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INVISIBLE CATCH: A CENTURY OF BY-CATCH AND UNREPORTED REMOVALS IN SEA FISHERIES, BELGIUM 1950-2010

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ABSTRACT

Publicly reported statistics on the production of fisheries available 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 its Exclusive Economic Zone (EEZ) and further afield were reconstructed for the time period 1950-2010 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 landings were 1.47 times that reported officially by ICES Fishstat.. Unreported landings and discards were estimated to represent respectively 1.9% and 30.0% of these total reconstructed removals. The results suggest that since the 1990s, over 50% of all Belgian removals from the Belgian part of the North Sea (BNS; i.e., Belgium's EEZ waters) are unreported landings and discards (IUU). The unreported landings and discards are increasingly taken by non-commercial, small-scale (<12m) vessels that are not subject to reporting and not taken into consideration in planning, monitoring and enforcement. While the present paper provides an initial 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.

INTRODUCTION

Belgium is a small (land area: 30,500 km^2) western European country with a single coast on the North Sea. The coastline is small and the EEZ is restricted by the proximity of the United Kingdom across the English Channel (Figure 1). As with most European fisheries, the industry in Belgium is well developed and monitored. Regulations in support of the Common Fisheries Policy (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. They are also requested to monitor and report on discards. This monitoring has led to a reform of the Common Fisheries Policy (2013), which will introduce a ban on discarding from 2015. Other European regulations have marine aspects, such as the Marine Strategy Framework Directive (MSFD), which establishes targets to achieve 'Good Evnironmental Status' (GES) and will require both effective monitoring and reliable historical data. However, besides historical gaps, where time-series are scarce and mostly date from after the start of intensive exploitation, there is no quantitative or qualitative assessment for the small-scale fisheries (<12m) in Belgium's coastal waters (within 12nm). Centralized reporting began in Belgium in 1929 (Lescrauwaet et al., 2010a), but as with most fishing nations, the routine data collection requirements were, until recently, limited to landings of the commercial fleet. Discards of the commercial fleet, landings and discards of the artisanal and recreational fleet, as well as land-based fishing activities are not covered by systematic reporting.

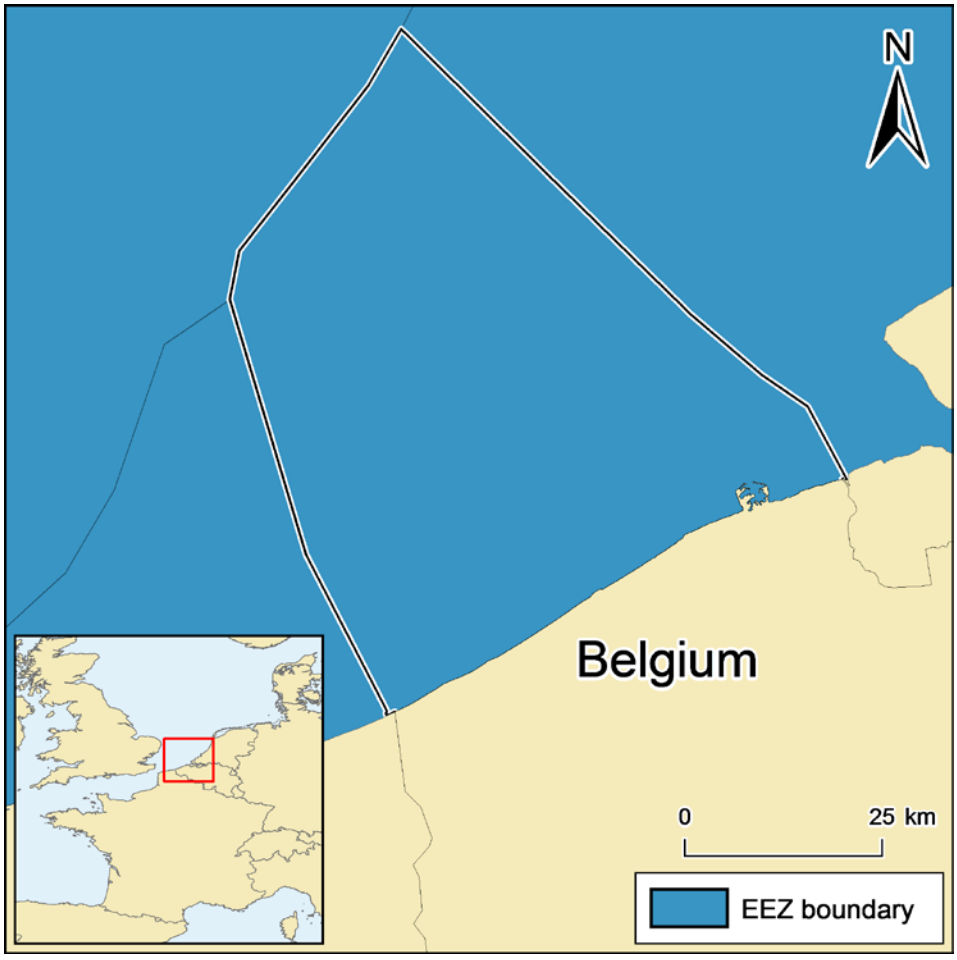

Figure 1. Boundary's of Belgium's EEZ.

Fisheries development in Belgium

Fleet, ports and employment

Belgium today has four coastal ports (Nieuwpoort, Oostende, Zeebrugge and Blankenberge) and besides the fish auctions located in Oostende, Zeebrugge and Nieuwpoort there are no other commercial landing points. Before World War II (WWII, 1939-1945) there were important settlements in Heist and Blankenberge to the east, in the Scheldt estuary, and in De Panne, Adinkerke, Oostduinkerke and Koksijde to the west. Together with the current fishing ports they harboured more than 500 vessels of which approximately 100 had open and half-open decks. In 2011, 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). 46 vessels are part of the Small Fleet Segment (max 221 kW engine power) of which 2 use passive gear and the others are beam trawlers for shrimp and flatfish. Of the small fleet, 21 are inshore vessels that make fishing trips of less than 48 hours within the range of 12 nautical miles. 43 vessels compose the Large Fleet Segment with an engine power between 221 kW and a maximum of 1,200 kW. The large fleet segment consists of 5 vessels using trammel nets, 4 using otter trawl and 34 large beam trawl vessels (≥662 kW). The Belgian commercial fishing fleet has no vessels under 10m or above 40m. Reconstructed time-series on fleet dynamics since 1830 (Lescrauwaet et al., 2012) 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 six-fold increase in average kW per vessel. The Belgian fleet today is highly specialized: more than 68% of the effort (days at sea) and 77% of total landings are achieved by beam trawlers in 2010, focusing primarily on flat fish species such as plaice (*Pleuronectes platessa*) and sole (*Solea solea*).

Landings

Since reporting began in 1929, Belgium fisheries recorded their maximum catch in 1947, of 81,000 t. Reported landings have since declined to a total of 22,000 t in 2010, only 26% of the 1947 catch. The most important species in terms of landings were cod (17% of all landings), herring (16%), plaice (14%), sole, whiting and rays. In terms of economic value, sole (31%) and cod (15%) were the most valuable (Lescrauwaet et al., 2010a). Since reporting started, 20% of all reported landings were fished from Belgium's 'coastal waters' which was the area responsible for nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans'. The boundaries of the reporting unit 'coastal waters' approximate the area of Belgium's EEZ (part of ICES subdivision IVc) and are explained in the Methods section. North Sea (south) (ICES fishing subdivision IVc, Figure 1)), Iceland (Va), North Sea (central-west) and North Sea (central-east) (the last two aggregated as IVb in ICES fisheries 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.

Gear

By 1930, the Belgian fleet had almost mostly converted from sail to motor enginges, and after WWII nearly all the commercial vessels were motor powered, however, the last steamer didn't cease operating until 1964 (Lescrauwaet et al 2012). In the first half of the 20th century, the otter trawl was the primary gear, along with drift nets that targetted pelagic fisheries. Pelagic trawls became important in terms of effort and landings after 1950 and remained so until 1965 (Gillis, 1962). After 1960, the beam trawl was introduced for targetting flatfish, which required an increase in technology and engine power (Polet et al 1998), which was subsidized by the Belgian government and supported by a royal decree (Lescrauwaet 2012). By 1985, fishing with otter trawls for herring, shrimp and other species represented 1%, 11% and 21% of effort in sea days (SD), respectively, wiith beam trawlling accounting for 62%. The remaining 5% of SD was taken by twin trawls (*spanvisserij)* targetting cod. More recently, otter trawling has occupied 10% of effort, compared to the shrimp beam trawl (14% of SD), flatfish beam trawl (68% of SD) and passive gear (1% of SD). Passive gears that are gaining importance include angling for cod and seabass, trammelnetting and gillnetting.

Aims

Effective fisheries management that takes an ecosystem-based approach depends on reliable data and must include total removals by all fisheries activities (even if only available as estimates), not just on officially reported landings (Zeller et al. 2009). This study aims to reconstruct the catches of Belgium's fisheries between 1950-2010, and include the aspects that are often excluded from official databases, such as illegal and unreported landings and discards. This report demonstrates the reconstruction process and in particular, documents the results according to the industrial, artisanal, subsistence and recreational fisheries. A more in-depth description and analysis of the specific fisheries that are important in to the sector in Belgium are presented in (Lescrauwaet et al. 2013).

METHODS

Baselines and sources

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 and is the database 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 1950-2010, is used as a baseline in the present study and throughout referred to as 'ICES Fishstat'.

HIFIDATA: 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 data from 1950-2010. 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 to 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', Fladen, and Moray-Firth.

ICES baseline data do not contain statistics with spatial reference to the Belgian EEZ or inshore waters. Only since 1996 has data been available for research purposes at a spatial scale that is of relevance to the Belgian EEZ. An additional challenge with the data by ICES rectangles is the position of these rectangles by which the data are aggregated. Although one of the 3 relevant reporting rectangles (31F2) has a significant proportion of its area within the Belgian EEZ, unknown but likely significant landings from the areas of 2 other rectangles (31F3, 32F2) should be taken into account (Figure 2). The HiFiDatabase however contains data reported for the 'coastal waters' from 1929-2010. These unique historical data were used in the present estimates of total removals at the scale of the Belgian EEZ for1950-2010. For the purpose of quality control, the reported landings for the 'coastal waters' (1950-2010) 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 Belgian EEZ and was applied to each of the fisheries reconstructed.

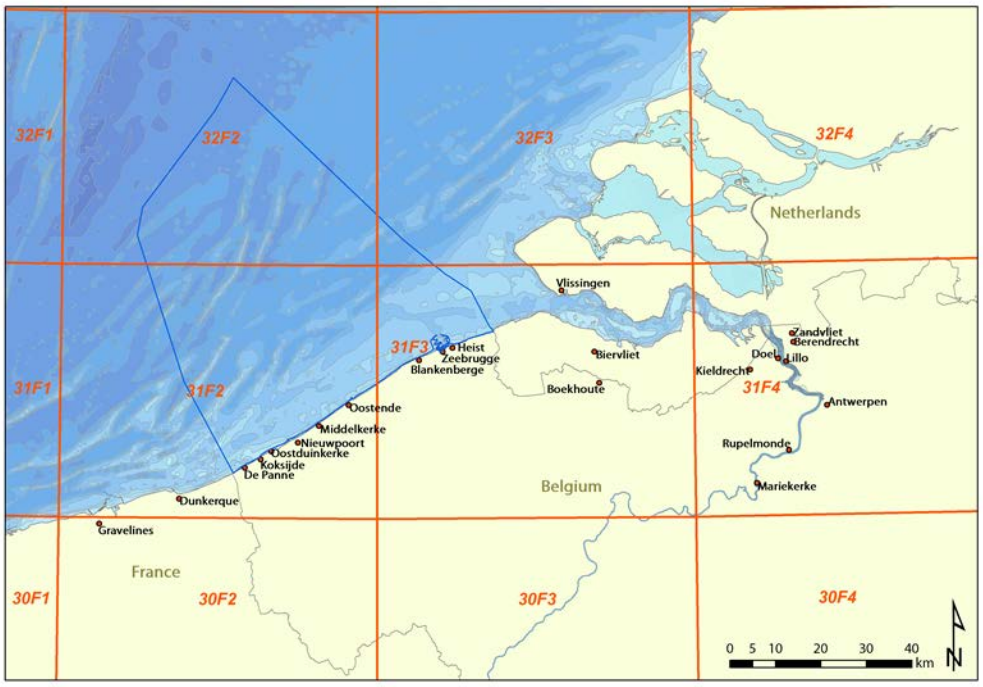

Figure 2. Map of the Belgian part of the North Sea or BNS (blue line) with overlapping ICES rectangles (31F2-31F3, 32F2-32F3).

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. 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 picked up 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. All taxonomic references were obtained from the World Register of Marine Species (WoRMS).

Adjustments to baseline

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 as such in the present reconstruction.

Specific industrial and artisanal fisheries

Each fishery was reconstructed separately, using the baselines and other data sources. An overview of the adjustments and source material is given in Table 1 and then described in more detail below.

Table 1: Overview of discard rates, survival rates, variables used in the calculation or as reference material for the present reconstruction, with an indication of source, by type of fisheries.

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 & Gilis (1965)
Commercial *Crangon* fisheries, Belgium	Discard rate	68%	Undersized *Crangon* and other fish (all discarded) in total catch of *Crangon* and fish. Fish discards composed of whiting, plaice, dab, and sole.	Leloup & 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)
Commercial *Crangon* fisheries, Belgium	Discard rate	60%	Discarded crab as a fraction of total *Crangon* landings and crab discards.	Leloup & Gilis (1965)
Recreational (semi-industrial) *Crangon* fisheries, Belgium	Annual catch	144 t	120 SD*60 vessels*20kg, since 1975	This study
Recreational/ subsistence *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)
Dutch commercial pelagic trawl fisheries	Discard rate	3.6%	38kg pelagic fish (mackerel, herring and saithe) discarded per 1,000kg marketable herring	Corten (1991)
Celtic sea winter herring fisheries	Discard rate	4.7%	Discards are mainly ubdersized 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 & sprat	Discard rate	4.5%		This study

Artisanal & subsistence fisheries, Belgium	Annual catch	120t herring 60t sprat	1950-1960	This study
Gadoid and other roundfish fisheries				
North Sea demersal (gadoid) fisheries	Annual discards	15,000 t 10,000 t	Cod Plaice	Garthe *et al.* (1996)
French gadoid trawlers, Celtic Sea (1997)	Discard rate	26%	Gadoid trawlers discard mainly target species: whiting& 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 >100mm mesh Cod in the demersal trawl 70-99mm, Cod in beam trawl >80mm	Horwood *et al.* (2006) *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)
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) Ulleweit *et al.* (2009)
UK beam trawl fleet, North Sea	Discard rate	50%	Average discard rate. Discard: mainly undersized dab& plaice, species with low market value (e.g. whiting& 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) Enever *et al.* (2007)
French benthic trawlers, Celtic Sea (1997)	Discard rate	24%	60% of discard consist of 4 bycatch species: red gurnard, horse mackerel, boar fish and grey gurnard.	Rochet et al. (2002)
Beam trawl fisheries, Belgium 2008	Discard rate	25%		Vandendriessche *et al.* (2008)
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); Lindeboom and De Groot (1998)
Recreational flatfish fisheries Belgium	% of commercial catch	9%	Estimate for Based on 280 vessels*120SD*fishing days*20kg per fishing trip	This study
Nephrops fisheries				
French *Nephrops* trawlers, Celtic Sea	Discard rate	55%	discards % of biomass whiting (41%), target *Nephrops* (20%). Data 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= 80mm	Stratoudakis *et al.* (2001)
Sea angling	Annual catch	50 t	2,000 anglers* 5 seadays* 5 kg catch, since 1970	This study
Sea angling Belgium EEZ				

Crangon fishery

Over the entire period, shrimp fisheries represented on average 10% of sea days 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 (semi-industrial) Crangon fisheries are based on Leloup and Gilis (1965) for the period 1950-1970, and on Polet (2004) for later years. Both studies report comparable discard rates and fractions of undersized Crangon in commercial landings (46% and 47%, see Table 1).

Adjustments to baseline

- Overall, almost 2,000 t of unreported *Crangon* landings were positively corrected for in the baseline by the local dataset (HiFiData) particularly in the decade 1950-1960 where under-reporting existed for brown shrimp.

- Discards: 1,100 t·year^{-1} of undersized shrimp is discarded by the commercial fleet, with over 1,700 t·year^{-1} of other fish. These were estimated at a 8.7%, 12.9%, 4.6% and 15.4% of the total shrimp fishery catch for plaice, sole, dab and whiting, respectively. Overall, for each kg of shimp landed, there is approximately 2.15 kg of discards. In addition to shrimp and fish discards, there are also high discards of North Sea Crab (ox crab; *Cancer pagurus*) (Leloup and Gilis 1965). It was estimated that for every kg of shrimp landed there was 1.5 kg of North Sea Crab discarded.

Recreational (semi-industrial) *Crangon* fishing

Recreational shrimp fishing occurs with frequency in Belgium and locally regarded as 'semi-commercial' because of their relative importance compared to commercial *Crangon* landings. However, vessels under 10 m are not required to report catches and the fishery is not part of the official fleet. Prohibitions are on the selling of catch, rather than catch limits. Although considered recreational, due to the fact that the fishery involves towed gear, S*ea Around Us* follows Martin (2012)'s recommendation that such fishing should be considered as large scale and therefore categorizes the activity as industrial.

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 same parameters used to estimate discards by the commercial fleet were applied here.

Recreational/subsistence

Other removals that were taken into account are the recreational-subsistence (sometimes referred to as artisanal) shrimp fisheries that operate from the beach (on foot and on horseback). We used detailed figures reported during WWII, when these fisheries were widespread practices for subsistence purposes by coastal residents, as a maximum estimate for this component. This fishery was considered to fulfil subsistence needs in the early period but to become mostly a recreational enterprise in the more recent years. Therefore, we applied an assumed breakdown of 80% subsistence/20% recreational in 1950 and interpolated to 10% subsistence/90% recreational in 2010.

Mortality that was not taken into account includes underwater discards such as tow path mortality or escape mortality caused by the gear, effect of changing or decreasing mesh size and other technological developments affecting by-catch of the gear. Ghost fishing caused by lost or abandoned trawl nets was considered negligible or zero (Depestele et al., 2012).

Herring and Sprat

Having seen unprecedented catches of herring during WWII, the fishery remained important in terms of landings afterwards, particularly between 1950 and 1965. After 1965, however ≤1% of the overall fishing effort expressed as sea days (SD) is assigned to the pelagic (herring and sprat) trawl (Anon., 1965; Tessens and Velghe, 2010, 2011).

Adjustment to baseline

- Overall, the HifiDatabase positively corrected landings of herring with approximately 10 t·year^{-1} between 1950 and 1960 as under-reported compared to the ICES baseline. For sprat, differences between the two databases were only due to rounding.

- Discards: 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). Morizur et al. (1996) refer to the Celtic Sea (winter) herring fishery as very selective with 99.5% of the total catch by weight consisting of the target species. Discards reported by Morizur et al. (1996) amounted to 4.7% (mainly herring) by weight of the total catch. Reasons for discarding were mostly due to market requirements leading to rejection of undersized and poor quality fish. Therefore a conservative rate of 4.5% from the lower discard estimates (Table 1) was applied to both herring and sprat fisheries, with a a species breakdown estimated according to Gills (1961).

- Artisanal/subsistence catches from open boats in territorial waters were carefully documented during WWII (Lescrauwaet et al., 2013 under review). Based on these records, an average of 120 $t \cdot year^{-1}$ of herring and 60 $t \cdot year^{-1}$ of sprat was added for the period 1950-1960 as a maximum for annual artisanal/subsistence catches. We assumed no artisanal/subsistence fishing for herring or sprat occurred after 1960, and no discards were taken into account in this artisanal/subsistence component.

Gadoid and roundfish fishery

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 with a few vessels remaining until 1995. An important part of the landings originated from the southern North Sea and from 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*), monkfish (*Lophius piscatorius*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*) and to a lesser extent whiting (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).

Adjustments to baseline

- Overall the HifiDatabase positively corrected landings with approximately 17,200 t of unreported landings mainly between 1950 and 1960. A flat discard rate of 25% was applied corresponding to the lower estimates in available literature (Table 1).

- Discards: Historical references on the selectivity and impact of the otter trawl and data on discards in roundfish fisheries are limited and 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. Demersal fisheries for gadoids are carried out by all North Sea coastal nations with various gear and different sources provide estimates of discarded weight in these different fisheries (Van Beek, 1990; Ehrich, 1994; Anon.,1995; Garthe et al., 1996; Rochet et al., 2002). *Rochet et al. (2002) reported for the French fleet operating in the Celtic Sea a total estimate of 30,000 t of discards in 1997, while landing about 63,000 t. Gadoid and *Nephrops* trawlers caused the majority of discards with respectively 25% and 55% of the catch weight being discarded (40% Coefficient of Variation in total biomass estimates). Gadoid trawlers discarded mainly their target species: whiting and haddock (together 47%), and also grey gurnard (13%).

- In the present reconstruction, the estimate of 25% from Rochet et al 2002 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). Discard survival rates of 0% were assumed for the estimate (ICES Discard Survival Table 2012).

- Reported landings from these species in artisanal/subsistence catches from open boats in territorial waters during WWII were negligible, except whiting (11 to 13 $t \cdot year^{-1}$ in the period 1941-1943 (Lescrauwaet et al., 2013 under review), and assumed to have remained so throughout the time period. Therefore artisanal or subsistence gadoid catch was added.

Flatfish (sole and plaice)

Before 1960, the Belgian fleet of steamer and motor engine powered vessels used the otter trawl as fishing gear in the 'mixed' 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 sea days (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). Reported landings of plaice and sole from the commercial fleet averaged approximately 10,500 $t \cdot year^{-1}$ between 1950 and mid-1980s. Between 1985 and 1995 increased annual landings of plaice raised the average to 18,200 $t \cdot year^{-1}$, which then decreased to an average 11,000 $t \cdot year^{-1}$ for the period 1996-2010.

Adjustment to baseline

- Overall, HiFiData corrected the baseline with 1,000 t of unreported plaice and 1,175 t of unreported sole, mainly between 1950 and 1960

- Discards: Vandendriessche et al. (2008) estimated the current levels of discarding and discard rates in the Belgian beam trawling and found an average 25% of catch was discarded with a composition of: 2% sole, 13% plaice, 7% dab, 10% bib, 4% cod, 3% anglerfish, 13% gurnards, 7% rays, 22% sharks. We applied a variable discard rate from 50% at the start of the time period (the average of reported North Sea flatfish beam trawl discard rates) to 25% at the end of the time period (Vandendriessche et al. (2008) to the reported landings. This was to account for the shift of fishing from the North Sea in the 1950s to western waters (Irish and Celtic Sea, Bristol Channel, English Channel) more recently. We also applied the species breakdown of Vandendriessche et al. (2008) to the annual discard estimates.

Nephrops fishery

Norway lobster (*Nephrops norvegicus)* is commonly caught using twinrig trawls in the North Sea. Belgian landings peaked in 1959 with 950 t and averaged 450 $t \cdot year^{-1}$ over the whole time period. A historic low was achieved in 2010 of 133 t and efforts are underway to reactive the fishery by diversifying the fishery couple with regeneration of coastal economies.

Adjustment to baseline

- Differences detected between the ICES Fishstat baseline and the local HiFiDatabase were due to rounding.
- Discards are generally high due to trawls typically using smaller meshes (80-90)mm than those targeting whitefish (Catchpole et al. 2005). Enever et al. (2009) reported discard rates of 36% in English and Welsh *Nephrops* trawl fisheries in the North Sea. Discards were mostly dab, whiting, plaice, legal-sized and undersized *Nephrops*, gurnards, cod, long rough dab, haddock, lemon sole and Dover sole, the majority of which were discarded due to being undersized. *Nephrops* trawlers off the Firth of Clyde (West of Scotland) discard 70% of total catch, mostly consisting of undersize demersal fish, in particular young whiting (Stratoudakis et al., 2001). No dedicated studies on discards and survival rates exist for Belgian *Nephrops* fisheries. However, Belgian vessels participated in Dutch-led studies exploring lower fuel and less discards in this fishery (Steenbergen et al., 2012). Hence, the estimates of discards in the present study are based on the similar Dutch *Nephrops* fishery. 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. These proportions were applied to the reported *Nephrops* landings.

Recreational and Subsistence

Recreational fisheries in Belgium include recreational *Crangon* fishing, 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. Recreational shrimp fishing was considered industrial due to the use of towed gear (Martin 2012) and is addressed in the *Crangon* fishery above.

Sea angling for cod and bass

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 (ILVO-Fisheries, 2007). The pilot study was based on the outcomes of angling contests organized by the Associations of Anglers (VVHV), which counts approximately 2,000 members as active sea anglers in 2006. In the present estimate, it was assumed that this form of sea angling has existed since 1970 (0 t), and a linear increase from was applied to a conservative estimate of 50 t in 1975, which remained constant throughout the reconstruction (2,000 anglers, 5 days at sea, 5kg catch). The 50 $t \cdot year^{-1}$ was split proportionally between cod (60%) and sea bass (40%) each year. These estimates are in the same order of magnitude as those for the Dutch recreational sea angling for cod and eel (Zimmerman et al., 2007; van der Hammen and de Graaf, 2012).

Unreported flatfish catch by 'recreational' or semi-commercial fisheries

As reported for the *Crangon* fisheries, recreational flatfish fisheries exist in Belgium, which also operate from smaller vessels that are not part of the commercial fishing fleet. Although flatfish are targeted today, it is acceptable to believe that other species may have been targeted over the last few 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 suggest that approximately 280 small vessels are involved operating from f 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 20kg per fishing trip. The same methods 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 1941-1943 (Lescrauwaet. et al., 2013 under review). Ghost fishing caused by lost or abandoned trawl nets was considered negligible or zero (Depestele et al., 2012). As in the *Crangon* fishery although they are generally considered recreational and 'semi-commercial', because the fishery utilizes towed gear, it is considered large scale (Martin, 2012) and all catches from it are classified as industrial in this reconstruction.

Unaccounted removals

A number of other gears which are not accounted for in the present estimates have been used in Belgian fisheries, although with much lower intensity and spatial coverage than those already described. These include seine nets, bottom dredges (1980s), trammel nets and other passive gear used in commercial fisheries but not covered here, and angling (other than for cod and sea bass) and netting from land (jetties, piers). The use of trammel nets in commercial fisheries is rather recent (since 2000) and discards are limited. No production statistics for such gears are available upon which to reconstruct total removals, let alone formulate assumptions.

Discard survival

Effects of changing or decreasing mesh size and other technological developments affecting by-catch of the gear (e.g., the short-lived introduction of the Vigneron-Dahl system, tickler chains, sumwing etc.), underwater discard mortality (e.g., Chopin, 1995), and predation and infection mortality (Broadhurst et al., 2006) are not taken into account in the estimates. According to these sources, such mortalities can be substantial, and should be considered for comprehensive stock assessments for all gear-types and fisheries. An important part of the cod discards in this fishery are not explained by MLS but by high-grading (Vandendriessche et al., 2008). Reported discard survival rates in beam trawl fishing gear can strongly vary according to experimental design, fishing techniques and environmental parameters (Jean, 1963; Van Beek et al., 1990; Berghahn et al., 1992; Lindeboom and De Groot, 1998; Lapithovsky, 2004; Rodriguez-Cabello et al., 2005; Enever et al., 2009). In the current exercise the precautionary approach leads to assume a survival rate at or near of zero for cod, whiting, pouting, dab, plaice and gurnards. Higher survival rates are reported for skates (42%) and rays (55%) (Enever et al., 2009), while sole (4%) (Lindeboom and De Groot, 1998) and lemon sole (7%) discard survival rates remain below 10%.

Other taxa

Several species were reported by ICES Fishstat over the time period that were not included in the fisheries reconstructed above. These were therefore added to the reconstruction, directly based on the totals reported to ICES and classified as industrial.

Belgium's EEZ

The information from the HiFiDatabase was used to categorize catches from Belgium's EEZ. However, some species not included in the reconstructed fisheries were reported to ICES as caught in area IVc, but without information on specific EEZ was unavailable. For these species, the average proportion of total catches inside/outside Belgium's EEZ for species with a known catch location in IV c was used.

RESULTS

Total reconstructed catches in Belgium for 1950-2010 were 1.47 t times the data officially reported by FAO for the same time period. Landings of the industrial sector accounted for nearly 70% of the total catch, with artisanal and recreational catches contributing 0.05% each. Subsistence fishing made up 0.01%. Discards were another major component, making up 30% of the total removals (Figure 3a)

Overall, catches decreased over time, despite an initial rise at the start of the time-series. Catches began at 83,300 t in 1950 and rose to a peak of 113,600 t in 1955. From there, catches decreased steadily to a minimum 31,600 t in 2006. After that, catches appeared to stabilize, with a small increase to 35,200 t by 2010.

The European plaice (*Pleuronectes platessa*) and Atlantic cod (*Gadus morhua)* were the most prevalent species in the Belgian catch over the 60 year period, with19% and 14% respectively. The common sole (*Solea solea*) and whiting (*Merlangius merlangus*) accounted for 7% each, with haddock (*Melanogrammus aeglefinus*) the next most common species, contributing 5% of the catch (Figure 3b).

Industrial

Making up almost the entirety of the catch, the catch profile of the industrial sector followed the trend of the overall catch throughout the time period. Catches rose from 83,100 t in 1950, to a maximum 113,400 t in 1955, decreasing to an average 33,000 $t \cdot year^{-1}$ for the last five years of the time period. Reported landings contribute 68% of the industrial catch, while unreported landings accounted for 2% and discards 30%.

The species composition of the industrial catch was virtually identical to the overall catch, with reference to the contribution of major taxa. Discards are estimated to consist mostly of Atlantic cod (17%), ox crab (10%), whiting (9%), sharks (8%), European plaice (8%) and common dab (7%).

Artisanal

Artisanal catches were entirely split between herring (*Clupea harengus*; 67%*)* and sprat (*Sprattus sprattus*; 33%) and were only present in the reconstructed catch for the period 1950-1960, totalling 180 t for each year.

Subsistence

Subsistence catches were only reconstructed for shrimp (*Crangon crangon*), and decreased across the entire time period, from 7.2 t in 1950, to 0.9 t in 2010.

Recreational

There was a small amount of recreational catch estimated for shrimp, Atlantic cod and seabass. Recreational increased slowly from 1.8 t in 1950 to 3.9 t in 1970. Then the cod and seabass fishery started up, causing the catch to jump up to 14 t and then increase to 58 t in 2010.

Belgium EEZ

Total catches in the Belgian part of the North Sea (BNS) were 17% of the removals for the entire Belgian fleet. Unreported landings and discards in the BNS were 3% and 48%, respectively. Catch composition was quite different to the overall catch, with shrimp (around 20%), ox crab (*Cancer pagurus,* 16%) and herring (15%) all fished in similar quantities. Flatfish were also important, with plaice (*Pleuronectes platessa*) contributing 10%, common dab (*Limanda limanda*) and sole (*Solea solea)* 5% each, with whiting (*Merlangius merlangus*; 9%) and cod (*Gadus morhua*; 6%) also important contributors.

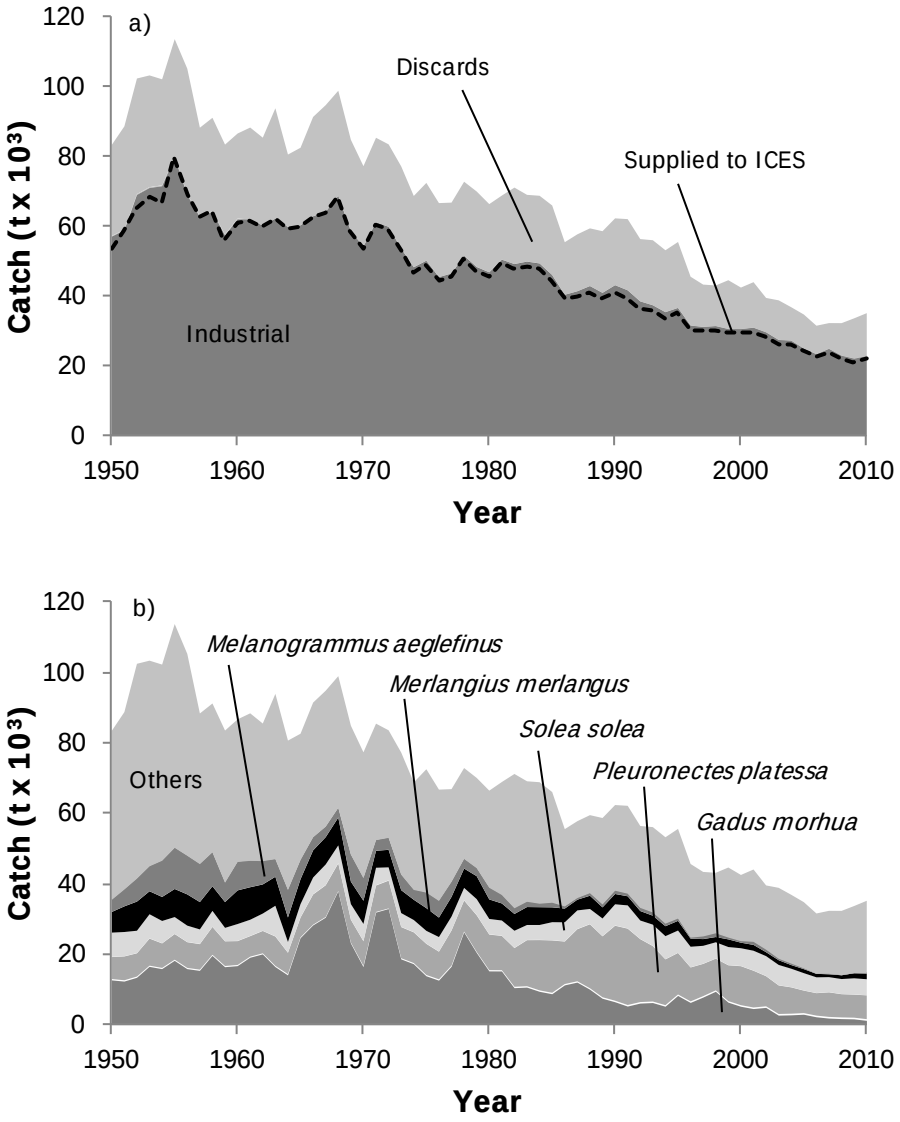

Figure 3. Reconstructed catches of Belgium, 1950-2010 by a) sector, including ICES/National baseline b) Primary taxa. 'Others' includes 70 taxa not mentioned individually.

DISCUSSION

Although the reconstructed catch total for the time period was 1.47 times that officially reported by ICES, aside from a relatively small amount of unreported catches, presumably from the small-scale sector, the discrepancy is largely due to unreported discards, given that the ICES baseline and the national HiFidatabase are comparable.

The reconstruction is largely based on historical landing statistics by type of fishery. Although this approach is widely applied and accepted, the reliability of the reconstruction could be improved by taking into account criteria related to fishing effort, fleet characteristics and environmental conditions, such as seasonality (Depestele et al 2011). Discard estimates would also be improved by more information on temporal and spatial variants, as well as survival rates. Insights into the historical impact of quota and market forces on discard behaviour would also help. In general, there is insufficient information regarding historical discarding in Belgian waters to validate the discard rates that were applied for the earlier years, however, they were applied with a conservative approach. The introduction of a European discard ban in 2015 under the reformed Common Fisheries Policy (CFP) (2013) will likely significantly change the profile of fish catches by Belgian and other European fleets.

In addition, underwater mortality such as towpath mortality and escape mortality and their effects on total mortality of commercial and non-commercial species require further studies. Finally, though anecdotal, information gathered from local ecological knowledge studies on socio-economic data on employment, income, fish consumption etc. can provide important references to support the reconstruction of missing time-series or validate the assumptions used in the historical reconstructions.

The importance of the small-scale fleet is a broad policy objective and the social and cultural role of small-scale fisheries is explicitly stated in the reform document 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 protected until 2022 and 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.

Within the BNS, unreported landings have increased, from 3% in the early 1980s, to an average of over 8% in the 2000s. Much of this is likely to be from the small-scale sector, indicating the increasing importance of small-scale (<12m) vessels that are not subject to rigorous reporting or taken properly into account in planning, monitoring and enforcement. Discards were higher than overall, averaging almost 52% over the whole time period, although since the 1990s the average was 57%. This is largely due to a shift in primary fisheries and gear types; in the earlier period pelagic fish were targeted, while more recently bottom towed gears have been favoured. From an environmental perspective, this is cause for concern as it represents a waste of valuable resources of food, energy and biological diversity, as well as impacting 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 that will help to meet targets such as, the Good Environmental Status (GES) set forward in the Marine Strategy Framework Directive (2008/56/EG), to improve stock assessments and achieving targets of maximum sustainable yield (MSY) in the CFP, and to achieve favourable conservation status (FCS) for the species and habitats protected in marine and coastal Natura 2000 sites. While not explicitly mentioned in its final statement, the UN 2002 declaration 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.

However, 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 food security, and for leisure and tourism for the wider population. These 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. Although this study refers to the particular situation of the Belgian fisheries, similar trends may exist in neighbouring countries around the North Sea.

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, employment, food safety and quality. In Belgium, the Fisheries Authority (department of Agriculture and Fisheries, Flemish government) together with the producers' organisation, Fisheries Research Institute ILVO and environmental NGO have taken first steps towards a more sustainable future for fisheries through a Strategy for Sustainable Fisheries, which is carried forward by its Task Force.

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.

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