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Recreational fisheries – characterization, quantification and biological impact on natural resources

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Abstract

Recreational fishing is of high social and economic value worldwide, and participation is increasing at a global scale. The extent and biological effect of recreational fisheries have only recently been characterized on a limited number of targeted stocks in Europe. Several studies have shown that there is an effect of recreational fisheries on stock status in Europe and globally, and the importance of acknowledging this sector is increasingly conceded. In Sweden, recreational fishing is defined by the Swedish Agency for Marine and Water Management as any fishing without a professional licence, i.e. fishing for own consumption, recreation, tourism and for competition. Annual surveys have shown that at least 1.4 million Swedes participate in recreational fisheries at least once per year, and total catches have been estimated to about 18 380 t. The species most frequently caught in Swedish recreational fisheries are perch, pike, brown trout, crayfish, lobster, Zander, salmon, Atlantic mackerel, Atlantic herring, and cod. Recreational fisheries are covered in national as well as international management strategies for sustainable fisheries, in particular the common fisheries policy (CFP). The CFP concerns adopting a precautionary approach to fisheries management, and in support of this the EU Data Collection Framework was introduced in 2001. In accordance with this, member states are obliged to collect data on e.g. recreational fisheries for selected species defined under the DCF (EU, 2008) or EU-MAP (EU, 2016). The current knowledge on recreational fisheries in Sweden is largely based on combined postal surveys and follow-up by telephone conducted by Statistics Sweden (SCB) on behalf of HaV.

In this essay, the current knowledge on the Swedish recreational fisheries, available methods and key species is reviewed. Important research topics needing further examination, aiding the fulfilling the data collection obligations and increasing the overall understanding and knowledge of the Swedish recreational fisheries, are stated.

Keywords: Recreational fisheries, western Baltic cod, Marine Recreational Fisheries Survey, sampling design, stock assessment

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1 Introduction

Recreational fishing is of high social and economic value worldwide, and participation is increasing at a global scale (Pauly & Zeller 2015). Despite a potential species overlap with commercial fisheries, and a substantial contribution to fishing mortality, the extent and effect of recreational fisheries have only recently been characterized on a limited number of targeted stocks in Europe (Eero et al. 2015). In the past, it has been a widely-held belief that the proportion and value of fish removal by recreational fisheries to commercial fisheries has been comparatively low, resulting in this component of fishing mortality being largely ignored in standard stock assessments as compared to that of commercial fisheries (Hyder et al. 2018). Therefore very little is known about whether recreational fisheries have an impact on natural resources, and hence also the extent of such an impact on the commonly fished stocks. Recently, however, several studies have shown that there is indeed an effect of recreational fisheries on stock status in Europe (van den Hammen et al. 2016, Hyder et al. 2018) and globally (Pauly & Zeller 2015), and the importance of acknowledging this sector is increasingly conceded (Arlinghaus et al. 2019).

In Sweden, recreational fishing is defined by the Swedish Agency for Marine and Water Management (HaV) as any fishing without a professional fishing licence, i.e. fishing for own consumption, recreation, tourism and for competition. The Swedish recreational fisheries have both fresh water and marine components, and the retained catches are roughly equally divided between these. In Sweden, annual surveys have shown that at least 1.4 million people participate in recreational fisheries at least once per year, and total catches have been estimated to about 18 380 t (statistikdatabasen.scb.se). In comparison, total Swedish commercial catches 2018 amounted to just over 200 000 t (Bergenius et al. 2018).

In environmental- and fisheries politics on both national and international levels, the implementation of ecosystem based approaches to management of natural resources has been stressed (Karlssen et al. 2014). An important prerequisite for such an approach is sufficient data on all forms of anthropogenic impact on the system in question in addition to general knowledge of the ecosystem, and the principles for

such data collection are set out in the Common Fisheries Policy (CFP, EU 2013). Recreational fisheries are included in the CFP specifically in recital 3 of the Basic Regulation (EU No 1380/2013), stating that "recreational fisheries can have a significant impact on fish resources, and that Member States should, therefore, ensure that they are conducted in a manner that is compatible with the objectives of the CFP". In addition, the scope of the CFP is to cover the conservation of "marine biological resources and the management of fisheries and fleets exploiting such resources", not specifying whether such fishing activity is commercial or recreational in nature. To support the implementation of the CFP, adopting a precautionary approach to fisheries management, the EU Data Collection Framework (DCF) was introduced in 2001. In accordance with this, member states are obliged to collect data on e.g. recreational fisheries for selected species defined under the DCF (EU, 2008) or EU-MAP (EU, 2016). With the current knowledge of the extent and character of recreational fisheries in Sweden such an obligation is difficult to fulfil.

In this essay, the current knowledge on the Swedish recreational fisheries, available methods and key species, is reviewed, and research questions needing answers in order for the above obligation to be met are stated.

2 Recreational fisheries in Sweden

Recreational fisheries is an important pastime activity in Sweden, with approximately 1.4 million people participating in this activity each year (http://www.statistikdatabasen.scb.se). Recreational fishing is popular in both inland and coastal areas, with freshwater and marine species being caught. Some recreational fisheries, such as that for pike (*Esox lucius*), are characterized by catch and release, while in others the end game is utilizing the catch as food. Other aspects of Swedish recreational fisheries are tourism and fishing contests.

2.1 Swedish HaV & SCB surveys

The current knowledge on recreational fisheries in Sweden is largely based on combined postal surveys and follow-up by telephone conducted by Statistics Sweden (SCB) on behalf of HaV. In Sweden, statistical surveys have been performed on an irregular basis since 1990, and from 2013 the design of the postal surveys commissioned by HaV has been consistent with only minor changes enabling a direct comparison between years.

2.2 Extent & characterization

Recent years development in recreational fishing saw an initial decrease in number of days spent fishing from 2013 until 2016 (from 15.4 to 10.3 million days), with a slight increase in 2017 (11.9 million days, Fig. 1).

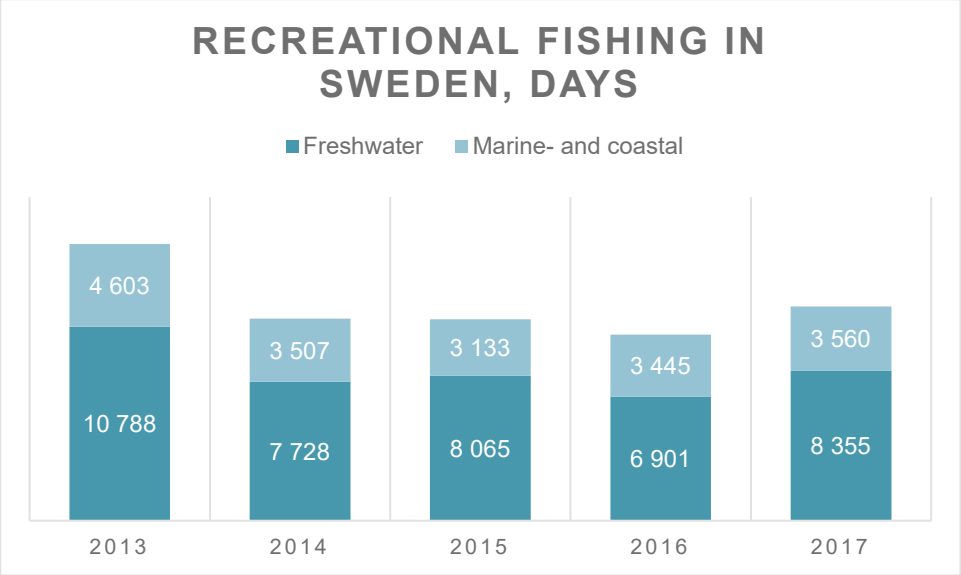
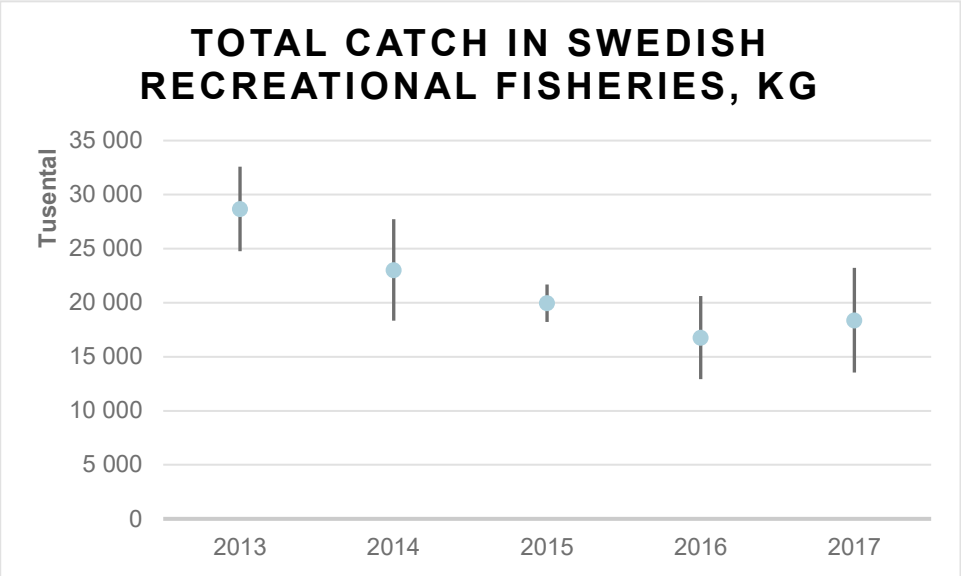


Figure 1. Total number of days spent on recreational fishing between 2013 and 2017, distributed between freshwater and marine- and coastal fishing.

The total weight of the catch is also seemingly decreasing, from an estimated 28 700 t in 2013 (of which 17 600 t were landed) down to about 18 400 t in 2017 (9 600 t landed) (Fig. 2). In 2017, recreational fishing effort was distributed unevenly between freshwater and marine (including coastal) areas with 8.4 million fishing days and 3.6 million days, respectively. This is only partly reflected in the catch, with 10 400 t caught in freshwater (5 300 t landed) and almost 8 000 t caught in marine areas (4 400 t landed), corresponding to 56 % and 44 % of the total catch, respectively.

The dominating species (by weight) caught in Swedish recreational fisheries are perch (*Perca fluviatilis*), pike (*Esox lucius*), brown trout (*Salmo trutta*), crayfish (Astacidea), lobster (*Homarus gammarus*), Zander (*Sander lucioperca*), salmon (*Salmo salar*), Atlantic mackerel (*Scomber scombrus*), Atlantic herring (*Clupea harengus*), and cod (*Gadus morhua*). The variation in species targeted is reflected in the various methods used, which also vary with the spatial and temporal scales, personal preference, tradition and underlying aim of fishing. Both hand held gears and passive gears such as nets, pots and fyke nets are used in Swedish recreational fisheries (http://www.statistikdatabasen.scb.se).



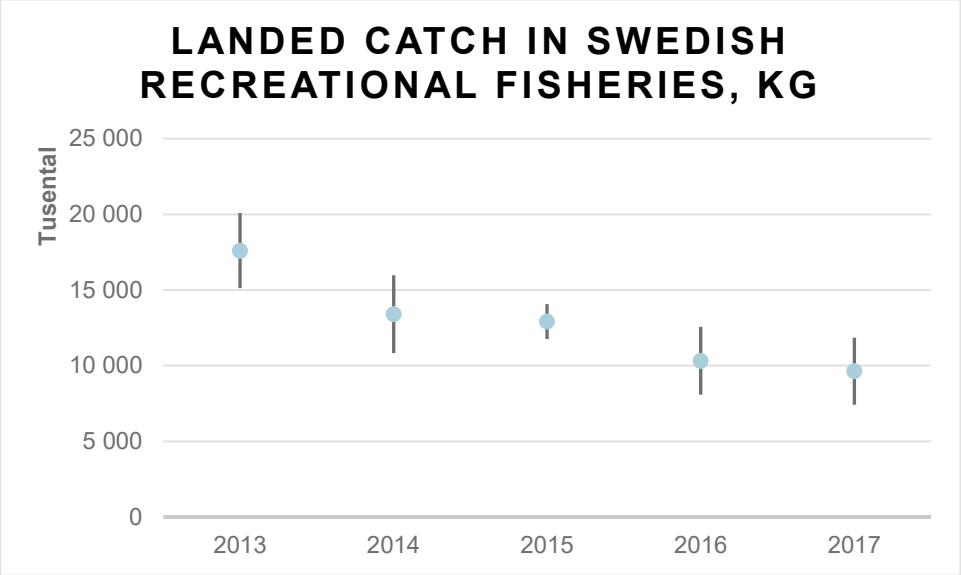
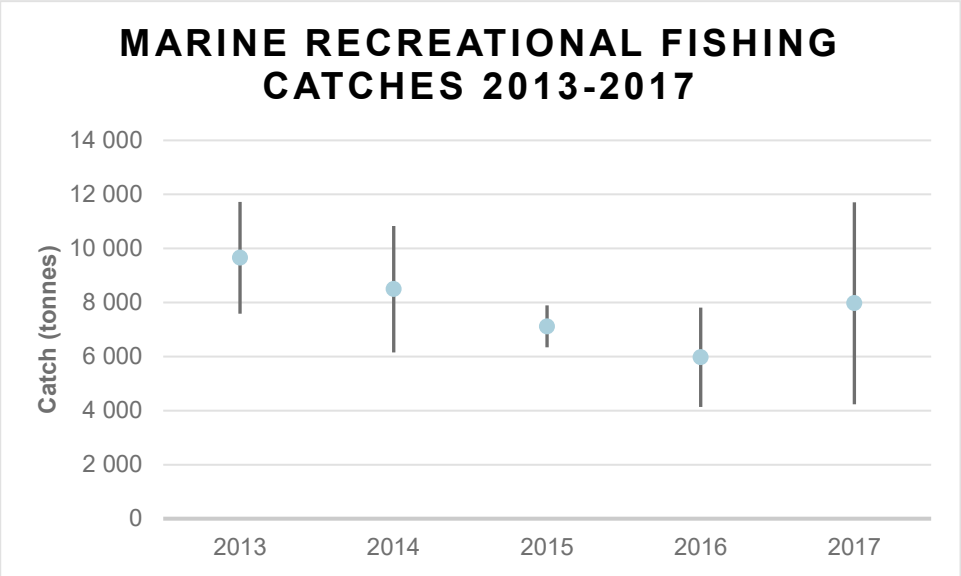


Figure 2. Total catches in recreational fisheries between 2013 and 2017 (in 1000 Kg). Vertical bars are showing margin of error.

2.3 Marine recreational fisheries in Sweden

The total catch in marine waters has been declining in the recent years, from 9 655 t in 2013 to 5 974 t in 2016 (Fig. 3). In the 2017 estimates the catch was increasing again, up to 7 974 t. There is however some uncertainties in these estimates, with

margin of error as high as 3 738 t (year 2017). Additionally, the SCB survey does not make a distinction between marine or coastal fishing, so some freshwater species will be represented in these numbers.



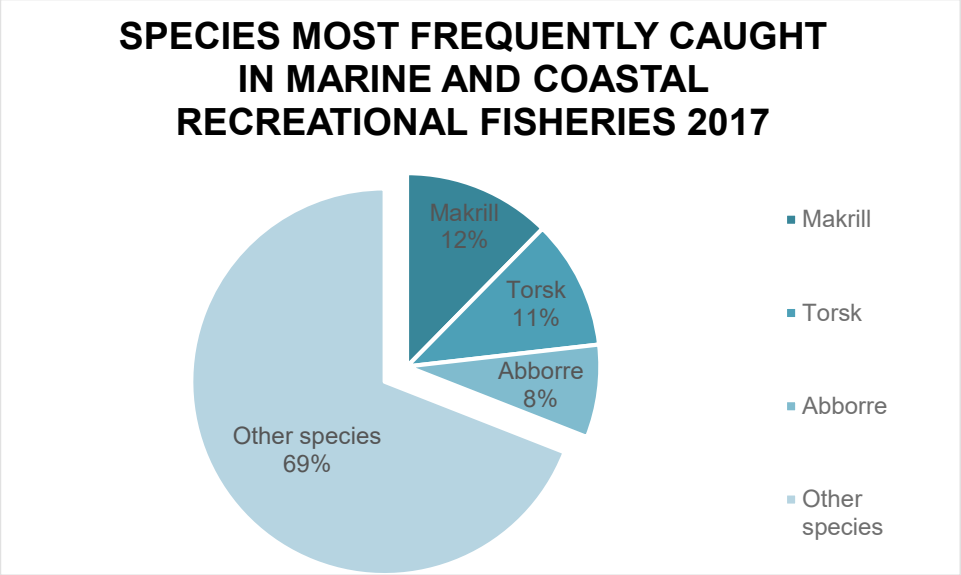


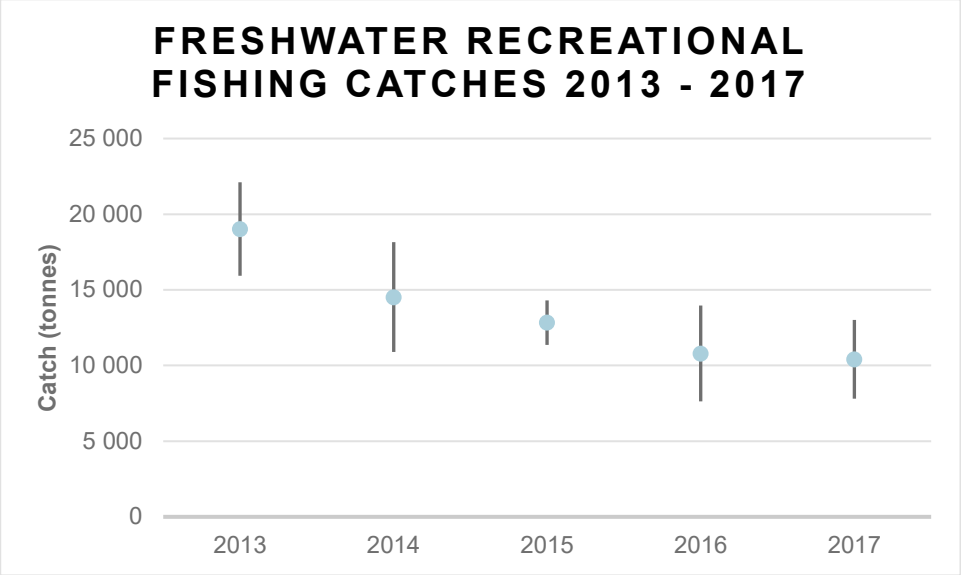
Figure 3. Catches in marine recreational fishing 2013 - 2017. Due to large uncertainties in estimates, catch of species where relative margin of error exceeded 35 % have been grouped into "other species". Vertical bars represent margin of error.

The most commonly targeted species in marine recreational fisheries in Sweden, as measured in total weight caught, are cod, mackerel, and perch (SCB 2017, Fig. 3). It should be noted that very large margins of error are associated with these estimates however, and in cases where the relative margin of error exceeded 35 % (margin of error above 70 %), estimates have been deemed too uncertain and have been omitted from the published material by the SCB. In figure 3b these are grouped as "other species".

In 2017, the total number of fishing days in marine waters was 3 560 000, and of these, about half were conducted from a boat (SCB 2017). The gears used in fishing has been classified into two categories, either handheld gear or gear aiming to catch larger amounts at a time. Handheld gear are active fishing gear such as fishing rods/angling devices, trolling and spinning. A total of 6 864 t of fish was caught with handheld gear in marine waters in 2017, 3 520 t of which was kept (Fig. 5, SCB 2017). Gear such as nets, pots and traps are found in the second category, i.e. passive gear. The total catch with this type of gear in 2017 was approximately 1 110 t in marine waters. Of this, 858 t were kept by the fisher. In 2017, 11 million days were fished with handheld active gear. The total number of days fished with passive gear in both freshwater systems and marine areas amounted to 1.1 million days. The number of days fished with the particular gear types cannot be estimated for marine waters separately.

2.4 Freshwater recreational fisheries

Freshwater recreational fisheries accounts for the largest part of recreational fishing in Sweden, with a total catch of 10 406 t in 2017 (SCB 2017). Even in this category there has been a decrease in total catch over the years 2013 to 2017. About 70 % of all fishing days were spent on freshwater recreational fisheries (Fig. 1). The most frequently caught species in freshwater recreational fisheries in 2017 were pike and perch (both ~13 % of total freshwater catches) (Fig. 4).



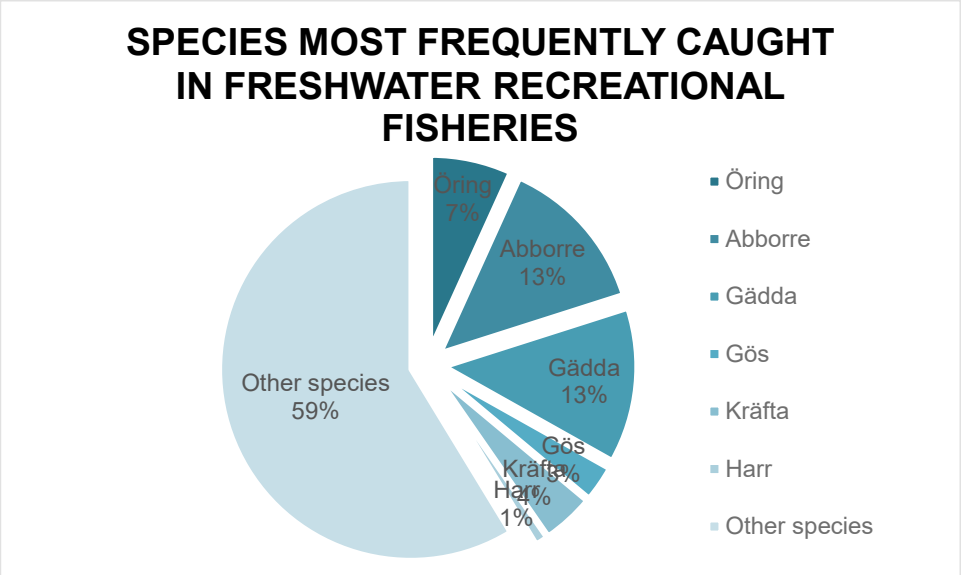


Figure 4. Catches in freshwater recreational fishing 2013 - 2017. Due to large uncertainties in estimates, catch of species where relative margin of error exceeded 35 % have been grouped into "other species". Vertical bars represent margin of error.

The total number of fishing days in freshwater were 8 350 000, of which 3 718 000 were spent fishing from a boat. About 86 % (8 919 t) of the total freshwater catch was caught with handheld gear, but less than 44 % of this was landed. Of the 1 487 t caught with passive gears, more than 90 % was landed (Fig. 5).

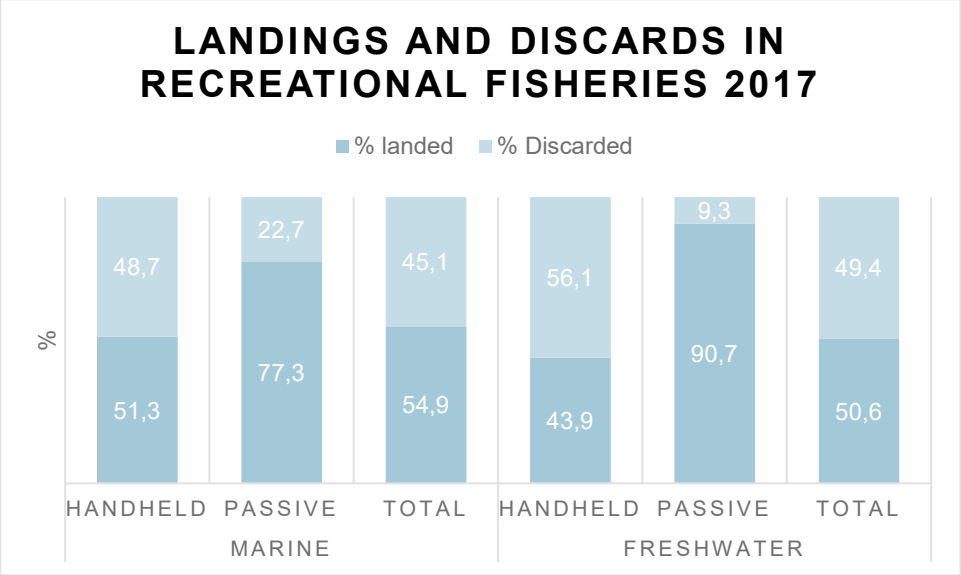


Figure 5. The percentage of landed and discarded/released catch for marine and freshwater recreational fisheries, divided by gear type.

2.5 Regulations and management of Swedish recreational fisheries

As an EU member state, Sweden is implementing the Common Fisheries Policy (CFP) (EU 2013). This policy is, among other objectives, intended to enable the conservation of marine resources and management of the fisheries targeting them. Although previously largely ignored in stock assessments, recent studies have shown recreational fisheries to have a significant impact on fish resources (Strehlow et al. 2012, van den Hammen et al. 2016, Hyder et al. 2018). It hence follows that recreational fisheries should be managed in accordance with the objectives of the CFP. In response to the need of suitable data, the Data Collection Framework was introduced in 2001, placing further demands on the EU member states with regards to which types of data to collect (EU 2008). Recently, these requirements were replaced by the EU Multiannual Programme (EU-MAP) for the period 2017-2019 (EU 2016). However, the data on recreational fisheries available, in particular relating to total removals, catches and releases in recreational fisheries, has not been sufficiently robust to enable a successful implementation of the CFP in Sweden.

The national responsibility for strengthening fish stocks and enforcing fishing legislation lies with the Swedish agency for marine and water management (HaV), an administrative authority working actively to ensure that the country's environmental objectives are achieved. Recreational fisheries in Sweden are regulated in "Fiskerilagstiftningen", in three statutes; "Fiskelag (1993:787)", "Förordning

(1994:1716) om fisket, vattenbruket och fiskerinäringen", and "Havs- och vattenmyndighetens författningssamling (HVMFS)". The first defines the right to fish in Sweden and within Swedish EEZ. The second statute concerns gear restrictions imposed by the government, while the last statute concerns amongst others regulations for conservation measures. The legislation is largely based on EU directives. Legislation concerning recreational fishing covers different aspects, such as fishing method, target species, location, time of the year, and size classes, in addition to annual changes due to variations in the stock status.

Gear regulations are in place for many types of gear, and most often vary with geographical location and target species. Regulations on appearance of surface buoys and markings of bottom set (e.g. nets, pots, and traps) and surface fishing gear (such as herring nets) ensures that information on the owner of the gear, as well as the placement and direction of placement when applicable, is provided. Closed seasons as well as closed areas are in place for certain areas or species, as are minimum allowed size of fish and shellfish, enabling individuals to spawn at least once before being captured. Furthermore, there are restrictions on the number of gears allowed (e.g. lobster pots), total length (e.g. fishing nets), mesh size, and number of fish caught (e.g. bag limit on cod, salmon and trout), diminishing fishing pressure on populations. For a complete and updated overview of restrictions, the HaV website should be consulted (www.havochvatten.se).

3 Assessing recreational fisheries

In the past, measures and assessments intended to ensure sustainable anthropogenic ecosystem exploitation have mostly been focused on commercial fisheries, assuming the recreational fisheries to be self-sustainable (Post et al. 2002). In a recent study Radford et al. (2018) showed that inclusion of recreational fisheries in stock assessments should be implemented due to the high proportion of total removals by the recreational fisheries for some European stocks, the marine recreational fisheries (MRF) catches varying between 2 % and 43 %. In the study, only 10 of the 20 stocks included in the assessment were found to have sufficient data for reliable estimates of recreational harvest, underlining the importance of regular surveys collecting marine recreational fisheries data. Similar conclusions are reached when examining global marine fisheries, recognizing that when including unreported catches such as recreational fisheries, discarded bycatch, underestimated artisanal and subsistence fisheries, total global catches are as much as 53 % higher than what is reported by Food and Agriculture Organization of the United Nations (FAO) (Pauly & Zeller 2016). Assessing recreational fisheries is however, in many instances, a daunting task. For recreational fisheries to be included in stock assessment, a variety of information and estimates are needed in addition to total removals, such as effort, catch per unit effort (CPUE), species targeted and caught, as well as age and size distribution of the catch (NRC 2006). Most often, recreational fisheries are subject to some legislations regarding the who, what, where and when of the fishery, but with no mandatory registering or reporting of landings, the demands on robust data are rarely met. Some monitoring of the recreational fisheries has been common though, mostly through surveys of fishing habits in the general population, combining information on social and economic factors with some anecdotal fish data (Roth et al. 2001, Ashford et al. 2009, Sparrevohn & Storr-Paulsen 2012). For some fisheries and in some countries, where fishing licences are mandatory, registries have been available and used as sampling frames for surveys (Ashford et al. 2009, Sparrevohn & Storr-Paulsen 2012), but CPUE and length distributions of the

catches are needed as well. Only recently have estimates of catches from some recreational fisheries been deemed robust enough for inclusion in stock assessments (Strehlow et al. 2012, Eero et al. 2015).

3.1 ICES Working Group on Recreational Fisheries Surveys

The International Council for the Exploration of the Sea (ICES), a global network of scientists committed to develop science and advice supporting sustainable use of the oceans, arranged a workshop in 2009 aiding the European countries in the process of developing sampling programs for recreational fisheries. As a spinoff of this workshop, the Working Group on Recreational Fisheries Surveys (WGRFS) was established. The group works to collect recreational fisheries data for their use in stock assessments, summarizing and quality assuring fishery data collected under the EU DCF (ICES 2016). During the work group meeting in 2016, the recreational fisheries data collected within Europe was compiled and assessed for their potential use in stock assessments (ICES 2016). In the 2018 WGRFS meeting, four stock assessments were reported to be including recreational data; Baltic salmon and sea trout, sea bass, and western Baltic cod (ICES 2018a). Pertaining to the western Baltic cod stock, German data has already been included in the stock assessment, but there is an urgent need for data from Swedish and Danish recreational fisheries to be included as well (ICES 2016, Eero et al. 2015). While surveys have shown the Swedish and Danish recreational fisheries to be responsible for relevant proportions of total landings of cod, making it very likely that recreational fisheries has an effect on spawning-stock biomass and fishing mortality, stock-specific estimates on removals have thus far been lacking (Hyder et al. 2018, Zeller et al. 2011). The WGRFS concluded that more detailed surveys are needed from the member states in order to support estimates of western Baltic cod fisheries in particular, stressing the need for reliable numbers on annual catches and releases, with weight, length and age compositions (ICES 2016). Such surveys are ongoing and catches from Swedish and Danish recreational cod fisheries are expected to be included in stock assessments in the near future.

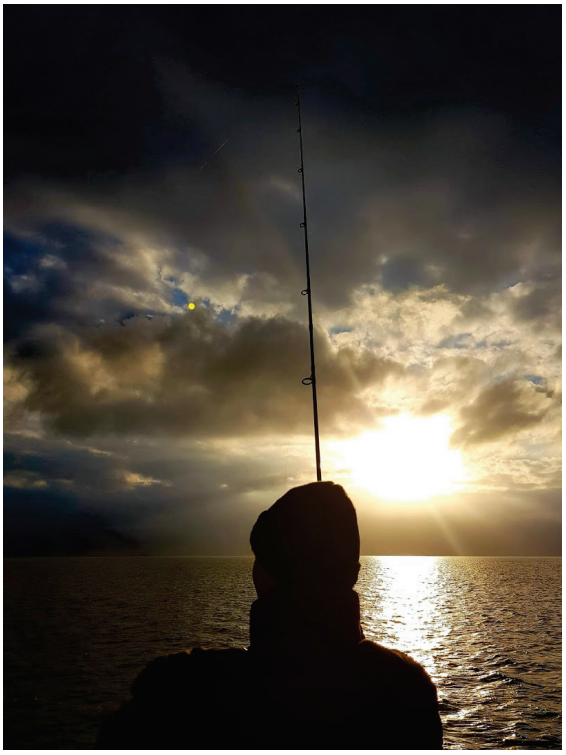


Figure 6. Recreational fisher fishing with rod and reel in the Sound. (Photo: Åke Ottosson)

3.2 Types of surveys / sampling methods

Recreational fishing surveys are and have been carried out across the globe in various forms, covering many different types of fishing as well as a diversity of species targeted, in addition to human dimensions such as social, economic and behavioural data (ICES 2016, Jiorle et al. 2016, Sparrevohn & Storr-Paulsen 2012, Ashford et al. 2009, NRC 2006, Roth et al. 2001). Being a popular social activity, marine recreational fisheries are now responsible for significant source of fishing mortality worldwide (Pauly & Zeller 2015, Radford et al. 2018). As the importance of including recreational fisheries in monitoring programmes has been increasingly stressed, the goals and objectives of fisheries management have changed too. This puts a different demand of data quality and accuracy on the monitoring systems employed for this sector.

The sampling modes for recreational fisheries data collection can roughly be divided into two categories, being of either offsite or onsite types (NRC 2006). Offsite sampling refers to surveys based on individual fishers remembering and volunteering information by answering various questionnaires on telephone interviews, postal surveys or in any other way, after the completion of their fishing trip, or by filling in logbooks or diaries. On-site sampling refers to surveys carried out at the fishing

grounds, such as access point surveys, roving surveys, or aerial surveys (Henry & Lyle 2003). These often involve direct contact with the fishers where they are performing the fishing, for example at their access points (ports or harbours) or on board for-hire tour-boats, collecting in situ data on effort and catches. The method chosen for a survey will vary with the aim of the survey, the spatial and temporal scale, and the type of fishery, but often a combination of off-site and on-site methods will be appropriate, usually limited by the availability of monetary and human resources. Often the recreational fisheries surveys are conducted by large spatial scale offsite telephone or mail surveys estimating effort, alone or in conjunction with on-site surveys measuring catch per unit effort allowing approximations of total catch or removals (van der Hammen & de Graaf 2015, Sparrevohn & Storr-Paulsen 2012, Strehlow et al. 2012, Ashford et al. 2010a, NRC 2006, NAS 2017).

3.2.1 Large scale telephone, mail or internet surveys

Offsite surveys such as telephone or mail interviews are cost-effective and can be achieved at large scales. The sampling frame is often public phone listings, registries or commercially available addresses in a desired area (Ashford et al. 2010b), interviewing a subsample of either recreational fishers in the case of license registries or the population in general. Usually, some information about the survey or its purpose as well as a guarantee of anonymity are provided, before questions are asked about the fishing activities of the interviewed and/or the household within a specified recall period (Ashford et al. 2010b, Sparrevohn 2013). The recall period in interview-based surveys is often a compromise between costs and shortening of the recall period, as a shorter recall period increases costs by requiring more frequent surveys while longer recall is associated with larger recall bias (Fisher et al. 1991, Connelly & Brown 1995, Connelly et al. 2000). Respondent-driven sampling is a type of chain-referral sampling or “snowball” sampling first developed as a tool for AIDS prevention intervention in the mid 90’s. It is a non-probability sampling technique particularly useful when studying so called “hidden populations”, where typically no sampling frame exists and that are characterized by strong privacy concerns (Heckathorn 1997). This is often the case for segments of the recreational fishing community, where often no license registry or catch reporting is mandatory. In other chain-referral sampling techniques the respondents are asked to identify other subjects, potentially leading to non-response bias due to privacy concerns. This bias associated with snowball sampling can be reduced by instead asking respondents to recruit new subjects to the study themselves, hence avoiding the identification of their peers (Griffiths et al. 2010).

3.2.2 Access point survey

To reduce error associated with recall surveys, independent catch rates are often assessed by intercepting fishers at the access points (Ashford et al. 2010a, Strehlow et al. 2012). These surveys are more expensive than off-site methods, and the demands on human resources are larger. They do however provide observations of high quality, having the advantage of a trained sampling agent performing species identification as well as taking biological measurements. A particular type of onsite survey is the bus route survey, a sampling program initially designed for recreational fisheries surveys on New York's Great Lakes and tributaries (Robson & Jones 1989). Bus route surveys have since been further developed and tested in estimates of various recreational fisheries (Kinloch et al. 1997, Lockwood 2000, Strehlow et al. 2012). As with other onsite surveys, recreational fishers are approached at public access points and boat ramps and are interviewed about their fishing habits, current fishing trip and other topics of interest, and their catch is inspected on site. What differs from other onsite surveys however, is that in creel surveys, the access points are mapped like a bus route with multiple prolonged stops in one working pass. The sampling agent has a predetermined schedule of arrivals and departures with prolonged stops for sampling, decided according to a randomized selection of starting point and direction on a cyclic route. This sampling design allows for sampling of large geographical areas with few survey agents, and with proper training correct species identification and length measurements can be ensured along with a consistent sampling.

Often also an effort component can be obtained, in counting angler activity or fisher units i.e. boats. When the count is carried out by the survey clerk, it is called a roving-access or roving-roving survey depending on whether complete or incomplete (i.e. when anglers are still actively fishing) trips are included. Counting can also be done from air, i.e. aerial-access or aerial-roving, or offsite by mail surveys, i.e. mail-access (Lockwood 2000, Vølstad et al. 2006). In some areas fishers can be intercepted at sea for interviews by agents using boat, or passive fishing gear with name and address can be registered hence creating a sampling frame for log book surveys (Sundblad et al. 2018).

3.2.3 Log-books/fishing journals

By continuously reporting their catches in diaries, along with information on the fishing trip such as mode (e.g. from a boat) and length of the trip, the recreational fishers are self-reporting actual catch and effort. Since they can report directly while they are fishing or immediately after, the recall period is eliminated and recall bias is avoided or decreased (Jiorle et al. 2016). There might however still be bias related

to avidity, e.g. different drop-out rates for fishers with different skills or activity levels (NAS 2017). Catch journals can be filled by e.g. individual fishers or by charter boats and tourist fishing industries, continuously or for only a set amount of trips, depending on the type of logbook and the provider (for example whether it was distributed by a scientist or downloaded by the user) (Vølstad et al. 2011, Papenfuss et al. 2015). Self-reporting catches can be performed in different media, e.g. as paper journals, web-based or smartphone applications, text messages, or as pre-printed pre-paid postcards (Baker & Oeschger 2009, Vølstad et al. 2011). As for all types of surveys, for the reported data to be useful in e.g. stock assessments, the reporting group of fishers have to be representative for the target population, the data has to be of high quality, and the amount of data has to be abundant. By introducing fishing licence registries, a sampling frame is created, from which a representative subsample of fishers can be drawn. With the development of easy-to-use smartphone fishing-apps, a multitude of additional data can be gathered with catch and effort data, such as whether conditions, invasive species, tag recaptures, water conditions and injuries, as well as providing updated information to the fisher about regulations (Venturelli et al. 2017). Some caution is however warranted as the type of anglers self-reporting via apps or internet might not be representative for the entire target population, and due to the potential coverage bias caused by the digital divide (NAS 2017).

3.2.4 Passive monitoring of effort

Recreational fisheries are unpredictable when it comes to effort, with a multitude of factors potentially affecting or driving both long- and short-term fluctuations in effort, such as weather, seasonal, human and social factors. Continuous monitoring programs are expensive, and usually gaps will exist between surveys that will have to be filled in by crude estimations based on extrapolation. As a supplement to large-scale monitoring or survey programs, camera monitoring effort has been suggested and applied successfully in several instances (Wise & Fletcher 2013, Hartill et al. 2016). Moreover, camera monitoring can reveal popular fishing spots and peaks in effort as well as within-day and within-week variation, thereby informing further angler survey designs.

Other passive methods exist, such as vehicle counters and parking ticket counters in parking lots adjacent to boat ramps or access-points, providing indexes of activity at these places (Wise & Fletcher 2013), as well as effort estimates provided by local marina staff (Sundblad et al. 2018).

3.2.5 Tag-recovery data

Reports on tag-recoveries can be used to assess the relative importance of recreational fisheries compared to commercial fisheries (Kleiven et al. 2016). Tagging data can also be used to evaluate post release survival of species caught in catch & release fisheries (Ferter et al. 2016).

3.3 Challenges in recreational fisheries survey designs

The complexity of recreational fisheries makes sampling and surveying it notoriously difficult. While commercial fisheries are performed under a licence, with strict regulations on factors such as documentation (mandatory log-books), allowed gear, quotas and landing/discarding, the recreational fisheries do not have to comply with such regulations and are comprised of people from all social, cultural and economic backgrounds, with differing motivation, frequency and intensity of activity. The fishers are also spread across age and geography, and while some are fishing from private boats, hired boats or on board charter- or tour-boats, others are shoreline fishers not always located in public ports or harbours. It follows that major challenges have to be overcome for the data collected to be sufficiently reliable and accurate whilst maintaining costs at reasonable levels, as monitoring all the different fishing modes in various locations and at different times is an unrealistic goal. To accomplish this task, several assumptions have to be made about the recreational fisheries and the partakers when surveying this field, many of which have yet to be verified.

The first issue complicating survey designs arises in identifying the target population and choosing a population frame from which to sample. If this sample does not accurately represent the population, either due to under-coverage, duplications or nonresponse, bias in the estimates can result (NRC 2006). Offsite surveys, using phone listings or licence databases where available, are inherently flawed by failing to include the segments of the population not having a land-line telephone or being exempt from having a fishing licence, while onsite surveys are unlikely to cover all possible sampling sites and will not intercept fishers with private access. Error might also arise if the response rate is low, either due to no answer, increasing use of mobile phones or refusal to participate in surveys, or simply if the fishers are not intercepted in the survey, i.e. they are not located where they were assumed to be found when the study was designed. If the part of the population missed in the survey differ from the sampled (included) population, bias in the estimates will result. Such assumptions hence need to be validated for estimates to be scaled up from the sample frame to the target population.

Ashford et al. (2010b) tested the assumption that catch per unit effort (CPUE) is the same for fishers using private access as for those using public access in their study on blue crab recreational fisheries in Maryland. They found that, although the monthly catches were similar between the two, fishers using private access caught that amount during more fishing trips resulting in much lower catch rates. When comparing catch data as reported by telephone with the onsite survey, they found the latter to overestimate catches by at least 25–63 %. In result, over- or underestimations of recreational catches can occur when exclusively sampling public access points in situations where the occurrence of private access is significant, and where there is a difference in CPUE between private and public access fishers.

Another difficulty in recreational fisheries survey design is correctly identifying and adjusting for sources of variation, such as the importance of both between-days variations in fisher behaviour as well as within-day variability. In their study, Ashford et al. (2013) found the within-day variability to account for a larger proportion of the blue crab catch variation than the between-day variation, and they found no significant difference between week and weekend.

When designing the questionnaires used in mail or phone surveys, an important consideration apart from the recall period is the catch quantity estimate unit the respondents are asked to report on. In a phone and interview-based recall survey in Denmark, Sparrevohn (2013) found significant differences between mean individual fish weight reported depending on the reporting preference of the respondent, i.e. if reporting in weight or number. In addition, it was found that the mean individual weight of fish calculated from the recalled and reported weights and numbers in the survey was different from the mean individual weights reported in other literature. Hence, when scaling the catch to the total population, the relative error in catch will be correlated to that caused by the weight- or number-reporting preference bias. Similarly, total catch estimates can also vary with the offsite survey method used, as demonstrated by Zarauz et al. (2015). By using the three different survey methods e-mail, phone, and post in their study, they found significant differences in total catch and effort estimates. The same study found experienced fishers with lower percentage of zero catches to be more likely to respond to the post-survey than less experienced fishers.

Errors might also arise in the sampling, for example due to recall bias in interview surveys, errors in species identification, or measurement errors when collecting the data. The recall bias may be reduced by shortening the time interval the fisher is asked to report from (Vaske et al. 2003, Sparrevohn 2013). Fisher et al. (1991) found that there was a statistically significant and dramatic increase in all recalled estimates, particularly in the number of fishing days and trips, with increasing recall period when comparing survey panels asked about fishing and hunting trips within periods ranging from 1 month up to a year prior to the interview. In

addition, the tendency towards overestimating ones activity with longer recall periods occurs slightly more for the avid fishers with frequent participation rates than for the less avid ones (Connelly & Brown 1995). This type of bias can be caused by either memory decay or telescoping (Connelly et al. 2000). Telescoping is a cognitive process by which pleasant or otherwise memorable events, such as the memory of trophy catches in recreational fisheries, are strong and hence are perceived as being more recent than they in fact were.

Concerns have been raised about the poor response rate and representativeness of self-reported data, and it has been suggested that the more avid anglers are more likely to report or that part of the population not using newer technology might be excluded in the case of app-data (Bray & Schramm 2001, Wise & Fletcher 2013, Jiorle et al. 2016). Recent studies have however shown that effort data from apps can be comparable to data from other more expensive survey methods such as creel surveys or mail surveys (Papenfuss et al. 2015). One major concern is however the recruitment and retention of fishers, as well as willingness to share data, but with continuous work in this field potentially overcoming such bias, recreational fisheries apps could provide cheap data on catches and effort in real-time for certain segments of the recreational fisheries, assuming a sampling frame can be defined (Venturelli et al. 2017). License registry surveys require a mandatory fishing license for recreational fishing. License exemptions (Age, fishing mode, access points etc.) results in incomplete sample frames. Such registries need also additional information, such as age, geography etc. and updated contact information.

These challenges underline the importance of thorough evaluation of the sources of variation and errors when designing surveys for assessing the recreational fisheries.

4 Implementation of recreational fisheries data in stock assessment

A Commission Implementing Decision (EU 2016/1251) of July 2016 regarding the management of fisheries 2017 – 2019 state that member states are obliged to gather biological data on stocks caught by recreational fisheries enabling estimations of annual volume (numbers and individual weights or length) of catches and releases of Atlantic salmon (*Salmo salar*), European eels (*Anguilla anguilla*), seatrout (*Salmo trutta*) (also in freshwater), Atlantic sea bass (*Dicentrarchus labrax*), Atlantic pollack (*Pollachius Pollachius*), elasmobranchs, Atlantic cod and highly migratory species as those dealt with by ICCAT (International Commission for the Conservation of Atlantic Tunas species), as well as on any additional species identified at a marine region level if needed for fisheries management purposes. Member states in the European Union are also obliged to ensure that recreational fisheries are conducted in a manner adhering to the CFP. At present, recreational data from only salmon, seatrout, cod and sea bass are included in stock assessments (ICES 2018a), but work is ongoing aimed at including more stocks.

5 The SLU-MRFS

In compliance with the EU Data Collection Framework, SLU is collecting data on recreational fisheries along the coast of Scania in southern Sweden in a sampling programme called SLU Marine Recreational Fisheries Survey (SLU-MRFS), with the aim to characterize, quantify and describe the extent of recreational fisheries and improve stock assessments and management of fish stocks. The survey has been ongoing since 2017, largely shaped by the urgent need of data on cod fisheries in The Sound (ICES subdivisions 23 and 24). Existing data on Swedish recreational fisheries are based on tertiary mail surveys carried out by SCB, but the nature of the design has rendered this massive dataset unsuitable for the current purpose. Additionally, changes in survey methods since the beginning in the 70's and inconsistencies as well as methodological errors (in the survey conducted during 2013-2015) have complicated direct comparison between surveys and hence between years. Due to the nature of the methodological error during the years 2013-2015, it can be assumed that a significant overestimation of recreational fishing extent is present in those years' estimates. During these years, the survey was performed in three steps, and only individuals who were classified as fishers were included in the next step of the survey. Hence, non-fishers are under-represented in the consecutive steps of the survey. Further complicating usage of this material for the purpose of stock assessments is the non-overlapping geographical divisions between the survey and the actual stock boundaries.

In response to the current data requirements, the SLU-MRFS was developed and initiated in 2017. The survey is multi-year and consists of a combination of methods, designed to achieve estimations of effort as well as catch in recreational fisheries on the southwestern Swedish coast. (See Fig. 7 for a schematic overview of the survey).

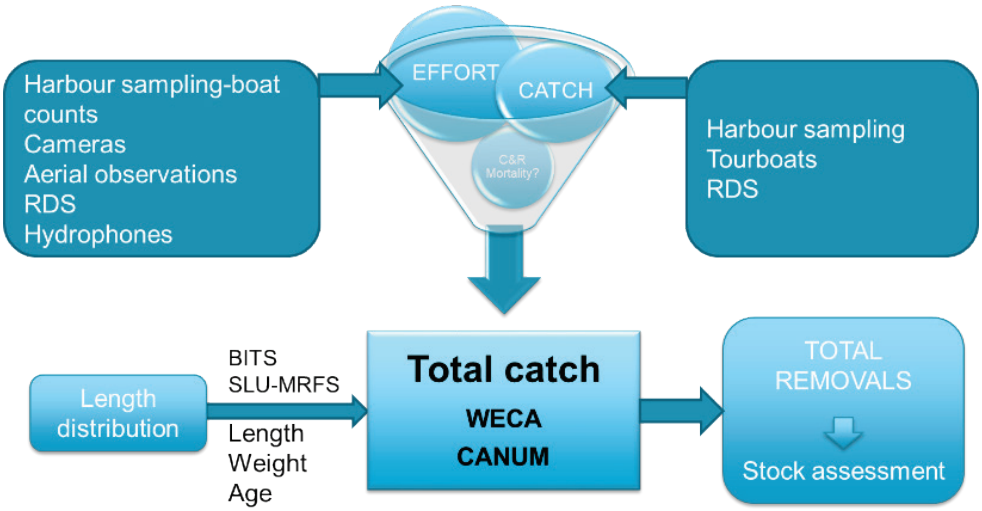


Figure 7. Schematic overview of the SLU-MRFS and the final incorporation of total cod removals into stock assessment of the Baltic cod.

In the SLU-MRFS, cod is of primary focus, but additional species are also sampled. The type of data collected is similar to that of commercial fisheries, and includes weight, length, and otolith samples for ageing.

5.1 Western Baltic cod

The Baltic cod are considered two biologically distinct stocks, the eastern and western Baltic cod, and are managed as such since 2005 (HaV 2016). The rough distinction can be made according to geographical location of cod, such that cod in SDs 25-32 (east of Bornholm) are termed eastern Baltic cod while those in SDs 22-24 are termed western Baltic cod (Fig. 8). Some overlap does occur though, with a mixture of eastern and western Baltic cod particularly in SD 24, as seen from otolith shape analyses that have been validated genetically (ICES 2017). In SD 24, mainly the Arkona basin, there is also intermediate genotypes, indicating interbreeding between eastern and western Baltic cod (Hüssy 2011).

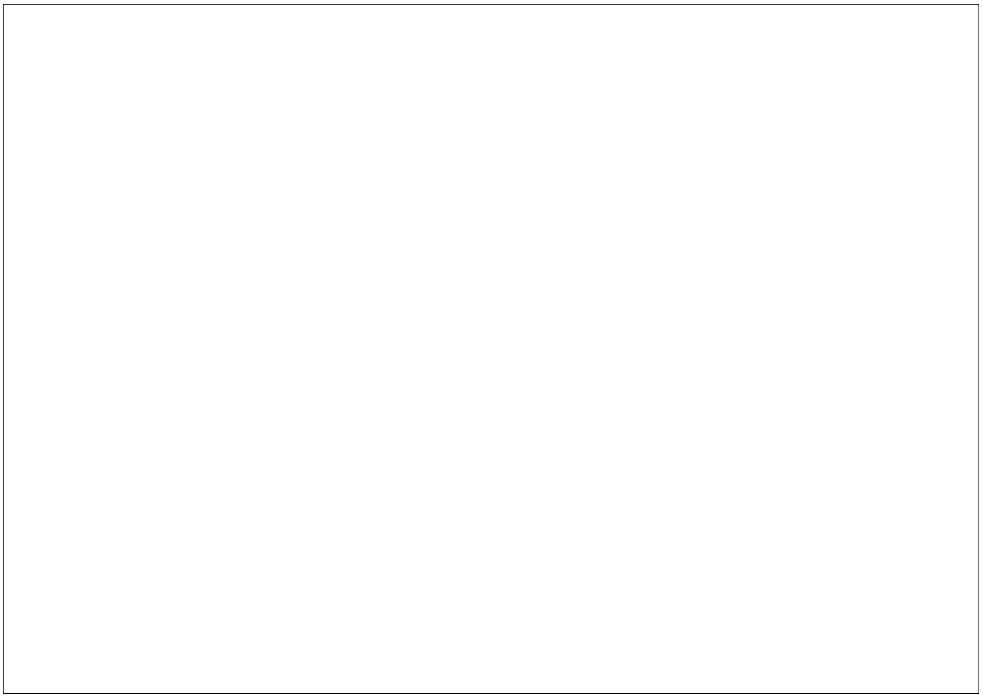


Figure 8. The division between eastern and western Baltic cod follows roughly the statistical division of the Baltic Sea into western and eastern Baltic Sea. The western Baltic Sea (SD 22-24) is coloured orange in the map.

The highly variable hydrographic conditions in the Baltic Sea, with a declining salinity as one moves east and north as well as large and varying hypoxic or anoxic areas, in addition to seasonally strong stratification diminishing exchange between bottom and surface layers, renders the brackish system a highly productive yet low-diversity ecosystem (Hüssy 2011, Möllmann et al. 2008). The Baltic cod appears to be adapted to withstand these conditions, assuming a role as top predator in the Baltic Sea, preying predominantly on sprat (*Sprattus sprattus*), herring (*Clupea harrengus*) or on smaller individuals of cod as well as on benthic prey (HaV 2018). Western Baltic cod, reaching maturity at ages between two and six years, spawn in the early spring (HaV 2016). Adult cod migrate between specific feeding and spawning areas, but the strength and direction of these migrations vary between years depending on environmental conditions (Hüssy 2011).

5.1.1 Stock status

The cod stock in SD 22-24, although being a relatively small stock, appears to be highly productive (ICES 2017). The stock has been fished at high intensities for

many years, at levels above FMSY for more than 30 years (ICES 2017), and recreational fisheries is contributing to increasing proportions of the total catch (ICES 2017).

The Western Baltic cod spawning stock biomass (SSB) has fluctuated considerably over the years, and has been below the limit reference point (B_{lim}) since 2008. In the 2017 ICES assessment, SSB was estimated to be below half of B_{lim} (ICES 2017), and despite a significant increase in SSB in the 2018 assessment the stock is still below the size reference point (ICES 2018b). The stock is characterized by an age structure with few age groups, and a large proportion of first-time spawners (Hüssy 2011). The stock is highly dependent upon the strength of recruitment, which has been low since 1994, and for 2016 and 2018 recruitment (age 1) reached historically low levels (ICES 2018b).

Prior to the current study, estimates on cod removals by the recreational fisheries sector have been based on the mail survey carried out by Statistics Sweden, going back to 2013 (Fig. 9). These numbers are based on cod fished from any Swedish waters, and hence are not according to cod stock.

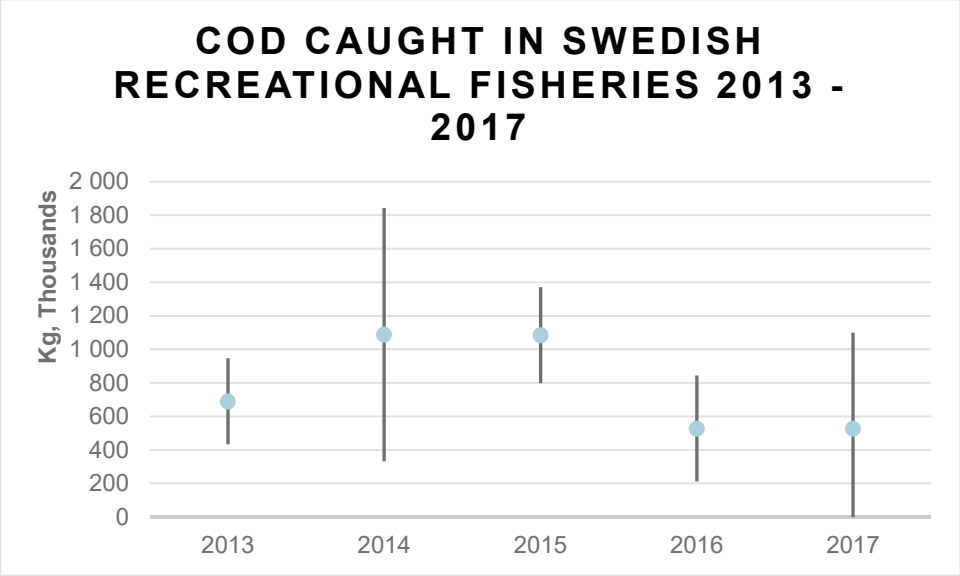


Figure 9. Cod caught in recreational fisheries in Sweden between 2013 and 2016. The centre indicate estimated catch in Kg (thousands), while the bars show standard deviation.

5.1.2 Management

Management rules are in place to regulate the catches of cod in the SD 22-24 (the Danish straits, the Sound and Arkona basin). Limitations on commercial fisheries in the Sound (SD 23), such as a complete trawl prohibition since the 1930s (due to

ship traffic in the area) and regulations on fishing net mesh size, has led to a relatively stronger cod stock in this region, with high biomass and a good size structure. This is in contrast to the cod stocks in the remaining Baltic Sea, as well as the Kattegat and Skagerak, where trawling is an important component of commercial fisheries.

In response to the declining stock, the EU council introduced new regulations on commercial cod fisheries in the Baltic Sea, including extended closure periods to protect spawning aggregations of cod as well as landing obligations. As of January 1st 2015, cod below a specified minimum size (35 cm) has to be landed whole but cannot be sold for human consumption (Landing obligation, HaV 2018, ICES 2017). The minimum mesh size for net fishing is set to 110 mm (HaV 2016).

With regards to recreational fisheries for the western Baltic cod, estimated to be a significant contributor to its overall fishing mortality, a daily bag limit per fisher was introduced from 2017 in SD 22-24 (EU 2016). This bag limit was defined as no more than three cod per fisher per day during February and March, and thereafter no more than five cod per fisher per day. In addition, a minimum size limit (38 cm) was introduced for cod caught in recreational fishery within this region (HaV 2016). The restrictions were continued in 2018, while for 2019 the bag limit has been increased to a total of seven cod throughout the year.

5.1.3 Current implementation of recreational fisheries data in stock assessment

Data from recreational catches have been included in western Baltic cod stock assessments since the 2013 benchmark workshop on Baltic multispecies assessments (WKBALT), ICES 2013). There are however uncertainties in these numbers, as only data from German recreational fisheries have been included. There is a large year-to-year variation in German recreational catches, in addition to the early years being extrapolated based on recent estimates (ICES 2017).

Although knowledge on recreational fisheries is currently limited, recreational removals of western Baltic cod have been estimated to be 52 % of total removals in Germany, while removals in Sweden and Denmark are preliminary estimated to be 9 and 15 % of the total removals (Hyder et al. 2018). Stock assessments not including recreational data can hence be said to largely underestimate total removals. Efforts to estimate and include Danish and Swedish recreational data in assessments are ongoing, and removals are expected to be included in western Baltic cod stock assessment from 2019.

5.2 The southwestern Swedish coast sampling

The southwestern Swedish coast is surveyed with a particular focus on cod, due to the urgent assessment needs of cod in this area. The area corresponds to ICES subdivisions 23 and 24, part of the western Baltic cod stock assessment unit (along with SD 22, see Fig.11 for ICES SD, ICES 2018b). The target population of the ongoing survey is those trips where recreational fishing is occurring in SD 23 and SD 24, while the population studied is all the fishing trips that end in that part of the Swedish coast, irrespective of the nationality of the fisher. Recreational fishing carried out in the same marine waters but ending the fishing trip in other regions or countries, such as Denmark, is hence not covered by the scope of the SLU-MRFS.
A registry of recreational access points in the area was created, to be sampled in two spatial strata; the south-western and the south coast covering ICES subdivisions 23 and 24 respectively (Fig. 8, Fig. 10), and four temporal strata (quarters).

Figure 10. The identified access points of the initial SLU-MRFS 2017. For the continuing sampling after 2017, the fringe municipalities (SD 21 and 25) are removed from the schedule. The western Baltic cod stock is defined as the cod stock found in SD 22-24.

The sampling originally carried out in 2017 occurred in sampling waves, a specified sampling period consisting of a predefined number of dates per sampling mode. The different modes covered were tour-boats, charter boats and private boats, and shore-

line fishers (Tab. 1). These sampling waves were systematically allocated throughout each quarter with a random start day in the first or second week of the quarter. In 2018, this design was slightly modified according to experience, and fringe communes are excluded from the survey. For the continuation in 2019, the effort and catch components of recreational fisheries will be surveyed separately. Stratification will be reduced, enabling a more targeted sampling for catch rate estimation.

Table 1. Number of sampling days per wave and quarter in 2017.

Sample size 2017	south-west (SD 23)		South (SD 24)	
	per wave	per quarter	per wave	per quarter
Tour-boats	1	6	1	3
Charter + private	2	12	1	6
shoreline (q3+q4)	2	12	2	12

5.3 Sampling design – tour-boats

The fishing mode tour-boat is assessed by on-board sampling at sea collecting data on effort and catches. A list of companies operating from the ports in the south-western and southern coasts was compiled, and sampling day is chosen according to wave allocation, while company and boat are drawn randomly. If the chosen boat is not available or not carrying a trip on the specified day, the next boat or company is chosen until a trip is booked.

Figure 11. Tour boat sampling. Cod are counted (catch and release), retained catch is measured and weighed, and otoliths are removed for later age determination. Photo: Åke Ottosson, Hege Sande

Sampling on-board tour-boats consists of two parts; an effort component and a catch component (Fig. 11). The number of anglers as well as hours fished is noted for effort. Harvested catch is counted and measured, as is the discarded catch as far as possible, depending on number of anglers and number of fish caught. Biological measurements of harvested catch takes precedence over discarded catch, and attaining complete discard data for individual anglers is prioritized over getting partial data for all anglers. Discarded catch is identified and counted, and as time allows, measured. Otoliths are taken for later age determination. The tour boat sampling has yielded abundant data of high quality, and has remained largely unchanged over the years 2017 – 2019.

5.4 Sampling design – charter boats and private boats

The fishing mode "charter boats and private boats" is sampled in access points of Scania, with the aim to collect data on recreational fishing effort and catches. Sampling waves with a predefined number of sampling days per wave with randomly allocated sampling shifts (day, evening or night) occurred six times per quarter in 2017 and 2018.

Within each coast, access points have been sampled in one randomly selected area (municipality) at a time (one whole day of a sampling wave spent in one municipality), regardless of the number of sample sites in that municipality (Tab. 2). Not all access points within a municipality were sampled in one day, and to avoid unnecessary long and erratic travelling times between sampling sites these were subclustered with order based on physical proximity.

Table 2. Simplified sampling design for the 2017 and 2018 SLU Marine Recreational Fisheries Survey.

	Sampling frame	Sampling unit (SU)	Selection method	Sampling effort
1SU	List of calendar days	Day	systematic w random start	12 SW coast
				6 S coast
2SU	Matrix of municipalities*work shifts	Municipality*work shift	random w replacement, unequal prob.	1 municipality*work shift per day
3SU	List of access points	Access point	random w/out replacement, equal prob.	2-7 per municipality*work shift
4SU	"list" of arrivals	Trip arrival	census	Not applicable

The municipalities with access points facing SD 23 and SD 24 were sampled with equal probability, however, two fringe municipalities were included in 2017. Random draw, with the probability of a fringe municipality set at 0.1 and of a main

municipality set at 0.9, was chosen in order to ensure sufficient coverage of the main municipalities while allowing some sampling of the fringe municipalities to occur. These were removed from the 2018 sampling. In a given sampling day three possible work shifts were possible, namely morning (0600-1400), afternoon (1400-2200) and night (2200-0600). For effort estimations, outgoing and incoming boat counts were performed during the allocated time in each harbour, while persons in incoming boats were approached and interviewed about their current fishing trip as well as their fishing during the last four months. Questions included in the questionnaire were e.g. target species, time and area fished, gear used, fishing mode and catch as well as releases composition, in addition to social-structural information such as age, sex and postal code. If fishing occurred, any catch kept was inspected and if possible measured. In 2019, sampling will be more concentrated on the high-activity harbours and less stratified in both time and place, based on experiences from sampling in previous years.

5.5 Sampling design – shoreline fishers

Fishing from the shoreline along the Swedish coast is difficult to estimate due to the large number of available fishing spots, rendering the entirety of the coastline as potential access-point for fishing. Representative sampling would require large resources, both in terms of staff time and monetary values. Shoreline recreational fishers encountered in or close to marinas visited by the on-site survey team are interviewed following the same questionnaire as that used for incoming boats in harbours and asked whether their catch can be assessed by the survey agent.

Figure 12. Cod otoliths are sampled on board tour boats and at access points for private boats, and added to numbered slots for later age determination by experienced otolith readers. Photo: Åke Ottosson (Landskronabåtarna).

5.6 Additional pilots and surveys under way

A pilot is under way with passive monitoring of effort in selected harbours using cameras. These cameras will aid in identifying periods of high fishing activity enabling a more targeted on-site survey, while also confirming whether or not assumptions on periods of low or zero activity holds true. Camera set-up will initially be in four relatively large harbours and in four relatively small harbours.

Due to issues in intercepting recreational fishers in SD 24, with zero reported catches in 2017 and one sampling day with catch in 2018, the current on-site creel survey has proven highly ineffective. The next step in reaching these otherwise so hard-to-reach fishers is an attempt at a respondent driven survey, where a few known and cooperative individuals will act as seeds. They will 1) provide data from their last fishing trip reported on a pre-paid post card, and 2) invite other fishers to participate.

Shoreline fishers are spread out along the coast, and on-site surveys could not reach and count all or maybe not even a representative proportion of them. Aerial surveys identifying hot-spots have been performed in 2017. For 2019, there are

plans on using drones equipped with cameras for effort estimation in areas where on-site surveys would otherwise be too demanding on time and human resources.

As there is a requirement to deliver not only catch data from recreational fisheries, but also releases, it is sensible to know the catch & release mortality of cod. Plans exist for such studies, yet no timeline has been set. At the time being, mortality estimates from German studies are being used (Weltersbach and Strehlow 2013).

6 Concluding remarks & research topics

The Swedish Board of Agriculture and Swedish Agency for Marine and Water management (HaV) owns the task of promoting a long-term sustainable fishery by the Swedish government. In their mission lies promotion of recreational fishing for social, recreational and health benefits, as well as generating societal and corporate economical value from fishing tourism (HaV 2017). The EU Data Collection Framework is obliging member states to collect data on e.g. recreational fisheries for selected species, as well as ensuring that recreational fisheries are conducted in manners adhering to the CFP. With the current knowledge of the extent and character of recreational fisheries in Sweden such obligations are difficult to fulfil. Considering recent knowledge that recreational fisheries in some instances worldwide are harvesting a significant proportion of the total catch (Pauly & Zeller 2015, van den Hammen et al. 2016, Hyder et al. 2018), it becomes clear that broader knowledge about recreational fisheries and the potential impact of recreational fisheries on fished stocks is needed. By pursuing the following research topics, knowledge gaps can be filled with the ultimate overarching goals of 1) Developing sound methods for characterizing and quantifying recreational fisheries, 2) quantifying the effort and removals in Swedish recreational fisheries and 3) applying this information in the evaluation of stock status for management purposes (Fig. 14).

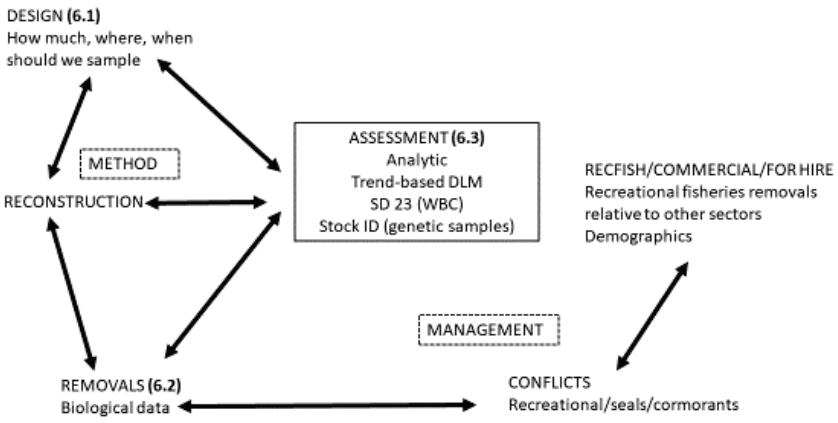


Figure 13. Schematic overview of research topics covered by the current project. DLM = Data Limited Methods; WBC = Western Baltic Cod.

6.1 Design, data, collection and analysis

-When, where and how much should we sample the recreational fisheries for routine assessment?

Recreational fisheries in Sweden can be split into a for-hire sector (tour-boats, charter-boats) and public (private boats, shore-line fishing), with fishing trips taking place along a vast coast (in the case of shore-line fishing) or starting/ending in a vast array of very dispersed ramps and access points, and differently sized marinas. An accurate estimation of all these components implies significant resources and/or significant assumptions in respect to the distribution of CPUE and Effort and similarities between commercial and recreational catches (e.g. in terms of length-at-age). To maintain future costs at reasonable levels and ascertain the quality of estimates obtained by the monitoring, current methods will be continuously developed, evaluated, and quality controlled. Reconstruction of recreational catches for periods where data is missing will be undertaken.

6.2 Removals, demographics and conflicts

-What are the total removals from recreational fisheries? What is their biological structure?

-How important are the different segments of the Swedish recreational fisheries? Is there biological and social overlap between them?

-Are recreational fisheries catching the same species and sizes as commercial fisheries?
-Are recreational fisheries catching the same species and sizes as top-predators such as seals or cormorants?

Available data and data collected during the project will be used to estimate the total catch of Swedish recreational fisheries on finfish (ex. cod). Estimates for the different components of the recreational fisheries (tour boats, charter boat, private boats, shoreline fishing) will be produced, and the segments will be compared in terms of catch species composition, size and age composition, and fishing hotspots. The total catches, biological composition and size- and age-distributions between the recreational and commercial fisheries will be analysed, and potential areas of conflict will be identified. Data on seal and cormorant diets could provide insights into potential overlap between prey items of top predators and recreational catches.

6.3 Assessment

-Application of new knowledge on recreational fisheries into preparation of data for stock assessment.

For some selected stocks (ex. the Western Baltic cod), the new quantitative information gained by the project on total catches and length- and/or age-composition will be applied into ICES analytical stock assessment. This will produce new estimates of stock size and commercial fishing versus recreational fishing mortality that will be used to provide management advice. Effort is central to the estimation of any fishing, but for some management applications of recreational fisheries the required add-on data may look very different. To this end, the potential of data from Sweden Statistics (Statistiska centralbyrån, SCB) and other sources to be used to produce a time series of recreational catches useful for assessment will be evaluated. Genetic sampling of cod in the Sound (SD 23) will shed light on the potential of treating this stock as a separate stock for assessment and management purposes.

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