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Original Article

Estimating catches of marine and freshwater recreational fisheries in the Netherlands using an online panel survey

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In this study we describe a two-phase survey design and implications of approaches to non-response adjustments on estimates of the total catch taken by Dutch recreational fishers, including marine catches for Atlantic cod and European seabass and European eel in freshwater. The survey comprised three main elements which were executed online: a screening survey to estimate the characteristics of the population of recreational fishers (number of fishers, their demographic profile and stated fishing avidity); a 12 month logbook survey to estimate effort and catch rates; and non-response follow up surveys to adjust for non-response. A response rate of 80% was achieved for the screening survey and, following non-response adjustment and limited data imputation, 89% for the logbook survey. Some logbook participants reported no fishing activity (drop-outs) and were removed from the analysis. In addition, logbook data were weighted in accordance with the stated avidity distribution in the population to address potential response bias based on avidity. Imputation and weighting for avidity influenced the catch estimates a little, whereas the removal of the fisher drop-outs was influential, linked to the rates of fisher drop-outs (18% for freshwater and 55% for marine fishers). Freshwater recreational fishing was more popular than marine fishing; 9.7% of the Dutch population participating in the former and 4.1% fishing in marine waters. In total an estimated 53.6 million freshwater fish were caught (2.6 million retained) and 13.6 million marine fish were caught (9.6 million retained). Respective catch estimates for Atlantic cod, European seabass and European eel were 0.70, 0.35 and 1.23 million fish (0.53, 0.23 and 0.34 million retained). We conclude that the survey design using an online panel may serve as an example for future surveys because of its efficacy to collect a rich set of data at relatively low cost compared to traditional survey methods.

Keywords: angling, *Anguilla anguilla*, bias, *Dicentrarchus labrax*, drop-out, *Gadus morhua*, logbook survey, non-response, online questionnaires, recreational fishing, stock assessment, survey design.

Introduction

Recreational fishing is a popular activity worldwide and although most recreational fishers make few fishing trips per year, collectively they can catch substantial quantities of fish (Coleman *et al.*, 2004; Van der Hammen and de Graaf, 2012). For some fish species, recreational fisheries have a significant impact on stocks (Coleman *et al.*, 2004; Cooke and Cowx, 2004, 2006), and therefore, there is an increasing need and awareness to provide reliable estimates of the recreational catch for inclusion in stock assessments (Coleman *et al.*, 2004; Arlinghaus and Cooke, 2005; Lewin *et al.*, 2006; Zeller *et al.*, 2008; Griffiths *et al.*, 2010; ICES, 2010, 2011, 2012; Ferter *et al.*, 2013; Rocklin *et al.*, 2014; Eero *et al.*, 2015). Since 2009, the Netherlands has been obliged to estimate recreational catches of cod (*Gadus morhua*) and European eel (*Anguilla anguilla*) as part of the common data policy (CEC, 2008). Other EU Member States also have been obliged to report catches of sea bass (*Dicentrarchus labrax*), Atlantic salmon (*Salmo salar*), and Atlantic bluefin tuna (*Thunnus thynnus*). The poor status of these stocks further emphasizes the importance of reliable catch estimates for all sectors (ICES, 2014a, b, c, 2015). For most European countries, the systematic collection of catch data for the recreational sector only commenced recently and many countries are now providing national or large-scale regional estimates of recreational catches (Vølstad *et al.*, 2011; Sparrevohn and Storr-Paulsen, 2012;

Strehlow et al., 2012; Ferter et al., 2013; Sparrevohn, 2013; Van der Hammen and de Graaf, 2013; Rocklin et al., 2014).

The dynamic nature of participation in terms of activity levels in space and time makes it challenging to accurately assess the number of persons actively engaged in recreational fisheries within given time frames and regions (Fedler and Ditton, 2001; Lyle et al., 2002; NRC, 2006; Hartill et al., 2011; Dempson et al., 2012; Jones and Pollock, 2013; Wynne-Jones et al., 2014). Reliable catch information can be difficult to obtain because surveys may be prone to a variety of biases which introduce sample and non-sample error (Pollock et al., 1994; Groves, 2006; Jones and Pollock, 2013). In off-site surveys, it is often difficult to achieve high response rates, which in turn may introduce "non-response bias" (Groves, 2006; NRC, 2006, Table 1) that arises if groups with specific fishing behaviours or characteristics have higher tendencies to refuse, neglect, or fail to respond to surveys. Ideally, surveys should be designed to maximize response rates and hence representativeness of the data provided, especially where participants are expected to record fishing activity over a period (Lyle et al., 2002; Jones and Pollock, 2013). Regular follow-ups of participants to remind and encourage ongoing participation is one such strategy (Lyle et al., 2002; Jones and Pollock, 2013); non-response follow-up to either assess and adjust for the non-response is an alternative approach (Jones and Pollock, 2013).

There are a number of reporting biases that can also affect data quality; they include recall, prestige, rounding or digit biases, and deliberate deception (Pollock et al., 1994). Problems of accurately recalling activity become exaggerated as the period of interest is extended; events can be forgotten or inaccurately recalled or events that occurred outside of the period of interest are included (known as "telescoping", Table 1). Recall bias is a complex issue that is influenced by factors such as the recall period and levels of activity but, as a rule, fishers tend to overestimate their catch and effort if the timespan between the event and reporting of the activity is large, e.g. surveys with recall periods of 2 or more months (Thompson and Hubert, 1990; Tarrant et al., 1993; Tarrant and Manfredo, 1993; Pollock et al., 1994; Connelly and Brown, 1995; Lyle et al., 2002; Jones and Pollock, 2013). Recall biases can be reduced by limiting reporting periods to the recent past and/or through the use of logbooks or diaries, where participants are expected to document their fishing activities and catch details shortly after they occur (Lyle et al., 2002; Wynne-Jones et al., 2014). Logbooks alone do not, however, guarantee that all trips will be recorded nor that information will be recorded accurately and there may also be a need to regularly prompt participants to record information to address both non-response and recall biases. To keep these potential biases as low as possible, it is necessary to develop a survey design which supports respondent participation and encourages accurate and complete data reporting as well as tracking and follow-up of non-respondents (Lyle et al., 2002).

Furthermore, to obtain high levels of precision, large numbers of participants are typically required. However, surveys designed to address or minimize the main biases and provide high precision tend to be costly using traditional sampling methods such as face to face or telephone contact. Contact with participants via the internet potentially represents a cost-effective alternative to telephone surveys; an option that has become possible in the recent years with the high rates of the Internet access within the populations of many developed countries.

The Netherlands has a population of almost 17 million people, and around 7 million households. Around 11% of the population is engaged in recreational fisheries, most fishing in freshwater (in rivers, canals, ponds, and lakes), whereas marine recreational fishing is less common (Van der Hammen and de Graaf, 2013). Most recreational fishers are anglers, although passive gears such as gillnets are also used occasionally. For fishing in freshwater, a licence is obligatory, whereas in marine waters, no licence is required. However, especially low avid fishers, fishing close to home, do not always purchase a licence.

This paper describes a large-scale online survey that was developed and applied to assess the recreational catch of key species by all methods in the Netherlands. The survey comprised a two-phase design, with an initial screening survey to determine the size and characteristics of the population of recreational fishers in the Netherlands and a monthly logbook survey which ran for 12 months to estimate catch, effort, and catch rates. To maximize response rates and data quality, three key components of the panel survey design were implemented; (i) use of a logbook coupled with Internet reporting of data, (ii) frequent contact with survey participants, and (iii) follow-up of non-respondents. We describe the survey design, analyse response rates, and estimate the implications of different approaches to addressing non-response on the estimates of total recreational marine and freshwater catch in the Netherlands. We apply the methods to two marine species, European sea bass (*D. labrax*) and Atlantic cod (*G. morhua*), and in freshwater to one species, European eel (*A. anguilla*).

Table 1. List of terms used in the text.

Term	Interpretation
Fisher drop-outs	Respondents who indicated an intention to fish during 2010, but did not fish during the logbook survey period
Fisher drop-ins	Respondents who indicated no intention to fish during 2010, but did fish during the logbook survey period
Avidity	The number of fishing trips (trips) undertaken within a year
Stated avidity	Reported avidity during 2009 based on the screening survey
Realized avidity	Realized avidity during 2010 as specified in the logbook survey
Quasi-representative sample	A quasi-representative sample is a constructed sample that reflects key attributes of the population
Non-response bias	Bias caused by non-responding participants of the survey. If groups with specific behaviour have more non-response, it causes bias
Recall bias	Recall bias occurs if there is time between the event and the survey. Respondents may forget or exaggerate as the period of interest is extended
Prestige bias	Prestige bias is the tendency for respondents to answer such that make them appear as performing better
Digit bias	If respondents have to answer with a number, they have the tendency to round to 5's and 10's
Telescoping	Telescoping is the perception of respondents that distant events are more recent than they are

Material and methods

Data collection

TNS-NIPO database

The screening and logbook surveys were administered by a large commercial marketing company (TNS-NIPO, www.tns-nipo.com), which sends online questionnaires about a range of topics (social, politics, products) to households in its database. The database is a quasi-representative sample of the Dutch population. Most households (~70%) in this database were recruited using a combination of random face to face and telephone recruitment surveys. This process resulted in underrepresentation of difficult target groups, such as immigrants, the elderly, low educated persons, and single-person households. Two methods were applied to further recruit individuals from these difficult target groups. First, selected existing participants were asked to recruit others (the so-called "snowball method"). This was done by asking if they knew persons belonging to these groups who would be interested in joining the TNS-NIPO database. About 10% of the database was recruited in this manner. Second, ~20% of participants were recruited through a purchased database that consists of most addresses in the Netherlands. Household size, socio-economic status, academic titles, and demographics are known for most addresses. Addresses and telephone numbers of difficult target groups can be purchased after selecting for these specific groups and then approached to join the TNS-NIPO database. The snowball method and the purchasing of addresses were continued until the percentages in the database of the difficult target groups approximated the proportions found in the Dutch population as reported by Statistics Netherlands (CBS, www.cbs.nl). No recruitment was done using the Internet, and self-recruiting of panellists was not allowed. In 2010, 94% of the Dutch population had access to the Internet (Statistics Netherlands), and thus potential coverage bias caused by limited Internet access is not expected to be significant.

The TNO-NIPO database was initiated in 1997 and has an ISO 9001-certificate. The database has a low turn-over in its membership (<10% year^{-1}) and is actively managed; addresses are checked monthly and members without a correct address are removed. If members respond to <10% of the questionnaires within 6 months, they are flagged as inactive and TNS-NIPO will try to contact them to make them active again (Scherpenzeel and Zandvliet, 2011). For each completed questionnaire, members receive points; if enough points are earned, they receive a gift card or air miles. To avoid potential fraud to obtain points, respondents cannot fill in the questionnaires faster than 30% of the average time (averaged over seven questionnaires) and answers are routinely checked for unusual or conflicting responses. To minimize non-response, respondents have at least 2 weeks to respond to each questionnaire and reminders are sent if they do not respond. If respondents have questions, they are able to contact a helpdesk by phone or e-mail and a website is available with information including FAQ's.

Screening survey

The screening survey was designed to estimate the total number and demographic profile of recreational fishers in the Netherlands. The survey was offered to 56 730 households in the TNS-NIPO database in December 2009 embedded in an omnibus questionnaire that covered a variety of different topics. Participants did not know the topics before filling in the questionnaire and were not allowed to skip individual topics. One member of the household filled in the questionnaire for each member of the family of 6 years of age and older. Respondents were asked whether each member of their household had fished recreationally in the Netherlands in marine and/or freshwater during 2009, what gear(s) they had used, if they were planning to do any recreational fishing in the Netherlands in 2010 and if they would be interested in participating in a 12-month logbook survey in 2010. In addition, participants who had fished during 2009 were asked to indicate the number of fishing trips (1–5, 6–10, 11–25, 26–50, or >50 trips) that were undertaken in the previous 12 months in an attempt to profile activity into broad avidity classes. This approach assumes that the responding member has knowledge of the fishing frequency of the other household members. In most situations, it is anticipated that respondents will at least know whether other members fished and whether fishing was frequent or not. Although participants had the ability to pause the survey, or ask other household members about their fishing behaviour, there remains some possibility of reporting bias. Furthermore, reporting of number of trips was based on 12-month recall and is expected to be overestimated (Lyle *et al.*, 2002; Jones and Pollock, 2013). Recognizing this issue, this *stated avidity* was only used to classify each respondent into an "avidity" group and not as a measure of effort in any of the calculations.

Logbook survey

The logbook survey was designed to monitor fishing activity in detail over 12 months, from March 2010 to February 2011. Participants were randomly selected from those respondents who, during the screening survey, had indicated an interest in participating in the logbook survey. Participants were selected with a probability of inclusion based on an analysis of demographics (age and gender) and stated avidity (based on water body type fished during 2009, namely marine and/or freshwater) such that the logbook sample matched ratios (stated avidity class by waterbody type) determined in the screening survey as much as possible. Selection was done on an individual rather than household basis: some members of the same household could be included in the survey, whereas others were not. Marine and freshwater fishers were treated as separate groups in the analysis. Fishers who indicated that they fished in both marine and freshwater would join both groups. The logbook survey was started by 1969 participants, of which 1541 planned to fish in freshwater and 1153 planned to fish in marine water. Of these, 725 planned to fish in marine and in freshwater. The minimum age of participation was 6 years. Logbook survey participants were sent a survey kit comprising a paper logbook for each month, a manual, and a species recognition card, with pictures and descriptions of the main marine and freshwater fish species. Participants were asked to record detailed information in the logbooks for each fishing trip undertaken and they were then contacted online once a month and requested to transfer the data recorded in their logbooks to an online questionnaire. The information in the monthly logbooks included: fishing location, water body type (marine or freshwater), time fishing commenced and time ended, gear used, species caught, and numbers by species that were retained or released. Participants were also expected to indicate if they had not fished during the month and therefore had no fishing data to report. The use of logbooks coupled with regular contact with participants was expected to minimize recall bias and encourage continued survey participation (Lyle *et al.*, 2002; Jones and Pollock, 2013).

Non-response follow-up

A proportion of the logbook survey participants provided data for some but not all months during the survey period. In an attempt to obtain information about the fishing activity of these partially responding participants in those months for which no data were reported, a non-response follow-up survey was sent out as an additional online questionnaire twice during the survey period. The first was sent out at 6 months and the second at the end of the logbook survey period. In this non-response survey, partially responding participants were asked whether they had fished in the months for which data were missing and, if they had, the number of fishing trips (not catch) that they had made in each of the missing months.

Data analysis

Response rates

Non-response occurred in all survey components. The screening survey was completed by 45 518 households (109 293 individuals), representing a household response rate of 80.2%. However, because the recreational fishing questions were embedded in the omnibus questionnaire with a range of questions involving different topics, and because respondents were not allowed to skip questions, we expect that this non-response would not result in a systematic bias, at least in terms of whether or not selected households included recreational fishers.

More than half of the logbook survey participants (1079, 54.8%, Figure 1) provided complete information for the full 12-month period, while 890 (45.2%) responded in some, but not in all months (partial non-response). The inclusion of all participants who responded at least once would mean that some provided incomplete data, whereas exclusion of these partially responding participants would result in the loss of a substantial amount of data and loss of overall precision due to the reduced size of the survey sample. In addition, if these partially responding participants differed in their fishing behaviour, their exclusion could result in the responding group being non-representative of the fisher population.

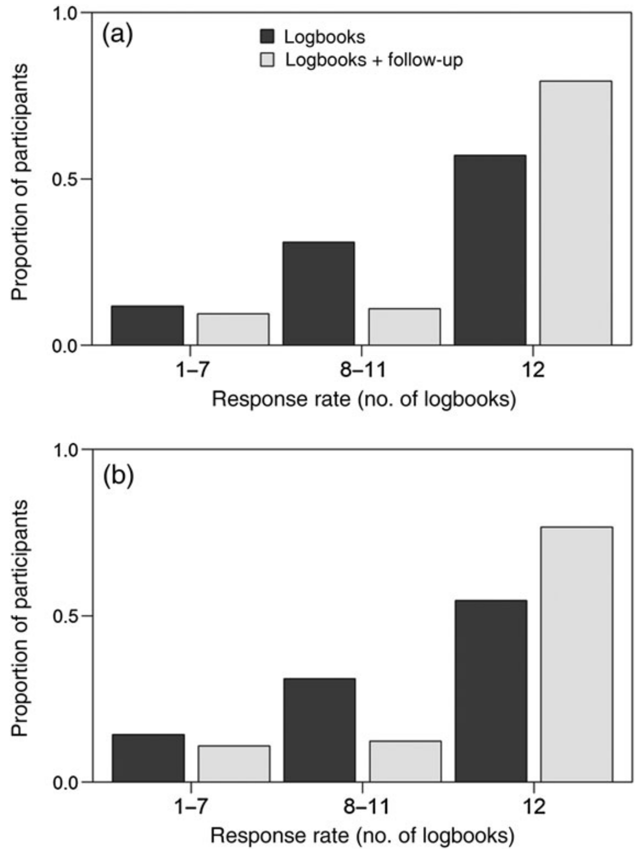

Figure 1. Response rate (proportion of participants) based on logbook reporting rates before and after follow-up survey adjustment for (a) marine fishers or (b) freshwater fishers. Data from logbooks only (dark grey) or from logbooks after follow-up survey adjustment (light grey).

Data imputation

The non-response follow-up survey was designed to collect information about the number of fishing trips undertaken in a given month but not catch information. In such instances, data for the missing catches were imputed in the following manner. Respondents who indicated that they had not fished in a specific month were assigned zero catch and effort and treated as having fully responded in that month. For respondents who indicated that they had fished in a given month, their fishing activity for the missing month was imputed using hotdeck imputation (Sarndal and Lundstrom, 2005). This is a method to replace missing values with observed values from a respondent (the donor), that is similar to the non-respondent with respect to characteristics possessed by both (for instance, demographics and avidity, Sarndal and Lundstrom, 2005; Andridge and Little, 2010). The strengths of the hotdeck method are that imputed values come from observed responses and are therefore also realistic values, that it can be applied independently of the distribution of the data, and that the correlation structure is preserved (Reilly, 1993; Andridge and Little, 2010). The donor values were chosen from respondents with the same stated avidity class (and waterbody type) and who had reported the same number of freshwater or marine fishing trips in the same month as the missing value of the recipient. Hence, the realized avidity was used to match donors with recipients and stated avidity was used to classify each respondent into an "avidity" group. Stated avidity was not used as a measure of effort in any of the calculations. Donors came from the same stated avidity group, because stated avidity was expected to influence catch rates because more avid fishers are likely to be more experienced and skilled fishers and the month is expected to affect the species targeted.

Participants who filled in their logbook questionnaires, supplemented with the non-response follow-up, less than eight times (8 months), were treated as non-respondents and excluded from the final analysis. This meant that there were participants for whom between 1 and 4 months of data were missing, with no follow-up fishing information available. For these missing months, the same hotdeck imputation procedure was followed but with the difference being that all of the information was imputed from a randomly selected donor from the same (marine of freshwater) stated avidity class and for the same month as the missing record. The information was imputed from the reported number of fishing trips and catches. This means that donors were chosen from the same stated avidity group, but that the realized number of fishing trips from the donor were used to impute the missing month of the recipient. This resulted in zero fishing trips if the donor indicated no fishing in the missing month. Imputation was done in R (R_Development_Core_Team, 2011), library StatMatch, function NND.hotdeck.

Fisher drop-outs

The population of fishers changes over time, with persons either leaving or entering recreational fishery (Fedler and Ditton, 2001;

Lyle *et al.*, 2009, 2014), for this purpose termed fisher "drop-outs" and fisher "drop-ins", respectively (Table 1). Fisher drop-outs were defined as persons intending to fish (i.e. logbook survey eligible) but who did not fish during the timespan of the logbook survey. The inclusion of these non-fishers in the analyses would have meant that estimates of catch and effort were negatively biased, relating to the population of intending fishers rather than the population of active fishers. This population of active fishers includes persons who entered the fishery without having expected to fish, so-called fisher drop-ins. In the absence of information about the number of such drop-ins, we have assumed equilibrium in terms of the number of active fishers between years (i.e. that the number and avidity profile of the fishing population determined during screening survey was the same as that during the logbook survey period). Thus, the non-fishing survey participants were excluded from the analyses and those participants who did fish were reweighted (see the *Weighting* section) to ensure that the total number of fishers did not change between 2009 and 2010. This was done for freshwater and marine fishers separately. Fishers who had indicated that they would fish in both water types, but did not fish in one of the water types during the timespan of the logbook survey, were characterized as fisher drop-outs for that water type, but not for the water type in which they did fish. Removal of fisher drop-outs was done after the hotdeck imputation.

Weighting

Removal of respondents who provided <8 months of data and of the fisher drop-outs resulted in a marked shift in the proportional representation of the stated avidity groups within the response group in marine waters but less so for the freshwater fishers (Table 2). To correct for differences in the composition of the avidity groups compared with the screening survey, data were reweighted to match the stated avidity profile established at screening. This was done by first estimating the mean yearly catches per fisher for each avidity group and subsequently multiplying this with the total number of fishers in each avidity group as established at the screening survey. This means that some logbook participants had somewhat higher weights than others. This was especially the case for low avid marine fishers, where the highest drop-out rate occurred (Table 2).

The expectation that fishers with higher stated avidity at screening would have larger numbers of realized trips during the logbook survey and catch more fish was tested using quasipoisson glm's with stated avidity as the explanatory factor and the total catch (numbers) or effort (trips) during the logbook survey as response variable.

Sensitivity

The approach described above will be referred to as the "standard approach". To calculate the effect of weighting for avidity, imputation, and the removal of fisher drop-outs, the total catches for freshwater and marine species (all species combined) were also estimated (i) without weighting for stated avidity, (ii) with only fully responding logbook participants, and (iii) without the removal of fisher drop-outs.

Number of fishers and catch estimation

Because the number of high avid fishers was relatively low, four stated avidity groups were established for freshwater fishers (1–5, 6–10, 11–25, >25 trips) and three for marine fishers (1–5, 6–10, >10 trips) by grouping the highest avidity groups.

To estimate the total catch, first the number of fishers in each stated avidity group and for both freshwater and marine was calculated as:

$$F_{a,w} = \frac{Fs_{a,w}}{N_s} \times N_{\mathrm{nl}},$$

where $F_{a,w}$ is the number of fishers per avidity group (a) and for both freshwater and marine water types (w), N_s the total number of participants in the screening survey (s), $Fs_{a,w}$ the number of fishers in the screening survey per water body type and avidity group and N_{nl} the total number of inhabitants ≥ 6 years old in the Netherlands (nl), which are obtained from CBS. Subsequently, for each avidity group, water body type, and species, the mean number of retained and returned yearly catches per fisher is estimated:

$$\bar{C}_{a,w,sp,r} = \frac{\sum_{fl} C_{f,a,w,sp,r}}{fl},$$

where $\bar{C}_{a,w,sp,r}$ is the average yearly catch per fisher for each avidity group, for freshwater and marine water types and species (sp) and r indicates released or retained fish. $C_{f,w,sp,r}$ is the yearly catch per individual fisher (fl). The total catch number for each species, for freshwater and marine and avidity group, is calculated by multiplying the yearly mean catch rate by the total number of fishers:

$$C_{a,w,sp,r} = \bar{C}_{a,w,sp,r} \times F_{a,w},$$

where $C_{a,w,sp,r}$ is the total yearly catch per avidity group, for freshwater and marine and species for retained or released fish. Subsequently, the values are summed over the avidities, to get to the total yearly catch by

Table 2. Avidity proportions for freshwater and marine observed in the screening survey during 2009, initial logbook survey sample (all initial participants included), and final dataset (adjustment for non-response and removal of fisher drop-outs).

	Stated avidity class (no. fishing trips)			
Marine	**1–5**	**6–10**	**>10**	
Screening	0.79 (3595)	0.13 (584)	0.08 (352)	
Initial sample	0.76 (1043)	0.16 (215)	0.08 (109)	
Final dataset	0.66 (297)	0.22 (97)	0.12 (53)	
Freshwater	1–5	6–10	11–25	>25
Screening	0.54 (5659)	0.23 (2451)	0.14 (1522)	0.09 (929)
Initial sample	0.49 (728)	0.24 (362)	0.16 (238)	0.11 (155)
Final dataset	0.48 (536)	0.24 (268)	0.16 (177)	0.12 (132)

The numbers between parentheses represent the sample sizes (number of participants in the avidity group).

species per water body type for retained or released catch components ($C_{w,sp,r}$):

$$C_{w,sp,r} = \sum_a C_{a,w,sp,r}.$$

Standard errors of the catches were estimated as following:

$$\text{s.e.} = \sqrt{\Sigma\left(F^2_{a,w} \times \frac{s^2_a}{n_a}\right)},$$

n_a is the number of fishers monitored in avidity group a. The sample estimate of the population variance per avidity group is s^2_a. For each avidity group, this sample variance is estimated by:

$$s^2_a = \frac{\Sigma(f_a - \overline{f_a})^2}{n_a - 1},$$

where f_a are the catches for each fisher in the avidity group $a.\bar{f}_a$ is the mean number of fish caught per fisher in the avidity group a.

Results

Population of fishers

The screening survey was completed by 45 518 households (~0.65% of all Dutch households) from which an estimated 1 689 000 persons, representing 10.9% of the resident Dutch population aged 6 years and older (~15 million), fished recreationally at least once during 2009. Based on water body, ~1 494 000 (9.7% of the population) fished at least once in freshwater, while 641 000 (4.1% of the population) fished at least once in marine waters during 2009 (Van der Hammen and de Graaf, 2013, Table 3). About 70% of marine fishers also fished in freshwater.

Logbook survey non-response

Of the 1969 participants who commenced the logbook survey, 1079 (54.8%) replied every month (750 marine fishers and 804 freshwater fishers, some fishers belonging to both groups). The remaining 890 participants (45.2%) responded between 1 and 11 times (representing 7337 survey months of data). Non-response follow-up surveys were completed by 593 participants and resulted in the return of data for 1090 out of 3343 of the missing survey months. The majority of the partially responding fishers indicated that they had not fished in the months for which no data were reported (82.2% of the missing months), and thus zero catch and effort were imputed. The follow-up survey also established that 148 participants had fished in one or more of the missing months (representing 188 survey months) and thus catches were imputed via the hotdeck method. The inclusion of the follow-up survey responses where all missing data were provided increased the number of fully responding logbook survey participants to 1526 (77.5%). Furthermore, by including all respondents who provided at least 8 months of data as noted in the methods, the number of logbook survey participants was increased to 1761 (89.4% of the original sample). Of 235 participants who responded between 8 and 11 times (partial non-response), a total of 505 months (2.1% of the months in the final sample) were imputed using the hotdeck imputation method.

Fisher drop-outs (persons who participated in the logbook survey but did not fish at all) accounted for 504 (55%) intending marine fishers and 224 (18%) intending freshwater fishers (Table 4). The highest percentages of fisher drop-outs occurred in the lowest avidity groups (Table 4).

Table 3. Number and percentage of freshwater and marine fishers in the Netherlands.

Dutch population[a]	15 456 763	
	% of fishers in screening survey	No. (thousands) of fishers in The Netherlands (± s.e.)
Marine	4.1	641 (9)
Freshwater	9.7	1494 (14)
Total fishers	10.9	1689 (17)

[a]Number of inhabitants ≥6 years in January 2010 (source: CBS).

Final dataset

After the removal of the fisher drop-outs, 93.4% (marine) and 92.4% (freshwater) of the dataset originated from the original logbooks; 3.5% (marine) and 3.9% (freshwater) of the months originated from the follow-up survey where fishers indicated that they did not fish; 1.2% (marine) and 1.0% (freshwater) of the data came from the follow-up survey where the fishers indicated that they had fished and 2.0% (marine) and 2.7% (freshwater) was missing data for which no follow-up information was available, and thus the number of fishing trips and catches were imputed.

Realized avidity and catches per stated avidity group

The mean realized avidities of the stated avidities 1–5, 6–10, and more than 10 yearly fishing trips in marine waters were 1.0, 2.4, and 6.0 yearly fishing trips, respectively. The groups with stated avidities in freshwater of 1–5, 6–10, 11–15, and more than 25 fishing trips had mean realized avidities of 5.4, 6.4, 9.0, and 16.8 yearly fishing trips, respectively. The increase in effort (realized avidity) with stated avidity was highly significant for both marine and freshwater (glm, quasipoisson: marine, $F = 116.6$, $p < 0.0001$, fresh, $F = 56.6$, $p < 0.0001$). Thus, as expected, participants in higher stated avidity groups had larger numbers of yearly fishing trips. The observed realized avidities from the logbooks were lower than the stated avidities from the screening the year before, apart from the two lowest avidity groups in freshwater. This was expected, because of the recall period of 1 year for the stated avidity. In addition, fishers do not necessarily fish with the same avidity from one year to the next year.

The mean annual catch per fisher (all species) also increased with stated avidity for both marine and freshwater fishers (Figure 2, marine: 15.7, 32.9, and 58.7 fish for the avidity groups 1–5, 6–10, and >10, respectively, freshwater: 26.5, 28.5, 53.7, and 84.0 fish for the avidity groups 1–5, 6–10, 11–25, and >25, respectively). This relationship was highly significant for both marine and freshwater fishers (glm, quasipoisson, marine: $p < 0.001$, fresh; $p < 0.001$). This confirmed that weighting for avidity was required to reduce bias that arose as a result of deviation in the ratios for the various avidity groups between the response group and the

Table 4. Proportion and number (between parentheses) of fisher drop-outs per avidity group for freshwater and marine fishers.

	Stated avidity class (no. of fishing trips)				
Marine	1–5	6–10	>10		Total
Fisher drop-outs	0.61 (426)	0.36 (55)	0.30 (23)		0.55 (504)
Freshwater	1–5	6–10	11–25	>25	
Fisher drop-outs	0.22 (136)	0.17 (54)	0.14 (30)	0.03 (4)	0.18 (224)

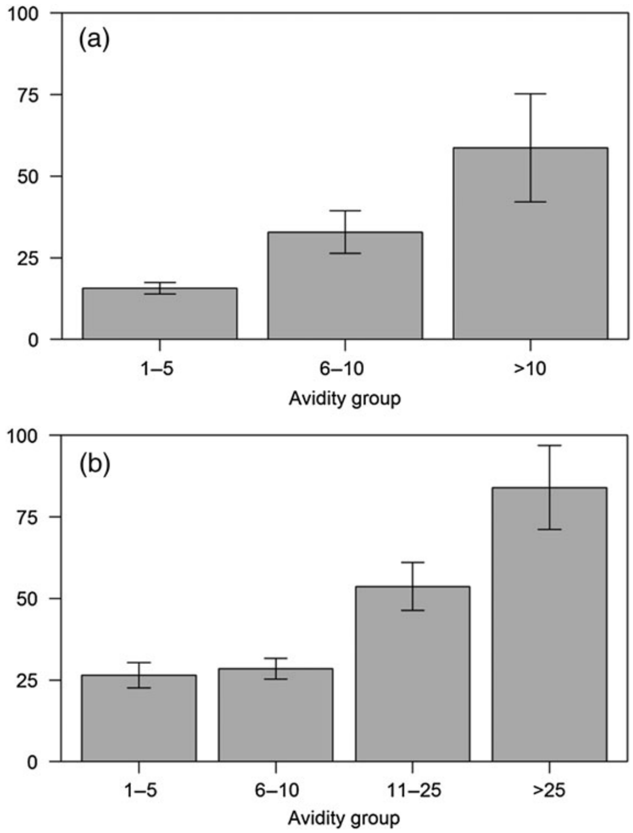

Figure 2. Mean annual total catch (number retained plus released; ± s.e.) per fisher in marine water (a) and freshwater (b) based on stated avidity group.

Table 5. Dutch recreational catches (thousands) in marine waters and %RSE (between parentheses).

	Retained	Returned	Total
Marine			
Gadus morhua	527 (15.9)	170 (26.6)	697 (14.9)
Dicentrarchus labrax	234 (37.6)	131 (26.7)	366 (30.1)
Total marine	9610 (6.8)	4005 (8.8)	13 615 (6.4)
Freshwater			
Anguilla anguilla	341 (31.1)	887 (20.5)	1228 (18.7)
Total freshwater	2560 (7.0)	51 085 (4.2)	53 645 (4.1)

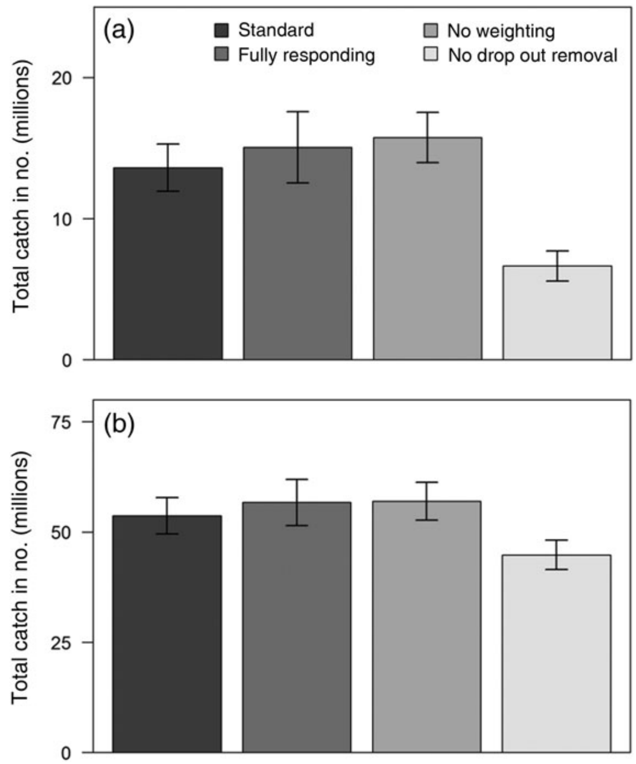

Figure 3. Total catch (retained + released) estimates (millions of fish, ± s.e.) by (a) marine and (b) freshwater recreational fishers for four different scenarios: (1) the standard approach (black, weighting for stated avidity, imputation, and fisher drop-out removal), (2) with only the fully responding logbook participants included in the analysis (dark grey, weighting for stated avidity, no imputation, and fisher drop-out removal), (3) without weighting (light grey, no weighting for stated avidity, imputation, and fisher drop-out removal), and (4) without the removal of fisher drop-outs (very light grey, weighting for stated avidity, imputation, no fisher drop-out removal).

population. In particular, the lowest avidity class was underrepresented in the response group, largely due to the removal of drop-outs, whereas the higher avidity classes tended to be overrepresented, indicating a positive bias on catch estimation if not corrected (Table 2).

Catch

An estimated total of 54 million freshwater fish was caught by recreational fishers in the Netherlands between March 2010 and February 2011, of which 2.6 million were retained (5%, Table 5). In marine waters, almost 14 million fish were captured, of which 9.6 million were retained (71%, Table 5). In freshwater, 1.2 million eel were caught (28% retained), while in marine waters, an estimated 0.70 million cod (76% retained) and 0.35 million sea bass (64% retained) were caught by recreational fishers.

The inclusion of fisher drop-outs would have resulted in the marine catch estimates being 51% lower and freshwater catch estimates 16% lower than the standard approach (Figure 3). When compared with the standard approach, catch estimates based on fully responding participants and those not weighted for stated avidity were considerably higher for marine (fully responding 11% higher and not weighted for stated avidity 16% higher) and somewhat higher for freshwater catches (fully responding 5.6% higher and not weighted 6.2% higher, Figure 3).

Discussion

One of the key challenges for recreational fisheries surveys, in particular those employing off-site survey methods, is to maximize response and data quality, especially in surveys involving a longitudinal component of data collection (Lyle *et al.*, 2002; Rocklin *et al.*, 2014). In this study, we report a novel and cost-effective approach to estimate recreational catches based on an online panel survey. By maintaining regular contact with participants and non-response follow up, we were able to achieve an effective response rate of almost 90% to a 12-month logbook survey, with limited need to impute or adjust for missing data. Survey non-response has increased in recent years (De Leeuw and De Heer, 2002; Curtin *et al.*, 2005; Groves, 2006; Massey and Tourangeau, 2013) and is particularly high in the Netherlands (De Leeuw and De Heer, 2002). In our survey design, only 10.6% of the logbook participants were excluded due to non-response. The use of an online survey helped to achieve the high response rate, providing participants with flexibility in terms of when and where they completed the questionnaire. Another advantage of online surveys is that it is possible to collect detailed information about the subject matter because the respondent is able to see the survey questions and take time to consider their responses. In our questionnaire, for example, we obtained information about catch and effort along with expenses associated with fishing, fish lengths, and general satisfaction of each fishing trip. Another important advantage of the method is the low cost of contacting and managing participants online compared with alternative methods, such as telephone surveys. This allows for a large number of participants to be managed, thereby increasing the precision of the estimates, with much of the core data entered by participants into the survey databases. The major challenge for online surveys is, however, how to undertake probability-based sampling. In this study, this issue was addressed by using a sampling frame developed to match key characteristics of the Dutch population, providing a quasi-representative sample of the general population, from which the characteristics of the fisher population were derived and could itself be representatively sampled. This approach largely reduces the biases associated with self-recruiting of panellists that is common to many web-based surveys (Lee, 2006; Bonnichsen and Olsen, 2015).

It is often debated that more avid fishers are more likely to respond to recreational fisheries surveys, resulting in a positive bias to catch and effort estimates (Jones and Pollock, 2013). Contrary to expectation in this study, there was no clear evidence that logbook response rates varied with stated avidity, although it should be noted that logbook respondents were selected from those who had already indicated a willingness to participate in a logbook survey at the screening survey. As such, this could be seen to suggest that adjustment for avidity would not greatly influence catch estimates. However, the greatest proportion of fisher drop-outs were in the lowest avidity groups, resulting in a positive bias to the higher avidity groups in the final dataset. This bias, compounded with the higher realized effort and higher annual catches for the higher avidity groups, highlighted the necessity for adjustment based on stated avidity; without such weighting, the total catch numbers would have been overestimated by ~16% for marine and 6% for the freshwater fisheries. Furthermore, this analysis also highlighted that knowledge of the avidity profile at the population level is useful in correcting for possible response biases based on survey uptake rates.

Not all persons who fished during 2009 and planned to fish in 2010 reported fishing activity during the logbook survey, indicating that individual participation can vary between years. To account for this dynamic, we assumed that these fisher drop-outs were replaced by fisher drop-ins, that is by persons who did not expect to fish, and thus the total number of recreational fishers did not change between 2009 and the period of the logbook survey, from March 2010 to February 2011. Fisher drop-outs were more prevalent among marine fishers (55%) than freshwater fishers (18%) and therefore catch estimates for the marine fishery would have been much lower (51%) had no adjustment been made, compared with freshwater catch estimates (16% lower). Higher drop-out rates occurred in all avidity groups of marine fishers, suggesting that fishing in marine waters may be more opportunistic than freshwater fishing in the Netherlands. Given the impacts of fisher drop-out and drop-in adjustment on catch estimates, a more accurate assessment of potential variation between years in fisher numbers is essential in future panel surveys. The inclusion of an additional screening survey at the end of the logbook survey to estimate the number of fishers and their stated avidity profile during the timespan of the logbook survey represents a potential solution. The issue of fishers drop-in and drop-out has been addressed in recent surveys conducted in Australia and New Zealand and has enabled this dynamic of inter-annual variation in participation to be measured directly (Lyle *et al.*, 2009, 2014; West *et al.*, 2012; Wynne-Jones *et al.*, 2014).

In marine waters, the overall retention rate was much higher than in freshwater (71% compared with 5%, Table 5), although retention rates differed substantially between species, with 76% of the cod, 64% of the sea bass, and 28% of the eel catch retained. Significantly, the retention rate for eel was over five times higher than the overall rate for all freshwater species, despite an eel capture ban. At the time of the survey, this ban had not been in place for very long (since October 2009), so it is unclear if some fishers were unaware of the ban. However, it does illustrate that at the time of the survey, there was some level of illegal fishing that should be assessed and also highlights the need to publicize the regulations. These findings illustrate that in the Netherlands, marine fishers take a large proportion of the catches home for consumption, whereas freshwater fishing is seen more as a sport fishery, with fishers returning most of the catch.

The statistical uncertainty around the total annual catch estimates was quite low (relative standard error—RSE—for fresh =4.1%, marine =6.4%, Table 5). As expected, for individual fish species, the %RSE's were higher. The sea bass catch estimates, for example, were quite uncertain. The reason was that few fishers caught many fish and many fishers caught zero or few fish, resulting in a skewed distribution. A recommendation for future recreational fisheries surveys is therefore to increase the number of logbook participants and in particular marine fishers. Furthermore, as individual variation was greatest in the higher avidity groups, oversampling of these groups and weighting for avidity represents a strategy to improve precision. Finally, the estimated catches of cod, sea bass, and eel by Dutch recreational fishers were substantial and should be considered in the management and assessment of the stocks.

Conclusions

In many developed countries, access to the Internet is high and growing and as such has the potential to provide a cost-effective option for data collection. If respondent selection is based on probability sampling and survey design includes comprehensive respondent management systems involving data quality checks and non-response assessment, an online survey has the potential to provide a reliable platform on which to collect detailed information at relatively low cost compared with traditional survey methods. This study represents an important case study and model for the ongoing monitoring of recreational fishing activity at a national scale.

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