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The Baltic Sea: Estimates of total fisheries removals 1950–2007

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ABSTRACT

The International Council for the Exploration of the Sea (ICES) reports to the general public fisheries 'landings' not 'total removals' for north-east Atlantic waters. Thus, public data do not include all anthropogenic removals, including discards. We reconstructed total removals for the nine countries (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden) fishing in the Baltic Sea by estimating their unreported removals. Estimated total removals of 53.5 million tonnes are 30% higher than the 41.3 million tonnes ICES reports publicly for 1950–2007. During 2000–2007, total removals are 35% higher than reported data suggest. The major components of unreported removals since 2000 were unreported landings, discards and recreational removals. Unreported landings were dominated by Poland (47%), Sweden (12%), Denmark (10%) and Latvia (8%), while discarding was dominated by Poland (21%), Denmark (19%), Finland (15%) and Sweden (14%). Finland (32%) and Sweden (30%) contributed the most to recreational removals. While ICES includes some estimates of unreported landings and discards in their stock assessment process, the lack of comprehensive and transparent public reporting on a society-owned resource presents a hindrance to accountability and ecosystem-based management.

1. Introduction

Concerns about a global crisis in marine fisheries (e.g., Pauly et al., 2002) has brought a realization that many fisheries often lack even the most fundamental data to understand and assess their impacts on marine ecosystems, i.e., time-series information on total removals. Time series statistics on total anthropogenic removals are crucial to fisheries management as they allow for first-order assessments of the scale of fisheries over time, and of the status of the species and populations upon which fisheries depend (Caddy and Gulland, 1983; Grainger and Garcia, 1996). However, catch data routinely collected and published in most countries consist mostly of 'nominal' data, i.e., removals that are landed (so-called 'landings'), rather than the total withdrawals from marine ecosystems. Several components of total fisheries removals are often not recorded, generally referred to as illegal, unreported and unregulated catches (IUU, Bray, 2000). Such unreported removals include illegally caught fish, globally estimated at 11–26 million tonnes year^{-1} (Agnew et al., 2008), discards (Kelleher, 2005), unreported landings (Zeller et al., 2006, 2007; Wielgus et al., 2010) and recreational removals (Coleman et al., 2004; Zeller et al., 2008). The omission of many such data in fisheries statistics has made it more difficult to evaluate the impacts of fisheries on ecosystems, and to keep the public informed about the state of fisheries (Zeller et al., 2009). Incomplete catch statistics are not an issue only for developing countries (e.g., see Jacquet et al., 2010), but also for developed countries with sufficient human and financial resources to maintain decent statistics (Coleman et al., 2004; Zeller et al., 2008). Thus, in order to foster a foundation for ecosystem-based resource management, as well as transparent public accounting, reporting on total withdrawals is important.

Unreported anthropogenic removals are widespread in Baltic Sea fisheries, where landings from commercial fisheries have largely been the only form of removals officially reported to the public (although stock assessments do account for some unreported removals, and some of these data are publicly available). According to the European Court of Auditors, the incompleteness and unreliability of catch data has prevented the Total Allowable Catch (TAC) system in the Baltic from functioning properly (Anonymous, 2007b). In addition, the regulatory and institutional frameworks have guaranteed neither the exhaustiveness of data collection, nor the detection of inconsistencies during validation. Consequently, the ICES scientific advisory processes related to managing Baltic Sea stocks have only partially satisfied the requirements of formal analysis. It has been argued that the current TAC system contributes to practices that are not sustainable (Nielson and Christensen, 2006). As TACs have increasingly restricted legal fishing without addressing the growing real fishing capacity, the motivation for and gains from IUU fishing tend to increase (Bray, 2000). Policy makers therefore generally underestimate the impact of fishing, thereby threatening ecosystem functions and the future economic viability of the fishing industry.

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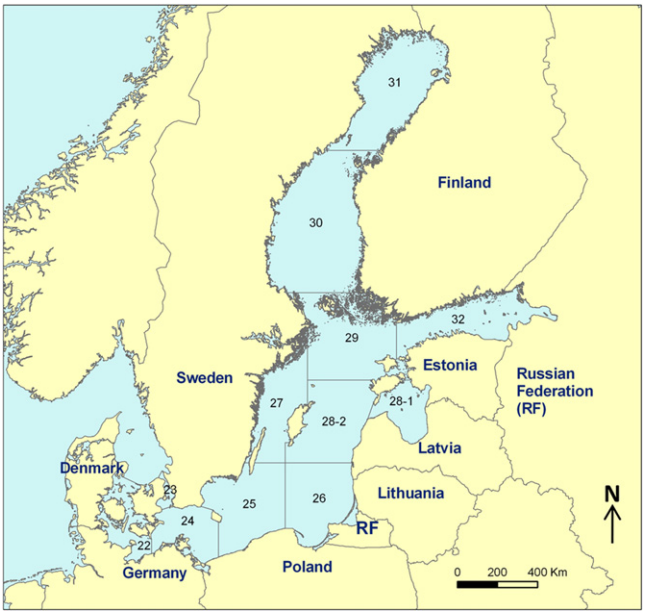

Fig. 1. Map of the Baltic Sea with ICES subdivisions and surrounding countries.

1.1. The Baltic Sea

The Baltic Sea is a semi-enclosed sea in northern Europe with a surface area of approximately 397,000 km^2 (http://www.seaaroundus.org/). Its nine coastal countries (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden, Fig. 1) are involved in national and international agencies to manage the sea and its resources. The Baltic Sea is a largely brackish-water body with large inputs of freshwater originating from rivers in the east and inputs of more saline water entering from the North Sea, and is often thought of as a large semi-enclosed estuary (Graneli et al., 1990).

The salinity gradients largely determine the species composition of this ecosystem, which comprises marine, freshwater and diadromous species. The western portion near Denmark, with the highest salinities, has the highest number of fish species, while the northern portions (Gulfs of Finland and Bothnia) are virtually freshwater, and have only ~20 fish species (Voipio, 1981). The International Council for the Exploration of the Sea (ICES) reports 153 taxa (including fish, mollusks, bivalves and crustaceans) being landed by fisheries in the Baltic Sea, but cod (*Gadus morhua*), herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) are the most important commercial species.

Fishing is known to impact heavily on the resources and state of the Baltic Sea. For example, cod and Gulf of Riga herring were considered overfished (ICES, 2008a), but more recently the status of the cod stocks has improved, and TACs are considered to be in line with scientific advice (ICES, 2010). The decline in cod biomass since the 1980s has led to altered trophic relationships that may affect the ecosystem (Österblom et al., 2007; Casini et al., 2008).

The areas within the Baltic Sea where national fleets were legally allowed to operate have also changed during the time period considered here (1950–2007). Earlier, countries claimed a 3, then a 12 nautical miles (nm) territorial sea. In 1978, Sweden became the first Baltic country to claim an Exclusive Economic Zone (EEZ, generally 200 nautical miles from shore or midline between neighboring countries) under the provisions of the United Nations Convention on the Law of the Sea (UNCLOS). The changes brought about by the introduction of EEZs during the later part of the 1980s had the effect of shrinking the fishing areas of some countries (Borberg, 1976). However, with the adoption of the Common Fisheries Policy by members of the EU in 1983, fishing fleets of member countries had access to each other's fishing areas (excluding the 12 nm territorial waters, unless fishing access agreements were established). With EU membership expanding since 1983, more of the Baltic Sea has come under EU management (Table 1).

Table 1
First year of independent reporting of landings for members of the former USSR, and year of entry into the EU for all coastal countries in the Baltic Sea area.

Country	Data reporting independent from USSR	Year of EU entry
Denmark	–	1973
Estonia	1991	2004
Finland	–	1995
Germany	–	1957[a]/1990[b]
Latvia	1991	2004
Lithuania	1992	2004
Poland	–	2004
Russia	1992	–
Sweden	–	1995

[a] West Germany: European Community founded in 1957 (became the EU in 1993).
[b] East Germany: reunification of Germany.

1.2. Catch data

The officially reported fisheries data, as presented by ICES on behalf of individual countries, are known to almost exclusively account for landings, not total removals (ICES, 2005). ICES Stock Assessment Working Group Reports provide some additional information and some data on 'unallocated catches' (unreported landings) and discards for some species, but not in a transparent manner. Unreported landings from working group reports are presented as Baltic Sea-wide total amounts, not by country, even though it is known that not all countries contribute data or estimates of unreported landings (Persson, 2010). The default approach by the working groups for estimating unreported landings is to substitute 'zero' for those countries not presenting data. This approach, unlike that for discarding, where ICES raises discard data from reporting countries to estimate Baltic-wide discards, leads to under-estimation of unreported landings. Further, the working group reports do not indicate which countries' data are included. This incomplete accounting in scientific stock assessment reports is done for confidentiality reasons demanded by member countries (ICES, 2005), but hinders transparent and publicly accountable catch reporting. To fully account for all removals, estimates of unreported removals, including estimates of discards and recreational catches, need to be evaluated and included. A data source called '*Fishframe*'[1] containing information on discards by gear type, species, country and year, as well as some data on unreported landings, is available to users approved by the hosts of *Fishframe*, being the Danish Institute for Fisheries Research. Approval to use these data requires formal permission to be obtained from each Baltic Sea country. We were advised that we would not be granted access to these data for the present study.

Data sources used in our study include national data, published and grey literature (e.g., unpublished reports), media sources and personal information based on communications and collaborations with fisheries experts from around the Baltic Sea region. Interestingly, many of the personal sources were very willing to share their knowledge and information with us, but expressed a clear preference for wanting to remain anonymous, out of concern about their perceived scientific standing or job security. We find it worrisome that scientists and fisheries experts are not willing to speak publicly on their knowledge and experience.

[1] http://dmz-web08.dfu.min.dk/BalticSea/FishFrame/.

Our approach to retroactively estimate total removals uses a bottom-up approach to reconstruct catch time series (Zeller et al., 2007). Such an approach often requires assumption-based inferences and interpolations, but is justified given the less acceptable alternative that users of official data will interpret non-reported or missing data components as zero removals (Pauly, 1998). Estimates of total removals derived from catch reconstructions will clearly not be statistically 'precise', as this would imply that our procedure, if applied multiple times, would yield similar results. Rather, these results are likely to be more 'accurate', in the sense that, given our conservative approach, our estimates will be 'less wrong', i.e., closer to the 'true' value than the currently assumed 'zero' catch substituted for 'no data'.

1.3. Aims

This study reconstructs total fisheries removals for the nine countries fishing in the Baltic Sea from 1950–2007, being Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. The present study summarizes a series of detailed technical reports published as a Fisheries Centre Research Report of the University of British Columbia (Rossing et al., 2010).[2] It is hoped that our work will help to better inform the public on likely levels of actual fisheries extractions, help policy makers to set more sustainable catch levels, and highlight the importance of unaccounted components of total removals.

2. Materials and methods

ICES maintains two publicly accessible databases that provide time series data of fisheries statistics. The '*ICES catch statistics database*' describes reported landings by country, species (or higher taxonomic grouping), ICES reporting area and year (Fig. 1). Here we call these data 'ICES landings'.

The second ICES database, called '*ICES stock assessment results database*', describes catches by selected stocks and year, and presents data used by the ICES stock assessment working groups for their annual stock assessments. Hence, this database only presents data on cod, herring, sprat, brill (*Scophthalmus rhombus*), dab (*Limanda limanda*), turbot (*Psetta maxima*), plaice (*Pleuronectes platessa*), flounder (*Platichthys flesus*), salmon (*Salmo salar*) and sea trout (*Salmo trutta*), and not on the remaining 140+ taxa that are landed. This second dataset also does not cover the full time period to 1950. As we utilize these data in conjunction with information taken directly from the ICES stock assessment working group reports, we refer to this combined data source (i.e., '*ICES stock assessment results database*' and ICES stock assessment working group reports) as '*ICES stock assessment working group data*'. This data source also contains data on unreported landings of cod, salmon and Riga herring, as well as some information on discards. Both ICES databases, and recent ICES stock assessment working group reports are available electronically from ICES (http://www.ices.dk/fish/statlant.asp).

As we aim to estimate total removals (as opposed to reported landings), all fisheries components were estimated for each of the nine Baltic countries. Here, the 'reported data' baseline is represented by '*ICES landings statistics*', not including the taxonomically and temporally incomplete '*ICES stock assessment working group data*'. To this reported data baseline, we added four components: (1) '*adjustments*' to ICES landings statistics (i.e., data source adjustments to reported landings, generally using national data sources), (2) '*unreported landings*', (3) '*discards*', and (4) '*recreational removals*'. Baltic Sea landings reported by ICES on behalf of non-Baltic countries (approximately 64,000 tonnes for 1950–2007) were included in our estimates, but no additional unreported removals were estimated for these countries (Zeller et al., 2010).[2]

The general methods presented here represent the default approach for each component for each country. However, whenever country specific data for any component were available, they replaced the default approach, as country-specific data were deemed more appropriate. Specific details for each country are described in the individual country technical reports underlying this study (see contributions in Rossing et al., 2010). To account for some political and economic differences between countries, we accounted for removal components by considering groupings of countries. Western countries were considered to include Denmark, Finland, West Germany (1950–1990) and Germany (after re-unification, 1991–2007), and Sweden; former eastern bloc countries included East Germany (1950–1990), Poland, Russia, and the Baltic states of Estonia, Latvia and Lithuania. The former eastern bloc countries Estonia, Latvia, Lithuania and Russia provided statistics to ICES as a single entity (now called 'former-USSR') before the dissolution of the USSR in the early 1990s, but as independent countries since then (Table 1).

2.1. Unreported removals

We define the electronic ICES landings statistics as the reported data baseline. Thus, all adjustments to ICES landings statistics (including data derived from national data sources or the '*ICES stock assessment working group data*' source), unreported landings, discards and recreational removals (unless reported as part of the ICES landings statistics, e.g., Finland) were treated as unreported removals. Each of these components was treated separately in both a taxon- and country specific manner. While we recognize that individual countries generally use their national data for internal uses and stock assessments (supplemented by other data contributed by stock assessment specialists), it is the electronic ICES landings dataset that represents the official EU record of fisheries removals, and is represented globally by FAO on behalf of the EU. Hence, we define unreported removals as anything not consistent with that particular baseline.

2.1.1. Adjustments to ICES landings statistics

Data source adjustments to ICES landings statistics were taken from ICES stock assessment working group data (database and reports) and nationally reported data. These adjustments were incorporated to present the best estimates of reported landings, and generally represented differences in reported landings between national government reports or stock assessment data and ICES landings data, especially for earlier decades. In some instances, such adjustments were negative, mainly due to misreported data in the ICES landings statistics compared to the more specific ICES stock assessment data.

National data were used for some countries in the early time periods (1950s) to fill gaps from the first year of ICES reported data back to 1950 (e.g., East Germany, Poland), and for allocating removals by the former USSR to its post-breakup components (Estonia, Latvia and Russia 1950–1990, Lithuania 1950–1991, Table 1). ICES has not retroactively disaggregated its 'former-USSR' data, thus not readily allowing for country-specific time series comparisons. Here, the post-1990 independent country data formed our baseline for the former USSR entities, to which we added disaggregated data from the USSR period (pre-1990s) from national sources. Given that most fisheries conducted during the USSR period from, e.g., Estonia, were essentially Estonian vessels crewed by Estonian fishers fishing under the flag of the

[2] The technical report is freely available at www.fisheries.ubc.ca/publications/reports/report18_1.php.

USSR, we considered these fisheries as essentially Estonian back to 1950.

2.1.2. Unreported landings

The ICES stock assessment working group data only contain Baltic-wide summary data of unreported landings for cod, salmon, and Riga herring. Unfortunately, ICES does not provide country-specific data in regards to unreported landings. Unreported landings of both cod and salmon were converted into percentages of the Baltic-wide reported landings for salmon and each cod stock (as reported in the ICES stock assessment data) to form anchor points. The Baltic-wide percentage rates, adjusted for countries known to not present unreported landings to ICES (e.g., Sweden, Persson, 2010), were then applied to the sum of each country's ICES landings statistics plus adjustments. As not all countries provide data (or even estimates) on unreported landings to stock assessment working groups, our unreported landings estimates will be conservative estimates at the aggregated level, but possibly over- (or under-) estimates for some individual countries. For the former Eastern Bloc countries, unreported landings were assumed to have begun following the dissolution of the USSR and the eastern bloc, and the reunification of Germany in the early 1990s. This was largely driven by information suggesting that there were few if any incentives to under-report landings to national agencies prior to this period.

2.1.3. Discards

Discards were separated into four categories: (1) '*underwater*' discards for herring and sprat caused by deployed gear, adjusted for survival of contact with the deployed gear; (2) '*ghostfishing*' caused by lost or abandoned gear, defined as mortality caused by the lost or discarded remnants of fishing gear, but without retention or use of the catch; (3) '*boat-based*' discards resulting from fisher's behavior (e.g., high-grading); and (4) '*seal damaged*' discards. Given our ecosystem perspective, we treat all mortality associated with fishing as 'removal', irrespective of its final fate (i.e., landed or discarded). Underwater discards refer to fish that are caught by deployed gear, but are pushed or escape through the mesh. Here, we apply such discarding only to herring and sprat, based on work by Rahikainen et al. (2004), who estimated the rate of underwater discarding for these gears. While other gear types targeting different species are likely to also experience underwater discarding, we had no useable information to reliably apply to other gear types or species. Hence, our estimates of this type of discard mortality (limited to herring and sprat) are conservative. Ghost fishing, which is a global problem (Macfadyen et al., 2009), refers to the continued ability of lost or abandoned fishing gear (especially modern synthetic nets) to cause mortality for fishes that come into contact with such gear. Mortality estimates for ghostfishing were used from Tschernij and Larsson (2003) and Brown et al. (2005) to determine the amount of discarded (un-used) catches caused by lost gear. Available information on discards was applied as a percentage rate to species specific total commercial landings (i.e., the sum of ICES landings, adjustments and unreported landings). ICES stock assessment working group reports contain data on discards for the cod stocks (ICES, 2007, 2008a), and for salmon (ICES, 2008b). A Danish study (Anonymous, 2006) examined boat-based discard practices, and was used to derive default discard rates for species other than cod and salmon. For the former eastern bloc countries, discarding was assumed to exist throughout the entire time period (1950–2007). Seal-damaged discards have been a concern in the Baltic Sea since at least the 1990s when seal populations increased from a previously depleted state (Österblom et al., 2007). This discarding refers to fish that are taken or damaged by seals while fishing gears are actively deployed, and is based on national sources as well as Königson et al. (2005) and Anonymous (2005, 2006).

2.1.4. Recreational removals

Most recreational fishing is essentially unregulated in the sense of catch reporting requirements. Hence, recreational catches are treated as unreported removals given that they represent a removal in terms of ecosystem extraction. Furthermore, Finish data reported in the electronic ICES landings data include some recreational removals since 1953, while other countries have not yet included such data. Estimates were made for all western countries and Russia back to 1950. In Poland, marine recreational fishing began around 1986 (Radtke and Dabrowski, 2007), while for former East Germany and the remaining former eastern bloc countries (Estonia, Latvia and Lithuania) recreational estimates were made once they became market economies (early 1990s), as previous legislation did not allow recreational fishing (R. Oeberst, pers. comm., Johann Heinrich von Thünen-Institut, Rostock, Germany).

3. Results

Our catch reconstruction estimated total removals taken from the Baltic Sea from 1950 to 2007 as approximately 53.5 million tonnes, adding 30% to the 41.3 million tonnes of landings reported by the ICES landings statistics (Fig. 2a). For 2000–2007, total removals were on average 35% higher than reported landings.

Unreported landings of about 5.7 million tonnes were the greatest source of unreported removals, adding 14% to the reported landings between 1950 and 2007, and about 24% since 2000 (Fig. 2b). Unreported landings of cod were the most substantial, representing about 35% of unreported landings of all species since 2000, while herring accounted for 33% (Fig. 2c).

Discards added 9% (3.8 million tonnes) to reported landings between 1950 and 2007, and 10% (over 650,000 tonnes) during 2000–2007 (Fig. 2b). Discards were dominated by cod (36%) and herring (30%) for the 1950–2007 time period, while sprat, herring and cod accounted for 31%, 30% and 17% of discards for 2000–2007, respectively (Fig. 2d).

Recreational removals totalled around 1.5 million tonnes since 1950 (or 29,000 tonnes·year^{-1} since 2000) and comprised about 3% of total removals (Fig. 2b).

Data source adjustments, dealing with omissions in the ICES electronic data, added 3% to reported landings (Fig. 2a vs. b). The majority were accounting artifacts due to the dissolution of the USSR and our re-allocation of these landings to individual former-USSR countries, rather than omissions in ICES data.

Country contributions to unreported removal components differed (Fig. 3). For 2000–2007, unreported landings were dominated by Poland (47%), Sweden (12%), Denmark (10%) and Latvia (8%), while discarding was dominated by Poland (21%), Denmark (19%), Finland (15%) and Sweden (14%). The significant volumes of unreported landings and discards by Poland were due to cod, with Poland accounting for around 74% of unreported landings and 34% of discards of cod (Rossing et al., 2010). For recreational removals, Finland and Sweden contributed 32% and 30% each, while Denmark and Germany accounted for 21% and 11%, respectively (Fig. 3).

National contributions to the difference between reported landings and total removals as reconstructed here varied between 28% and 48% for the 1950–2007 time period, and between 20% and 80% for the more recent years (Table 2, Fig. 4). Estimates of unreported removals for each country were generally dominated by unreported landings, while discarding appeared to have increased as a fraction of total unreported removals for the more recent period (Table 2). Noteworthy are the general inclusion of some recreational removals in reported data by Finland, and the substantial fraction of unreported landings by Poland (Table 2), particularly

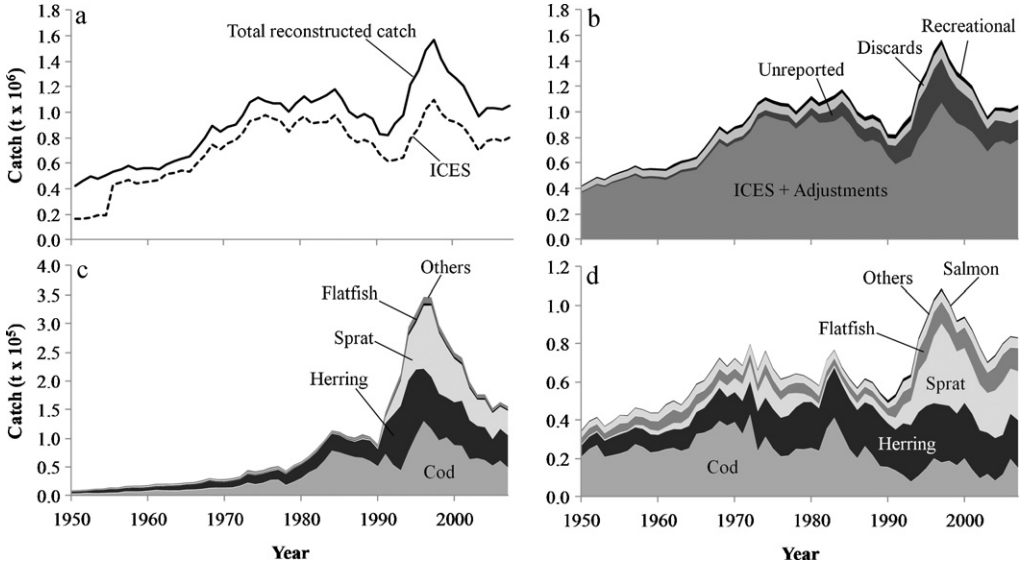

Fig. 2. Fisheries removals by all countries fishing in the Baltic Sea for the period 1950–2007; (a) total reconstructed removals (solid line) as well as landings reported to the ICES landings statistics (dashed line); (b) total reconstructed removals by category, including ICES + data source adjustments, unreported landings, discards and recreational removals; (c) total unreported landings by taxon, with cod, herring and sprat dominating unreported landings; and (d) total discards by taxon, with cod, herring, sprat and salmon dominating discards.

since the 1990s (Fig. 4g). Overall, each country has a mismatch between reported landings and estimated total removals (Fig. 4).

4. Discussion

Our reconstruction of total marine fisheries removals for the nine coastal countries bordering the Baltic Sea Large Marine Ecosystem (LME) suggested that fisheries between 1950 and 2007 caught or killed approximately 30% (i.e., 12 million tonnes) more fish than the data officially reported by these countries suggest. For the most recent period (2000–2007), this difference increased to 35%. These differences between official statistics and likely total removals highlight the magnitude of fishing mortalities that are unaccounted for by the records officially provided by countries to ICES and presented as Baltic Sea fisheries removals to the public. We consider our reconstruction to be relatively conservative, as our assumptions used minimum values whenever we were given a choice (Rossing et al., 2010). Thus, true removals may have been higher than our reconstructed estimates. Nevertheless, our reconstruction for the coastal countries of the Baltic Sea represents the best currently available estimate of total removals between 1950 and 2007, and provides an improved baseline for management of fisheries resources and the Baltic Sea.

The ICES landings statistics provide reported landings, yet ICES presents these as 'catches'; this implication of equality between 'landings' and 'catches' is problematic in light of known, but unaccounted-for removals. Furthermore, the incomplete nature of data reported by ICES on behalf of its member countries means information on total removals are not available to the public, who are the resource 'owners'. Our reconstruction provides an improved dataset (freely available to the public at http://www.seaaroundus.org/sponsor/baltic.aspx), displaying clearly disaggregated removal data for each country.

Table 2
Country-specific percentage difference between total reconstructed removals and reported landings for Baltic Sea countries, and percentage contribution of each unreported component, for 1950–2007 and 2000–2007. Note that percentages may not add to or may exceed 100% due to ICES data source adjustments (see text for details).

Country	Difference: total vs. reported removals (%)		Unreported removals (%)[a]					
	1950[b]–2007	2000–2007	1950–2007			2000–2007		
			Unreported	Discards	Recreational	Unreported	Discards	Recreational
Denmark	41	33	47	41	11	46	38	15
Estonia	28[c]	25	7	8	0.1	57	41	2
Finland	29	24	51	28	–[d]	54	46	–[d]
Germany	36	28	22	32	5	44[e]	36[e]	22[e]
Latvia	28[c]	28	7	6	0.07	69	30	1
Lithuania	48[f]	44	6	7	1	61[e]	34[e]	9[e]
Poland	35	80	67	20	0.2	83	16	0.5
Russia	28[f]	25	5	6	0.5	66	31	3
Sweden	31	20	52[g]	25[g]	30[g]	72[g]	35[g]	27[g]

[a] Percentages may not add to, or may exceed 100% due to ICES data source adjustments, or re-allocation of former USSR removals to individual countries.
[b] Or year of independence.
[c] 1991–2007.
[d] Majority of recreational removals have been reported since 1953.
[e] Data source adjustments were negative for this period due to over-reporting of cod landings based on lower catch tonnage reported in stock assessment documents compared to the ICES landings database.
[f] 1992–2007.
[g] Data source adjustments were negative for the entire period due to misreporting of landings based on lower catch tonnage reported in stock assessment documents compared to the ICES landings database.

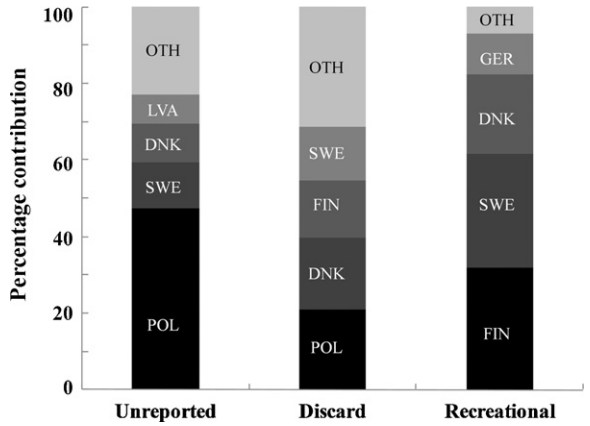

Fig. 3. Country contributions (as percentages) to the three major unreported removal components: unreported landings, discards and recreational removals. Shown are the four major contributors in each component, with the remaining five countries pooled as 'other' countries. POL: Poland, SWE: Sweden, DNK: Denmark, LVA: Latvia, FIN: Finland, GER: Germany, OTH: others.

Our reconstruction suggests that unreported landings account for 47% of unreported data (i.e., ignoring data source adjustments), confirming that this is the largest unreported component in the Baltic Sea (BSRAC, 2007; Sporrong, 2007). Overall, Poland, Denmark and Sweden were responsible for the bulk of unreported landings, particularly in recent years (Rossing et al., 2010). Poland and Denmark's unreported landings were dominated by cod, while Sweden's unreported landings were dominated by herring and sprat (Rossing et al., 2010). Such prevalence of unreported landings highlights significant management and enforcement issues. These countries receive the largest share of the Baltic TAC for these species (Anonymous, 2007a), and bear responsibility for curbing the behaviors driving unreported landings. Unreported landings contribute to unaccounted fishing mortalities which can skew scientific data, has the potential to bias stock assessments and the resulting scientific advice to management, directly impacts decisions made by policy-makers, contributes to tax evasion, and misleads the public's opinion on the health of a common resource. While ICES stock assessment working groups do account for some unreported landings, the lack of country-specific data transparency in ICES stock assessment working group reports make it impossible for interested parties and the general public to assess country compliance and enforcements (Pfeiffer and Nowak, 2006).

Discards were the second largest contributor to unaccounted removals. Boat-based discarding is generally the most significant form of discarding (Rossing et al., 2010), but is also the easiest to address, since human behavior is the sole determinant. Given the increasing consideration of ecosystem-based management approaches, such wasteful practices need to be addressed. Ghostfishing has been recognized by UNEP and FAO as an issue of global significance, as abandoned fishing gear now represent an estimated 10% of all marine litter (Macfadyen et al., 2009). Underwater discards of herring and sprat by pelagic trawls have no simple solution, except improved preventative design and modification of gears (Matsuoka, 2008). Seal-induced discards are of importance mainly in eastern Baltic countries (Estonia, Finland, Latvia, Lithuania and Russia). This problem has grown since the early 1990s when grey seal (*Halichoerus grypus*) populations began recovering from previous declines and increased considerably. There have been advances in gear design which have been successful in reducing mortalities caused by seals (e.g., Hemmingsson et al., 2008).

Recreational fishing is largely an 'unregulated' activity with regards to catch data reporting. It contributed approximately 3% to total removals for all countries. Thus, in contrast to elsewhere (e.g., Zeller et al., 2008), recreational fishing does not appear to be, overall, an important component of Baltic Sea fisheries removals. However, for several species and in some countries (e.g., Sweden and Finland), recreational removals are substantial and need addressing in resource management. Little information was available for this non-commercial sector (except for Finland), thus countries need to implement systems to regulate and estimate recreational removals. This will help all fisheries stakeholders become accountable for impacts on the Baltic Sea.

4.1. Management implications

Observations on data completeness and transparency are summarized below, along with suggestions for management actions. We take an ecosystem-based management point of view, requiring accounting for '*total removals*' (i.e., everything killed by fishing activities) rather than '*landings*' (i.e., only retained and reported removal).

Our major concern is the lack of transparency in published fisheries data in the ICES stock assessment working group reports and associated electronic data. It was not evident from the publicly available material, which countries did, or did not contribute data on unreported removals, or to what extent. Yet, transparency has been identified as a key feature for sustainable management of fisheries, when compared to other factors such as robustness of scientific advice, or implementation and enforcement of regulations (Mora et al., 2009). Thus, ICES and its member countries need to identify a way to lift the veil of secrecy around unreported landings and discard data due to current confidentiality agreements.

It is well recognized that the only successful method of obtaining comprehensive information on total removals is through industry-independent observer programs. In order to be unbiased, this requires complete (i.e., 100%) observer coverage of every vessel fishing in an ecosystem. Unless observer coverage is 100%, fishers' behavior changes when an observer is onboard, resulting in biased accounting and unreliable estimates of removals (Benoît and Allard, 2009). Complete observer coverage is also beneficial for enhancing buy-in, trust and co-operation within industry and between industry, science, management and the general public, as it removes the current uncertainty in information and data. This has been shown successfully elsewhere (e.g., Canada, Branch, 2006). Costs for such coverage can be considerable; however, physical on-board observers are not required at all times. Remote video monitoring systems recording and remotely relaying all fishing operations and catches, combined with Satellite Vessel Monitoring Systems (VMS) for spatio-temporal activity monitoring, can be installed on all vessels to account for location and level of activity. Together with custom-designed analysis software, this allows for cost-effective land-based accounting to be performed. Thus, all vessels can be monitored, resulting in fully transparent utilization of public resources, enhancing compliance with rules, and even countering tax evasion. Random, unannounced onboard observer trips can then be used to ground-truth video data.

Discarding is wasteful, increasingly so with the move towards ecosystem-based management. To minimize our fisheries impact on marine ecosystems, discarding needs to be eliminated or reduced substantially, as has been done with relative success by Norway (Kelleher, 2005). Thus, ICES and all member countries need to establish a complete discard ban, requiring all removals to be landed. Such a ban can only be successfully implemented through full observer coverage.

We recognize that not all discarded fish die as a result of being caught. Thus, a total discard ban may increase the total mortality rate of some species (e.g., more hardy species such as skates). However, the additional demand and challenges of having to retain

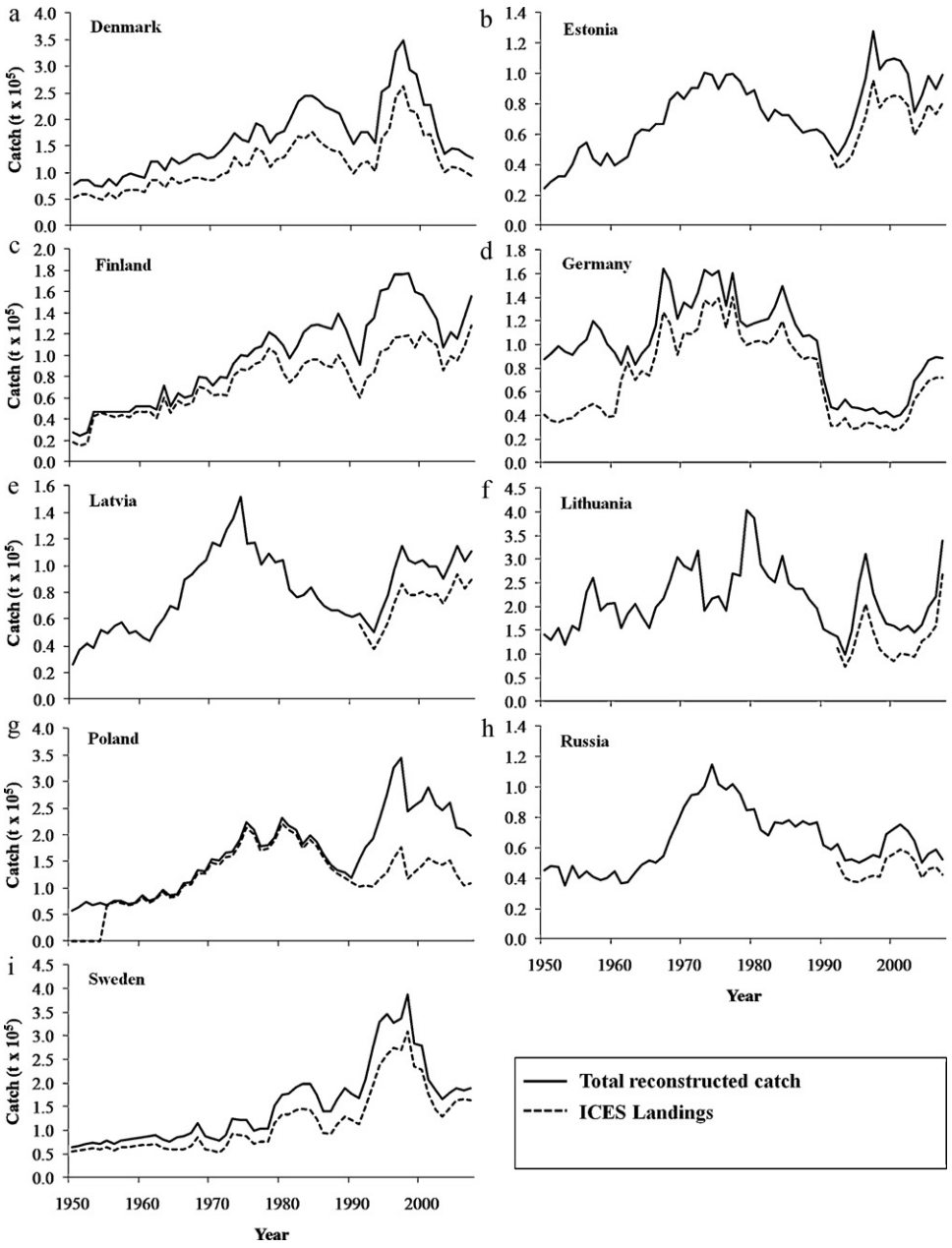

Fig. 4. Removals by the nine Baltic coastal countries (a–i) in the Baltic Sea for the period 1950–2007, showing for each the total reconstructed removals (solid line) as well as landings reported to the ICES landings statistics (dashed line). The large discrepancies between reconstructed removals and ICES landings for (d) Germany and (g) Poland in the 1950s is driven by different start dates for reporting to ICES by former East-Germany (1961) and Poland (1956).

discards generally encourages fishers to seek fishing areas, methods and behaviors that reduce unwanted by-catch (Branch et al., 2006). Furthermore, landed by-catch that would otherwise be discarded can be utilized at least by fishmeal and fishoil production plants, thus potentially reducing demand for fisheries that specially target catch for fishmeal. This could contribute significantly to more efficient use of marine resources, as currently around 1/3 of global landings are destined for fishmeal (Alder et al., 2008).

Little information exists on recreational fisheries in most Baltic Sea countries (except Finland). This lack of data hinders assessing this sector's impact on the ecosystem. Therefore, the importance of recreational fishing has often been underestimated (Coleman et al., 2004; Zeller et al., 2008). Comprehensive and regular estimates of recreational removals help determine ecosystem impacts, and provide information on conservation measures to ensure recreational fishing opportunities for future generations. Given the dispersed nature of recreational fishing, and the difference between commercial fisheries (relatively few fishers with high catches) and recreational fishing patterns (many fishers, each with a relatively small catch), annual recreational surveys may not be cost-effective for all countries. Thus, ICES and member countries should establish regular surveys (every 4–6 years) of total recreational removal, by species, area and gear category in every country. Survey results need to be expanded country-wide and interpolated between survey years. The resultant estimates by species, country, gear and area should be incorporated into the public ICES catch database, and clearly identified as recreational.

Overall, current arrangements do not account comprehensively and transparently for the use of a public resource taken from the Baltic Sea. ICES and its member countries need to acknowledge their responsibility to better public accounting and address the shortcomings identified here.

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