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Using interview-based recall surveys to estimate cod *Gadus morhua* and eel *Anguilla anguilla* harvest in Danish recreational fishing

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Marine recreational fishing is a popular outdoor activity in Denmark, practised by both anglers and passive gear fishers. However, the impact on the targeted stocks is unknown, so to estimate the 2009 harvest of cod *Gadus morhua* and eel *Anguilla anguilla*, two separate interview-based surveys were initiated and carried out in 2009/2010. The first recall survey exclusively targeted fishers who had been issued with the mandatory Danish fishing licence. The second survey was designed to identify those who fish without a licence. It was estimated that 1231 t of cod were harvested in 2009, corresponding to 4.8% of the entire Danish cod yield (recreational harvest + commercial landings). Area differences were found, and, in certain areas, the recreational harvest of cod accounted for more than 30% of the total yield. The majority (81%) of the recreational cod harvest was taken by anglers. Eels, however, are almost exclusively caught with passive gear (fykenets) and a total of 104 t year^{-1} was harvested, which corresponds to 19% of the entire Danish eel yield. The inclusion of the harvest taken by fishers without a valid licence was important and added almost 20% to the estimated harvest.

Keywords: angling, recreational fishing, recall survey, stock assessment, tourist fishing, the sound.

Introduction

Within Europe, the management of recreational fishing has so far mainly been conducted on a national level and without including the catches in either stock assessment or ecosystem-based management (Lewin *et al.*, 2006; Pawson *et al.*, 2008). However, fishing mortality due to recreational fishing has, in some areas, been estimated to be comparable with or even more than that observed in the commercial fishery (e.g. Coleman *et al.*, 2004; Morales-Nin *et al.*, 2005), and in many EU member states, there is an increasing awareness of its impact (Lewin *et al.*, 2006). As a consequence, the EU Council has, since 2008, obliged member states to estimate the recreational harvest as a part of the Common Fisheries Policy (EC, 2008). Due to this obligation, Denmark has initiated a recall survey to estimate the harvest of cod *Gadus morhua* and eel *Anguilla anguilla* in Danish waters.

Denmark has ~5.5 million residents; 2.5 million on the mainland—the Jutland peninsula—and the rest on islands. Denmark has an extensive coastline that stretches over 7013 km and most citizens live within 50 km of the coastline (Agerskov and Bisgaard, 2011). Recreational fishing in marine waters has therefore become an important national outdoor leisure activity. Two major and fairly different categories of fishing can be identified in recreational fishing; angling and passive gear fishing. Passive gear fishing is carried out using stationary gear such as gillnets and fykenets and is a tradition that has been practised for centuries. It resembles the commercial fishery in the sense that the gear used is similar, but, unlike the commercial fishery, it is illegal for recreational fishers to sell their catch. Furthermore, there are effort restrictions by which each licence holder can only fish with a total of six gillnets/fykenets, of which only half may be gillnets. For recreational fishing, the length of the gillnets may not exceed 39 m and they must be placed 100 m or more away from the coastline and 500 m from most freshwater outlets. These restrictions are mainly set up to protect seatrout *Salmo trutta trutta*. Passive gear is typically deployed from small boats with a very limited radius of activity, which in practice means that this type of fishery is more or less limited to the near coastal areas. The main target species in fykenets is eel (Sparrevohn *et al.*, 2009). Earlier, recreational fishing using eel trawl and longlines was also practised, but eel trawling is now prohibited and longline catches are limited. Since 1 February 2009, the eel recovery plan (EC, 2007) has commenced a closing of recreational eel fishing from 10 May to 31 July, a period which is intended to result in a 50% effort reduction. Cod are caught with both gillnets

and fykenets but mainly within certain areas and periods (Sparrevohn *et al.*, 2009; Sparrevohn and Storr-Paulsen, 2010).

The other major recreational fishing activity is angling, which is carried out along the coastline, from constructions such as peers, bridges, etc., or with boats as platforms. Besides closed seasons and a minimum landing size for species such as cod and eels, there are no-fishing zones around the mouths of some rivers and streams. Excepting on a few salmon rivers, bag limit regulations are not used in Denmark. In angling, the main target species is seatrout, but garfish *Belone belone*, cod and salmon are also caught regularly (Rasmussen and Geertz-Hansen, 2001). In a previous recall survey, 16.5% of the Danish population considered themselves anglers and 12.5% claimed to have been fishing within the last year (Bohn and Roth, 1997). Of these, 25% had mainly fished in streams, 30% in lakes, and 27% in put and take ponds. However, the majority of 73% had fished in marine waters. The willingness of the Danes to pay for their recreational fishing is among the highest in the Nordic countries (Roth *et al.*, 2001; Toivonen *et al.*, 2004), which underlines the importance of this leisure-based activity in Denmark.

Recall surveys are used to collect information on effort, catches or harvest in the recreational fishing in most European member states (ICES, 2010a). A recall survey is a type of off-site survey that relies on collecting information through mail, telephone, or Internet interviews, where respondents are asked to recall, e.g. their catches, fishing pattern, or number of days fished, within a specific time frame.

In Denmark, domestic as well as tourists anglers, between 18 and 65 years of age, have to purchase a licence for the price of €19 for 1 year, €13 for 1 week, or €5 for 1 d. Likewise, all passive gear fishers have to pay €37 $year^{-1}$ for a licence (Table 1). Both types of licences are personal, non-transferable, and can be bought online or at post offices (see www.fisketegn.dk for further information on the licence system and how to purchase a licence). Personal information of the purchaser, such as a unique social security number and address, will be listed, regardless of how the licence is purchased. Therefore, the list containing this information provides an easy and cost-efficient sampling frame for contacting anglers and passive gear fishers. The reason is that the number of persons who need to be contacted, e.g. in relation to a recall-based interview survey, is reduced compared with a situation where the entire population needs to be sampled. Therefore, this particular type of survey was chosen to estimate the harvest from Danish recreational fishing. The main drawback is that recall surveys are known to be associated with several biases, of which non-response and recall biases are the most dominant (Tarrant *et al.*, 1993; Connelly and Brown, 1995; Lyle *et al.*, 2002; Vaske *et al.*, 2003). Therefore, any recall survey should ideally be supported by other sampling approaches, such as diaries and/or onsite surveys (ICES, 2010a).

The present study has two main objectives; first, to present two interview-based recall surveys providing estimates of eel and cod harvest in Danish recreational angling and passive gear fishing, and second, to compare the quantity harvested in the recreational fishery with the total yield, the latter being defined as the commercial landings plus the recreational harvest.

Material and methods

A combined telephone and Internet survey was designed together with Statistic Denmark which, besides assisting with constructing the questionnaires, was responsible for the respondent contact. Two recall surveys, with their own questionnaires and group of respondents, were carried out. The first survey, the "licence list survey", specifically targeted that part of the Danish population with a valid annual fishing licence. When a licence is issued, the Danish social security number of the purchaser is registered, providing an efficient way to contact these persons. However, the list does not cover: (i) tourists (since they do not have a Danish social security number), (ii) those fishing without a valid licence, and (iii) people with a valid reason not to have a licence. The second survey, the "omnibus survey", targeted a subsample of the entire Danish population. This survey was intended to estimate the number of fishers who fished without a valid licence and with how much effort they did so. In this survey, no questions concerning their harvest were asked.

Licence list survey

This recall survey targeted fishers with an annual licence valid on 1 February 2010 when the interview was initiated. Since two lists are available, one for anglers and one for passive gear fishers, two surveys were conducted using almost identical questionnaires. Respondents were randomly selected and initially contacted by letter, wherein they were encouraged to fill out the questionnaire on the Internet. If no answer was received within a week, the respondent was contacted by telephone up to six times, and if contact was made, they were given the opportunity to answer the questionnaire over the phone. The questionnaire contained detailed questions on species harvested and fishing effort within the last 12 months. The respondent was explicitly told only to report those catches that were kept (i.e. the harvest) and not to include discarded or released fish. To estimate harvest by ICES managing areas and quarters, the respondents were asked to provide the information on that level, facilitated by enclosing a Danish version of the map shown on Figure 1 in the letter. In the Danish licence system, it is also possible to issue a licence that is valid for 1 d or 1 week. However, the number of these issued is small compared with the number of annual licences (Table 2). Therefore, no separate interview was conducted for these, although they were accounted for in the total harvest estimation [Equation (2)]. There are legitimate reasons for anglers not to have a licence: (i) persons younger than 18 years or older than 65 years, (ii) private landowners fishing in their own waters, and (iii) put and take angling. In contrast, all passive gear fishers are obliged to purchase a licence before being allowed to fish. Purchasing a licence for passive gear fishing automatically gives the right to angle as well and in order to include this group of persons in

Table 1. Number of angler and passive gear year licenses issued, during the period 1999–2009.

	1999	2000	2001	2002	2003	2004[a]	2005	2006	2007	2008	2009[b]
Anglers	150 526	151 529	156 769	150 925	152 534	–	160 942	156 474	160 664	160 186	156 000
Passive gear	33 575	31 709	33 715	33 888	33 516	–	33 430	34 277	33 787	35 221	34 000

[a]No data available.
[b]Supplementary data.

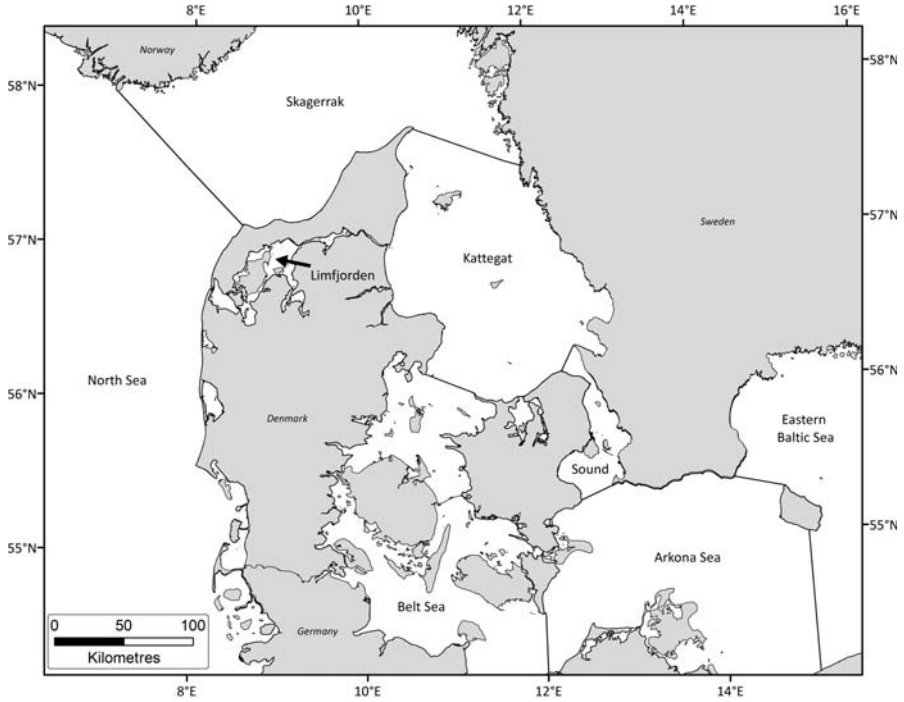

Figure 1. Map of areas sampled. The Eastern Baltic corresponds to ICES subdivision (SD) 25, the Arkona Sea to SD 24, the Sound to SD 23, the Belt Sea to SD 22, and the Kattegat to SD 21. The Skagerrak and North Sea are SD 20 and IVb, respectively. In ICES Limfjorden is a part of IVb, but since this area has an important recreational value, it was treated as an independent area.

Table 2. Values used in Equation (1) to estimate passive gear fishery and angling harvest.

		License (ρ)				Effort (ε)			
	Respondents (n)	Year (a)	Week (w)	Day (d)	Without (m)	Year (a)	Week (w)	Day (d)	Without (m)
Passive gear	1 585	34 000	–	–	13 520	24.7	–	–	13.6
Angling	1 929	156 000	17 800	22 200	98 894	9.2	3	1	3.2

Effort is in days per year.

the survey, all passive gear fishers were asked whether they also angled, a group then referred to as "angling with a passive gear licence". Therefore an additional interview was, conducted with this group to estimate their harvest when angling.

In the licence list surveys, the respondent had the opportunity to report harvest by either weights (kg) or numbers. To provide all estimates in weight, it was necessary to multiply the number with a mean fish size. The average size of eels and cod above the minimum landing size caught in the passive gear fishery was taken from Sparrevohn *et al.* (2009). Eel larger than the minimum landing size caught in fykenets was set to an average length of 47 cm, corresponding to a weight of 188 g. Cod caught in fykenets above the minimum size was set to 39 cm, corresponding to a weight of 540 g. Cod caught in gillnets was set to 47.5 cm, which corresponds to 975 g. Since no estimate on the average weight for cod caught angling was available, a value of 1500 g per fish was used.

Omnibus survey

The omnibus survey consists of monthly telephone interviews carried out by Statistic Denmark where questions are asked on behalf of, for example, companies, newspapers, and research institutes. Questions concerning recreational fishing were embedded during the October, November, and December omnibus in 2009. The practice for the omnibus survey is that a random phone number is dialled and the interview carried out if the person is between 16 and 74 years. After a series of non-fishery-related questions, respondents were asked if they had fished within the last 12 months and, if so, whether a licence had been purchased or not. Those without a licence were asked for their reason for not having one. Furthermore, respondents were asked how many days they fished to estimate whether people fishing without a licence did so with the same effort as people with a licence. Respondents in the last two interview rounds were asked if they had fished as tourists outside Denmark within the last 12 months and, if so, in which countries.

Analytical methods

Estimating the total harvest of cod and eels in the Danish recreational fishing was done by initially estimating the harvest based on the reported data from the licence list recall survey. These values were then extrapolated to the entire population of fishers (all licence holders and fishers without a licence) using the

information collected during the omnibus survey. Different efforts for those fishing without a licence vs. those with a weekly or daily licence were accounted for in the calculation. To compute the total harvest ($\hat{Y}_{ij}$) of either cod or eel per quarter (i) and area (j), the following equation was used:

$$\hat{Y}_{ij} = \frac{\sum_{k=1}^{n_{ij}} y_{ijk}}{n} N, \quad (1)$$

where n is the number of respondents and y the reported harvest per respondent (k). The total population N is computed as:

$$N = \left(\rho_a + \rho_w \frac{\varepsilon_w}{\varepsilon_a} + \rho_d \frac{\varepsilon_d}{\varepsilon_a} + \rho_m \frac{\varepsilon_m}{\varepsilon_a}\right), \quad (2)$$

where ρ is the number of licences issued being valid for a year (a), week (w), or day (d). The number fishing without a licence (m) was computed using the estimated percentage that fished without a valid mandated licence (Table 3), multiplied by the actual number of Danish citizens between age 18 and 65, which on 1 January 2010 was 3 416 369 persons (Agerskov and Bisgaard, 2011). The values were weighted with the fishing effort ε, which, for those holding an annual licence, was derived from the omnibus survey and assumed to be 1 d for those holding a daily licence and 3 d for those holding a weekly licence. All values used can be found in Table 2.

To estimate the standard error of Equation (1), a new variable (y'_{ij}) is defined, where $y'_{ij} = y_{ij}$ if a unit is in the ij domain and 0 otherwise. This means that if a given respondent has not reported any harvest in a given domain then the harvest in that domain is set to zero. The computation is done according to Cochran (1977, p. 37) as:

$$s(\hat{Y}_{ij}) = \frac{Ns'}{\sqrt{n}} \sqrt{1 - \left(\frac{n}{N}\right)}, \quad (3)$$

where s'^2 is calculated as:

$$s'^2 = \frac{1}{N-1} \left(\sum_{ij=1}^{n} y'^2_{ij} - \frac{Y'^2_{ij}}{N}\right). \quad (4)$$

The relative standard error (RSE) was computed as the standard error divided by the estimate. According to the EU Council, the quarterly harvest in each area should be expressed at a level 1 standard. This requires that the 95% confidence level must not exceed $\pm 40\%$ of the estimate, which is identical with an RSE lower than 20.4%.

Results

Licence list survey

In all, 2111 persons holding a passive gear licence were contacted by letter, and of these, 1585 participated in the recall survey with 959 answering via the Internet and 626 via the telephone interview. Only 50 persons refused to participate, but a further 476 persons did not have a telephone number, could not be reached, or could not be interviewed due to language problems. Despite holding a valid licence, 39% answered that they had not fished within the last 12 months. Out of the persons interviewed, a total of 167 fished exclusively with fykenets and 500 fished with gillnets only, whereas 281 fished with both the types of gear. In addition, 11 fishers fished with gear such as traps and shrimp nets, which were not further analysed. In all, 2724 anglers were contacted by letter; 734 did not have a telephone or could not be reached, 61 refused to participate, and 1929 participated in the recall survey. The majority, 1129, answered via the Internet and 800 via the telephone. In all, 73% had been fishing within the last 12 months and cod were caught and kept by 16%.

Omnibus survey

During October, November, and December 2009, a total of 958, 957, and 968 persons was interviewed, respectively. When asked whether they had fished within the last 12 months, 133, 149, and 125, respectively, were identified. Approximately 10% of those fished with passive gear and 90% were anglers. For both anglers and passive gear fishers, approximately half had a licence and half did not. Excluding the group that had a valid reason for not holding a licence, 23 and 28% of all anglers and passive gear fishers, respectively, were estimated to fish without a licence (Table 3). The effort for anglers fishing without a licence was approximately one-third compared with anglers with a licence, whereas the effort was about half when it came to passive gear fishers (Table 2). The percentages that fished in other countries were 2.8, 2.1, and 3.3%, and Sweden plus Norway were by far the most important countries visited (Table 4). The main part of the tourist fishers (~60%) reported only one trip to other countries, although some reported as many as 12.

Estimated harvest

The 2009 harvest of eels in fykenets was estimated to be 104 t (RSE = 13%) with an unequal distribution between areas and quarters. The majority of eels were harvested from August to October and almost half was taken in the Belt Sea (Table 5). The total cod harvest, covering both angling and passive gear fishing, was estimated to be 1231 t year^{-1}. The smallest harvest was in the fykenet fishing, where only 21 t (RSE = 17%) were caught

Table 3. The number of omnibus survey respondents.

Month	Respondents	Category	Question 1	Question 2	Valid reason	Invalid reason	Active fishers (%)	Invalid reason (%)
December	968	Angling	116	58	30	28	12.0	24.1
		Passive gear	9	7	0	2	0.9	22.2
November	957	Angling	132	69	33	30	13.8	22.7
		Passive gear	17	8	2	7	1.8	41.2
October	958	Angling	119	59	34	26	12.4	21.8
		Passive gear	14	8	3	3	1.5	21.4

Questions 1 and 2 show the number of respondents that answered yes to "Have you fished within the last 12 month?" or "Have you been issued with a license?", respectively. If the respondent did not hold a license, they were grouped according to whether they had a valid reason or not. Active fishers are those that have fished, with or without a license, within the last 12 months.

Table 4. The numbers of respondents declaring to angle outside Denmark in the October, November, and December omnibus surveys, respectively.

	October	November	December
Sweden	11 (39 228)	7 (24 989)	16 (56 469)
Norway	9 (32 095)	3 (10 710)	6 (21 176)
Faroe Island	3 (10 698)	2 (7 140)	0 (0)
Greenland	1 (3 566)	0 (0)	2 (7 059)
Rest of Europe	4 (14 265)	3 (10 710)	7 (24 705)
Rest of the world	3 (10 698)	6 (21 419)	5 (17 647)
Numbers that angled outside Denmark	28 (99 852)	20 (71 397)	32 (112 938)

The number in parenthesis is the number of respondents scaled to the Danish population between age 18 and 65, which on 1 January 2010 corresponded to 3 416 369 persons (Agerskov and Bisgaard, 2011).

and kept per year. In the gillnet fishery, it was estimated that 219 t (RSE = 24%) were harvested per year and that the largest part (39%) was taken during the period February to April. In all, 62% of the respondents holding a passive gear licence also angled. When angling, this group harvested 226 t cod per year (RSE = 11%), with the majority taken in the North Sea and Skagerrak. The total harvest of cod in 2009 by passive gear fishers was estimated to be 465 t (RSE = 12%). Anglers with an angling licence harvested the majority, 763.0 t year^{-1} (RSE = 6%), with 31% taken in the Sound. On the most detailed domain level (area and quarter), the RSE was on average 53% and, only in three domains, it was lower than 20%.

Discussion

So far, recreational fishing has in general been considered to be of low efficiency and, therefore, unable to harm or impact the targeted fish stocks. This is exemplified by the fact during the period 1990–2000 only a marginal number of those papers dealing with declines or collapses of fisheries (13 of 4904) in high impact North American journals has dealt with recreational fisheries (Post *et al.*, 2002). There are, however, some indications that recreational fishing can affect the fish population even in the marine environment (Pollock, 1980; Schroeder and Love, 2002; Morales-Nin *et al.*, 2005; Lewin *et al.*, 2006) and it has been suggested that the worldwide harvest from recreational fishing represents 12% of the total fish yield (Cooke and Cowx, 2004). This corresponds well with the present study, where recreational fishing for cod accounted for 4.8% of the total yield (i.e. recreational harvest plus commercial landings), but in some areas was as high as 33% and thus comparable to the landings in the commercial fishery. Similarly, the recreational fishing for eels was found to account for 19% of the total annual yield.

Eel harvest

Eels are almost exclusively caught in fykenets with a total harvest of 104 t in 2009. Since fykenets deployed in salt water are rather sensitive to wave action and current, this fishing is mainly carried out in the inner Danish waters, more specifically in wind- and wave-protected fjords, belts, and sounds. This is reflected in the very low harvest of eels in the North Sea, Skagerrak, and Eastern Baltic. The Belt Sea was the area with the highest harvest of eels, followed by the Kattegat and Limfjord. In a 1997 recall survey, the total annual harvest of eels in the legal recreational fishery was estimated to be 138 t, which at that time corresponded to 20% of the total landings (EC, 2007), a figure very similar to the 19% estimate in the present study. That the harvest only decreased by 34 t was to some extent unexpected, as a couple of factors were thought to have decreased the recreational harvest during the latter years. First, the eel stock has continuously decreased (ICES, 2009) and, second, on 1 February 2009, an eel recovery plan was implemented with the goal of decreasing the effort by 50%. This meant a closure of recreational fykenet fishing from 10 May to 31 July, a period which was earlier known to have a high catch per unit effort (cpue) of eels (Pedersen *et al.*, 2005).

Cod harvest

The present study found that in 2009, a total of 1231 t cod was harvested in the Danish recreational fishing, a quantity corresponding to 4.8% of the total Danish cod yield that year. The recreational cod harvest was, however, very unequally distributed between areas and fishing categories. The main part (81%) of cod was harvested by anglers, whereas the remaining 19% was taken in the passive gear fishing, mainly with gillnets. Annual commercial landings in the Sound [ICES subdivision (SD) 23] have fluctuated around 1900 t (ICES, 2010b) in the period 2003–2008. However, a spatial and temporal closure (to protect cod in the main spawning season) of the Sound commencing in early 2009 reduced the commercial landings to 567 t in that year (ICES, 2010b). Consequently, recreational fishing accounted for 33% of the total Danish cod yield in the Sound and angling alone for 30%. The angling catches might be even higher, since the cod harvest reported in numbers was converted into weight assuming an average mass of 1500 g. The average weight of cod caught and kept by anglers in the Sound is probably somewhat higher at least during winter, when spawning fish are targeted and fish >10 kg are caught regularly. However, although the Sound was the area with the highest total recreational harvest of cod, it does not necessarily reflect an overfishing of the stock. Actually, the Sound cod is considered to be in a relatively healthy condition, with a high cpue and a wide age distribution compared with the adjacent waters (Svedäng *et al.*, 2004; Svedäng *et al.*, 2010). In the western (SD 22–24) and the eastern (SD 25–32) Baltic, Danish commercial fishing for cod accounted for 8438 and 8295 t in 2009, respectively (ICES, 2010b). In this light, recreational fishing was relatively high for the western and minor for the eastern Baltic and accounted for, respectively, 6.9% and <1% of the total cod yield. In the Kattegat, 36.9 t cod were harvested in recreational fishing annually; 33.5 t in angling and 3.3 t from gillnet and fykenet fishing. However, due to the current very low commercial landings (134 t in 2009), the recreational harvest is equivalent to 22% of the total Danish cod yield in this area. That the recreational harvest accounts for the same relative amount of the total yield as observed in the Sound is a result of the low commercial landing for this area rather than a large recreational fishery. Looking at the absolute values, the recreational cod harvest in the Kattegat was tenfold lower than in the Sound.

In the North Sea and Skagerrak, commercial Danish 2009 landings were estimated by ICES to be 4406 and 3018 t, respectively (ICES, 2010c). The catches in the recreational fishing from these areas were estimated to be 196 and 286 t year^{-1}, corresponding to 4.3 and 8.7% of the cod yield in these areas.

The estimated harvests presented here might even be an underestimation of the recreational fishing impact on the stock. Not only the actual harvest should be considered, but also the indirect impact of a raised mortality of those fish caught then released (Cooke and Cowx, 2004; Ferten, 2011).

Table 5. Cod and eel harvest (Y) in t year^{-1} with corresponding RSE.

	Central North Sea			Skagerrak			Limfjorden			Kattegat			The Sound			Belt Sea			Arkona Sea			Eastern Baltic			Total		
	Y	RSE	*h*	*Y*	RSE	*h*	*Y*	RSE	*h*	*Y*	RSE	*h*	*Y*	RSE	*h*	*Y*	RSE	*h*	*Y*	RSE	*h*	*Y*	RSE	*h*	*Y*	RSE	*h*
Eel harvest in fykenets																											
February–April	–	–	0	–	–	0	0.7	57	5	1.6	37	11	0	–	0	7.1	40	25	1.0	56	5	–	–	0	10.4	29	46
May–July	0.3	60	3	0.0	98	1	2.1	65	11	1.2	51	7	0.5	61	4	3.1	44	28	0.7	80	3	0.2	98	1	8.1	26	58
August–October	3.0	56	9	0.7	65	4	9.2	20	40	23.6	45	55	5.5	38	18	32.4	20	143	7.2	26	30	0.8	53	4	82.4	16	303
November–January	0.0	69	2	0.0	98	1	0.3	91	2	0.4	69	3	0.1	73	2	2.3	38	18	0.4	65	4	0.0	98	1	3.5	28	33
Total	3.3	51	14	0.7	61	6	12.3	19	58	26.8	40	76	6.0	35	24	44.9	16	214	9.3	22	42	1.0	46	6	104.4	13	440
Cod harvest in fykenets																											
February–April	–	–	0	–	–	0	0	–	0	0	–	0	0	–	0	1.1	51	4	0.8	98	1	–	–	0	2.0	51	5
May–July	–	–	0	–	–	0	0	–	0	0.0	98	1	0	–	0	0.4	67	3	–	–	0	–	–	0	0.4	64	4
August–October	0.1	98	1	–	–	0	0.4	59	4	2.1	41	15	2.8	44	7	11.0	27	55	0.6	58	4	–	–	0	16.8	20	86
November–January	–	–	0	–	–	0	0	–	0	0	–	0	0	–	0	1.5	44	6	0.0	98	1	–	–	0	1.5	43	7
Total	0.1	98	1	–	–	0	0.4	59	4	2.2	41	16	2.8	44	7	14.0	22	68	1.4	61	6	–	–	0	20.8	17	102
Cod harvest in gillnets																											
February–April	3.5	56	7	44.9	87	14	1.6	98	1	0	–	0	6.9	54	10	12.5	44	23	13.9	53	8	1.0	67	3	84.4	48	66
May–July	2.5	48	7	1.6	58	5	0.3	98	1	0.1	65	3	2.8	39	9	4.3	29	19	2.7	56	6	2.7	43	6	17.0	17	56
August–October	0.4	69	3	30.4	85	7	0.8	61	3	0.5	48	7	3.4	46	11	9.0	34	39	13.3	77	10	4.5	46	7	62.4	45	87
November–January	0.8	73	2	22.2	71	12	0	–	0	0.6	73	3	6.4	50	14	21.0	57	23	3.9	45	8	–	–	0	54.8	37	62
Total	7.2	33	19	99.1	50	38	2.6	63	5	1.2	40	13	19.6	27	44	46.8	29	104	33.9	38	32	8.3	30	16	218.6	24	271
Cod harvest angling with a passive gear license																											
February–April	6.3	35	10	22.9	58	20	0	–	0	0.5	64	3	6.3	26	27	5.8	39	24	5.1	41	10	6.9	61	7	53.8	27	101
May–July	10.5	34	23	17.0	28	19	0	–	0	2.8	59	7	4.6	28	17	5.5	29	27	10.3	44	12	9.0	54	9	59.7	15	114
August–October	31.4	51	23	16.9	37	19	0	–	0	0.9	52	6	9.4	26	35	7.2	25	39	9.8	37	12	5.6	47	9	81.3	22	143
November–January	4.8	47	6	9.9	44	12	0	–	0	0.7	83	2	4.8	27	23	6.2	24	31	1.3	69	2	3.2	48	5	30.9	18	81
Total	53.1	32	62	66.7	24	70	0	–	0	4.9	38	18	25.1	14	102	24.7	15	121	26.6	24	36	24.6	29	30	225.8	11	439
Total cod harvest on passive gear license																											
February–April	9.8	30	17	67.8	60	34	1.6	98	1	0.5	64	3	13.2	31	37	19.5	30	51	19.9	39	19	7.9	54	10	140.2	30	172
May–July	12.9	29	30	18.7	26	24	0.3	98	1	3.0	56	11	7.4	23	26	10.2	20	49	13.1	37	18	11.8	42	15	77.2	12	174
August–October	31.9	51	27	47.3	56	26	1.1	46	7	3.5	29	28	15.6	20	53	27.2	17	133	23.8	46	26	10.1	33	16	160.6	21	316
November–January	5.6	42	8	32.1	51	24	0	–	0	1.3	57	5	11.3	31	37	28.7	42	60	5.2	37	11	3.2	48	5	87.2	24	150
Total	60.3	28	82	165.8	31	108	3.0	56	9	8.3	25	47	47.5	13	153	85.5	17	293	61.9	23	74	32.9	23	46	465.2	12	812
Cod harvest angling with a angling license																											
February–April	31.6	28	16	40.2	33	18	–	–	0	3.9	65	4	71.6	18	73	34.7	41	24	10.7	58	5	6.1	37	14	198.9	13	154
May–July	27.1	31	16	37.3	28	19	0.4	100	1	9.9	38	12	58.9	20	55	40.9	42	27	12.3	49	8	18.4	41	14	205.2	13	152
August–October	45.2	30	17	27.8	27	22	0.2	100	1	10.9	36	16	41.6	17	56	38.5	25	39	14.8	57	7	18.0	50	14	197.0	12	172
November–January	32.1	44	9	14.8	48	6	0.3	100	1	3.9	55	6	61.5	22	64	40.7	35	31	7.4	47	6	3.8	34	14	164.4	15	137
Total	136.0	17	58	120.1	16	65	0.9	60	3	28.6	22	38	233.6	10	248	154.8	18	121	45.0	28	26	46.3	26	56	765.4	6	615

The number of respondents that reported a harvest within a given domain is denoted h.

Sources of errors

Relying on respondents' ability to remember catches or effort within a specific period is subject to several sources of bias, such as digit preference, telescoping, non-response bias, and rule-based estimation. Digit preference is when the respondent will have a tendency for rounding figures to 0 or 5, a tendency that typically will increase with increasing recalling period (Huttenlocher *et al.*, 1990; Tarrant and Manfredo, 1993). In this study, we did see a tendency for some digit preference, especially when reporting the harvest in weight, but whether this would increase or decrease the total estimated harvest is difficult to decide. Telescoping is when respondents report an event, such as the capture of a trophy fish, although it actually happened outside the time frame asked. This could mean an overestimation, especially in the angling harvest of cod, where some trophy fishing takes place. The bias introduced by non-response emerges as the fishers with the lowest participation rate will have the highest non-response rate (Tarrant and Manfredo, 1993), but since the non-response rate in the present survey was low, this is not likely to have caused any major problems. Another potential source of bias is recall bias where the respondents are unable to recall their catches and effort correctly. This is partly due to a general tendency to exaggerate the participation rates in recreational events, including among fishing (Tarrant *et al.*, 1993). This over-estimation of the participation rate can indirectly lead to an over-estimation of the harvest, if a rule (multiples) is applied by the respondent when trying to remember the catches during a given time frame. Typically, an average catch per trip is memorized then multiplied by the assumed number of trips (Vaske *et al.*, 2003). For fishing, it has been estimated that the effort was over-estimated by 45% in a 12-month recall period compared with diaries (Connelly and Brown, 1995), and hence, this could impose a large overestimation in the present study, especially for the passive gear fishing, where several fish are typically caught during one single fishing event. This should be investigated further, e.g. as suggested by the ICES Planning Group on Recreational Fisheries (ICES, 2010a) by a dual frame approach where recall surveys are supported by either diaries or on-site surveys, such as access point interception or aerial-based counting (Vølstad *et al.*, 2006).

Finally, an important source of errors can emerge while using a mean fish size to transform the harvest reported in numbers into weights. In the present study, we used one single species-specific average weight for all areas/quarters, although the minimum landing size differs between areas and the average weight will probably also fluctuate between seasons. For eels, the minimum landing size is 38 cm except for the Limfjord, where the size is 35.5 cm. However, this is unlikely to make any changes, as the weight difference between these two sizes is only 20 g. For cod, the minimum landing size is 30 cm in the Skagerrak/Kattegat, 35 cm in the North Sea, and 38 cm elsewhere. These rather large differences can potentially become a source of error and are a subject that could ideally be investigated using a diary survey approach.

Although several biases might appear in the type of recall surveys presented here, the margin between respondents claiming to have a valid licence and the actual number of licences issued was very small. In 2009, the preliminary number of licences issued—including week and day licences—was 230 000, which is close to the 229 000–275 000 estimated in the omnibus survey.

The angler recall survey targets only Danish citizens, and if the tourist harvest was to be examined, it would require an alternative survey approach (Vølstad *et al.*, 2011). In our study, around 3% of the Danes interviewed had fished as tourists in other countries, especially Sweden, which is very close and easily accessible. There is no precise estimation of the number of tourists travelling to Denmark to fish, but the potential number of angling tourists is high. In Germany, there are around 3 300 000 anglers (Anon., 2007) and of the Berlin–Brandenburg population around half claimed to have been on an angling holiday within the last year (Arlinghaus *et al.*, 2008).

When estimating the harvest, the precision for the passive gear estimates was, in general, lower than for angling. When computing the RSE, it is assumed that the population sampled is infinitely large compared with the sampling size, and if this assumption is not met, then the RSE tends to be overestimated. However, as long as the number of respondents does not exceed 5% of the population surveyed, the finite population correction can be ignored and the overestimation will be minor (Cochran, 1977, p. 24). Less than 1% of the total number of anglers was included in the survey, but for passive gear fishers, 4.6% of the population was actually sampled. Hence, at least some of the higher RSE is caused by the estimation method that does not include finite population corrections. The heterogeneity of anglers and their behaviour patterns are unquestionably important and have been investigated in several papers (Arlinghaus *et al.*, 2008; Johnston *et al.*, 2010), but whether these results can be applied to passive gear fishers is not known.

Conclusion

Using a licence list recall survey and including those fishers that were fishing without licence showed that the recreational harvest was, in some areas, comparable with commercial landings. This is partly a result of decreasing commercial landings, rather more than it actually illustrates the magnitude of the recreational fishery. Nevertheless, it exemplifies that especially when stocks are overfished and below their natural size, fishing mortality caused by recreational fishing can be an important factor that should be accounted for in the stock assessment, recovery plans, and ecosystem bases management. The harvest of fishers without a valid licence was important, as it increased the estimated harvests by 20%. Hence, recall surveys designed to estimate harvest and catches should not only be based on the fishing licence list but also include those fishing without the mandatory licence.

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References

Agerskov, U., and Bisgaard, M. P. 2011. Statistical Yearbook. www.dst.dk/yearbook.

Anon. 2007. The German recreational fisheries' cod catch in the Baltic and North Seas, 2004–2006. Report of a Pilot Study in Support of

the National Fisheries Data Collection Programme Corresponding to Commission Regulation (EC) No 1581/2004, 7. Appendix XI (Section E), para.3.

Arlinghaus, R., Bork, M., and Fladung, E. 2008. Understanding the heterogeneity of recreational anglers across an urban-rural gradient in a metropolitan area (Berlin, Germany), with implications for fisheries management. Fisheries Research, 92: 53–62.

Bohn, J., and Roth, E. 1997. Survey on angling in Denmark 1997—results and comments. *In* Socio-Economics of Recreational Fishery, pp. 79–88. Ed. by A.-L. Toivonen, and P. Tuumaimem. Nordic Council of Ministers, Temanord, Copenhagen. 106 pp.

Cochran, W. G. 1977. Sampling Techniques, 3rd edn. Wiley, New York. 428 pp.

Coleman, F. C., Figueira, W. F., Ueland, J. S., and Crowder, L. B. 2004. The impact of United States Recreational Fisheries on marine fish populations. Science, 305: 1958–1960.

Connelly, N. A., and Brown, T. L. 1995. Use of angler diaries to examine biases associated with 12-month recall on mail questionnaires. Transactions of the American Fisheries Society, 124: 314–422.

Cooke, S. J., and Cowx, I. G. 2004. The role of recreational fishing in a global fish crisis. BioScience, 54: 857–859.

EC. 2007. Council Regulation (EC) No 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel. Official Journal of the European Union, L248/17.

EC. 2008. Council Regulation (EC) No 199/2008 of 25 February 2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy. Official Journal of the European Union, L60/1.

Ferten, K. 2011. Marine Angling Tourism in Norway: the interactions between behavior, management and catch. MSc thesis, University of Bergen, Bergen. 89 pp.

Huttenlocher, D., Hedges, L. V., and Bradburn, N. M. 1990. Reports of elapsed time: bounding and rounding processes in estimation. Journal of Experimental Psychology: Learning, Memory and Cognition, 16: 196–213.

ICES. 2009. Report of the 2009 Session of the Joint EIFAC/ICES Working Group on Eels. ICES Document CM 2009/ACOM: 15. 540 pp.

ICES. 2010a. Report of the Planning Group on Recreational Fisheries. ICES Document CM 2010/ACOM: 34. 162 pp.

ICES. 2010b. Report of the Baltic Fisheries Assessment Working Group. ICES Document CM 2009/ACOM: 07. 621 pp.

ICES. 2010c. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak. ICES Document CM 2010/ACOM: 13. 1048 pp.

Johnston, F. D., Arlinghaus, R., and Dieckmann, U. 2010. Diversity and complexity of angler behavior drive socially optimal input and output regulations in a bioeconomic recreational-fisheries model. Canadian Journal of Fisheries and Aquatic Sciences, 67: 1507–1531.

Lewin, W-C., Arlinghaus, R., and Mehner, T. 2006. Documented and potential biological impacts of recreational fishing: insights for management and conservation. Reviews in Fisheries Science, 14: 305–367.

Lyle, J., Coleman, A. P. M., West, L., Campbell, D., and Henry, G. W. 2002. New large-scaled survey methods for evaluating sport fisheries. *In* Recreational Fisheries: Ecological, Economic and Social Evaluation, pp. 207–226. Ed. by T. J. Pitcher, and C. Hollingworth. Blackwell Publishing, Oxford. 288 pp.

Morales-Nin, B., Moranta, J., García, C., Tugores, M. P., Grau, A. M., Riera, F., and Cerdà, M. 2005. The recreational fishery off Majorca Island (western Mediterranean): some implications for coastal resource management. ICES Journal of Marine Science, 62: 727–739.

Pawson, M. G., Glenn, H., and Padda, G. 2008. The definition of marine recreational fishing in Europe. Marine Policy, 32: 339–350.

Pedersen, S. A., Støttrup, J., Sparrevohn, C. R., and Nicolajsen, H. 2005. Registreringer af fangster i indre danske farvande 2002, 2003 og 2004 – slutrapport in series. DFU-rapport, Danmarks Fiskeriundersøgelser, Charlottenlund. 149 pp. (in Danish).

Pollock, B. 1980. Surprises in the Queensland angling study. Australian Fisheries, 39: 17–19.

Post, J. R., Sullivan, M., Cox, S., Lester, N. P., Walters, C. J., Parkinson, E. A., Paul, A. J., *et al.* 2002. Canada's recreational fisheries: the invisible collapse? Fisheries, 27: 6–17.

Rasmussen, G., and Geertz-Hansen, P. 2001. Fisheries management in inland and coastal waters in Denmark from 1987 to 1999. Fisheries Management and Ecology, 8: 311–322.

Roth, E., Toivonen, A. L., Navrud, S., Bengtsson, B., Gudbergsson, G., Tuunainen, P., Appelblad, H., *et al.* 2001. Methodological, conceptual and sampling practices in the surveying of recreational fisheries in the Nordic countries—experiences of a validation survey. Fisheries Management and Ecology, 8: 355–367.

Schroeder, D. M., and Love, M. S. 2002. Recreational fishing and marine fish populations in California. CalCOFI Reports, 43: 182–190.

Sparrevohn, C. R., Nicolajsen, H., Kristensen, L., and Støttrup, J. G. 2009. Registrering af fangster i de danske kystområder med standardredskaber fra 2005–2007. Nøglefiskerrapporten 2005–2007. DTU Aqua-Rapport, DTU Aqua, Charlottenlund. 72 pp. (in Danish). ISSN: 1395-8216, ISBN: 978-87-7481-110-7.

Sparrevohn, C. R., and Storr-Paulsen, M. 2010. Eel and cod catches in Danish recreational fishing: survey design and 2009 catches. DTU Aqua-Report, DTU Aqua, Charlottenlund. 23 pp. ISSN: 1395-8216, ISBN: 978-87-7481-110-7.

Svedäng, H., Hagberg, J., Börjesson, P., Svensson, A., and Vitale, F. 2004. Bottomfisk i Västerhavet. Fiskeriverkets havsfiskelaboratorium, 6. 46 pp. (in Swedish).

Svedäng, H., Stål, J., Sterner, T., and Cardinale, M. 2010. Consequences of subpopulation structure on Fisheries Management: cod (*Gadus morhua*) in the Kattegat and Øresund (North Sea). Reviews in Fisheries Science, 18: 139–150.

Tarrant, M. A., and Manfredo, M. J. 1993. Digit preference, recall bias and nonresponse bias in self reports of angling participation. Leisure Sciences, 15: 231–238.

Tarrant, M. A., Manfredo, M. J., Bayley, P. B., and Hess, R. 1993. Effects of recall bias and nonresponse bias on self-report estimates of angling participation. North American Journal of Fisheries Management, 13: 217–222.

Toivonen, A-L., Roth, E., Navrud, S., Gudbergsson, G., Appelblad, H., Bengtsson, B., and Tuunainen, P. 2004. The economic value of recreational fisheries in the Nordic countries. Fisheries Management and Ecology, 11: 1–14.

Vaske, J., Huan, T. C., and Beaman, J. 2003. The use of multiples in anglers' recall of participation and harvest estimates: some results and implications. Leisure Sciences, 25: 399–409.

Vølstad, J. H., Korsbrekke, K., Nedreaas, K., Nilsen, M., Nilsson, G. N., Pennington, M., Subbey, S., *et al.* 2011. Probability-based surveying using self-sampling to estimate catch and effort in Norway's coastal tourist fishery. ICES Journal of Marine Science, doi:10.1093/icesjms/fsr077.

Vølstad, J. H., Pollock, K. H., and Richus, W. 2006. Comparing and combining effort and catch estimates from aerial-access designs, with applications to a large-scale angler survey in the Delaware River. North American Journal of Fisheries Management, 26: 727–741.

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