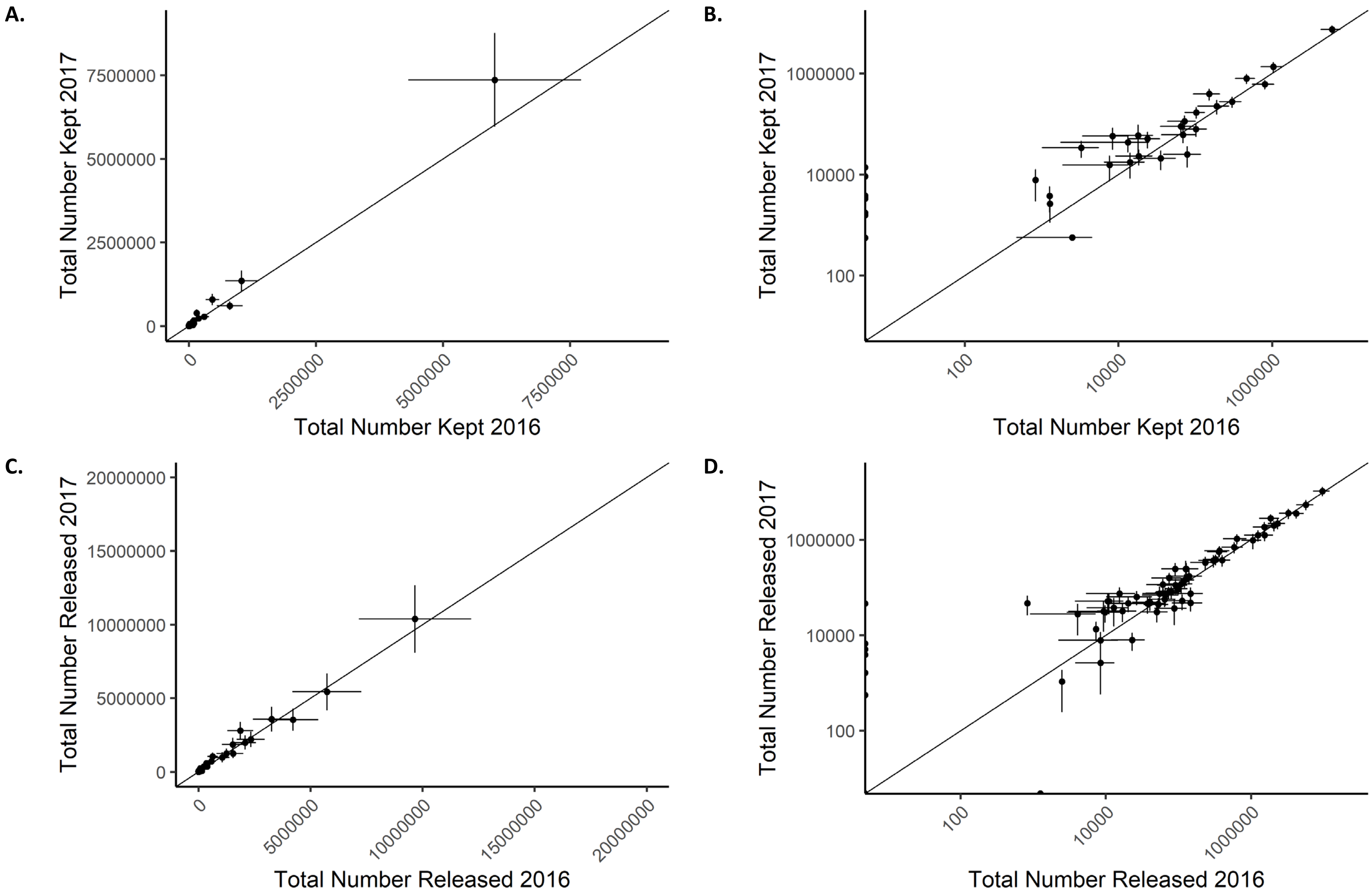


Figure 6. Comparisons of numbers of fish kept (A&B) and released (C&D) by species in 2016 and 2017. The results are provided on the normal (A&C) and logarithmic scale (base 10) (B&D). Solid line shows where the values are equal.

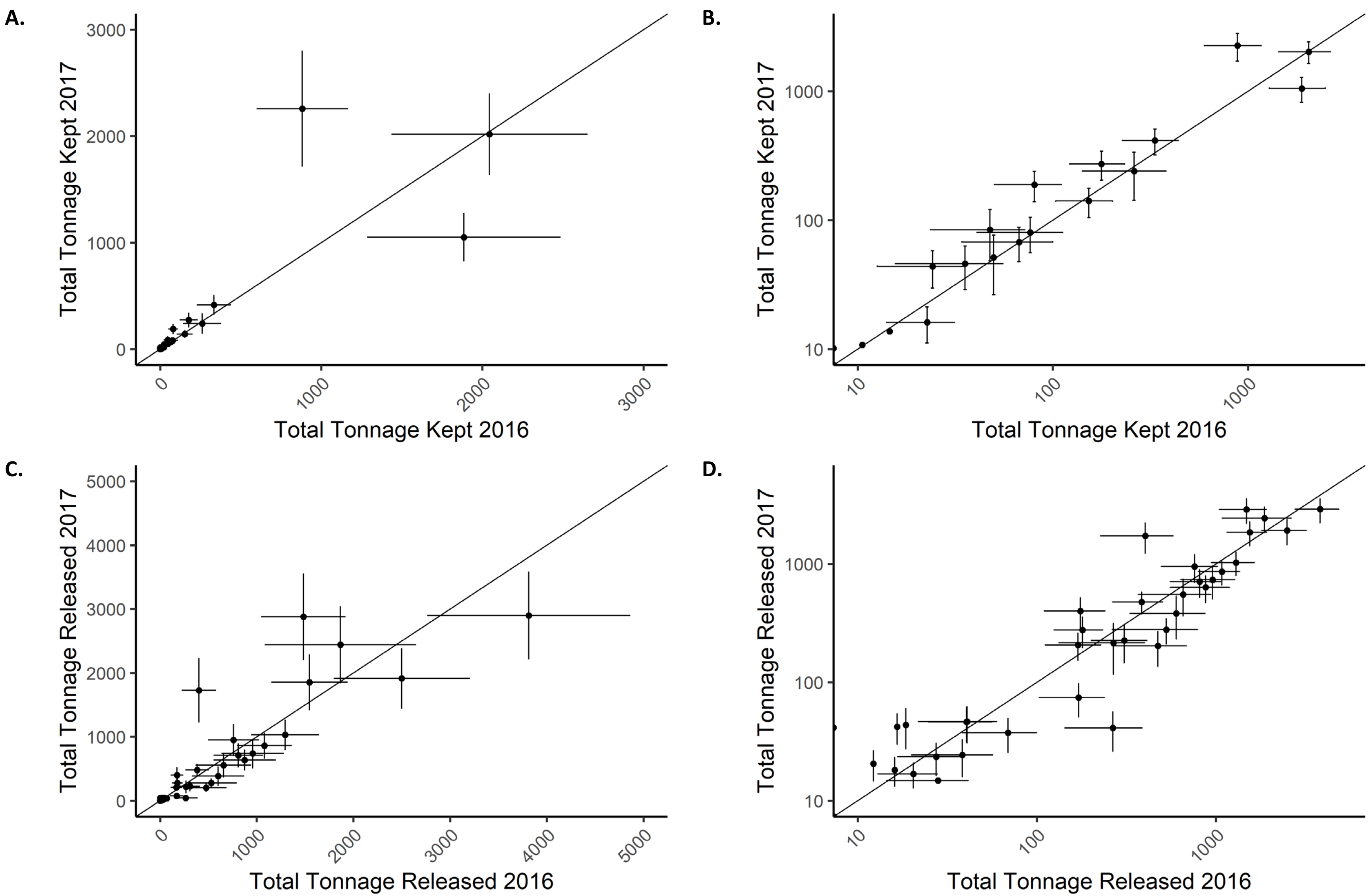


Figure 7. Comparisons of tonnage of fish kept (A&B) and released (C&D) by species in 2016 and 2017. The results are provided on the normal (A&C) and logarithmic scale (base 10) (B&D). Solid line shows where the values are equal.

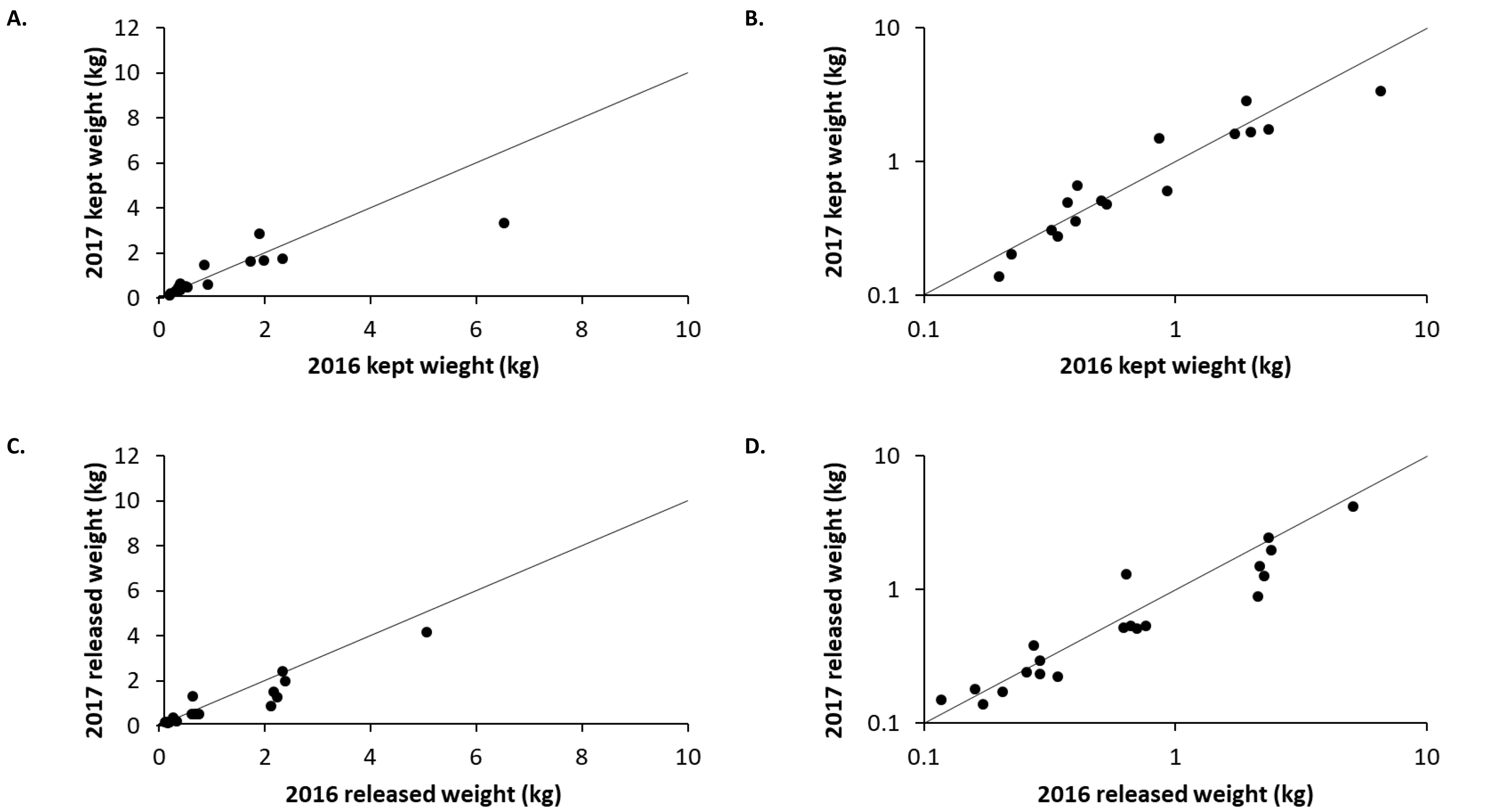


Figure 8. Comparisons of average weights of fish kept (A&B) and released (C&D) by species in 2016 and 2017. Solid line shows where the values are equal.

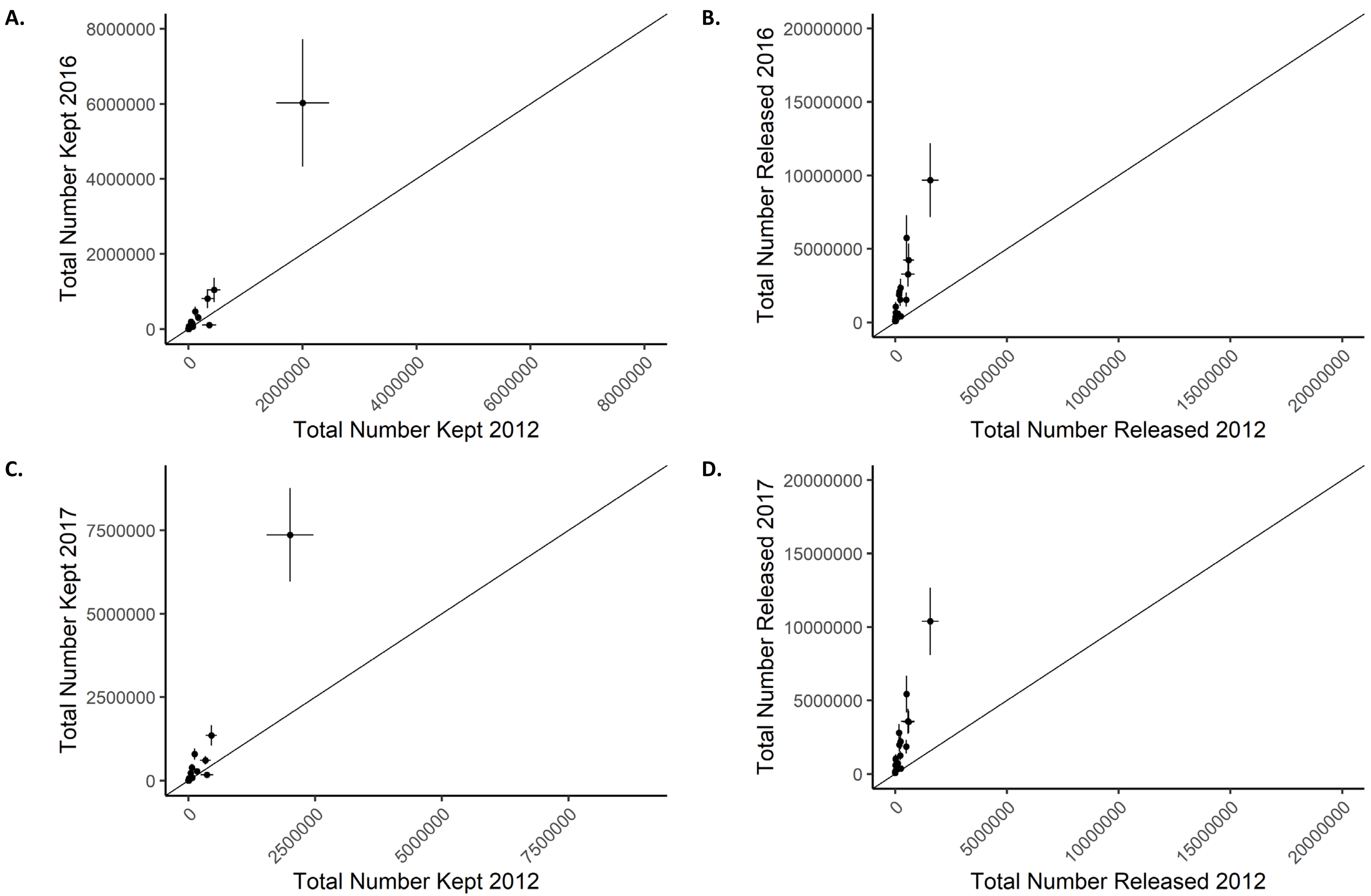


Figure 9. Comparisons of numbers of fish kept (A&C) and released (B&D) by species in 2016 (A&B) and 2017 (C&D) with 2012 by English sea anglers. Solid line shows where the values are equal.

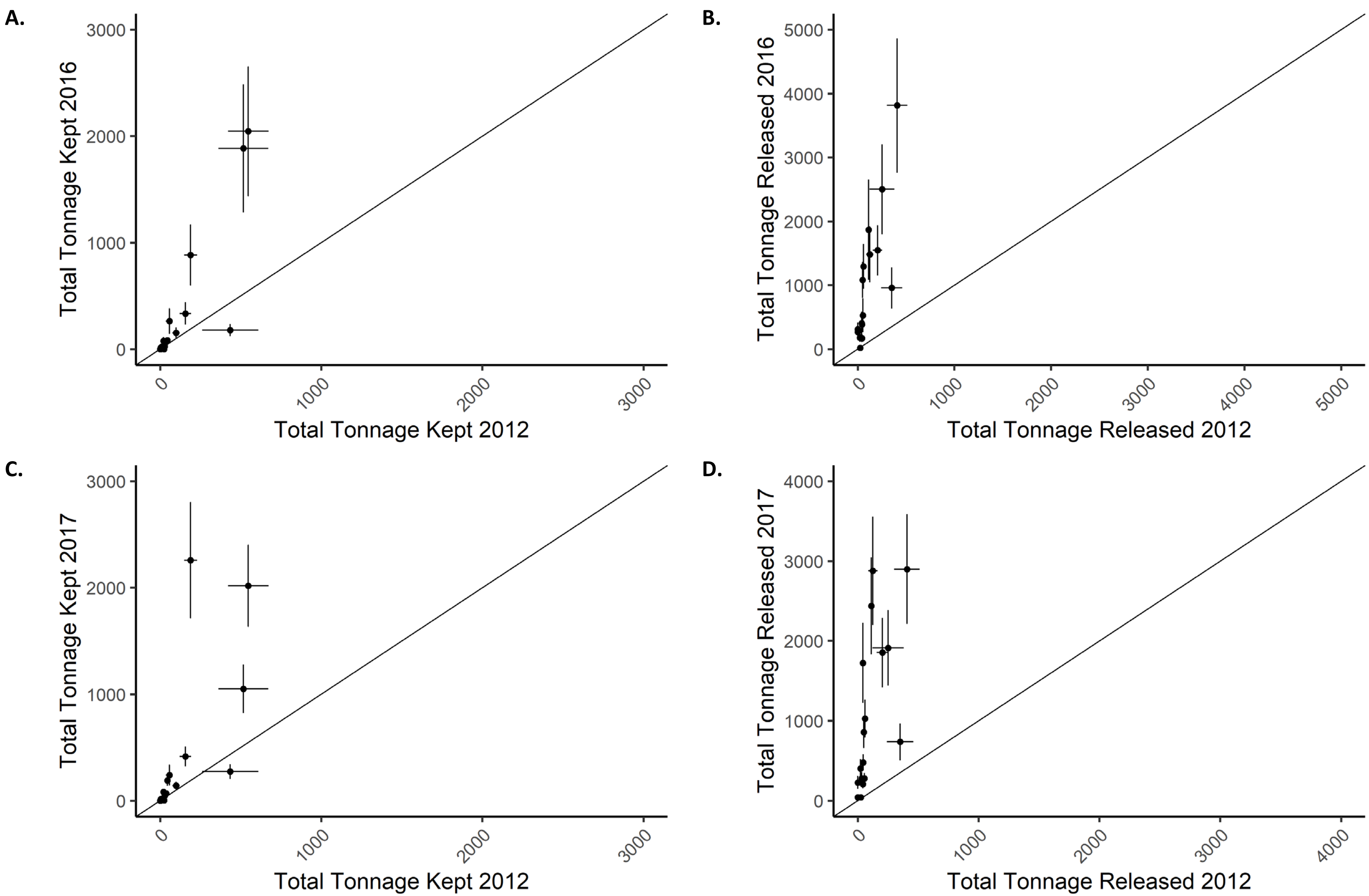


Figure 10. Comparisons of tonnage of fish kept (A&C) and released (B&D) by species in 2016 (A&B) and 2017 (C&D) with 2012 by English sea anglers. Solid line shows where the values are equal

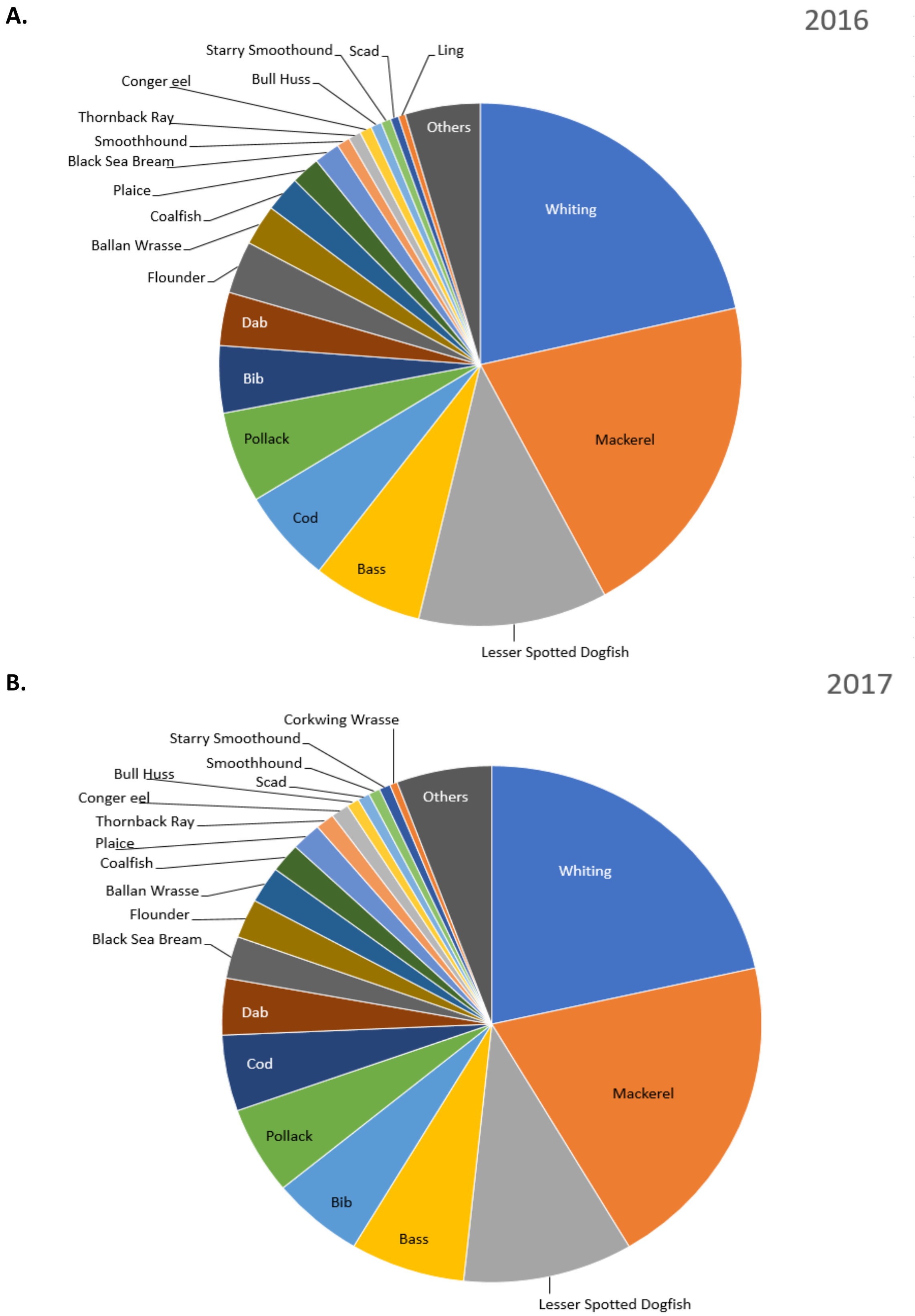
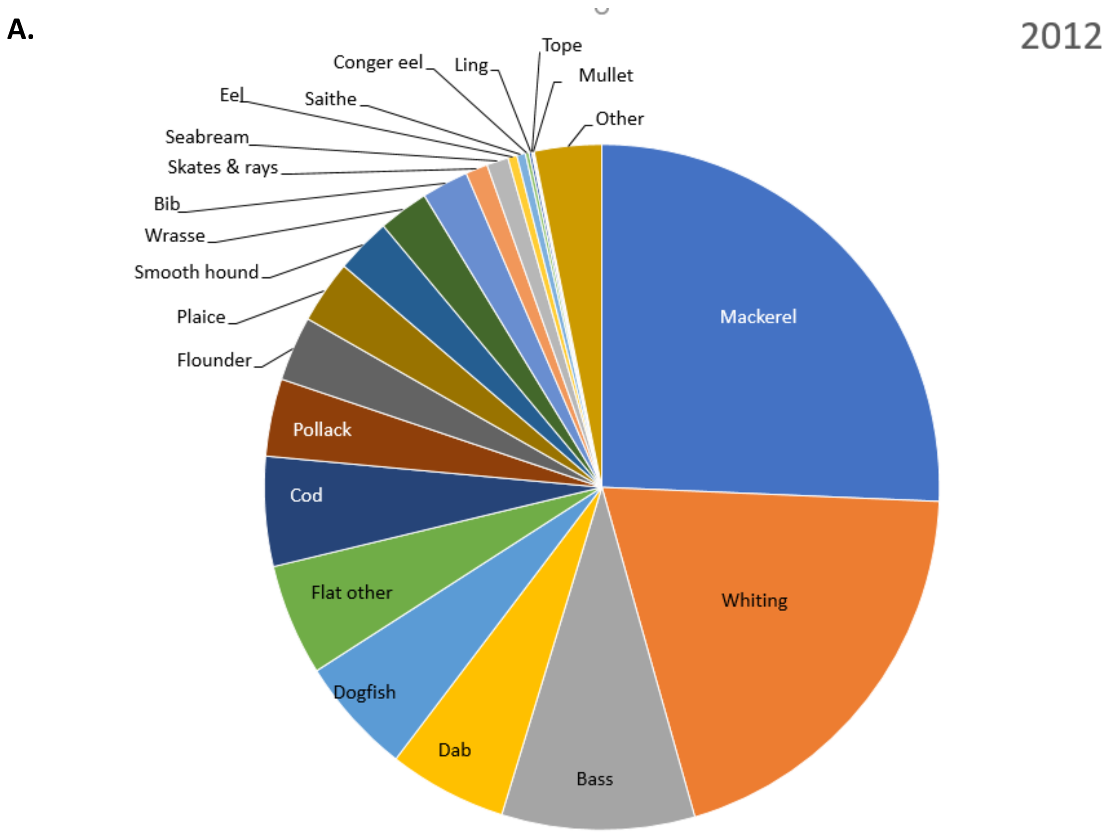


Figure 11. Catch composition by number for the UK in 2016 (A) and 2017 (B) with the top 20 most commonly caught fish displayed.



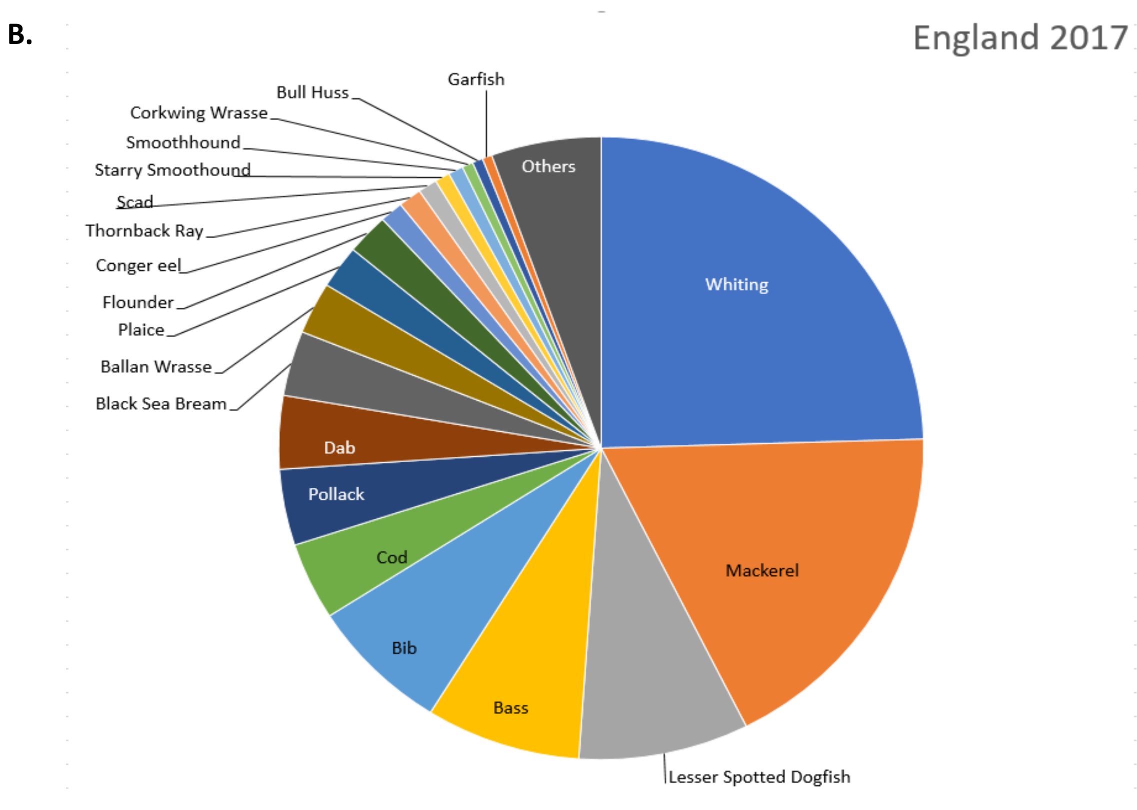


Figure 12. Catch composition by number for the England in 2012 (A) and 2017 (B) with the top 20 most commonly caught fish displayed.

3.2.3 Catches reported under the Data Collection Framework

Reporting is required under the Data Collection Framework (DCF) of catches (kept and released numbers and tonnage) of sea bass, cod, eel, pollack, salmon, sea trout, elasmobranchs and highly migratory ICCAT species (e.g. Atlantic Bluefin Tuna). Catches of diadromous species eel, sea trout and salmon were minimal, but there were significant catches of sea bass, cod and pollack (Figure 13). Catches were similar in 2016 and 2017 for most species apart from pollack and cod where there were differences in number and tonnage (Figure 13). The kept and released components of the catch were generally higher than in 2012, especially for the released component (Figure 13). The exception was for sea bass, where the kept component of the catch has reduced due to the implementation of bag limits and closed seasons since 2015 (Figure 13).

For most of the DCF species, it was not sensible to partition catches between countries or ICES areas due to the small number of reports of catches. However, this was done for the two common species cod and sea bass (Figure 14; Figure 15). These results are uncertain due to the small numbers of diarists in the individual countries. However, the majority of cod and bass is taken in England due to the higher number of anglers, but the difference is far greater with bass than cod as would be expected due to the different distributions of species (Figure 14). Catches of sea bass are mainly in the south west (VIIe&f), but fish are caught in the southern north sea (IVc), English Channel (VIId) and Celtic Sea (VIIg&h) (Figure 15). Cod have a more even distribution of catches around the UK with the largest catch in the central North Sea (VIIb) (Figure 16).

Length-frequency histograms were calculated for all species where sufficient data were available and could be raised. Examples are provided for sea bass (Figure 16) and cod (Figure 17). These show the uneven nature of the distribution due to the relatively small numbers of lengths, but reasonable agreement between the years (Figure 16; Figure 17). Generally fish that were released were smaller than those kept (Figure 16; Figure 17).

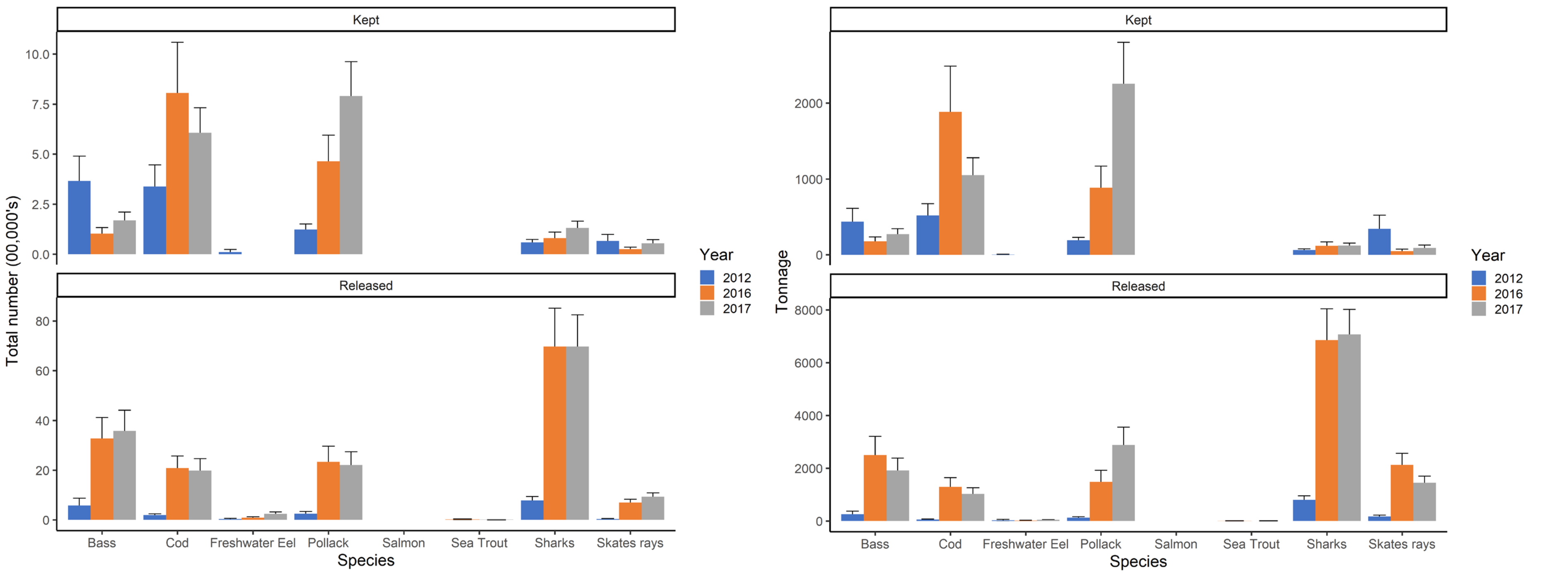


Figure 13. Numbers and tonnage of DCF reported fish kept and released by sea anglers resident the UK in 2012, 2016 and 2017. The results for 2012 are for England only. There were insufficient data for provide tonnages salmon, sharks and skates and rays. Error bars represent standard errors.

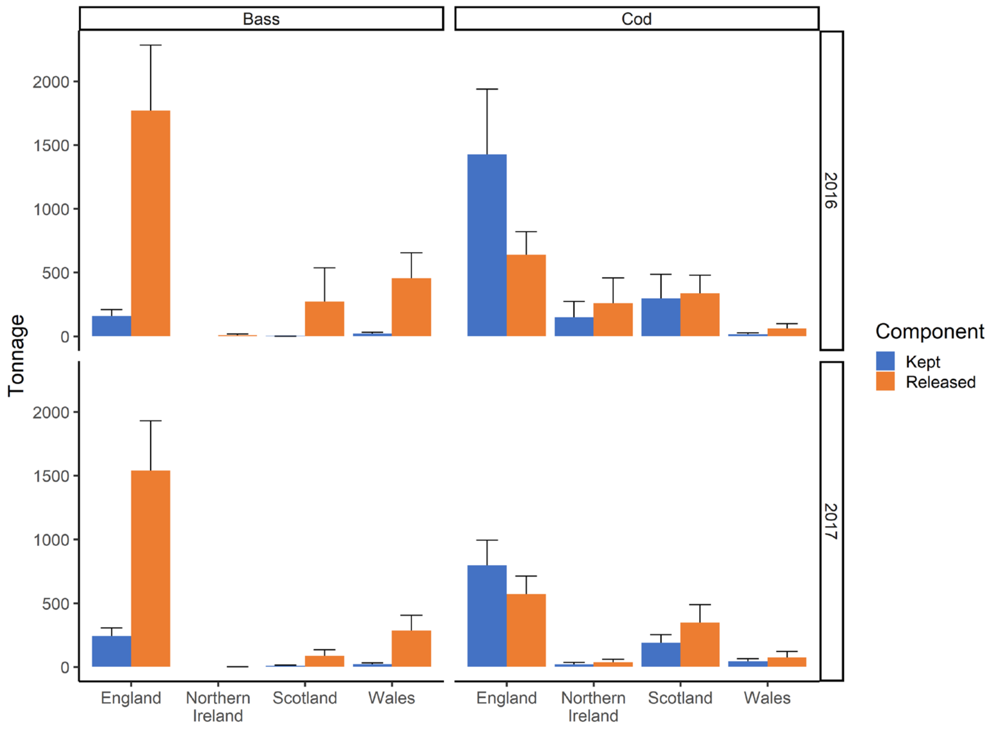


Figure 14. Tonnages of cod and sea bass kept and released by anglers resident in different countries within the UK in 2016 (top) and 2017 (bottom). Error bars represent standard errors.

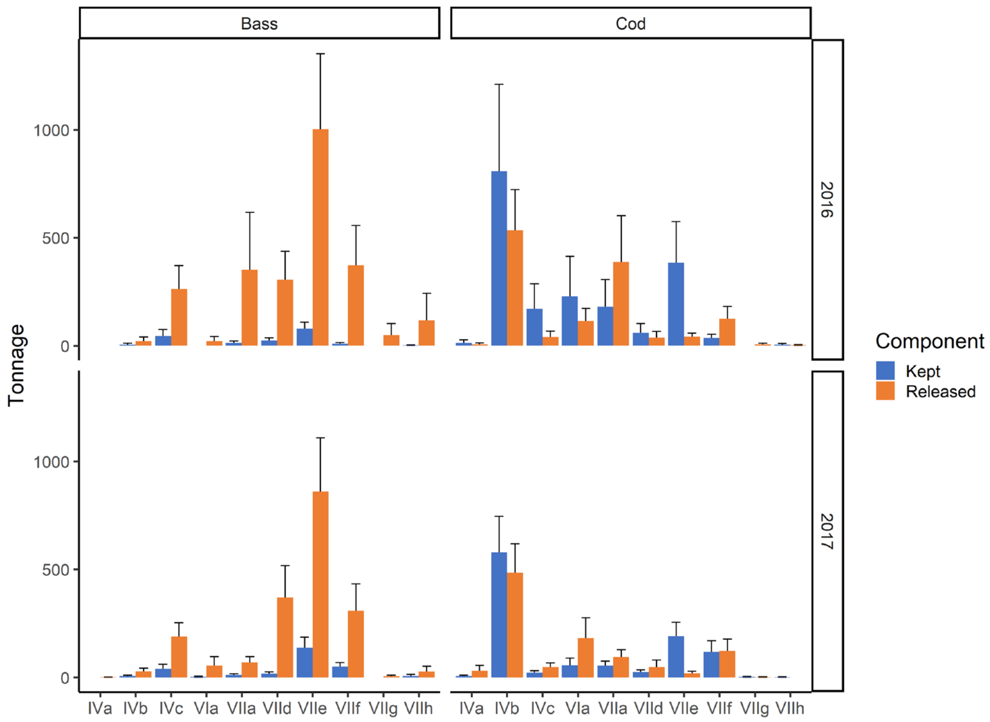


Figure 15. Tonnages of cod and sea bass kept and released for ICES areas by sea anglers resident in the UK in 2016 (top) and 2017 (bottom). Error bars represent standard errors.

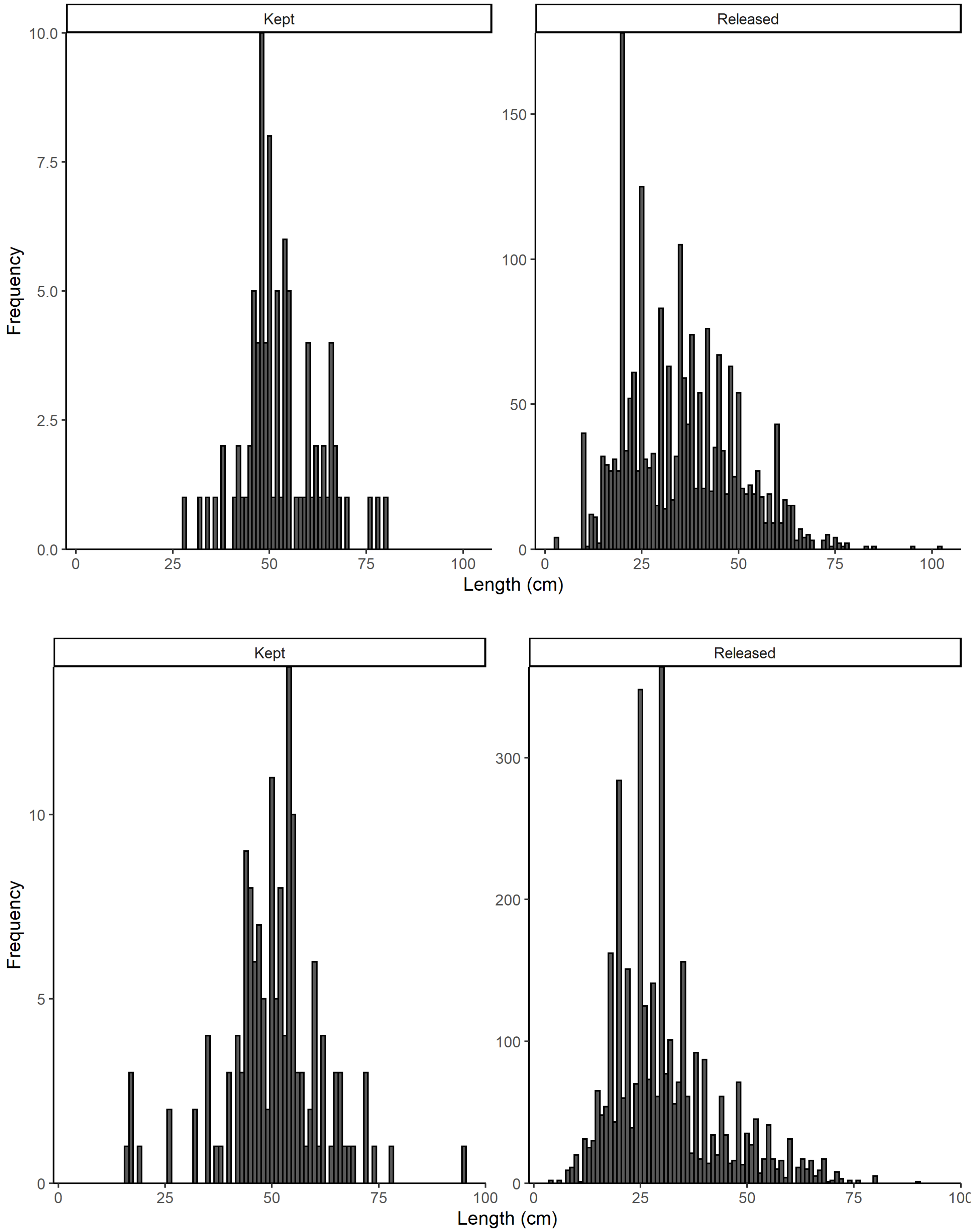


Figure 16. Length frequency histograms for sea bass in 2016 (top row) and 2017 (bottom row), both kept (left side) and released (right side) for 2016.

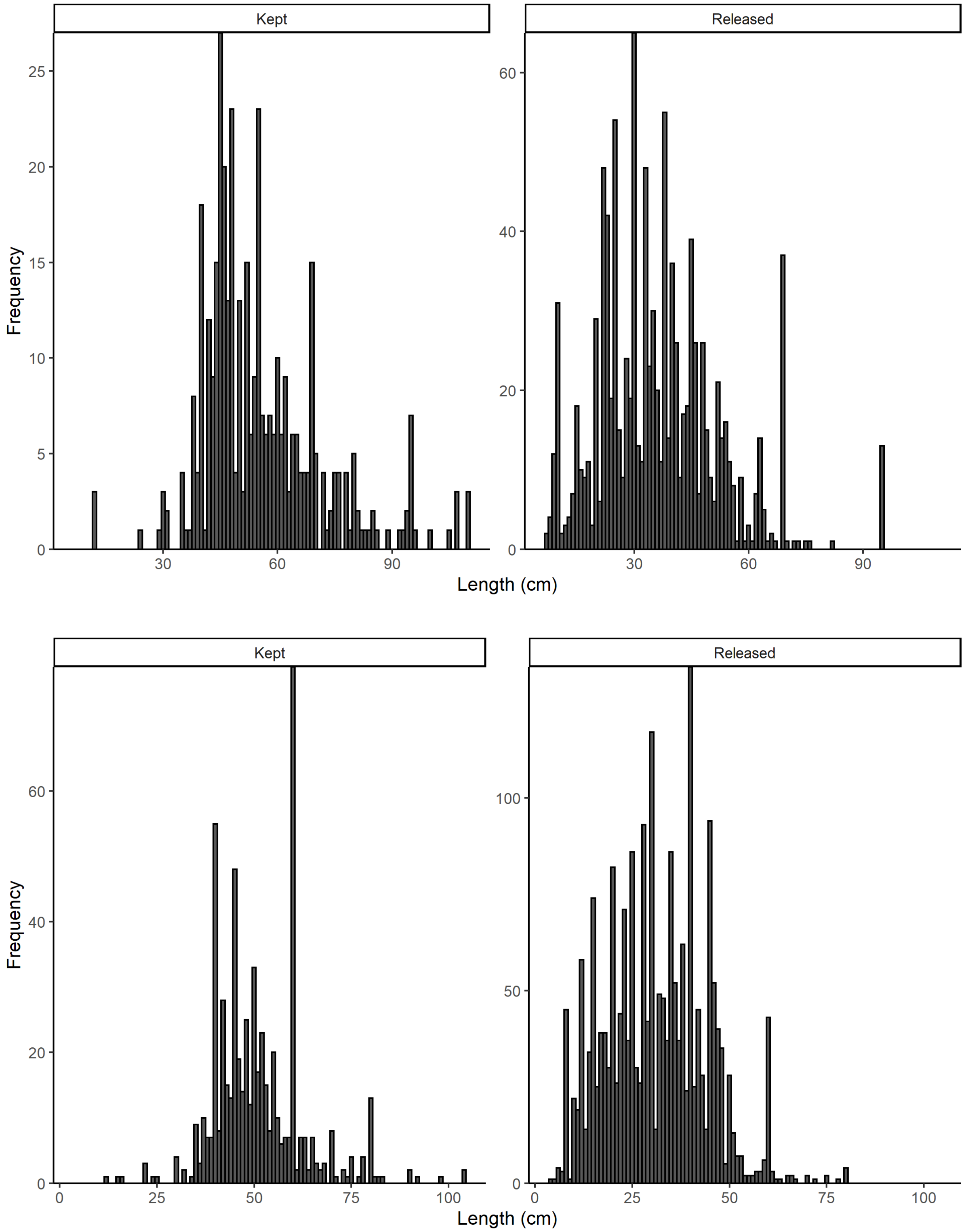


Figure 17. Length frequency histograms for cod in 2016 (top row) and 2017 (bottom row), both kept (left side) and released (right side) for 2016.

4 Discussion

4.1 Catch estimates

Total annual catches by sea anglers resident in the UK in 2016 and 2017 were estimated by recruiting a nationwide panel of sea anglers to record their catches during the year in diaries. Firstly, approaches were developed for raising the panel's catches to the population level, and for estimating precision of catch estimates (Figure 3). This included specifying thresholds beyond which a species had enough observations to calculate raised catch numbers or weight, filling missing length data, converting lengths to weights, trimming to reduce the influence of small numbers of anglers reporting very large catches, selection of an appropriate post-stratification for reweighting the panel data to better reflect the population, and estimating precision. A hotdecking approach was tested for imputing catch data for months where anglers failed to enter any data, but was not used due to the limited impact on the results.

In total, 100 species were caught by sea anglers on the panel, with numbers of fish caught estimated for 68 species over the two years of which 20 in 2016 and 32 in 2017 had enough data to calculate annual catch tonnages. The total number of fish kept or released was 49.7 million in 2016 and 54.5 million in 2017, with a release rate of around 80% for both years. Release rates varied widely across species. The majority of catches were by English sea anglers due to the large proportion of UK sea anglers resident in England. Catches, releases, and catch composition were similar in 2016 and 2017. For the DCF species, catches were minimal for diadromous species, but high for cod, bass, and pollack. The distribution of catches between UK countries and ICES sea areas were as expected with most sea bass being caught by English anglers in the south west and a more even spatial distribution for cod.

4.1.1 Potential bias

All approaches for collecting data on sea angling are subject to error, due to the varied and dispersed nature of the activity. This arises from two sources: measurement error (precision) and biases from issues with design and implementation of each survey and methods used for extrapolation (Pollock et al. 1994; ICES 2010; Jones and Pollack, 2013). Whilst diary surveys have been shown to represent good value for money and are used in many countries (Bellanger and Levrel, 2017), they are subject to a larger set of biases than on-site approaches (Jones and Pollack, 2013). For this survey, there will be uncertainty in the UK estimates of numbers of sea anglers from the WPS, catches by individuals from the diary panel, and the data analysis. These are discussed in detail in this section.

The WPS is an omnibus, randomised face-to-face survey of 12000 people in the UK (see Annex 1 for full details). As the participation rate in sea angling is less than 2%, this led to fewer than 200 respondents in both 2016 and 2017 reporting that they had gone sea angling. This low number of respondents made the estimates of numbers of sea anglers imprecise and limited the amount of post-stratification that could be implemented for reweighting the panel data to be more representative of the population. A much larger survey would increase the number of respondents, reducing the error and would allow a higher level of stratification, but is not feasible within the current WPS which covers a very wide range of other watersports activity. Another approach could be to combine WPS data over two or more individual years, if there is reason to believe that angler numbers and fishing patterns change only slowly in the short term, although this approach will introduce some bias.

Ideally, a diary panel should be a picked at random from a population of sea anglers to ensure it is as representative as possible. This is very difficult as there is no complete list of sea anglers in the UK (e.g. a fishing licence or other registration system). Randomised telephone or postal surveys can be used for estimating fishing effort as well as recruiting people to the diary panel, but can have low response rates. It was therefore deemed appropriate to use a self-selected sample of volunteers from a list of sea anglers, following publicising of the survey in angling media and events and through contacts with people who have participated in other angling surveys, using angling-related incentives such as prizes of fishing tackle in periodic draws. This may have attracted more avid, engaged, and experienced anglers, increasing the potential for bias in catch estimates. In addition, getting infrequent anglers to contribute was also very difficult. The composition of the final panels in 2016 and 2017 differed from the respondents to the WPS surveys, particularly in relation to avidity, which was lower on average in the WPS. Different approaches were tried to increase participation by those who fish rarely including face-to-face recruitment, but this remained a challenge.

Bias was reduced where possible by reweighting the sample to reflect the known population, using the WPS population survey data on variables such as avidity and main angling method, but it was unlikely that all sources of bias were corrected (e.g. skill and experience). Several different methods for post-stratification were tested to reweight the diary panel to reflect the population in terms of avidity, age, or sea angling method. However, this does not fully remove bias, which must be taken into consideration when the data are used. Many factors have been shown to influence catch rates of anglers, such as motivations for participation (Arlinghaus, 2006; Beardmore et al., 2011; Fedler and Ditton, 1994). For example, fishers motivated by catching fish to eat will have lower release rates than those who fish for sport (Beardmore et al., 2011). If anglers who are more motivated or skilled are more likely to volunteer for surveys, this would increase the potential for over-estimating the average catch rates in the population based on catch diaries as these characteristics are not currently recorded in the WPS and the diary panel. Understanding any residual bias that has not been corrected in the current survey would highlight how best to use this survey to support decision making. Additional data collection has been added to the 2019 survey to collect data to assess the level of residual bias.

There were challenges during the analysis that should be revisited. There were issues with completion rates with diarists with six or more months of data who were included in the analysis, but the assumption was that these individuals did not fish in months with missing data. Significant effort was put into reminding diarists to ensure all data were provided, but obtaining complete data was very difficult. Additional changes have been made to the online diary system to make completion easier and more efficient that should increase rates in future years. Finally, the biological data on the sizes of the fish were limited and missing in some cases. This reduced the accuracy of mean individual fish weights and hence estimates of total catch weights. More complete data on lengths of retained and released fish are needed to increase the accuracy of tonnages calculated. This can be achieved by improving completion of lengths by diarists or increasing the numbers of diarists in future surveys.

Despite the approach for angling surveys being well understood (Jones and Pollock, 2013; Pollock et al., 1994), there were still challenges with developing the analysis. For rarer species, there was often insufficient data to allow robust estimation of catch numbers or catch weight. In this study quantitative estimates of catch numbers were only provided for species with at least 15 catch records, and catch weights were provided only if five or more than people recorded over 50 individual fish. The impact of changing the numbers of lengths and people needed to estimate tonnages could be tested in future, but were deemed reasonable for this study. The impact of missing data due to incomplete diaries is an important issue (see above), but hotdecking to impute missing months of data had little impact on the results, so was not used. Finally, it would be useful to consider different approaches for the analysis where the relationship between catch rate and characteristics of diarists (age, avidity, platform) is modelled. Once the relationships are understood, the model could be used to provide more robust estimates of catches for the UK.

4.2 Comparison with previous estimates

Catches estimated from the surveys in 2016 and 2017 were consistently higher in England than from the on-site survey of England in 2012, particularly for released fish, despite the overall composition of catches being similar (Armstrong et al., 2013). It is unlikely for this to be only a result of random sampling error in estimates of catch rates obtained from the on-site and diary surveys, as the differences were observed over many species. Three potential reasons for these differences are: 1) the true total catches of many species increased substantially between 2012 and 2016; 2) annual fishing effort or numbers of anglers (needed for raising catch rate estimates of all species to total annual catches), were under- or overestimated due to random sampling error in the nationwide population surveys; and 3) there were different types and extent of bias associated with the design and implementation of the on-site surveys in 2012 and the diary surveys in later years. As the 2012 data are for only one year and used different survey methods, it has not been possible to determine the extent to which the increased catch estimates are due to survey bias, random sampling error or changes in fish abundance. It is likely that a combination of these factors generated the differences.

The number of sea anglers interviewed in the ONS and WPS nationwide population surveys is small, leading to relatively low precision in key estimates from these surveys such as numbers of days fished (needed for raising on-site estimates of catch per day in 2012) and numbers of people going sea angling (needed for the diary surveys in 2016-17). It is possible that the 2012 estimates of effort were too small due to random sampling error, or that the 2016 and 2017 angler numbers were over-estimated.

Biases inherent in the design and implementation of the surveys are a possible source of the difference in catch estimates between years. In 2012, a randomised survey design was used to estimate mean catch per day of shore and private boat anglers interviewed on site, and these estimates were combined with the total annual number of angling trips obtained from the nationwide ONS face-to-face survey to estimate total catches (Armstrong et al., 2013). Annual charter boat catches were estimated from diaries completed by skippers of charter boats selected at random from a list of vessels. Several important sources of bias in the 2012 surveys are recognised – these include recall of shore and boat fishing effort by ONS survey respondents; recall of data on released fish by anglers interviewed on site or by charter skippers; areas of coast excluded from the sampling frame; extrapolation of daily shore catches for anglers interviewed part way through their trip; length-of-stay bias due to shore anglers fishing for longer periods of the day being more likely to be interviewed (a method was developed to try and corrected for this); restriction of on-shore sampling to dawn to dusk only, and refusals by some charter skippers to participate.

For the 2016 and 2017 diary surveys, there was potential for bias due to the self-selecting nature of the diary panel, and no information was available on the profile of anglers who do not respond. The recruitment campaign for the panel aimed at having the same breakdown by UK country as estimated from earlier population surveys such as used in 2012, but it was not possible to have targets by avidity or other characteristics that could affect catches. Data from the WPS indicated that higher-avidity anglers and older anglers were over-represented in the panel, and there were other differences in profile related for example to predominance of main angling platform (e.g. shore only vs mixed shore and boat). Bias due to avidity, platform, and age was corrected by post-stratification and reweighting during raising of estimates, using the WPS survey data on numbers of sea anglers in different avidity groups, platforms and age groups to reweight the panel data to be more representative of the population. This process was however limited by the number of respondents in the WPS and no correction was possible for over-representation of characteristics such as experience, skill and motivation which are likely to influence catch rates irrespective of avidity. During 2019, a randomised mail shot with incentives has been used to recruit a separate sample of sea anglers to complete diaries and compare their characteristics and catch rates with the current diary panel, although there is still an element of self-selection in the response of anglers who receive the letters.

It was possible that catches have changed significantly over the period, as sea angling catches will fluctuate in response to changes in fish abundance. For example, time series from Germany have shown large variation in catch rates between years (Strehlow et al., 2012). Whilst it is expected that that catches vary between years, the differences in the present studies between 2012 and 2016 or 2017 were larger over a wide range of species than the differences between 2016 and 2017, indicating that this was unlikely to account for all the difference. In addition, angling surveys elsewhere show how different survey techniques can lead to greatly varying results. Differences between two and 50% have been found between harvest estimates from on-site and off-site surveys in New Zealand, with the largest differences for the rarest species (Hartill et al., 2015). The main causes were underestimates of effort at boat ramps and non-reporting of zero catches (Hartill et al., 2015). This only included the harvested component which was most similar in this study, and no comparisons exist of the released component. To assess this robustly would need side-by-side on-site (creel) and off-site (diary) surveys in the same year, so should be considered in future.

4.3 Future work

There are a number of key areas of further work needed to develop the current approach and understand how best to use the data to support decision making. Some of which are already underway, but others would require further funding to progress.

Improving the precision of the estimates can be done through increasing the sample sizes in the WPS and the diary panel. The limited number of sea anglers interviewed in the WPS restrict the numbers of strata that can be used in raising and generate a significant proportion of the overall error. There are two potential solutions: combine data from a number of years or increase the WPS sample size. Combining years of the WPS is reasonable as participation rates are unlikely to vary much over a short period, so this will be tested in the analysis of future surveys. However, a large bespoke survey would be the most robust way of increasing precision, but this would require significant additional resource to implement. Increasing the size of the diary panel and the completion rates by diarists are key to improving data collection. New approaches are needed to recruit new diarists, as a significant number are lost each year due to survey fatigue. A number of significant improvements have been made to increase the utility of the system to sea anglers including app-based data entry and the ability to share catches. Technology can be used to increase the accuracy of the results, such as mobile phone apps which are used to record data in real-time (Venturelli et al., 2017), reducing the recall bias which exists when fishers enter data after a fishing session has finished. Other valuable information can also be collected from apps such as location and duration automatically, reducing the time demands on survey participants. Further development to the app-based data entry is needed to fully realise the potential of this approach. Once the data have been collected, there are a number of different statistical analyses that could be done. The traditional analytical approach for these surveys that uses post-stratification is complex and inefficient. An alternate approach that could be tested in future is to use statistical models.

Given the differences between the catch estimated in this survey (especially the released component) and results from the on-site survey in 2012, it would be useful to understand the potential biases in each of the surveys. Understanding the residual bias that has not been corrected in the current survey would demonstrate how best to use the data to support decision making. There are a number of approaches for this that vary in cost. Firstly, including questions about experience and importance of angling in the WPS would allow for biases around motivation and experience to be corrected. Motivation and experience vary greatly amongst anglers, with the most engaged anglers more likely to contribute to the diary. As a result, correcting for biases around motivation and centrality to lifestyle is likely to improve the robustness of the estimates. Questions about skill and experience have been added to the WPS in 2019 that can be used to understand the drivers for catch rate and included in the raising to correct for bias. Secondly, a small probability-based survey has been implemented in 2019 involving randomised mailshot to recruit diarists. Differences in catches between the random sample and the existing diary panel will be used to assess and correct for bias due to self-selection. The most robust way to understand the level of bias would be to do a side-by-side comparison between on-site (diary) and off-site (creel) in the same year that includes both the retained and release components of the catch. A similar approach is used in other parts of the world (e.g. Western Australia), where diary surveys are run annually with an on-site creel survey done every five years for comparison. This approach will generate the times series of catches needed for that can be used in stock assessment, so regular (annual) consistent data collection is required to capture trends in sea angling catches (Hyder et al., 2017; 2018). This will allow recreational catches to be included in stock assessment and ensure sustainable level of exploitation.

5 References

Andrews, R., Brick, J.M., Mathiowetz, N.A., 2014. Development and Testing of Recreational Fishing Effort Surveys: Testing a Mail Survey Design. Final Report. 56 pp.

Arlinghaus, R., 2006. On the Apparently Striking Disconnect between Motivation and Satisfaction in Recreational Fishing: The Case of Catch Orientation of German Anglers. North Am. J. Fish. Manag. 26, 592–605.

Armstrong, M., Brown, A., Hargreaves, J., Hyder, K., Munday, M., Proctor, S., Roberts, A., Roche, N., Williamson, K., 2013. Sea Angling 2012 – a survey of recreational sea angling activity and economic value in England. Defra, London, UK. 16pp.

Beardmore, B., Haider, W., Hunt, L.M., Arlinghaus, R., 2011. The Importance of Trip Context for Determining Primary Angler Motivations: Are More Specialized Anglers More Catch-Oriented than Previously Believed? North Am. J. Fish. Manag. 31, 861–879.

Bellanger, M., Levrel, H., 2017. A cost-effectiveness analysis of alternative survey methods used for the monitoring of marine recreational fishing in France. Ocean Coast. Manag. 138, 19–28.

Fedler, A.J., Ditton, R.B., 1994. Understanding Angler Motivations in Fisheries Management. Fisheries 19, 6–13.

Hartill, B.W., Edwards, C.T.T., Jacobson, L., 2015. Comparison of recreational harvest estimates provided by onsite and offsite surveys: detecting bias and corroborating estimates. Can. J. Fish. Aquat. Sci. 72, 1379–1389.

Hyder, K., Weltersbach, M.S., Armstrong, M., Ferter, K., Townhill, B., Ahvonen, A., Arlinghaus, R., Baikov, A., Bellanger, M., Birzaks, J., Borch, T., Cambie, G., de Graaf, M., Diogo, H.M.C., Dziemian, Ł., Gordoa, A., Grzebielec, R., Hartill, B., Kagervall, A., Kapiris, K., Karlsson, M., Kleiven, A.R., Lejk, A.M., Levrel, H., Lovell, S., Lyle, J., Moilanen, P., Monkman, G., Morales-Nin, B., Mugerza, E., Martinez, R., O'Reilly, P., Olesen, H.J., Papadopoulos, A., Pita, P., Radford, Z., Radtke, K., Roche, W., Rocklin, D., Ruiz, J., Scougal, C., Silvestri, R., Skov, C., Steinback, S., Sundelöf, A., Svagzdys, A., Turnbull, D., van der Hammen, T., van Voorhees, D., van Winsen, F., Verleye, T., Veiga, P., Vølstad, J.-H., Zarauz, L., Zolubas, T., Strehlow, H. V, 2018. Recreational sea fishing in Europe in a global context-Participation rates, fishing effort, expenditure, and implications for monitoring and assessment. Fish. 19, 225–243.

ICES, 2018. Report of the Working Group for the Celtic Seas Ecoregion (WGCSE). Copenhagen, Denmark. ICES CM 2018/ACOM:13. 1251 pp.

Jones, M., Pollock, K.H., 2013. Recreational Angler Survey Methods: Estimation of Effort, Harvest, and Released Catch. In: Zale, A.V., Parrish, D.L., Sutton, T.M. (Eds.), Fisheries Techniques. American Fisheries Society, Bethesda, Md., American Fisheries Society, Bethesda, Md., pp. 883–919.

NOAA, 2014. The 2014 recreational saltwater fisheries summit summary report. Silver Spring, Maryland, USA. 8 pp.

Pollock, K.H., Jones, C.M., Brown, T.L., 1994. Angler surveys and their application to fisheries management. American Fisheries Society, Special Publication 25, Bethesda, Maryland.

Radford, Z., Hyder, K., Zarauz, L., Mugerza, E., Ferter, K., Prellezo, R., Strehlow, H.V., Townhill, B., Lewin, W.-C., Weltersbach, M.S., 2018. The impact of marine recreational fishing on key fish stocks in European waters. PLoS One 13, e0201666.

Silva, J.F., Ellis, J.R., Ayers, R.A., 2013. Length-weight relationships of marine fish collected from around the British Isles, Sci. Ser. Tech. Rep. Cefas Lowestoft 150. 109 pp.

Strehlow, H. V., Schultz, N., Zimmermann, C., Hammer, C., 2012. Cod catches taken by the German recreational fishery in the western Baltic Sea, 2005-2010: implications for stock assessment and management. ICES J. Mar. Sci. 69, 1769–1780.

van der Hammen, T., de Graaf, M., Lyle, J.M., 2016. Estimating catches of marine and freshwater recreational fisheries in the Netherlands using an online panel survey. ICES J. Mar. Sci. 73, 441–450.

Veiga, P., Ribeiro, J., Gonçalves, J.M.S., Erzini, K., 2010. Quantifying recreational shore angling catch and harvest in southern Portugal (north-east Atlantic Ocean): implications for conservation and integrated fisheries management. J. Fish Biol. 76, 2216–2237.

Venturelli, P.A., Hyder, K., Skov, C., 2017. Angler apps as a source of recreational fisheries data: opportunities, challenges and proposed standards. Fish. 18, 578–595.

Wynne-Jones, J., Gray, A., Hill, L., Heinemann, A., 2014. National panel survey of marine recreational fishers 2011 – 12: harvest estimates. Crown Copyright - Ministry for Primary Industries. 139 pp.

Appendix 1. Numbers and tonnages

Numbers and tonnages of fish retained and released by sea anglers resident in the UK. These were raised to the total population after discarding fishermen missing 6 or more months of data and trimming using "strata 12" for 2016 and "strata 15" for 2017. Standard errors are provided in square brackets.

Species	Numbers 2016 Retained	Released	2017 Retained	Released	Tonnage 2016 Retained	Released	2017 Retained	Released
Baillon's Wrasse	0	9361 [6320]	0	31474 [19518]	NA	NA	NA	NA
Ballan Wrasse	834 [965]	1250609 [441273]	7740 [4798]	1238200 [330942]	0.7 [0.8]	875.8 [320.3]	11.5 [7.6]	633.6 [165.7]
Bass	102804 [29387]	3273594 [839929]	168693 [41837]	3577383 [834095]	177.5 [55.4]	2500.9 [703.7]	272 [68.6]	1912.7 [471.8]
Bib	190933 [82813]	1871944 [573982]	224108 [70042]	2793796 [590575]	76.7 [35.7]	384.9 [121.1]	80.2 [24.5]	477.6 [102.1]
Black Goby	0	4090 [3182]	0	27613 [17659]	NA	NA	NA	NA
Black Sea Bream	151427 [57338]	641346 [228391]	391105 [99599]	1044071 [253181]	80.4 [30.2]	175.5 [65.8]	188 [49.8]	400.7 [119.4]
Blonde Ray	0	109117 [46801]	0	117656 [43941]	NA	NA	0	382.6 [151.8]
Blue Shark	0	7361 [8519]	0	13333 [5800]	NA	NA	NA	NA
Brill	1285 [1404]	1249 [1365]	2633 [1531]	0	NA	NA	NA	NA
Bull Huss	7633 [5764]	324975 [107059]	15375 [8036]	388036 [95891]	49.8 [40.2]	759.8 [264.4]	51.5 [25]	948.4 [252.1]
Coalfish	35655 [19830]	1062247 [323185]	20847 [8667]	972814 [345744]	14.6 [7.6]	307.6 [107.3]	13.7 [5.9]	225.6 [80.7]
Cod	805647 [252947]	2084671 [479193]	605913 [125914]	1985560 [476263]	1886 [600.9]	1293.8 [351.3]	1050 [229.3]	1027.8 [236.6]
Common Goby	0	834 [965]	0	47003 [20650]	NA	NA	NA	NA
Common Skate	NA	NA	0	3894 [2582]	NA	NA	NA	NA
Conger eel	0	367992 [139338]	1565 [1040]	583106 [146732]	0	1866.3 [783.9]	2.2 [1.4]	2438.8 [606.3]
Corkwing Wrasse	0	129390 [54120]	0	246545 [71159]	NA	NA	0	20.6 [5.9]
Couch's Sea Bream	0	0	0	6687 [4492]	NA	NA	NA	NA
Cuckoo Wrasse	0	147151 [71557]	0	74355 [24662]	NA	NA	NA	NA
Dab	102186 [38443]	1534011 [475305]	79015 [23474]	1851499 [459574]	22.7 [8.6]	179.7 [55.3]	16.1 [5]	276.4 [82.1]
Dover Sole	3266 [2244]	26659 [16517]	33717 [12163]	63055 [20600]	NA	NA	NA	NA
Dragonet	0	8500 [6266]	0	7880 [3733]	NA	NA	NA	NA
Five bearded Rockling	0	40403 [17396]	0	48837 [16142]	NA	NA	NA	NA
Flounder	64955 [29636]	1550072 [462385]	89240 [26692]	1242640 [308567]	24.2 [11.6]	528.1 [265.3]	43.8 [14]	277.7 [68.7]
Freshwater Eel	0	90303 [32086]	0	246405 [75677]	NA	NA	0	42 [12.4]
Garfish	8414 [5005]	122092 [43787]	57385 [26135]	142122 [43536]	NA	NA	12 [4.9]	23.4 [7.3]
Gilthead Sea Bream	0	9775 [6860]	9117 [5516]	30261 [11995]	NA	NA	NA	NA
Golden Grey Mullet	0	8451 [4667]	0	2641 [2064]	NA	NA	NA	NA
Goldsinney Wrasse	0	66066	0	69388	NA	NA	NA	NA

	Numbers				Tonnage			
	2016		2017		2016		2017	
Species	Retained	Released	Retained	Released	Retained	Released	Retained	Released
		[34462]		[28110]				
Greater Weever Fish	NA	NA	1743 [1947]	555 [603]	NA	NA	NA	NA
Grey Gurnard	0	112915 [46074]	1703 [1901]	52296 [18919]	NA	NA	NA	NA
Haddock	14201 [7692]	88250 [41427]	17481 [9223]	36702 [20177]	NA	NA	NA	NA
Herring	78545 [39924]	37558 [26964]	24815 [11194]	46087 [18040]	NA	NA	NA	NA
Lesser Sandeel	NA	NA	3809 [2929]	0	NA	NA	NA	NA
Lesser Spotted Dogfish	72203 [28952]	5733857 [1532297]	112133 [32219]	5427552 [1257364]	67.1 [32.9]	3813.1 [1050.4]	67.6 [20]	2898.6 [687.2]
Lesser Weever	0	52884 [19618]	0	44159 [15595]	NA	NA	NA	NA
Ling	69247 [33106]	147837 [66576]	60651 [19379]	47712 [16112]	NA	NA	NA	NA
Mackerel	6020514 [1700314]	4218825 [1129168]	7361029 [1398647]	3540578 [757228]	2044.7 [609.1]	1079.1 [281.9]	2018.3 [383.6]	857.9 [202]
Plaice	302172 [94907]	585780 [193198]	274993 [66455]	698792 [174189]	153 [49.4]	169.9 [59]	140.4 [36.2]	206.7 [54]
Pollack	463813 [130990]	2335496 [626712]	790444 [171300]	2204080 [536664]	883.2 [284.5]	1482.3 [436.9]	2257.2 [545.1]	2877.5 [679.6]
Poor Cod	2501 [2031]	139929 [71958]	568 [617]	172588 [57296]	NA	NA	0.1 [0.1]	5.3 [1.7]
Red Band Fish	0	2498 [2730]	0	1070 [828]	NA	NA	NA	NA
Red Gurnard	0	100318 [33086]	13814 [4816]	93480 [22082]	NA	NA	3.9 [1.4]	16.8 [4.1]
Rock Goby	NA	NA	0	46015 [27736]	NA	NA	NA	NA
Rock cook Wrasse	NA	NA	0	1624 [1339]	NA	NA	NA	NA
Sand Goby	NA	NA	0	5098 [2450]	NA	NA	NA	NA
Sandeel	13264 [11481]	10615 [6867]	43137 [15528]	51823 [20917]	NA	NA	NA	NA
Scad	17996 [10163]	234878 [89664]	59007 [36826]	332438 [102940]	3.6 [2]	40.5 [15.8]	8.2 [5]	46.1 [15.3]
Sea Scorpion	0	50414 [20600]	0	30747 [12286]	NA	NA	NA	NA
Sea Trout	0	23168 [11355]	0	7959 [3215]	NA	NA	NA	NA
Shad	0	1249 [1365]	0	0	NA	NA	NA	NA
Shanny	0	11041 [5654]	0	51973 [24569]	NA	NA	NA	NA
Shore Rockling	0	80126 [31131]	0	80658 [24620]	NA	NA	0	7.6 [2.5]
Small Eyed Ray	0	73356 [25744]	3587 [2434]	78789 [24246]	NA	NA	NA	NA
Smelt	0	16999 [9366]	0	32017 [13221]	NA	NA	NA	NA
Smoothhound	0	399742 [120411]	3324 [2289]	371131 [96584]	0	957.4 [322.6]	2 [1.7]	735.4 [231.9]
Spotted Ray	0	64752 [26655]	0	56200 [17365]	NA	NA	NA	NA
Spurdog	0	126184 [63238]	0	244093 [119248]	0	267.5 [134.9]	0	215.7 [100.2]
Starry Smoothound	0	302965 [114517]	0	367140 [103539]	0	655.5 [288.2]	0	552.7 [192.6]
Thick Lipped Grey Mullet	0	20345 [8681]	555 [603]	47090 [16913]	NA	NA	NA	NA
Thin Lipped Grey Mullet	0	12938 [7487]	0	37578 [22247]	NA	NA	NA	NA
Thornback Ray	24000	361008	50663	562095	47.7	810.4	84.2	708.2

Species	Numbers 2016 Retained	Released	2017 Retained	Released	Tonnage 2016 Retained	Released	2017 Retained	Released
	[10707]	[110851]	[18041]	[139235]	[24.1]	[257.4]	[36.1]	[190.7]
Three bearded Rockling	0	61043 [25004]	0	115922 [35719]	NA	NA	0	11.7 [4.4]
Tompot Blenny	0	15404 [10035]	0	74244 [25848]	NA	NA	NA	NA
Tope	0	74967 [32415]	0	159187 [41643]	NA	NA	0	1724.5 [502.3]
Tub Gurnard	1267 [1384]	61564 [25956]	3737 [1975]	75471 [19762]	NA	NA	1.4 [0.7]	18.2 [5.1]
Turbot	18403 [9257]	55076 [22974]	23068 [8122]	74345 [28967]	NA	NA	45.9 [16.9]	46.4 [15.7]
Undulate Ray	0	91773 [40886]	0	111185 [37497]	NA	NA	0	202.5 [67.5]
Whiting	1038716 [323009]	9665413 [2508061]	1351382 [309547]	10378188 [2297463]	333.8 [106.2]	1544.9 [393.9]	413.6 [93]	1853.1 [436.2]

Appendix 2. Average weights

Average weight in grams for all fish species, raised to the total population after discarding fishermen missing 6 or more months of data. Raising used the method “strata 12” for 2016 and “strata 15” for 2017.

	2016		2017	
Species	Retained	Released	Retained	Released
Baillon's Wrasse	NA	184	NA	98
Ballan Wrasse	863	700	1489	512
Bass	1726	764	1612	535
Bib	402	206	358	171
Black Goby	NA	17	NA	11
Black Sea Bream	531	274	481	384
Black mouthed Dogfish	NA	NA	NA	NA
Blonde Ray	NA	5514	NA	3252
Blue Shark	NA	46	NA	30
Brill	1040	1022	905	NA
Bull Huss	6523	2338	3346	2444
Coalfish	409	290	658	232
Cod	2341	621	1733	518
Common Goby	NA	NA	NA	6
Common Skate	NA	NA	NA	10628
Conger eel	NA	5071	1393	4182
Corkwing Wrasse	NA	95	NA	83
Couch's Sea Bream	NA	NA	NA	140
Cuckoo Wrasse	NA	261	NA	327
Dab	222	117	204	149
Dover Sole	499	153	418	199
Dragonet	NA	28	NA	27
Five bearded Rockling	NA	77	NA	67
Flounder	372	341	491	223
Freshwater Eel	NA	184	NA	171
Garfish	178	225	210	165
Gilthead Sea Bream	NA	873	1113	474
Golden Grey Mullet	NA	331	NA	765
Goldsinney Wrasse	NA	40	NA	41
Greater Weever Fish	NA	NA	148	148
Grey Gurnard	NA	113	360	118
Haddock	745	318	616	402
Herring	126	99	154	116
Lesser Sandeel	NA	NA	4	NA
Lesser Spotted Dogfish	930	665	603	534
Lesser Weever	NA	32	NA	29
Ling	3770	1800	3945	862
Mackerel	340	256	274	242
Norway Pout	NA	NA	NA	NA
Pilchard	NA	NA	NA	NA
Plaice	506	290	511	296
Pollack	1904	635	2856	1306
Poor Cod	67	50	94	31
Red Band Fish	NA	NA	NA	NA
Red Gurnard	NA	204	281	179
Rock Goby	NA	NA	NA	10
Rock cook Wrasse	NA	NA	NA	0
Sand Goby	NA	NA	NA	3
Sandeel	44	50	51	31
Scad	199	172	138	139
Sea Scorpion	NA	99	NA	57
Sea Trout	NA	398	NA	731
Shad	NA	75	NA	NA
Shanny	NA	20	NA	24
Shore Rockling	NA	96	NA	94
Small Eyed Ray	NA	2334	1748	940

Species	2016 Retained	Released	2017 Retained	Released
Smelt	NA	0	NA	0
Smoothhound	NA	2395	611	1982
Spotted Ray	NA	1069	NA	668
Sprat	NA	NA	NA	NA
Spurdog	NA	2120	NA	884
Starry Smoothound	NA	2164	NA	1505
Stingray	NA	NA	NA	NA
Thick Lipped Grey Mullet	NA	913	795	927
Thin Lipped Grey Mullet	NA	618	NA	675
Thornback Ray	1987	2245	1661	1260
Three bearded Rockling	NA	121	NA	101
Tompot Blenny	NA	63	NA	52
Tope	NA	5377	NA	10833
Tub Gurnard	550	261	366	241
Turbot	1930	742	1988	624
Undulate Ray	NA	5179	NA	1821
Whiting	321	160	306	179

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