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Invisible catch: A century of bycatch and unreported removals in sea fisheries, Belgium 1929–2010

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ABSTRACT

Publicly reported statistics on the production of fisheries refer to 'landings' as opposed to 'catch'. However, well-informed decisions and evaluation of the impacts of fisheries on ecosystems must be based on total removals, so including the part of the catch that is discarded at sea or not reported as landings. Total removals by Belgian fisheries from all ICES fishing areas and from the Belgian part of the North Sea (BNS) from 1929 to 2010, were reconstructed by including unreported and misreported landings of the commercial fleet, unreported landings by the recreational and artisanal/subsistence fisheries and by estimating discards for the most important fisheries. Total reconstructed removals were estimated at 5.2 million t or 42% higher than the 3.7 million t publicly reported over this period. Unreported landings and discards were estimated to represent respectively 3.5% (0.2 million t) and 26% (1.3 million t) of these total reconstructed removals. The reconstructed total removals on the BNS were estimated to be 55% higher than the 0.8 million t publicly reported over this period. Discards represent an average annual of 34% of the total removals on the BNS over the entire period. The results suggest that since the 2000s, approximately 50% of all Belgian removals from its EEZ are unreported landings and discards (IUU). The unreported landings and discards are increasingly taken by non-commercial, small-scale (<12 m) vessels that are not subject to reporting and not taken into consideration in planning, monitoring and enforcement. While the present paper provides a first attempt to reconstruct historical total removals for Belgium's sea fisheries, it also addresses the gaps in data and information that need to be resolved to improve the reliability of the estimates of unaccounted removals. The reconstructed time series provides a context for the wider debate about how to move to more sustainable fisheries, what the role of small-scale fisheries are, how to achieve the agreed policy targets in Belgian marine waters and in particular in the marine areas protected under the EU Habitat and Bird directives

1. Introduction

Well-informed decisions in support of ecosystem-based resource management in the marine environment must be based on total removals by fishing activities and not just on officially reported landings (Zeller et al., 2009). The total removals by fishing can be summarized as the publicly reported plus the total of *illegal, unreported and unregulated catches* or IUU (Pauly, 1998; Bray, 2000). Publicly reported statistics on fisheries generally refer to commercial landings which are only a part of the catch and hence of the total removals. The difference between publicly reported versus total anthropogenic removals includes several components. Besides the unreported and misreported commercial landings (Zeller et al., 2006; Zeller et al., 2007), part of the catch is discarded at sea by fishers (Kelleher, 2005), suffers unaccounted underwater mortality in the fishing gear (Collie et al., 2000; Rahikainen et al., 2004; Kaiser et al., 2006; Depestele et al., 2008) or is removed by recreational/artisanal fishing (Coleman et al., 2004; Zeller et al., 2008). It is widely accepted that the dumping of fish at sea is unethical and represents a substantial waste of resources (Diamond and Beukers-Stewart, 2011). Resolution 57/142 (2002) of the United Nations urges states and regional organizations to develop and implement techniques to reduce and eliminate bycatch and fish discards. In many cases, there are considerable uncertainties in stock assessments as a consequence of low stock size, inaccuracies in catch data (total removals) and variability in survey indices. These uncertainties add to the challenges of setting targets for the recovery of stocks in a changing natural environment. In the pursuit of an ecosystem-based approach in the marine environment, it has become increasingly important to document and quantify total

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removals. Data Collection Regulations in support of the Common Fisheries Policy CFP (EU Council Regulation 1543/2000 and Commission Regulations 1639/2001, 1581/2004 and 199/2008) require European Member States to collect data on technical, biological and economic aspects of their national fisheries, and their impact on the marine ecosystem. Regulation COM(2007)136 requests member states to collect data and report on discards. As a follow-up of this regulation and the outcomes of the revised CFP regarding the so-called 'discard-ban', it is anticipated that from 2015 formal reporting on commercial landings will be extended with commercial discards and removals from non-commercial fishing so as to obtain a more complete view on total removals from the marine ecosystem by fisheries and improve stock assessments. Moreover, for the establishment of criteria and definition of good environmental status (GES) for the Marine Strategy Framework Directive MSFD (2008/56/EG), both the current information on total removals and the historical reference conditions are important. Besides the gaps in historical information, there is no quantitative or qualitative assessment of the small-scale fisheries (<12 m) within 12 nautical miles or territorial waters of Belgium. Historical time-series are scarce and available time-series mostly date from after the start of intensive exploitation. In Belgium, centralized reporting on landings of sea fisheries at the species level started in 1929 (Lescrauwaet et al., 2010a). As is the case for most fishing nations, the routine data collection requirements related to sea fisheries production in Belgium were – until recently – limited to landings of the commercial fleet. Discards of the commercial fleet, landings and discards of the recreational fleet, and artisanal and land-based fishing activities are not covered in systematic reporting.

Belgium today has four coastal ports (Nieuwpoort, Oostende, Zeebrugge and Blankenberge) and besides the fish auctions located in the ports, there are no other or dispersed commercial landing points. The Belgian commercial sea fishing fleet consists of 86 ships, with a total engine capacity of 49,135 kW and a tonnage of 15,326 GT (Tessens and Velghe, 2012). According the EU definition (EC Council Regulation Nr 1198/2006), none of the vessels or fisheries operating in the Belgian fleet can be considered as small-scale fisheries, except for one 11.8 m vessel operating drift and/or fixed nets. Reconstructed time-series on fleet dynamics since 1830 (Lescrauwaet et al., 2013) show a decrease of 85% in the fleet size between 1946 and today, while the fleets' overall engine power has decreased by only 5% in that same period. This 85% decrease in fleet size was compensated by a 10-fold increase in average gross tonnage and a sixfold increase in average kW per vessel. After a maximum of 81,000 t reported (fresh weight) landings in 1947, annual landings of the Belgian fleet declined steadily to only 22,000 t in 2010. Since reporting started, 20% of all reported landings have originated from the 'coastal waters' while these fishing grounds contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans' (Lescrauwaet et al., 2010a). The Belgian fleet today is highly specialized: more than 68% of the effort (seadays, SD) and 77% of total landings are achieved by beam trawlers in 2010, focusing primarily on flatfish species such as plaice (*Pleuronectes platessa*) and sole (*Solea solea*).

The present work contributes to the reconstruction of total present and historical removals by Belgium in its EEZ and in other countries' waters by estimating the unreported catch and the discards, based on the best available scientific data and information. These estimates help to better inform the public on current and historical levels of fisheries removals and underline the importance of unaccounted components of total removals. They can support informed decision making towards more sustainable catch levels, in particular for the EEZ. The paper also provides an overview of relevant historical sources reporting on bycatch, discards and unreported catch that can be of use for similar exercises in other countries. Finally, remaining gaps and uncertainties that need to be removed in order to fully reconstruct the historical total removals by Belgian fisheries in the eight-two years from 1929 until 2010 are identified.

2. Materials and methodology

2.1. Data and information sources

2.1.1. ICES Fishstat database

The 'ICES Official Catch Statistics' electronically available from the ICES webpages, describes reported landings by country, species (or higher taxonomic grouping), ICES reporting area and year. It is the electronic database that is publicly available for redistribution and used as the EU official report on fisheries 'catch' to the Food and Agriculture Organization of the United Nations (FAO). The version 2012 – with updated time-series up to 2010 – is used as a baseline in the present study and throughout referred to as 'ICES Fishstat'.

2.1.2. HiFiDatabase: historical fisheries database (landings and value of landings)

Based on fragmented and disperse data sources, including previously uncovered original reporting cards, time-series for Belgian sea fisheries were standardized, quality controlled and integrated from 1929 onwards. The detailed procedures for quality control and integration of data are explained in Lescrauwaet et al. (2010b). The resulting historical fisheries database (HiFiDatabase) contains data by species (41), by port of landing in Belgium (4) and in 'foreign ports,' and by fishing area of origin (31) (Lescrauwaet et al., 2010a). Landings in the HiFiDatabase are reported as 'dead weight' and hence were converted to live weight to compare to the ICES Fishstat. Compared to the ICES Fishstat, the HiFiDatabase offers advantages in temporal coverage (data from 1929 onwards), temporal scale (monthly values), weight class (e.g. 5–7 weight classes for sole) and taxonomic resolution (less grouping). It also provides more detailed information at the spatial scale as it contains a reporting unit for the western central North Sea (IVb-1) and the eastern central North Sea (IVb-2), and it is the only source of historical information on landings originating from the 'coastal waters' (IVc), and Fladen, and Morray-Firth (IVa). The Belgian coast is 67 km long and located in the province of West-Flanders (region of Flanders, Belgium). The Belgian EEZ or Belgian part of the North Sea (BNS, Fig. 4) is 3457 km^2 (0.5% of the North Sea area). The unique historical data reported for the 'coastal waters' from 1929 to 2010 (HiFiDatabase) were used in the present estimates of total removals at the scale of the BNS.

ICES baseline data do not contain statistics with spatial reference to the BNS or inshore waters. Only from 1996 onwards, data are available for research purposes at a spatial scale if ICES rectangles. A challenge with the data by ICES rectangles is their position within the BNS. Although one of the 3 relevant reporting rectangles (31F2) has a significant proportion of its area within the BNS, unknown but likely significant landings from the areas of 2 other rectangles (31F3, 32F2) should be taken into account (Fig. 4). The HiFiDatabase however contains data reported for the 'coastal waters' from 1929 to 2010. These unique historical data were used in the present estimates of total removals at the scale of the BNS. For the purpose of quality control, the reported landings for the 'coastal waters' (1929–2010) were compared to the fragmented historical source documents that report at ICES statistical rectangle. The data for the combined rectangles 31F2 and 31F3 provide a fair match (<10% difference) with the historical time-series for the 'coastal waters'. Considering the spatial scale of the BNS, this time-series is therefore considered to provide an acceptable representation of the landings originating from the BNS. North Sea (south) (ICES fishing subdivision IVc, Fig. 1), Iceland (Va), North Sea (central-west) and North Sea (central-east) (the last two aggregated as IVb in ICES fisheries

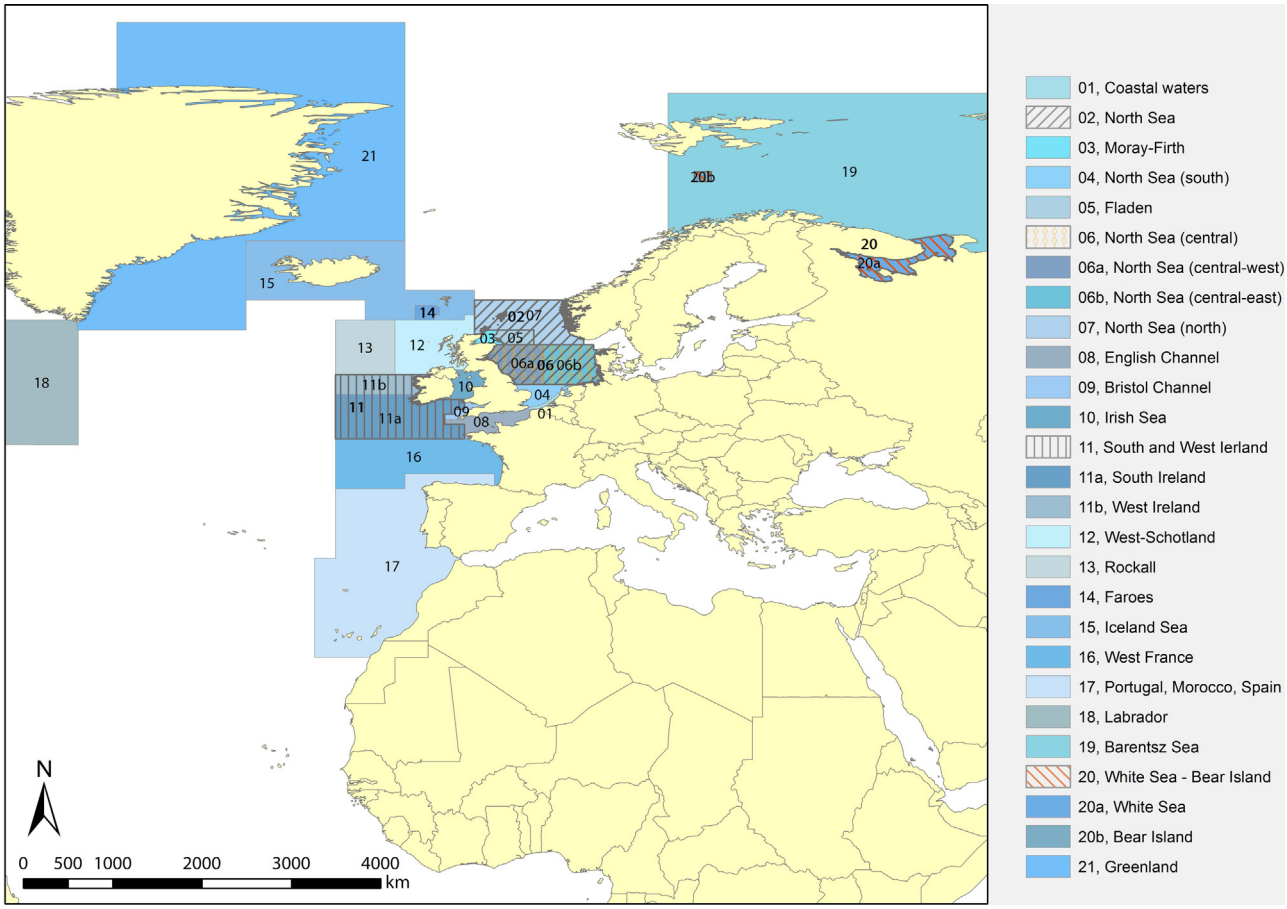

Fig. 1. Boundaries and names of fishing areas where the Belgian fleet was active between 1929 and 2010, as referred to in historical data sources. *Source*: 'Marine Regions' www.marineregions.org (VLIZ).

statistics) were the next most important fishing areas in terms of reported landings. Overall, 73% of all landings originated from only 5 of the 31 fishing areas where the fleet operated historically.

Inconsistencies between the ICES Fishstat (version 2008) and HiFiDatabase – in particular for the years between 1929 and 1960 – were previously reported by Lescrauwaet et al. (2010b). The ICES Fishstat version 2008 was amended by ICES in 2012. The differences between the HiFiDatabase and the Fishstat 2012 (our baseline for this study) are considered as unreported removals and are included in the present reconstruction.

2.1.3. Historical literature and literature databases

Literature databases were searched for historical publications and references related to unreported catch (Web of Science, JSTOR, Google Scholar, IMIS). Flanders Marine Institute (VLIZ) manages the Integrated Marine Information System IMIS for Belgium, which provided crucial relevant historical information to complete the estimates (see citations in Section 2.3 and list of references). Much of this information is contained in previously unpublished manuscripts that were disclosed in IMIS to this purpose, or in publications in native languages (Dutch, French) that are not indexed by global scientific literature databases focusing on English-speaking literature. These references contain information that is potentially relevant for similar exercises in other fishing nations around the North Sea. Relevant historical legislation with an impact on sea fisheries management (fleet, effort, gear, etc.) was obtained from the historical timeline on sea fisheries application of VLIZ. All taxonomic references were obtained from the World Register of Marine Species WoRMS.

2.2. Adding components

The separate components (see Section 1) were quantified or estimated and added to the baseline to reconstruct total removals (as opposed to reported landings) for Belgian sea fisheries. To structure this stepwise process, the categorisations as defined in Zeller et al. (2010) were used in the approach:

(1) 'adjustments' to the baseline ICES Fishstat, based on HiFi-Database (see Section 2.1), and considered as 'unreported' landings
(2) other unreported landings from the commercial fleet
(3) discards: mainly 'boat-based' discards resulting from fishers' behaviour (e.g. the so-called high-grading)
(4) recreational removals and artisanal/subsistence fisheries, not included in the reported landings

Discard is considered to be the dumping of the un-wanted portion of the catch whereas by-catch is the part of the catch that is captured incidentally to the target species and as such may have some economic value. With regards to (3), the proposed 'discard ban' (COM(2007) 136) has revived the debate related to the need to take into account survival rates of certain species of discarded fish and invertebrates in order to achieve more accurate discard mortality estimates as part of stock assessments. The results of survival rate studies have been shown to be highly dependent of the experimental design, the environmental conditions (season, fishing area, temperature, depth, etc.) and fishing conditions (gear, duration of tow or soaking time, weight of the catch, etc.) (Depestele

et al., 2008). While acknowledging the potential survival rates of discarded fish and invertebrates, a precautionary approach is taken in the present reconstruction.

The baseline adjustments, unreported landings and recreational removals were added to the baseline data. Information on discards and discard rates was generally applied as a percentage rate to the reported plus the unreported catches of specific species, by type of fisheries. Any assumptions adopted in the present estimates on discarding are science-based. Estimates on recreational fisheries are founded on expert judgement from people that have >30 years experience in the field. Where insufficient information is available for the estimation of a missing component, this is indicated and identified as a challenge for future research. This stepwise and bottom-up approach was conducted for the most important fisheries in Belgium between 1929 and 2010: the otter and beam trawl *Crangon* shrimp fisheries, the pelagic trawl fisheries for herring and sprat, the otter trawl *Nephrops* fisheries, the otter trawl fisheries for cod (*Gadus morhua*) and other roundfish, the beam trawl flatfish fisheries (sole and plaice), and recreational sea angling (see Section 3). Other fisheries or fishing gear such as dredges, seine nets and trammel nets were not taken into account in the reconstruction because of their limited contribution to total landings and fishing effort. Mortality that was not taken into account includes underwater discards such as tow path mortality or escape mortality caused by the gear, changing or decreasing mesh size and other technological developments affecting bycatch of the gear. Ghost fishing caused by lost or abandoned trawl nets was considered negligible or zero (Depestele et al., 2012).

2.3. Approach and assumptions by type of fisheries

Estimates, variables and bibliographic sources used in the present reconstruction of total removals are listed by type of fisheries (Table 1).

2.3.1. Shrimp fisheries (Crangon crangon)

2.3.1.1. Commercial shrimp fisheries (reported and unreported landings, and discards). The Belgian fisheries for brown shrimp are mainly conducted by small (<221 kW) vessels that operate within Belgian territorial waters and to a lesser extent in northern France and Dutch waters. In 1929 approximately 250 vessels participated in the shrimp fisheries, in 1950 these were 187 (otter trawlers, single net) whereas today less than 30 vessels (beam trawler, double beam, 22 mm mesh size) are full-time active in the shrimp fishery. Part of these 30 vessels operate from foreign (Dutch) ports under Belgian flag since at least 1990 (Churchill, 1990; Hoefnagel, 1998) and hence report their landings in foreign (Dutch) ports as part of the Belgian statistics. Over the entire period, shrimp fisheries represented on average 10% of SD of the total fishing effort of the Belgian fleet (Annual reports 'Landings and value of landings', Flemish government Fisheries Agency). The estimation of discards in both the commercial and recreational *Crangon* fisheries is based on Leloup and Gilis (1965) for the period 1929–1970, and on Polet (2004) for later years. Both report comparable discard rates and fractions of undersized *crangon* in commercial landings (46% and 47%, see Table 1).

2.3.1.2. Recreational Crangon fisheries. In Belgium it is not mandatory for vessels less than 10 m to report catches. Recreational shrimp fisheries operate in the Belgian coastal waters, from smaller vessels (<8 m) using towed gear. Although they are locally regarded as 'semi-commercial' shrimp fisheries given their relative importance if compared to commercial *Crangon* landings, they are not part of the official fishing fleet. There is no limit to the catch of *Crangon* for the recreational fleet, but the prohibition is on commercializing the catch. The vessels can only operate within the 3 nm zone and make use of only one towed net per vessel (max. 3 m wide for beam trawl and 4.5 m for otter trawl). Regular surveys on ships' safety regulations conducted by government officers along the ports and mooring sites in Belgium, show that approximately 60 recreational vessels are involved and operate from the 4 ports. A conservative estimate of their catches is based on an effort of 120 SD per vessel and catches of 20 kg per fishing trip, although catches of up to 100 kg per fishing trip may be achieved (E. Hiele, Shipping Control Service, federal government, pers. comm.). The proportion of the recreational catch versus the commercial catch over the last 5 years was used to backcalculate recreational catch, assumed to exist at least from 1975.

Other removals that were taken into account are the recreational-artisanal shrimp fisheries that operate from the beach (on foot and on horseback). Figures reported during WWII, when these artisanal fisheries were widespread practices for subsistence purposes by coastal residents, were used as a maximum estimate for this component.

2.3.2. Herring and sprat fisheries

2.3.2.1. Commercial herring and sprat fisheries (landings and discards). Before and during the WWII, Belgian herring fisheries mainly used drift nets and otter trawl nets. During WWII, when fishing was only allowed during daytime and within territorial waters, unprecedented catches of herring and CPUE values were reported from Belgian coastal waters (Lescrauwaet et al., unpublished data). The herring fishery remained important after WWII in terms of landings in particular between 1950 and 1965 and after 1965, $\leq$1% of the overall fishing effort expressed as SD is assigned to pelagic trawling (Anon., 1965; Tessens and Velghe, 2010, 2011). Although from 1950 onwards the pelagic trawl was gradually introduced (Gilis, 1962), the bottom otter trawl and the pelagic trawl were used simultaneously until 1965. Gilis (1961) compared both gear in terms of effort, landings, LPUE and bycatch, reporting that in 1958 pelagic trawl landings contained 91.8% of the targeted herring, compared to 65.3% in the otter trawl. Gilis (1961) reported details on the bycatch by species (supporting material, Table a), however without making reference to discards in this or any of his other thorough studies on Belgian pelagic herring trawl fisheries throughout the 1940s–1960s.

There are few historical references with regards to discards in pelagic (herring) fisheries that can be used for extrapolation in the North Sea (Garthe et al., 1996). Discard rates for the North Sea and the Celtic Sea were reported as close to 5% in the 1990s (Kirkegaard, 1991; Morizur et al., 1996). In the present study, a conservative discard rate of 4.5% was applied for the commercial herring and sprat fisheries.

Artisanal/subsistence catches from open boats in territorial waters were carefully documented during WWII (Lescrauwaet et al., unpublished data). Based on these records, an average of 120 t of herring and 60 t of sprat was added for the period 1929–1960 as a maximum for annual artisanal/subsistence catches. We assumed no artisanal/subsistence fishing for herring occurred after 1960, and no discards were taken into account in this artisanal/subsistence component. There are no records or indications of the existence of a recreational fisheries targeting herring or sprat in this period.

2.3.3. Gadoid and other roundfish

2.3.3.1. Commercial gadoid and other roundfish trawl fisheries (landings and discards). The otter trawl was the main fishing gear in the 1950s. It was replaced by the beam trawl in the *Crangon* fisheries by the end of the 1950s and in the flatfish fisheries by 1965 in Belgium (Lescrauwaet et al., 2013). Although currently Belgium has no directed fishery for cod or gadoids, specific *métiers* such as the pair-trawlers fishing for cod were important in the past. They operated in Icelandic waters until 1975, a few vessels until

Table 1
Overview of discard rates, survival rates and other variables used as reference material for the present reconstruction, with an indication of source, by type of fisheries. The variables and rates used in the calculation for the reconstruction are indicated in bold.

Fishery	Variable	Value	Comment	Source
Brown shrimp (Crangon crangon) fisheries				
Commercial *Crangon* fisheries, Belgium	**Undersized Crangon**	**46%**	**Undersized *Crangon* fraction in *Crangon* total catch (1949–1964)**	**Leloup and Gilis (1965)**
Commercial *Crangon* fisheries, Belgium	**Undersized Crangon**	**47%**	**Undersized *Crangon* fraction in *Crangon* total catch. Discards composed of whiting, plaice, dab, and bib**	**Polet (2004)**
Commercial *Crangon* fisheries, Germany	Discard rate	40–50%		Avia et al. (2011)
Recreational *Crangon* fisheries, Belgium	**Annual catch**	**144 t**	**Estimated catch in 2010 is based on 60 vessels*120SD*20 kg = 144 t, corresponding to 8% of the commercial catch in 2005–2010.**	**This study**
Recreational *Crangon* fisheries, Belgium	**% of commercial catch**	**8%**	**Starting 1975, recreational catch estimates are 8% of annual commercial catch**	**This study**
Artisanal *Crangon* fisheries, Belgium	**Annual catch**	**9 t**	**Based on data reported during WWII**	**This study**
Crangon fisheries, Portugal	Discard survival rate	4%		Gamito and Cabral (2003)
Crangon fisheries, Solway Firth (Scotland)	Bird predation	0.5–4.5%	Predation on *Crangon* discards	Lancaster and Frid (2001)
Herring and sprat, pelagic fisheries				
Herring fisheries, Belgium	Bycatch	35% 9%	By catch of non-target in otter trawl Bycatch of non-target in pelagic trawl	Gilis (1961)
Celtic sea winter herring fisheries	Discard rate	4.7%	Discards are mainly undersized target species	Morizur et al. (1996)
Danish pelagic trawl fisheries	Discard rate	5%	Herring as target species (if mackerel is targeted, discard rate is 20%)	Kirkegaard (1991)
Belgian pelagic trawl fisheries herring and sprat	**Discard rate**	**4.5%**	**1929–2010**	**This study**
Artisanal and subsistence fisheries, Belgium	**Annual catch**	**120 t 60 t**	**Herring, 1929–1960 Sprat, 1929–1960**	**This study**
Gadoid and other roundfish fisheries				
French gadoid trawlers, Celtic Sea (1997)	Discard rate	26%	Gadoid trawlers discard mainly target species: whiting and haddock (together 47%) and grey gurnard (13%). Data 1997	Rochet et al. (2002)
Trawlers, Skagerrak and North Sea areas	Cod discard rate	14% 34% 47%	Cod in the demersal trawl >100 mm mesh Cod in the demersal trawl 70–99 mm, Cod in beam trawl >80 mm	Horwood et al. (2006) *after* STECF (2005)
Icelandic and foreign fleet in Icelandic waters	Discard rate	1–14% 1–28%	Cod discard rates in Icelandic cod fisheries Haddock discard rate (based on all gear combined)	Forrest et al. (2001)
Belgian demersal trawl for roundfish	**Discard rate**	**25%**	**1929–2010**	**This study**
Flatfish fisheries (sole and plaice)				
Flatfish beam trawl, southern North Sea	Discard rate	71–95%		Catchpole et al. (2005)
German flatfish and other beam trawlers, North Sea and the NE Atlantic	Discard rate	56–72%	Discards mostly composed of dab, whiting, plaice, grey gurnard and undersized brown shrimp (Ulleweit et al., 2009).	Borges et al. (2005), EU (2008) and Ulleweit et al. (2009)
UK beam trawl fleet, North Sea	**Discard rate**	**50%**	**Average discard rate. Discard: mainly undersized dab and plaice, species with low market value (e.g. whiting and dab)**	**MRAG (2007)**
Beam trawls (flatfish), English Channel, Irish Sea, Celtic Sea	Discard rate	42–67%	Discard: mainly dogfish, whiting, gurnards, common cuttlefish, plaice and dab, and undersized haddock	Borges et al. (2005) and Enever et al. (2007)
French benthic trawlers, Celtic Sea (1997)	Discard rate	24%	60% of discarded weight consist of 4 bycatch species: red gurnard, horse mackerel, boar fish and grey gurnard.	Rochet et al. (2002)

Table 1 (*Continued*)

Fishery	Variable	Value	Comment	Source
Beam trawl fisheries, Belgium 2008	**Discard rate**	**25%**	**Composition of the discarded weight: sole (2), plaice (13%), dab (7%), bib (10%), cod (4%), anglerfish (3%), gurnards (13%), rays (7%), sharks (22%)**	**Vandendriessche et al. (2008)**
Recreational flatfish fisheries Belgium	**Annual catch**	**672 t**	**Estimated catch in 2010 based on 280 vessels*120SD*fishing days*20 kg per fishing trip**	**This study**
Recreational flatfish fisheries Belgium	**% of commercial catch**	**9%**	**Starting 1970, recreational catch estimates are 9% of annual commercial catch**	**This study**
Beam trawl fisheries, North Sea	Discard survival rate	0%	Higher survival rates reported for skates (42%) and rays (55%), while sole (4%) and lemon sole (7%) discard survival rates remain below 10%	van Helmond and van Overzee (2008) and Lindeboom and De Groot (1998)
Nephrops fisheries				
French *Nephrops* trawlers, Celtic Sea	Discard rate	55%	Discards in % of biomass: whiting (41%), target *Nephrops* (20%). Data for 1997	Rochet et al. (2002)
English and Welsh *Nephrops* trawlers, North Sea	Discard rate	36%	Discards: dab, whiting, plaice, legal-sized and undersized *Nephrop*s, gurnards, cod, long rough dab, haddock, lemon sole, Dover sole. Discards mainly due to <MLS	Enever et al. (2009)
Nephrops trawlers, Firth of Clyde (W-Scotland)	Discard rate	70%	Discard, mostly demersal fish, in particular young whiting < MLS. Typical mesh size = 80 mm	Stratoudakis et al. (2001)
Belgian *Nephrops* fisheries	**Discard rate**	**75%**	**Discard composition: 30% Nephrops (90% of which are legal size), 27% dab, 18% whiting, 15% plaice, 2% cod and 8% other fish**	**This study**
Sea angling				
Sea angling Belgium EEZ	**Annual catch**	**50 t**	**Estimated catch is based on 2000 anglers*5 SD*5 kg catch, since 1970**	**This study**

1995 (Lescrauwaet et al., unpublished data). An important part of the landings originated from the southern North Sea and in the central North Sea: first in the western part of the central North Sea from 1960 to 1975, afterwards in the eastern part. Icelandic waters were also the main fishing grounds for otter trawl fisheries targeting ling (*Molva molva*), redfish (*Sebastes norvegicus and S. mentella*), monkfish (*Lophius piscatorius*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*) and to a lesser extent whiting (*Merlangius merlangus*) (Lescrauwaet et al., 2010a). Today the otter trawl has recovered some importance due to its lower fuel consumption compared to the beam trawl (Tessens and Velghe, 2008, 2009, 2010).

Historical references on the selectivity and impact of the otter trawl and data on discards in roundfish fisheries are limited.

No studies or survey reports related to discarding proportions in the demersal roundfish fisheries for Belgium or for demersal (roundfish) trawlers fishing Iceland waters in the period 1960–1975 were identified in screened databases. To conclude, while acknowledging the significant variability in the estimates of weight and species composition of discard fractions in the demersal whitefish fisheries (otter trawler) depending on the fishing area, season and specific gear (Forrest et al., 2001; Rochet et al., 2002; Horwood et al., 2006), historical sources suggest that discarding in this fishery is not a recent practice related to the CFP and quota restrictions. Instead, in the past 50 years the weight-based proportion of discards in the catch may have decreased due to increasing mesh sizes and improvements in gear selectivity. In the present estimate, the lower discard estimate of 25% was applied over the sum of the landings of species targeted in this fishery (cod, ling, haddock, redfish, monkfish, saithe, whiting). While it is recognized that this is a simplistic approach based on assumptions, it is a precautionary approach and can be justified over the less acceptable alternative of interpreting non-reported or missing data components as zero removals (Pauly, 1998).

2.3.4. Flatfish beam trawl fisheries (sole and plaice)

2.3.4.1. Commercial flatfish beam trawl fisheries (landings and discards). Before 1960, the Belgian fleet of steamer and motor engine powered vessels used the otter trawl as fishing gear in the 'fresh fish' fisheries for targeted sole and plaice (Gilis, 1954). By 1965, the beam trawl had become widely introduced. In 1985, beam trawling accounted for 62% of SD and by 2006 this segment of the fishing effort had further increased to 79% of total SD. In 2010, beam trawl represented 68% of the SD (Anon., 1965; Tessens and Velghe, 2010).

No quantitative information is available to estimate historical discards and survival rates for this fishery by the Belgian fleet. Vandendriessche et al. (2008) estimated the current levels of discarding and discard rates in the Belgian beam trawling. In their study, 30% of a total of 109 sampled hauls was located in fishing areas in the southern and central North Sea, where approximately 30% of the reported landings of sole were caught that year. The authors found that on average 25% of the catch weight in this fishery is discarded. The conclusions are specific for the Belgian beam trawlers and reflect the current as opposed to the historical situation. It must be noted however that the current core of the spatial distribution of the Belgian beam trawling fleet has moved away from the North Sea and towards the western waters (Irish and Celtic Sea, Bristol Channel, English Channel). Whereas in the mid 1950s nearly all of the sole (97%) was caught in the North Sea, this proportion decreased to 40% in the 1980s and further to 30% after 2000, in

favour of the western waters. This may help explain why current discard rates reported for the Belgian flatfish beam trawling fleet (Vandendriessche et al., 2008) are lower than those reported for the Dutch, German and UK fleet operating mainly in the North Sea (Borges et al., 2005; Catchpole et al., 2005; MRAG, 2007; Enever et al., 2007; EU, 2008; Ulleweit et al., 2009), but similar to the discard rate value of 24% reported by Rochet et al. (2002) for the French benthic trawlers in the Celtic Sea. Vandendriessche et al. (2008) reported the composition of the discarded weight as follows: 2% of sole, 13% of plaice, 7% of dab, 10% of bib, 4% of cod, 3% of anglerfish, 13% of gurnards, 7% of rays, 22% of sharks. These proportional values 'by-species' were accounted for in the present reconstruction. For the reconstruction of the historical discards, a time variant discard rate was applied taking into consideration the proportion of landings originating from the North Sea (50% discard rate cfr. the average of the reported North Sea flatfish beam trawl discard rates) and the proportion of landings originating from the western waters (25% discard rate, as in Vandendriessche et al., 2008).

2.3.4.2. Recreational flatfish fisheries. As reported for the *Crangon* fisheries (see Section 2.3.1), recreational flatfish fisheries exist in Belgium, which operate from smaller vessels that are not part of the official or commercial fishing fleet. Although flatfish are targeted today, it is acceptable to believe that other species may have been targeted over the last decades depending on their relative abundance on economic value. These fisheries have existed for at least 30 years (E. Hiele, pers. comm.) and for the current estimate it was assumed that they started in the 1970s. Regular surveys conducted by government officers along the ports and mooring sites in Belgium confirm that approximately 280 small vessels are involved in this recreational activity and operate from the 4 ports. A conservative estimate was derived based on an average effort of 120 fishing days per vessel, 280 vessels and average catches of 20 kg per fishing trip. The parameters applied to estimate discards by the commercial fleet were applied to estimate discards in the recreational segment. Reported landings in artisanal/subsistence catches during WWII were negligible for sole (less than 0.5 t per annum) and amounted to 2–19 t of plaice between 1941 and 1943 (Lescrauwaet, unpublished data).

2.3.5. Nephrops fishery

2.3.5.1. Commercial Nephrops fisheries (landings and discards). Today, Norway lobster (*Nephrops norvegicus*) in the North Sea is commonly caught using a twinrig trawler, which is composed of two nets towed by one vessel along the seabed. Between the two nets a heavy weight keeps the net at the bottom, while otter boards are used to keep the mouth of the net open while trawling. The twinrig trawl is lighter than the beam trawl and it is towed at lower speed (4 knots), which results in lower fuel costs and less bottom disturbance (van Helmond and van Overzee, 2008). The Minimum Landing Size (MLS) of Norway lobster in the North Sea (ICES area IV) is 25 mm of carapace length.

No dedicated studies on discards and survival rates exist for Belgian *Nephrops* fisheries (Stratoudakis et al., 2001; Rochet et al., 2002; Enever et al., 2009). However, Belgian vessels participated in Dutch-led discard studies in this fishery (Steenbergen et al., 2012). Hence, the estimates of discards in the present study are based on the Dutch *Nephrops* fishery, which uses similar gear, engine power and fishing grounds. Discard estimates (weight-based) in *Nephrops* fisheries in the North Sea range between 76.5% and 84.2% (Belgian vessel and gear) (Steenbergen et al., 2012). According to van Helmond and van Overzee (2008), discards were composed of 30% *Nephrops* (90% of which were legal-sized), 27% dab, 18% whiting, 15% plaice, 2% cod and 8% other fish. The latter weight proportions for discarded species were taken into account, based on the reported *Nephrops* landings and a conservative discard rate of 75%.

There are no written reports or other communications related to unreported landings of *Nephrops*, or to the existence of a recreational fishery for this species. This is partly explained by the distance of the traditional fishing grounds.

2.3.6. Sea angling: cod, sea bass (Dicentrarchus labrax), and other species

Recreational fisheries include all forms of fishing that do not pursue commercial objectives. Little information exists on recreational fisheries in most North Sea countries (Zeller et al., 2011). Recreational fisheries in Belgium include recreational *Crangon* fishing (Section 2.3.1), fishing from the coastline (angling from the beach, shrimp fishing on feet or on horseback, and the setting of passive nets along the low watermark) and sea angling. Except for the use of fixed (passive) nets from the beaches, recreational fisheries are not subject to licensing. Sea anglers are not allowed to fish at night and are allowed a daily maximum of 20 kg per angler, of which cod is not allowed to exceed 15 kg. The magnitude of recreational angling on the Belgian part of the North Sea (BNS) has so far only been addressed in a pilot study which estimated recreational angling for cod on the BNS at 100–200 t per annum (Goffin et al., 2007). The pilot study was based on the outcomes of angling contests organized by the Associations of Anglers (VVHV), which counts approximately 2000 members as active sea anglers in 2006. In the present estimate, a low of 50 t per annum was applied (2000 anglers, 5 days at sea, 5 kg catch), assuming this form of sea angling existed at least since 1970. These estimates are in the same order of magnitude as those for the Dutch recreational sea angling for cod and eel (Zimmermann et al., 2007; Van der Hammen and de Graaf, 2012). Systematic sea bird counts by the Institute for Nature and Forest Research (INBO) recording the presence of sea anglers have shown a clear overlap between the position of anglers and shipwrecks (E. Stienen in Goffin et al., 2007).

2.3.7. Unaccounted removals

A number of other gears which are not accounted for in the present estimates have been used in Belgian fisheries, however with much lower intensity and spatial coverage than those presented in (a) to (f) in this section. These include seine nets, bottom dredges (1980s), trammel nets and other passive gear used in commercial fisheries, and angling and netting from land (jetties, piers). The use of trammel nets in commercial fisheries is rather recent (since 2000). The coastal municipalities issue licenses for passive beach nets and in 2006 approximately 250 licenses were issued in 4 municipalities (Goffin et al., 2007). Regulations prohibit the use of trammel (multi-layered gillnets) as well as the use of gillnets below low watermark, sets maximum lengths and total number of nets, and enforces the minimum landing sizes of species (royal decree KB 1989-08-14, KB 2001-12-21 and ministerial decision 2006-12-21).

3. Results

3.1. Total reconstructed removals by the Belgian sea fisheries 1929–2010

Total removals by Belgian fisheries from 1929 to 2010 were reconstructed by including the unreported landings of the commercial fleet, the unreported (here 'estimated') landings by the recreational and artisanal fisheries and by estimating discards for 6 of the most important fisheries based on the estimators described above (see Section 2.3). The reported landings for these 6 fisheries together represent approximately 80% of all reported landings over 1929–2010. Publicly reported landings over the period 1929–2010 amounted to 3.7 million t, with a peak of 81,000 t in 1947 (ICES Fishstat) and gradually decreasing to 22,000 t in 2010 (Fig. 2). However, the total reconstructed removals were estimated at 5.2 million t

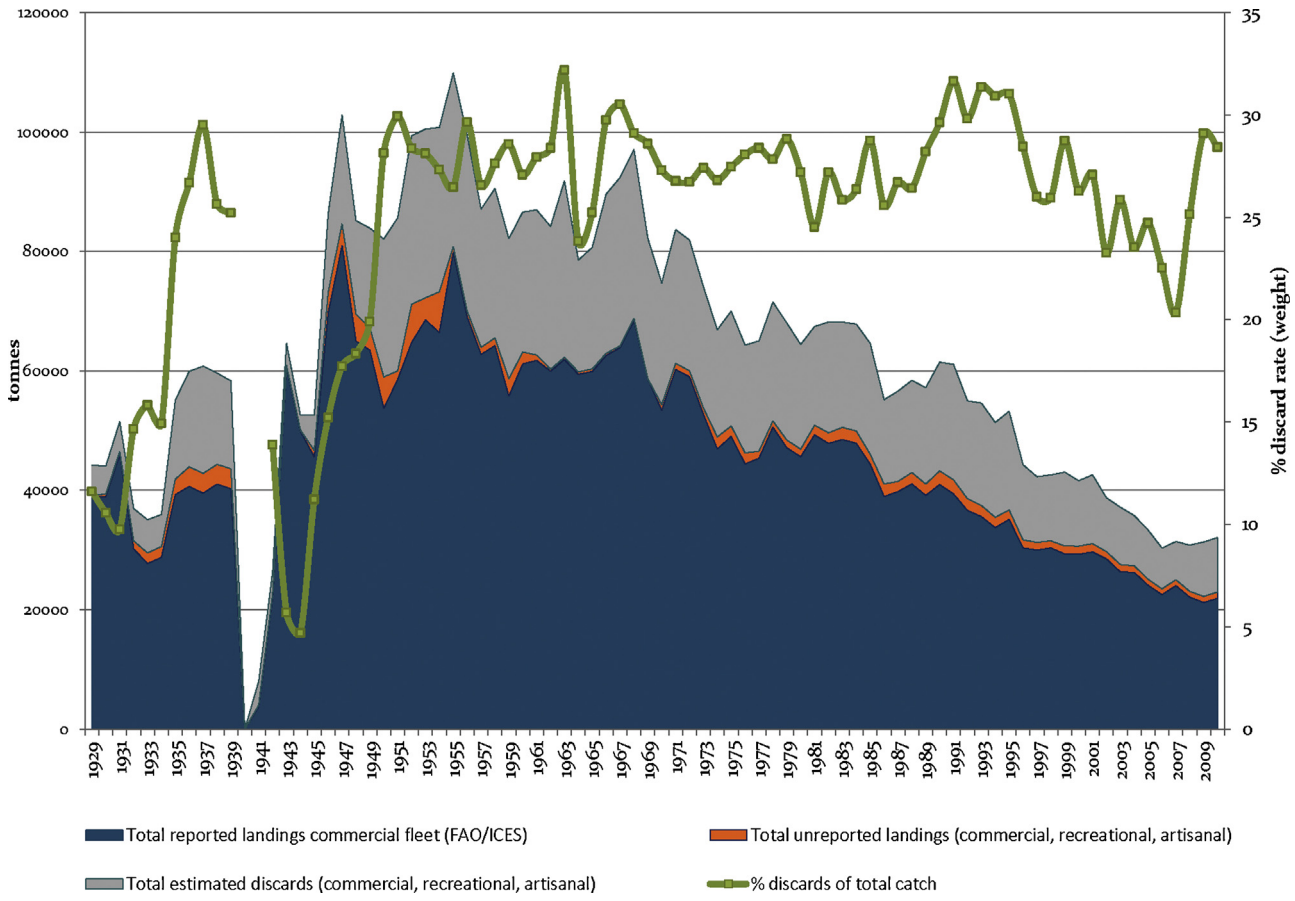

Fig. 2. Total reported landings of the commercial fleet (ICES baseline 2012), unreported landings (unreported commercial landings, landings from recreational, artisanal fisheries) and discards in tonnes (t, left-hand axis), by the Belgian sea fisheries 1929–2010. The right-hand axis shows the annual discards as a percentage of the reconstructed total removals. See text for details.

Table 2
Overview of the amounts (t or 1000 kg) and proportions (%) of the reported and unreported landings and of the estimated discards for 6 fisheries in the Belgian sea fisheries 1929–2010.

	Reported landings (×1000 kg)	% of total reported landings	Unreported landings (×1000 kg)	% of total unreported landings	Discards	% of total discards
Crangon fisheries	106,053	2.9	11,900	6.5	254,281	18.6
Pelagic fisheries (herring and sprat)	619,924	16.7	5580	3.0	27,897	2.0
Nephrops	28,085	0.8	2315	1.3	91,199	6.7
Flatfish beam and otter trawl (plaice and sole)	827,198	22.3	55,069	29.9	528,918	38.8
Gadoid (otter trawlers)	1,342,631	36.3	41,600	22.6	461,410	33.8
Sea angling	–	–	2050	1.1	–	–
Other species	777,846	21.0	65,358	35.5	–	–
Total all reported landings Belgian sea fisheries	3,701,737 (70.5%)	100	183,873 (3.5%)	100	1,363,705	100

or 42% higher than the 3.7 million t publicly reported over this period. Table 2 gives an overview of the amounts (t) and proportions (%) of the unreported landings and of the estimated discards for each of the 6 reviewed fisheries considered in this reconstruction. Overall, unreported landings were estimated to represent 3.5% (0.2 million t) and discards 26% (1.3 million t) of these total reconstructed removals.

3.2. Unreported landings

Overall, the unreported landings amounted to 0.2 million t with a median annual value of approximately 1300 t and a maximum of 9300 t in 1948. The unreported landings were particularly important between 1935 and 1955 and mostly due to underreporting in the baseline. The unreported landings of sole and plaice in commercial and recreational fisheries (55,100 t) and the unreported landings of the commercial fisheries for gadoid and roundfish in bottom trawlers (41,600 t) made up the major part of these unreported landings between 1929 and 2010 with respectively 30% and 23%.

Most of the unreported landings of *Crangon* by the commercial fleet (8100 t) are explained by underreporting before 1955; the recreational shrimp fisheries contributed to the unreported landings with an estimated 3800 t and starting from 1975. Together they represent 11,900 t or 6.5% of the unreported landings overall.

Underreporting for the commercial pelagic fisheries was negligible (10 t herring). 120 t of herring and 60 t of sprat – estimated from artisanal/subsistence fishing between 1929 and 1960 – explain for 3% of the total unreported landings.

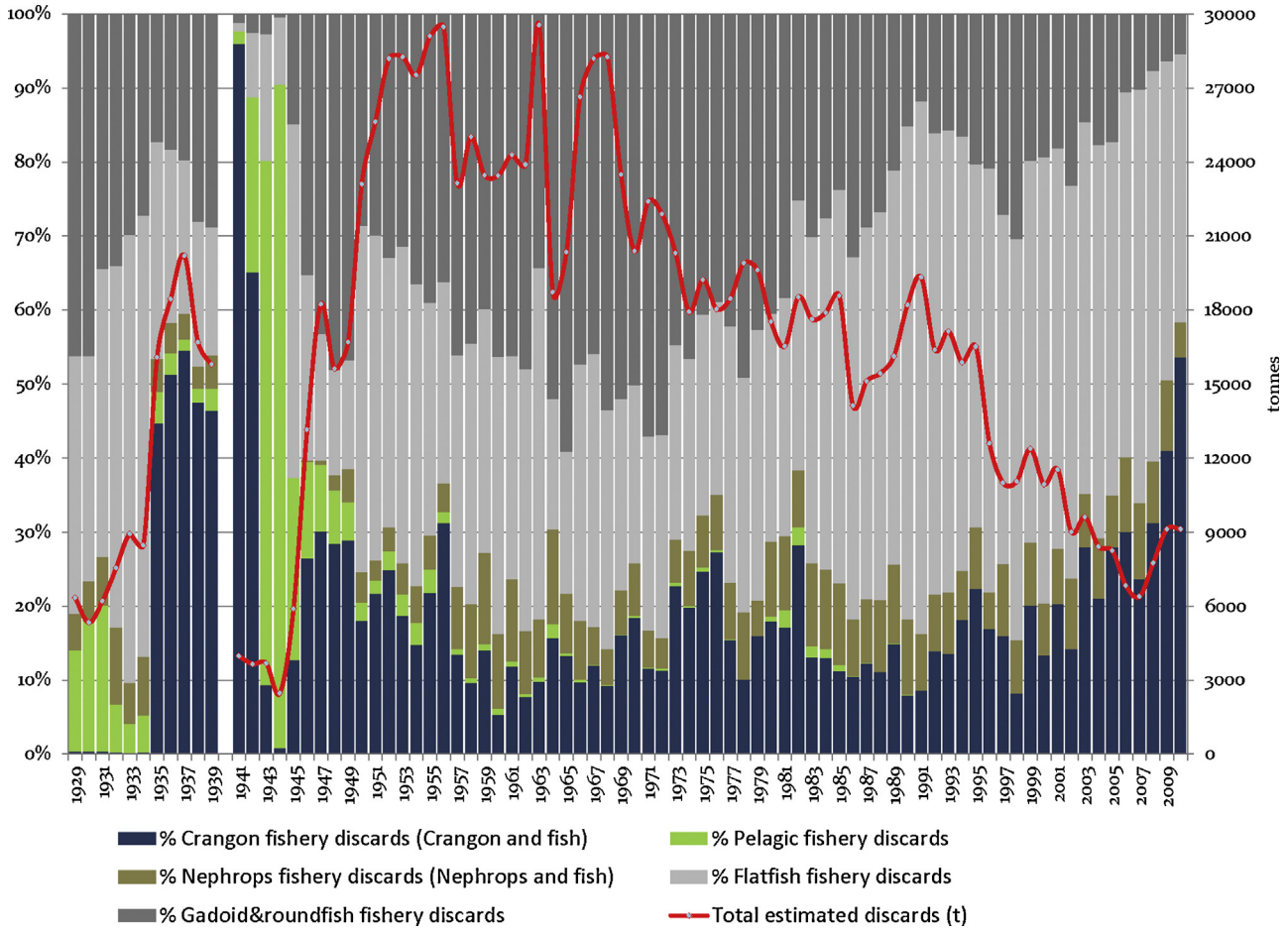

Fig. 3. Total estimated discards (t, right-hand axis) by the Belgian sea fisheries 1929–2010 and percentages of the discards for the 6 fisheries covered in the present reconstruction. For sea angling no discards were considered. See text for details.

Nearly all of the unreported landings in the Belgian commercial fleet targeting gadoid and roundfish (Section 2.3.3), is explained by underreporting before 1968. Overall, 23% of all unreported landings refers to this fishery (Table 2). Reported landings for this fishery from 1950 to 1975 averaged 30,000 t per year. After 1975 the decline in the landings are to a large extent explained by the 'cod wars' which gradually excluded the foreign fleet from Icelandic waters. Currently less than 2000 t of fish are landed for the 7 taxa covered by this reconstruction.

Landings of plaice and sole from the commercial fleet averaged approximately 5000 t per year before WWII and 10,000 t per annum between 1950 and mid 1980s. Between 1985 and 1990 the annual landings of sole and plaice in this fishery increased and peaked to nearly 23,600 t in 1991. The recreational fisheries for sole and plaice, which were assumed to have started in 1970, explain the largest portion of total unreported landings. Underreporting of sole and plaice landings amounted to 5800 t and date from before 1960.

The 2315 t of unreported *Nephrops* landings correspond to the commercial fleet and mainly before WWII.

Sea angling was not included in public reporting and the estimated recreational landings of 50 t per year from 1970 to 2010 represent 1% of all unreported landings. The unreported landings and the estimated discards by recreational and artisanal fisheries are mainly from the Belgian part of the North Sea. Although recreational and artisanal fisheries are included in the overall reconstruction presented in this section, they are discussed in further detail in the reconstructed total removals for the BNS in Section 3.2.

3.3. Discards

Discards were estimated for each of the 6 fisheries covered in the present reconstruction (Fig. 3). The major components of the discards since 1929 were the discards in flatfish fisheries (528,900 t or 39% of the total discards) and the discards in gadoid and roundfish fisheries (461,400 t or 34% of the total discards). The discards in the *Crangon* fisheries (254,300 t or 19% of the total discards) and *Nephrops* fisheries (91,200 t or 7% of total discards) consisted mainly of their target species: respectively 39% of all discards in *Crangon* fisheries and 30% of all discards in *Nephrops* fishery are target species. Plaice, dab and whiting make up significant proportions of the discards in the directed fisheries for *Crangon*, *Nephrops* and flatfish (sole and plaice).

The proportion of discards from the total catch was estimated to reach a historical high of 32% in 1963 (29,500 t), and a median value of 16,600 t per annum. After the peak in 1963, total estimated discards gradually declined to less than 15,000 t. In the early 1990s however, the discarded proportion of the total reconstructed removals was estimated to peak again around 31% (19,000 t), before decreasing to 6500 t in 2007. Before 1935, no data are available for the shrimp fisheries and therefore both the discards (t) and the discarded proportion of *Crangon* fisheries in the total discards were underestimated. Between 1935 and WWII the *Crangon* fisheries constituted the main source of discards (15,000–18,000 t) representing 45–55% of all discards. During WWII, pelagic fisheries were the main fisheries practiced and therefore explain nearly all discards. From 1955 until 1980 the gadoid and roundfish fisheries

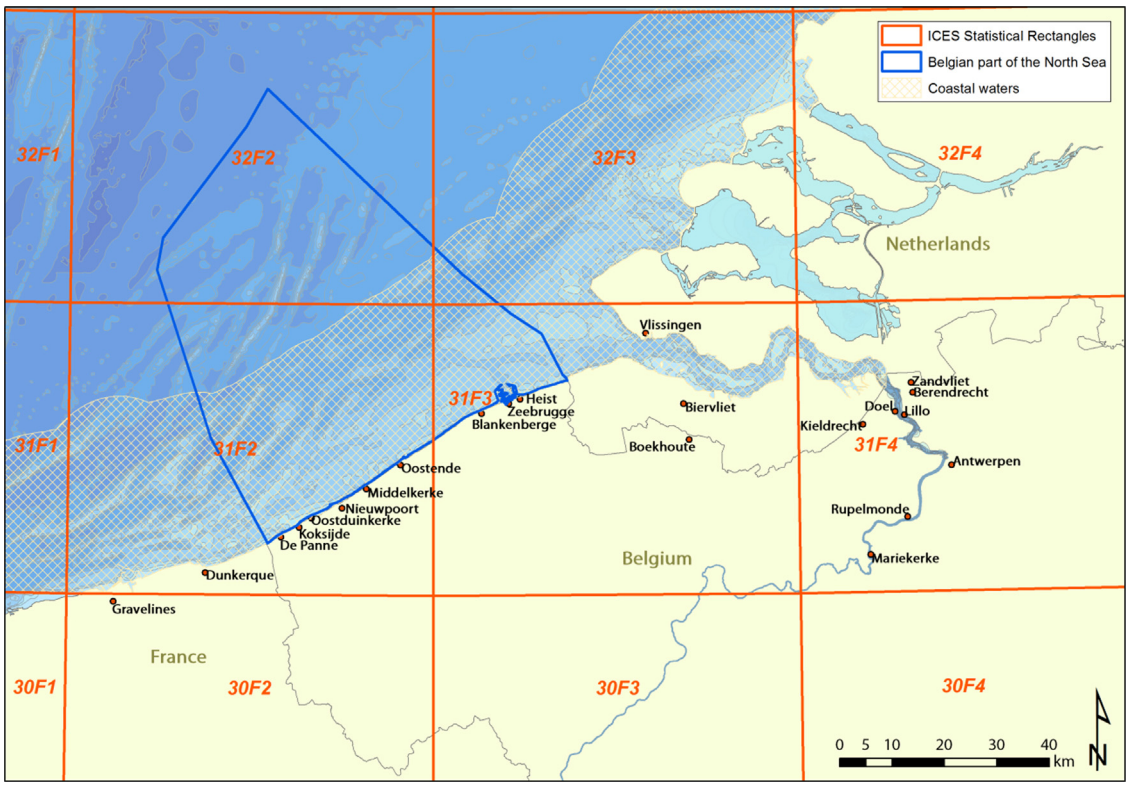

Fig. 4. Map of Belgium coastline and its Exclusive Economic Zone EEZ or Belgian part of the North Sea BNS (blue line), current and historical fishing ports and overlapping areas with ICES rectangles. ICES rectangle shape file layer created by the Danish Institute for Fisheries Research (DIFRES).

explain the largest proportion of discards with a maximum estimate of 15,100 t and up to 60% of the overall annual estimated discards. From 1980 to 2000, the beam trawl fisheries explain most of the discarded weight with up to 72% of the estimated discards in 1991. The recent increases in landings from the *Crangon* fisheries also explain the proportional increase of discards (%) since 2009 in the present estimates (Fig. 3). Reported landings of shrimp by the commercial fleet average 1350 t per annum, with a maximum of 4282 t in 1956. Nearly the same weight (i.e. 1290 t per annum) of undersized shrimp is discarded, while on average more than twice the weight of undersized fish is discarded in this fishery (plaice 6%, sole 3%, dab 10%, whiting 12%). The discard estimates in the *Nephrops* fisheries peaked in 1959 (2900 t) when highest landings were achieved (970 t).

3.4. Total reconstructed removals from the Belgian part of the North Sea by the Belgian sea fisheries 1929–2010

The reported landings from the BNS (see Section 2, Fig. 4) follow a similar pattern as that for the fisheries as a whole (Lescrauwaet et al., 2010a) from 1929 to 2010.

A first period (1929–1940) characterized by pelagic and shrimp fisheries, is followed by a peak in landings of pelagic species during and after WWII (1942–1964). Cod is the dominant species in the reported landings from 1965 to 1980. After the mid 1980s the composition of the reported landings is less dominated by a single species. Herring and sprat (49%), brown shrimp (12%), cod (9%), plaice (6%), whiting (4%) and sole (3%) represent an important proportion over the entire period (Fig. 5). Over the entire period, reported landings from the BNS amount to 841,700 t (dead weight). The median of annual reported landings over the entire period is 8100 t with a peak value of 60,500 t in 1943 and a minimum of 1900 t in 2007 (Fig. 5).

The sum of the publicly reported landings, the unreported landings and the estimated discards add up to the reconstruction of the total removals in the BNS. Following the approach applied in Sections 2.3.1–2.3.7, the unreported removals for the BNS from 1929 to 2010 amount to 59,600 t and the total discards in this period are estimated at 407,300 t (see Table 3). The reconstructed total removals for the BNS were therefore estimated at 1.3 million t or 55% higher than the 0.8 million t publicly reported over this period. Because of the presence of recreational (hence unreported) fisheries in coastal or nearby territorial waters, and the fact that the *Crangon* fisheries are by nature coastal fisheries, these two components contribute with an important proportion to the total

Table 3
Overview of the amounts (t) and proportions (%) of the reported and unreported landings and of the estimated discards for 6 fisheries in the Belgian sea fisheries from the BNS, 1929–2010.

	% of total reported	% of total unreported	% of total discarded
Commercial fleet pelagic (herring and sprat)	48	–	4
Shrimp fisheries *Crangon crangon*	13	14	69
Beam (flatfish) and otter trawl (non-shrimp)	39	–	27
Recreational trawling (fish)	–	86	–
Total Belgium EEZ (=100%) rounded numbers (in 1000 t)	842 (100%)	60 (100%)	407 (100%)

<0.01 is not listed or indicated by '–'.

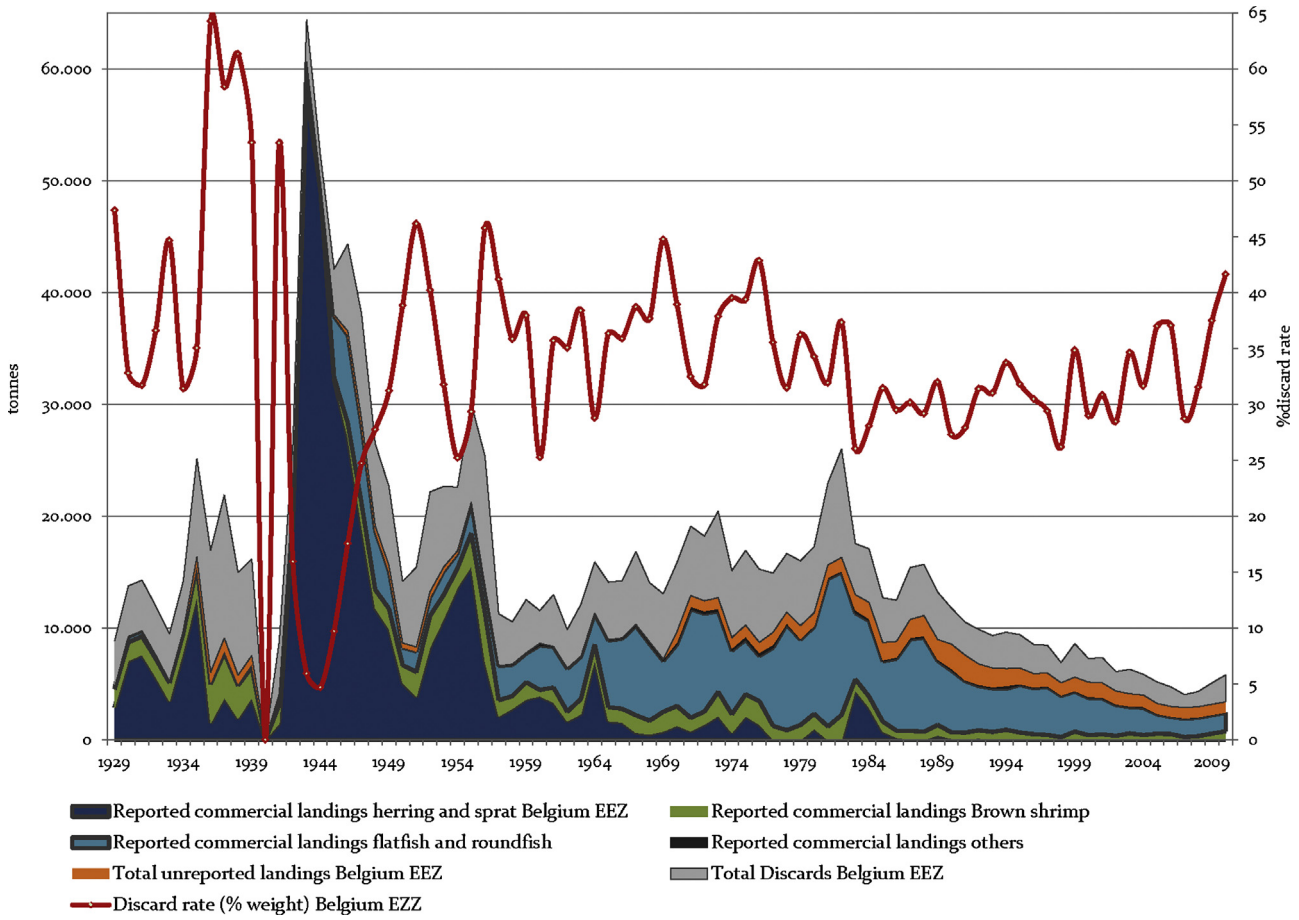

Fig. 5. Total reported landings of the commercial fleet (ICES baseline 2012), unreported landings (unreported commercial landings, recreational and artisanal fisheries) and discards (t, left-hand axis), by the Belgian sea fisheries 1929–2010 from the BNS. The right-hand axis shows the annual discards as a percentage of the reconstructed total removals. See text for details.

unreported removals from the BNS. In particular since the late 1980s this proportion is estimated to range between 15% and 20% of the total removals by Belgian fisheries from the BNS.

The estimates of annual discarded weight on the BNS range between 4600 t and 12,800 t. Annual discards fluctuated between 5% and 64% of total removals from the BNS. The lower percentage coincides with the period when pelagic fisheries provided the main source of fish from the BNS (1940–1948) whereas the higher percentages coincide with the periods when brown shrimp make up an important proportion of the landings (1935–1939). It is estimated that shrimp fisheries (commercial and recreational) represents 69% of all discards on the BNS in the entire period, whereas trawling for roundfish and flatfish is estimated to represent 27% and pelagic fisheries 4%. Based on the literature sources consulted (see Section 2.3.1), it is expected that both historically as in recent times, whiting, plaice, dab, sharks and shrimp were the most discarded species on the BNS.

4. Discussion

This first reconstruction of total removals by Belgian sea fisheries from 1929 to 2010 is largely based on historical landing statistics by type of fisheries. It does not take into account criteria related to vessel characteristics, fishing effort or environmental conditions (local features of fishing areas, seasonality). This approach is widely applied and accepted in current studies on discard estimates. The estimates presented here are based on a conservative approach and lowest ranges of reported discards rates.

Whereas the baseline does not allow distinguishing the landings from the BNS within the broader fishing area IVc, the HiFiDatabase allows for an analysis at a scale comparable with the boundaries of the Belgian EEZ. Since formal reporting started, roughly one fifth of all landings of the Belgian sea fisheries originated from the BNS, while these waters contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans' (Lescrauwaet et al., 2010a,b). Fisheries in this area have generated 1000 kg/ha compared to the fishing area of the Bristol Channel (southwest UK) which is 2 times larger and generated 77 kg/ha over similar time frame of exploitation. The BNS has been a continuous and nearby source of food for the local population, of economic turnover and profit, direct and indirect employment and an area for recreational fishing. The results presented here suggest that:

- Since the 2000s, approximately 50% of all Belgian removals from the BNS are unreported landings and discards (IUU). This does not include benthic invertebrates.
- The unreported landings and discards are increasingly taken by non-commercial, small-scale (<10 m) 'recreational' vessels that are not subject to reporting and not taken into consideration in planning, monitoring and enforcement.
- The proportional importance of recreational fisheries has increased substantially in the last 4 decades, and currently may represent near to 20% of all removals by the Belgian fisheries in the BNS.
- The total fish discarded by the Belgian fisheries on the BNS may range between 30% and 40% of all Belgian landings from the BNS.

Based on estimates of fish discarded by the foreign fleet on the BNS (Depestele et al., 2012), our hypothesis is that since the 1990s, all fish and shrimp discarded by both the Belgian and the foreign fishing operations on the BNS together approximates 50% of the total reported landings (t) of Belgian commercial sea fisheries (all fisheries, all species, all fishing areas).

From an environmental perspective, this is cause for concern as it represents a waste of valuable resources of food, energy and biological diversity, and generates a non-quantified impact on the food web, seabed and ecosystem services in the coastal environment. From an ecosystem perspective this information – as well as the information on the activities of the foreign fleet on the BNS – must be included in particular to obtain reliable data in compliance of e.g. the GES targets set forward in the MSFD (2008/56/EG), to improve stock assessments and achieving targets of maximum sustainable yield MSY in the CFP and to achieve favourable conservation status for the species and habitats protected in marine and coastal Natura 2000 sites. While not explicitly mentioned in its final statement, the United Nations Resolution (2002) intended to also cover unregulated and unreported catches by recreational fisheries from 2004 onwards. The daily allowable catches in recreational fisheries must also be connected to EU quota regulations and recovery plans for cod and plaice.

Also in terms of social, economic and cultural considerations, the unreported removals and discards represent wasted or lost opportunities for local jobs and security for the formal fishing industry, for secure food, and for leisure and tourism for the wider population. To quantify the non-perceived economic value due to IUU, the total hypothetical value of the unreported and discarded fish and shrimp by the Belgian fisheries from the BNS was calculated based on HiFiData economic information by species and by year (Lescrauwaet et al., unpublished data). Expressed as prices 2010 (corrected for inflation) and based on the average price EUR/kg of the commercial landings, our calculations show that the total value of the unreported and discarded weight corresponds to approximately 90% of the value of commercial landings considering the entire period 1947–2010. This calculation may represent an overestimation since discards are mostly undersized and therefore of lower commercial value.

It is important to note however that the Dutch and French fleets also obtain substantial amount of landings from the BNS, which currently may exceed 4 times the landings reported by the Belgian commercial and recreational fisheries covered in this section. Depestele et al. (2012) estimated the current discards from different métiers from the Belgian, Dutch and French commercial fleets on the BNS, by using landings and discard sampling data and raising the outcome at the fleet level (2006–2008). Their results indicated that total discards on the BNS from all commercial fleets and métiers together may reach values around 8000 t of fish and shrimp per year and up to 25,000–30,000 t per year if benthic invertebrates are included. This estimate of discarded fish on the BNS is in the order of magnitude of current reported annual landings by the total Belgian commercial sea fisheries (18,000–22,000 t).

The estimates of landings and discards of the recreational fleet targeting brown shrimp and fish are based on assumptions and cover at least 4 decades. The estimates indicate that recreational fisheries need to be taken into account when looking at historical, current and cumulative impact of fisheries on the BNS. The catches and efforts of the recreational fleet targeting brown shrimp and flatfishes and their impact on the coastal ecosystem will be the subject of systematic surveying in the context of the national data gathering programme for the CFP and the monitoring in compliance of targeted GES. ICES and member countries need to establish regular surveys (every 4–6 years) of total recreational removal, by species, area and gear category. The Data Collection Regulations of the CFP require European Member States to collect data on technical, biological and economic aspects of their national fisheries and their impact on the marine ecosystem, and to collect data and report on discards. As a consequence of the 'discard-ban', formal reporting on commercial landings will be extended with commercial discards and removals from non-commercial fishing.

Depestele et al. (2012) studied the impact of trammel nets on different components of the marine ecosystem of the BNS (sea birds, benthos, fish stocks, marine mammals). Sea bird and marine mammal by-catch was investigated through strandings data, questionnaires and independent observers, and in cooperation with fishers. The results indicate there is a potential danger for diving seabirds and harbour porpoises (*Phocoena phocoena*) which is listed on the EU habitat directive annexes (92/43/EEG) and directive 812/2004, protected by the royal decrees KB 1980-09-22 and KB 2001-12-21 and targeted by ASCOBANS. Haelters and Kerckhof (2005) found that a significant part of the dead strandings on Belgian beaches was caused by drowning in trammel nets, in particular in the first quarter of the year when nets are set for sole and plaice. Regulations prohibit the use of trammel (multi-layered gillnets) as well as the use of gillnets below low watermark, sets maximum lengths and total number of nets, and enforces the minimum landing sizes of species (royal decree KB 1989-08-14, KB 2001-12-21 and ministerial decision 2006-12-21).

5. Conclusions

In the present reconstruction of total removals by the Belgian commercial, recreational and artisanal sea fisheries for the period 1929–2010, total removals were estimated at 5.2 million t, which is 42% higher than the 3.7 million t publicly reported over this period. Unreported landings and discards were estimated to represent respectively 3.5% (0.2 million t) and 26% (1.3 million t) of these total reconstructed removals. After the peak in 1963 (29,500 t) and the period of increased discard rates (31%) in the early 1990s, total estimated discards gradually decreased to 6500 t in 2007.

The reconstructed total removals on the BNS were estimated at 1.3 million t or 55% higher than the 0.8 million t publicly reported over this period. Discards on the BNS represent an average annual of 34% over the entire period. These numbers do not take into account the non-commercial benthic invertebrate species, or the landings and discarding by foreign vessels (mainly Dutch and French) from the BNS.

The HiFiDatabase allows for an analysis at a scale comparable with the boundaries of the Belgian EEZ and offers opportunities for advanced research on seasonal and annual trends in historical landings, effort, and economy of the fisheries. The outcomes of the reconstruction suggest that the unreported landings and discards are increasingly taken by non-commercial, small-scale (<10 m) vessels that are not subject to reporting and suggests that small-scale fisheries currently may represent near to 20% of all removals by the Belgian fisheries in the BNS and that since the 1990s, all fish and shrimp discarded by both the Belgian and the foreign fishing operations on the BNS together approximate 50% of the total reported landings (t) of Belgian commercial sea fisheries (all fisheries, all species, all fishing areas).

The social and cultural role of small-scale fisheries is explicitly stated in the EC Green paper on the Reform of the CFP. Policy options to support small-scale fisheries include special treatment under the European Maritime and Fisheries Fund EMFF, the exemption from particular management requirements and safeguards in a context of rights-based management systems with e.g. transferable quota. The 12 nm limit that is reserved for coastal fisheries is also extended

for another 10 years. It is therefore important to further quantify recreational and non-commercial fishing activities within the BNS, and their position and importance in comparison to commercial coastal fisheries.

Although the approach followed for the present reconstruction is widely applied and accepted in current studies on discard estimates, expanding and refining the approach by taking into account criteria related to vessel characteristics and to environmental conditions (local features of fishing areas, seasonality) should improve reliability of the outcomes (Depestele et al., 2011). Time-variant discard rate estimates are needed by fishing area and discard survival rates need more focused research by fishing métier and varying environmental conditions. Insights in the historical impact of quota and market forces on ship-board discard behaviour are also needed to improve the estimates. Also, underwater mortality such as towpath mortality and escape mortality and their effects on total mortality of commercial and non-commercial species require further studies. Also, the non-perceived or non-quantified socio-economic benefits and externalized environmental costs need to be taken into account in future strategies and planning for more sustainable fisheries.

Finally, taking into account total removals is one aspect in moving towards an ecosystem-based approach and planning for future socio-economic viability of fisheries. A more integrated view takes into account aspects of energy and fuel consumption to steam towards distant grounds, employment, food safety and quality. In Belgium, the Fisheries Authority (department of Agriculture and Fisheries, Flemish government) together with the producers' organization, Fisheries Research Institute ILVO and environmental NGO have taken first steps towards a more sustainable future for fisheries by developing a joint Strategy for Sustainable Fisheries.

In spite of the remaining gaps and uncertainties, the current estimates provide a first overview of historical trends and current estimates of the IUU by Belgian fisheries and in particular by the Belgian fleet on the BNS. As such they can support the wider debate about how to move to more sustainable fisheries, what the role of small-scale fisheries are, how to achieve the agreed policy targets in Belgian marine waters and in particular in the marine areas protected under the EU Habitat and Bird directives. Although this study refers to the particular situation of the Belgian fisheries, similar trends may exist in neighbouring countries around the North Sea.

Authors' contributions

Conceived project outlines: AKL JM MV. Designed the data rescue and reconstruction: AKL JM. Performed the data rescue and reconstruction: AKL. Wrote the paper: AKL JM MV ET HP.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.fishres.2013.05.007.

References

Anon., 1965. De Belgische zeevisserij: aanvoer en besomming 1965. Dienst Zeevisserij: Oostende. Series of annual reports of the Fisheries Service on 'Value and landings of Belgian Sea Fisheries', 49 pp.

Avia, D., Diamantis, C., Neudecker, T., Berkenhagen, J., Müller, M., 2011. The North Sea brown shrimp fisheries. Study Requested by the European Parliament (IP/B/PECH/IC/2010_102)., pp. 108.

Bray, K., 2000. A Global Review of Illegal, Unreported and Unregulated (IUU) Fishing. Expert Consultation on Illegal, Unreported and Unregulated Fishing, FAO: IUU/2000/6, 53 pp.

Borges, L., Rogan, E., Officer, R., 2005. Discarding by the demersal fishery in the waters around Ireland. Fish. Res. 76, 1–13.

Catchpole, T.L., Frid, C.L.J., Gray, T.S., 2005. Discards in North Sea fisheries: causes, consequences and solutions. Mar. Policy 29, 421–430.

Churchill, R.R., 1990. Quota hopping: the Common Fisheries Policy wrongfooted? CML Rev. 27 (2), 209247, Common Market Law Review. Kluwer Academic, Dordrecht. ISSN 0165-0750.

Collie, J.S., Escanero, G.A., Valentine, P.C., 2000. Photographic evaluation of the impacts of bottom fishing on benthic epifauna. ICES J. Mar. Sci. 57, 987–1001.

Coleman, F.C., Figueira, W.F., Ueland, J.S., Crowder, R.B., 2004. The impact of United States recreational fisheries on marine fish populations. Science 305, 1958–1960.

Depestele, J., Courtens, W., Degraer, S., Derous, S., Haelters, J., Hostens, K., Moulaert, I., Polet, H., Rabaut, M., Stienen, E., Vincx, M., 2008. WAKO: Evaluatie van de milieu-impact van Warrelnet- en boomKOrvisserij op het Belgisch deel van de Project SD/NS/08A – An integrated impact assessment of trammel net and beam trawl fisheries WAKO-II SSD – Science for a Sustainable Development – North Sea 209 Noordzee: Eindrapport. ILVO-Visserij, Oostende, België, 185 pp. (+Annexes) (in Dutch).

Depestele, J., Vandemaele, S., Vanhee, W., Polet, H., Torreele, E., Leirs, H., Vincx, M., 2011. Quantifying causes of discard variability: an indispensable assistance to discard estimation and a paramount need for policy measures ICES. J. Mar. Sci. – J. Cons. Int. Explor. Mer. 68 (8), 1719–1725.

Depestele, J., Courtens, W., Degraer, S., Haelters, J., Hostens, K., Houziaux, J.-S., Merckx, B., Polet, H., Rabaut, M., Stienen, E.W.M., Vandendriessche, S., Verfaillie, E., Vincx, M., 2012. An Integrated Impact Assessment of Trammel Net and Beam Trawl Fisheries WAKO II: Final Report. Belgian Science Policy Office, Brussels, 233 pp.

Diamond, B., Beukers-Stewart, B.D., 2011. Fisheries discards in the North Sea: waste of resources or a necessary evil? Rev. Fish. Sci. 19 (3), 231–245, http://dx.doi.org/10.1080/10641262.2011.585432, First published on: 20 June 2011 (iFirst).

Enever, R., Revill, A., Grant, A., 2007. Discarding in the English Channel, Western approaches, Celtic and Irish Seas (ICES subarea VII). Fish. Res. 86, 143–152.

Enever, R., Catchpole, T.L., Ellis, J.R., Grant, A., 2009. The survival of skates (Rajidae) caught by demersal trawlers fishing in UK waters. Fish. Res. 97, 72–76.

EU, 2008. On the implementation of the policy to reduce unwanted by-catch and eliminate discards in European fisheries. In: Commission Non-Paper, 13 pp.

Forrest, R., Pitcher, T.J., Watson, R., Valtýsson, H.P., Guénette, S., 2001. Estimating Illegal and Unreported Catches from Marine Ecosystems: Two Case Studies. Fisheries Centre Research Reports, UBC Vancouver, vol. 9, nr. 5., pp. 81–93.

Gamito, R., Cabral, H., 2003. Mortality of brown-shrimp discards from the beam trawl fishery in the Tagus estuary. Port. Fish. Res. 63 (September), 423–427.

Garthe, S., Camphuysen, C.J., Furness, R.W., 1996. Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. Mar. Ecol. – Prog. Ser. 136, 1–11.

Gilis, Ch., 1954. La pêche belge aux poissons demersaux dans la Mer du Nord au cours des années 1946-1953: son évolution par rapport à l'effort de pêche. Etudes de l'Institut d'Etudes Maritimes d'Ostende. Institut d'Etudes Maritimes, Oostende, pp. 24.

Gilis, Ch., 1961. De haringcampagnes: I. 1958–59, II. 1959–60, III. 1960–61=Les campagnes harenguières: I. 1958–59, II. 1959–60, III. 1960–61. In: Studies van het Zeewetenschappelijk Instituut Oostende=Etudes de l'Institut d'Etudes Maritimes d'Ostende, 1961(1). Zeewetenschappelijk Instituut=Institut d'Etudes Maritimes, Oostende, 74 pp.

Gilis, Ch., 1962. I. De Belgische haringcampagne 1961-62 in de sector Sandettie. II. De Belgische haringvisserij in de sector Sandettie van 1930 tot 1960. In: Studies van het Zeewetenschappelijk Instituut Oostende=Etudes de l'Institut d'Etudes Maritimes d'Ostende, 1962(1). Zeewetenschappelijk Instituut=Institut d'Etudes Maritimes, Oostende, 56 pp.

Goffin, A., Lescrauwaet, A.-K., Calewaert, J.-B., Mees, J., Seys, J., Delbare, D., Demaré, W., Hostens, K., Moulaert, I., Parmentier, K., Redant, F., Mergaert, K., Vanhooreweder, B., Maes, F., De Meyer, P., Belpaeme, K., Maelfait, H., Degraer, S., De Maersschalck, V., Derous, S., Gheskiere, T., Vanaverbeke, J., Van Hoey, G., Kuijken, E., Stienen, E., Haelters, J., Kerckhof, F., Overloop, S., Peeters, B., 2007. MIRA

Milieurapport Vlaanderen, Achtergronddocument 2006: Kust & zee. Vlaamse Milieumaatschappij, Erembodegem, pp. 180.
Haelters, J., Kerckhof, F., 2005. A remarkable increase in the number of stranded harbour porpoises Phocoena phocoena at the Belgian coast. In: Mees, J., et al. (Eds.), VLIZ Young Scientists' Day, Brugge, Belgium 25 February 2005: Book of Abstracts. VLIZ Special Publication, 20, p. 39.
Hoefnagel, E., 1998. Legal but controversial: quota hopping, the CFP and the Treaty of Rome. In: Symes, D. (Ed.), Property Rights and Regulatory Systems in Fisheries. , pp. 80–91.
Horwood, J., O'Brien, C., Darby, C., 2006. North Sea cod recovery? ICES J. Mar. Sci. 63, 961–968.
Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V.S., Somerfield, P.J., Karakakkis, I., 2006. Global analysis of response and recovery of benthic biota to fishing. Mar. Ecol. Progr. Ser., 1–14.
Kelleher, K., 2005. Discards in the world's marine fisheries: an update. In: FAO Fisheries Technical Paper 470. UN Fisheries and Agriculture Organisation, Rome.
Kirkegaard, E., 1991. Discard Sampling Programme for the North Sea Danish Participation (2nd part). EC DG XIV study contract 1990/9 Danish Institute for Fisheries and Marine Research, Charlottenlund.
Lancaster, J., Frid, C.L.J., 2001. The fate of discarded juvenile brown shrimps (*Crangon crangon*) in the Solway Firth UK fishery. Fish. Res. 58, 95–107.
Leloup, E., Gilis, Ch., 1965. Zeedieren waargenomen in de experimentele garnalenvangsten (1949–1964)=Animaux marins observés dans les pêches expérimentales aux crevettes (1949–1964). Studies van het Zeewetenschappelijk Instituut Oostende=Etudes de l'Institut d'Etudes Maritimes d'Ostende, 1965(2). Zeewetenschappelijk Instituut=Institut d'Etudes Maritimes, Oostende, 26 pp.
Lescrauwaet, A.K., Debergh, H., Vincx, M., Mees, J., 2010a. Fishing in the past: historical data on sea fisheries landings in Belgium Mar. Policy 34 (6), 1279–1289.
Lescrauwaet, A.K., Debergh, H., Vincx, M., Mees, J., 2010b. Historical marine fisheries data for Belgium: Data sources, data management and data integration related to the reconstruction of historical time-series of marine fisheries landings for Belgium. In: Fisheries Centre Working Paper Series, 2010–08. University of British Columbia, Vancouver, pp. 69.
Lescrauwaet, A.K., Fockedey, N., Debergh, H., Vincx, M., Mees, J., 2013. Hundred and eighty years of fleet dynamics in the Belgian sea fisheries. Rev Fish Biol. Fish., Online first: 15 pp. hdl.handle.net/10.1007/s11160-012-9287-1.
Lescrauwaet, A.K., Vincx, M., Mees, J., Flooded by herring, unpublished data.
Lindeboom, H.J., De Groot, S.J., 1998. IMPACT-II. The Effects of Different Types of Fisheries on the North Sea and Irish Sea Benthic Ecosystems. Netherlands Institutes.
Morizur, Y., Tregenza, N., Heessen, H., Berrow, S., Pouvreau, S., 1996. Bycatch and Discarding in Pelagic Trawl Fisheries – Final Report Contract EC DG XIV-C-1 Study BIOECO/93/017. IFREMER.
MRAG, 2007. Impact Assessment of Discard Policy for Specific Fisheries: Final Report. European Commission Studies and Pilot Projects for Carrying Out the Common Fisheries Policy. No FISH/2006/17.
Pauly, D., 1998. Rationale for constructing catch time series. Eur. Commun. Fish. Cooperation Bull. 11 (2), 4–5.
Polet, H., 2004. Evaluatie van de bijvangst in de Belgische visserij op grijze garnaal (*Crangon crangon* L.) en van technische middelen om teruggooi te verminderen=Evaluation of by-catch in the Belgian brown shrimp (*Crangon crangon* L.) fishery and of technical means to reduce discarding. Universiteit Gent, Gent, ISBN 90-5989-004-3 (PhD Thesis), 212 pp.
Rahikainen, M., Peltonen, H., Pönni, J., 2004. Unaccounted mortality in northern Baltic Sea herring fishery—magnitude and effects on estimates of stock dynamics. Fish. Res. 67, 111–127.
Rochet, M.-J., Peronnet, I., Trenkel, V.M., 2002. An analysis of discards from the French trawler fleet in the Celtic Sea. ICES J. Mar. Sci. 59, 538–552.
STECF, 2005. STECF Sub-group SGRST Evaluation of the Cod Recovery Plan Appendix 4, 71 pp. http://www.stecf.jrc.cec.eu.int/meetings/sgrstsep2005/Appendix%204%20ToR%202%20draft%2020051024.pdf
Steenbergen, J., Machiels, M., Nijman, R., March 2012. LFD: Less Fuel and Discards in visserij op Noorse Kreeft. Eindrapportage. IMARES Rapport 036.12.
Stratoudakis, Y., Fryer, R., Cook, R., Pierce, G., Coull, K., 2001. Fish bycatch and discarding in Nephrops trawlers in the Firth of Clyde (west of Scotland). Aquat. Living Resour. 14 (September–October (5)), 283–291.
Tessens, E., Velghe, M., 2008. De Belgische zeevisserij: aanvoer en besomming 2008. Vlaamse Overheid. Departement Landbouw en Visserij. Afdeling Landbouw- en Visserijbeleid. Zeevisserij, Brussel, 103 pp.
Tessens, E., Velghe, M. (Eds.), 2009. Uitkomsten van de Belgische zeevisserij 2008. Vlaamse Overheid. Departement Landbouw en Visserij. Afdeling Landbouw- en Visserijbeleid. Zeevisserij, Oostende, 30 pp.
Tessens, E., Velghe, M., 2010. De Belgische zeevisserij: aanvoer en besomming 2009. Vlaamse Overheid. Departement Landbouw en Visserij. Afdeling Landbouw- en Visserijbeleid. Zeevisserij, Oostende, 109 pp.
Tessens, E., Velghe, M. (Eds.), 2011. De Belgische zeevisserij: aanvoer en besomming 2010. De Belgische zeevisserij: aanvoer en besomming, 2010. Vlaamse Overheid. Departement Landbouw en Visserij. Afdeling Landbouw- en Visserijbeleid. Zeevisserij, Oostende, 115 pp.
Tessens, E., Velghe, M., 2012. De Belgische zeevisserij 2011. Aanvoer en besomming. Vloot, quota, vangsten, visserijmethoden en activiteit. De Belgische zeevisserij: aanvoer en besomming, 2011. Dienst Zeevisserij, Oostende, 120 pp.
United Nations Resolution, 2002. A/RES/57/142 2002.
Ulleweit, J., Stransky, C., Panten, K., 2009. Discards and discarding practices in German fisheries in the North Sea and Northeast Atlantic during 2002–2008. J. Appl. Ichthyology 26 (s1), 54–66.
Vandendriessche, S., Moreau, K., Anseeuw, D., Vandemaele, S., 2008. Teruggooi in de boomkorvisserij: Optimalisatie van het onderzoek, Evaluatie van reducerende Technische maatregelen en Sensibilisering van de sector: Projectrapport 'TOETS'. ILVO Visserij, Oostende, 175 pp.
van Helmond, A.T., van Overzee, H.M., 2008. Discard sampling of the Dutch beam trawl in 2006. CVO Report no. 07.011, Ijmuiden, The Netherlands, 46 pp.
Van der Hammen, T., de Graaf, M., 2012. Recreational Fishery in the Netherlands: Catch Estimates of cod (*Gadus morhua*) and eel (Anguilla Anguilla) in 2010. Report Number C014/12. IMARES Wageningen UR, 61 pp.
Zimmermann, C., Schultz, N., Gebel, A., Hammer, C., 2007. The German recreational fisheries' cod catch in the Baltic and North Seas, 2004–2006 (Dorsch/Kabeljau-Fänge durch die deutsche Freizeitfischerei der Nord- und Ostsee 2004–2006).
Zeller, D., Booth, S., Craig, P., Pauly, D., 2006. Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. Coral Reefs 25, 144–152.
Zeller, D., Booth, S., Davis, G., Pauly, D., 2007. Re-estimation of small-scale fisheries catches for U.S. flag island areas in the Western Pacific: the last 50 years. Fisheries Bulletin 105, 266–277.
Zeller, D., Darcy, M., Booth, S., Lowe, M.K., Martell, S.J., 2008. What about recreational catch? Potential impact on stock assessment for Hawai's bottomfish fisheries. Fish. Res. 91, 88–97.
Zeller, D., Cheung, W.W.L., Close, C., Pauly, D., 2009. Trends in global marine fisheries – a critical view. In: Wrammer, P., Ackefors, H., Cullberg, M.s. (Eds.), Fisheries, Sustainability and Development. Royal Swedish Academy of Agriculture and Forestry, Stockholm, pp. 87–107.
Zeller, D., Booth, S., Bale, S., Rossing, R., Harper, S., Pauly, D., 2010. Fisheries catches from the Baltic Sea Large Marine Ecosystem: 1950–2007. In: Rossing, P., Booth, S., Zeller, D.s (Eds.), Total Marine Fisheries Extractions by Country in the Baltic Sea: 1950–Present. Fisheries Centre Research Reports 18(1). Fisheries Centre, University of British Columbia, Vancouver, pp. 7–38.
Zeller, D., Rossing, P., Harper, S., Persson, L., Booth, S., Pauly, D., 2011. The Baltic Sea: estimates of total fisheries removals 1950–2007. Fish. Res. 108, 356–363.

Personal communications

E. Tessens. Dienst Zeevisserij, Departement Landbouw en Visserij, Vlaamse Overheid.
E. Hiele (pers. comm.). Dienst Scheepvaartcontrole, FOD Mobiliteit. June 2012.

Web references

Belgium Royal decree 1/03/1958 on beam trawls: http://ww w.vliz.be/imis/imis.php?module=ref&refid=206773.
Marine Species WoRMS. www.marinespecies.org.
ICES FISHSTAT. http://www.ices.dk/fish/CATChSTATISTICS.asp (accessed January 2012).
Flanders Marine Institute, Historical timeline on sea fisheries application: www.vliz.be/cijfers_beleid/zeevisserij/timeline.php.