Original Article

Does recreational catch impact the TAC for commercial fisheries?

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The western Baltic cod is one of the first fish stocks in Europe that, since 2013, includes recreational catches in stock assessment and fisheries management advice. In this paper, we investigate the sensitivity of the calculated commercial total allowable catch (TAC) to including recreational catches in stock assessment. Our results show that the most crucial aspect in terms of the impact on commercial TAC is the assumption on recreational catch dynamics relative to that of commercial fisheries used in forecast. The results were less sensitive to the information on the historical amount and age structure of recreational catch. Our study is intended to inform potential debates related to resource allocation between the commercial and recreational sectors and contribute to developing a general framework for incorporating recreational catches in fisheries management advice in ICES.

Keywords: recreational catch, stock assessment, TAC.

Introduction

Over the last decades, recreational fishing has grown in importance worldwide and recreational harvest has in some cases become comparable with or even exceeds that of commercial fisheries (Cooke and Cowx, 2006; Ihde *et al.*, 2011). Similarly, the potential impacts of recreational fisheries on marine fish stocks, which were often neglected in the past, are gaining increasing attention (McPhee *et al.*, 2002; Coleman *et al.*, 2004; Cooke and Cowx, 2004; Lewin *et al.*, 2006). In Europe, marine recreational fisheries are also gaining importance (Pawson *et al.*, 2008; Ferter *et al.*, 2013), and regular collection of catch data from this sector for selected species in European Community waters was initiated in 2001 (EC, 2001). Subsequent investigations have revealed notable proportions of total removals taken by recreational fisheries, for example, for sea bass in French waters (Herfaut *et al.*, 2013) and cod in the western Baltic Sea (Strehlow *et al.*, 2012). In 2013, the recreational catches of western Baltic cod were for the first time included in the stock assessment (ICES, 2013a), being one of the first stocks in Europe to take into account recreational catches in fisheries management advice.

Different from commercial fisheries, obligations for catch reporting and official catch recording systems are usually not in place for recreational fisheries. Therefore, large efforts are devoted to developing surveys and other methods to obtain estimates for the magnitude of recreational catch (Vølstad *et al.*, 2006; Griffiths *et al.*, 2010; Veiga *et al.*, 2010; Dorow and Arlinghaus, 2011). The resulting estimates are therefore most likely associated with relatively high uncertainties, similar to other sources of fish removals not directly registered, such as discards in commercial fisheries (e.g. Punt *et al.*, 2006). The quality of different sources of fisheries information is evaluated in ICES by relevant expert groups that decide whether or not the information is appropriate to be incorporated in stock assessments. For western Baltic cod, ICES decided to include the German recreational catch data in the stock assessment (ICES, 2013a). In this paper, we focus on the next steps and new challenges for the advisory process that follow after the recreational catch has been incorporated in stock assessment and subsequently become part of fisheries management advice.

Establishing clear procedures for how recreational catch should be treated in calculating total allowable catch (TAC) for commercial fisheries is required. Further, when recreational catch is incorporated in stock assessment and subsequent management advice, the allocation of resources between the commercial and recreational fisheries becomes explicit, and can raise conflicts between the two sectors (Cooke and Cowx, 2004; Arlinghaus, 2005; Borch, 2010).

To enable informed discussions on these matters, it must be emphasized to first understand the impact on the commercial TAC that results from adding recreational catches to the stock assessment model. The purpose of this study is to quantitatively demonstrate the sensitivity of the commercial TAC to recreational catches, using scenario analysis. The analyses are based on the example of the western Baltic cod, but address general questions relevant for developing a framework for considering recreational catches in fisheries management advice in ICES.

Material and methods
Background information on recreational catch of western Baltic cod

Recreational cod catches in the western Baltic Sea are mainly taken by private and charter boats and to a small degree by land-based fishing methods. The only regulative measure applied for the recreational fishery for cod is the legal minimum landing size that is 38 cm, as is for commercial fisheries. National marine surveys revealed that the recreational fishery removes considerable amounts of biomass from the western Baltic cod (ICES, 2011; Sparrevohn and Storr-Paulsen, 2012; Strehlow *et al.*, 2012); for example, in 2010, recreational harvest (combined for Denmark, Germany, and Sweden) accounted for 25% of the total landings (commercial landings + recreational harvest; ICES, 2013a). The largest share of recreational catch is taken by Germany, and for this country also the longest time-series of data are available. Therefore, during the ICES benchmark assessment for western Baltic cod, German recreational data were decided to be included in the stock assessment (ICES, 2013a). German recreational catches fluctuate around 2000 t annually (Figure 1), which accounted for 10–14% of the international total catch of this stock in the last 5 years. In the future, Danish and Swedish recreational catch is intended to be included in the stock assessment as well.

The German marine recreational data collection programme follows a multiannual, multistage survey design (see Strehlow *et al.*, 2012, for further information). An off-site survey (mail–diary) is used to estimate effort. On-site, a stratified random sample of access points and days is used to estimate catch rates (cpue). Data on length distributions of recreational catches are collected onboard charter vessels trips. Other data sources include self-reported length samples from fishing events. Length–weight relationships and age–length keys from commercial sampling and research surveys are used to convert the recreational catch numbers at length to total weight and numbers-at-age. The sampling design, accuracy, and precision of the estimates are documented in Strehlow *et al.* (2012). An analysis of the calculated harvest data in numbers (2005–2010) by bootstrapping estimated a relative standard deviation between 14.9 and 17.3% for the different estimates (Strehlow *et al.*, 2012).

German recreational fisheries data are available from 2005 onward. The stock assessment for western Baltic cod covers the years back to 1970. The recreational catch for years before 2005 were extrapolated using the average catch from 2005 to 2011, taking into account the historical development of marine recreational fishing in the former eastern Germany (GDR) after unification (see ICES, 2013a, for further details). The recreational fishery catches mainly cod at age 1–3. Including recreational catches in stock assessment resulted in an average 6–7% (up to 15% in some years) higher spawning-stock biomass and recruitment estimates compared with the assessment with no recreational catch (Figure 1). The influence on fishing mortality (F) for reference ages (3–5) was minor (estimated an average of 2% lower than without recreational

catch). The uncertainties in assessment results, represented by 95% confidence intervals of the estimates, were similar in the assessments with or without recreational catch. More information of the effect of recreational catch on stock assessment results can be found in ICES (2013a).

Scenario analyses of the impact of recreational catch on TAC

Calculation of commercial TAC for western Baltic cod in ICES currently treats recreational catch similarly to commercial discards, i.e. assuming recreational catch in forecast years to be a fixed proportion of total catch that is subsequently set aside when calculating TAC for commercial landings (ICES, 2013b). However, the impact of recreational catch on commercial TAC has not been explicitly investigated. Furthermore, the possible alternative options for dealing with recreational catch in TAC calculation and resulting impacts on catch limits for commercial fisheries have not been explored.

In this paper, a series of stock assessments with short-term forecasts were performed to investigate the effect on the commercial TAC advice of including recreational catch in the stock assessment. The investigated scenarios addressed combinations of the following aspects of recreational catch: (i) the amount of recreational catch, (ii) the age structure of recreational catch, (iii) allocation between commercial and recreational fisheries in TAC calculation, and (iv) the overall fishing mortality relative to the management target. Below each of these aspects is explained in further detail, and an overview of the investigated scenarios is presented in Table 1.

### The amount of recreational catch
Three scenarios of the amount of recreational catch were tested: (i) no recreational catch, (ii) the observed amount of recreational catch, as included in the ICES assessment of the western Baltic cod, and (iii) the observed amount multiplied by factor 3 in each year in the time-series. The total international recreational catch of western Baltic cod is probably not higher than assumed in option (iii), given that Germany takes the largest share of recreational catch, which is represented by the observed amount.

Age structure of recreational catch
The scenarios of age structure included: (i) the observed age structure, as used in the ICES assessment, (ii) the observed age structure moderately changed towards a larger proportion of older fish (Modified 1, Figure 2), and (iii) the observed age structure substantially modified towards a larger proportion of older fish (Modified 2, Figure 2).

Catch allocation in calculating TAC
Three options were explored: (i) the recreational catch-at-age in a year for which TAC was calculated (e.g. 2014) was assumed to be a fixed proportion of the total catch-at-age, and set equal to the proportion observed in the last data year (e.g. 2012). This option was followed by ICES in 2013 (ICES, 2013b), (ii) the amount of recreational catch-at-age in forecast was assumed equal to that in the last data year, and (iii) the partial fishing mortality-at-age due to recreational catch was assumed equal to that in the last data year. The three different catch allocation options were applied for each of the scenarios of the "amount" and "age structure" of recreational catch (Table 1). The total fishing mortality in the intermediate year was kept at status quo, following the procedures applied in ICES assessments (ICES, 2013b).
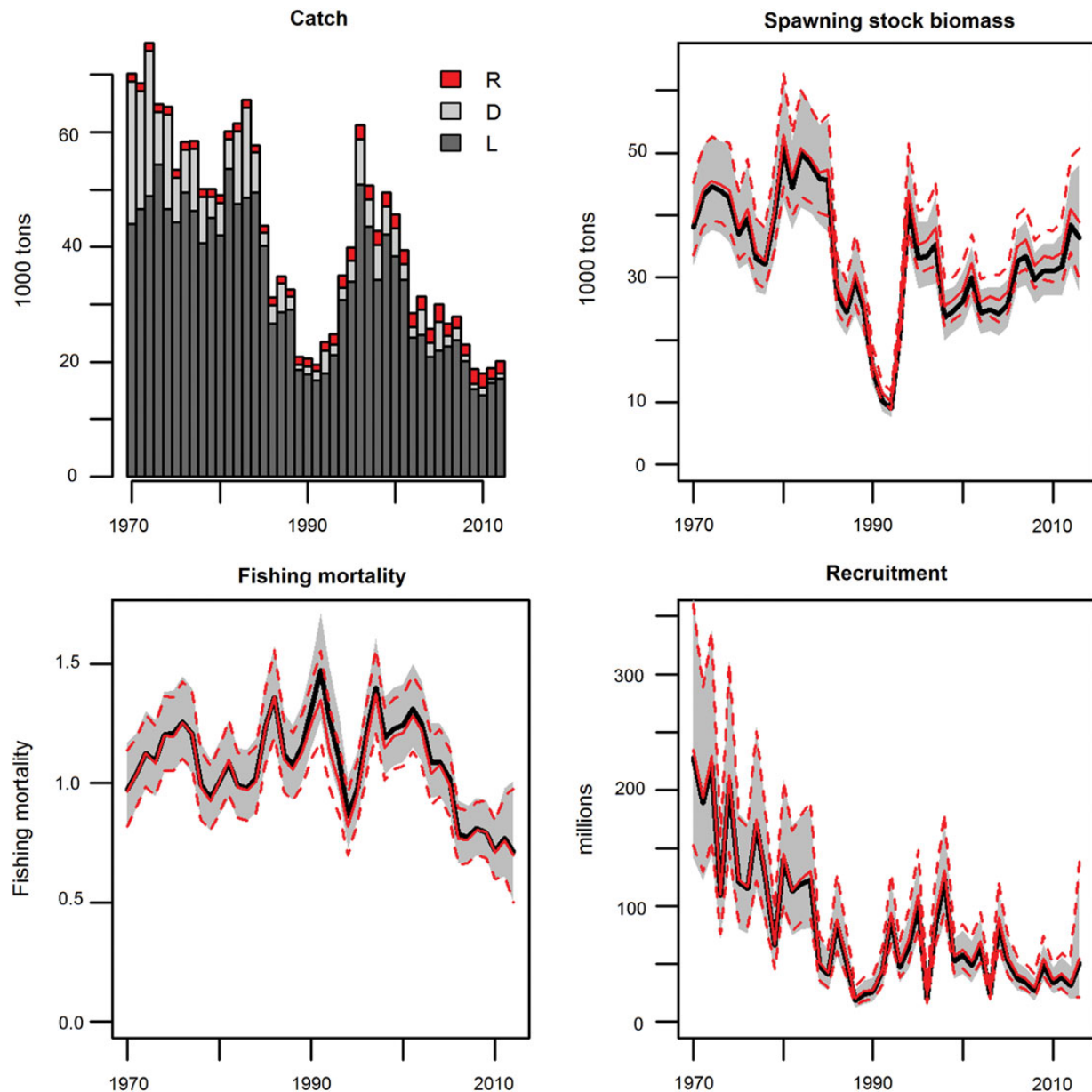
Figure 1. The recreational catch (*R*) of western Baltic cod compared with commercial landings (*L*) and discards (*D*), and comparison of spawning-stock biomass, fishing mortality (ages 3–5) and recruitment (age 1) from stock assessments with (red lines) and without (black lines) including the recreational catch estimates (from ICES 2013a). Stippled lines and shaded areas show 95% confidence intervals in the estimates, respectively.

Target fishing mortality

For each of the scenarios, two examples of target values of total fishing mortality (*F* at ages 3−5), 0.60 and 0.26, were used. These values correspond to *F* targets in the present management plan for the western Baltic cod (EC, 2007) and to maximum sustainable yield (MSY; F_{MSY}), respectively. The calculated TACs in scenario analyses corresponded to fishing mortalities set equal to these targets (Table 1).

The stock assessments were performed using the state space stock assessment model (SAM; Nielsen and Berg, 2014) that is used to assess the western Baltic cod stock in ICES. Full time-series of input data (1970–2012) was included in the assessment in each scenario. The input data and model settings were identical with these used in ICES assessments (ICES, 2013b), apart from the recreational catch-at-age that varied according to the scenarios defined. The TAC calculation in short-term forecast was performed deterministically, using survivors and fishing mortalities in the final year from SAM assessments for given scenarios. The recruitment in forecast years was based on geometric mean of the estimates for 2001–2011.

In each scenario, the calculated TAC corresponded to commercial landings. In presentation of the results, the TACs calculated for scenarios 1–6 (Table 1) were compared with scenario 0, where no recreational catch was included in the assessment.

Table 1. The scenarios (0–6) run in stock assessments and TAC calculations.

Scenario id.	Amount of recreational catch	Age structure of recreational catch	Catch allocation options	F targets
0	0	–	1, 2, 3	0.6, 0.26
1	Observed	Observed	1, 2, 3	0.6, 0.26
2	Observed × 3	Observed	1, 2, 3	0.6, 0.26
3	Observed	Modified 1	1, 2, 3	0.6, 0.26
4	Observed × 3	Modified 1	1, 2, 3	0.6, 0.26
5	Observed	Modified 2	1, 2, 3	0.6, 0.26
6	Observed × 3	Modified 2	1, 2, 3	0.6, 0.26

The amount of recreational catch corresponds to zero (0), observed, and three times the observed (Observed × 3) recreational catch. The age structure used in scenarios (Observed, Modified 1, and Modified 2) is shown in Figure 2. The three different options for catch allocation in forecast: (1) recreational catch assumed as a fixed proportion of the total catch; (2) the amount of recreational catch assumed equal to that in the last data year; (3) the partial fishing mortality due to recreational catch assumed equal to that in the last data year (see the Material and methods section for further explanation).
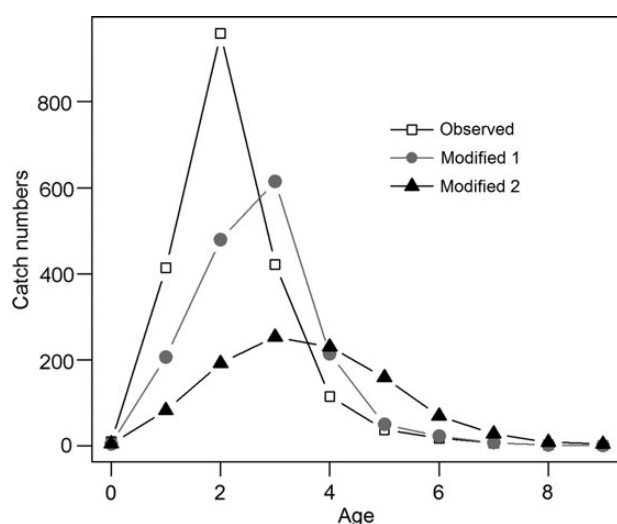
Figure 2. The observed age distribution of recreational catch and the two modified scenarios (Modified 1 and Modified 2) used in the analyses. Each scenario sums up to the same catch weight.

Results

Our results show that including recreational catches in the assessment has negligible impact on the commercial TAC, given the present amount and age structure, and assuming recreational catch to be a fixed proportion of the total catch in TAC calculation (as currently done in ICES; Figure 3a and d; scenario 1). Under the assumption of recreational catch being proportional to the total catch, the effect on TAC remains low even if the amount of recreational catch is increased threefold and/or the age structure is moderately changed towards a larger proportion of older fish (Figure 3a and d; scenarios 2–4). This is because by including recreational catch in the assessment, the overall stock size is estimated larger, compared with the assessment with no recreational catch. Thus, the two processes, on the one hand generating a larger stock by adding recreational catch, and on the other hand setting a proportion of the total catch aside for recreational fisheries, outbalance each other.

In contrast, the impact on the TAC is considerably larger when recreational catch is assumed either to be a fixed amount (Figure 3b and e) or exert a fixed partial fishing mortality ($F_{recreational}$) on the stock (Figure 3c and f). In this case, the magnitude and direction of impact (either positive or negative) on the commercial TAC depends on the level of fishing mortality in the last assessment year relative to the target. When the current fishing mortality is close to the target (as for the target at 0.6 in our example, Supplementary Figure S1), the commercial TAC is not sensitive to the investigated options of separating recreational and commercial catch in forecast (Figure 3a–c). In the opposite case, when the current *F* is substantially above (or below) the target and consequently has to be reduced (or increased) when calculating TAC, assuming constant recreational catch will result in remarkably lower (or higher) commercial TAC than would be the case if no recreational catch was included in the assessment (Figure 3d–f). Similar effects occur when the recreational fishing mortality is assumed constant.

The commercial TAC was not very sensitive to the age structure of recreational catch. Currently, the recreational catch of cod in the western Baltic Sea is dominated by relatively young individuals (mainly age-group 2). The tested scenarios show that a moderate change in age structure towards a larger proportion of older fish generally gave similar results in terms of the calculated TAC, compared with the scenarios with the observed age structure (Figure 3, compare scenarios 1 and 3, or 2 and 4). Only at a substantially larger proportion of older fish in recreational catch, a higher commercial TAC was obtained, compared with the scenarios with observed (or moderately changed) age structure. This is because a relatively larger proportion of older fish in catches results in lower fishing mortality estimate, generally allowing for a higher TAC. Thus, at present situation and according to the different recreational catch scenarios we have tested, the biological advice on TAC is relatively robust to moderate uncertainties in age information for recreational catch.
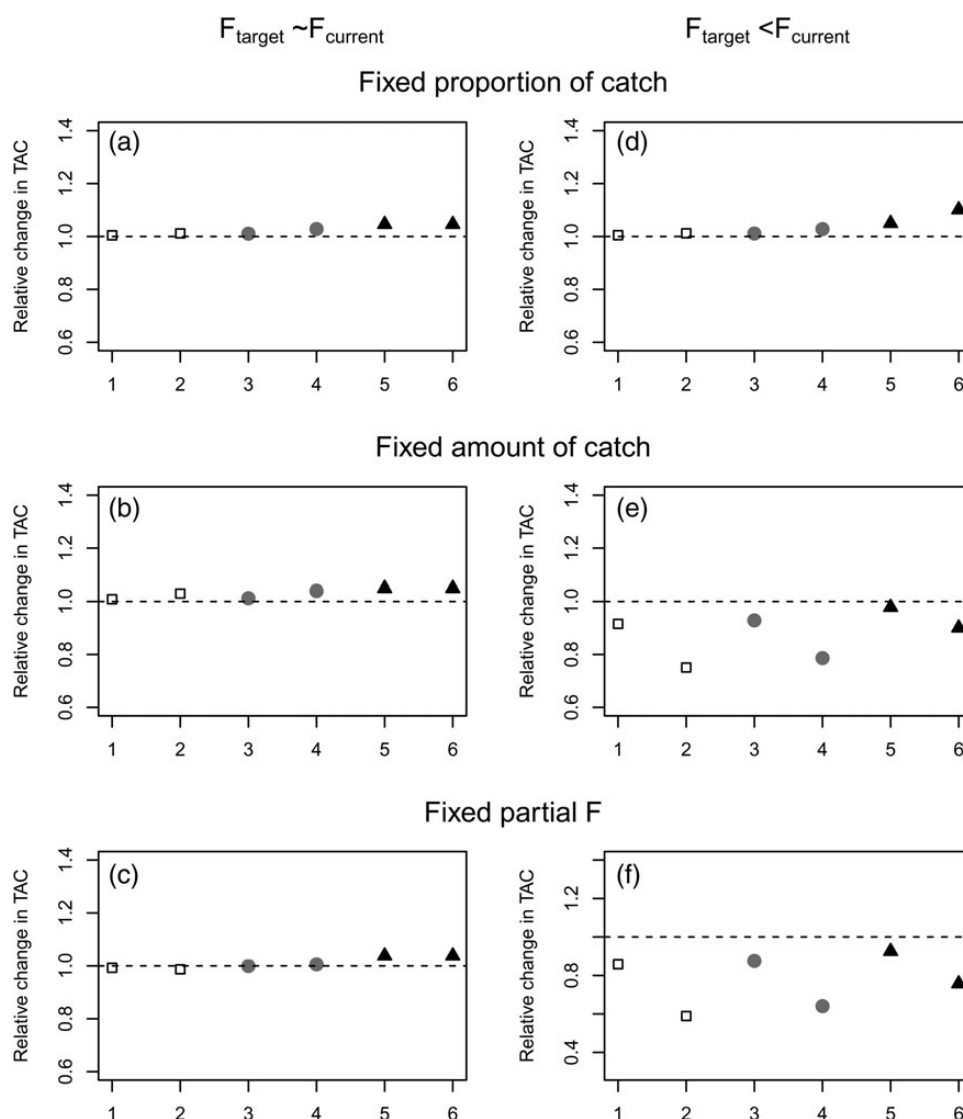
Discussion
Accounting for recreational catch in TAC advice
One of the key considerations for fisheries management advice is uncertainty in catch information. Similar to any other source of input data to stock assessment, a discussion is needed within the ICES community on deciding on a case-by-case basis when the quality of recreational catch information is sufficient that its addition to a stock assessment improves the quality of assessment and advice, instead of degrading it. Best practice guidelines leading to minimum bias and accurate estimate of precision at the design, implementation, and analysis of recreational sampling schemes are available in ICES (2012, 2013c). Further, detailed recommendations concerning the frequency and coverage of recreational fishery surveys have been made by the ICES Working Group on Recreational Fisheries Surveys (ICES, 2013c). In the case of the western Baltic cod, adding recreational catch did not notably change the uncertainties in assessment results represented by confidence intervals of the estimates from ICES assessments (Figure 1) or from the scenarios tested in this paper (Supplementary Figure S2).

Once a decision is made to include recreational catch in the stock assessment, new challenges for fisheries management become apparent, essentially related to resource allocation between the commercial and recreational catch sectors. Borch (2009) explains that to make deliberate decisions, the fisheries management needs to accept marine recreational fisheries as a "new" stakeholder. There

$F_{target} \sim F_{current}$ $F_{target} < F_{current}$

Fixed proportion of catch

Fixed amount of catch

Fixed partial F

Figure 3. The change in calculated TAC corresponding to different scenarios of recreational catch (scenarios 1–6 in Table 1, shown in *x*-axis) relative to the scenario of no recreational catch (scenario 0 in Table 1). Numbers above or below 1 indicate a higher or lower TAC in a particular scenario, compared with the assessment with no recreational catch (scenario 0).

are different options where in the process the resource allocation between the two competitive users, commercial and recreational fisheries, can take place. In the biological advice, the TAC can be set to correspond to total allowable harvest that subsequently is divided between the commercial and recreational sectors by managers (Batstone and Sharp, 1999). This approach is, for example, followed for some US stocks where the stock assessment is providing total catch estimates (e.g. NOAA, 2012). Alternatively, TAC advice can be provided for the commercial catch sector only, as is currently done for the western Baltic cod in ICES (ICES, 2013b). However, in this process, an allocation of a certain share for recreational sector is still taking place. This is because the *F* targets, such as those corresponding to MSY, shall represent total removals from the stock by all fleet segments, regardless of whether commercial or recreational. Thus, following these overall *F* targets, and providing a TAC only for the commercial sector, inevitably involves allocating a certain amount to the recreational fisheries. Contrasting with the approach

described above where the resource allocation is done by managers, in the latter case, the allocation takes place as part of a scientific process.

Regardless of where in the process allocation is imposed, clear rules for distributing the resource between commercial and recreational users are needed, which are not yet well established in Europe. Economic theory suggests that allocation of resources between users should be based on the equating of respective marginal values, so that aggregate societal benefits are maximized (e.g. Edwards, 1991). However, Common Fisheries Policy (CFP) in Europe as well as the Magnuson–Stevens Act (MSA), which is the primary basis for fisheries management in the United States, make it clear that allocation decisions should not be guided by economic principles alone, but also take into account social objectives. Thus, fisheries management generally seeks to meet on the one hand the goals of economic efficiency and at the same time secure the coastal, small scale, and recreational fishers (EC, 2009). Plummer

et al. (2012) provide an overview of current Fisheries Management Plans in the United States within the context of regulated allocations between commercial and recreational sectors. For most US fisheries that possess a commercial/recreational allocation scheme, the initial allocations were determined by historical harvest patterns. The stocks that have had the allocation ratio changed, mostly increased the allocation share for the recreational sector. These changes in allocation shares, e.g. for the greater amberjack, *Seriola dumerili*, and red grouper, *Epinephelus morio*, were based on perceptions of fairness, inequity, stability, and conflict mitigation. In contrast, a greater share of Spanish mackerel, *Scomberomorus maculatus*, was awarded to the commercial sector as the recreational sector was deemed to not be utilizing the original allocation share. Thus, in United States, economic efficiency has not been a key determinant of allocation changes. In general, the lack of a formal efficiency analysis has been deemed to be a function of poor economic, market, and social data availability (Agar and Carter, 2012).

In the case of the western Baltic cod and European fisheries in general, the analyses of historical harvest patterns are limited by relatively short time-series of recreational data. With no allocation rules in place, and the recreational catch not being managed, the commercial TAC for the western Baltic cod is currently calculated assuming the same relative proportion of recreational catch as observed in the prior year. This may not be most appropriate, given that commercial fisheries are constrained by catch and effort limits as well as driven by economic considerations, which do not impact recreational fisheries in a similar way (Pereira and Hansen, 2003; Coleman *et al.*, 2004; Cooke and Cowx, 2006; Strehlow *et al.*, 2012). However, analyses of the dynamics of recreational catches compared with commercial ones and the response of recreational catch to factors like changes in stock size are currently lacking. Thus, alternative assumptions may be similarly hard to justify. Continued data collection will allow investigating the temporal dynamics of recreational catch in the future and improving the understanding of recreational fishing patterns.

Managing recreational catch

Once the TAC is established and sector allocations are assigned, either implicitly or explicitly, the process of managing and monitoring sector allocations becomes a high priority. Monitoring the commercial sector is generally well established and quota utilization is tracked via landings transactions reports. Accounting for and tracking the utilization of the recreational sector quota, when established, is an entirely different matter. Tracking the recreational harvest for key species is accomplished in the United States via a statistically relevant official survey process. The newly implemented Marine Recreational Information Programme (MRIP) attempts to randomly survey marine anglers and generate estimates of effort, catch, and trip expenditures. The resulting recreational catch estimate is thus based on a survey sample and an extrapolation process, that may introduce sources of error that may exceed that associated with a rigid accounting process for commercial harvesters. Such potential errors may lead to inaccurate estimates of recreational effort and harvest.

The uncertainties related to monitoring recreational catch are an issue regardless of whether or not the recreational catch is directly managed, as it can also compromise the estimates of stock size. However, setting legally binding catch limits for recreational harvest has additional disadvantages related to large administrative costs and non-compliance issues (Gigliotti and Taylor, 1990; Sullivan, 2002, 2003). Further, traditional yield-based goals have little meaning for recreational fisheries (Larkin, 1977). Recreational

management objectives may be more about angling quality, thus the fishing effort that produces MSY may differ from the level providing maximum total satisfaction (Cox *et al.*, 2003; Radomski, 2003; Pereira and Hansen, 2003; Hussain and Tschirhart, 2010; Post and Parkinson, 2012).

However, if there is a need to reduce overall fishing mortality, the recreational effort and catch may also require management actions. Similar to commercial fisheries, possible recreational management measures include minimum landing sizes, daily bag limits, spatial and temporal closures, as well as, gear and bait restrictions. As mentioned above, the recreational western Baltic cod fishery is currently only regulated by a minimum landing size. A simple calculation using the German data showed that daily bag limits, e.g. nine cod per angler, had the potential to reduce the harvest up to 33% while only affecting 11% of the anglers (Strehlow *et al.*, 2012). Increasing release rates may have a positive effect on the stock, given the estimated mean survival rates of 88.8% for boat-based releases of western Baltic cod (Weltersbach and Strehlow, 2013). However, given the relatively high angling effort and limited range of alternative sites from ports of origin in the western Baltic Sea effort is likely to remain high (*cf.* Allen *et al.*, 2013). Further, understanding the behavioural response of anglers to recreational fisheries management will be important to assess individual measures, such as bag limits, etc. and their effectiveness. Using a socio-ecological model, Hunt *et al.* (2011) showed that fishing dynamics were strongly influenced by inverse density-dependent catchability risking overexploitation and collapse of local fish stocks, aggravated by more catch-oriented behaviour.

Conclusions and future needs

The persistent lack of reliable catch estimates of European marine recreational fisheries remains one of the biggest challenges for stock assessments and fisheries managers today. This fact is exacerbated given the fragmented nature of recreational fishing activities such as shore anglers, charter boat anglers, private boat anglers, gillnetters, fykenetters, etc. and their weak representation at national and European levels. The required precision of recreational sampling schemes and type of data collected (e.g. length composition) for shared stocks should be agreed upon on a regional level (ICES, 2012). A recently launched nationwide telephone screening survey followed by a 1-year diary study and quarterly recalls will improve the estimates of German marine recreational catches, and thus the quality of stock assessment in the future.

The quality of recreational catch information is also important for resource allocation between commercial and recreational catch sectors. In situations when recreational catch is poorly known, procedures may be needed to stabilize the interannual variations in the relative allocations. Management strategy evaluation methods frequently applied to commercial fisheries could be useful to decide on a suitable approach and explore the effects of potential errors in data and in management implementation in relation to the effectiveness of harvest control rules (HCR), including catch allocations between commercial and recreational sectors. This could be a fruitful area of fisheries modelling and could lead to consideration of risk-based HCRs; e.g. if including recreational catch creates considerable additional uncertainty in assessment results, a larger precautionary buffer may be needed when setting TACs, or in other cases, simpler assessment methods and decision rules may be needed.

The calculation of commercial TAC in ICES currently applies an allocation between commercial and recreational fisheries on relatively *ad hoc* basis, while alternative options and their pros and

cons have not been formally discussed or decided. In our analyses, the approach chosen to distribute the catch between the two sectors changed commercial TAC from 0 to 40%. Thus, well-documented and approved HCR to calculate commercial TAC, taking into account recreational fisheries are needed. We consider it particularly important to ensure transparency of the resource allocation between the different catch sectors. Further, a clear basis for the approach dealing with recreational catch in TAC advice needs to be established, as the implications for commercial TAC can be large. Furthermore, it must be emphasized to recognize the sensitivity of the calculated TAC to alternative assumptions and take into account related uncertainties. Our analyses are intended to inform potential debates on these matters and contribute to developing general procedures for incorporating recreational catch in the biological advice in ICES.

Supplementary data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

Acknowledgements

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