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PRELIMINARY RECONSTRUCTION OF TOTAL MARINE FISHERIES CATCHES FOR THE NETHERLANDS IN THE NORTH SEA (1950-2010)

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ABSTRACT

Dutch marine fisheries are reconstructed from 1950-2010 within its Exclusive Economic Zone (EEZ) equivalent waters in the North Sea. The International Council for the Exploration of the Seas (ICES) publically available electronic data are used a 'reporting' baseline for the reconstruction. Data and information from ICES stock assessments, peer-reviewed literature, grey literature and local experts are used to estimate Illegal, Unreported and Unregulated (IUU) catch. Estimates of IUU catch are made in terms of discards, unreported, over-reported, and recreational and subsistence catch and are used to improve the reported baseline. Our preliminary reconstructed catch within Dutch EEZ equivalent waters is nearly 2 times the reported baseline catch. The reconstructed catch slightly decreases from a catch of 233,000 t in 1950 to 176,000 t in 2010 with a peak of nearly 500,000 t in 1985. Atlantic herring (*Clupea harengus*) comprises the largest amount of the reported catch from 1950 to 2010; however, larger catches are only present in the earlier decades. European plaice (*Pleuronectes platessa*) represents the second largest reported catch and becomes more prevalent in the later decades. Discards comprise the largest portion of unreported catches, with common dab (*Limanda limanda*) the most discarded species. The discrepancy between ICES reported catch and our preliminary reconstructed catch is largely driven by discards from various trawl fisheries, which we argue need to be reported as part of catch reporting in an ecosystem setting. Given that fish are a public resource, the reconstructed catch demonstrates the need for fisheries data to be more transparent to the public (including differentiation between and transparent accounting of landed catch and discarded catch).

INTRODUCTION

The Netherlands is a coastal, low-lying country in Europe with a long history of fishing. Much of the country falls below sea level and is bordered by dykes. During the earlier decades of the 20th century, much of the coastal land was altered for human needs. The Zuiderzee was closed off from the Wadden Sea and the Lauwerszee was turned into a fresh water lake (de Jonge *et al.* 1993). By doing so, the Netherlands converted expansive areas of their wetlands and brackish waters into fresh water, limiting marine fisheries and changing species composition (de Jonge *et al.* 1993). These environmental alterations had minimal effects on the economy. Total value of the catch for the Netherlands in 2000 was estimated at €325 million (Eurostat 2009), and in 2002, agriculture, forestry and fisheries comprised only 2.5% of the economy[1]. While the Netherlands has a relatively small fishing fleet, they managed to have the 5th highest catch tonnage in the EU in 2007 valued at €736 million (Eurostat 2009). The Netherlands have a successful fisheries sector; however, the country is not fully dependent on this sector of the economy.

[1] Holland Trade
http://www.hollandtrade.com/search/ShowBouwsteen.asp?bstnum=158&location=%2Fsearch%2FShowResults.asp%3Fsortering%3DPublicatiedatum%2BDESC%26submit.y%3D0%26submit.x%3D0%26tekst%3Dfisheries%26I2.x%3D0%26I2.y%3D0&highlight=fisheries (Accessed March 24, 2014)

The Netherlands joined the European Union (EU) in 1952, and until 1974, the North East Atlantic Fisheries Commission (NEAFC) was the primary management body in Europe (Smit 2001). The NEAFC managed the Dutch fleet using simple technical measures such as mesh size and minimum landing sizes (MLS) (Smit 2001) until 1976 with the introduced of Total Allowable Catch (TAC) limits for six species, including European plaice (*Pleuronectes platessa*) and common sole (*Solea solea*) (Salz 1996). At this time, the Netherlands also introduced Individual Quotas (IQ) by weight from the national quota for sole and plaice (Salz 1996). Non-transferable quotas for Atlantic cod (*Gadus morhua*) weren't introduced until 1981 in the form of 'k-documents' (Salz 1996). In 1976, the management of the Dutch fleet switched to the European Commission's (EC) Common Fisheries Policy (CFP) (Smit 2001), which dealt with gear restrictions, mesh regulations and closed seasons and areas (Rijnsdorp *et al.* 2006). The CFP began to implement TAC quotas in 1983 for a number of species (Davidse 2001). The CFP estimates a TAC for a particular stock and this quota is divided into smaller TACs for each country within the EU. Shortly after the introduction of the CFP, engine power was limited to 2000 HP with a maximum 12 m beam (Salz 1996). Prior to 1986, engine power was able to reach over double the CFP restrictions (Salz 1996). The reduction in vessel engine power likely had a positive effect on flatfish stocks being heavily targeted by beam trawls at this time.

North Sea fisheries for flatfishes and some other demersal species have been the most important for the Dutch fleet since the 1960s with the introduction of double beam trawling (Rijnsdorp *et al.* 2008). By the 1970s, the beam trawl fleet had grown larger and more important than the otter trawl fleet (Rijnsdorp *et al.* 2008). Effort in this fleet doubled between 1978 and 1994 but has since been relatively stable (ICES 2002a). During this time, the beam trawl fleet was not only increasing in numbers but vessels were increasing in size as well as towing speed (Bergman and Hup 1992) and up until 1984, a single vessel may have had up to 15 tickler chains (de Groot 1984). It has become the largest métier in the Dutch fleet with 374 vessels in 2008 (Catchpole *et al.* 2008). While the beam trawl fishery is generally mixed, the main targets are common sole and European plaice (van Beek 1998). The Netherlands caught an average of 43% of total European plaice catch from 1993-2000 (Grift *et al.* 2003). Dutch fisheries may be small in terms of numbers of vessels, however, they are powerful and destructive due to relying heavily on beam trawling for flatfishes and brown shrimp (*Crangon crangon*) (ICES 2002a). Beam trawling for flatfishes in the North Sea is known to produce a large amount of by-catch, which consists mostly of both commercially important and unimportant juvenile flatfishes (ICES 2002a; van Keeken *et al.* 2007).

The brown shrimp fishery is one of the most controversial fisheries in the North Sea. There is no maximum allowable catch or quota for brown shrimp in the North Sea, but present stocks seem to show no sign of overfishing (Aviat *et al.* 2011). In addition to the lack of management on the EU CFP front, there are no seasonal closures in the Dutch fleet i.e., they are permitted to fish all year round (Aviat *et al.* 2011). The Dutch vessels are among the most powerful operating in the North Sea brown shrimp fishery with 225 shrimping licenses, coming in just behind the German fleet (Aviat *et al.* 2011). Two large Dutch companies, Heiploeg and Klaas Puul, handle up to 80% of the European brown shrimp market, while the Dutch cutter fleet for brown shrimp only produces 47% of the EUs shrimp (Aviat *et al.* 2011). The majority of shrimp caught by the Dutch fleet are treated with benzoic and sorbic acids before taking a 14 day journey to Morocco to be peeled in large factories (Aviat *et al.* 2011). The treated and peeled shrimp is usually sold to Belgium which is the largest consumer market in the EU (Aviat *et al.* 2011).

Another commercially important fleet in the Netherlands is the pelagic freezer trawl which targets Atlantic herring (*Clupea harengus*), Atlantic horse mackerel (*Trachurus trachurus*), Atlantic mackerel (*Scomber scombrus*), blue whiting (*Micromesistius poutassou*), greater argentine (*Argentina silus*) and European pilchard (*Sardina pilchardus*) (van Helmond and van Overzee 2009). This fleet mostly works in the northern sub-division (IV a) of the North Sea, but some of the catch is reported in sub-divisions IV

b+c and is used in this reconstruction. These vessels are large but have a greater selectivity than the beam trawl vessels targeting flatfishes.

This reconstruction, while preliminary, will produce a more inclusive (i.e., including discarded by-catch) representation of total Dutch catch within their North Sea Exclusive Economic Zone (EEZ) equivalent waters from 1950-2010. The Netherlands' total catch is estimated using public data from the International Council for the Exploration of the Sea (ICES) as a baseline. Additional catch is estimated as unreported, over-reported, discarded by-catch as well as unreported recreational and subsistence catches. These catches are estimated using grey literature, peer-reviewed literature, ICES stock assessments and local expert opinion.

METHODS

Landings data

Landings data for the Netherlands are acquired through the publically available ICES electronic landings database[2]. The data are provided for 1950-2010 and are used as a reported baseline for this reconstruction. All fresh water taxa are omitted from this reconstruction. The Dutch EEZ equivalent waters overlap with ICES management divisions IV b and IV c (Figure 1). The Netherlands data are reported in various arrangements of management areas over time. From 1950-1960, all reported landings are designated area IV (not specified) or IV. Again from 1984-1987, landings are reported in area IV (not specified). For all other years, landings are reported by sub-divisions IV a, IV b and IV c.

Spatial proportions of the area IV sub-divisions (IV a, IV b and IV c) are calculated for 1958 and 1961. These proportions were applied to the total catch of area IV (unspecified) for previous years in order to better estimate catch within the EEZ equivalent waters.

For 1984-1987, spatial proportions of the area IV sub-divisions (IV a, IV b and IV c) are calculated from 1983 and 1988. The proportions are interpolated between 1983 and 1988. The interpolated proportions for 1984-1987 are applied to the IV (unspecified) total catch during this time period.

Additional adjustments were made to account for various invertebrate taxa in 1962. Many common invertebrate taxa are reported in IV b+c (not specified) in 1962. Spatial proportions are calculated for 1961 and 1963. These proportions are then interpolated and applied to the general landings in 1962.

Landings data are further split into industrial (large-scale commercial) and artisanal (small-scale commercial) sectors according to gear designations in Martin (2012). For the purpose of this reconstruction, all dragged gear is considered industrial, and as nearly all Dutch fisheries are trawls, only a few small coastal mollusc fisheries are designated as artisanal (Martin 2012). All mollusc taxa landings were split 20% artisanal and 80% industrial in 1950. These proportions are interpolated to 5% artisanal and 95% industrial in 2010.

[2] ICES http://www.ices.dk/marine-data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx (Accessed January 11, 2014)

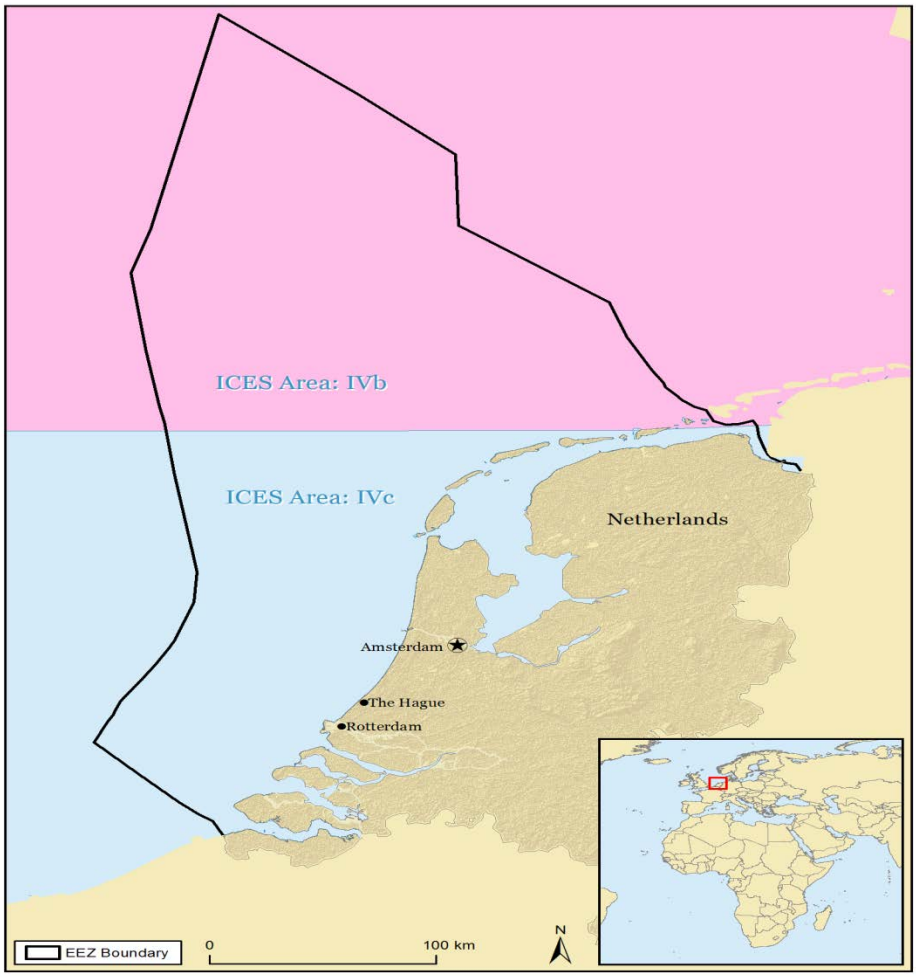

Figure 1. The Netherlands EEZ equivalent waters and corresponding ICES management areas

Unreported catches

ICES stock assessments (ICES 2002a, 2002b, 2003a, 2012a, 2012c, 2012d) provide an 'unallocated' catch estimate, which represents reported catch for Europe without designating it to the actual country of origin. Most of the data become available in the late 1980s and early 1990s until 2010. There are both positive and negative values of 'unallocated' catch. There is one 'unallocated' value representing a total for Europe each year. We assume that the Netherlands share of 'unallocated' landings is proportional to their share of reported landings.

Negative 'unallocated' catch is estimated due to over-reporting of catch. These values are treated as negative adjustments for the corresponding stocks and years.

We treat positive 'unallocated' catch as unreported catch. Unreported catch is estimated by the same means as negative adjustments from 'unallocated' catch. A rate of unreported catch is calculated in relation to reported landings. The rate for the first year of unreported data is applied to all reported landings of the corresponding taxa back to 1950 for a time series of likely unreported catch. There is an exception for European plaice. The unreported rate from the second year of available data is used as a conservative assumption because it was more inline with the general trend than the first year.

Discards

Discard estimates are taken from ICES stock assessments (ICES 2002a, 2002b, 2003a, 2012a, 2012c, 2012d) for Atlantic herring, Atlantic mackerel, haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*). A value for discards is estimated in a similar manner to the 'unallocated' catch in that there is one total discard estimate for all of Europe. We assume that the Netherlands proportion of total European landings is equal to its proportion of European discards for specific stocks. Discard information becomes available in the early 1990s. A discard rate based on the total estimated catch (reported landings and unreported landings) is calculated for each year with an available discard estimate. For years with missing data, the rates are interpolated and discards are then calculated. The discard rate for the first year with available data is applied to the total catch back to 1950.

Further discard estimates are made for the flatfish fisheries in the Netherlands. There are no discard estimates for Dutch flatfish targeted fisheries. Flatfish landings comprise 36% of the reported landings in the Netherlands. We assume that flatfish discard rates in the Netherlands are similar to those from German European plaice and Common sole targeted fisheries from Ulleweit *et al.* (2010). We determine a total rate of discards and then divide the total proportionally amongst discarded taxa.

Finally, brown shrimp are a commercially very important fishery in the Netherlands. Belgian Norway lobster (*Nephrops norvegicus*) discard estimates are often used as a proxy for those in the Netherlands (ICES 2002a). We assume that the same can be done for the brown shrimp fishery because gear types and sorting procedures are the same in countries fishing in the North Sea. We use a discard rate and discarded species composition from the reconstruction of Belgian catch from 1950-2010 (Lescrauwaet *et al.* 2013).

Recreational catch

The Netherlands collects data for many species through surveys but reports only Atlantic cod and European eel (*Anguilla anguilla*) to ICES (ICES 2012b). We use numbers of recreational fishers (both freshwater and marine) from 1993-2004 (Vriese *et al.* 2007) and another anchor point of 1.6 million fishers in 2009 (de Graaf 2010). The number of fishers is interpolated between 2004 and 2009 and 1.6 million fishers are carried forward to 2010. The anchor point of 885,000 fishers from 1993 is assumed constant back to 1980. A per capita rate of fishers from the Dutch population is calculated from 1980 and reduced by 50% and used as a per capita anchor point in 1950. The per capita rate is then interpolated from 1950-1980 and used to calculate number of recreational fishers for the entire time series.

An anchor point of 360 t of cod (ICES 2012b) is divided by number of fishers in 2010 to determine a recreational catch rate. The catch rate is reduced by 50% in 1950 and catch rates are interpolated between to complete the time series. Cod catch is then estimated each year using interpolated catch rates. The same method is used for eel with a 2010 anchor point of 26.5 t (ICES 2012b).

We realize that in using a number of recreational fishers that includes both freshwater and marine, we are likely over estimating the number of fishers and therefore the catch. However, we have only included cod and eel as they were the only two taxa with recorded data. Therefore, we believe that we are underestimating the tonnages of other recreationally important species which are also of commercial importance (Atlantic mackerel, European flounder, European plaice, common dab, common sole, European sea bass etc.) (de Graaf 2010). We assume that the overestimation of fishers and the underestimation of taxa will largely cancel each other out, and that our estimate is likely a conservative representation of total marine recreational catch from 1950-2010 in the Netherlands.

Subsistence catch

Periwinkles (*Littorina littorea*) and whelks (*Buccinum undatum*) were still caught for food from the 1950s until the 1970s (Wolff 2005). We use values found in Wolff (2005) as anchor points for subsistence catch in the Netherlands (Table 1). The Netherlands developed in a similar way as the rest of Western Europe over the course of the 20th century. With more economic growth in the 1950s and more time for leisure (Hurkens and Tisdell 2004), any remaining subsistence fishing likely ended by 1980 and was replaced with recreational fishing.

Table 1. Anchor points for subsistence catches (t) within the Dutch EEZ equivalent waters. Note that the dashed line (-) indicates an interpolation

	Taxon	
Year	Periwinkle	Whelk
1950	32	65
1960	32	60
1969	-	17
1970	13	-
1980	0	0

RESULTS

Reported landings

Dutch reported landings total just under 9.4 million tonnes from 1950-2010, with approximately 50% of landings reported in both sub-divisions IV b and IV c (Figure 2a). Landings remain fairly steady over the time series with a slight decline over time from 129,000 t in 1950 to 81,000 t in 2010 (Figure 2a). There is an earlier peak in catch in 1963 (207,000 t) followed by two declines in the late 1960s and again in the late 1970s (Figure 2a). This coincides with the collapse of herring stocks and soon after, the closure of the fishery (ICES 2003b, 2012a). There are two additional larger peaks in 1985 (245,000 t) and 1989 (257,000 t) which result from the sudden boom of common edible cockle (*Cardium edule*) fisheries (Figure 2b). These are followed by a collapse in the fishery and a final peak in 1998 with 192,000 t (Figure 2b). Finally, there is a steady decline in landings to 2010.

Atlantic herring is the most important commercial species in the early portion of our analysis, comprising 54% of the total reported catch from 1950-1967 (Figure 2b). It is evident that as the Atlantic herring stocks were collapsing, European plaice became of more importance in Dutch commercial fisheries (Figure 2b). European plaice comprises approximately 30% of the reported landings from 1968-2010. Atlantic cod also carries importance with the third largest reported landing by species from 1950-2010, behind Atlantic herring and European plaice. Atlantic cod catches are low in 1950 (1,300 t) but reach an average of approximately 31,000 $t \cdot year^{-1}$ from 1966 to 1986, and decline again to 2,600 t in 2010 (Figure 2b). There are a few shifts in commercially important taxa over time which seems to be mostly the result of over-fishing and stock declines.

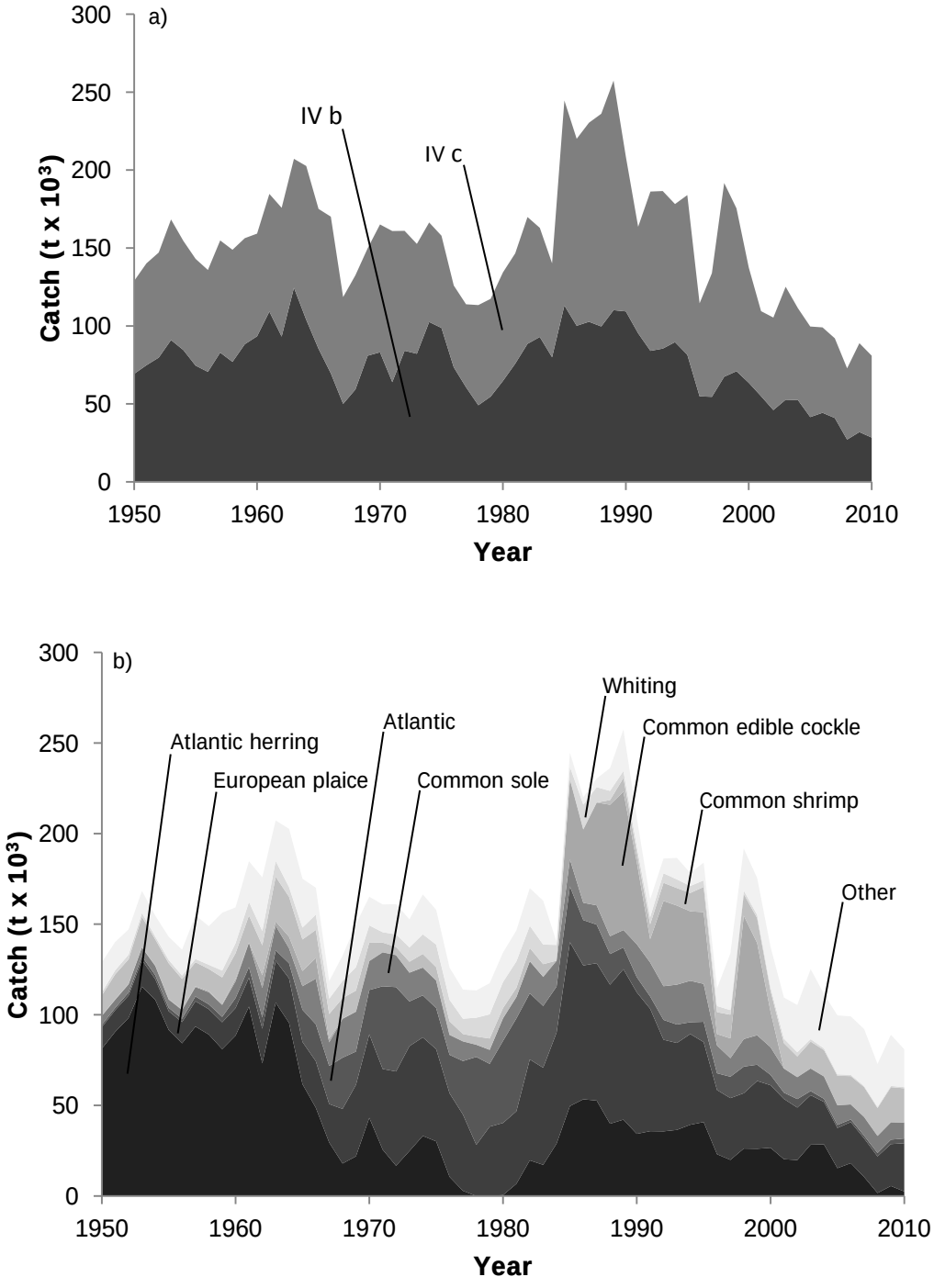

Figure 2. Reported landings by the Netherlands in the waters of the Netherlands between 1950-2010 by a) ICES management area within the Dutch EEZ; and b) major taxonomic groups.

Unreported catches

The total unreported catch is approximately 1.9 million tonnes from 1950-2010. Atlantic herring comprises 59% of the unreported catch and European plaice represents 25% (Figure 3). These are also the two commercially most important taxa over the time series. Other species included are haddock, Atlantic mackerel, Atlantic horse mackerel, whiting and saithe (*Pollachius virens*).

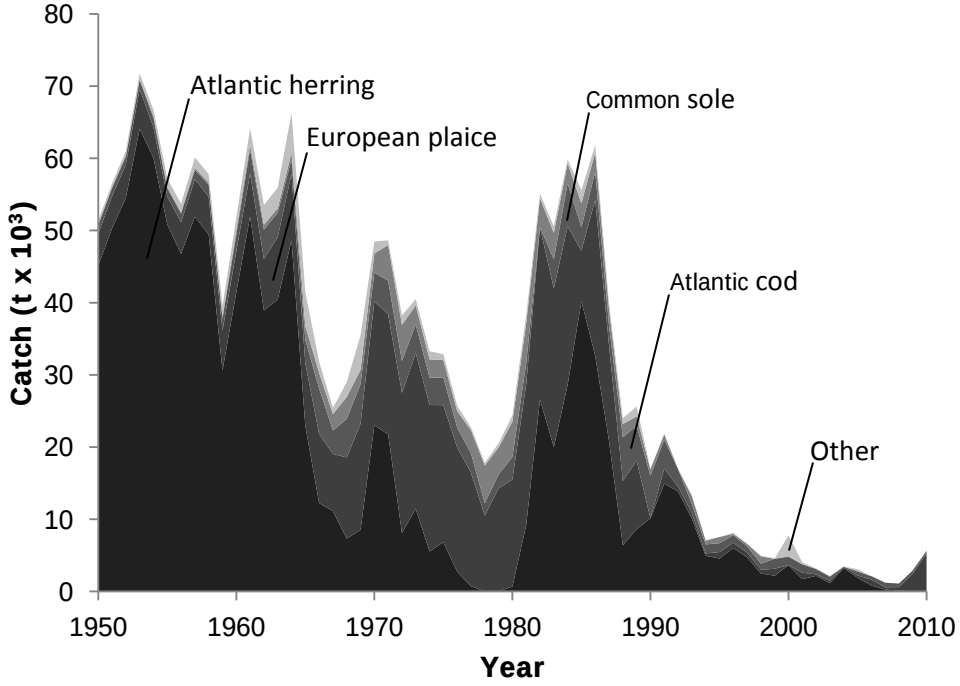

Figure 3. Dutch unreported catches for 1950-2010 as reconstructed here.

Discards

Dutch discards total 7.1 million tonnes from 1950-2010. Common dab (*Limanda limanda*) and European plaice comprise 37% and 31% of discards, respectively. These discards mostly consist of juveniles from shrimp and flatfish trawl fisheries in the North Sea and Wadden Sea. Discard rates used are based on recent accounts of discarding and applied to past catches. This does not take into account that there were likely shifts in gear restrictions over this time series. However, we do not account for all fisheries in the Netherlands and we consider this to be a conservative estimate.

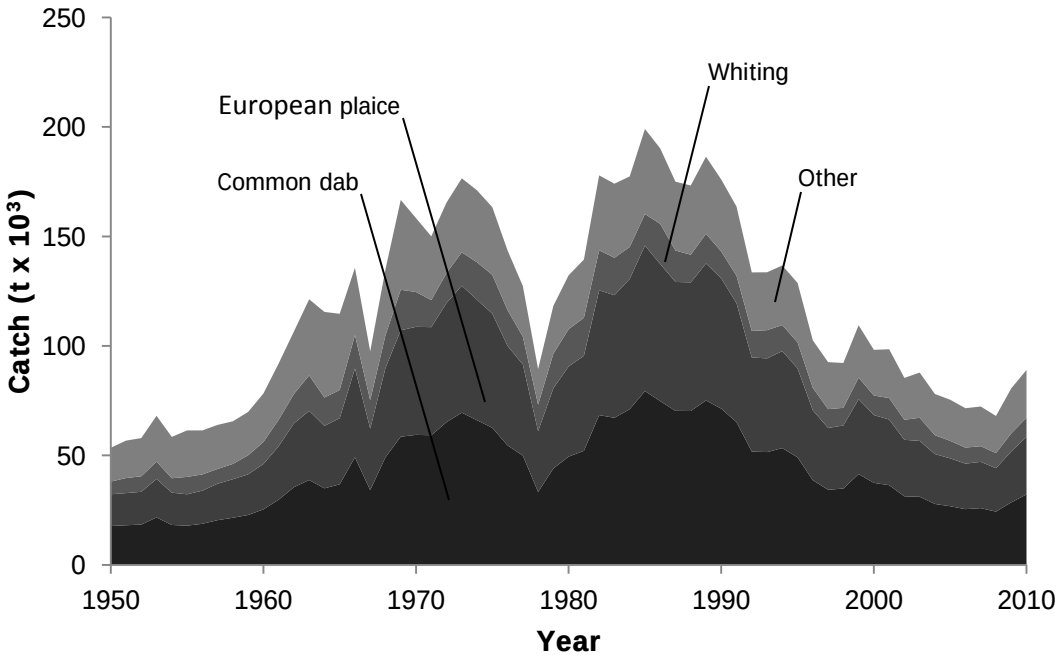

Figure 4. Total estimated Dutch discards by major commercial taxa 1950-2010.

Recreational catch

Dutch recreational catch as estimated here totals just over 9,000 t from 1950-2010. Due to the reconstruction approach taken, Atlantic cod accounts for 93% of the catch and European eel accounts for 7%. Recreational fishing totals approximately 38 t in 1950 and steadily increases to just over 380 t by 2010.

Subsistence catch

Subsistence catch for the Netherlands as estimated here consists of periwinkle and whelk, and totals approximately 1,700 t over the time period 1950-1979. Here, subsistence fisheries are assumed to have ended by 1980 (Wolff 2005). Periwinkles comprise 64% and whelks 36% of the subsistence catch. There were likely other species caught for subsistence purposes in the early time period such as flatfishes. However, we could not find any quantitative information.

Total catch

The reconstructed total catch for Dutch fisheries in their EEZ equivalent waters is just under 18.5 million tonnes which is almost twice the reported catch of just under 9.4 million tonnes (Figure 5a). Discards make up the largest portion of the catch missing from the reported data, comprising 39% of the reconstructed catch (Figure 5a). Unreported landings represent 11% of the reconstructed catch (Figure 5a).

European plaice comprises 27% of the reconstructed total catch, mostly due to our estimates of plaice discards (Figure 5b). Atlantic herring makes up approximately 21% of the reconstructed total catch. Common dab, common sole and brown shrimp all become more prominent in the reconstruction,

comprising 15%, 5.8% and 5.7%, respectively. These species are discarded heavily in both the brown shrimp trawl and the mixed flatfish trawl fishery (van Beek *et al.* 1990; ICES 2002a; van Keeken *et al.* 2007; Ulleweit *et al.* 2010; Lescrauwaet *et al.* 2013). The reconstruction demonstrates the importance of accounting for discarded tonnages to use for management decision.

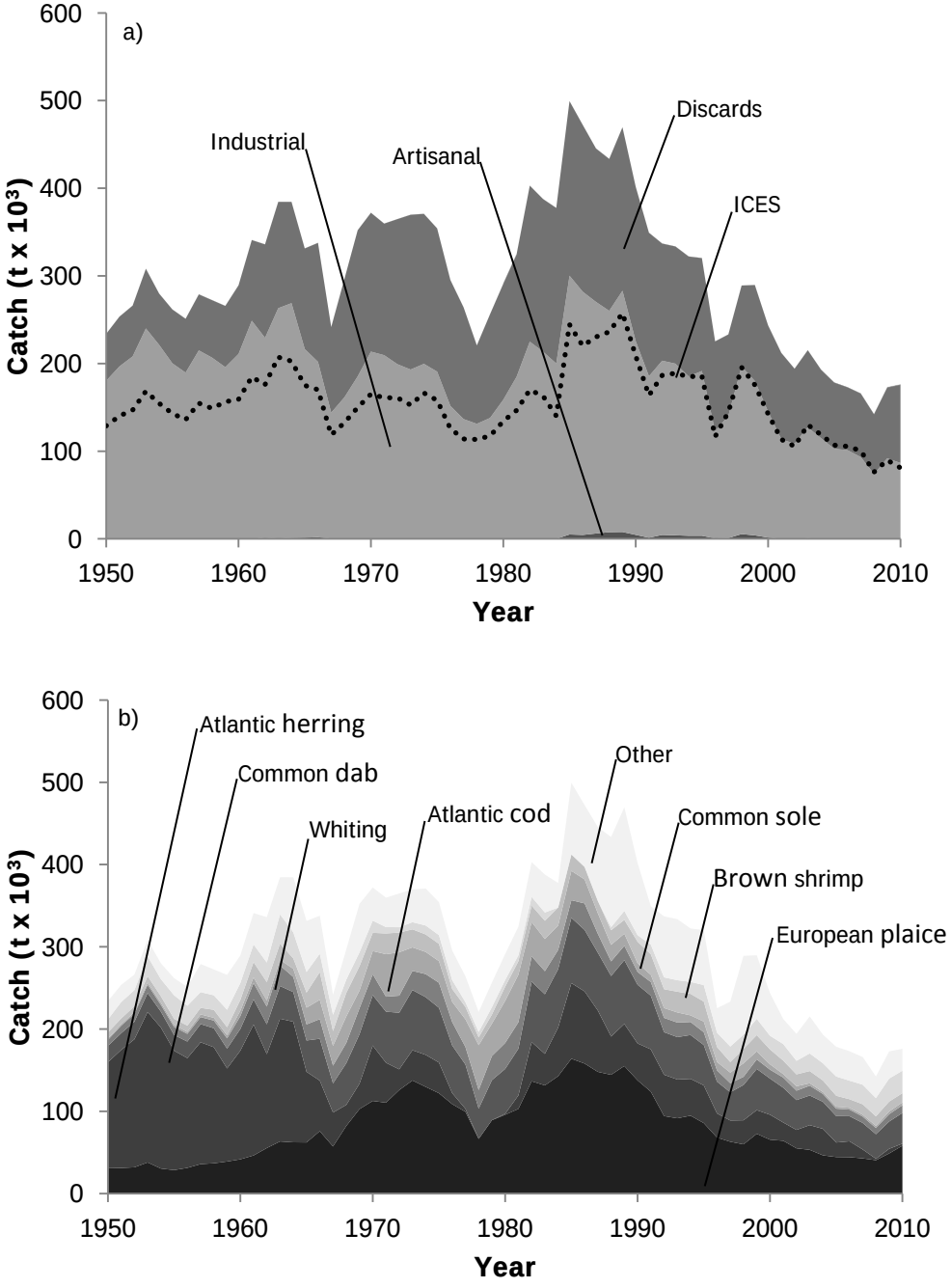

Figure 5. Reconstructed total catch by the Netherlands in the Dutch EEZ equivalent waters for 1950-2010 by a) sector (note that the dotted black line represents the reported baseline data as adjusted from ICES data); and b) major taxonomic groups.

DISCUSSION

The preliminary catch reconstruction conducted here for the Netherlands within their EEZ equivalent waters from 1950-2010 suggests that total catches (i.e., including discarded catch) is nearly 2 times the landings reported to ICES over the same time series and within the same areas. The largest contribution to the reconstruction is estimated discards (39% of the reconstructed total catch). Estimates of unreported catch from ICES stock assessments also make a sizable contribution (11%) while recreational and subsistence catch estimates are hardly significant (less than 1% each).

The estimates of subsistence catch are based on anchor points derived from Wolff (2005) and only include common periwinkle and whelks. We believe this is a reasonable estimate, as flatfish species were also likely caught in the earlier decades of the time series for subsistence purposes. These species, along with herring and other shellfish are not included due to lack of available quantitative data.

Recreational catch from 1950-2010 is estimated in a similar fashion to subsistence, using anchor points from ICES (2012b) for Atlantic cod and European eel. We use these anchor points to determine a per capita rate based on an estimated number of Dutch recreational fishers from Vriese *et al.* (2007) and de Graaf (2010), which includes both marine and fresh water fishers. European flounder (*Platichthys flesus*), garfish (*Belone belone*), Atlantic mackerel, common dab, European plaice, common sole, whiting and European seabass (*Cicentrarchus labrax*) are all species known to be targeted by recreational fishers (de Graaf 2010). Therefore, we assume that our over-estimate of fishers and under-estimate of taxa and tonnage will cancel each other out to produce a reasonable estimate of total recreational catch form 1950-2010.

It is not mandatory to report recreational catch or, in many cases, be in possession of a license (Pawson *et al.* 2008) in the Netherlands, so it can be difficult to estimate an accurate tonnage to properly represent the catch. However, the Dutch Ministry of Economic Affairs, Agriculture, Nature and Innovation, with the assistance of IMARES Wageningen UR and the Royal Dutch Angling Association (Sportvisserij Nederland), is making efforts to survey recreational fishers for more accurate estimates of catch, both retained and released (de Graaf 2010).

Unreported catch in the Dutch commercial fisheries mostly occurs as a result of the TAC quota system implemented across EU countries. Our estimate of unreported catch covers values deemed as 'unallocated' in ICES stock assessments (ICES 2002a, 2002b, 2003a, 2012a, 2012c, 2012d). We view positive 'unallocated' values as catch that is known to the relevant ICES working group experts, but is not assigned to a fishing country, and are not included in the publically available database. These values are likely to be the result of some countries exceeding their TAC and not wanting to be held accountable. It is impossible for us to determine which countries this catch is actually coming from, so we assume that each country's 'unallocated' catch is in proportion to their reported landings share.

Our estimate of unreported catch only includes Atlantic herring, European plaice, common sole, Atlantic cod, Haddock, Atlantic mackerel, Atlantic horse mackerel, whiting and saithe (ICES 2002a, 2002b, 2003a, 2012a, 2012c, 2012d). This estimate covers many of the commercially important taxa but excludes unreported estimates of common edible cockle, brown shrimp, common dab and turbot which comprise nearly 18% of the total reported commercial catch. Many of these taxa are heavily discarded, in addition to likely being substantially under-reported. This highlights the importance of properly assessing these stocks and making the data more available and transparent to the general public.

Discarded by-catch is one of the most important issues in European fisheries (Anon. 2008). Discarding has been a heavily overlooked problem in the Netherlands and Europe during the 20th century. It is difficult to precisely estimate discarded tonnages due to changing management decisions as well as shifts

in market conditions over time (Rijnsdorp *et al.* 2006; Aarts and Poos 2009). However, having zero discards for earlier decades is not a viable solution either. There is recognition of the importance of discard data because any estimate of discards is closer to the actual catch, as reported landings are largely underestimated (Daan 1976). The Netherlands began to collect discard data as part of an EU initiative, project 98-097, but the data were never made public as it 'upsets' many in the industry (ICES 2002a). This is a short-sighted approach, given that fish stocks are a public resource, and the use of such a public resource needs to be accounted for in a transparent manner.

The EU CFP during the analyzed time period had TACs at the cornerstone of their policy, which provide fishers with incentive to discard commercially invaluable species and high-grade the valuable ones (Aarts and Poos 2009). The main Dutch fisheries in the North Sea target flatfishes, shrimp, and pelagic species. We assess discards from all three of these fisheries separately and conservatively.

Discards for pelagic species such as Atlantic herring, Atlantic horse mackerel and Atlantic mackerel are monitored by ICES through stock assessments (ICES 2002b, 2003a, 2012a, 2012d). Pelagic trawls often discard large amounts of their target species, including Atlantic mackerel, Atlantic horse mackerel, blue whiting and Atlantic herring (Morizur *et al.* 1996; Borges *et al.* 2008). It has been estimated that Dutch herring trawls discard herring at a rate of 3-6% (Kelleher 2005 supplementary material), which is nearly in line with our 3.1% (IV c) and 0.1% (IV b) for herring (1950-1993). Atlantic mackerel is estimated to be discarded at a rate of 30-60% in the Dutch herring trawl fishery (Kelleher 2005 supplementary material). This is much higher than our estimated rate of 7.7% used from 1950-1986. Our estimate for discards of pelagic species from Dutch pelagic trawls is conservative, as it excludes any commercially unimportant taxa.

Further discard estimates were made for the brown shrimp fishery using a rate of 53% of the reported brown shrimp catch from a reconstruction of Belgian brown shrimp fishery discards in the North Sea (Lescrauwaet *et al.* 2013). We justify this estimate because the Netherlands use Norway lobster (*Nephrops norvegicus*) discard data from Belgium, as they don't have any of their own (ICES 2012c). This discard rate is lower than the 83.3% for the Belgian shrimp trawl in the North Sea Kelleher (2005) and covers only commercially important taxa. There are far more species discarded as a result of a beam trawl dragging on the ocean floor than brown shrimp, plaice, dab, sole and whiting. It's clear that this fishery is destructive on a variety of levels; it trawls the North Sea floor with heavy beam trawls, and obtains large amounts of by-catch in the form of juvenile flatfishes (Aviat *et al.* 2011).

Discard composition in the mixed flatfish fishery are similar to the brown shrimp fishery. German plaice and sole discard rates were used for the Dutch flatfish fishery for a thorough species composition of discarded catch (Ulleweit *et al.* 2010). Large numbers of juvenile plaice are discarded due to small mesh size targeting sole (van Keeken *et al.* 2007). Even larger amounts of common dab are discarded due to it having less commercial importance than plaice and sole (van Beek *et al.* 1990). Discards in this fishery were becoming so prevalent, that the 'Plaice Box' was implemented in 1989 to help protect nursery grounds (ICES 2002a). This management strategy only resulted in discards increasing just outside the border of the Plaice Box but has recently decreased (ICES 2002a; van Keeken *et al.* 2007).

The EU has reformed the CFP to include a discard ban beginning in 2014. Similar discard bans have been implemented in Norway, the Faroe Islands and Iceland for decades but management also takes away the incentive to discard in these nations. This reform is being implemented at a time when traditionally unimportant species (i.e., common dab, European flounder, Norway pout, grey gurnard) have become more marketable in the last decade (Catchpole *et al.* 2008). This in turn with a growing interest for more fuel-efficient and sustainable gears such as electric pulse trawling may positively affect stocks in the coming decades (ICES 2002a).

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