Participation, effort, and catches of sea anglers resident in the UK in 2018 & 2019

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Executive summary

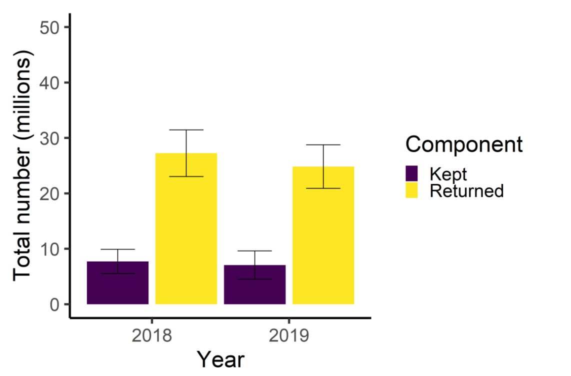
Sea angling is a popular activity in the UK that has social and economic benefits, but can also impact on fish stocks. Data on sea angling participation, catches, and economics are needed by government and stakeholders to support well-informed decisions and sustainable management of fisheries. Here, we provide estimates of the numbers of sea anglers, how often they fish, and what they caught in the UK in 2018 and 2019. We used the approach developed in 2016–17, combining the outputs from two surveys each year.

Area	2018	2019
UK	758	551
England	566	375
Wales	59	62
Scotland	64	42
Northern Ireland	69	72

Box 1. Numbers of sea anglers (thousands).

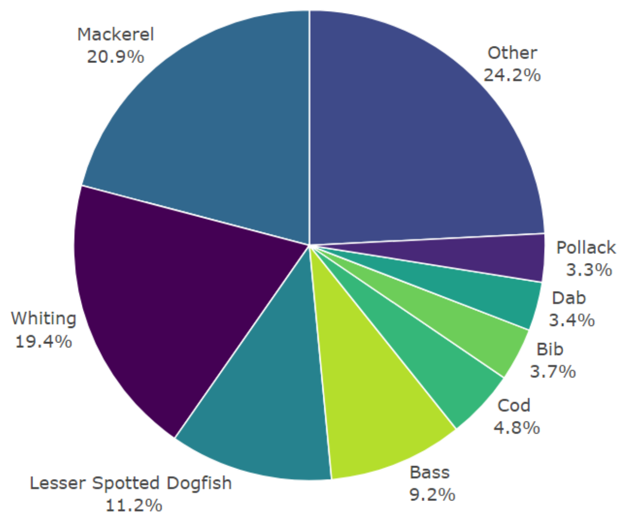
Questions on sea angling were included in a survey of 12,000 UK residents (Watersports Participation Survey - WPS) to estimate the numbers of sea anglers, and how often they fished from the shore and boats. It was estimated that 758,000 (2018) and 551,000 (2019) adults of over 16 years old went sea angling in the past year (Box 1). They had fished for over 6 million days each year. Participation estimates were lower than in 2016 and 2017, but the confidence intervals overlapped meaning that this may simply be due to uncertainty in the estimates. The second of the two surveys each year was designed to estimate the average annual catch of each species by individual anglers. A nationwide panel of sea anglers was recruited to complete a diary recording all their marine recreational angling activities and catches (www.seaangling.org). A total of 1,706 diarists signed up in 2018 and 2,188 in 2019, with 736 in 2018 and 988 in 2019 providing data on their fishing sessions. Each year, diarists recorded over 8,500 fishing sessions and catches of over 70,000 fish of around 100 different species.

Numbers of sea anglers from the WPS were combined with mean annual catch per angler from the diary panel to estimate total UK catches. This included correcting for differences in frequency of fishing (avidity) and age between the diary panel and the UK WPS survey. Estimates of numbers caught were produced for around 55 species and tonnages for about 40 species. This resulted in total catches of 46 and 43 million fish, 80% of which were released (Box 2). Catch composition was similar between years with mackerel, whiting, lesser spotted dogfish, and sea bass caught most commonly (Box 3). There were differences between years in the relative abundance of some less commonly caught fish. However, precision of the estimates was low for some species, so must be considered when comparing between years and when used for decision making.



Box 2. Total number of fish kept and released by UK sea anglers in 2018 and 2019.

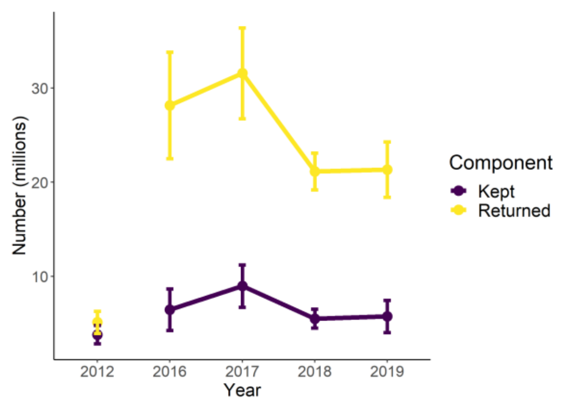
Total annual catch estimates were slightly lower than in 2016–17 using the same survey approach, although release rates were similar. The species compositions (Box 3) were also generally similar to 2016–17. However, catch estimates for England for 2016–19 were much higher than obtained in the 2012 survey programme, particularly for released fish (Box 4). The 2012 survey was for England only and used an onsite approach. As the 2012 data are for only one year for England and used different survey methods, it was not possible to determine the extent to which the higher 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.



Box 3. Species composition of fish caught by UK sea anglers in 2019.

Two approaches were used to understand the potential for bias in the current survey. Firstly, 120 diarists were recruited using a postal survey of 50,000 randomly selected houses in three regions of the UK (validation panel). The demographic and avidity profile of the validation panel was more similar to the diary panel than to the overall population of sea anglers from the WPS. An explanation is that older and more avid anglers were more likely to volunteer to keep a catch diary. It is possible that the approach used to recruit diarists has limited impact, instead driven by the types of anglers that are willing to keep a diary. Secondly, a new approach was developed to test the robustness of the analysis using statistical models to estimate catch rates. The model generated similar results to the existing approach, so is likely to be implemented in future as it represents a more efficient and robust approach.

Further work is needed to improve the robustness of the survey and estimates. Improving the precision of estimates of participation and angler characteristics is important and could be done through a larger bespoke survey that covers all angling. Increasing the size and representativeness of the diary panel, and development of the statistical modelling approaches for analysis would also improve robustness of the results. Finally, it is important to undertake a side-by-side comparison between the diary and onsite approaches. This is needed to validate the diary programme and understand the differences in catches from 2012.



Box 4. Total number of fish kept and released by English sea anglers.

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1. Introduction

The aim of the UK sea angling survey was to estimate participation, effort, and catches of sea anglers resident in the UK each year. Two separate surveys were combined to achieve this. Firstly, an existing nationwide survey of UK residents (Watersports Participation Survey - WPS) was used to estimate fishing effort in terms of how many people go recreational sea fishing, and how often they use different methods. Secondly, a nationwide panel of sea anglers was recruited to complete a diary recording all their sea angling activities and catches during the year, from which the average catch per unit effort (CPUE) was calculated.

This report describes the methodology for estimating participation, effort, and catches by sea anglers resident in the UK for 2018 and 2019, compares the results with previous surveys, and discusses the implications for future surveys. The approach is similar to the one used in 2016 and 2017, which is described in detail elsewhere (Hyder *et al*., 2020b). Where the methods are the same, a short summary will be provided along with a reference to previous documents. Where methods in 2018 and 2019 have differed significantly, a detailed description is provided. A mobile app was developed to make data entry easier for diarists. There are two main additions to previous surveys to assess the robustness of the outcomes. Firstly, creation of a validation panel in 2019 based on a random sample of sea anglers drawn from three areas in the UK which was used to help identify bias in the main panel. Secondly, testing of a new statistical approach method using a Bayesian analytical model for estimating catches is used to test the robustness of the existing analysis.

The remainder of this section provides context for the current study that is needed to interpret the results in the context of previous research. This includes: general information on the importance of recreational fisheries (Section 1.1); a description of the range of survey approaches for recreational fisheries data collection (Section 1.2); and the outcomes from previous studies of sea angling in the UK (Section 1.3).

1.1. Importance of marine recreational fisheries

Marine recreational fisheries (MRF) are important activities creating economic impacts (e.g., Hyder *et al*., 2017; 2018) and social benefits through physical health and well-being (McManus *et al*., 2011; Armstrong *et al*., 2013; Griffiths *et al*., 2017), but can also impact on fish stocks (Hyder *et al*., 2017; 2018; Radford *et al*., 2018; Lewin *et al*., 2019). Information on the social, economic, and biological impacts of MRF is needed to underpin balanced management, so data collection programs have been introduced to provide evidence for decision makers (e.g., Hyder *et al*., 2017; 2018; 2020a). These data collection programmes provide evidence to help national and international policy makers make balanced and well-informed decisions (Hyder *et al*., 2018), and help non-governmental organisations to develop their own policies and advise on best practice (ICES, 2017). Data are also needed to support management of fish stocks, impact on the environment, planning, and development of the blue economy (ICES, 2015).

Catches of some species can be large enough to impact on fish stocks (Hyder *et al*., 2017; 2018; Radford *et al*., 2018; Lewin *et al*., 2019). In addition to fish kept for eating (Cooke *et al*., 2018), these catches include fish that are released but die due to injuries or stress (Kerns *et al*., 2012). High MRF release rates are found for many species in Europe (Ferter *et al*., 2013). MRF has only been included in stock assessments and management in Europe for European sea bass, western Baltic cod, Baltic sea trout, and Atlantic salmon in the Baltic, as insufficient data are available for other species (Hyder *et al*., 2018). Exclusion of recreational catches from assessments may affect the ability to manage fish stocks sustainably.

Until 2020, it was a statutory requirement under the EU Data Collection Framework (DCF) for the UK to report recreational catches and releases of cod, sea bass, pollack, elasmobranchs, eel, salmon, and highly migratory species (the EU Data Collection Framework (Council Regulation (EC) No 199/2008) and the Multi-Annual Programme (Council Regulation (EU) 2017/1004)). Since leaving the EU, the UK is an independent coastal state with control over its territorial waters, with aspirations for world class fisheries management including recreational fisheries. Recreational fishing is included in the UK Fisheries Act (2020) alongside the provision of funding to support angling promotion and development. As such, information on the social, economic, and biological effects of MRF is important for future UK fisheries management.

1.2. Approaches for sea angling surveys

The diverse and dispersed nature of MRF makes data collection a challenge (Hyder *et al*., 2020a). Where no comprehensive lists of fishers or their catches exist (e.g., through licences), it is necessary to carry out independent surveys of MRF effort and catch per unit effort to estimate numbers caught, along with collection of data on lengths or weights of individuals caught where needed to estimate tonnages (Pollock *et al*. 1996; ICES, 2010; Jones and Pollock, 2013). Onsite (e.g., creel, aerial, camera) and offsite (e.g., household) approaches are used to estimate the fishing effort (e.g., numbers of anglers, trips, boats). Data on CPUE can also be estimated from a representative sample of fishers using onsite (e.g., access point, roving creel) and offsite (e.g., diary, recall) approaches. Catches of the sampled fishers are raised to the whole population using the results from both surveys, correcting for differences between the compositions of the sample and the population (e.g., age, number of fishing trips (avidity), fishing platform (boat, shore), gear (mode)). The approaches for data collection vary, and there is no single preferred method, as each is subject to different potential biases (Pollock *et al*. 1996; ICES, 2010; Jones and Pollock, 2013). Bias in sea angling surveys can arise at the design stage, for example insufficient spatial coverage or use of non-random sample selection methods. During implementation, additional biases can arise such as non-response, prestige bias (exaggeration), recall errors, and rounding up or down of numbers. (Pollock *et al*. 1996; ICES, 2010; Jones and Pollock, 2013). Finally, the methods used to analyse the survey data can also lead to bias.

Different methods can be used to reduce biases as much as possible. Catch and effort survey designs are often selected based on a detailed evaluation of logistics, staffing and resources needed, available budget, likely response of anglers, potential for bias, and the types and quality of information needed by end users. Logbook (or diary) surveys involving recruitment of a representative panel of fishers are a popular method of collecting marine recreational fishing data in Europe and potentially worldwide. This is due to the low cost per sample (Bellanger and Levrel, 2017) and the ability to collect detailed catch, demographic, and effort data. Diary surveys only provides information on resident fishers, so additional or sampling or different methods are needed where there are large tourist fisheries. The survey approaches used can impact on the outcome as there are different challenges and biases, which can affect the magnitude of the estimates (Hartill *et al*., 2015).

1.3. Sea angling in the UK

Sea angling using rod and line is the most common form of MRF in the UK, so has been the subject of a number of studies (e.g., Drew, 2004; Simpson and Mawle, 2005, 2010; Radford and Riddington, 2009; McMinn, 2013; Armstrong *et al*., 2013; Roberts *et al*., 2017; Brown *et al*., 2019; Hyder *et al*., 2020b; MMO, 2020). These studies are summarised below and cover the participation, effort, economics, social benefits, and catches made by sea anglers in part or the whole of the UK.

1.3.1. Participation and effort

As there are no complete lists of marine recreational fishers nor licensing schemes in the UK, an independent study is required to estimate fishing effort (see Pollock *et al*., 1994; ICES, 2010; Jones and Pollock, 2013). Several studies have estimated the numbers of sea anglers and participation rates in the individual countries of the UK (e.g., Drew, 2004; Simpson and Mawle, 2005, 2010; Radford and Riddington, 2009; Armstrong *et al*., 2013; McMinn, 2013; Hyder *et al*., 2020b). In 2003, a survey in England and Wales estimated there were 1.1 million sea anglers equating to a participation rate of 5% for over 16 year olds (Drew, 2004). Surveys to assess public attitudes to angling in England and Wales found that 2 million (5%) and 1.9 million (4%) of individuals aged 12 years or over in 2005 and 2010, respectively, had been sea angling in the past year (Simpson and Mawle, 2005; 2010).

In 2012, participation and effort in Great Britain (England, Wales, and Scotland) was carried out using a face-to-face survey of over 12,000 households. This estimated that 2.2% or 1.08 million people of 16 years or older had been sea angling in the past year, with 884,000 from England, 125,000 from Scotland, and 76,000 from Wales (Armstrong *et al*., 2013). Sea anglers fished for 4.8 million days, the majority of which was from shore, and 4.3 days were fished on average annually by each angler (Armstrong *et al*., 2013). Other surveys showed that in 2009, there were an estimated 125,188 sea anglers of 18 years or older in Scotland (Radford and Riddington, 2009) and 64,800 sea anglers of 18 years or older (3.6% participation) in Northern Ireland in 2012 (McMinn, 2013).

An existing annual survey of 12,000 UK residents (Watersports Participation Survey - WPS) was extended in 2015 to estimate fishing effort in terms of how many people went recreational sea fishing, and the number of days on which they fished from the shore or from different types of boats (Hyder *et al*., 2020b). On average, 823,000 UK residents aged 16 years or older went sea angling in the years 2015–2017, representing a participation rate of 1.6%. Numbers of sea anglers were greatest in England, and within England were largest in the South West (Hyder *et al*., 2020b). Sea anglers fished for 7.0 million days each year, which equated to 8.5 days per angler each year between 2015 and 2017 (Hyder *et al*., 2020b). Most effort was from the shore (5.1 million days), followed by private boats (3.0 million days) and kayaks and charter boats (0.3 million days each) (Hyder *et al*., 2020b).

Participation varies between countries and is driven by a variety of factors (Arlinghaus *et al*., 2015). Motivations for sea angling affect participation and are diverse, including relaxation, experiencing nature, exercise, personal consumption, and socialising (Fedler and Ditton, 1994; Arlinghaus, 2006; Beardmore *et al*., 2011; Armstrong *et al*., 2013). In the UK, motivation was related to catching fish and the quality of the environment in which they fish (Brown *et al*., 2019). Catch-based motivations emphasised the importance of catching many fish and a variety of fish. A healthy and beautiful environment to fish in was the most important environmental factor and about half of respondents showed a personal attachment to the place they fished most recently (Brown *et al*., 2019).

1.3.2. Economic and social benefits

Several studies have been done in the UK to assess the economic value and impact of sea angling (Drew, 2004; Lawrence, 2005; Radford and Riddington, 2009; Armstrong *et al*., 2013; Monkman *et al*., 2015; Roberts *et al*., 2017; Brown *et al*. 2019; Hyder *et al*., 2020b). In 2003, the expenditure by sea anglers resident in England and Wales was estimated at £538 million per year supporting nearly 19,000 jobs directly and £71 million of supplier income (Drew, 2004). Residents and visitors that were active sea anglers spent a total of £165 million in south west England in 2004 (Lawrence, 2005). In 2009 in Scotland, the impact of sea angling was estimated to be £70 million and supporting 3,148 jobs (Radford and Riddington, 2009). The annual expenditure of sea anglers in Wales was estimated as £39 million for visitors and £87 million for residents, supporting around 1,700 jobs (Monkman *et al*., 2015).

Similar approaches were taken to estimate the total economic impact of sea angling in England in 2012 (Armstrong *et al*., 2013, Roberts *et al*., 2017) and the UK in 2016–17 (Hyder *et al*., 2020b). Surveys were done of trip and capital expenditure by individual anglers and raised to the total population (Table 1). Then an input-output methodology was used to calculate the total economic impact of sea angling (Table 1).

Total economic impact studies are not generally used to assess the impact of a change in policy. This is because complete cessation of sea angling would only to lead to a partial loss of the total economic impact generated as most anglers would redistribute their spend to other recreational activities (EFTEC, 2015). For example, a total cessation of sea angling in Scotland would lead to a net loss of about 53% of the economic impact created (Radford and Riddington, 2009). In 2012, sea angling in England had a relatively large economic impact compared to its participation rate (Armstrong *et al*., 2013), so spending on other recreational activities may not offset the economic loss completely, but this depends on how the spend is redistributed. In addition, sea angling generates income in coastal communities, so may be lost to these vulnerable communities if it was spent on non-coastal leisure. This makes it difficult to use the economic impact approach to assess the impact of policy, instead stated or revealed preference approaches are usually used for this purpose (EFTEC, 2015).

Table 1. Economic impact of sea angling (£M is million pounds; GVA is Gross Value Added; 2012 England and 2016–17 UK).

Measure	2012	2016	2017
Total expenditure (£M)	£1233	£1108	£1318
Direct impact:			
• **Expenditure (£M)**	£831	£696	£847
• **Jobs (thousands)**	10.4	7.7	8.9
• **GVA (£M)**	£357	£326	£388
Total economic impact:			
• **Expenditure (£M)**	£2097	£1577	£1936
• **Jobs (thousands)**	23.6	13.6	16.3
• **GVA (£M)**	£978	£696	£847

Choice experiments, a stated preference approach, can be used to assess willingness-to-pay (WTP) for a hypothetical change in the angling experiences (e.g., catches, size of fish, bag limits etc.). This allows an assessment of the impact of different management measures on the economic value of sea angling (i.e., the consumer surplus derived from sea angling) (EFTEC, 2015). A choice experiment was carried out to assess the impacts of regulations, catch, retained catch, and cost on sea angling preferences in the UK, and evaluated how willingness-to-pay changes in response to different management strategies (Brown *et al*., 2019). The marginal willingness-to-pay (MWTP) was £22 for the first cod caught and kept, and £30 for the first sea bass caught and kept. There was a reduction in additional willingness-to-pay with each extra fish caught and kept. The value of trips was largely derived from keeping the fish, rather than from releases due to minimum landing size (MLS), bag limits, or catching and keeping other fish, suggesting that catching fish to eat is important (Brown *et al*., 2019).

There are both personal and societal benefits derived from sea angling. These include benefits to society from the individual actions of sea anglers, such as involvement in environmental improvement work and volunteering (McManus *et al*., 2011; Armstrong *et al*., 2013; Griffiths *et al*., 2017). The National Angling Survey in 2018 showed that 57% of anglers (of whom a quarter fished in the sea) had been involved in environmental improvement volunteering in the preceding 12 months (Brown, 2019), which was similar to earlier studies (e.g., Armstrong *et al*., 2013). In addition, just under half would be interested in contributing to citizen science data collection (Brown, 2019). This was also reflected in Brown *et al*. (2019) which showed that three quarters of sea anglers would contribute to data collection. In terms of personal benefits, 72% of anglers in the National Angling Survey said that angling helped to keep them healthy, 27% said it was their main way of being physically active and 70% said it helped them deal with stress (Brown, 2019).

1.3.3. Catches

Total annual catches by sea anglers in England were estimated in 2012 using several survey methods to give estimates for angling from the shore, private or rented boats (including kayaks) and charter boats (Armstrong *et al*., 2013). For shore and private/rented boats, sea angling effort, in terms of the total numbers of angler-days spent fishing in England, was estimated from a face-to-face survey. The average CPUE (numbers of fish per day) for shore and private/rented boat angling was estimated using an onsite roving creel survey of known shore angling marks and boat landing sites. The mean CPUE estimates were multiplied by the total effort to give total catches of each species in the survey year, separately for shore and private/rented boats. A separate survey of charter boats was carried out in which skippers selected at random each month provided data on their catches during the month (Armstrong *et al*., 2013). Regional average CPUE was raised using the known number of charter boats in each region. A total of 10.1 million fish were caught in England in 2012 by all sea anglers. The most common species caught by number were mackerel and whiting (Armstrong *et al*., 2013). Shore anglers released around 75% of the fish caught, many of which were undersized, and boat anglers released around 50% of their fish (Armstrong *et al*., 2013). Numbers of fish kept and released were estimated for 20 species or species groups. Tonnages were estimated for sea bass ranging from 380–690t with 230–440t retained, and cod was between 480–870t with 430–820t retained (Armstrong *et al*., 2013).

In 2016 and 2017, a diary panel was recruited to participate in an offsite catch diary programme to give estimates of CPUE of each species in terms of catch per angler per year. These were combined with estimates of effort (total number of anglers who fished in the year) from the WPS in 2016 and 2017 to estimate catches using a similar approach to the current survey (Hyder *et al*., 2020b). In total, 100 fish species were reported as being caught by sea anglers fishing in the UK, and the data were sufficient to estimate total numbers caught 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% (Hyder *et al*., 2020b). The majority of catches were by English sea anglers, due to the high proportion (73%) of UK sea anglers resident in England (Hyder *et al*., 2020b). Catch composition was similar in 2016 and 2017, and the top four most common species in terms of numbers of fish caught were whiting, mackerel, dogfish, and bass in the same order in each year. The next four most common species were cod, pollack, dab and bib, but these appeared in a different order in the two years (Hyder *et al*., 2020b). Released fish were generally smaller than kept fish of the same species and voluntary catch and release of fish was common (Hyder *et al*., 2020b).

Catches and catch composition were similar in 2016 and 2017 for the UK, with some difference in the order of most common species. Comparisons with 2012 were only possible for England as the 2012 survey did not cover the whole of the UK. Composition of catches in England was similar for 2012, 2016 and 2017. Catch estimates for England from the 2016 and 2017 surveys (Hyder *et al*., 2020b) were higher across many species than from the 2012 survey (Armstrong *et al*., 2013), particularly for released fish. As the 2012 data are for only one year and used different survey methods, it was not possible to determine the extent to which the increased catch estimates were due to survey bias, random sampling error, or changes in fish abundance. It is likely that a combination of these factors generated the differences. Although a method was applied to reweight the diary panel to be more representative of the population in terms of avidity, age or predominant sea angling method, some bias may remain if sea anglers who complete a diary are on average more experienced or skilled than the general population, as this may affect their catches and expenditure. It was possible that catches have changed significantly over the period, as sea angling catches will fluctuate in response to changes in fish abundance (e.g., Strehlow *et al*., 2012). In addition, angling surveys elsewhere have shown how different survey techniques can lead to greatly varying results. Differences of between 2% and 50% found between harvest estimates from onsite and offsite surveys in New Zealand, with the largest differences for less common species (Hartill *et al*., 2015). Hartill *et al*. (2015) only compared the harvested component; no comparisons exist for the released component.

2. Methods

The overall aim of the survey programme was to estimate the numbers and tonnages of fish of each species kept and released by sea anglers aged 16 and older resident in the UK, along with the associated estimates of precision. Two independent surveys provided data on effort and CPUE:

- Watersports Participation Survey (WPS): a face-to-face survey of 12,000 households across the UK that provided a population level estimate of the numbers, demographic profile, and activity of sea anglers in the UK (Section 2.1).
- Sea angling diary: a year-long online catch diary tool and app that provided a record of the trip-by-trip catches from a self-selecting UK-wide panel of sea anglers. Mean CPUE in terms of annual catch of each species per angler was estimated from the diary (Section 2.2).

The total annual catch of a species in any defined stratum (e.g., region, age) was estimated. This was done by multiplying the total number of anglers in the WPS who recorded angling activity in that stratum (the effort) by the average annual catch per angler for that stratum (CPUE) in the sea angling diary panel (Section 2.3). The raised catches were then summed over strata as required. This type of two-stage survey is done for most sea angling surveys where census data are not available (see Pollock *et al*., 1994; Jones and Pollock, 2013)

Whilst the WPS uses a strictly controlled random stratified design to minimise bias, the diary panel is self-selecting following a wide range of efforts to seek volunteers. Its composition in terms of age profile, stated avidity, fishing platforms, and other characteristics differs systematically from the composition of the WPS sea angling respondents. To reduce bias in the total catch estimates, a procedure was adopted to reweight the panel members so that the weighted panel composition matched that of the WPS respondents (Section 2.3). This procedure is commonly used in such surveys where robust independent data on the population composition are available.

An additional approach was adopted to assess the potential for bias in the 2019 survey due to non-probabilistic recruitment of diarists. This involved comparing the composition of a probabilistic sample of sea anglers from a postal survey of selected regions of England with the composition of the standard diary panel for 2019 (validation panel; Section 2.4.1). A model-based estimation approach was also developed to test the sensitivity of the annual catch estimates to the analytical methods used (Section 2.4.2).

2.1. Participation and effort

The WPS started in 2002 with the aim of monitoring participation in water sports and has run every year since. A full description of the survey approach is provided in Hyder *et al*. (2020b), with a short summary of the approach provided below.

A face-to-face survey of 12,000 UK households was done during September 2018 and September 2019 to estimate annual participation and trends in watersports activities. The sampling frame was created from non-overlapping areas of similar population sizes within a single Government Office Region. This used the 2011 census small area statistics and postcode address file. Each year, 605 sample points were selected across the UK and addresses chosen at each sampling point. Then a sample was obtained of 13, 15, or 17 individuals of 16 years or older in London, and 15, 17, or 19 individuals elsewhere. Further details of the selection procedure can be found in Hyder *et al*. (2020b).

During the face-to-face interview, background information on the respondent is gathered before asking if they have taken part in any of the 32 different watersports activities. In 2018, sea angling activities were split into: sea angling (rod and line/handline) from a kayak; sea angling (rod and line/handline) from a private or rental boat; sea angling (rod and line/handline) from a charter boat; and sea angling (rod and line/handline) from the shore. In 2019, sea angling using rod and line was separated from sea angling using a handline. If the respondent answered yes to any of these categories, they were then asked how many days that they had fished in the UK in the last year. In 2019, additional questions were asked about the experience (years fished, consistency of fishing) and skill (self-stated). A minimum of 10% of surveys were checked by trained validators to ensure consistency of data collection and identify issues with survey approaches.

Responses were weighted based on the interviewee’s location, age, sex, and social grade. A breakdown of demographics published by the Office of National Statistics (ONS) was used to raise the weighted samples (questionnaire responses) to the entire population of the UK over the age of sixteen. Participation rates, numbers, and days fished in 2018 and 2019 were calculated for the UK and compared to previous surveys.

2.2. Diary panel

The Sea Angling Diary[1] has been running since 2016. Each year, sea anglers are recruited to keep catch diaries. A full description of the approach can be found in Hyder *et al*. (2020b), but the key approaches for recruitment (Section 2.2.1) and data collection from diarists (Section 2.2.2) are summarised below.

2.2.1. Recruitment

Recruitment of diarists in 2018 and 2019 involved using an appropriate, cost effective method to identify a representative sample of people who fish for recreation in the sea and who were willing to keep catch diaries. As there are no comprehensive lists of sea anglers in the UK, it was necessary to derive a sample by other means. Normally, a telephone or postal survey would be used to recruit a probabilistic sample of sea anglers. However, both participation rates and response rates to these surveys are relatively low in the UK,

[1] www.seaangling.org

meaning that this approach would be too expensive at a national level to generate sufficient numbers of diarists for a panel. Instead, diarists were recruited through a variety of different means including those adopted in previous years (e.g., websites and forums, face-to-face, flyers) (Hyder *et al*., 2020b) and additional methods utilising other social media (e.g. Facebook, Google). To assess the representativeness of the diary panel, characteristics (stated avidity, location, age) were compared to the population derived from the WPS. A small regional validation panel was also constructed from respondents to a postal survey (Section 2.4.1).

Each year, the target was to generate a diary panel of at least 1,515 sea anglers, including 90, 105, 165, and 1,155 from Northern Ireland, Scotland, Wales, and England, respectively. The partitioning was based on the proportion of the total number of sea anglers residing in each country as estimated in the WPS. To achieve this target number of diarists, participants from previous years were retained and new diarists recruited through a variety of different means described below. The rates of retention and volume of new recruits varied by year due to differing recruitment methods, periods, and contexts.

Recruitment occurred from July 2017 onwards for the 2018 panel, and during the period of November 2018 to February 2019 for the 2019 panel, although diarists were able to sign up at any point during the year. Recruitment varied between years (Table 2), but was done by contacting an existing database of anglers by email, through angling clubs, internet fora, adverts in published media, social media, and face-to-face. Promotional flyers were sent to angling businesses (charter boats and tackle shops), angling federations, and clubs. Recruitment for 2018 included a period from July to November 2017, which is described in Hyder *et al*. (2020b). In addition, from 2018, business cards were distributed via FishingMegastore to their mail order customers throughout the year. The email database was boosted in 2019 through delivery of the National Angling Survey in 2018, and specific communication was made with respondents from that survey who indicated that they went sea angling. In 2018, diarists from the previous year were retained unless they indicated that they wished to be removed, but consent to continue participation was confirmed in 2019, resulting in a lower number of retained diarists.

Table 2. Recruitment methods utilised and number of contacts made.

Publicity	Method	Number sent (2018)	Number sent (2019)
Substance angler contact database	Email	15,933	28,275
Charter boats	Email/telephone/post	255	257
Clubs	Email/telephone/post	143	148
Tackle shops	Email/telephone/post	326	332
Federations	Email/telephone/post	11	11
Events/angling sites	Face-to-face	2	2
Events/angling sites	Materials sent	3	1
Magazines, etc.	Press release sent	3	3
Forums/websites	Press release sent	13	13
Posters	Print distributed	0	500
Leaflets	Print distributed	0	200
Business cards	Print distributed	5,000	10,000
Promotion of the mobile app by email to Substance angler contact database	Email	-----	23,577

Potential diarists completed a sign-up survey providing information about their demographic characteristics (e.g., age, location), fishing habits (e.g., avidity, areas, species), and fishing ability (e.g., self-stated skill, experience, consistency of fishing). Once the sign-up survey was complete, diarists were given a fish identification booklet, tape measure, and waterproof notebook to record details of location, methods, and catches for each session. An explanation was provided of the recording requirements, including location, duration, method, and catches. Access was given to the online diary system and mobile app to record catches each month.

2.2.2. Data collection

Diarists recorded whether they had fished each month, and details of each session (location, duration) including catch (species, size, kept or released). The data were anonymised, so that individual anglers could not be identified, and no entries could be linked to an individual. Each fishing location recorded was 'jittered' - moved in a random direction by a small, fixed distance - which resulted in small changes to the actual location in order to protect individual marks. All personal data was removed from the database before data analysis. Significant effort was put into following up with diarists to ensure that data were completed each month, but there were still issues with missing data. Diarists were sent reminders by email three times every month to help maximise response rates. Two of the emails used a mail merge to specify for each diarist which data were missing for that month. The third email reminder in each month was converted to a newsletter in 2019 to increase engagement. Reminder push notifications were sent to those with the app twice a month. Text polls were sent for each missing month in 2019 to diarists on a biweekly basis beginning in August 2019. Responses where individuals had not fished were recorded and updated. Individuals who responded to say that they had fished were further contacted either via email or phone. In addition, at various stages, diarists who had not logged in, had not entered data, or had missing data were contacted by telephone. To further help recruit and encourage data entry, incentives were provided in the form of prize draws for tackle and Amazon vouchers, and electronic copies of Sea Angler magazine.

The Sea Angling Diary tool was developed in 2016 for data entry (see Hyder *et al*. 2020b for a full description). Diarists had to record whether they fished in a month or not, as an absence of data entry could not be assumed to indicate that no fishing had taken place. Diarists were asked to 'lock' their month once all data had been entered for the month, so that it was clear that data entry was complete. To maximise data entry, significant effort was put into development of a system that was user friendly and provided summary statistics of an individual angler's catches. The structure was hierarchical and started with a 'Calendar' page with a simple one click to record fishing or no fishing activity. If fishing had occurred, then a 'Session' was added that included location duration and method. If catch was identified on the Session screen, then a 'Catch' page was generated where all catch details were captured (Figure 1).

Improvements have been made to the system each year to make data entry simpler and more intuitive, and increase the benefits to the sea angler. This has included development of a mobile app released in 2019 that works on iOS and android for data entry (Figure 1) in addition to the online system. This allowed diarists to record data during a fishing session in ‘real-time’ using mobile phones and was designed to: make data entry easier and more immediate; reduce recall bias and inaccuracy; and improve data completion. The mobile app was designed to make participation in the diary panel more appealing to a wider group of sea anglers and provided new ways of contacting and engaging with diarists. The app mirrored the functions, data fields, and style of the diary tool, and data was synced between the two so users could use both or either interface. In addition, several new features were developed for the tool after reviewing diarist feedback. In 2019, these included: the ability to record target species; and a shared dashboard, where diarists could opt to share details of some of their sessions with other diarists (precise locations were hidden, and data anonymised). In 2019, 31% of recorded sessions were shared.

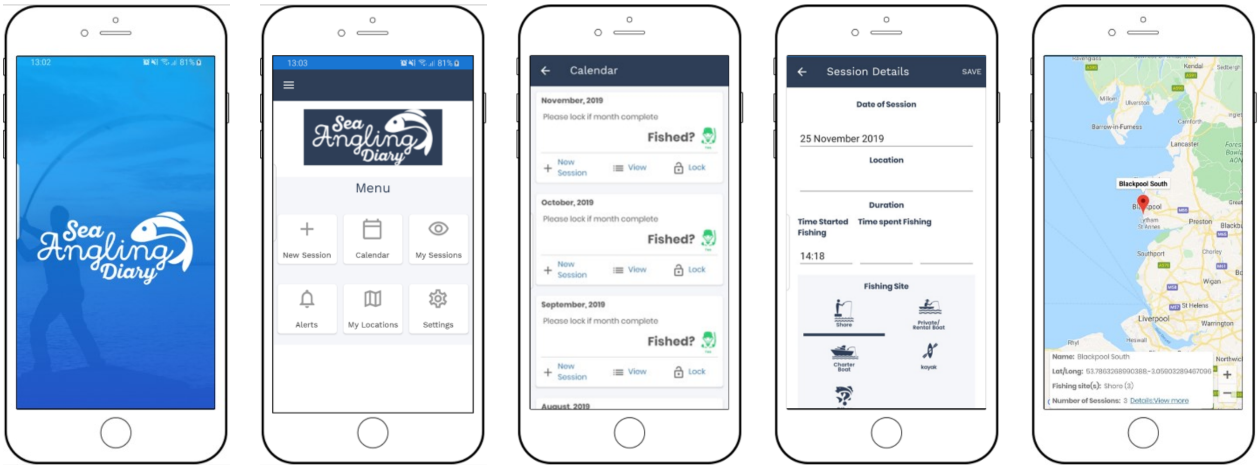


Figure 1. Screenshots from the Sea Angling Diary mobile app. From left to right, the images show the start-up screen, menu, calendar, session details, and location mapping.

2.3. Catches by UK sea anglers

The number and tonnages of each species retained and released was estimated using the same approach as 2016–17 (see Hyder *et al*. 2020b). The approach used post-stratification to correct for bias in the diary panel through reweighting of each individual’s diary data based on demographic characteristics of anglers from the WPS.

A general schema for the analysis process is provided in Figure 2. No estimates of catch numbers were provided for any species where there were fewer than four diarists or 15 records for that species, as these were considered too uncertain to provide robust estimates. In addition, tonnages were not calculated for species with fewer than five diarists or 50 individual fish reported. Only diarists who had fished and provided six or more months of data were included and the highest and lowest three catches in the panel were removed (trimmed) to reduce this impact of single large catches.

Different post-stratification and reweighting approaches were tested in comparison with a baseline analysis with no post-stratification. The choice of the final stratification was based on the number of individuals in the diary and WPS in each stratum, and the values of three diagnostics (bias discount, average absolute differences, and volatility; Hyder *et al*. 2020b) that together provide an overview of the impact of the stratification on the final estimates. The choice was made to achieve the minimum sufficient stratification to allow a robust reweighting based only on characteristics (e.g., avidity) that had a demonstrable impact on catch estimates, whilst maintaining a sufficient number of anglers per stratum in both the WPS and the diary panel. This led to the adoption of eight post-strata based on four avidity (<4, 4-8, 9-19, 20+ days) and two age (<55, 55+ years old) categories for both years, which provided a reasonably high bias discount, high average absolute difference, and low volatility compared with no post-stratification.

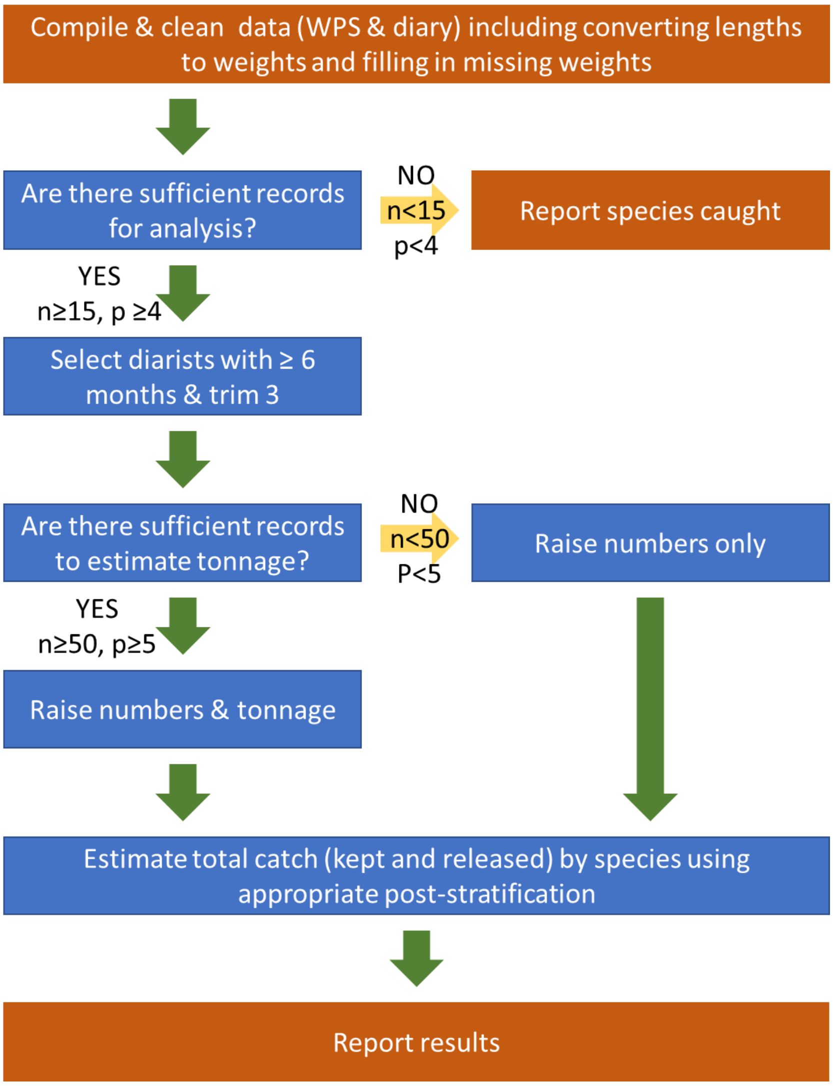


Figure 2. Schematic demonstrating the final estimation procedure for each species and/or group. Stratification was based on avidity (<4, 4-8, 9-19, 20+ days) and age (<55, 55+ years old) for both 2018 and 2019. Adapted from Hyder *et al*. (2020b).

The numbers of fish kept and released (total and catch per angler) and release rates were estimated for each stratum, then summed across all strata to give annual totals for the whole of the UK and the associated estimates of precision. The catches for England only were compared with results from 2012 (Armstrong *et al*., 2013), 2016, and 2017 (Hyder *et al*. 2020b). The catch composition by numbers caught was evaluated for 2018 and 2019 for the UK, and a separate analysis of the compositions within England only was done for comparison with results of the 2012 surveys given by Armstrong *et al*. (2013).

2.4. Assessment of potential bias

There will be uncertainty in the estimates that arises from two sources: measurement error (precision); and bias resulting from issues with design, implementation, and data analysis methods for each survey (Pollock *et al*. 1994; ICES 2010; Jones and Pollock, 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 Pollock, 2013). To assess the potential for bias in the 2018–19 survey, the impact of self-selection of diarists was assessed against a probabilistic sample from a postal survey (validation panel). In addition, a model-based estimation approach was used to test the sensitivity of the results to the analytical method.

2.4.1. Validation panel

The composition of the diary panel was inevitably biased to some extent by the method of seeking volunteers for the panel, which involved targeting anglers through existing survey participant lists, flyers, face-to-face interviews, and social media. These contacts could have reached a non-representative group of sea anglers (e.g., including more avid and enthusiastic anglers than in the population). Only a fraction of the anglers contacted will register a desire to do the survey, and these may also be non-representative of the population of anglers. To gain some insights into these issues, 50,000 households in three regions (North West, East, and South West of England) were selected at random and sent information by post about the sea angling survey, and an invitation to complete a questionnaire and participate in a validation panel. The regions were selected to represent different fishing opportunities that capture the variety of sea angling in the UK. The target was to recruit a validation panel of 100 sea anglers: 36 from the North West; 12 from the East; and 52 from the South West of England (Table 3). The number of mail shots was based on a calculation that 50,000 households would have 100,000 adults (an average of two adults per household). Based on the participation rates from 2012 (2.2%) and 2016–17 (1.7%), it was assumed that around 2% (2,000) of these adults went sea angling. The maximum response rate was estimated to be 20% (400) of whom 25% (100) would sign up to join the diary panel.

Table 3. Number of postal surveys sent to each target region (South West, East and North West of England) based on calculated probability of anglers in the population.

Region	Probability	Anglers	Population	Inverse probability	Number of surveys
South West	0.028	119,416	4,230,564	35	10,715
East	0.017	27,514	1,573,099	57	17,291
North West	0.014	80,990	5,889,729	73	21,994
Total	0.019	227,920	11,693,392	165	50,000

Material supplied in each mail shot consisted of a two-sided survey that replicated the online recruitment survey for the diary panel, a covering letter, and a return pre-paid addressed envelope. Respondents could also complete the survey online. Survey responses were then processed and respondents that wanted to sign-up were added to the validation panel. Where the respondent signed up, but screening data were missing, phone calls and emails were sent to request missing information prior to the individual being added to the project. To encourage participation and data provision, participants on the validation panel were incentivised with £5 Amazon vouchers for each completed month in their diary (including backdated months in 2019). The recruitment process for the validation panel differed from the diary panel only in the way that individuals were contacted; a random sample from a postal survey for the validation panel and convenience sample for the diary panel. Both approaches still suffer from response bias where certain types of anglers may be less likely to respond (e.g., people who fish only occasionally or are less skilled or enthusiastic). Follow-up waves of mail shots to households that did not respond to the first mail shot to obtain information on the reasons and to encourage participation in the panel were beyond the scope of the project.

Once recruited, the validation panellists were treated in the same way as the diary panel. They were provided with a species identification guide, waterproof diary, and access to online and mobile tools. Panel members reported catches on a monthly basis, receiving the same reminders and follow-up as the diary panel (see Section 2.2). The potential for bias in the diary panel recruitment process was assessed by comparing the composition (e.g., age, avidity, experience) and catch rates of the diary panel, validation panel, and the WPS. This was done using Bayesian comparison tests (Kruschke, 2013) that modelled the ordered categorical variables of age, avidity, and experience (Bürkner and Charpentier, 2020), and the continuous variable of catch rate.

2.4.2. Model-based catch estimates

A second potential source of bias was created through the analysis procedure. The standard post-stratification approach was developed to account for biases in the sampling and create estimates that are as representative as possible of the wider population. However, due to the small numbers of diarists in each stratum of both the WPS and diary panel, there was a limit to the number of individual strata that can be used in the post-stratification. This leaves the potential for bias as well as potentially unstable estimates across years. An alternative approach for analysis was conducted, using statistical modelling to assess the impact of different angler characteristics on catches. This had the benefit of utilising all the results to create the model, which was both more efficient and generated more stable estimates.

A principled Bayesian modelling approach was developed based on multilevel regression and poststratification (MRP). This approach has been used to generate accurate estimates from non-probabilistic pre-election polling in US and UK elections, and the UK Brexit referendum (Lauderdale *et al*., 2020). A Bayesian framework was used instead of a traditional frequentist approach, as it was better able to deal with multiple data sources and missing data. It also allowed the incorporation of prior information (Bürkner and Vuorre, 2019), for example, existing information on the size of the angler population in the UK. The Bayesian approach was also more robust and was able to estimate models for which frequentist maximum likelihood-based methods fail (Eager and Roy, 2017).

MRP used a similar poststratification as used in the previous analysis of the diary panel and WPS data (Hyder *et al*., 2020b), splitting anglers into mutually exclusive categories. However, MRP differed in how it estimated the catch weights of anglers in each stratum. Instead of reweighting the raw results, MRP involved creating a model of what an angler in this category was expected to catch, based on the data in the Sea Angling Diary. Using a model for this estimate allowed information to be shared across angler categories. For example, although young avid anglers had different catches to older avid anglers, the model was able to partially share information between these two categories to get a better estimate of the catches of both categories. Sharing this extra information allowed separation of the underlying patterns of catch rates from the variation among individual anglers.

2.4.2.1. Developing the model

Data were included in the analysis from the WPS if the respondent was aged 16 or older. Diarists were included from both the diary panel and validation panel if they were: aged 16 or older; lived in the UK; and provided at least 6 months of data. Skill level was not available for all diarists, so missing skill values were imputed using the R package ‘mice’ (van Buuren and Groothuis-Oudshoorn, 2011).

The first goal was to identify the key variables that drive catch rates. A range of methods were run to provide a holistic view of the causes of catch rates and the dependencies between them. Firstly, a Directed Acyclic Graph (DAG) model (Textor and van der Zander, 2016) was used to identify the causal relationships between important variables. Then Maximal Information-based Nonparametric Exploration (MINE) statistics were calculated to assess interdependencies between these variables (Reshef *et al*., 2011). MINE was used as it accounted for both linear and non-linear relationships between variables. A penalised regression called ‘Lasso’ was used to identify which parameters could be removed from a model without damaging predictive accuracy. In addition, a method called ‘Boruta’ identified which variables were most useful using a random forest model (Kursa and Rudnicki, 2010). Variables that were seen as important across these four methods were deemed relevant for the model.

The model was developed by starting with an empty model with no independent variables that used a gamma hurdle distribution. Gamma hurdle distributions are useful as they are non-negative, continuous, and allow the variance to increase with the mean. The model was developed by iteratively adding variables that were revealed to be important. The variables were used to predict the three parameters that determine a hurdle gamma distribution: the mean, the shape, and the hurdle probability. To compare and select the most appropriate multilevel model a ‘Leave-One-Out’ cross validation was run.

Ideally, effort from the WPS would also have been modelled and then combined with the model of catch per angler to raise catches at the UK level. However, this was not possible within the timescales. Instead, a post-stratification approach was used to reflect differences in the characteristics of sea anglers between the sample from the diary and the overall population of sea anglers. To overcome the low number of sea anglers in the WPS and reduce error, responses from multiple years of the WPS (2017–19) were used. This was run as a clustered survey and a formula-based standard error calculation was added to the model. Due to limitations in the size of the WPS, the number of variables that can be used in the model was restricted. The final model selected was based on selecting the variables that best predict catch rates, identifying bias in the sample, and looking at alternative ways to post-stratify.

Assuming a normal distribution, the mean and the standard deviation were used from the WPS as the calculated standard error. The uncertainty in both the model and the WPS were combined by taking random draws from both the catch model and the WPS. These were multiplied together and averaged. This incorporated both the uncertainty from the model and WPS, and the 95% confidence interval was derived from distribution of these draws.

2.4.2.2. Comparison with the existing approach

To assess the impact of model-based catch estimates, a comparison was made with the results using the existing approach (Section 2.3). This was done for the both the estimates and levels of precision. Individual species and total catches were compared for the 2018 and 2019 surveys.

3. Results

3.1. Participation and effort

3.1.1. Participation

There were 153 and 116 respondents to the WPS that had been sea angling in 2018 and 2019, respectively. From this, it was estimated from the WPS that 758,000 16+ year olds in the UK went sea angling in 2018, and 551,000 in 2019, representing a participation rate of 1.0-1.4% each year (Table 4A, Figure 3A). Numbers of sea anglers were greatest in England, but participation rates were highest in Northern Ireland and Wales (Table 4B, Figure 3B). There was an apparent trend of decline in the numbers and participation rate in the UK over time, but the confidence intervals overlapped in most cases (Table 4, Figure 3). Respondent numbers are low in individual countries, especially in Northern Ireland, Wales, and Scotland, so small variations in response may significantly affect population estimates at that level. In addition, use of handline was separated from rod and line in the WPS in 2019, which may also have generated some reduction in the totals. The totals were driven by the numbers of sea anglers in England. On average, the most common recreational sea angling method across all five years was fishing from the shore (Figure 4).

Table 4. Sea angler numbers, participation rates, days fished by platform, and days fished by an individual in 2012 and 2016–19. All data is for the residents in the UK only. 95% confidence intervals are given in brackets.

Measure	2012	2016	2017	2018	2019
A. Numbers (thousands)					
Total sea angling UK	1150	874 (717-1177)	902 (692-1145)	758 (557-973)	551 (370-726)
England	884	607 (447-823)	677 (507-903)	566 (412-779)	375 (252-557)
Wales	76	99 (47-209)	69 (29-167)	59 (23-154)	62 (24-160)
Scotland	125	88 (40-194)	81 (36-184)	64 (25-160)	42 (13-130)
Northern Ireland	65*	80 (35-182)	75 (32-175)	69 (28-168)	72 (30-175)
Total non-angling methods	---	131	242	172	125
B. Participation (%)					
Total sea angling UK	2.2	1.7	1.7	1.4	1.0
England	2.2	1.4	1.5	1.3	0.8
Wales	3.1	3.8	2.6	2.4	2.4
Scotland	2.4	2.0	1.7	1.3	0.9
Northern Ireland	3.6*	5.2	4.8	4.5	4.7
Total non-angling methods	---	0.2	0.5	0.3	0.2
C. Effort (million days)					
Total sea angling	4.8†	7.5	6.7	6.0	6.1
Kayak	---	0.3	0.3	0.3	0.1
Private and rented	0.5†	1.2	1.6	1.9	1.2
Charter	0.4†	0.2	0.3	0.4	0.3
Shore	3.9†	5.8	4.5	3.3	4.4
D. Effort (days/angler)					
Total sea angling	4.2†	8.6	7.4	7.9	11.0

*Northern Ireland numbers are from McMinn (2013).

†2012 figures are for England only.

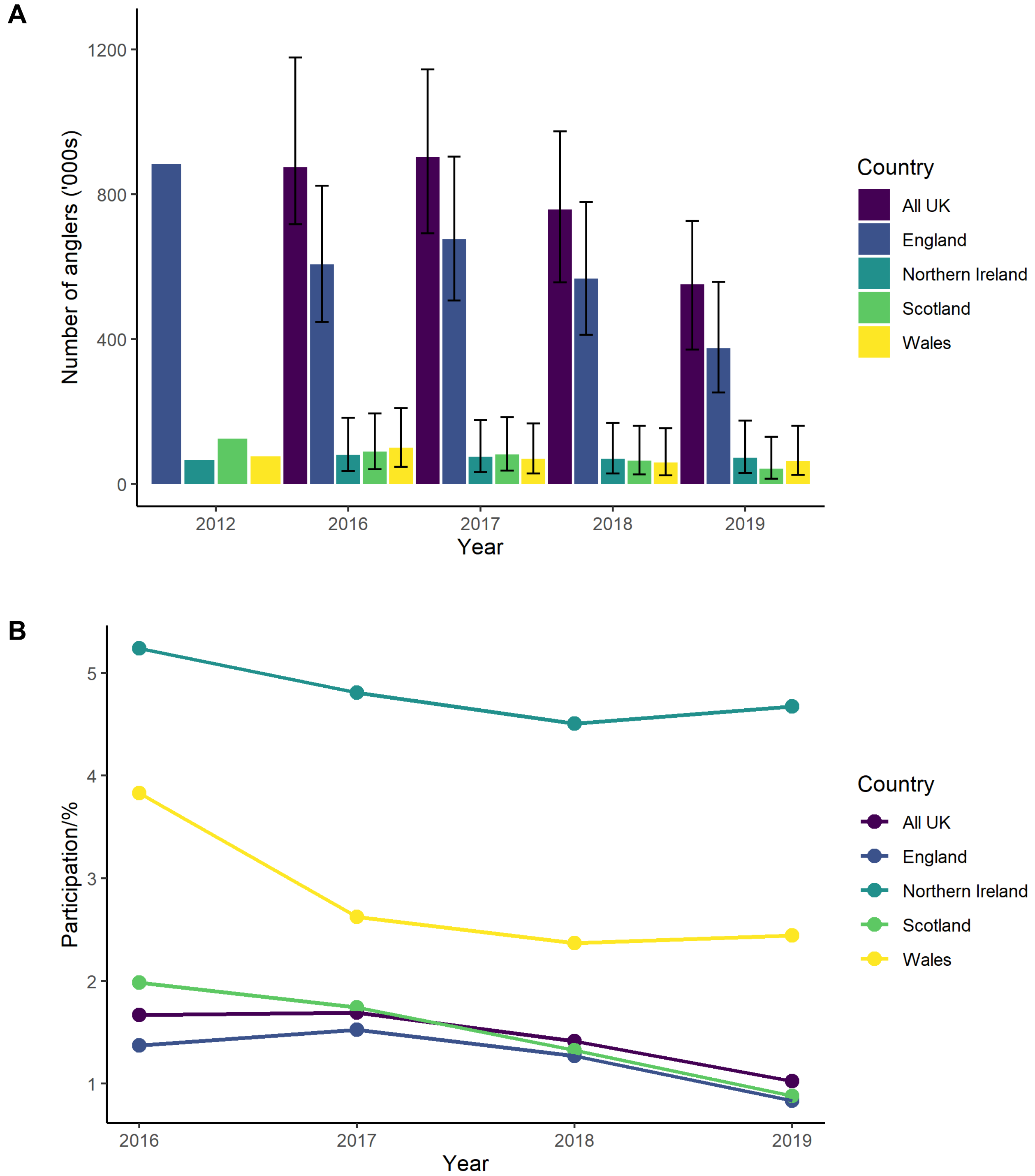


Figure 3. The total number of anglers (thousands) (A) and participation rate (B) in recreational sea angling in the UK in 2016–2019. Error bars on (A) represent 95% confidence intervals.

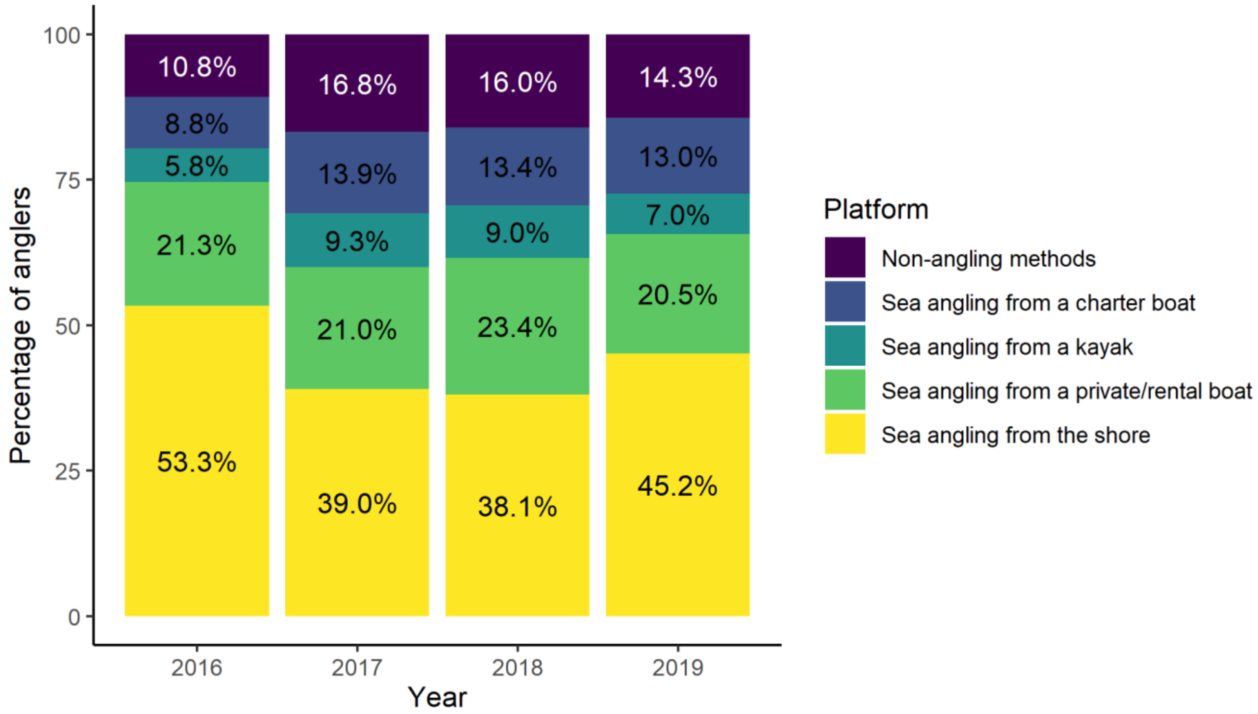


Figure 4. The percentage of UK sea anglers fishing from different platforms in 2016–2019.

Most sea anglers were male, but the percentage of males was lower than in most other surveys at an average of 81% over all five years. The majority of sea anglers were between 35 and 55 years old (Figure 5A). Sea anglers were mainly working class or non-workers (social grade groups C2, D, and E), with a lower portion from the middle class (social grade groups A, B, and C1)[2] (Figure 5B).

3.1.2. Effort

Sea anglers fished for 6.0 and 6.1 million days in 2018 and 2019, respectively, with most effort from the shore, followed by private and rented boats (Table 4). This related to 7.9 and 11.0 days per angler in 2018 and 2019, respectively (Table 4). Total days fished was lower in 2018–19 than 2015–17, but was higher than in 2012 (Table 4). Most sea anglers fished between two and five times a year, and this was reasonably consistent across all years of the WPS despite some variation between avidity categories (Figure 6).

[2] https://en.wikipedia.org/wiki/NRS_social_grade

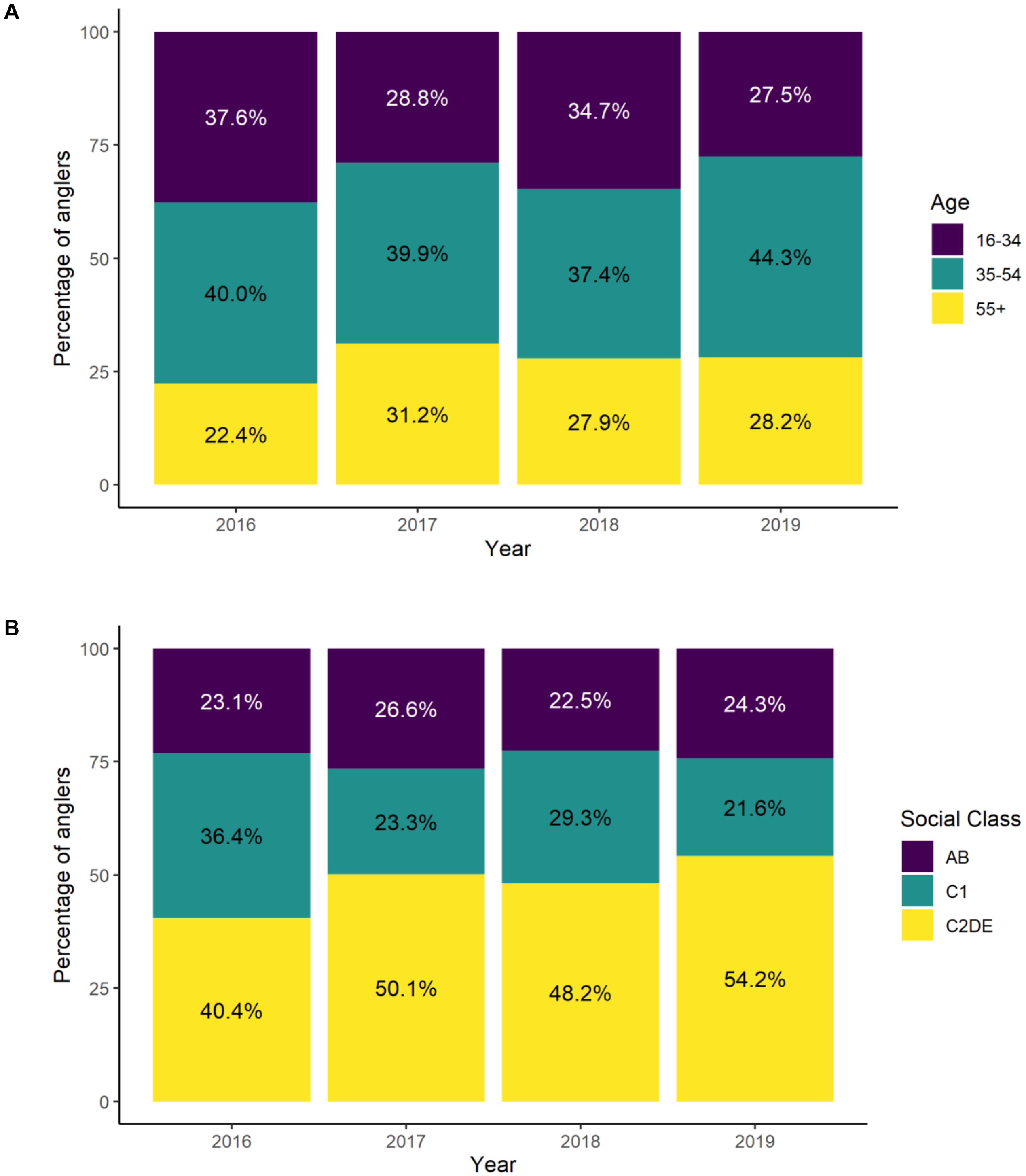


Figure 5. The percentage of UK sea anglers by age (A) and social grade group (B) in 2016–2019.

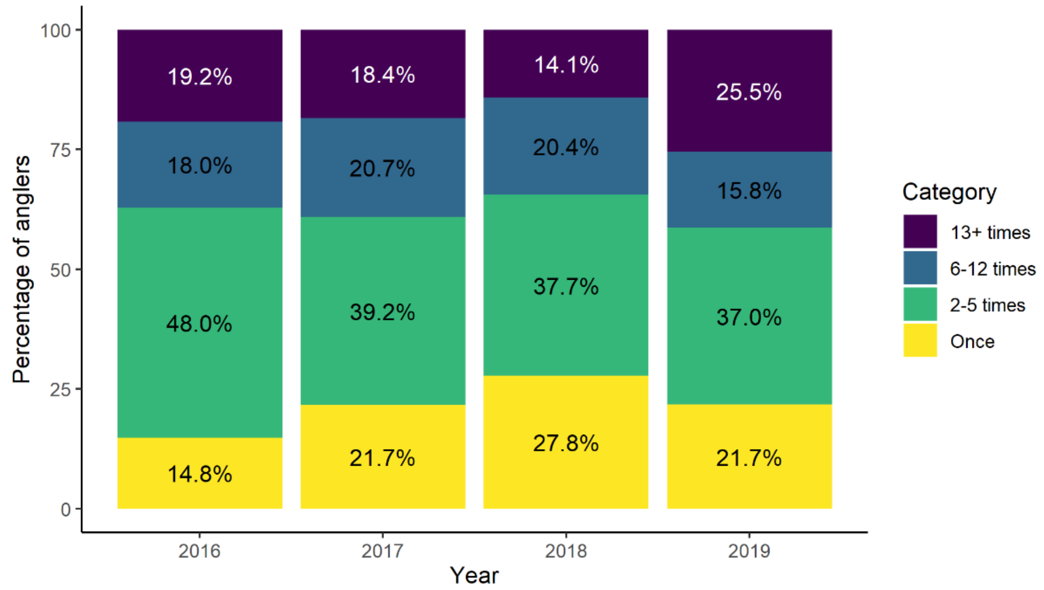


Figure 6. The percentage of sea anglers by avidity (number of days fished in the last 12 months) in 2016–19.

3.2. Diary panel

3.2.1. Recruitment

In total, 1,706 and 2,188 sea anglers participated in the diary panel in 2018 and 2019, respectively (Table 5). In 2018, this consisted mainly of existing 2017 diarists and some from general promotion. In 2019, the diary panel consisted mainly of diarists from the broader recruitment exercise, and fewer existing diarists (Table 5). The differences were due to a number of factors. Recruitment for 2018 was undertaken from summer 2017 (Hyder *et al.*, 2020b) with those recruited starting in 2017. In 2019, consent was required for all diarists, so there was loss of many existing diarists that did not complete the consent form. Many new recruits in 2019 came from emails to respondents to the 2018 National Angling Survey, who were sea anglers and had consented to be contacted about future surveys. The majority of those agreeing to keep a diary were resident in England, followed by Wales, Scotland, and Northern Ireland (Table 6). Recruitment was close to the target in all regions apart from Northern Ireland, where accessing diarists was more difficult. Comparison with the WPS showed that the diary panel had similar regional composition (Table 6), but the diary panel had a higher proportion of older (Table 7) more avid (Table 8) sea anglers.

Table 5. The responses and numbers signed up to the diary panel from each type of publicity.

Mode	2018	2019
Existing diarists	1,387	652
Signed up from emails	----	731
General promotion (business cards etc.)	319	643
Face-to-face events	0	28
Mobile app promotion	----	134
Total	1,706	2,188

Table 6. The percentage of diarists by region and country in comparison with the population of sea anglers from the Watersports Participation Survey (WPS). Percentages have been calculated for common categories in the diary panel and WPS to allow comparison.

	2018			2019		
Category	**Count**	**%**	**%WPS**	**Count**	**%**	**% WPS**
East Midlands	66	3.9	1.4	83	3.8	5.8
East of England	163	9.7	4.6	228	10.5	3.7
London	45	2.7	5.9	59	2.7	2.6
North East	103	6.1	6.9	123	5.7	4.7
North West	124	7.4	13.7	293	13.5	4.3
South East	338	20.1	18.8	412	19.0	24.4
South West	359	21.4	10.9	362	16.7	11.5
West Midlands	47	2.8	6.5	94	4.3	5.4
Yorkshire & Humber	84	5.0	5.6	133	6.1	5.5
England Total	1,329	79.2	74.3	1,787	82.2	67.9
Northern Ireland	72	4.3	8.9	49	2.3	13.4
Scotland	137	8.2	8.6	129	5.9	7.1
Wales	141	8.4	8.3	209	9.6	11.7
Other (non-UK)*	27	----	----	14	----	----
Total	1,706	100.0	100.0	2,188	100.0	100.0

*(Non-UK) category includes diarists with a home address in the Republic of Ireland, Channel Islands, the Isle of Man or France.

Table 7. The percentage of diarists by age in comparison with the percentage of the population of sea anglers from the Watersports Participation Survey (WPS). Percentages have been calculated for common categories in the diary panel and WPS to allow comparison.

	2018			2019		
Category	**Count**	**%**	**% WPS**	**Count**	**%**	**% WPS**
16-34	301	17.7	34.7	253	11.6	27.5
35-54	729	42.8	37.4	751	34.5	44.3
55+	673	39.5	27.9	1,172	53.9	28.9
Prefer not to say	3	----	----	12	----	----
Total	1,706	100.0	100.0	2,188	100.0	100.0

Table 8. Stated avidity[3] profile of diarists compared to the percentage of the population of sea anglers from the Watersports Participation Survey (WPS). Percentages have been calculated for common categories in the diary panel and WPS to allow comparison.

	2018			2019		
Category	**Count**	**%**	**% WPS**	**Count**	**%**	**% WPS**
Frequent (> 35 days)	528	32.5	4.3	445	23.3	8.9
Regular (13-35 days)	518	31.9	9.8	567	29.7	16.6
Occasional (6-12 days)	349	21.5	20.4	515	26.9	15.8
Rare - 2-5 days	187	11.5	37.7	330	17.3	37.0
Once	42	2.6	27.8	55	2.9	21.7
Not in last 12 months	0	----	----	200	----	----
Never	0	----	----	12	----	----
Other	82	----	----	64	----	----
Total	1,706	100.0	100.0	2,188	100.0	100.0

[3] Stated avidity was taken at the time of sign-up to the diary and related to participation in the preceding 12 months. The time series varied according to the date of sign up. For some diarists in 2018 and 2019 who signed up in previous years, their stated avidity referred to their participation in 2015 and 2016. Actual avidity of diarists from the days recorded fishing in the diary was significantly less frequent, meaning that the difference in actual avidity to the population may not be as great as when comparing stated avidity.

In the 2019 screening survey, diarists were asked about the number of years they had been sea angling, whether their 'angling career' had had any significant gaps and a self-assessment of their skill level. As some diarists joined before these questions were added, data are not available for all participants in 2019. The diary panel had more people who classified themselves as 'intermediate' in experience (Table 9), but fewer who classed themselves as 'beginners' than the general sea angling population in the WPS (Table 10). In comparison to the WPS, diary panel members were less likely to have had very long gaps in their fishing (Table 11).

Table 9. The number of years since diarists first went sea angling, and the percentage that entered data in 2019. Percentages (%) have been calculated after removal of blank data to allow direct comparison of common categories with WPS.

Years Angling	Count	%	% WPS
0-5	194	10.1	21.1
6-10	85	4.4	14.5
11-15	108	5.6	8.7
16-20	155	8.1	10.5
21-30	233	12.1	17.8
31-40	374	19.5	10.8
41-50	441	23.0	6.9
51-60	256	13.3	7.6
61-70	61	3.2	1.3
70+	12	0.6	0.7
Blank	269	-----	-----
Total	2,188	100.0	100.0

Table 10. The self-declared skill level of angling in the diary panel, and the percentage that entered data in 2019. Percentages (%) have been calculated after removal of blank data to allow direct comparison of common categories with WPS.

Skill level	Count	%	% WPS
I am a beginner sea angler who has been a small number of times	211	11.0	22.5
I am an intermediate sea angler with a reasonable amount of experience	1,053	54.9	42.3
I am an experienced sea angler with some specialist skills	417	21.7	18.4
I am a very experienced sea angler in a variety of different environments	237	12.4	16.8
Blank	270	-----	-----
Total	2,188	100.0	100.0

Table 11. The consistency of going angling for members of the diary panel, and the percentage that entered data in 2019. Percentages (%) have been calculated after removal of blank data to allow direct comparison of common categories with WPS.

Consistency	Count	%	% WPS
Yes - almost every year	639	33.3	40.3
Yes, but with some small gaps not fished	514	26.8	21.4
No, there have been some significant gaps	548	28.5	18.5
No, there have been some very long gaps	217	11.3	19.8
Blank	270	-----	-----
Total	2,188	100.0	100.0

3.2.2. Data collection

3.2.2.1. Activity

A total of 736 diarists in 2018 and 988 in 2019 reported fishing (Table 12). This resulted in 8,755 and 10,016 sessions recorded in 2018 and 2019, respectively (Table 12). The average number of sessions fished was between 10 and 12 each year, with a similar average number of hours fished each session (Table 12). Despite regular reminders, only around half of the diarists provided 6 months of data, and one third provided data for the full 12 months (Table 13). Higher completion rates were observed for older diarists (Table 14).

Table 12. Summary of fishing activity in 2018 and 2019.

Item	2018	2019
Total diarists in study	1,706	2,188
Total diarists fishing in year	736	988
Total sessions recorded	8,755	10,016
Average number of sessions per diarist in the study	5.1	4.6
Average number of sessions per diarists who fished	11.9	10.1
Average session length	4.5	4.4
Total fishing hours recorded	39,413	44,086
Average number of hours per diarist in the study	23.1	20.1
Average number of hours per diarists who has fished	53.6	44.6

Table 13. Percentage of diarists entering some, 6 months, and 12 months of data by home region or country, in 2018 and 2019.

	2018			2019		
Location	% Entering data	% 6 months data	% 12 months data	% Entering data	% 6 months data	% 12 months data
East Midlands	68.2	42.4	25.8	62.7	47.0	33.7
East of England	71.2	48.5	38.0	68.0	48.7	33.3
London	60.0	28.9	22.2	64.4	50.8	37.3
North East	66.0	46.6	32.0	69.9	43.1	28.5
North West	76.6	52.4	36.3	60.1	40.3	26.3
South East	66.0	42.9	31.1	70.4	49.0	32.5
South West	65.5	49.9	36.5	75.1	55.2	38.4
West Midlands	74.5	59.6	46.8	75.5	50.0	27.7
Yorkshire & Humber	67.9	45.2	34.5	65.4	49.6	31.6
England Total	67.8	46.9	34.2	68.7	48.5	32.4
Northern Ireland	52.8	33.3	22.2	61.2	40.8	24.5
Scotland	78.8	52.6	38.0	65.1	45.7	28.7
Wales	65.2	47.5	36.9	67.9	47.4	28.7
Other	35.7	25.9	14.8	71.4	57.1	35.7
Total	67.3	46.5	33.9	68.2	48.1	31.7

3.2.2.2. Catch records

A total of 70,508 (2018) and 73,726 (2019) fish of almost 100 different species were recorded by diarists. Release rates were high, with 79% of all fish recorded by diarists released, which was similar to previous years. Despite the diversity of fish caught, 78% were attributed to ten species (Figure 7). The top five species caught by diarists in 2018 and 2019 by number were whiting, mackerel, lesser spotted dogfish, sea bass, and cod (Figure 7).

For the European Union Data Collection Framework (DCF) species, the most caught in both 2018 and 2019 were sharks and dogfish, followed by sea bass and Atlantic cod (Table 15). The most common group of fish caught were common roundfish[4] (Table 16), and most records were for the North Sea, English Channel, and Irish Sea (Table 15). Release rates were high across all species and areas (Table 15-Table 17).

Table 14. Age profile of the diarists signed up and percentage (%) entering data, in 2018 and 2019.

Age	2018 % Entering data	2018 % 6 months data	2018 % 12 months data	2019 % Entering data	2019 % 6 months data	2019 % 12 months data
16-34	49.2	30.6	16.6	51.0	28.9	10.7
35-54	63.4	44.3	32.0	65.1	43.9	25.6
55+	75.0	56.2	43.7	74.1	55.1	40.2
Prefer not to say	0.0	0.0	0.0	58.3	25.0	25.0
Total	65.4	46.5	31	68.2	48.1	31.7

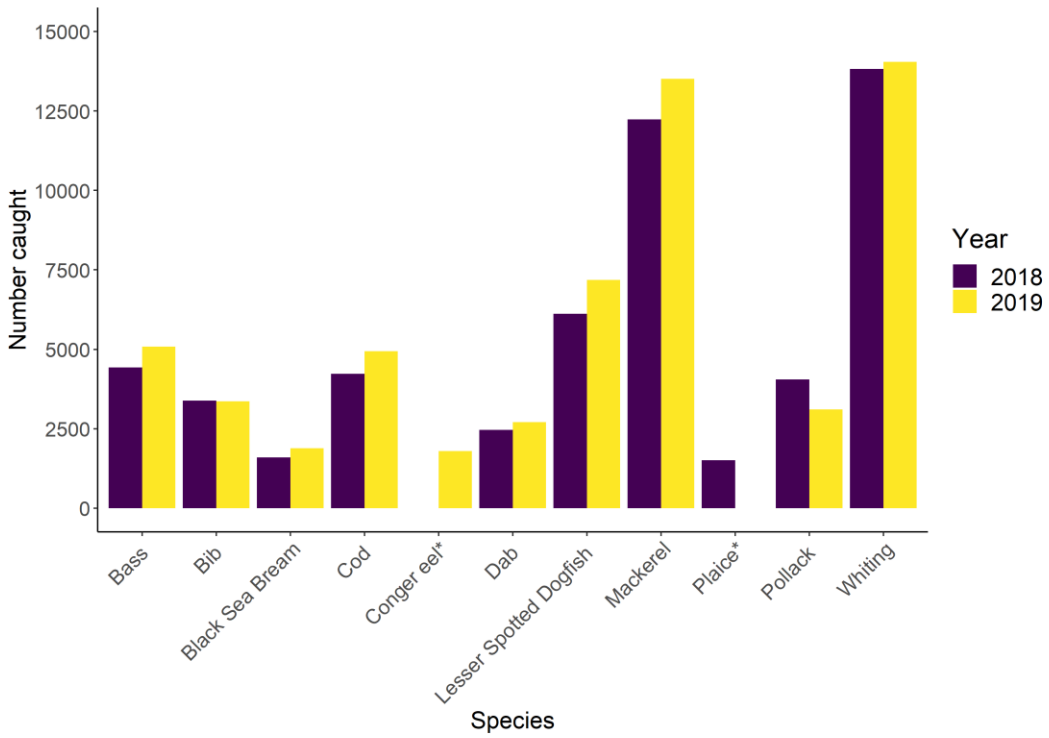


Figure 7. Top species caught in 2018 and 2019. * denotes where the species was in the top ten for only one year.

[4] Roundfish is not a scientific grouping but one used in common parlance by sea anglers and used in the diary. “Roundfish are fish which are round in the cross-section and have a body which tapers to a tail... Roundfish is a wide-ranging term which includes some of the most common fish found in UK waters." https://britishseafishing.co.uk/fish-species/roundfish/.

Table 15. The numbers of DCF species retained and released, and release rates in 2018 and 2019.

DCF Species	2018 Kept	2018 Released	2018 Released (%)	2019 Kept	2019 Released	2019 Released (%)
European sea bass	95	4,331	97.9	317	4,771	93.8
Cod	1,328	2,901	68.6	1,211	3,724	75.5
Sharks and dogfish	307	8,188	96.4	207	9,103	97.8
Skates and rays	221	1,601	87.9	113	1,795	94.1
Freshwater eel	0	297	100.0	2	285	99.3
Salmon	0	10	100.0	0	0	---

Table 16. The fish kept and released for each fish group in 2018 and 2019.

Groups	2018 Kept	2018 Released	2018 Released (%)	2019 Kept	2019 Released	2019 Released (%)
Common round fish	11,443	33,909	74.8	13,102	34,360	72.4
Dogfish& shark species	307	8,188	96.4	207	9,103	97.8
Flatfish	940	4,943	84.0	764	5,474	87.8
Other	7	211	96.8	26	182	87.5
Other fish species	811	3,315	80.3	824	2,897	77.9
Wrasse	51	2,567	98.1	15	2,074	99.3
Seabreams & Mullets	465	1,448	75.7	424	1,885	81.6
Skates & Rays	221	1,601	87.9	117	2,122	94.8
Rare& Unusual Species	7	16	69.6	32	8	20.0
Tuna	0	0	---	1	4	80.0
Crabs and lobsters	12	46	79.3	13	92	87.6
Total	14,264	56,244	79.8	15,525	58,201	78.9

Table 17. The fish kept and released by International Council for the Exploration of the Sea (ICES) divisions[5] in 2018 and 2019. Note that the totals are different to the previous table due to excluding non-UK catches.

Area	2018 Kept	2018 Released	2018 Released (%)	2019 Kept	2019 Released	2019 Released (%)
4a Northern North Sea	60	98	62.0	95	225	70.3
4b Central North Sea	2,616	4,203	61.6	2,579	5,083	66.3
4c Southern North Sea	1,492	8,375	84.9	790	6,621	89.3
7b West of Ireland	45	100	69.0	23	90	79.6
6a West of Scotland and Northern Ireland	704	5,328	88.3	774	2,416	75.7
7a Irish Sea	1,188	7,066	85.6	2,292	9,516	80.6
7d Eastern English Channel	1,130	6,338	84.9	1,872	7,907	80.9
7e Western English Channel	6,226	16,970	73.2	6,004	15,830	72.5
7f Bristol Channel	529	6321	92.3	618	8,714	93.4
7g Celtic Sea North	84	579	87.3	181	836	82.2
7h Celtic Sea South	56	165	74.7	56	188	77.0
Total	14,130	55,543	79.7	15,284	57,426	79.0

[5] https://www.ices.dk/data/maps/Pages/default.aspx

3.3. Catches by UK sea anglers

3.3.1.2018 and 2019 catch estimates

A total of 98 species were caught in 2018 and 99 in 2019 by sea anglers, but insufficient data were available to raise catches for 43 and 41 species in 2018 and 2019, respectively (Table 18). In total, it was possible to generate catches for 55 species in 2018 and 58 in 2019, but tonnages for 43 species in 2018 and 40 species in 2019.

The total number of fish kept and released using the original analysis method were similar in 2018 (46 million) and 2019 (43 million) (Figure 8A), with around 80% of all fish released (Figure 8B). More fish were caught and released in England than Scotland, Wales, and Northern Ireland (Figure 8C&D), due to the higher number of anglers in England. For individual species, the results were similar for 2018 and 2019 for both number and tonnages of fish kept and released (Figure 9A, B, D&E), but there was variation in individual fish weights between years (Figure 9C&F). The overall catch composition was similar in 2018 and 2019 with the same 10 most commonly caught species found in similar proportions and mackerel and whiting the most commonly fish caught (Figure 10).

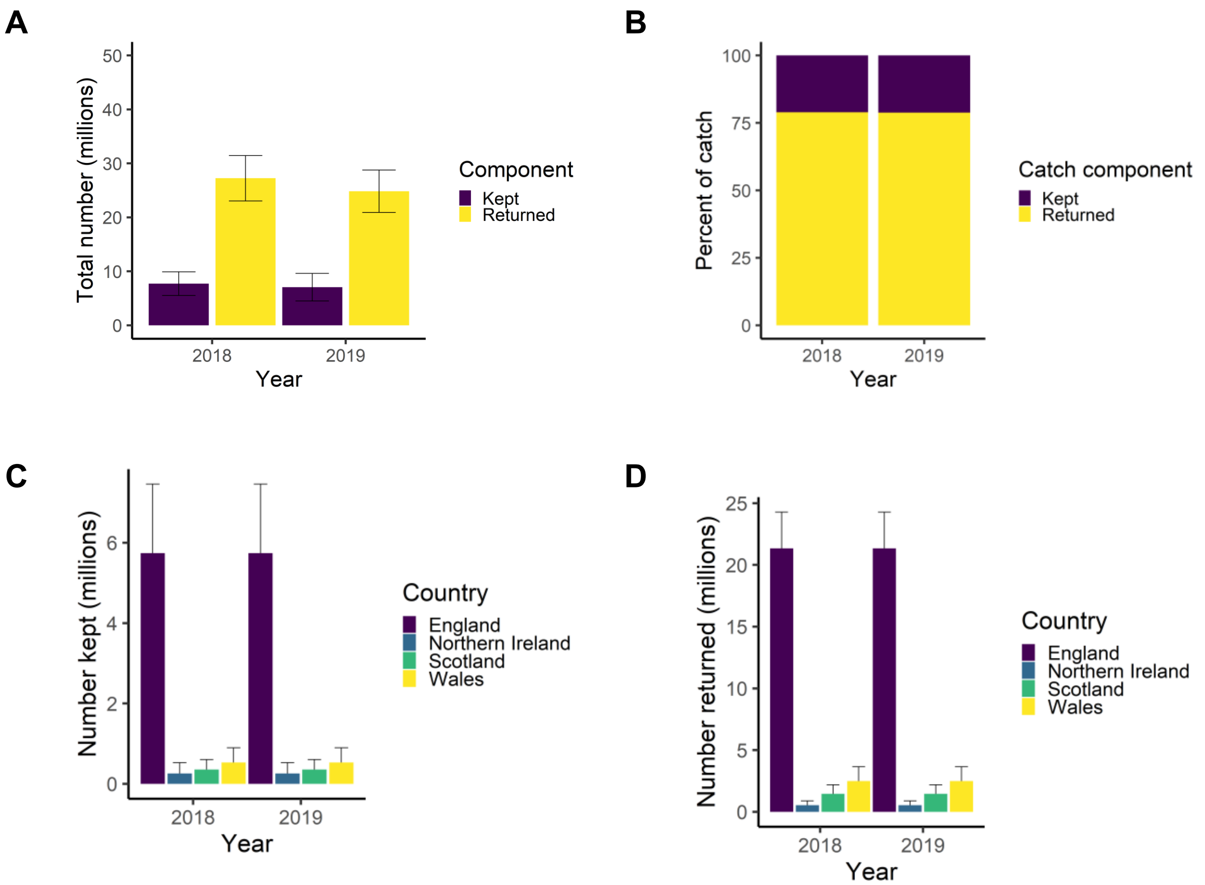
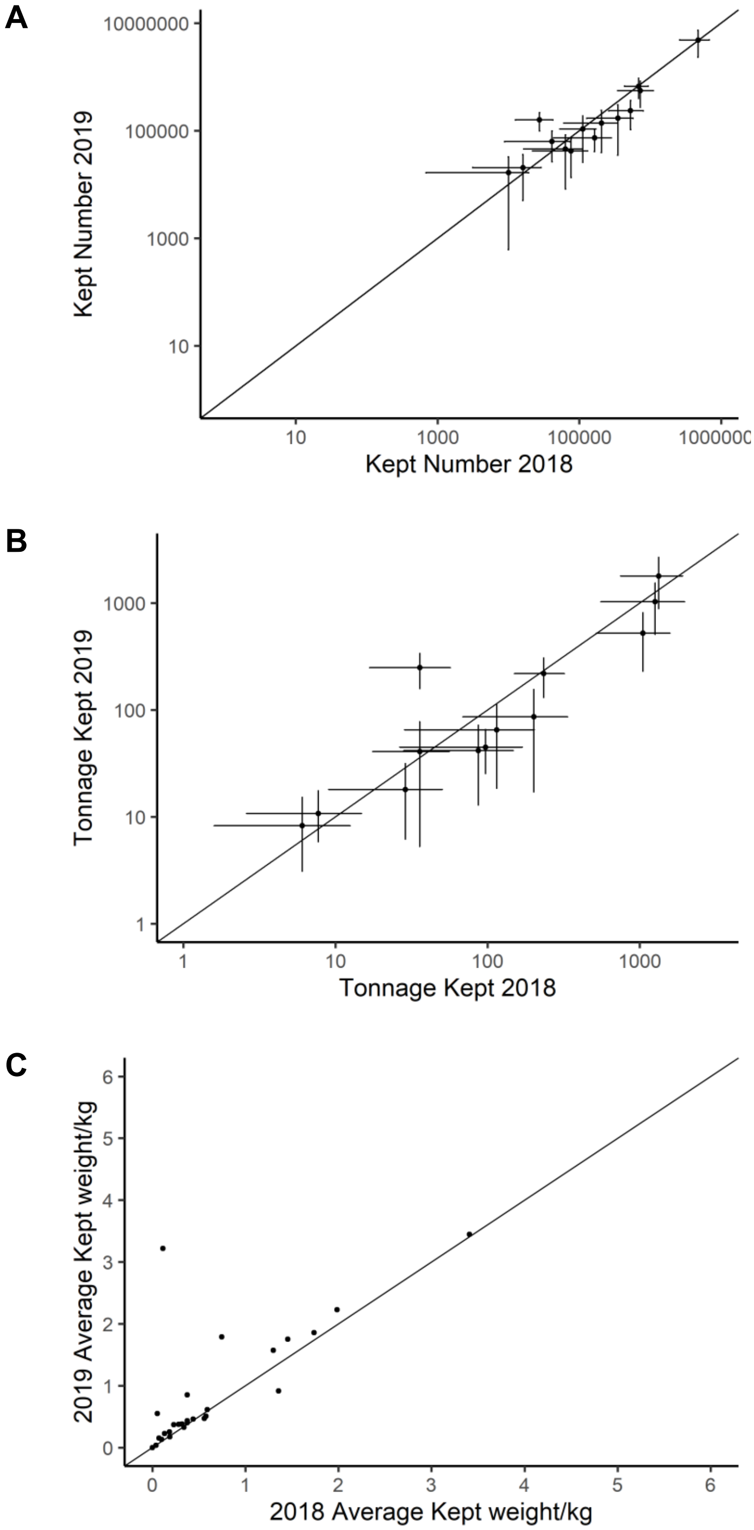


Figure 8. Numbers of fish kept and released (A), release proportions (B), and numbers of fish kept (C) and released (D) for individual countries within the UK in 2018 and 2019. The error bars represent 95% confidence interval.

Table 18. Species excluded from the analysis in 2018 and 2019 because there were fewer than 15 recorded entries in the diary, or they were caught by fewer than four diarists.

2018	2019
Blue Shark	Anchovy
Brown Crab	Atlantic Saury
Common Goby	Blue-fin Tuna
Couch's Sea Bream	Blue Shark
Dragonet (common)	Blue Whiting
European Squid	Brill
Four-bearded Rockling	Brown Crab
Giant Goby	Bull Rout (short spined sea scorpion)
Golden-Grey Mullet	Comber
Greater Pipefish	Common Goby
Greater Weever Fish	Couch's Sea Bream
Hake	Dragonet (common)
Halibut (Atlantic Halibut)	European Squid
John Dory	Four-bearded Rockling
Lemon Sole	Golden-Grey Mullet
Leopard-spotted Goby	John Dory
Lesser Forkbeard (Tadpole Fish)	Leopard-spotted Goby
Lesser Sandeel	Lesser Sandeel
Lobster (Common Lobster)	Lobster (Common Lobster)
Lumpsucker (Lumpfish)	Long Rough Dab (American Plaice)
Megrim (Cornish Sole, Whiffy)	Megrim (Cornish Sole, Whiffy)
Northern Squid	Northern Squid
Norway Pout	Porbeagle Shark
Pilchard	Red Band Fish (Ribbonfish)
Pogge	Red Sea Bream
Porbeagle Shark	Rock cook Wrasse
Red Band Fish (Ribbonfish)	Sand Goby
Red Mullet (Striped Mullet)	Sand Sole
Rock cook Wrasse	Sea Trout (Brown Trout)
Salmon (North Atlantic Salmon)	Shad (allis)
Sea Trout (Brown Trout)	Shad (twaite)
Shad (twaite)	Shanny (common blenny)
Shanny (common blenny)	Smelt (Big-scaled)
Smelt (Big-scaled)	Smelt (Small-scaled)
Smelt (Small-scaled)	Spanish Mackerel
Solenette	Sprat (skipper)
Spanish Mackerel	Starry Ray (Thorny Skate)
Sprat (skipper)	Stingray (Common Stingray)
Starry Ray (Thorny Skate)	Triggerfish
Topknot	Vivaporous Blenny (eelpout)
Vivaporous Blenny (eelpout)	White Sea Bream
White Sea Bream	
White Skate (Bottle-nose Ray, Spear Nosed Skate)	



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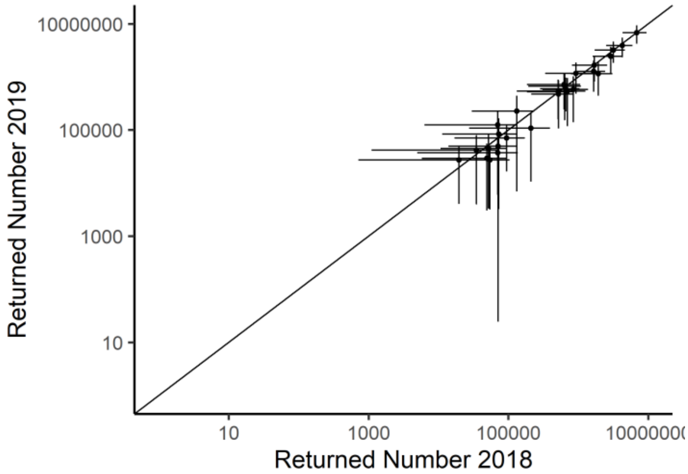

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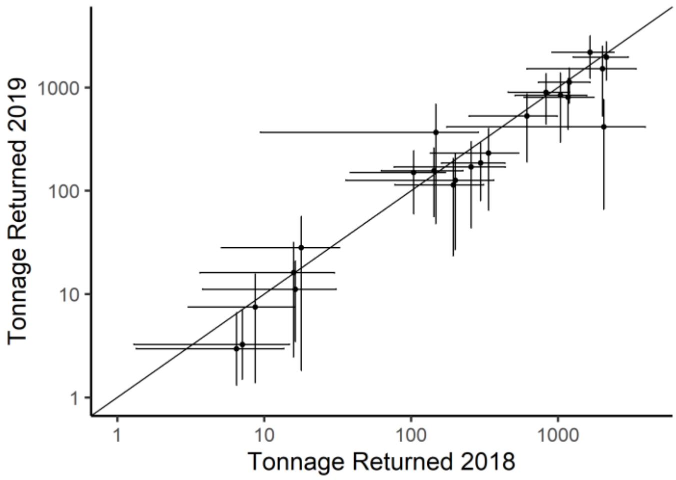

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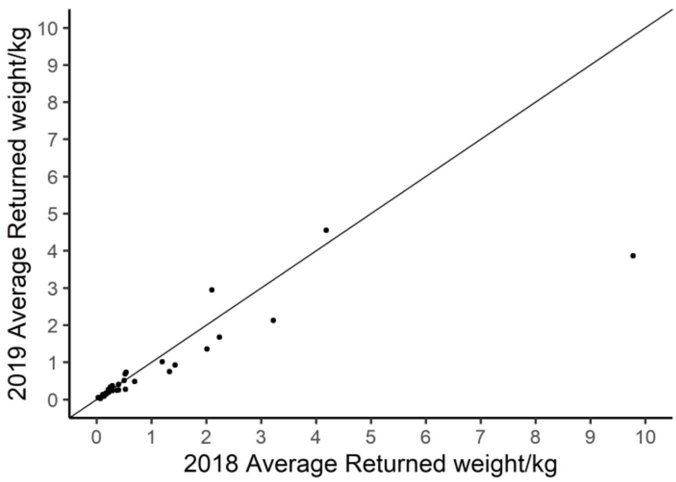


Figure 9. Comparisons of numbers (A&D), tonnages (B&E), and individual fish weights (C&F) of fish kept (A-C) and released (D-F) by species in 2018 and 2019. The results for A, B, D & E are provided on the logarithmic scale (base 10), the solid line shows where the values are equal, and error bars are 95% confidence interval. A logarithmic scale has equal spacing between orders of magnitude (1, 10, 100, 1000 etc.) and helps interpretation of species with low catch estimates. The solid line shows where the values are equal, so a point on this line indicates estimates from the two years are the same. If the error bars cross the solid line, this indicates that the difference is not significant.

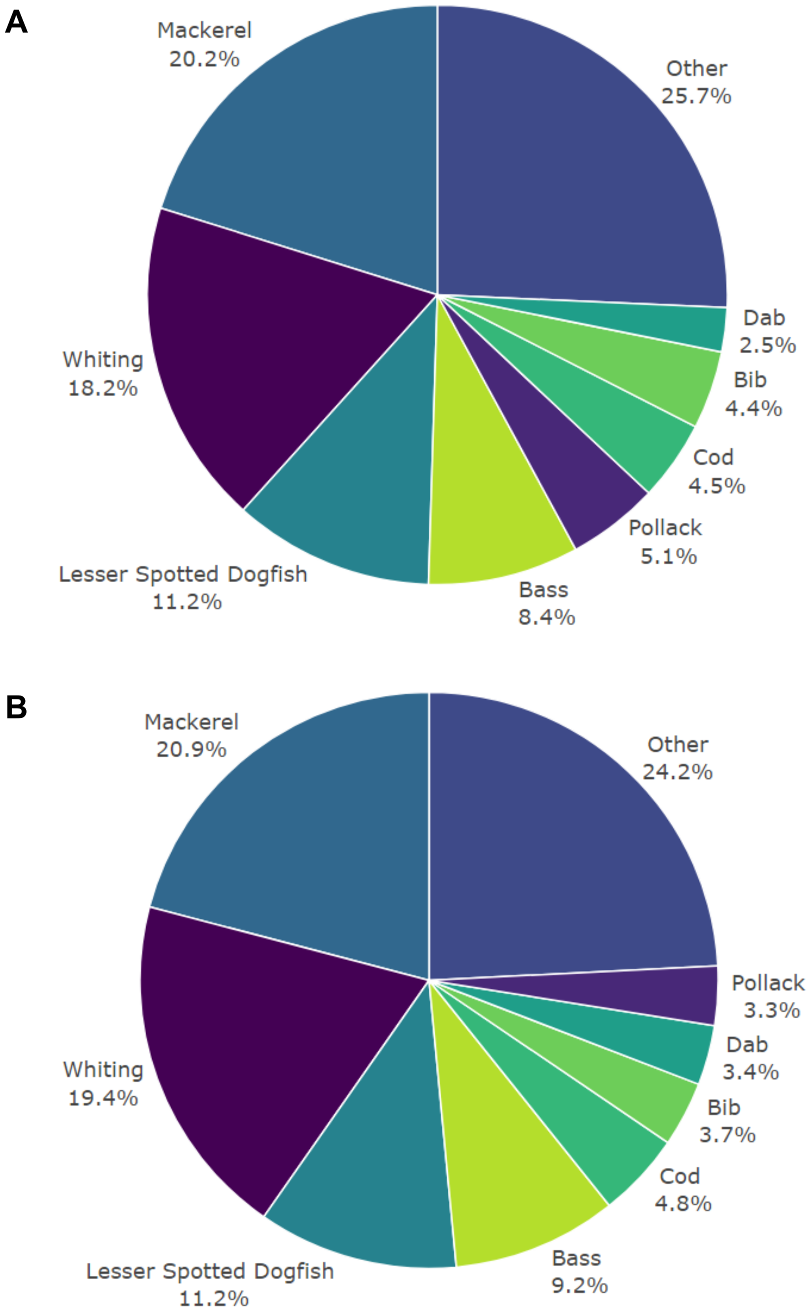


Figure 10. Catch composition by number for the UK in 2018 (A) and 2019 (B) with the top 10 most commonly caught fish displayed.

The EU Data Collection Framework species, sea bass, cod, pollack, and elasmobranchs (sharks, skates, and rays) catch totals were similar in 2018 and 2019, with the exception of pollack, where catch numbers were lower in 2019 (Figure 11A). A similar picture was seen for tonnage (Figure 11B). The catches can be partitioned by International Council for the Exploration of the Sea (ICES) divisions[6], but the results have large errors due to the low

[6] https://www.ices.dk/data/maps/Pages/default.aspx

numbers of diarists in individual regions. However, for sea bass the majority of catches were taken in the English Channel (Figure 12), whereas for cod they were in the North Sea (Figure 12). Length-frequency of fish caught can be constructed for commonly caught species and was similar across the two years for sea bass and cod.

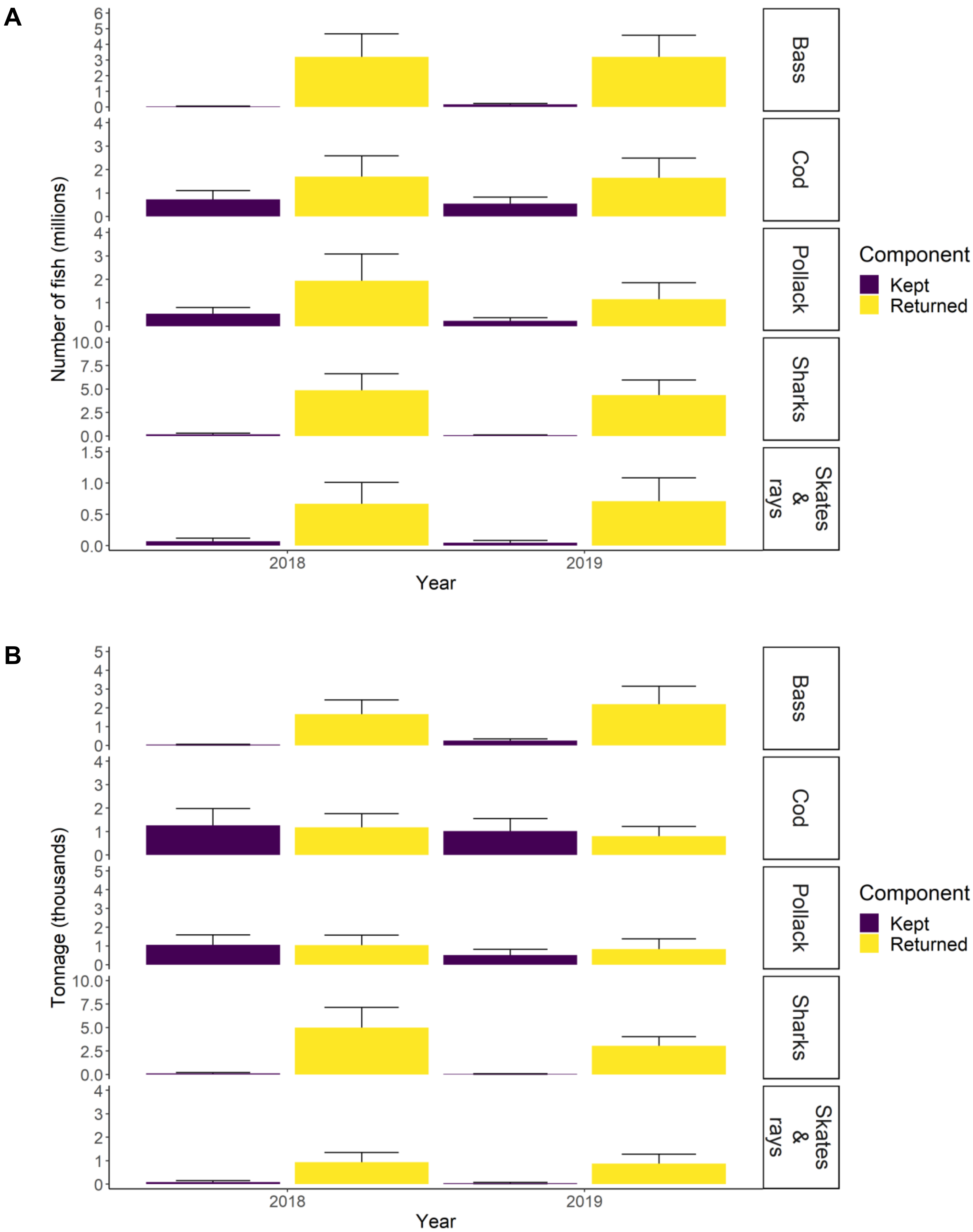


Figure 11. Numbers (A) and tonnage (B) of data collection framework species kept and released by sea anglers resident the UK in 2018 and 2019. Error bars are 95% confidence intervals.

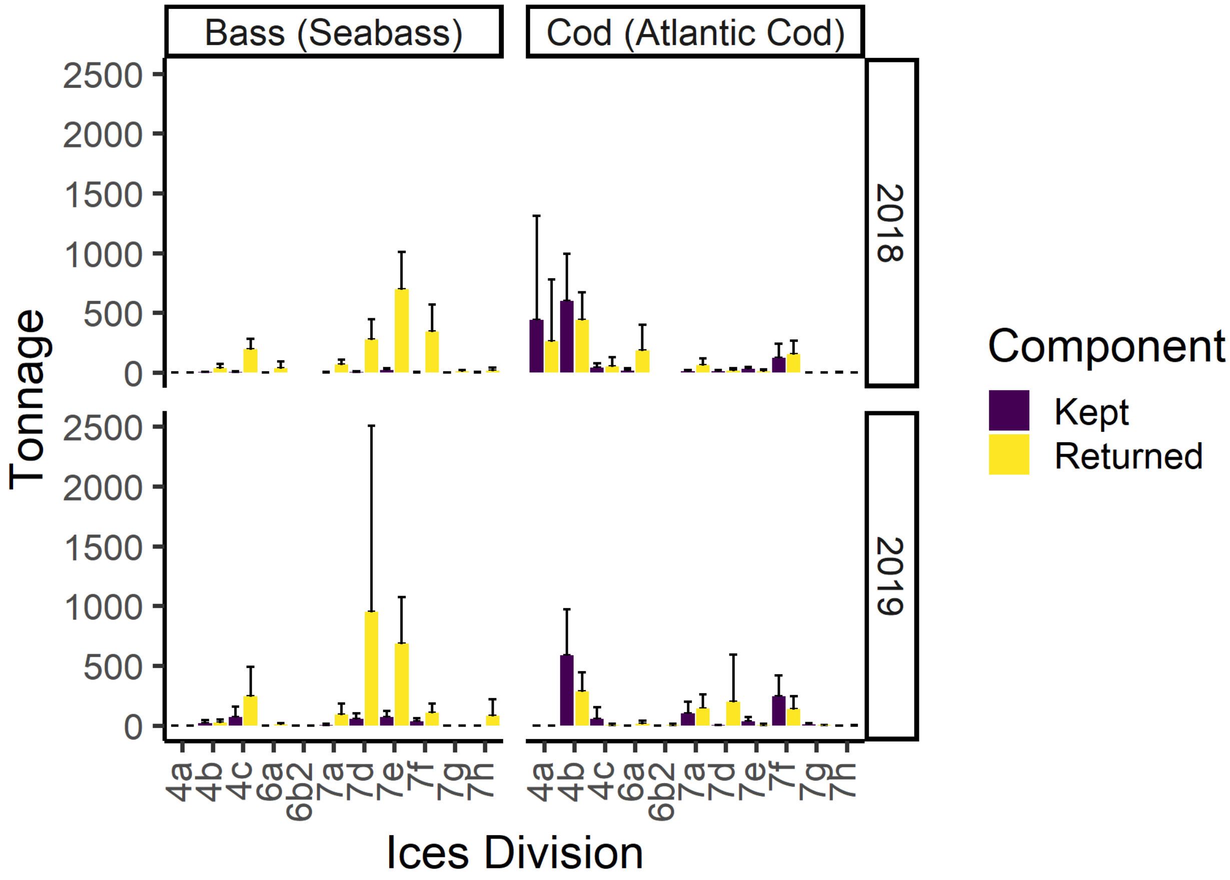


Figure 12. Tonnages of cod and sea bass kept and released for ICES divisions by sea anglers resident in the UK in 2018 (top) and 2019 (bottom). ICES divisions represent the North Sea (4a-c), English Channel (7d-e), Celtic Sea 7g-h), Bristol Channel (7f), Irish Sea (7a), West of Scotland (6a and 6b2)[7]. Error bars represent 95% confidence interval.

3.3.2. Comparisons with previous studies

The number of fish kept and released was reasonably consistent between 2016 and 2019, but the total appeared to be slightly lower for 2018–19 than in 2016–17 (Figure 13A). Release rates were similar across all years of the diary programme from 2016-19 at over 77% (Figure 13B). The number of fish kept and released estimated using the diary approach (2016-19) was higher than the onsite survey in 2012 for England (Figure 13A), with the difference larger for the released component, reflecting the higher release rates in 2016-19 (Figure 13A). Catch composition was similar for all years including similar results for 2012 and 2019 for England only (Figure 14).

[7] https://www.ices.dk/data/maps/Pages/default.aspx

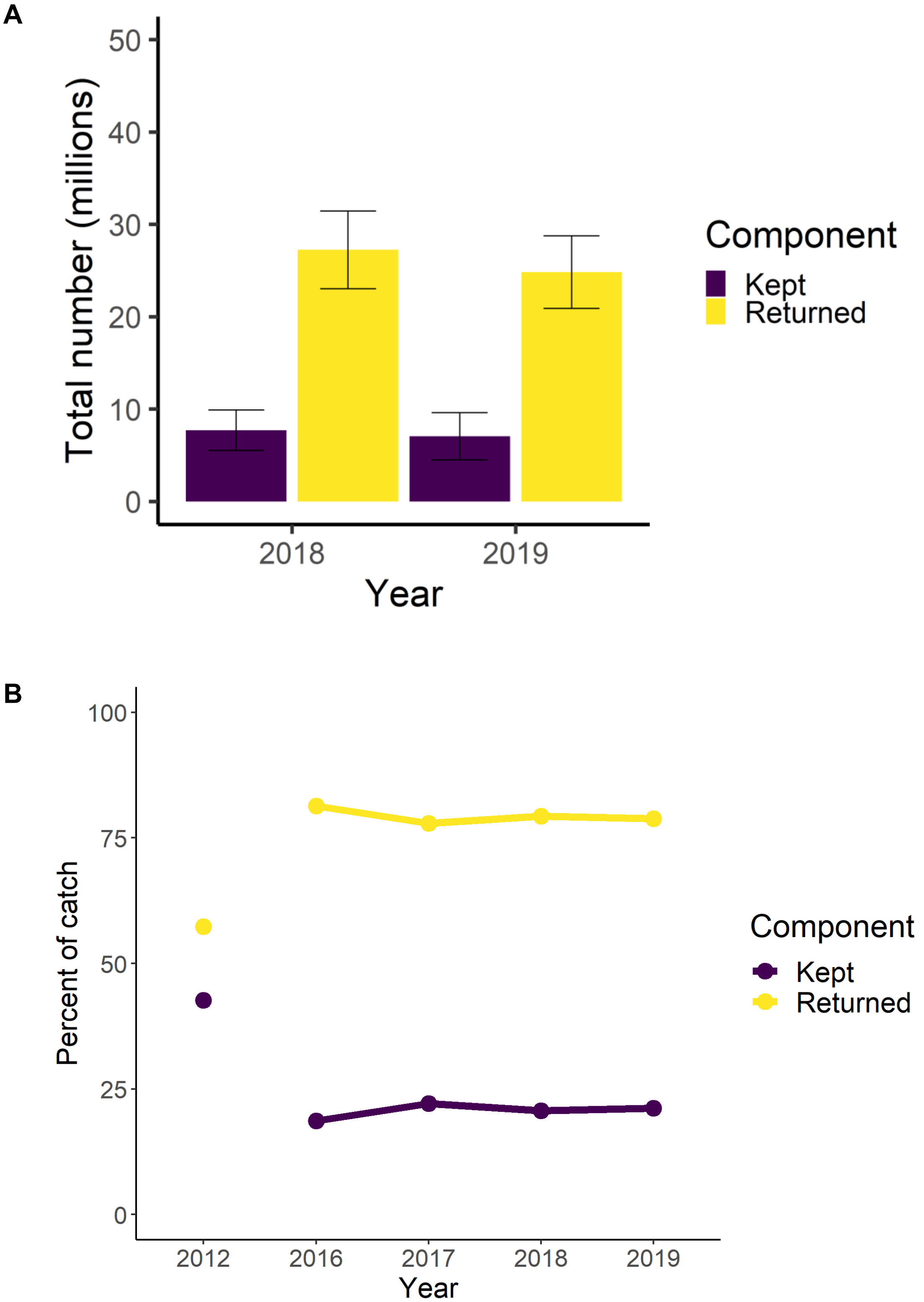


Figure 13. Numbers of fish kept and released (A) and release proportions (B) in 2012, 2016–19 for England only. The error bars in (A) represent 95% confidence intervals.

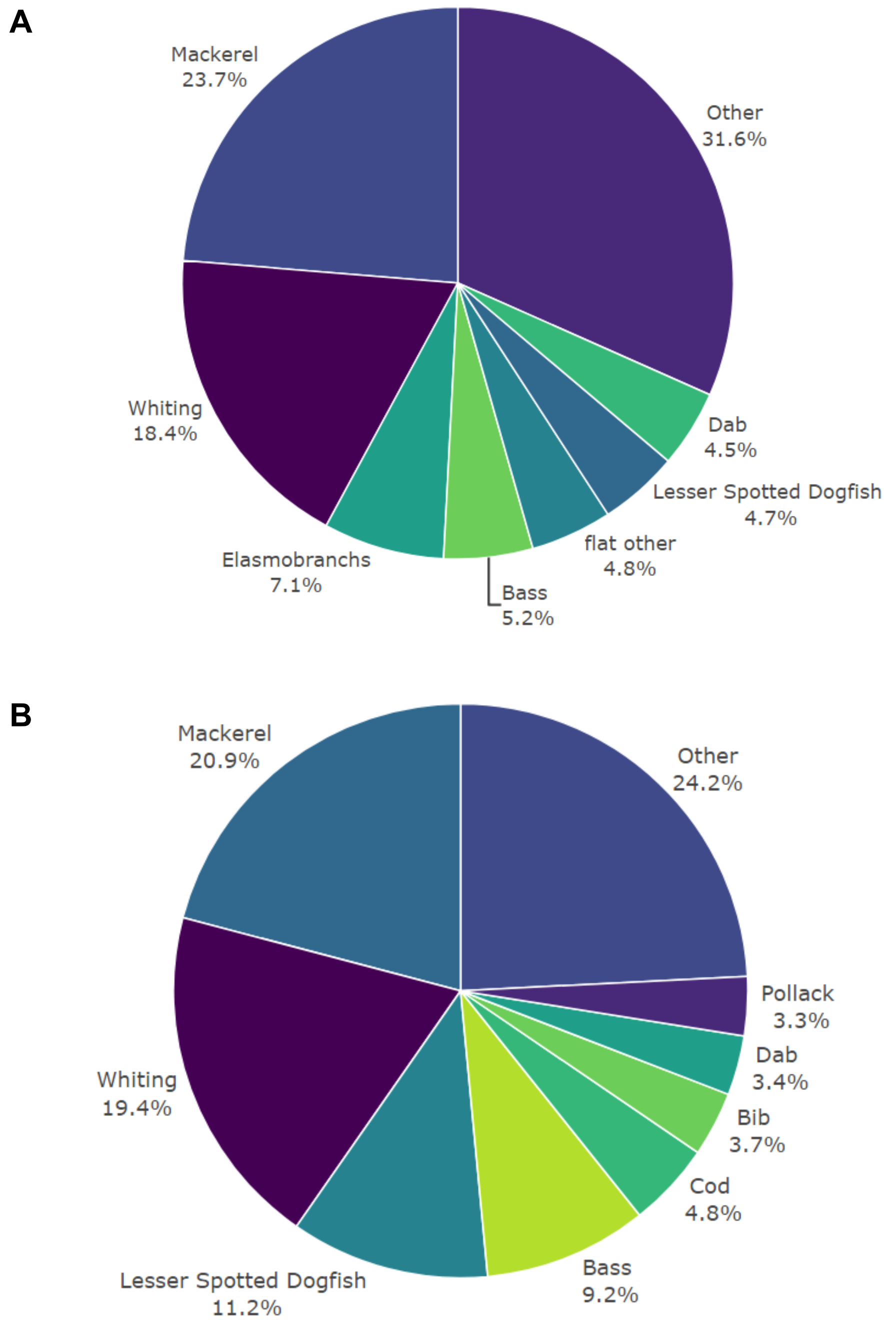


Figure 14. Catch composition by number for England in 2012 (A) and 2019 (B) with the top 10 most commonly caught fish displayed.

Catches of EU Data Collection Framework species were similar from 2016–2019 for cod, and elasmobranchs (sharks, skates, and rays), but pollack catches fluctuated particularly in terms of tonnage in 2017 and the kept component of sea bass varied (Figure 15). Fluctuations in sea bass catches reflected changes in the legislation, and variation in pollack catches was driven by differences in both numbers and sizes of individual fish caught between years. For England, numbers of released fish estimated in all years from 2016 onwards using the diary panel were much higher than the onsite survey in 2012 for DCF species (Figure 15) and all species in general (Figure 16), as was observed in 2016 and 2017 (Hyder et al. 2020b). Differences for kept fish were much smaller.

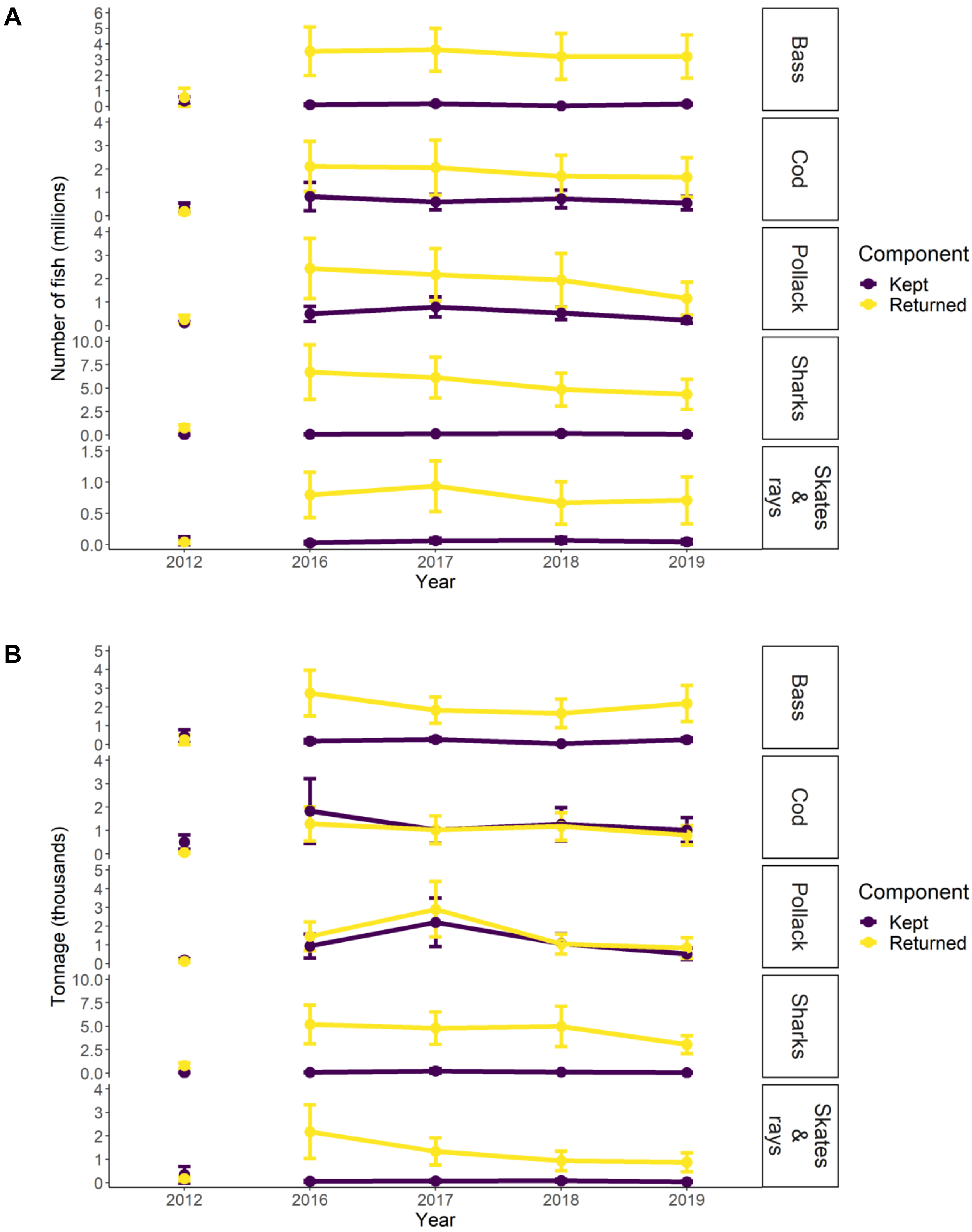
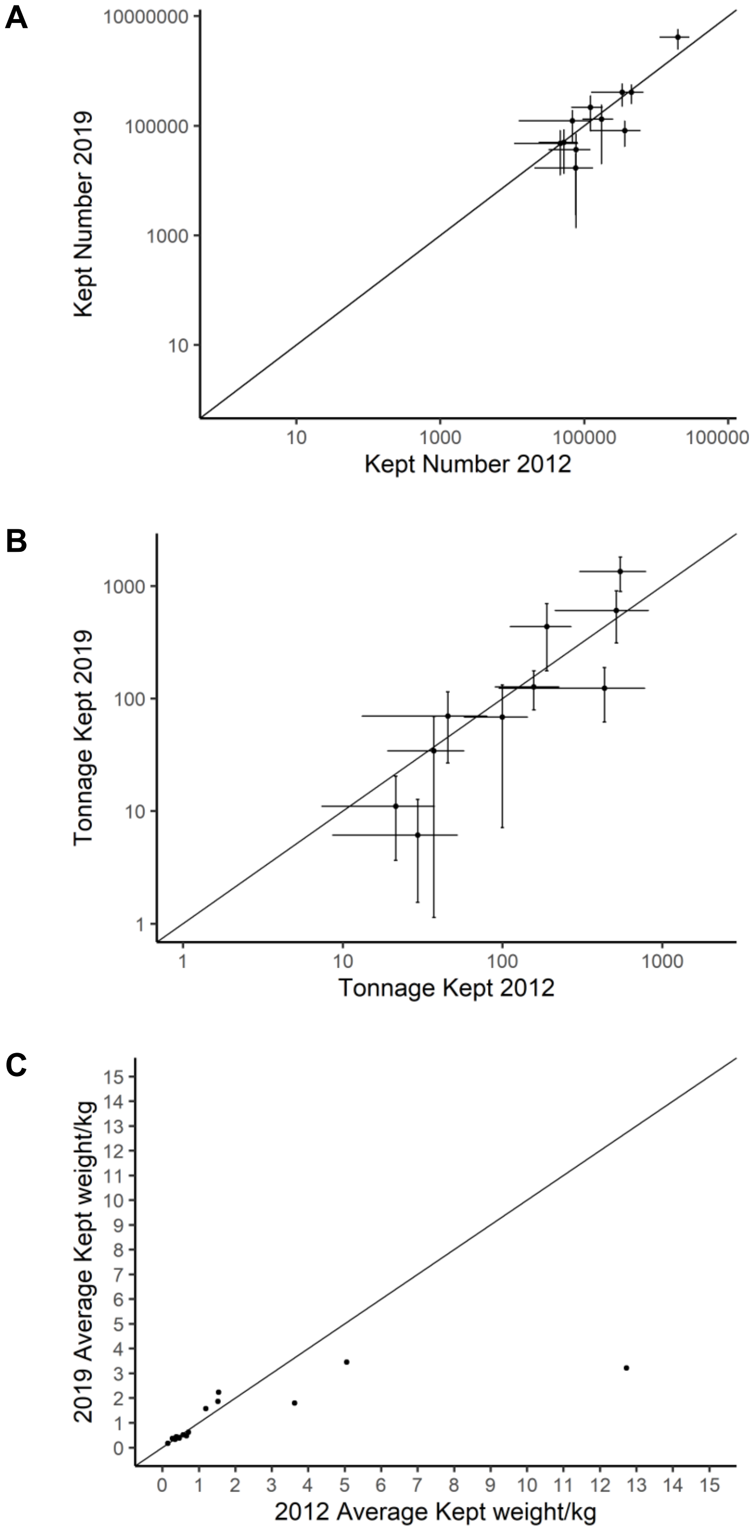


Figure 15. Numbers (A) and tonnage (B) of data collection framework species kept and released by sea anglers resident the England in 2012 and the UK in 2016–19. Error bar are 95% confidence intervals.



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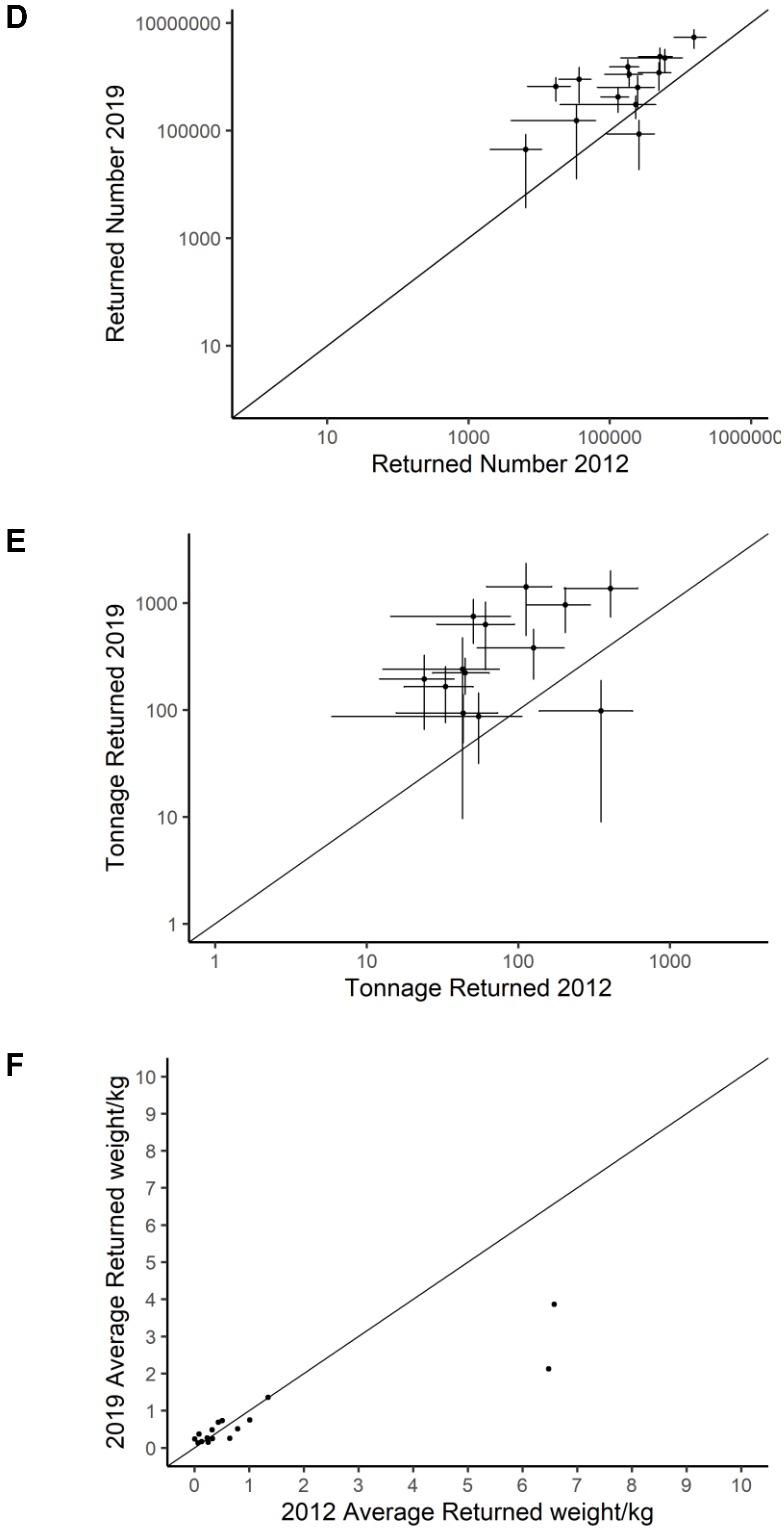


Figure 16. Comparisons of numbers (A&D), tonnages (B&E), and individual fish weights (C&F) of fish kept (A-C) and released (D-F) by species in 2012 and 2019 for England only. The results are provided on the logarithmic scale (base 10), the solid line shows where the values are equal, and error bars are 95% confidence interval. A logarithmic scale has equal spacing between orders of magnitude (1, 10, 100, 1000 etc.) and helps interpretation of species with low catch estimates. The solid line shows where the values are equal, so a point on this line indicates estimates from the two years are the same. If the error bars cross the solid line, this indicates that the difference is not significant.

3.4. Assessment of potential bias

3.4.1. Validation panel

3.4.1.1. Data collection

The validation panel aimed to create probabilistic sample of diarists within three regions of England with recruitment through a postal survey. In total, 225 responses were received, 215 by post and 10 online, of which 120 signed up to take part in the validation panel in 2019 (Table 19). This included 37, 29, and 54 sea anglers from the East, North West, and South West, respectively (Table 20) which met the target for each region.

Table 19. The number and type of responses to the postal recruitment survey.

Response	Count	% responses
Yes	120	53.3
No	69	30.7
Blank	5	2.2
Unusable	31	13.8
Total	225	100.0

Table 20. The numbers and percentage of validation panel diarists by region.

Location	Count	%
East of England	37	30.8
North West	29	24.2
South West	54	45.0
Total	120	100.0

Over 450 sessions were recorded by the validation panel, with 63 out of the 120 diarists providing data (Table 21). When the fish are grouped, most fish caught were common roundfish, with 64% released in 2019 (Table 22). Catches were recorded by diarists across six ICES divisions, with the greatest number of fish recorded in the Irish Sea (Table 23). The highest release rate was in the Bristol Channel, which is similar to the 2018 and 2019 diary panel, and the lowest release rate was in the West of Scotland and Northern Ireland.

Table 21. Summary of fishing activity from the validation panel and diary panel in 2019.

Item	Validation Panel	2019 Diary Panel
Total diarists in study	120	2,188
Total diarists fishing in year	63	988
Total sessions recorded	464	10,016
Average number of sessions per diarist in the study	3.9	4.6
Average number of sessions per diarists who fished	7.4	10.1
Average session length	4.1	4.4
Total fishing hours recorded	1,914	44,086
Average number of hours per diarist in the study	15.9	20.1
Average number of hours per diarists who has fished	30.4	44.6

Table 22. The numbers of different types of fish kept and released by the validation panel.

Groups	Kept	Released	Released (%)
Common round fish	999	1,775	64.0
Dogfish & shark species	26	803	96.9
Flatfish	33	200	85.8
Other fish species	16	125	88.7
Wrasse	1	140	99.3
Seabreams & Mullets	25	47	65.3
Skates & Rays	3	87	96.7
Total	1,103	3,177	74.2

Table 23. The numbers of fish recorded by the validation panel in different ICES divisions.

ICES Area	Kept	Released	Released (%)
4b Central North Sea	62	36	36.7
4c Southern North Sea	209	877	80.8
6a West of Scotland and Northern Ireland	31	11	26.2
7a Irish Sea	500	1,303	72.3
7e Western English Channel	270	660	71.0
7f Bristol Channel	31	290	90.3
Total	1,103	3,177	74.2

3.4.1.2. Comparison of participant characteristics

The validation panel had a slightly higher rate of data entry than the diary panels in 2018 and 2019; this was expected as they had a higher incentive. Validation panel diarists fished less often in 2019 than the diary panel and their sessions were shorter (Table 21). The profile of the validation panel was older (Table 24) and less avid (Table 25) than the diary panel, but had a similar experience (Table 26), skill (Table 27), and consistency (Table 28). However, the validation panel showed different characteristics to the WPS, with more older (Table 24), avid (Table 25) sea anglers, and fewer inexperienced (Table 26) and very experienced (Table 27) sea anglers. Consistency of sea anglers varied in profile (Table 28). The validation and diary panel were similar indicating that the impact of non-probabilistic sampling for the diary panel was limited in relation to the characteristics of anglers on the panels.

Table 24. Age profile of the validation panel, diary panel and WPS in 2019. Percentages have been calculated after removal of blank data to allow direct comparison of common categories with WPS.

	Validation		Diary		WPS
Age	Count	%	Count	%	%
16-34	16	13.3	253	11.6	27.5
35-54	47	39.2	751	34.5	44.3
55+	57	47.5	1,172	53.9	28.9
Other	----	----	12	----	----

Table 25. Avidity profile of the validation panel, diary panel and WPS in 2019. Percentages have been calculated after removal of blank data to allow direct comparison of common categories with WPS.

	Validation		Diary		WPS
Avidity	Count	%	Count	%	%
Frequent (> 35 days)	15	15.3	445	23.3	8.9
Regular (13-35 days)	26	26.5	567	29.7	16.6
Occasional (6-12 days)	30	30.6	515	26.9	15.8
Rare - 2-5 days	23	23.5	330	17.3	37.0
Once	4	4.1	55	2.9	21.7
Not in last 12 months	17	----	200	----	----
Never	5	----	12	----	----
Other	----	----	64	----	----
Total	120	100.0	2,188	100.0	100.0

Table 26. Experience profile of the validation panel, diary panel and WPS in 2019. Percentages have been calculated after removal of blank data to allow direct comparison of common categories with WPS.

	Validation		Diary		WPS
Years Angling	Count	%	Count	%	%
0-5	11	9.3	194	10.1	21.1
6-10	5	4.2	85	4.4	14.5
11-15	2	1.7	108	5.6	8.7
16-20	11	9.3	155	8.1	10.5
21-30	23	19.5	233	12.1	17.8
31-40	22	18.6	374	19.5	10.8
41-50	20	16.9	441	23.0	6.9
51-60	18	15.3	256	13.3	7.6
61-70	4	3.4	61	3.2	1.3
70+	2	1.7	12	0.6	0.7
Blank*	2	----	269	----	-----
Total	120	100.0	2,188	100.0	100.0

Table 27. The skill level of angling in the validation panel, diary panel and WPS in 2019. Percentages have been calculated after removal of blank data to allow direct comparison of common categories with WPS.

	Validation		Diary		WPS
Skill level	Count	%	Count	%	%
I am a beginner sea angler who has been a small number of times	19	16.1	211	11.0	22.5
I am an intermediate sea angler with a reasonable amount of experience	66	55.9	1,053	54.9	42.3
I am an experienced sea angler with some specialist skills	24	20.3	417	21.7	18.4
I am a very experienced sea angler in a variety of different environments	9	7.6	237	12.4	16.8
Blank*	2	----	270	----	0.0
Total	120	100.0	2,188	100.0	100.0

Table 28. The consistency of angling in the validation panel, diary panel and WPS in 2019. Percentages have been calculated after removal of blank data to allow direct comparison of common categories with WPS.

	Validation		Diary		WPS
Consistency	Count	%	Count	%	%
No, there have been some very long gaps	21	17.8	217	11.3	19.8
No, there have been some significant gaps	27	22.9	548	28.6	18.5
Yes, but with some small gaps not fished	32	27.1	514	26.8	21.4
Yes - almost every year	38	32.2	639	33.3	40.3
Blank*	2	----	270	----	----
Total	120	100.0	2,188	100.0	100.0

The Bayesian comparison test was conducted to compare the number participants in each avidity, age, and skill group between the diary panel, the WPS, and the validation panel. The models showed that there was no significant difference in avidity across the validation panel, diary panel, and WPS. However, there was a bias towards older participants in the diary panel. Skills were similar in the diary and validation panels, but were higher than the WPS. This indicated that the variables age and skill level should be included in the model-based estimates to correct for differences between the sample and population.

3.4.2. Model-based catch estimates

3.4.2.1. Developing the model

The first step in developing the model-based catch estimates was to identify the key variables to include in the model. These are variables that have the greatest influence on catch rate. The results from the minimal Directed Acyclic Graph (DAG) model indicated the need for factors related to individual characteristics, fishing preferences, and legal aspects (e.g., catch restrictions) (Figure 17). The Maximal Information-based Nonparametric Exploration (MINE) showed that avidity and skill or experience were important in predicting catch. The Boruta algorithm identified location, avidity, months fished, and weight of fish kept or returned as important variables (Figure 18). Based on all of these methods, age, years angling, avidity, home region, consistency (both long and short term) and skill level were the variables that play a role in determining catch, so were included in the model.

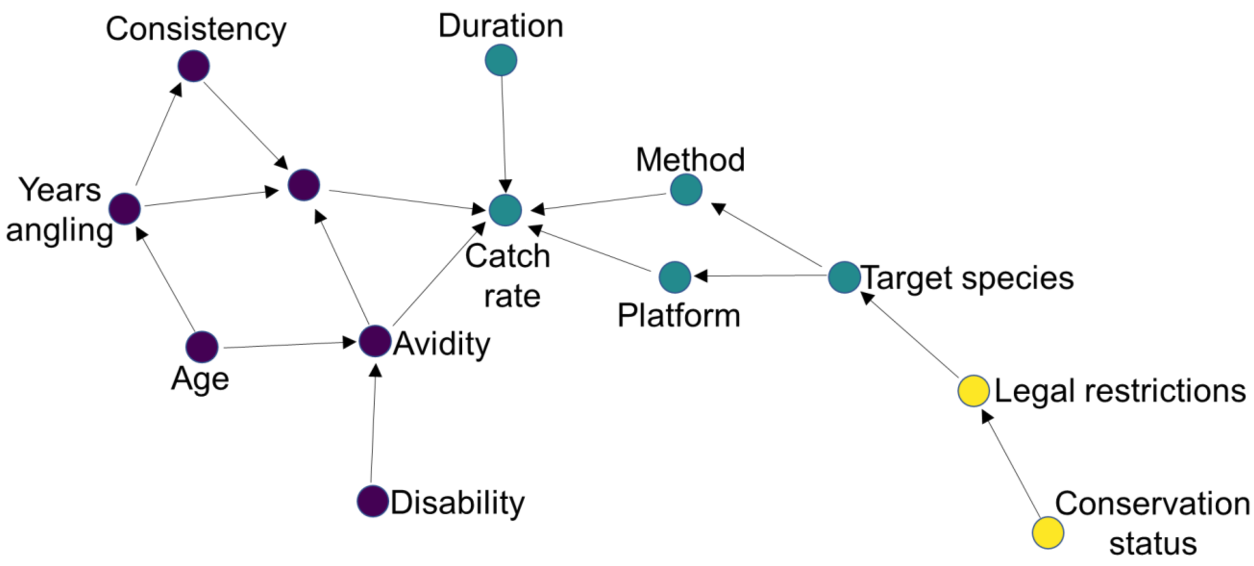


Figure 17. The minimal Directed Acyclic Graph (DAG) model including key groupings related to individual characteristics (purple), fishing preferences (green), and legal aspects (yellow).

An 'empty model' was created with a normal distribution. A gamma hurdle distribution was fitted to prevent spurious negative catches. A gamma hurdle distribution is continuous and allowed the variance to increase with the mean, which is common for ecological data. The random effects within the gamma hurdle were then added for both the hurdle and the distribution shape. The model was formatted and age, years angling, avidity, home region, consistency (both long and short term), and skill level were added, which were the variables defined as important when determining catch rates. To compare and select the most appropriate multilevel model a 'Leave-One-Out' cross validation was run. This found that including age, avidity, species, and skill generated the best model.

From the methods conducted including selecting the variables that 'best' predict catch rates, identifying bias in the sample, and looking at alternative ways to post-stratify, the final model was confirmed. This model used age and avidity as the main variables to determine catch. The final model used first a multilevel regression model which grouped effects on avidity, age, and species. It used a hurdle gamma distribution with a logit link. Avidity, defined as number of fishing sessions, was grouped by "3 or less", "4-8", "9-19" and "20+". Age was grouped as "16-54" and "55+". The multilevel model provided an estimate for the intersection of each of these variables for species kept and released (Figure 19).

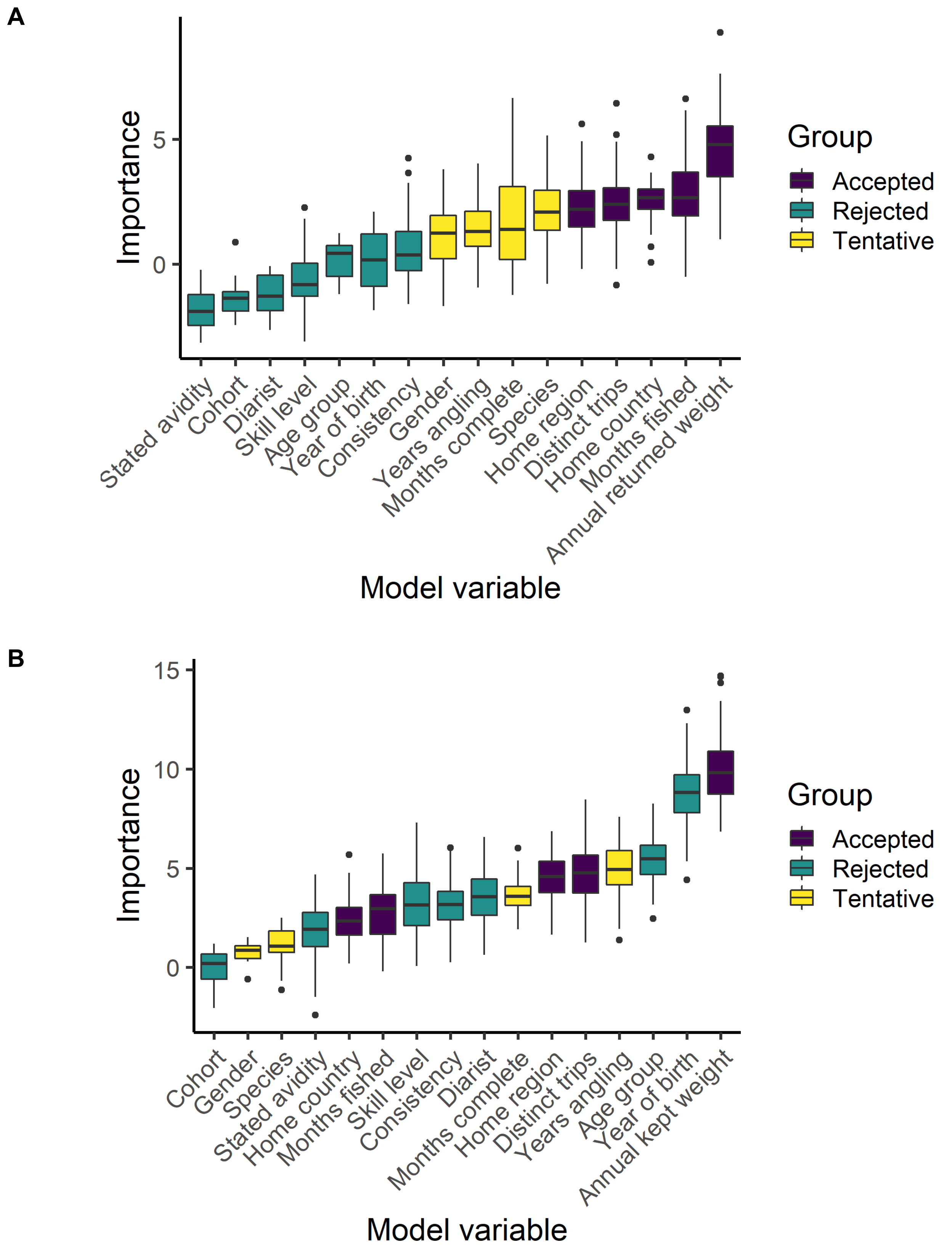


Figure 18. Importance of variables in predicting fish kept (A) and released (B) using a Boruta feature selection algorithm. The variables in purple represent 'confirmed' variables, whilst green is 'rejected', yellow are not yet confirmed or rejected.

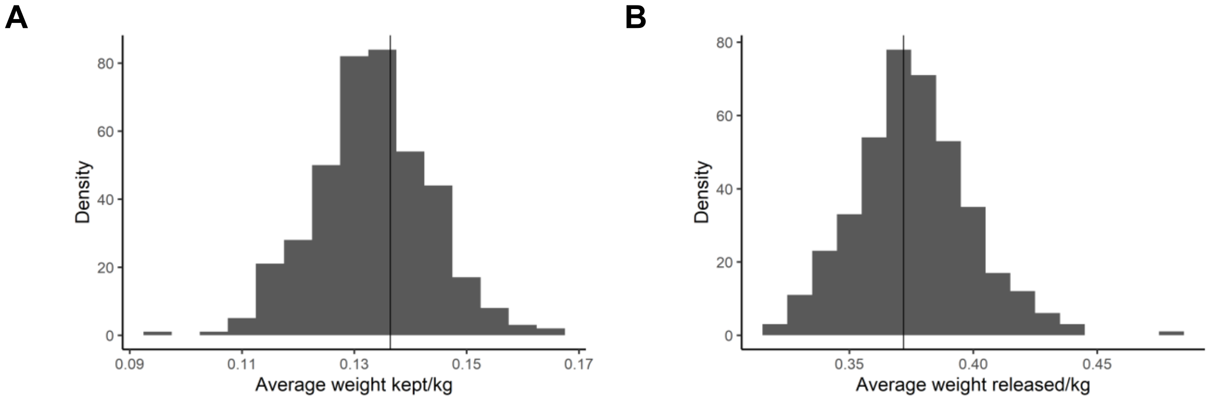
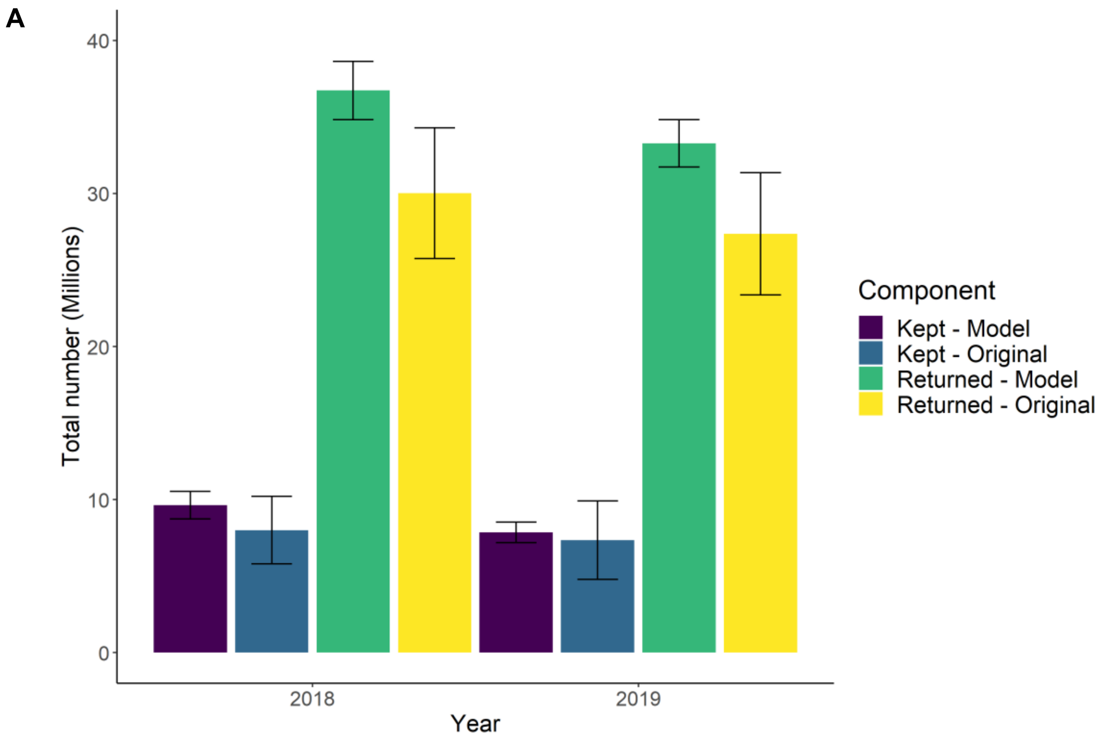


Figure 19. Posterior predictive checks for the Bayesian model using a hurdle gamma distribution with a logit link model. The graphs show predicted average kept (A) and returned weights (B) as a histogram with the mean value from the data shown as a line.

3.4.2.2. Comparison with existing method

Model-based estimates were higher and more precise than the existing method for total numbers and tonnages, but the differences were unlikely to be significant as the confidence intervals overlap (Figure 20). However, the differences varied between species with model-based estimates for less commonly caught species higher and more commonly caught species lower than the existing method (Figure 21). Similar release rates were predicted by both the model and existing method, and were in the region of 80%. This provides a greater degree of belief in our existing method, but a model-based approach is likely to be used in future if it performs well across a number of years, as it is more robust, efficient, and consistent. However, the model-based approach needs further development, which should focus on modelling both effort and catches per angler, and inclusion of multiple years in the model.



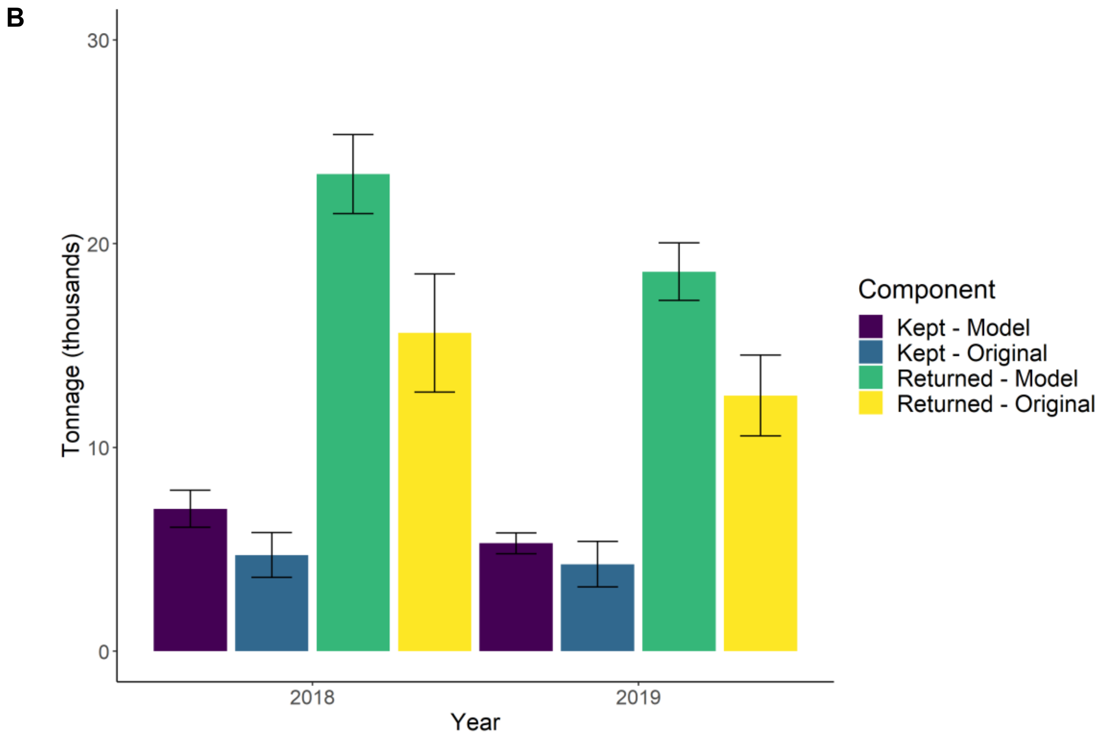
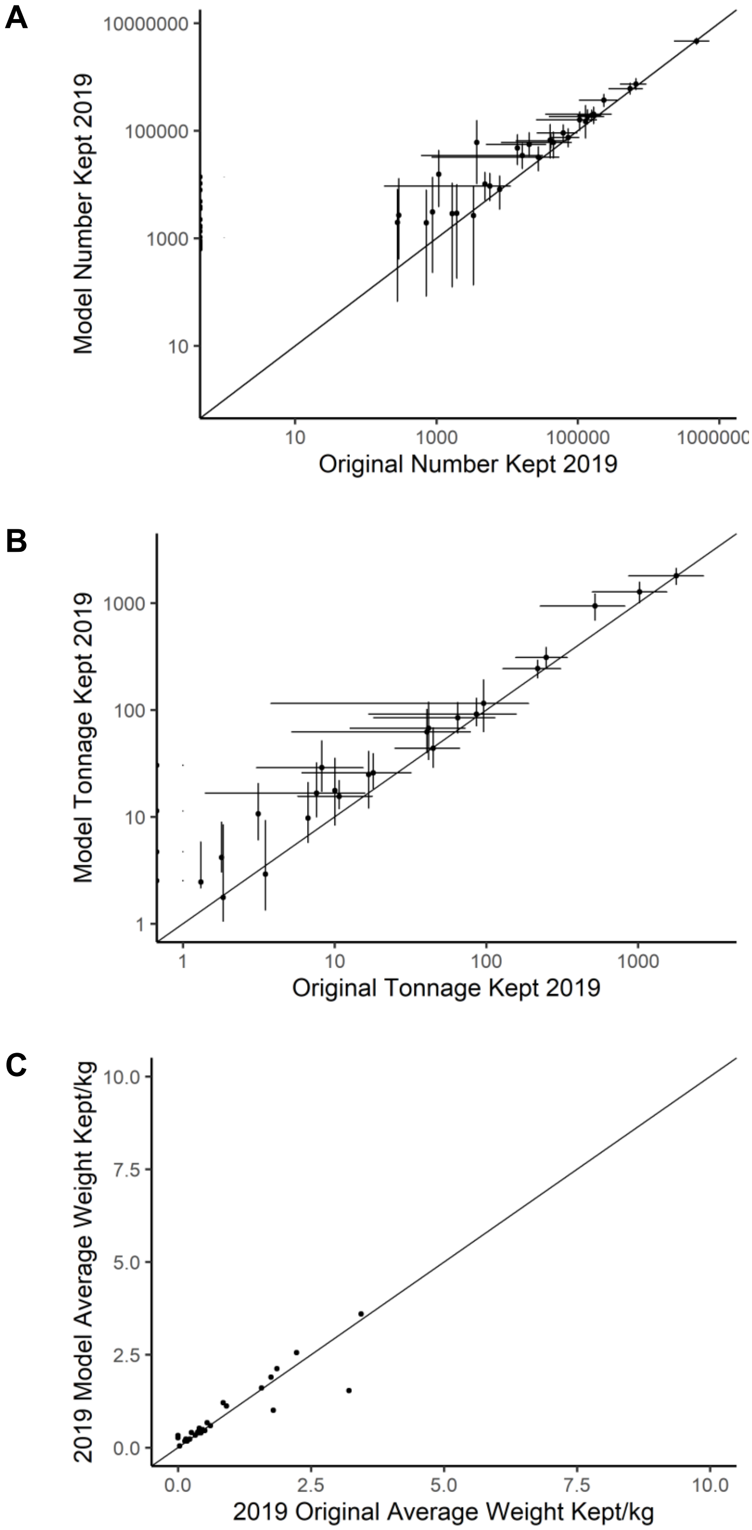


Figure 20. The total number (A) and weight (B) of all species for 2018 and 2019 using the existing method and model-based catch estimates.



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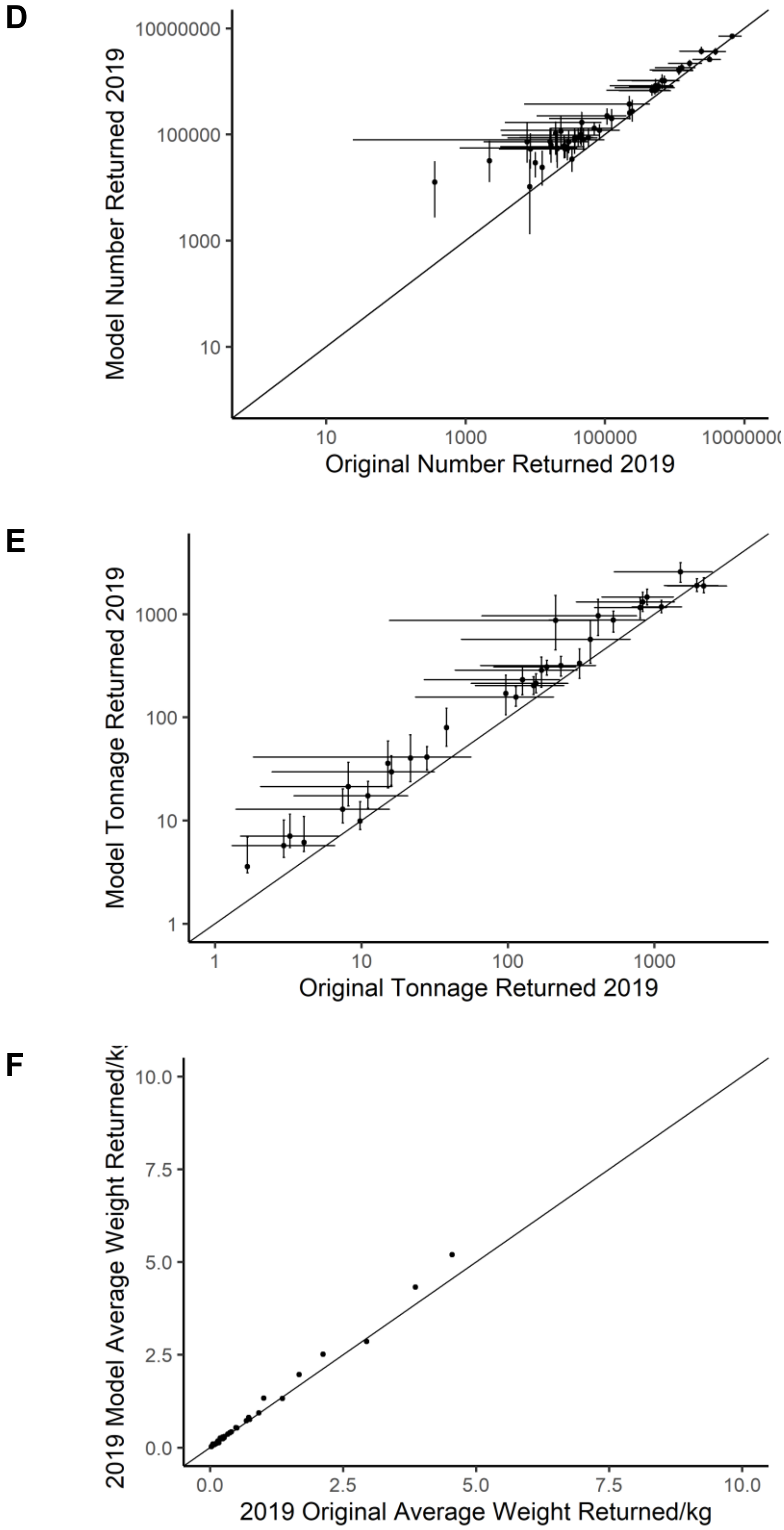

Figure 21. Comparisons of numbers (A&D), tonnages (B&E), and individual fish weights (C&F) of fish kept (A-C) and released (D-F) for individual species in 2019 estimated using the model and existing approach. The results are provided on the logarithmic scale (base 10), the solid line shows where the values are equal, and error bars are 95% confidence interval. A logarithmic scale has equal spacing between orders of magnitude (1, 10, 100, 1000 etc.) and helps interpretation of species with low catch estimates. The solid line shows where the values are equal, so a point on this line indicates estimates from the two years are the same. If the error bars cross the solid line, this indicates that the difference is not significant.

4. Discussion

4.1. Diary panel recruitment and engagement

Data collection approaches have been improved continually since the implementation of the Sea Angling Diary in 2016 in order to increase both the number and the completion rates of diarists. This has been done to improve the representativeness of the diary panel, increase precision of estimates generated, and maximise the utility of data generated.

Recruitment methods in 2018 and 2019 were adapted to address some biases identified in 2016 and 2017 (Hyder *et al*., 2020b). Face-to-face recruitment in 2017 generated a good number of new diarists, but was expensive and the completion rates from those recruited were low, yielding few data. Hence, increased use of social media and distribution of information via FishingMegastore was used more effectively. In addition, in 2019 a high number of diarists were recruited from a database of those who took part in the National Angling Survey in autumn 2018, and who had agreed to be contacted about angling research. During 2019, specific online promotion of the mobile app was also successful in recruiting diarists. More targeted, country-specific promotion of the project was used to recruit anglers from Northern Ireland, Wales, and Scotland to improve the representation of sea anglers in those countries. This resulted in a total of 1,706 in 2018 and 2,188 in 2019 diarists signing up across the UK, which was higher than previous years. England had the largest number of diarists, with recruitment in Wales and Scotland also resulting in the target numbers of diarists. Recruitment of diarists in Northern Ireland was challenging. The regional breakdown of diarists was similar to the WPS, indicating good coverage, except in Northern Ireland. However, the estimate of population of sea anglers for Northern Ireland in 2019 was unexpectedly high, possibly reflecting minor changes in responses from a small sample and uncertainty in the WPS estimates. Diarists were generally older, more avid, and had been fishing for more years. This suggests that there was some bias in the composition of the diary panel compared with the general population of sea anglers due to the fact that more engaged anglers are more likely to sign up to diary surveys. Future recruitment would benefit from increased targeting of diarists that fish more rarely and are less experienced, and increasing the number of diarists from in Wales, Scotland, and Northern Ireland, such as through more targeted social media promotion to those countries. In addition, it would be useful to increase the sample size of the WPS to reduce uncertainty in the composition of the sea angling population that is used to make these comparisons, especially in relation to national and regional estimates.

Only around half the diarists provided six months or more data, despite a significant amount of effort being put into reminders, improvements to the systems to ease data entry, and increasing benefits to the individual sea anglers. Time was invested during 2018 and (in particular) 2019 in developing the online tool and mobile app. Adding engaging features such as logging target species and the shared dashboard has been popular among diarists, with almost a third of all recorded sessions in 2019 being ‘shared’ in this way, even though the ability to share had only been in operation for one third of the year (since the autumn 2019). The development of the mobile app also proved to be a popular option. The use of the mobile app in future years of the Sea Angling Diary Project could increase accuracy of the results, as it is able to record data in real-time, whilst people fish, reducing the recall bias and non-entry of data which exists when fishers enter data after a fishing session has finished. The proportion of diarists with 6 months data was greater in 2019 than 2018 which could be an indication of the benefits of the mobile app. Further investigation of this in 2020 will be beneficial as data will be available for a full 12-month period of app use. Improvements to the online tool, including adding photos of catches were made in 2020 and live recording will be added to the app in 2021. Whilst it was not possible to ascertain the reasons for non-completion, anecdotal evidence from follow-up calls suggested that this was due to not fishing or lack of time. Given the significant effort in recruiting diarists and the potential for non-response bias, it is important to develop approaches that enhance completion rates and maximise the data provided by each diarist.

4.2. Participation and catches in 2018 and 2019

The numbers and participation rates in sea angling were lower in 2019 than 2018 according to the WPS. However, the small annual numbers of survey respondents that had been sea angling each year limits the precision of the participation estimates, so it is possible that these differences are simply due to uncertainty. However, it may also be due minor changes in the 2019 WPS survey wording to ensure that those who used handlines were not counted in angling participation totals. This was done as it was suspected that the term meant that people who fished for crabs with handlines were being included in angling population totals. In addition, revised direction was given to interviewers to ensure that only those who were actually fishing with a rod and line themselves were counted. The number of days fished was reasonably consistent between years. Generally, sea anglers were aged between 24 and 64, and had many years of consistent angling. Many factors have been shown to affect participation rate (Arlinghaus *et al*., 2015), but given the age profile and the consistency and longevity of sea angling, it is unlikely that participation fluctuates greatly between years. Hence, increased sampling is needed to improve the precision of estimates and characterisation of the demographic profile of the sea angling population. This could be generated using the WPS or a bespoke survey that covers all forms of angling.

Catches for 2018 and 2019 were similar in total for both numbers and tonnages. Catch composition was similar for both years, with mackerel and whiting the most commonly caught fish. Released rates were also similar and in the range of 80%, with released fish generally smaller than retained fish. Sufficient data were available to raise around 55 species for numbers and around 40 for tonnages. This was limited by the number of diarists reporting catches and the number of length measurements provided. Despite analytical approaches being well understood for angling surveys (Pollock *et al*., 1994; Jones and Pollock, 2013), there are still challenges during the analysis of results that need to be resolved (Hyder *et al*., 2020b) (see Section 4.4).

There was variation between years for individual species, but for most species there was agreement between years as the errors overlapped. Differences in catches between years for individual species was driven by the number and characteristics of the sea angler population from the WPS, and the number and weight of fish caught reported by diarists. Participation was lower in 2019 than 2018, resulting in slightly lower estimates of total catches, but within the bounds of the error. Catches by individual anglers are likely to vary between years based on local abundance of fish and decisions about what to target. In fact, catches by sea anglers have been found to vary greatly between years in other fisheries (Strehlow *et al*., 2012). However, the estimates are based on a small sample of sea anglers in the diary and the WPS which generates uncertainty, so it is important to consider the errors around the measurements when assessing the results. There is uncertainty in all estimates that are generated from any sample, as not every individual in the population is measured like is done in a census. This is true of all quantities used in fisheries science and every other scientific endeavour, so is incorporated into all decisions that are made. As a result, any use of the data from these surveys should include an assessment of the impact of the uncertainty on the outcome. Where the errors are large in comparison to the estimate (coefficient of variation is greater than 50%), then the results should be interpreted with extreme caution.

4.3. Comparisons with previous surveys

Two sets of previous participation and catches estimates exist that provide a direct comparison for the 2018–19 catches. These were: an extensive sea angling survey in England in 2012 using a nationwide population surveys to estimate fishing effort and an onsite survey to collect catch data directly from anglers (Armstrong *et al*., 2013); and comparison with previous years from the sea angling diary (Hyder *et al*., 2020b).

Participation appeared to decline across the period, dropping in the UK from 2.2% in 2012 to 1.0% in 2019. There are errors in the estimates of participation, due to the low numbers of sea anglers identified in the national surveys. For example, if the participation rates in sea angling are 2%, then a survey of 12,000 people should generate responses from 240 sea anglers. Hence, small changes in the response rate can lead to large differences in the participation. In addition, some changes were made to the WPS questions to remove handlines and making it clear that you had to have been angling (not simply accompanied someone else that was angling) that may have reduced the overall numbers. Despite this uncertainty it is important to track this change, as participation rates have been shown to be lower in countries with higher GDP (Arlinghaus *et al*., 2015). There are many factors that could contribute to a potential decline in sea angling participation the UK, but further research is needed to understand the potential drivers. This research need was also identified as necessary within the National Angling Strategy (Brown, 2019).

From 2016 to 2019 using the offsite diary approach, the composition of catches and the release rates were similar, but there does appear to be a decline in the total catch throughout the period. This was probably driven mainly by the lower participation rates in sea angling in 2018–19 than 2016–17, but there will also be differences in catches by individual anglers. Catches of individual species varied between years, driven by the differences in numbers and composition of the angling population, and the numbers and sizes of fish reported by diarist. The limited size of both the WPS and the diary panel result in imprecise estimates for many of the species. Hence, it is important that the errors are considered alongside any estimates when making comparisons between years and using the data to support decisions (Section 4.2).

For England, there were large differences between the 2016–19 offsite diary surveys (this study; Hyder *et al*., 2020b) and 2012 estimates using an onsite approach (Armstrong *et al*., 2013). Whilst the species composition was similar, the magnitude of catches and release rates were much higher in 2016–19 than in 2012 (see Hyder *et al*., 2020b for a comprehensive discussion). It is unlikely that this is only the result of random sampling error in estimates of catch rates obtained from the onsite and diary surveys, as the differences were observed for many species. There were three potential reasons for these differences: 1) catches increased substantially between 2012 and 2016–19; 2) annual fishing effort or numbers of anglers were under- or overestimated; and 3) different types and extent of bias were associated with the design and implementation of the onsite surveys in 2012 and the diary surveys in 2016–19. 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.

Biases inherent in the design and the implementation of the surveys are the most likely source of the differences in catch estimates between years. In the 2012 surveys, these included: recall of shore and boat fishing effort; 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; restriction of onshore sampling from dawn to dusk only, and refusals by some charter skippers to participate (Armstrong *et al*., 2013). In 2016–19, a self-selected diary panel was used, and bias in its composition in terms of age and stated avidity was corrected using WPS data when estimating catch and expenditure for all sea anglers in the UK (this study; Hyder *et al*., 2020b). It is possible that sea anglers that complete a diary may have been fishing longer than the general population, and this might affect their catches and expenditure. Those who fish rarely are less likely to be included in our surveys and less likely to complete data. The different potential bias structures created by the different survey instruments in 2012 and 2016-–19 make the results from the surveys difficult to compare. Survey methods have been shown to have an impact on the results. Differences between 2% and 50% have been found between harvest estimates from onsite and offsite surveys in New Zealand, with the largest differences for harvest only of the less commonly caught species (Hartill *et al*., 2015), but no comparison exists of the released component of the catch. To assess this robustly would need side-by-side onsite (creel) and offsite (diary) surveys completely in the same year.

4.4. Assessment of potential bias

All approaches for collecting data on sea angling are subject to error. Uncertainty in the UK estimates of participation, effort, and expenditure 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 Pollock, 2013). Diary surveys are used in many countries (Bellanger and Levrel, 2017), but are subject to a larger set of biases than onsite approaches (Jones and Pollock, 2013). In 2018–19, two sources of potential bias were examined relating to the composition of the diary panel and the analytical method used.

4.4.1. Composition of diary panel

The precision of the results generated for the UK or any smaller geographic areas or other survey strata increases with the size of the diary panel in that stratum, so it is important to recruit enough diarists in each stratum to achieve the precision that is needed. The diary panel increased in size from 2016–19, but completion rates for 6 months of data were around 50%. Significant efforts were made to increase the number of diarists, through broader and varied channels (e.g., social media), improvements to the system, and benefits for anglers. Engagement from more sea anglers, across a broader range of experience, skill, and avidity, alongside higher completion rates would improve the robustness of the estimates from the diary. In addition, more effort was made to recruit diarists across all countries of the UK to increase the utility of data at a national level, but further efforts are needed to generate catch estimates with acceptable accuracy and precision for all the species and areas of interest.

The largest challenge for the offsite diary approaches to estimating catches is developing a sufficiently representative panel of sea anglers that requires the least possible post-stratification and reweighting to reduce bias. Usually, recruitment of diarists would be done using a randomised telephone or postal survey to generate a probabilistic sample of sea anglers that are representative of the sea angling population. Due to the low participation and response rates to surveys in the UK, this would be very challenging due to the large numbers of individuals needed to be contacted to generate a reasonably sized diary panel. For this reason, a non-probabilistic approach was used to generate the diary panel involving a wide range of outreach methods to seek volunteers across all regions and angler characteristics. This has the potential to introduce biases in panel composition in terms of demography (e.g., age, location, social group) and fishing characteristics (e.g., avidity, skill, experience, species targeted) that affect the levels of catches.

To assess bias, a small validation panel was recruited of 120 sea anglers from three English regions using a postal survey of 50,000 houses. In addition, questions about skill and experience were added to the WPS and diary sign up. The profile of the validation panel was slightly older and less avid than the diary panel, but had a similar experience, consistency, and skill. The validation panel showed different characteristics to the WPS, with older, more avid, and experienced anglers. Although the validation panel was much smaller than the diary panel, the composition was closer to the diary panel than the WPS. Further analysis is needed to compare catch rates, composition, and sizes of individual fish in the validation and diary panels. However, it is possible that the non-probabilistic approach used to recruit diarists has limited impact on results, instead panel composition is driven by the types of anglers that are willing to keep a diary. One possible explanation is that older and more avid anglers are more likely to volunteer to keep a catch diary. This suggested that the bias in the diary panels may be driven more by factors determining whether or not a person signs up for the survey having been contacted or seen requests to volunteer. 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.

4.4.2. Catch estimation methods

A traditional post-stratification analysis approach was developed for the 2016–17 survey (Hyder *et al*., 2020b). This used the age, avidity, or sea angling method to correct for differences between the diary panel (sample) and the WPS (population). Many different combinations of the post-stratification approach were tested to develop the most robust analysis method using the data available. However, the number of characteristics that could be included was limited by the number of sea anglers responding to both the diary and WPS (Hyder *et al*., 2020b). Hence, the analysis was a trade-off between the number of individual strata and the numbers of anglers in each stratum, limiting the precision of the estimates. In addition, the ‘best’ post-stratification approach varied between years, generating an additional source of uncertainty. Statistical model-based approaches have been used in many other fields and are starting to be applied to recreational fisheries to explain factors driving catches (e.g., Tate *et al*., 2020; Navarro *et al*., 2020). These have also been used successfully with non-probability sampling to generate reasonable estimates from election polls (Lauderdale *et al*., 2020).

To test the potential of model-based catch estimation, a Bayesian model was developed to evaluate and select predictors of catch rate such as age, avidity, and experience. The outputs of this model was used with the WPS population data for estimation of total catches. The results show potential for improvement in catch estimation compared with the standard post-stratification and reweighting procedure used so far, by allowing greater use of data across the years. As a result, it is likely that a model-based approach should be used in future, but needs further development. To maximise the benefits of model-based estimation and ensure the robustness of the approach, a model needs to be developed for both effort from the WPS and catches from the diary. In addition, multiple years need to be included in the analysis to ensure that factors affecting a single year do not drive the magnitude of the results and to increase the robustness of annual estimates. A simulation study is also needed to demonstrate the benefits of the approach. Finally, these approaches are complex and difficult to explain, so some simple communication needs to be developed to ensure that the approach can be understood by the angling community.

4.5. Further work

Further work is needed in the following areas: improving estimates of effort and characteristics of the sea angling population; increasing the size and representativeness of the diary panel; improving data completion from the diary panel; development of model-based analyses; and side-by-side validation with parallel onsite surveys. Progress was made in 2018–19 in terms of increasing the size of the diary panel, improving tools for data completion, and assessing the impact of non-probability sampling on the composition of the panel through an independent validation panel. In addition, improvements were made to the analytical approach with the development of model-based estimates. However, further work is still required.

The numbers of sea anglers sampled in the WPS is low, limiting the number of variables that can be used in the analysis, the reliability of population estimates at national and regional levels, and the precision of the final estimates. A larger survey is needed, which could be done by either increasing the sample size of the WPS or developing a large bespoke population survey solely focussed on angling. The WPS is done by a consortium, so it is unlikely that the participants would want to increase the sampling effort due to the impacts on costs. The alternative is to run a national study of angling participation and anglers' effort, something which is also needed in research on freshwater angling. This would likely involve working with angler associations, the angling trade, and other agencies to understand the demographics, skill level, and number of anglers in the UK. Conducting a large-scale bespoke survey on angling would be useful both for this study and other research areas such as angler attitudes to policy and the economics of sea angling. This could also cover both freshwater and sea angling, so provide a consistent set of data that is used and agreed by the whole angling community. This has been proposed within the Evaluation Framework for the National Angling Strategy (Brown, 2021). This would also have the benefit of providing an engagement tool with the angling community, and allow the potential to recruit diarists through a probability-based approach, who could be added to the validation panel. However, this would require additional resource to implement.

Increasing the size and representativeness 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. Social media approaches have been developed since 2019, but recruitment will become more challenging each year as more anglers have already been part of the panel. Support from the angling community would be useful to increase participation, alongside the ability to publicise to new lists of anglers. This could take the form of a co-developed citizen science project working in partnership between researchers and the angling community. In addition, many diarists do not enter data for all months restricting the number of diarists that can be used in the analysis. Improving the experience of diarists through the further development of the mobile app (such as live tracking and allowing freshwater catches) and diary system is likely to increase completion rates and improve data quality. 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, but more use of technology is needed to enhance the user experience (e.g., real-time catch reporting).

Four years of estimates have been generated using the diary, providing a time series and large data set for analysis. To improve the precision of estimates and consistency across years, model-based catch estimation was developed and showed promising results. However, further development of the analytical approach is needed before this can be used. This should focus on developing models of effort, including multiple years in the models, and a simulation study to assess the robustness of the model. In addition, methods are needed for communication of the modelling as these are complex and challenging to understand. Additional work is underway in 2020 to continue the development of the models.

Progress was made this year in understanding the impact of non-probabilistic selection of the diary panel, which showed that the current recruitment programme for the panel yielded similar composition to a smaller panel recruited from the randomised postal survey. This suggested that differences in composition compared with the WPS were due more to the types of anglers willing to keep a diary than the methods for seeking volunteers. However, further work is needed to compare catch rates and other potential differences in composition between the diary and validation panels.

There are large differences between the results from the onsite 2012 (Armstrong *et al*., 2013) and the diary approach in 2016–19 (this study and Hyder *et al*., 2020b) for England. However, there are biases in both the onsite and offsite surveys and they were done in different years, making the reasons for the difference difficult to assess. The most robust way to understand the impact of bias would be to do a side-by-side comparison between onsite and offsite (diary) 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 onsite creel survey done every five years for comparison. This approach will generate times series needed for stock assessment, so regular (annual) consistent data collection is required to capture trends in sea angling catches (Hyder *et al*., 2017; 2018; 2020a).

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[8] http://www.cefas.co.uk
[9] http://www.substance.net

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Appendix 1. Species catches & weights

The total raised number, tonnage, and individual fish weights of each species kept and returned calculated using the current post-stratification method. Numbers in brackets are standard errors.

	Numbers				Tonnage				Weight (g)			
	2018		2019		2018		2019		2018		2019	
Species	Kept	Released	Kept	Released	Kept	Released	Kept	Released	Kept	Released	Kept	Released
Baillon's Wrasse	---	15427 (86)	---	2211 (64)	---	---	---	---	---	---	---	---
Ballan Wrasse	5783 (59)	850108 (33)	---	577934 (39)	1.6 (61)	338.6 (30.7)	---	231.4 (36.9)	278	398	---	400
Bass (Seabass)	27742 (28)	3207085 (23)	157986 (19)	3201281 (22)	36 (28.6)	1668.1 (23.1)	248.4 (19)	2187.6 (22.4)	1299	520	1572	683
Bib (Pouting, Pout, Pout-Whiting)	112514 (27)	1661621 (23)	107663 (39)	1269095 (30)	35.8 (27.5)	298.1 (23.5)	41 (45.9)	185.3 (29.2)	318	179	381	146
Black Goby	---	---	---	20766 (82)	---	---	---	---	---	---	---	---
Black Sea Bream	206307 (36)	642677 (36)	138378 (37)	662918 (39)	115.1 (38.8)	257.5 (36)	65.1 (37.5)	170 (38.2)	558	401	470	256
Black-mouthed Dogfish	---	---	---	8589 (69)	---	---	---	---	---	---	---	---
Blonde Ray	---	25907 (57)	---	46606 (47)	---	108.4 (58.8)	---	212 (47.5)	---	4185	---	4550
Brill	1290 (104)	746 (77)	---	---	---	---	---	---	---	---	---	---
Bull Huss (Greater Spotted Dogfish, Nursehound)	13222 (59)	274530 (39)	4650 (74)	259782 (36)	12.7 (56.8)	585.2 (39.6)	5.5 (58.5)	661.1 (36.4)	960	2132	1180	2545
Coalfish (Saithe, Coley)	16123 (41)	698734 (41)	20583 (38)	537073 (40)	6.1 (46)	200.7 (42)	8.2 (38.3)	126.3 (40.6)	376	287	401	235
Cod (Atlantic Cod)	731866 (27)	1703547 (27)	553622 (26)	1654391 (26)	1273.3 (28.7)	1180.7 (25.6)	1028.7 (26.1)	804.4 (26.2)	1740	693	1858	486
Common Skate	---	---	---	16380 (60)	---	---	---	---	---	---	---	---
Conger eel	1091 (67)	627564 (36)	---	714333 (34)	5.8 (65)	2021.6 (35.4)	---	1517 (33.2)	5334	3221	---	2124
Corkwing Wrasse	956 (91)	297519 (54)	---	305084 (57)	---	15.6 (52.8)	---	21 (57.7)	0	53	---	69
Cuckoo Wrasse	1736 (59)	88708 (49)	---	45833 (61)	0.4 (71)	22.4 (50.8)	---	15.2 (60.6)	234	252	---	332

Species	Numbers				Tonnage				Weight (g)			
	2018		2019		2018		2019		2018		2019	
	Kept	Released	Kept	Released	Kept	Released	Kept	Released	Kept	Released	Kept	Released
Dab (Common Dab)	41364 (40)	934579 (32)	62828 (30)	1168671 (30)	7.7 (40.5)	104.7 (32.7)	10.7 (28.5)	150.3 (31.1)	187	112	171	129
Dover Sole (Common Sole, Black Sole)	10087 (48)	73218 (43)	16517 (49)	83741 (49)	4.4 (53.7)	15.9 (42.5)	7.6 (48.3)	16 (46.4)	441	217	459	192
Five-bearded Rockling	---	31289 (57)	---	26143 (55)	---	---	---	---	---	---	---	---
Flounder (European Flounder, Fluke)	77127 (36)	666488 (29)	41782 (35)	596255 (32)	28.9 (36.9)	143.8 (29)	17.9 (36.5)	156.2 (33)	375	216	430	262
Freshwater Eel (Common Eel, Silver Eel)	---	227954 (47)	2051 (88)	134200 (45)	---	28.4 (47.1)	0.3 (96)	24.3 (47.4)	---	125	125	181
Garfish (Needlefish, Garpike, Sea Pike)	60846 (50)	214395 (38)	10768 (57)	58879 (43)	8.1 (50.3)	39.5 (39.1)	1.8 (57.7)	7.4 (43.4)	133	184	171	125
Gilthead Sea Bream	1606 (84)	17488 (79)	4166 (61)	24407 (55)	---	---	---	---	---	---	---	---
Goldsinney Wrasse	---	44455 (53)	---	16952 (64)	---	1.4 (57.9)	---	---	---	30	---	---
Greater Weever Fish	---	---	---	362 (106)	---	---	---	---	---	---	---	---
Grey Gurnard	30141 (93)	71550 (41)	1675 (98)	49347 (51)	5.6 (93.1)	9.6 (41.1)	0.4 (98.2)	4.1 (52.4)	185	134	251	82
Haddock	16252 (74)	29775 (56)	3779 (95)	7654 (61)	11.9 (72.1)	15.6 (53.9)	---	---	735	523	---	---
Herring	48212 (62)	12969 (52)	128670 (78)	12643 (54)	4.8 (60.8)	0.7 (53.9)	16.8 (77.6)	0.7 (68.2)	99	55	131	53
Lesser Spotted Dogfish (LSD)	165265 (38)	4262455 (21)	73312 (23)	3887944 (21)	97.7 (37.8)	2147.3 (20.7)	44.8 (23.6)	1963.8 (20.6)	591	504	611	505
Lesser Weever	---	19780 (49)	---	27104 (43)	---	---	---	---	---	---	---	---
Ling (Common Ling, White Ling)	41229 (61)	49686 (45)	27980 (49)	29142 (46)	140.5 (66)	66.1 (45.9)	96.3 (49.5)	21.8 (59.4)	3407	1330	3443	747
Mackerel	4747311 (23)	2937522 (23)	4833803 (27)	2443713 (26)	1337.1 (22.4)	835.8 (22.9)	1795.5 (26.2)	899.7 (26)	282	285	371	368
Pilchard	---	---	---	8377 (103)	---	---	---	---	---	---	---	---
Plaice	351222 (32)	522507 (30)	169597 (40)	474986 (40)	202 (33.8)	194.5 (30.9)	86.1 (41.5)	113.9 (40.9)	575	372	508	240
Pollack (Lythe)	531609 (26)	1936829 (30)	234687 (28)	1152924 (31)	1055.5 (25.9)	1044.4 (26)	523 (28.9)	838.8 (33.1)	1986	539	2228	728
Poor Cod	1199 (75)	192841 (50)	1087 (89)	247592 (66)	0.1 (75.4)	7.9 (51.1)	0.2 (88.6)	9.8 (67.1)	70	41	149	40
Red Gurnard	8206 (52)	94704 (42)	4913 (54)	70958 (39)	1.9 (51.8)	16.4 (42.2)	1.8 (56)	11.1 (39.7)	230	173	368	157

Species	Numbers				Tonnage				Weight (g)			
	2018		2019		2018		2019		2018		2019	
	Kept	Released	Kept	Released	Kept	Released	Kept	Released	Kept	Released	Kept	Released
Red Mullet (Striped Mullet)	---	---	---	10070 (63)	---	---	---	---	---	---	---	---
Rock Goby	1288 (101)	34268 (66)	---	19733 (74)	---	---	---	---	---	---	---	---
Sand Goby	---	1544 (104)	---	---	---	---	---	---	---	---	---	---
Sandeel (Greater Sandeel)	23395 (54)	24155 (61)	40755 (65)	20576 (49)	0.9 (54.3)	1.7 (62.7)	1.3 (66.1)	0.5 (51.1)	39	69	32	25
Scad (horse mackerel)	33290 (60)	132385 (39)	14052 (53)	225007 (49)	4.4 (61.2)	17.9 (39.3)	3.1 (51.8)	28.1 (49.5)	131	135	223	125
Sea Scorpion (long-spined)	2315 (101)	23995 (44)	---	33964 (73)	---	---	---	---	---	---	---	---
Shore Rockling	---	70803 (47)	---	37143 (43)	---	7.1 (49)	---	3.3 (43.2)	---	101	---	88
Small-Eyed Ray (Painted Ray)	4907 (91)	35144 (49)	296 (104)	41649 (46)	---	50.4 (50.9)	---	38.2 (51.2)	0	1433	0	917
Smoothhound (Gummy Shark, Smut)	5223 (69)	351225 (41)	2171 (81)	267395 (37)	3 (92.1)	561.5 (37.1)	3.9 (80.5)	472.4 (38.6)	573	1599	1790	1767
Spotted Ray	427 (104)	25977 (52)	725 (97)	23421 (63)	---	13.1 (50.1)	---	---	0	505	---	---
Spurdog	2362 (83)	70605 (46)	---	125146 (44)	13 (82.7)	148.1 (48)	---	368.3 (44.5)	5504	2098	---	2943
Starry Smoothound	1288 (96)	318272 (40)	1960 (68)	227758 (52)	1 (96)	640.4 (39.9)	3.5 (68.2)	309.4 (53.3)	748	2012	1790	1359
Thick Lipped Grey Mullet	10293 (75)	6527 (64)	---	18144 (69)	---	---	---	---	---	---	---	---
Thin Lipped Grey Mullet	2920 (78)	29571 (96)	---	25218 (74)	---	---	---	---	---	---	---	---
Thornback Ray (Roker)	64169 (38)	517172 (33)	45656 (42)	523664 (36)	87.2 (35.1)	619.5 (30.6)	41.8 (36.7)	527.4 (32.7)	1359	1198	915	1007
Three-bearded Rockling	854 (102)	54916 (46)	3351 (98)	27023 (45)	0 (102.3)	6.5 (48.2)	1.8 (98.2)	3 (45.7)	54	119	549	109
Tompot Blenny	---	76255 (45)	---	37095 (54)	---	2.2 (45.1)	---	1.7 (54.2)	---	29	---	45
Tope	3787 (89)	211965 (44)	285 (101)	107474 (46)	0.4 (88.8)	2073.1 (46.9)	0.9 (100.6)	414.8 (42.9)	115	9780	3215	3860
Tub Gurnard (Yellow Gurnard, Tubfish)	6585 (63)	52216 (40)	7854 (59)	44673 (47)	2.5 (61.3)	8.7 (39)	6.7 (61.4)	7.5 (48.3)	377	167	850	167
Turbot	10818 (51)	47667 (53)	5767 (49)	30349 (48)	15.7 (49.5)	25.2 (56.3)	10.1 (51.8)	8.2 (44.5)	1453	528	1750	269
Undulate Ray	---	64423 (51)	888 (101)	57926 (57)	---	144.3 (50.6)	---	97.1 (53.1)	---	2241	0	1676

Species	Numbers				Tonnage				Weight (g)			
	2018		2019		2018		2019		2018		2019	
	Kept	Released	Kept	Released	Kept	Released	Kept	Released	Kept	Released	Kept	Released
Whiting	692117 (19)	6918998 (19)	668321 (21)	6753895 (19)	234.2 (18.5)	1200.8 (19.6)	219 (21.1)	1123.5 (19)	338	174	328	166

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We are the government's marine and freshwater science experts. We help keep our seas, oceans and rivers healthy and productive and our seafood safe and sustainable by providing data and advice to the UK Government and our overseas partners. We are passionate about what we do because our work helps tackle the serious global problems of climate change, marine litter, over-fishing and pollution in support of the UK's commitments to a better future (for example the UN Sustainable Development Goals and Defra's 25 year Environment Plan).

We work in partnership with our colleagues in Defra and across UK government, and with international governments, business, maritime and fishing industry, non-governmental organisations, research institutes, universities, civil society and schools to collate and share knowledge. Together we can understand and value our seas to secure a sustainable blue future for us all, and help create a greater place for living.

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