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Insights into the users of a citizen science platform for collecting recreational fisheries data

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ABSTRACT

Citizen science platforms, including smartphone applications, that allow anglers to report information about fishing trips and catches may be a low-cost source of data that can feed into the science and management of recreational fisheries. However, information about potential biases in these data, such as the representativeness of user characteristics and retention patterns is largely lacking. Here, we examine the characteristics and retention patterns of the users of a Danish citizen science smartphone application and website that allow anglers to report data from fishing trips. Using data from a roving creel survey of sea trout (*Salmo trutta*) anglers as an independent source for calibration, we found that users of the citizen science platform were younger, more specialized, and had higher catch rates than non-users. On the citizen science platform, 21% of the users were active (i.e., contributed data at least once, three months after creating an account), with an additional 22% using the platform as a source of information (e.g., catch statistics or regulations) for at least three months. These sustained users were older and ascribed a higher importance to angling as a hobby compared to those who stopped using the platform within three months. Data from similar platforms are unlikely to be representative of all anglers and, as a result, research is required to determine what issues this will bring for population extrapolations.

1. Introduction

Recreational fisheries in industrialized countries are the most important fisheries in most inland and many coastal areas (Arlinghaus et al., 2015, 2019). However, properly monitoring a large and highly disperse population of anglers is challenging (Arlinghaus et al., 2019; Hyder et al., 2017, 2018; Pollock et al., 1994). Citizen science platforms that allow anglers and other recreational fishers to record the details of their fishing trips and catches (e.g., website, smartphone apps) are growing in popularity (Gutowsky et al., 2013; Venturelli et al., 2017). When designed properly, such platforms can be a valuable and low-cost source of citizen science data with potential to feed into the science and management of recreational fisheries (Venturelli et al., 2017). This includes collecting traditional fisheries data (e.g., effort and harvest) as well as novel data (e.g., how anglers interact with ecosystems, management, and the resource in space and time). There are multiple challenges related to citizen science platforms in general (Conrad and Hilchey, 2011; Dickinson et al., 2010; Hyder et al., 2015), and angler apps in particular (Venturelli et al., 2017). Research is needed to understand the strengths and limitations as well as the possible biases of this methodology.

Numerous factors motivate users to participate in a citizen science project (e.g., Nov et al., 2011; Raddick et al., 2013; Rotman et al., 2012). Decades of research on the human dimensions of anglers has revealed systematic differences among participants and non-respondents of surveys (e.g., Choi et al., 1992; Pollock et al., 1994). In this context, the avidity and psychological involvement that people have with their leisure activity constitute key dimensions of heterogeneity among anglers (Bryan, 1977; Ditton et al., 1992). Similar to the case of participation in angler surveys (e.g., Dorow and Arlinghaus,

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2011, Pollock et al., 1994), avidity and psychological involvement are likely to affect who is being recruited and retained in angling citizen science platforms. It therefore stands to reason that anglers contributing to citizen science projects, dealing with recreational fisheries, encompass the more avid and psychologically involved anglers.

Addressing angler heterogeneity is important to fully understand the beliefs and attitudes of anglers, their behavior, and their catching abilities. For example, more specialized anglers have a greater ability to catch fish, all else being equal (Monk and Arlinghaus, 2017). Recreation specialization (Bryan, 1977) provides a unifying framework for understanding variation in behavior and psychological attachment among outdoor recreationists, including anglers. Specialization is a multidimensional construct comprising behavior, cognition, and affect (Scott and Shafer, 2001). The behavioral dimension encompasses measures that describe the intensity of time and resource investment that an angler engages with (Ditton et al., 1992). The cognitive dimension refers to the level of skill or knowledge, which can range from beginner to expert (Salz and Loomis, 2005). The affective dimension relates to the way that an individual self-identifies with the recreational activity, which can be seen as the level of personal commitment to or psychological involvement in angling (Scott and Shafer, 2001). It is often operationalized as the centrality of fishing in an angler's lifestyle (e.g., Sutton, 2003) or the degree of angler involvement (Kyle et al., 2007). The application of the specialization construct ideally measures all subdimensions (Scott and Shafer, 2001) and tests its predictive ability for other metrics of interest (e.g., usage of citizen science platforms) (Beardmore et al., 2013).

The quality and quantity of citizen science data depends, not only on the degree of bias around participation, but also on user retention patterns (Lewandowski and Specht, 2015; Schmitz et al., 2018; Sharpe and Conrad, 2006; Wiggins, 2013). Retention, which can be seen as the sustained engagement beyond initial participation (West and Pateman, 2016), can improve data quality. An example being, that data quality improves with user experience (Beaubien and Hamann, 2011; Edgar and Stuart-Smith, 2009). Research into user retention has characterized the effect of several factors (e.g., motives and project management), but rarely the drivers that affect the retention rates in specific citizen science projects (Beirne and Lambin, 2013).

Our objectives were to investigate possible differences in recreation specialization among users and non-users of a Danish citizen science platform for recreational anglers, and to assess sustained engagement beyond initial participation. We used a roving creel survey to explore differences in age, specialization, and catch rates for users and non-users of the citizen science platform among a population of Danish coastal sea trout (*Salmo trutta*) anglers that were intercepted on-site while angling. We also analyzed retention patterns, including the role of age and importance of angling as a hobby, for a sample of Danish platform users. We tested the hypothesis that users of the citizen science platform were more specialized. We also tested whether platform users had higher catch rates than non-users.

2. Methods

2.1. The citizen science platform

The citizen science platform Fangstjournalen (https://fangstjournalen.dtu.dk) allows anglers to submit data about their fishing trips. The platform includes a smartphone application and a webpage. It was designed by fisheries researchers to collect data for the management of recreational fisheries (e.g., information about catch rates, size distributions, and real-time angler behavior), and as a vehicle to inform anglers about regulations and other developments. The platform works as a logbook that the individual angler can use to keep track of fishing trips and catches. The submitted data are processed and fed back to the angler as summary statistics (see Venturelli et al., 2017 for an illustration of the dataflow between users and the platform). Fangstjournalen was first launched the 15 January 2016. By August 2019, approximately 10500 users had created an account and registered over 45000 fishing trips. Information about the platform were spread through articles in angling magazines and talks at angling clubs, in an attempt to recruit anglers to the platform. Creating an account on the platform triggers a series of optional questions related to demographics (e.g., gender and place of residence) and various human dimensions, such as self-stated avidity and importance of angling as a hobby (scale from 1 to 10, where 10 is a statement that angling is the most important and 1 that angling is the least important leisure activity in a person's life). The importance of angling as a hobby is often used as an index of psychological commitment (e.g., Ditton and Sutton, 2004; Oh et al., 2011; Oh and Ditton, 2006; Sorice et al., 2009). More rigorous, multi-item indices for measuring commitment exist (e.g., centrality to life-style), but are difficult to integrate into apps due to respondent fatigue.

The primary function of the platform is to register fishing trips. Users enter information about trip and effort (e.g., trip duration, trip location, and target species) and catch and harvest (e.g., species caught, number of each species caught, and number of each species harvested). In addition, information about weather (e.g., wind speed, wind direction, temperature, and air pressure) is automatically logged (see Venturelli et al., 2017 for a full overview of the data collected by the platform). The platform includes secondary functions that can also provide benefits to the angler. Users can see catch statistics, and realtime regulation information such as the location of closed areas. The platform also records the date and time of the most recent login, which is useful for inferring retention. User activity on the platform is recorded regardless of whether a user registers a fishing trip, which allowed us to identify users who logged in solely to access the secondary functions.

2.2. Roving creel survey

We used a roving creel survey to identify differences in the characteristics of users and non-users of the citizen science platform. The roving creel survey targetted shore-based recreational fishing (rod and line) mainly for sea trout, a key target species for coastal angling in Denmark (Skov et al., 2020). This is also reflected on the citizen science platform were approximately 60 % of all registered trips target coastal sea trout. The creel survey was conducted in spring 2017 on the island of Funen (Fig. 1). The island consists of 460 km of coastline with diffuse access points for anglers. The survey comprised 79 designated interview sites (DIS) (Fig. 1) that were chosen with the help of an angling guidebook that was published by the local municipalities. Each DIS was assigned a level of popularity: not very busy, medium busy, or busy corresponding to a 50, 75, or 100% chance that the clerk would visit a specific DIS in the roving creel survey. This site popularity index was based on expertise from local anglers and Sea Trout Funen, a secretary formed by the local municipalities.

The survey was planned as a stratified random multistage design following Pollock et al. (1994). Stratification was done by type of day (i.e., weekdays and weekends/holidays) and time of day (i.e., morning and evening periods). The morning period was defined as an eight hour period from one to nine hours after sunrise, and the evening period was defined as the eight hour period before sunset. These definitions of morning and evening periods accounted for changes in day length and light levels. The randomization process included choosing: a) a random starting location from the 79 DIS; b) a random travel direction (i.e., clockwise or counter clockwise); and c) whether to visit a specific site based on the site popularity index. The survey was conducted by the same clerk to avoid interviewer bias (Pollock et al., 1994). A total of 72 days between 1 March 2017 and 31 May 2017 were sampled, with a typical sampling day being 8 hours long. Anglers encountered in the survey were asked to participate in an interview involving questions related to demography and behavior. This included four questions

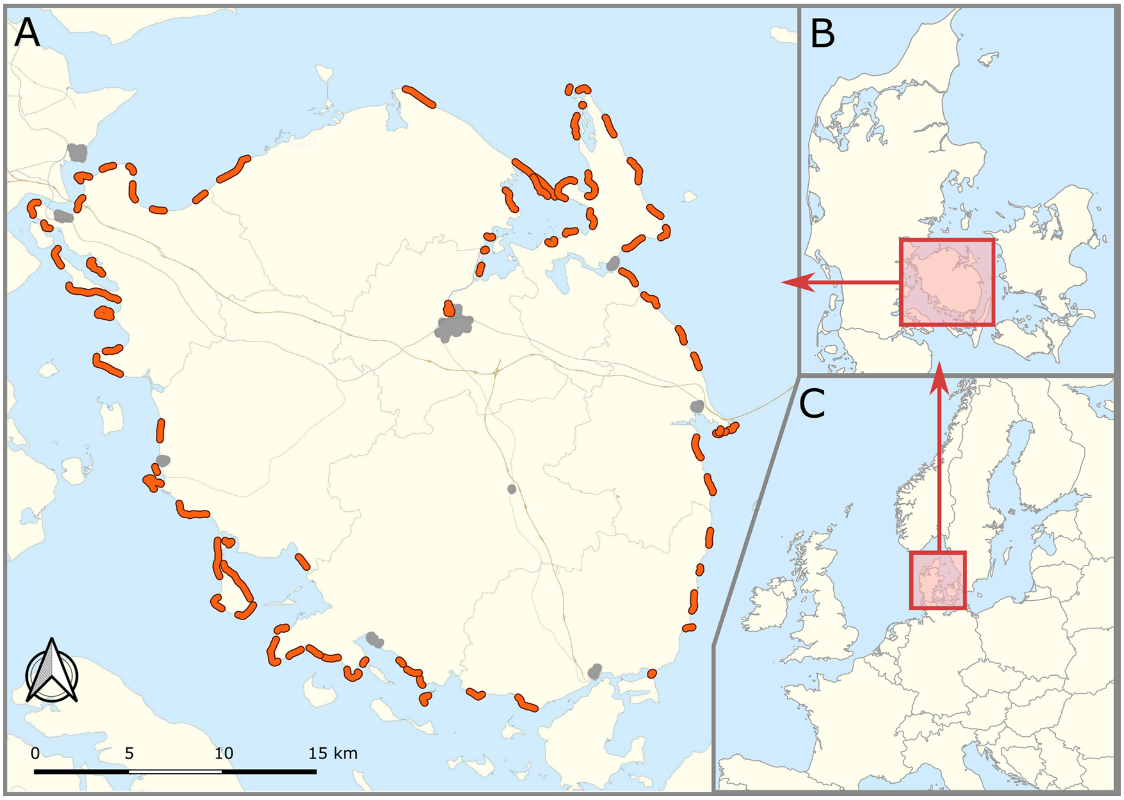

Fig. 1. The roving creel survey of sea trout anglers took place on the island of Funen in Denmark (B) and Europe (C) from 1 March 2017 to 31 May 2017, inclusive. The center of Funen is located at ~55° 21′ 0″ N, 10° 21′ 0″ E (A). Highlighted areas of the coastline represent the 79 designated interview sites.

Table 1
An overview of how sea trout angler clothing and gear were scored during the creel survey. The scale (1 = low specialization, 10 = high specialization) was based on prices that were found on websites that were specialized in selling fishing gear and clothing to coastal anglers.

Score	Clothing	Gear
1	No waders and no wading jacket	Spinning – Fiberglass rod and old reel
2	No waders with jacket or low-end wading jacket (e.g., Ron Thompson/Kinetic)	Spinning – Low-end sets (cheap rod and reel combo deals)
3	Standard waders (neoprene, PVC, breathable) without jacket (e.g., woolen sweater)	Spinning – low-end rod and reel (e.g., Ron thompson/Kinetic/Okuma)
4	Standard waders with jacket (e.g., everyday raincoat)	Spinning – medium-end rod and reel (e.g., Shimano vengeance, catana, and alivio)
5	Standard waders with low-end wading jackets (e.g., Ron Thompson/Kinetic)	Spinning – High-end rod and reel (e.g., Shimano beastmaster, speedmaster and technium)
6	Standard waders with medium-end wading jackets (e.g., Geoff Anderson/Scierra)	Fly – Low-end rod and reel (e.g., Pool 12/Ron Thompson)
7	Standard waders with high-end wading jackets (e.g., Simms/Vision)	Fly – Medium-end rod and reel (e.g., guideline/greys)
8	High-end waders with wading boots and low-end wading jackets (e.g., Ron Thompson/Kinetic)	Fly – high-end rod and reel (e.g., Scierra/A.jensen)
9	High-end waders with wading boots and medium-end wading jackets (e.g., Geoff Anderson/Scierra)	Spinning – Very high-end rod and reel (e.g., Shimano lesath/stella)
10	High-end waders with wading boots and high-end wading jackets (e.g., Simms/Vision)	Fly – Very high-end rod and reel (e.g., loop/sage/hardy) including 2-hand fly rods

regarding behavioral avidity to capture the behavioral dimension of specialization: number of fishing trips in the last three months; number of coastal fishing trips in the last three months; number of fishing trips in the last 12 months; and number of coastal fishing trips in the last 12 months. Anglers were also asked to provide their age, rank the importance of angling compared to their other hobbies, and classify their angling skills. The latter two items constitute simple measures of the affective (psychological) and cognitive components of recreational fishing specialization (Beardmore et al., 2013). By the end of each interview, the clerk also scored two subjective measures of the angler's degree of specialization between 1 (low) and 10 (high) based on visual inspection of the angler's clothing and gear, respectively (Table 1). This approach assumed that emotionally and behaviorally more committed and specialized anglers also carried very specialized equipment and clothing that identifies anglers (e.g., fly fishers) with particular sub-segments of the hobby (Bryan, 1977).

2.3. *Contrasting users and non-users of the citizen science platform*

The creel clerk asked anglers if they were planning to register their fishing trip on Fangstjournalen or register as a user. This question allowed the separation of anglers into either self-stated users or non-users of the citizen science platform. Anglers were also asked for their fishing effort (hours of angling) up to the interview, as well as the number of fish (sea trout) caught, so that we could compare catch rates between users and non-users.

Recreation specialization is multidimensional construct and must be treated as such (Scott and Shafer, 2001). Yet, there is no universal way

Table 2
Factor loadings from the principal component extraction. Items with admissible factor loadings (> 0.5), marked in bold, were used to form the two sub-dimensions of recreation specialization.

Questions/Items	Component 1	Component 2
Hobby importance	0.355	**0.529**
Angling skills	0.149	**0.615**
All trips last 12 months	**0.772**	0.316
All trips last 3 months	**0.920**	
Coastal trips last 3 months	**0.913**	0.102
Coastal trips last 12 months	**0.851**	0.272
Clothing specialization	0.126	**0.839**
Gear specialization	0.102	**0.831**

of capturing the three sub-dimensions of specialization (Beardmore et al., 2013). We used principal component analyses to assess covariance of the indicator variables, and latent constructs to identify the three sub-dimensions of specialization. After a z-transformation (standard normal distribution with mean = 0, SD = 1), we combined the specialization-related items mentioned above from the creel survey and the creel clerk's assessment of specialization (i.e., observations about gear and clothing) into principal components using factor analysis with varimax rotation. Factors with eigenvalues > 1 and items with factor loadings > 0.5 were considered to be admissible and interpreted as revealing the behavioral, affective, or cognitive dimension of specialization or a combination of sub-dimensions (see Beardmore et al., 2013 for a similar approach). The internal consistency of each factor was assessed using Cronbach's alpha with an acceptance level of 0.6 (Arlinghaus and Mehner, 2005 and references therein). Finally, scores for each of the factors, as measures of specialization by sub-dimension, were calculated by summing the z-score of the individual items in a factor. We used linear models to test for differences in the recreational specialization and age of self-stated users and non-users of Fangstjournalen. We used a generalized linear model (glm) following a negative binomial distribution with a log link, and effort (hours of angling) as an offset (Kuparinen et al., 2010; Monk and Arlinghaus, 2017) to test for differences in catch rates between self-stated users and non-users. We verified that all models met regression assumptions by investigating homogeneity (i.e., fitted values vs residuals), independence (i.e., residuals vs covariates), and influential observations (i.e., Cook's distance). We also conducted a simulation study to ensure that the negative binomial glm used to investigate catch rates accounted for the zero inflation that was present in the data (see supplementary material A for details).

2.4. Retention patterns of platform users

We investigated platform retention from 1 January 2016 to 1 January 2018 (inclusive). We focused on long-term patterns by restricting our analysis to users who created an account in the period 1 January 2016 to 1 July 2016 (inclusive). Retention patterns were explored by examining the number of days that users were active beyond initial participation. We defined initial participation as being active for a maximum of 90 days after account creation. Users who were active beyond initial participation were divided into two categories: 1) those who showed activity on the platform from 91-365 days after account creation; and 2) those who were active more than a year after account creation. Initial participation and the two categories for users moving beyond initial participation defined three periods of retention that we used in the exploration of retention patterns (short-, medium- and long-term). The retention analyses also distinguished between: users who registered at least one fishing trip (i.e., primary-function users); and users who logged into the platform at least once after creating an account, but never registered a fishing trip (i.e., secondary-function users).

We used the demographic and human dimensions data that were collected via the platform to compare self-stated age and importance of angling as a hobby relative to other leisure activities among the retention periods (i.e., short-, medium-, and long-term). The latter was used as a secondary measure of the psychological dimension of specialization. This enabled us to explore whether the potential differences in specialization among users and non-users from the on-site survey were also revealed in differences in commitment among short, medium and long-term users of the platform. Users were not required to submit this information, so the analysis only included the subset of users who provided answers. A linear model was used to test for differences in age between retention periods. Ordinal logistic regression was used to investigate the role of importance of angling as a hobby for the retention periods. All statistical analyses were done in R version 3.6.1 (R Core Team, 2019), using MASS (Venables and Ripley, 2002), ggplot2 (Wickham, 2016), plyr (Wickham, 2011), tidyverse (Wickham, 2017), and psych (Revelle, 2018) R packages.

3. Results

3.1. Contrasting users and non-users of the citizen science platform

The roving creel survey encountered 460 Danish anglers. Four hundred and forty-one (96%) of these participated in the survey. Three hundred and sixty-eight (83%) of survey participants were sea trout anglers. The final sample frame consisted of the 344 Danish sea trout anglers that responded to the question "Are you planning to register your fishing trip on Fangstjournalen or are you maybe registering as we speak?". This corresponded to 93% of the interviewed Danish sea trout anglers (see supplementary material B for details). Factor analysis with varimax rotation identified two principal components that described sub-dimensions of angler specialization. The first principal component combined the four roving creel survey questions regarding avidity (Table 2) into a scale that we interpreted as behavioral commitment ($\alpha = 0.91$). The remaining questions formed a scale that we interpreted as psychological commitment and skill ($\alpha = 0.72$). No clear difference between the users and non-users within behavioral commitment was observed ($F = 3.22$, $df = 1$, $p = 0.07$). However, users scored significantly higher in psychological commitment & skill compared to the non-users ($F = 4.02$, $df = 1$, $p < 0.05$) (Fig. 2). Platform users were also younger (age 42.3 years ± 3.52, 95% CI, n = 46) than non-users (age 48.5 years ± 1.59, 95% CI, n = 295) ($F = 8.35$, $df = 1$, $p < 0.01$). Users of the platform caught 0.78 sea trout per hour (0.39 – 1.58, 95% CI, n = 45), while non-users caught 0.24 sea trout per hour (0.18 – 0.34, 95% CI, n = 289). This suggests that users are catching 3.25 times more sea trout per hour, compared to the non-users

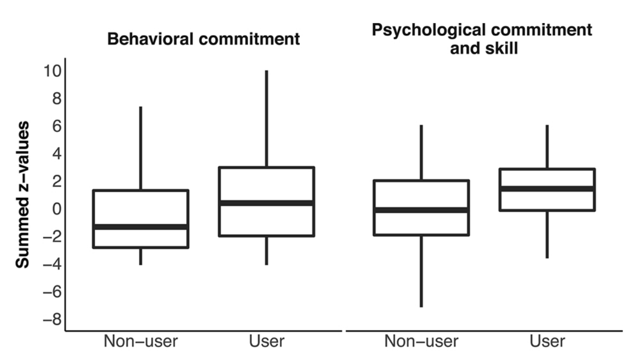

Fig. 2. Recreation specialization as measured by behavioral commitment and psychological commitment and skill for users and non-users of the Fangstjournalen platform. Data were from the roving creel survey of sea trout anglers that was conducted on Funen from 1 March 2017 to 31 May 2017, inclusive.

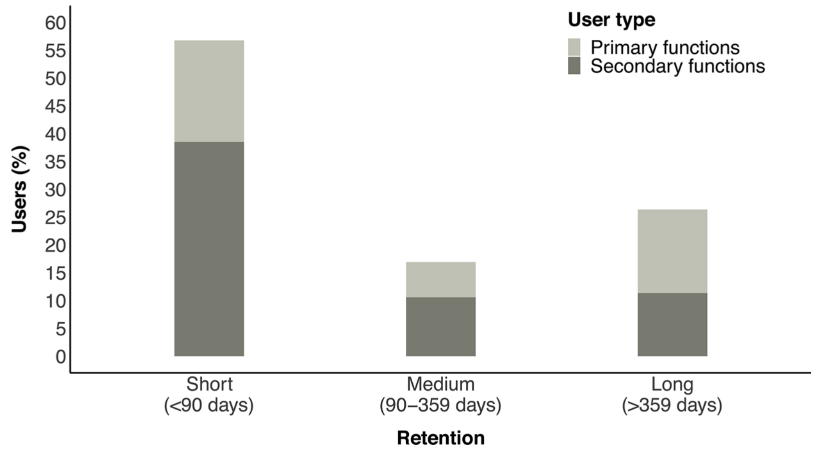

Fig. 3. Short-, medium-, and long-term retention patterns between 1 January 2016 and 1 January 2018 (inclusive) of Danish anglers who created an account between 1 January 2016 and 1 July 2016 (inclusive), and used primary and secondary features within the Fangstjournalen platform.

(χ^2 = 8.57, df = 1, p < 0.01). See supplementary material C for details.

3.2. Retention patterns of platform users

A total of 2106 users joined Fangstjournalen from 15 January 2016 to 1 July 2016 (inclusive) and registered 10750 fishing trips from 1 January 2016 to 1 January 2018 (inclusive) (see supplementary material B for details). Fifty-seven percent of the users stopped using the platform less than 90 days after creating an account (short retention). Another 17% were active between 91 and 359 days (medium retention), and the remaining 26% were active for more than 359 days (long retention) (Fig. 3). Across all retention groups, 40% of users used the primary functions (fishing trip registration), while 60% only used the secondary functions. Age differed between the three retention groups (F = 13.71, df = 2, p < 0.001) in that users with short retention (age 45.1 years ± 0.79, 95% CI, n = 1194) were significantly younger than users with long retention (age 48.8 ± 1.16, 95% CI, n = 554). The three retention groups stated high importance of angling as a hobby, but the ordinal logistic regression model predicted a higher chance of scoring low/medium importance values (1 – 7) for the short retention group, and a higher chance of scoring high importance values (8 – 10) for the long retention group (χ^2 = 13.67, df = 2, p = 0.001) (Fig. 4). Thus, long retention platform users were psychologically more committed anglers. See supplementary material C for details.

4. Discussion

4.1. Contrasting users and non-users of the citizen science platform

Based on our findings, citizen science platform users constituted a more specialized segment of the sea trout angling population. This result was primarily driven by between-group differences in psychological commitment and skill, and a smaller difference in behavioral commitment. This finding is consistent with other studies that have found that psychological commitment and skill were better predictors of recreational specialization than behavioral commitment (e.g., Beardmore et al., 2013). We note that the factors included in the behavioral commitment dimension (e.g., number of fishing trips) may have been biased due to recall periods of three and twelve months (Connelly et al., 2000; Connelly and Brown, 1995; Osborn and Matlock, 2010), such that users were unable to accurately recall the number of fishing trips that they had taken in the given period (Pollock et al., 1994). Such bias could be an additional explanation as to why no clear difference in behavioral commitment was observed. Greater involvement and avidity of platform participants was similar to other studies in which participants of angler surveys constituted the more specialized and avid angler segments (e.g., Dorow and Arlinghaus, 2011; Fisher, 1996; Pollock et al., 1994).

We visually assessed angler gear and clothing during our roving creel survey. These measures of commitment are rare in the human dimensions literature. Visual-based metrics are somewhat subjective, but easy to obtain and do not burden respondents. Our visual

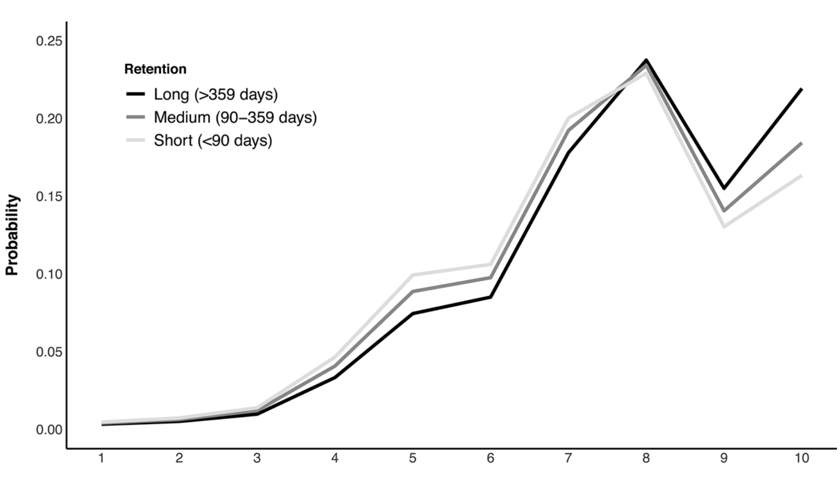

Fig. 4. Output from an ordinal logistic regression model in which the probability of short-, medium-, and long-term retention between 1 January 2016 and 1 January 2018 (inclusive) was predicted from how users who created a Fangstjournalen account between 1 January 2016 and 1 July 2016 (inclusive) stated the importance of angling as a hobby (Likert scale 1-10).

assessment of commitment grouped well within the psychological commitment and skill dimensions in the principal component extraction (Table 2). Therefore, we recommend using visual inspections as an alternative component in future on-site studies of recreational specialization.

Citizen science programmes in general are often favored by older individuals (e.g., 60 – 70 years (Sheppard et al., 2017), 43 years (Raddick et al., 2013), 55 plus years (Wolcott et al., 2008). Platform users were, on average, 6 years younger than non-users (42 vs. 48 years of age). Younger participants are common for crowdsourcing sites such as Wikipedia (Glott et al., 2010), and could result from a higher technology affinity among younger people (Czaja et al., 2006). Additionally, more specialized anglers are known to have a higher degree of media interactions (Ditton et al., 1992), and social media and technology-based media today constitute the prime source of information for younger generations (Lenhart et al., 2010). Hence, we propose that the users of technology-driven citizen science platforms are biased toward younger anglers, even in countries such as Denmark in which ~87% of the population uses the internet and smartphones (DST, 2018).This overrepresentation of a younger angling segment could affect values, attitudes, norms and angler behavior, and needs to be studied further.

The tendency of our platform to attract a more committed segment of the sea trout angling population could also bias the data. An angler's level of specialization, particularly psychological commitment, strongly influences attitudes toward management, behavior, ability to catch fish, and harvesting patterns (Beardmore et al., 2013; Bryan, 1977; Dorow et al., 2010; Fisher, 1997; Heermann et al., 2013; Monk and Arlinghaus, 2017; Oh and Ditton, 2006). Likewise, we found that more committed and skilled sea trout anglers tended to show higher catch rates. Catch and effort data are important components of fisheries assessment (e.g., Cooke and Cowx, 2004; Jansen et al., 2013; Maunder and Punt, 2013), and are regularly used in stock assessments (Campbell, 2015). Therefore, any bias in these metrics (e.g., due to relatively high skill and avidity among specialized users) could affect the relevance of citizen science data to fisheries management, and might require proper standardization (Campbell, 2004). Interestingly, if one uses platform data to generate an index catch per unit effort, the fact that more skillful anglers are overrepresented might be beneficial in reducing variance. However, if data are inaccurate due to underlying bias, higher precision is of less value. Moreover, more skillful anglers might lead to catch rate hyperstability (i.e., catch rates stay higher than underlying abundance, Ward et al., 2013), strongly reducing the value of catch rates as an index of fish abundance. Although we observed higher catch rates among platform users, it should be noted that variation in the effect size was high due to the relatively low sample size (n = 45 for platform users). Hence, we recommend additional research to explore the extent to which angling citizen science data are biased by the overrepresentation of specialized, skillful anglers. These studies could ultimately lead to the development of context-dependent correction factors for those fisheries in which citizen science data are collected by a nonrepresentative sample of anglers.

4.2. Retention patterns of citizen science platform users

To our knowledge, this is the first study to address user retention patterns for citizen science platforms aimed at collecting data to support recreational fisheries. We found that 43% of platform users accessed either primary (trip log) or secondary (i.e., information-based) functions, and that 26% of users were active for at least a year. However, the actual behavior of the secondary users is uncertain because we only knew that these users logged in to the platform. Although we assume that these users benefitted from the secondary functions, a proportion of these users may have activated the app for some other reason (including accidentally). Of the users who registered fishing trips (i.e., accessed primary functions), 21% were retained after three months, and 15% were still active after one year. Hence, retention after three months was between 21% and 43% depending on participant type. These retention rates are high relative to the 3-month mean of ~5% among apps in general (Venturelli et al., 2017 and references therein), and one-year retention rates < 10% that are typical among online citizen science projects (Parrish et al., 2019). In contrast, the projects "Coastal Observation and Seabird Survey team" and "Precipitation watch Programme" had one-year retention rates of 54 and 50%, respectively (Parrish et al., 2019; Sheppard et al., 2017). The high retention rates in these programs could be due to an emphasis on community-based fieldwork, and participant training. Future research should identify minimum retention rates for ensuring a sufficient flow of quality data, and ways to boost retention rates for angler platforms.

We found that platform users who were retained for more than a year were significantly older than those users who left before three months. Thus, whereas our roving creel survey implied that the platform appealed to a younger segment of the sea trout angler population, our analysis of platform use suggests that it was the older anglers that were retained the longest. The retention of older participants is consistent with evidence from other citizen science projects (e.g., Raddick et al., 2013; Sheppard et al., 2017; Wolcott et al., 2008).

Retention was also slightly higher among those platform users for whom angling was a more important hobby. Hence, the users who were retained the longest were also the most committed anglers that joined the platform. The tendency to retain the most committed and specialized anglers may be explained by the fact that the platform was partly marketed as an opportunity to support fisheries management and conservation. This opportunity may be more attractive to specialized anglers, who tend to be more interested in conservation (Ditton et al., 1992; Oh and Ditton, 2008). Retention in citizen science projects is influenced by a variety of factors such as motivation, avidity, attitudes, beliefs, demographics, and personality (Bradley, 1999; Cnaan and Cascio, 1999; Rotman et al., 2012; Ryan et al., 2001). The literature on angler diary programs (Cooke et al., 2000) and apps in general (Pechenkina et al., 2017; Sturm et al., 2018) also emphasizes the relevance of user experience.

Further research is needed to identify and evaluate retention strategies for angling citizen science platforms (including angler apps). This should include an understanding of the potential temporal dependent biases caused by selective dropouts. Our results suggests that committed and potentially more skilled anglers are retained longer – which could result in an overrepresentation of these potentially more skilled anglers – but that this could be balanced by the replacement of dropouts by new recruits to the platform.

5. Conclusions

A roving creel survey among sea trout anglers revealed that users of an angling citizen science platform were younger, more specialized, and higher catch rates than non-users of the platform. Similar bias toward more dedicated, avid, and specialized anglers has been observed for other recreational fishing survey methods such as mail and internet surveys (e.g., Jones and Pollock, 2012). To balance this bias, we encourage platform developers to consider and implement recruitment and retention strategies that are especially attractive to the less avid and specialized anglers. For example, platforms could reward anglers who share fishing trip information with information about fishing techniques, easy-to-access fishing areas, child-friendly fishing spots, on-site fishing regulations, etc. Moreover, we must devise ways to correct and address the data stream if it is to be used for management purposes (e.g., to index stock abundance from CPUE data) because the platform users are generally more specialized and skilled (i.e., have higher catch rates). Despite their tendency to attract dedicated and specialized anglers, citizen science platforms such as Fangstjournalen have the potential to provide useful information for managers of recreational fisheries (Jiorle et al., 2016; Venturelli et al., 2017). For example, when properly addressed through standardization (Campbell, 2004, 2015) even biased samples can reveal trends in catch rates or other metrics. Addressing these biases is an important avenue of future research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Casper Gundelund: Conceptualization, Methodology, Software, Formal analysis, Writing - original draft. **Robert Arlinghaus:** Conceptualization, Methodology, Writing - review & editing. **Henrik Baktoft:** Software, Formal analysis, Writing - review & editing. **Kieran Hyder:** Validation, Writing - review & editing. **Paul Venturelli:** Validation, Writing - review & editing. **Christian Skov:** Conceptualization, Methodology, Writing - review & editing, Supervision, Project administration.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.fishres.2020.105597.

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