Changes in angler demography and angling patterns during the Covid-19 lockdown in spring 2020 measured through a citizen science platform

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ABSTRACT

From 11 March to end of May 2020 a lockdown was imposed in Denmark due to the Covid-19 outbreak. Concurrently a 20% increase in sales of mandatory national angling licenses was reported in Denmark, suggesting an increase in angling participation. Here, we use data collected from a citizen science platform for recreational anglers to a) explore whether the increase in participation affected multiple characteristics of the anglers that registered to the citizen science platform in spring 2020, and b) explore changes in angling effort and catch patterns during the lockdown as reported to the platform. The results indicate that the platform was able to detect changes in the characteristics of the participants in the Danish recreational angling during the Covid-19 lockdown, i.e. participants were younger, more likely to live in urban areas, less experienced, stated angling as a less important hobby, and less likely to be from outside of Denmark. The spring 2020 participants did not conduct more fishing trips compared to previous years, but their effort patterns differed. The effort patterns revealed a shift in fishing activity from weekend to weekday and, during the day, a shift in fishing activity from midday to early evening. These changes most likely reflect the extraordinary conditions that most Danes experienced during the lockdown. We found relatively lower catch rates and a trend towards retaining more fish, among the participants that registered in spring 2020. The results are discussed in relation to biological implications and lessons learned about data collection from citizen science platforms.

1. Introduction

Recreational fishing is an important leisure activity for many people, and takes place in many marine and freshwater areas [1,2]. The importance of recreational fishing as a fisheries sector is illustrated by the considerable socioeconomic benefits it can provide, but also the potential negative impacts on ecosystems and fish populations (e.g., [1–3]). Benefits and impacts from recreational fishing, such as angling, is likely to be affected by changes in participation patterns. Participation is likely to vary in time and space as it is influenced by multiple factors, such as changes in population demography, fishing quality, and societal-level development (e.g., [4–6]).

During spring 2020, Denmark was locked down due to the Covid-19 outbreak. On 11 March 2020 the Danish Prime Minister ordered citizens working in the public sector with non-essential functions to stay at home and employers in the private sector were urged to allow their employees to work from home if possible. In addition, all daycare, primary school, secondary education, universities, libraries, indoor cultural institutions and similar places, were closed for a period during spring. The borders to

Denmark were also closed, effectively preventing international traveling for a prolonged period. Most of these initiatives prevailed until mid-April 2020 where a slow and gradual reopening of the country was initiated. Clearly, the Covid-19 outbreak caused an abrupt and immediate change in the life patterns of Danish citizens. One potential result of these changes was an increase in angling participation among the Danish citizens, documented by a 20% increase in the sale of the mandatory national fishing license in spring (i.e., March, April and May) 2020 compared to the same period in 2018 and 2019 [7]. Little is known about the demography, and angling behavior of these additional anglers.

Data from anglers can be collected in many ways, such as offsite surveys conducted using the internet or onsite surveys where anglers are interviewed in person (e.g., [8]). More recently, citizen science projects in combination with electronic platforms, including smartphone applications (apps; e.g., [9]), have emerged. Here, citizen scientists can share data about fishing trips and catches with researchers and managers and in return get a variety of potential benefits [9]. One example is from Denmark, where the citizen science program Fangstjournalen since 2016 has encouraged Danish anglers to submit information about their

fishing trips (e.g., [10]). Recruitment of anglers to the platform has been continuous since January 2016 and by December 2020, close to 13.000 anglers have registered as participants on the platform. However, only ∼ 1200 different participants have, on average, been active per year (i. e., contributed with data). Still, the active participants have on average submitted ∼ 10.000 fishing trips per year which, at least for some fisheries, have provided a useful database to explore different aspects of recreational fisheries [11]. During the Covid-19 pandemic traditional data collection activities, especially onsite surveys, may have been impaired in many regions or countries, e.g. due to travel restrictions of clerks/inspectors or public offices being locked down. Hence, alternative data sources, such as citizen science data, have become increasingly important.

This study aims to further our knowledge about characteristics of the new anglers that entered the Danish recreational fishery during the Covid-19 lockdown in spring 2020 and, additionally, to provide insights into the usefulness of data collection from citizen science platforms. First, we explore characteristics of the participants that registered to the citizen science platform Fangstjournalen during the Covid-19 lockdown in spring 2020, i.e. a period with a 20% increase in license sales. We do this by comparing user demographics and importance of angling as a hobby of the participants that were registered during the Covid-19 lockdown in Denmark (i.e., spring 2020) to participants that were registered during the same period in the three previous years. We hypothesize that the participants registered in spring 2020 have a higher share of relatively inexperienced participants compared to participants registered in spring 2017, 2018, and 2019. Further, we explore whether data collection patterns could be affected by a subsequent change in participant characteristics caused by the Covid-19 lockdown. Again, we approach this by comparing the demographics and importance of angling as a hobby between participants registered in spring 2017, 2018, 2019, and 2020, but this time only for the subset of anglers who provided data from their fishing trips. Potential differences between the overall population of participants and the data providers could be an indicator of potential biases in data collection. Second, we explore if patterns of angling effort and catch, as reported to the citizen science platform, changed during the Covid-19 lockdown period in spring 2020, compared to spring 2017, 2018, and 2019. Since a large proportion of Danes worked from home during the lockdown period, we hypothesize that angling activity in general would increase and that daily effort patterns would change e.g. a shift in effort from weekends to weekdays. We also hypothesize that a potential increase in recruitment of more inexperienced anglers in 2020 could be reflected in catch rates and harvest patterns.

2. Materials and methods

2.1. The citizen science platform Fangstjournalen

Fangstjournalen (https://fangstjournalen.dtu.dk/) is a Danish citizen science program, where anglers can register information from their fishing trips. Fangstjournalen operates on a platform that primarily works as an angling logbook. The platform can be accessed via a webpage or a smartphone app. To join the citizen science program anglers must register on the platform. Upon registration, participants are asked to enter demographics (e.g., age and place of residence) and items related to angler psychology and angling experience (e.g., importance of angling as a hobby and years spent angling). Apart from place of residence it is optional to provide these data. The platform automatically logs the date of registration. After the registration, participants have the possibility to register their fishing trips. In these registered trips, the participants can state details of their catch (e.g., number of fish caught and number of fish released) and effort (e.g., date and hours spent fishing). The Fangstjournalen smartphone app is available in Danish and also German and English languages and hence available for Danish anglers and international angling tourists.

2.2. Statistical analysis

First, participants who joined the "Fangstjournalen" platform in the period 11 March to 31 May in 2017, 2018, 2019, and 2020, corresponding to the Covid-19 lockdown period in spring 2020, were identified. This made it possible to compare characteristics of participants who registered during the Covid-19 lockdown (henceforth spring 2020) to characteristics of participants who registered within the same period in 2017, 2018, and 2019 (henceforth spring 2017, 2018, and 2019). Next, angling experience, demographics, and importance of angling as a hobby for all new participants and subsequently for the subset of participants who provided data from their fishing trips were compared. Finally, various patterns of angling effort and catch, from the fishing trip data, were explored.

2.2.1. Angling experience and demographics

Angling experience was estimated as the proportion of a participants' lifetime where angling was a hobby. This was calculated by dividing years since first angling experience by age, i.e. information stated by the participants upon recruiting to the platform. We compared angling experience of participants recruited in spring 2020 to participants recruited in spring 2017, 2018, and 2019 using a generalized linear model (GLM) following a binomial distribution with a logit link.

With regards to demography, the variables nationality, age, gender, and place of residence was compared between participants recruited in spring 2020 and participants recruited in spring 2017, 2018, and 2019. Nationality was explored by comparing the shares of Danish and foreign participants in the different years. For Danish participants, the comparison also included age, gender, and place of residence. Due to data limitations, it was not possible to make similar comparisons for foreign anglers. Age was compared between participants in the different years using linear models and gender was compared using logistic regression. In relation to place of residence, the probability of participants living in rural or urban areas, was investigated using logistic regression. Urban areas were defined as being the municipalities of the four largest cities in Denmark (i.e., Copenhagen, Aarhus, Odense, and Aalborg). The rest of Denmark was considered rural.

2.2.2. Importance of angling

The comparison of importance of angling as a hobby, between participants in the different years, was based on the answers to the question: "How important is angling as a hobby", which were presented on a Lickert scale (e.g., [12]) from one (low importance) to ten (high importance). Importance of angling as a hobby was compared using ordinal logistic regression.

2.2.3. Data providers

Only a subset of the anglers who sign up for the citizen science platform provide data from their fishing trips, i.e. ∼ 25%. To explore whether potential changes in participant characteristics, in spring 2020, also could influence data collection from the citizen science platform, demographics, experience, and importance of angling as a hobby was compared between the subset of users who provided data after registration in the different years. This was done using the same approaches as described above, i.e. used to analyze all the participants recruited in spring 2017, 2018, 2019, and 2020. Data providers were defined as those who registered at least one fishing trip in the period 11 March to 31th May.

2.2.4. Angling effort and catch patterns

Aspects of angling effort for fishing trips conducted during the Covid-19 lockdown period (11 March 2020–31 May 2020) by the data providers recruited in spring 2020 was compared for fishing trips conducted within the same periods in 2017, 2018 and 2019, by data providers recruited in spring 2017, 2018, and 2019. The average number of fishing trips conducted by the data providers was compared using a GLM

following a negative binomial distribution with a log link, to account for overdispersion. Next, daily effort patterns, i.e. the probability of a fishing trip being conducted in either weekend or weekday, was compared using logistic regression. Finally, hourly effort patterns were inspected using the relative hourly effort calculated for each hour within the day (i.e., from 01:00–24:00), for both weekdays and weekends.

Catch patterns, here referring to catch rates (i.e., fish per trip) and voluntary release rates (i.e., proportion of fish released that were eligible for harvesting) were compared between data providers recruited in spring 2020 and data providers recruited in spring 2017, 2018, and 2019. In order to secure a sufficient and consistent data set for these comparisons, only catch rates and voluntary release rates for sea trout (*Salmo trutta*) were investigated, as it is the most popular species to fish for in Denmark [13] and the most prevalent target species reported on the platform [10]. Catch rates for fishing trips conducted in the period 11 March to 31 May, were compared between data providers recruited in spring 2020 and data providers recruited in spring 2017, 2018, and 2019, using a GLM following a negative binomial distribution with a log link. As potential differences in catch rates between data providers could be a result of yearly variation (e.g., changes in fish abundance or catchability), the catch rate comparison was extended to include all data providers on the platform (i.e., participants that were recruited outside of spring in either of the years, but were fishing within the period 11 March to 31 May in 2017, 2018, 2019, and 2020, respectively). This made it possible to compare catch rates of the "new" participants recruited in spring, in the given years, with "older" (and maybe more experienced) participants, which in turn gives a relative assessment of catch rate levels. Catch rates between "new" and "older" participants in 2017, 2018, 2019, and 2020 was compared using GLMs following a negative binomial distribution with a log link. For the voluntary release rates the fraction of released sea trout that was available for harvest was compared between data providers recruited in spring 2020 and participants recruited in spring 2017, 2018, and 2019. Voluntary release rates were compared using a GLM following a binomial distribution with a logit link.

All statistical analyses were conducted in R version 3.6.1 [14], using MASS [15], tidyverse [16], and ggplot2 [17] R packages.

3. Results

3.1. Angling experience and demographics

Seven hundred and six new Danish participants and 20 international participants (i.e., postal code outside Denmark) registered with the citizen science platform in spring 2020 (Table 1). For Danish participants, it was slightly more compared to spring 2019, but less than in spring 2017 and 2018 (Table 1) For international users, the number of new participants were $\sim$ 60–80 in spring 2017, 2018, and 2019, while it dropped markedly to 20 during the Covid-19 lockdown in spring 2020 (Table 1). Due to the low number of international participants in 2020 this paper only focus on Danish participants.

There was a significant difference in angler experience between years (df $=$ 3, LRT $=$ 465.9, p $<$ 0.001; Fig. 1). Post-hoc analysis revealed that the participants recruited in spring 2020 had significantly less angling experience ($\sim$ 10%) compared to the participants recruited in spring 2017 (z $=$ 20.9, p $<$ 0.001), 2018 (z $=$ 14.6, p $<$ 0.001), and 2019 (z $=$ 15.9, p $<$ 0.001). Between 56% and 73% of the participants filled out this information upon registration (Table 1).

There were also differences in age between years (df $=$ 3, F $=$ 56.4, p $<$ 0.001; Fig. 2) and post-hoc analysis revealed that the participants recruited in spring 2020 were significantly younger (5–10 years) compared to the participants recruited in spring 2017 (t $=$ 13.0, p $<$ 0.001), 2018 (t $=$ 6.7, p $<$ 0.001), and 2019 (t $=$ 5.5, p $<$ 0.001).

No differences were found in relation to gender (df $=$ 3, LRT $=$ 5.16, p $=$ 0.16). Between 80% and 97% of the participants provided this information upon registration (Table 1). In the comparison of place of residence, we found significant differences (df $=$ 3, LRT $=$ 12.0, p $=$ 0.007; Fig. 3) and post-hoc analysis revealed that the participants recruited in spring 2020 were more likely ($\sim$7%) to be from urban areas compared to the participants recruited in spring 2017 (z $=$ -2.8, p $=$ 0.006), 2018 (z $=$ -2.89, p $=$ 0.004), and 2019 (z $=$ -2.7, p $=$ 0.006). It was mandatory to provide postal code upon registration so all participants provided this information (Table 1).

3.2. Importance of angling

In the comparison of the importance of angling as a hobby, there was also significant differences between years (df $=$ 3, LRT $=$ 39.7, p $<$ 0.001; Fig. 4). The participants recruited in spring 2020 stated that they considered angling as a significantly less important hobby compared to participants recruited in spring 2017 (t $=$ 6.3, p $<$ 0.001), 2018 (t $=$ 3.9, p $<$ 0.001), and 2019 (t $=$ 3.3, p $=$ 0.001). The response rates, i.e. participants who answered this question upon registration varied between 57% and 74% (Table 1).

3.3. Data providers

When exploring differences between years among the subset of anglers who actually contributed with data, the differences found among all new participants (presented above) were less pronounced or disappeared entirely. There was no differences in place of residence (df $=$ 3, LRT $=$ 4.40, p $=$ 0.22) or gender (df $=$ 3, LRT $=$ 4.6, p $=$ 0.20). Differences in importance of angling as a hobby were significant between years but only at a 90% significance level (df $=$ 3, LRT $=$ 7.4, p $=$ 0.06; Fig. 5; Table 2). Post-hoc analysis revealed that data providers in 2020 placed less importance to angling as a hobby compared to data providers in 2017 (t $=$ 2.55, p $=$ 0.01), while no differences were observed when compared to data providers from 2018 (t $=$ 0.95, p $=$ 0.34) or 2019 (t $=$ 1.16, p $=$ 0.25). For age there was an overall difference between years (df $=$ 3, F $=$ 13.39, p $<$ 0.001), and post-hoc analyses revealed that the only difference was between 2020 and 2017 with data providers from 2020 being significantly younger (t $=$ 5.1, p $<$ 0.001). No difference in age was found when 2020 was compared to 2018 (t $=$ 1.2, p $=$ 0.21) or 2019 (t $=$ 0.49, p $=$ 0.61).

Table 1

Overview of the number of Danish and international participants who registered to the citizen science platform during spring 2017, 2018, 2019, and during the Covid-19 lockdown in spring 2020. The number and response rate, in parentheses, of participants who provided data about angler characteristics during registration is also shown.

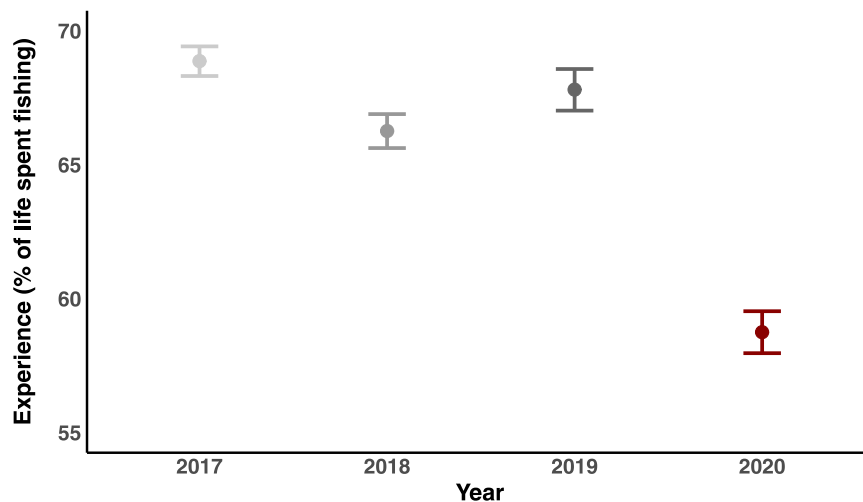|	Spring 2017	Spring 2018	Spring 2019	Spring 2020
Danes	757	788	547	706
International	61	79	71	20
Age	678 (90%)	666 (85%)	467 (85%)	568 (80%)
Gender	737 (97%)	749 (95%)	517 (95%)	662 (94%)
Place of residence	757 (100%)	788 (100%)	547 (100%)	706 (100%)
Experience	552 (73%)	485 (62%)	321 (59%)	395 (56%)
Importance of angling as a hobby	559 (74%)	478 (61%)	326 (60%)	402 (57%)

Fig. 1. Angling experience of participants registered in the period 11 March to 31 May 2017, 2018, 2019, and 2020. Angling experience is calculated as the proportion of lifetime spent fishing, by dividing years spent fishing by age. The dots represent mean experience, while the bars are a 95% confidence interval for the estimate.
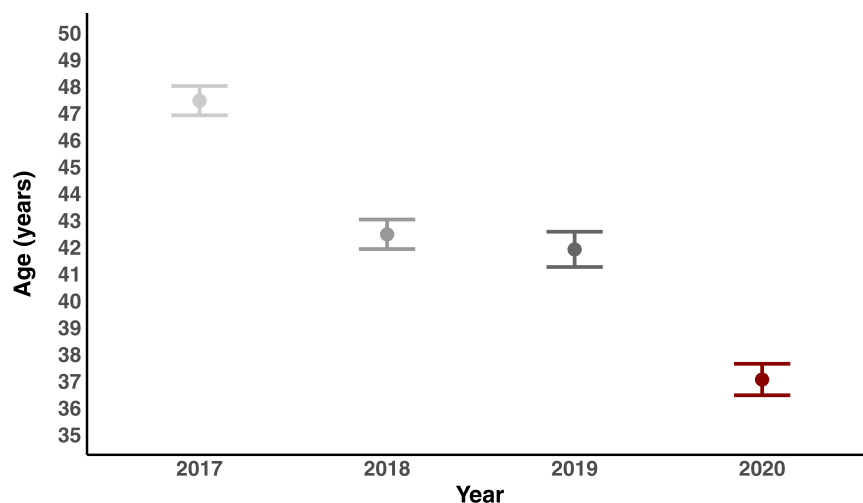

Fig. 2. Age of participants registered in the period 11 March to 31 May 2017, 2018, 2019, and 2020. The dots represent mean age, while the bars are a 95% confidence interval for the estimate.

The only difference that clearly prevailed among data providers compared to the total population of new users was in angler experience (df = 3, LRT = 26.7, p < 0.001; Fig. 6) where post-hoc analyses revealed that data providers from 2020 were significantly less experienced compared to data providers from 2017 (z = 4.8, p < 0.001), 2018 (z = 3.2, p = 0.001), and 2019 (z = 1.7, p = 0.09). However, the differences were clearly smaller among the data providers (Fig. 6) compared to all participants (Fig. 1). Response rates for the data providers on the questions for demographics and importance of angling as a hobby varied between 69% and 98% (Table 2).

3.4. Angling effort and catch patterns

No difference in number of fishing trips, across target species, was found between participants recruited in spring 2020 and participants recruited in spring 2017, 2018, and 2019 (df = 3, LRT = 2.6, p = 0.45). Based on the data providers who reported fishing trips (i.e., 17–35% of the recruited participants), the average number of fishing trips per participant between years were stable (i.e., ~ 3.5 fishing trips per participant within the period). In the comparison of daily effort (i.e., weekdays and weekends), we found a significant difference at a 90%

significance level (df = 3, LRT = 6.5, p = 0.09; Fig. 7).

Post-hoc analysis revealed that a higher proportion of participants recruited in spring 2020 were fishing on weekdays compared to participants recruited in spring 2017 (z = 2.5, p = 0.01), 2018 (z = 1.9, p = 0.05), and 2019 (z = 1.7, p = 0.09). When exploring hourly effort, i. e. when during the day participants went angling, participants recruited in spring 2020 had a different hourly effort distribution compared to participants recruited in spring 2017, 2018, and 2019, on weekdays (Fig. 8a) and on weekends (Fig. 8b). Based on visual inspections of the patterns, it seems clear that effort on weekdays peaked at around 19:00 for participants recruited in spring 2020, while it was earlier for participants recruited in spring 2017, 2018, and 2019.

Another tendency is that weekday effort for participants recruited in spring 2020 is lower around midday (i.e., 11:00–15:00) compared to participants recruited in spring 2017 and 2018. In weekends, the effort for participants recruited in spring 2020 also peaks later in the day (i.e., 13:00 – 14:00) compared to the participants recruited in spring 2017, 2018, and 2019 (i.e., 10:00–12:00). Additionally, the participants recruited in spring 2020 generally have lower weekend effort in the period from 08:00–12:00 and higher effort in period from 18:00–22:00, compared to participants recruited in spring 2017, 2018, and 2019.
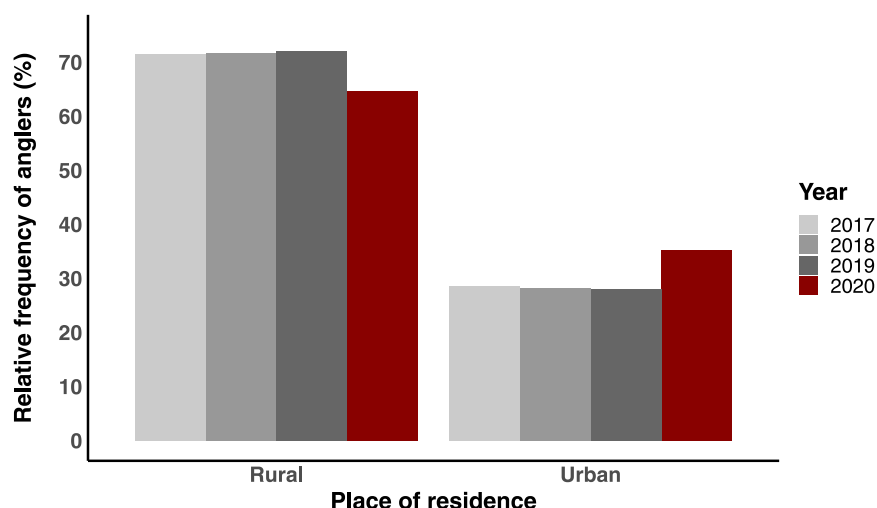
Fig. 3. Residence of participants registered in the period 11 March to 31 May 2017, 2018, 2019, and 2020. Urban refers to the municipalities of the four largest cities in Denmark, namely Copenhagen, Aarhus, Odense, and Aalborg, while rural refers to the rest of Denmark. The bars display the relative frequency of anglers living in either urban or rural Denmark.
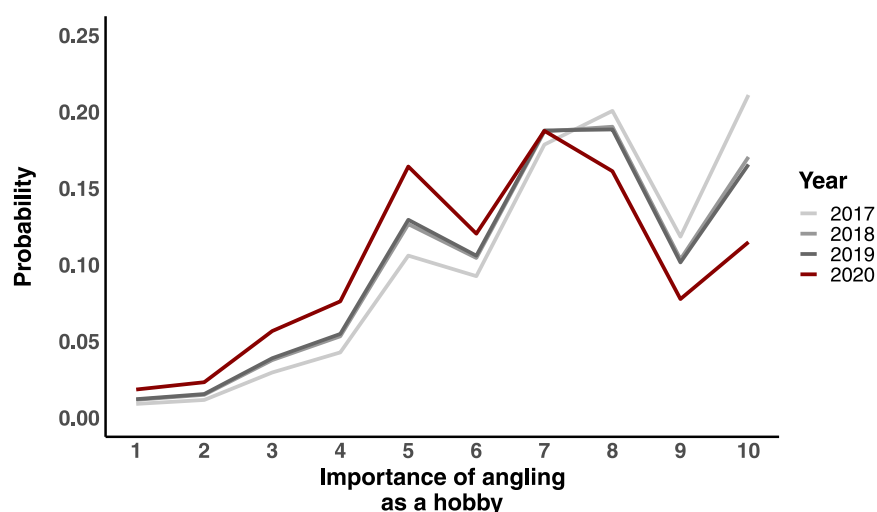

Fig. 4. Output from an ordinal logistic regression model that estimates the probability of stating importance of angling as a hobby, on a Lickert-scale from one (not important) to ten (most important), for participants registered in the period 11 March to 31 May 2017, 2018, 2019, and 2020.

There was a significant difference in catch rates of sea trout between participants recruited in spring 2020 and participants recruited in spring 2017, 2018, and 2019 (df = 3, LRT = 36.9, p < 0.001, Table 3). Post-hoc analysis revealed that participants recruited in spring 2020 had significantly lower catch rates compared to participants recruited in spring 2017 (z = 5.3, p < 0.001) and 2019 (z = 2.3, p = 0.02). Participants recruited in spring 2020 also had significantly lower catch rates compared to participants recruited in spring 2018 at a 90% significance level (z = 1.8, p = 0.076). There was no difference in catch rates between "new" and "older" participants in 2017 (df = 1, LRT = 0.49, p = 0.48). In contrast, there were significant differences between "new" and "older" participants in 2018 (df = 1, LRT = 8.6, p = 0.003), 2019 (df = 1, LRT = 8.9, p = 0.003), and 2020 (df = 1, LRT = 17.3, p < 0.001). On average, the "new" participants recruited in spring 2020 had the highest difference in catch rates compared to the "older" participants, i.e. ~ 50% less fish per trip. In 2018 and 2019 it was ~ 30% and ~ 35% less fish per trip, respectively.

For voluntary release rates, there was a significant difference between years (df = 3, LRT = 12.9, p = 0.004; Fig. 9, Table 3). Post-hoc analysis revealed that participants recruited in spring 2020 stated a

significantly lower frequency of voluntary release rates compared to participants recruited in spring 2019 (z = 2.6, p = 0.008) whereas no differences were found when comparing participants recruited in spring 2020 to participants recruited in spring 2017 (z = 0.5, p = 0.59) and 2018 (z = 1.5, p = 0.12).

4. Discussion

When the Covid-19 pandemic hit the world in spring 2020 many countries introduced lockdowns to minimize contact between people. During that period, e.g. March to May, recreational fisheries, in line with many other leisure activities, experienced unusual amplitudes in participation rates. For example, participation in marine recreational fisheries in Germany likely decreased, especially among nonresidents, as travel was prohibited and marinas were closed, the latter preventing launching of boats during the lockdown, but at the same time Germany experienced increased participation in inland recreational fisheries (Harry Strehlow, Thünen Institute of Baltic Sea Fisheries, Germany, personal communication). Other countries, such as Denmark, experienced a marked increase in fishing license sale during the Covid-19
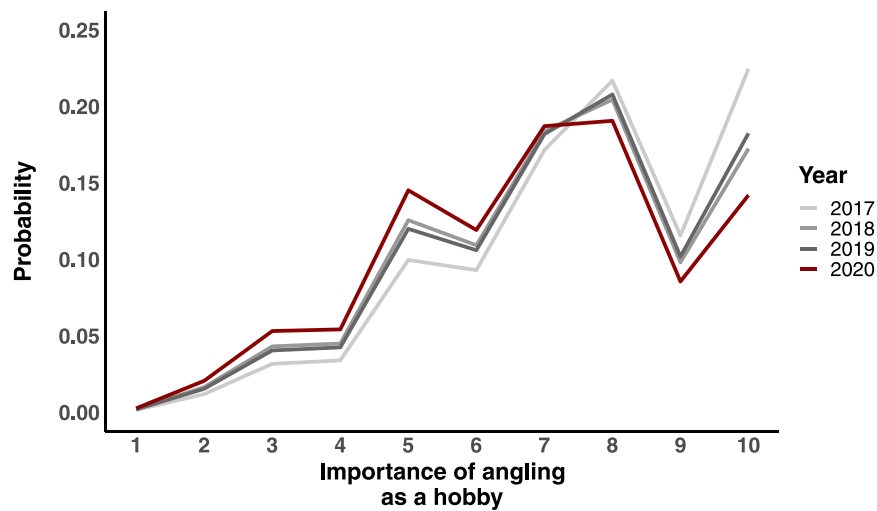
Fig. 5. Output from an ordinal logistic regression model that estimates the probability of stating importance of angling as a hobby, on a Lickert-scale from one to ten, for participants registered in the period 11 March to 31 May 2017, 2018, 2019, and 2020, who registered at least one fishing trip on the platform (i.e., data providers).

Table 2
Overview of the number of new registered participants during spring 2017, 2018, 2019, and during the Covid-19 lockdown in spring 2020 who provided data to the citizen science platform during the spring period following their registration. The number and response rate, in parentheses, of data providers who provided data about angler characteristics during registration is also shown.

	Spring 2017	Spring 2018	Spring 2019	Spring 2020
Data providers in total	264	172	124	123
Age	241 (91%)	156 (91%)	113 (91%)	106 (81%)
Gender	259 (98%)	164 (95%)	121 (98%)	120 (98%)
Place of residence	264 (100%)	172 (100%)	124 (100%)	123 (100%)
Experience	212 (80%)	130 (76%)	93 (75%)	85 (69%)
Importance of angling as a hobby	215 (81%)	129 (75%)	96 (77%)	90 (73%)

lockdown in spring 2020, i.e. 78.283 annual licenses were sold in March-May 2020, which, compared to the same period in spring 2018 and 2019, corresponds to an increase of 20% [7]. In this study, we hypothesized that the increase in fishing license sale would affect the demography of anglers who recruited to a citizen science platform in spring 2020, during the Covid-19 lockdown. We aimed to learn how the Covid-19 lockdown affected the participant demography and the

general population of anglers, assuming that the citizen science participants to some extent reflected the general population of anglers. We highlight potential data biases and discuss potential biological implications of the observed change in participation.
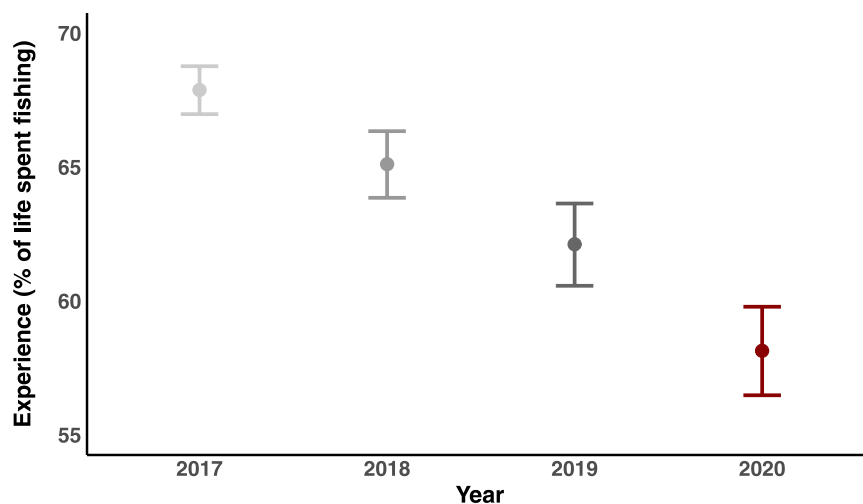

Fig. 6. Angling experience of participants registered in the period 11 March to 31 May 2017, 2018, 2019, and 2020, who registered at least one fishing trip on the platform (i.e., data providers). Angling experience is calculated is the proportion of lifetime spent fishing, by dividing years spent fishing by age. The dots represent mean experience, while the bars are a 95% confidence interval for the estimate.
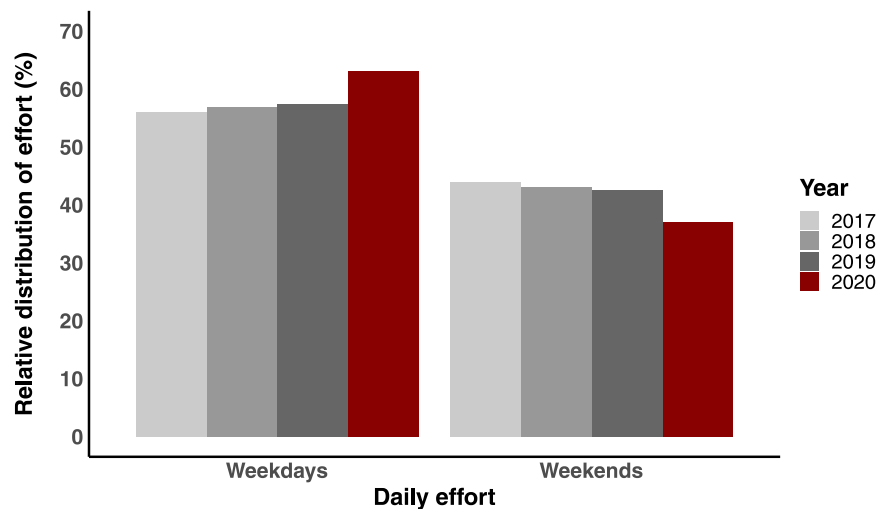
Fig. 7. Daily effort (i.e., weekdays and weekends) for fishing trips conducted in 11 March to 31 May 2017, 2018, 2019 or 2020, of participants, registered in the period 11 March to 31 May 2017, 2018, 2019 or 2020. The bars display the relative frequency of fishing trips conducted on either weekdays or weekends.
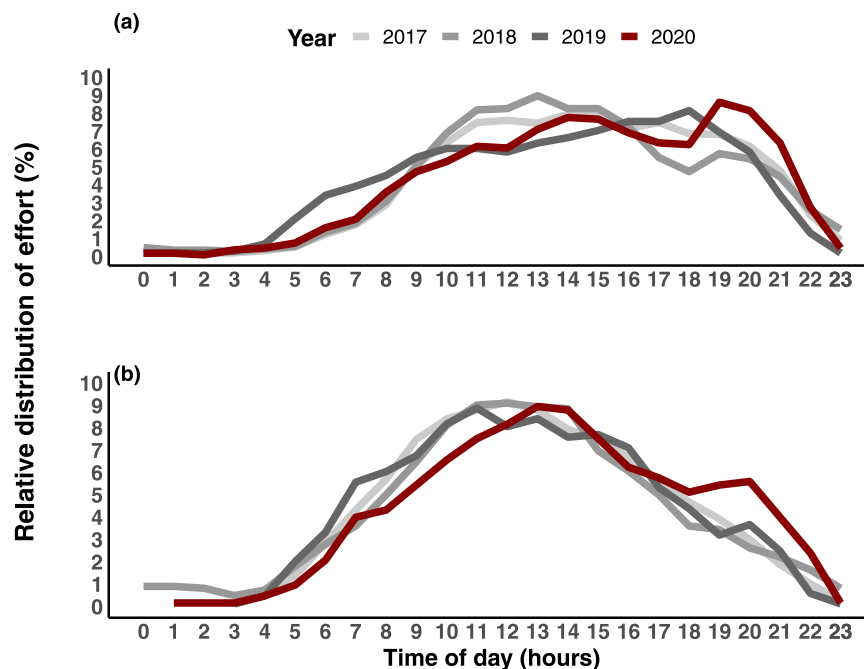

Fig. 8. Hourly effort for fishing trips conducted in 11 March to 31 May 2017, 2018, 2019 or 2020, of participants, registered in the period 11 March to 31 May 2017, 2018, 2019 or 2020, respectively. The lines represent the relative hourly distribution of effort on weekdays (a) and weekends (b).

4.1. Angling experience and demographics

The citizen science platform was available in German and English to capture data from international fishing tourists. Not surprisingly, the number of international participants that joined the citizen science platform in spring 2020 was markedly lower compared to spring 2017, 2018, and 2019, most likely reflecting that travel into Denmark was restricted during the period.

We confirmed the hypothesis that the Danish participants that registered in spring 2020 had a higher share of relatively inexperienced participants compared to previous years, potentially reflecting that new anglers with relative low experience dominated the concurrent 20% increase in national fishing license sales. There was also an increase in the share of anglers from the major cities, which we did not expect. Other studies have shown that participation is generally lower in urban areas (e.g., [4]). We have no immediate explanation to this, but it could

be caused by a relationship between urbanization and age, i.e. that younger people are overrepresented in urban areas compared to rural areas. This is supported by a post hoc analysis among all participants on the platform in which, there was a clear indication that participants registered in urban areas tended to be younger than participants registered in rural areas, i.e. urban participants are on average 3 years younger than participants from rural areas (df = 1, F = 22.6, p < 0.001; data not shown).

4.2. Importance of angling

From the answers to the question: "How important is angling as a hobby", it was evident that participants registered in spring 2020 found angling to be a less important hobby compared to participants registered in spring 2017, 2018, and 2019. It has been shown that specialization within a hobby such as angling, can be evaluated as a multi-dimensional

Table 3

Overview of the number of participants who provided various data about fishing trips and various catch information (only sea trout) to the citizen science platform during spring 2017, 2018, 2019, and during the Covid-19 lockdown in spring 2020. Effort and catch information (in italic) include the number of fishing trips, daily and hourly effort (across all target species), and catch rates and voluntary release rates specifically for sea trout.

	Spring 2017	Spring 2018	Spring 2019	Spring 2020
Number of fishing trips conducted, daily effort, and hourly effort				
# of participants/# of fishing trips	264/1036	172/583	124/444	123/430
Catch rates of sea trout				
# of participants/# of fishing trips for sea trout/# of caught sea trout	184/734/562	104/340/156	61/196/103	64/250/83
Voluntary release rates of sea trout (> 40 cm)				
# of participants/# of released sea trout /# of caught sea trout	99/157/317	47/60/101	27/43/60	28/18/40
Catch rates of sea trout ("older" participants)				
# of participants/# of fishing trips for sea trout/# of caught sea trout	488/2897/2106	451/2600 /1754	404/2425/2034	361/2408/1528

construct consisting of a cognitive, behavioral, and psychological dimension [18]. Although we are far from being able to evaluate recreational specialization among the citizen science participants in this study, the theory behind could be useful to consider when discussing our results. The psychological dimension has been shown as the most influential predictor of recreation specialization [19]. In the evaluation of the psychological dimension several questions similar to the one asked upon registration, about importance of angling as a hobby, are often used to estimate how central a hobby is in a persons' lifestyle (e.g., [20–23]). We tentatively suggest, that the relatively low importance that the participants registered in spring 2020 put on angling as a hobby could reflect that they are a less specialized segment, compared to participants registered in spring 2017, 2018, and 2019. This is also supported by the finding that anglers from 2020 seemed less experienced compared to anglers from previous years, although experience is separate measure within the behavioral dimension of the specialization construct.

4.3. Data providers and implications for data collection

Since only a subset of participants contribute with fishing trip data following registration, demography and importance of angling as a hobby was compared among the participants who provided data in the different years. Interestingly, the clear differences between age and place of residence, did not emerge for the data providers. Only differences in angling experience were still present, with the data providers in spring 2020 still being less experienced compared to the previous years. However, differences between years were less clear but this was mostly

driven by data providers in 2018 and 2019 being less experienced in these years compared to all participants. Looking only at level of experience among data providers (Fig. 6) and all new participants in spring 2020 (Fig. 1), we see few differences. There were still statistical differences in answers to the question "How important is angling as a hobby", but within a 90% significance level, when looking only at data providers. However, there was still the same trend, namely that data providers in spring 2020 put lower importance on angling as a hobby.

The potential difference in demography and importance of angling as a hobby for data providers compared to all participants highlight some of the potential biases that data collection through citizen science platforms face. If the data providers are not representative to the general population of anglers (e.g., [10]) care should generally be taken when attempts are made to extrapolate citizen science data to the total angling population. Extrapolating using data from citizen science participants, with biased catch rates or effort patterns compared to the general angling population, could potentially misinform fisheries managers and politicians. A scenario, which could ultimately lead to erroneous management decisions. That being said, a recent study supports that data from citizen science platforms in some cases can provide fisheries metrics (e.g., catch rates and release rates) that are comparable to traditional survey methods despite of some demographic differences in participants between the different surveys [11].

Another lesson learned from this study is that data quality are likely to benefit from collecting various information about participants (e.g., demography, experience, hobby importance and more) upon registration or beyond. If available, such data further the knowledge about participant characteristics and makes it possible compare these to the
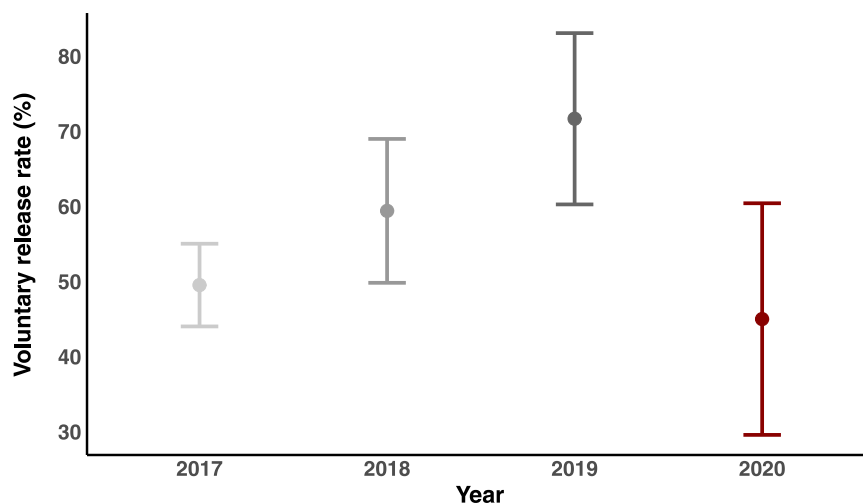

Fig. 9. Voluntary release of sea trout for fishing trips conducted in 11 March to 31 May 2017, 2018, 2019, and 2020, of participants, registered in the period 11 March to 31 May 2017, 2018, 2019, and 2020. Voluntary release is the proportion of sea trout released, which are otherwise permissible to retain and eat (i.e., above minimum size limit). The dots represent mean voluntary release, while the bars are a 95% confidence interval for the estimate.

characteristics of the general population of anglers. A comparison between groups would make it possible explore for potential biases and if possible, subsequently correct for these. However, it should be noted that an increase in number of questions asked to the participants upon (or following) registration comes with a risk of response fatigue which could affect participation levels e.g. via reduced recruitment and retention. In addition, data collection from recreational fisheries are undersupported in many places [3], which implies that little is known about the population of anglers in these areas. With that in mind, results from this study suggests that future studies should focus on understanding differences between data providers in citizen science programs and the general angler population, possibly by identifying mechanisms behind user recruitment and data contribution on citizen science platforms. Having said that, data collected by citizen science platforms may, despite existence of inherent sources for biases, still give insights into recreational fisheries as discussed by e.g., [9,11,24], and illustrated by the present study.

4.4. Angling effort, catch patterns and biological impact

Given that many Danes were working from home, or some not working at all, during prolonged periods of spring 2020, we hypothesized that the average number of fishing trips per participant would have increased. Our expectations were also increased by social and traditional media reporting a particular interest in angling during the Covid-19 lockdown. However, we found no difference in the number fishing trips conducted, in the comparison of participants registered in spring 2020 to participants registered in spring 2017, 2018, and 2019. This could reflect that individual effort did not change markedly, despite an increase in number of user registrations. Alternatively, it can be a result of underreporting from the participants registered in spring 2020 although we would argue that the level of underreporting likely would be similar between years. Further, a recent study where data from the citizen science platform "Fangstjournalen" was compared with other methods, e.g. creel survey and recall survey, suggest that underreporting is not a major problem [11]. However, it should be noted that the study from Gundelund and co-authors focused only on specialized sea trout (*Salmo trutta*) anglers and may therefore not reflect the total population of Fangstjournalen participants.

In contrast to the number of fishing of trips, differences were found for other angling effort patterns. For example, the participants registered in spring 2020 reported a higher share of fishing trips conducted in weekdays, which most likely reflect that they had more leisure time available, during weekdays, due to the Covid-19 lockdown. There were also differences in the hourly effort patterns. The participants registered in spring 2020 displayed a peak in fishing effort in early evening on weekdays. This could suggest that these people were still working from home and went on a fishing trip after work hours. Interestingly, for participants registered in spring 2020, we see the same early evening peak in fishing effort in weekends, suggesting that other mechanisms also could have been in play.

Angling can impact fish populations indirectly through e.g. pollution and disturbance [25], and more directly through harvest of fish and potentially overfishing [3,26,27]. This implies that an increase in angling participation ultimately results in stronger biological impact on fish populations. Seen in that perspective, it is interesting that the catch rates reported by the data providers registered in spring 2020 seemed lower than usual. This is illustrated by participants registered in spring 2020 having lower catch rates compared to participants registered in spring 2017, 2018, and 2019. Moreover it is also supported by the fact that the difference in catch rates between "new" participants and the likely more experienced "older" participants, fishing in the same spring period, were highest in 2020. The latter difference supports that the low catch rate estimate among the new participants, registered in spring in 2020, was not an artifact of 2020 being an unusual year with a low density of sea trout. Clearly, the potential bias between data providers

and all new participants, highlighted above, should be kept in mind when discussing the reasons for these differences in catch rates. However, the data providers in 2020 tended to be less experienced and to put lower importance on angling as a hobby, although not to the same extent as for all new participants. We therefore tentatively argue that it is possible that these less experienced and less dedicated participants that registered during the Covid-19 lockdown had lower angling skills which was reflected as lower catch rates. A relationship between self-reported skill and catch rates has previously been shown [28]. Is it worth noting, that the present study only evaluated catch rates for coastal sea trout angling. This is a relatively specialized type of angling (e.g., [10]) in which catch success could depend more on angling experience, compared to less specialized recreational fisheries. We acknowledge that the differences in catch rates also could be influenced by the change in daily effort patterns observed in 2020, i.e. if catchability of sea trout is generally higher around midday (peak effort time in spring 2017, 2018, and 2019), and lower around early evening (peak effort time in spring 2020). We do not have the required data to investigate sea trout catchability, which should be studied further.

We also found a tendency towards lower voluntary release rate among the participants registered in spring 2020. We recognize that this was only statistically significant when compared to the voluntary release rate of participants registered in spring 2019, but note that voluntary release rates in 2020 among new participants in general, was lower than any previous year. Based on this trend, we find it interesting that the specialization theory [29] predicts that inexperienced anglers with low specialization should have a higher consumption orientation and hence retain more of their captured fish compared to more specialized anglers [29–31]. Therefore, given the lack of experience and potential lack of specialization among the data providers registered in spring 2020, a low voluntary release rate among these could be expected. Alternatively, the higher affinity for retention could also simply reflect their low catch rate, e.g. when catch rates are high you may be more prone to release the second or third fish you catch after you harvest a sea trout.

Angling activities can have indirect biological impacts on ecosystems (e.g. through pollution with fishing gear or disturbance of wildlife while angling [25]) as well as direct biological impact e.g. through increase in fishing mortality (e.g., [26,27]). A 20% increase in angling participation in Denmark as a response to the Covid-19 lockdown, clearly have potential to increase fishing mortality e.g. an increase in the number of active anglers, that catch and retain fish, will likely increase the overall fishing mortality. However, the present study demonstrates that the relationship between fishing mortality and the number of new participants in a given fishery is unlikely to be straightforward. Compared to the existing angler population, new anglers may have different effort patterns, catch rates, and affinities for retaining the fish they catch. This corroborates with other studies that highlight how angler heterogeneity has significant impacts on catch rates (e.g., [10,28]) and harvest patterns, e.g. through variations in catch orientation (e.g., [32,33]). Further, the direct and indirect biological impacts cannot be evaluated solely on basis of participation patterns of national anglers. In fact, the present study suggests that increased biological impact as result of increased participants during the Covid-19 lockdown could be somewhat counterbalanced by reduced participation by international fishing tourists.

5. Conclusions and study limitations

This study demonstrates that the Covid-19 lockdown in spring 2020 affected the demography, psychology, and angling effort of participants recruiting to a citizen science platform. Compared to participants registered in spring 2017, 2018, and 2019, the participants registered in spring 2020 were younger, more likely to live in urban areas, and less experienced anglers that put less importance on angling as a hobby. In addition, there was a clear decrease in the participation of international anglers on the platform in spring 2020. These findings potentially reflect

the concurrent changes in angling participation that occurred in Denmark during the lockdown, when an increase in license sales of 20% was observed. Some of the clear differences between participants registered in spring 2020 and participants registered in previous years disappeared in the comparison of the data providers (i.e., participants who provided data from fishing trips). This highlights that data collection through citizen science platforms can face data bias issues that need future attention.

We found no increase in number of fishing trips conducted among the participants registered in spring 2020 who provided data, but found changes in when they went fishing, i.e. an increase in weekday fishing activity and, within the day, an increase in angling during early evening. These changes most likely reflect the extraordinary working and family life conditions that most Danes experienced during the Covid-19 lockdown in spring 2020. The data providers during the Covid-19 lockdown in spring 2020 had different catch and harvest patterns compared to participants in previous years which potentially relate to inexperience. However, it is unclear if this ultimately affected the overall biological impact from these new recruits, i.e. resulted in an increase or decrease in fishing mortality, as the anglers, registered in spring 2020, on one hand had lower catch rates but on the other hand also displayed a trend towards retaining more of their caught fish.

We acknowledge that some of the presented data potentially suffer from non-response bias, which would imply that some segments are more likely to answer the non-mandatory questions used in the analyses. We have no information available to correct for this. However, the average response rate for non-mandatory questions was 76% (range 57–97%) and therefore comparable to other studies (e.g., [34,35]). Most important, we acknowledge that the participants who sign up to participate in a citizen science platform are unlikely to be fully representative for the total population of anglers [10] and care should be taken if extrapolating data to the wider angling population. However, given the lack of alternative data sources, we tentatively suggest that the clear changes in demography, psychology and behavior among the citizen science participants registered during the Covid-19 lockdown in spring 2020, gives some insight into how Covid-19 may have affected recreational fisheries in Denmark and potentially also in similar countries where increases in participation may have been observed.

During the Covid-19 pandemic onsite surveys of fisheries, including recreational fisheries, may have been challenged in many regions, especially during lockdown periods where public offices, in charge of surveys, may have been closed down and travel of personal restricted or prohibited. In such periods, alternative data sources such as citizen science data may be of particular use. This study demonstrate aspects of this. For example, we were able to demonstrate that a vast amount of data was collected during the pandemic and also that the collected data was useful, e.g. to provide insights about changes in recreational fisheries during the Covid-19 lockdown in spring 2020. Further, the present study supports that citizen science platforms and related apps can be a useful supplement to other data collection initiatives for recreational fisheries (see [9] for a review of challenges and opportunities with the method). For example, a recent study [11] showed how fisheries metrics (e.g., catch rates and release rates) from the Fangstjournalen platform was very similar to data from more traditional survey types (e.g. creel and recall surveys) supporting that angler apps can be of use. This is relevant information not least since app data are likely to grow in use among managers and researchers in the future [24]. Nonetheless, there is a strong need for further evaluation of the data quality from citizen science projects in general and angler apps in particular (e.g., [24]).

CRediT authorship contribution statement

Casper Gundelund and Christian Skov: Conceptualization, Investigation, Writing - original draft, Writing - review & editing; **Casper Gundelund**: Data curation, Formal analysis, Methodology; **Christian Skov**: Funding acquisition, Project administration.

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