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Reconstructing Ireland's marine fisheries catches: 1950-2010

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ABSTRACT The wasteful practice of discarding catch is one of the major problems associated with European fisheries. Despite this, estimates of discarded catch are not included in the 'Official Catch Statistics' database (1905 to present) collected and maintained by the International Council for the Exploration of the Sea (ICES). Furthermore, removals through recreational sea angling and estimates of other forms of unreported landings are often also missing from this dataset. Here, total discarded catch and unreported landings made by Irish commercial fishing vessels, and the total amount of fish caught and retained through Irish sea angling activities within the Northeast Atlantic from 1950 to 2010 have been estimated. Total reconstructed catches were 19.3% and 20.9% higher than the officially recorded total landings as reported by ICES from the Northeast Atlantic, and those estimated as being from within the Irish Exclusive Economic Zone (EEZ), respectively. Discarded catch was proportionately the largest component of the reconstruction, representing 12.7% of the total catch within the Irish EEZ. The Irish catch reconstruction presented here is by no means assumed to represent the complete record of total removals and the authors encourage further efforts to improve upon this attempt. However, considering the current absence of estimated values for discarded catch, recreational removals and other unreported landings from

officially and publically reported data, we feel that our reconstruction provides an improved baseline estimate of more accurate total Irish marine fisheries catch that has not previously been made publically available.

Keywords: Irish fisheries, Discarding, IUU fishing, Recreational catches

INTRODUCTION

The waters surrounding Ireland are diverse and productive, containing important spawning grounds and nursery areas for many different species of fish (Marine Institute, 2009). For centuries, these waters have supported fisheries targeted by Irish and other European fishing fleets including those from Spain, France, Belgium and the UK (McArthur, 1959; de Courcy Ireland, 1981; Molloy, 2004). Historically, the most important species contributing to total marine fish landings by weight have been pelagic species such as Atlantic mackerel (*Scomber scombrus*), Atlantic herring (*Clupea harengus*) and more recently, Atlantic horse mackerel (*Trachurus trachurus*) and blue whiting (*Micromesistius poutassou*). Nephrops (*Nephrops norvegicus*) and demersal species such as whiting (*Merlangius merlangus*), Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and European plaice (*Pleuronectes platessa*) have also notably contributed to total marine fisheries landings, while shellfish such as European lobster (*Homarus gammarus*) and crab (*Cancer* spp.) have been of particular significance to the inshore fisheries sector, serving as an important resource base for Irish coastal communities (Marine Institute, 2009; Marine Institute, 2011a; ICES, 2011).

Ireland's Exclusive Economic Zone (EEZ) is located within FAO Fishing Area 27 (Figure 1). The waters of the Northeast Atlantic have been segregated into a series of divisions and sub-divisions, used for geo-referencing fisheries management areas by the International Council for the Exploration of the Sea (ICES). ICES provides scientific advice in relation to fisheries management both to the Irish government and to the European Commission (EC). The Irish EEZ is contained entirely within ICES Sub-areas VI and VII, however ICES Sub-areas VI and VII extend beyond the Irish EEZ, into the high seas or the EEZs of neighbouring countries.

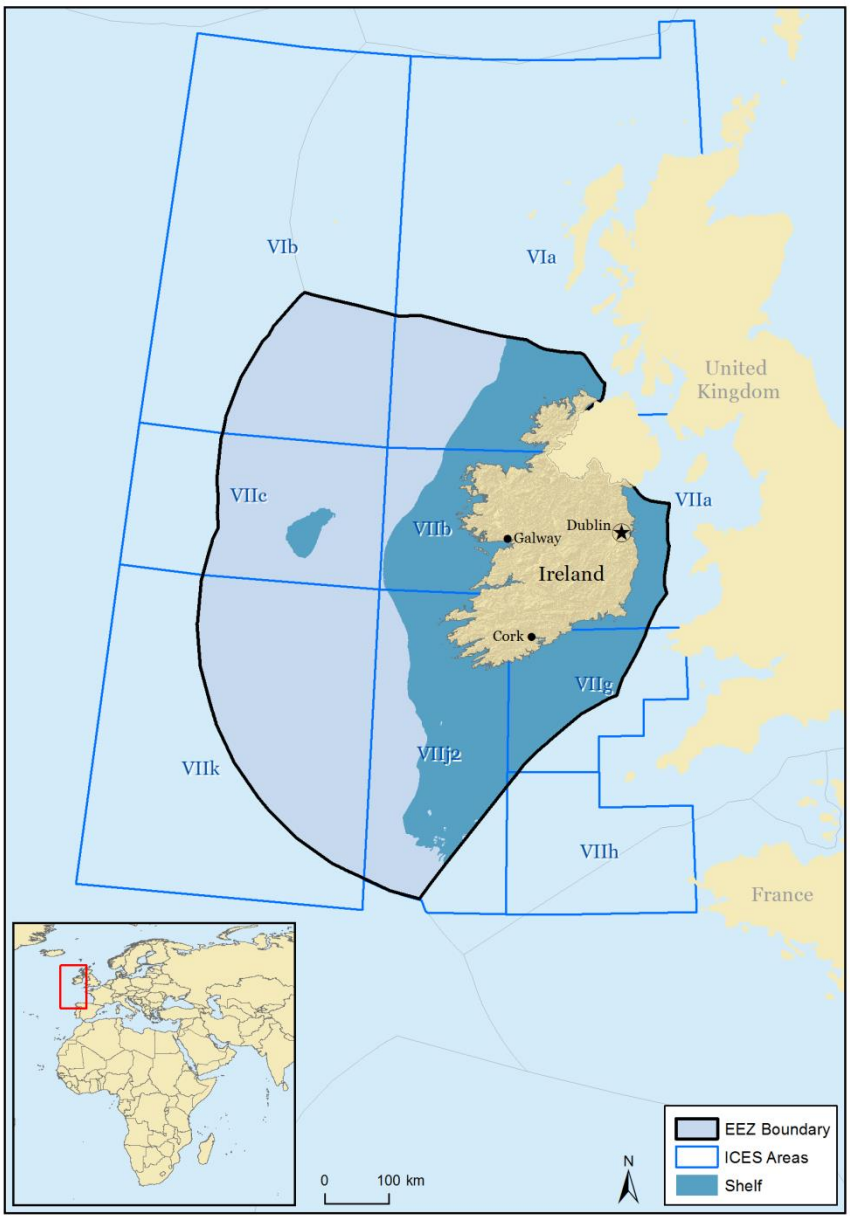

Figure 1 The Irish Exclusive Economic Zone (EEZ) and the ICES Divisions around the Irish Coast. Image generated by the *Sea Around Us* Project, courtesy of Christopher Hoornaert.

Fish caught within all EU EEZs are managed as a common resource, shared between the Member States that have commercial interests in these stocks (EC, 2009a). The EU's Common Fisheries Policy (CFP) governs European fisheries within all Member State EEZs through Total Allowable Catches (TACs), which are partitioned into stock quotas among countries, and a complex system of technical measures including minimum landing sizes,

area closures and gear restrictions (EC, 2009a). The CFP has been criticised for failing to achieve social, economic or environmental sustainability within the European fishing industry since its establishment in 1983 (EC, 2009b; Khalilian et al., 2010; EC, 2011). The many problems associated with the CFP have included high levels of discarding and high-grading (Borges et al., 2005; Marine Institute, 2011b), failure to follow scientific advice and fleet overcapacity that has been maintained through government subsidies (EC, 2009b; Khalilian et al., 2010; EC, 2011; Österblom et al., 2011).

Presently, of the commercial fish stocks where Ireland has a share of the TAC, 13 out of 38 (i.e., 34%) for which sufficient scientific data exist to estimate stock status, are being overfished relative to Maximum Sustainable Yield (MSY) (Marine Institute, 2012). In addition, a number of stocks which were once the main focus of important targeted fisheries are now considered depleted or collapsed (Marine Institute, 2009; Marine Institute, 2012). For 30 out of 59 stocks (i.e., 50.8%), there is insufficient scientific data for estimating stock status relative to MSY and this is a major factor contributing to the uncertainty of scientific advice (Marine Institute, 2012). Limited data on discards and unreported landings have also been responsible for the uncertainty of stock assessments (Marine Institute, 2012). ICES scientists have acknowledged that for a number of stocks, management by TAC is inappropriate because only the landings are controlled, and these quantities are not representative of total catches (Marine Institute, 2012).

ICES provides scientific advice on fisheries stocks within the Northeast Atlantic based on data submitted to ICES as part of the EU's Data Collection Framework (DCF) and under a number of international monitoring programmes (ICES, 2012). Estimates of discarded and unreported catch (recorded as 'unallocated') for a limited number of stocks have been considered in recent years by ICES scientists when producing and issuing scientific advice. When provided in publically accessible reports, however, these data are

only represented by one annual value for each stock, without any information given on which countries provided these values, and thus for which fishing fleets the estimated discarding or unreported catch rates apply. Furthermore, the 'Official Catch Statistics' database accessible online and maintained by ICES, only contains nationally reported annual quantities of commercially landed fish. Records contained within this dataset do not include annual estimates of discarded, recreational and other unreported catches.

Irish fisheries landing statistics are currently reported to ICES by the Irish Sea Fisheries Protection Authority (SFPA). Included within these statistics are the officially recorded landings made by Irish commercial fishing vessels measuring ten meters or more, reported by ICES sub-area and for the most part to species level. Vessels measuring less than ten meters are not required to carry logbooks and landings that are made by these vessels are not directly monitored or reported but instead are estimated through the examination of sales notes, which are required for all first point of sale transactions where over ten kilograms of fish are sold (INTERREG, 2001; Marine Institute, 2007; C. O Shea, pers. comm., SFPA).

Long-term datasets of fisheries landings can provide some insights into temporal trends in marine resource use (e.g., Pooley, 1993; Pauly et al., 1998; Pinnegar et al., 2003; Miller et al., 2012). However, fisheries 'landings' typically do not represent total fisheries 'catches' and thus trends in landings data do not necessarily provide an accurate indication of the potential ecological impacts of fishing activities in a particular marine area (Zeller et al., 2009). In addition, stock-specific landings statistics may not provide adequate information for the purposes of fisheries stock assessment (Marine Institute, 2011a). Long-term fisheries 'catch' datasets which incorporate reconstructed estimates of all fisheries removals can provide opportunities for improved interpretations of fisheries trends and cumulative potential impacts that fishing activities may be having on particular stocks or ecosystems (Zeller et al., 2007; Zeller et al., 2011). Caution should be practiced in interpreting trends

from reconstructed ‘catch’ records however, as they represent estimated catch quantities. Thus, while more statistically ‘accurate’ (i.e., closer to a true, unknown value), these estimates may be less statistically ‘precise’ than reported ‘landings’ data alone.

In this study, total discarded, recreational and other unreported catch made through Irish fishing activities within the Northeast Atlantic from 1950 to 2010 have been estimated through a process of extrapolation and interpolation between known and approximated data anchor points (Pauly, 1998; Zeller et al., 2007; Zeller et al., 2011). In addition, adjustments have been made to the existing ICES dataset, informed by national government data sources (Zeller et al., 2011). The objective of this study was to create, for the first time, a more comprehensive record of all Irish marine fisheries removals from 1950 to 2010. Due to limitations in the availability of data, however, the process of creating this reconstructed dataset has required informed assumptions and interpretations. Thus, the authors acknowledge that this reconstruction represents a first attempt and encourage others to improving upon the present data.

MATERIALS & METHODS

Available through ICES are a range of different datasets containing information relevant to fisheries management within the Northeast Atlantic Ocean. The ‘Official Catch Statistics’ database maintained by ICES contains landings reported by species and ICES fishing area. ICES also maintains publically accessible records relating to stock assessment results, presenting data on a much more limited number of commercially important species. Within these records, for a limited number of stocks, estimated quantities of discarded or ‘unallocated’ catch are provided. However, these records are only available for a few years

and do not specify which countries are contributing to the discarded or unreported catch. For the purpose of this reconstruction, we have made use of both sources of ICES data, the latter of which has been obtained through the Irish Marine Institute, contained within tables provided in their annual 'Stockbook' fisheries advice publication, for stocks relevant to Irish marine waters (Marine Institute, 2011a). We will refer to these data as being from the 'ICES stock assessment results database' (Zeller et al., 2011). For this reconstruction, data obtained from the 'Official Catch Statistics' database available through ICES have been used as the 'reported data baseline' (since these are the data officially reported to the global community via FAO) onto which estimates for identified missing components of total anthropogenic removals have been added (Zeller et al., 2011). An exhaustive search for data and reference materials relating to fishing, fisheries and fish stocks in Ireland was completed as part of this reconstruction. Uniquely different approaches were used in the completion of each step of this process and have been outlined within the following sections.

Adjustments to existing ICES landings statistics

Landings made by Irish vessels for the years 1950 to 2010 were extracted from the 'Official Catch Statistics' database, obtained online at www.ices.dk/fish/CATChSTATISTICS.asp. In an attempt to evaluate the accuracy, completeness and consistency of the landings reported within this dataset, additional datasets were obtained through various national sources, and comparisons were made between the quantity of landings recorded, taking into consideration the reporting units and categories used.

Live weight conversions

A series of hard-copy annual government reports entitled the 'Sea and Inland Fisheries Reports' were obtained for the years 1950 to 1984. These reports contained records of the

landed weight of fish caught by Irish vessels, landed at Irish ports. As these reports were produced by the various government agencies which have been responsible for fisheries over the past fifty years, the records submitted annually to ICES also likely originated, or were processed to some degree from these same agencies. When this dataset was compared to only the landings made by Irish vessels fishing in Sub-areas VI and VII extracted from the 'Official Catch Statistics' dataset from ICES, for the years 1950 to 1960, the data matched well, though from 1961 onwards, quantities recorded for demersal species differed.

ICES stated that the data contained within the 'Official Catch Statistics' database are reported in 'live weights' as opposed to 'landed weights', which represents processed product weight (e.g., gutted, beheaded, filleted; FAO, 2012). In reporting live weights, landed weights are converted back to live weights using species-specific conversion factors.

After careful consideration of the differences observed between the two datasets compared, we concluded that these differences were likely due to a reporting error on behalf of ICES. It appeared as though the quantities recorded from 1950 to 1960 were in fact recorded as landed weight. To correct this data inconsistency, we obtained live weight conversion factors from the Irish Marine Institute (M. Clarke, pers. comm., Marine Institute) and converted Irish landing values within the 'Official Catch Statistics' for 1950 to 1960 from landed weight to live weight.

Inshore catches

Over 80% of Ireland's fishing fleet operates within territorial inshore waters, generally not more than 12 miles off Ireland's coast. This fleet is mainly comprised of vessels less than 12 meters in length which largely rely on local stocks of shellfish including crab, European lobster, shrimp (*Palaemonidae* spp.), great Atlantic scallop (*Pecten maximus*), whelk (*Buccinum undatum*) and common edible cockle (*Cerastoderma edule*) (Marine Institute,

2007). Vessels under ten meters in length are not required to keep fishing logbooks, and as recently as 2007, a large fraction of the vessels working in the inshore sector were not properly licensed or registered (Connolly et al., 2001; Marine Institute, 2007). Landings made by the inshore sector, which are ultimately reported to ICES, are currently estimated primarily through the examination of sales notes which are required for all transactions involving the sale of over ten kilograms of fish or shellfish (Marine Institute, 2007; C. O Shea, pers. comm., SFPA). This system of data collection has been criticised for not providing a reliable long-term inshore fisheries dataset (Connolly et al., 2001; Marine Institute, 2007; O. Tully, pers. comm., Marine Institute).

In an attempt to improve the accuracy of the shellfish landings data currently recorded within the 'Official Catch Statistics' database, alternative national data sources which were deemed more reliable than existing ICES records were consulted, where available. Data from these sources, listed in Table 1, were used to replace existing data within the baseline ICES dataset, or to guide interpolations and/or assumptions, which resulted in positive or negative catch data adjustments.

Table 1 Data sources for inshore catch data adjustments.

Common name	Scientific name	Time period of replacement	Data source
Common edible cockle	*Cerastoderma edule*	2004-2010	Marine Institute (2011c)
Deep-sea red crab	*Chaceon affinis*	2004-2010	Marine Institute (2011c)
Edible crab	*Cancer pagurus*	2004-2010	Marine Institute (2011c)
European lobster	*Homarus gammarus*	2004-2010	Marine Institute (2011c)
Great Atlantic scallop	*Pecten maximus*	2004-2010	Marine Institute (2011c)
Green crab	*Carcinus maenas*	2004-2010	Marine Institute (2011c)
Native oyster	*Ostrea edulis*	2004-2010	Marine Institute (2011c)
Periwinkle	*Littorina littorea*	1950-1991	61% higher than ICES data, adjusted first by Marine Institute (2011c), assumptions based on Cummins *et al*. (2002).
Periwinkle	*Littorina littorea*	1991-2010	51% higher than ICES data, adjusted first by Marine Institute (2011c), assumption consistent with percentage increase applied in 2000 based on Cummins *et al*. (2002).

Periwinkle	*Littorina littorea*	2000	Cummins *et al*. (2002)
Periwinkle	*Littorina littorea*	2004-2010	Marine Institute (2011c)
Queen scallop	*Aequipecten opercularis*	2004-2010	Marine Institute (2011c)
Razor clam	*Ensis* spp.	2004-2010	Marine Institute (2011c)
Shrimp	*Palaemon serratus*	2004-2010	Marine Institute (2011c)
Spinous spider crab	*Maja squinado*	2004-2010	Marine Institute (2011c)
Spiny lobster	*Palinurus elephas*	1950-2001	O. Tully (pers. comm., Marine Institute)
Spiny lobster	*Palinurus elephas*	2002-2003	Linear interpolation between data provided by O. Tully (pers. comm., Marine Institute) and Marine Institute (2011c).
Spiny lobster	*Palinurus elephas*	2004-2010	Marine Institute (2011c)
Surf clam	*Spisula solidissima*	2004-2010	Marine Institute (2011c)
Velvet crab	*Necora puber*	2004-2010	Marine Institute (2011c)
Venus clam	*Venerida* spp.	2005-2006	Marine Institute (2011c)
Whelk	*Buccinum undatum*	1965-1986	Fahy *et al*. (2004)
Whelk	*Buccinum undatum*	1995-2003	Fahy *et al*. (2004)
Whelk	*Buccinum undatum*	2004-2010	Marine Institute (2011c)

Assignment of ICES reported landings to the Irish EEZ

Although the ICES 'Official Catch Statistics' dataset only contains reported fisheries 'landings', not 'catches', landings within this dataset have been recorded according to the ICES fishing areas where they were caught rather than the fishing ports where they were landed. Recorded areas include all locations within the Northeast Atlantic where Irish fishing vessels have been reported catching fish, including those outside ICES Sub-areas VI and VII, the areas which overlap with Ireland's EEZ (Figure 1). For the purposes of this reconstruction and to allow for country-specific global comparisons, it was necessary to separate landings made by Irish vessels within the Northeast Atlantic into two categories; landings made by Irish vessels within the Irish EEZ and landings made by Irish vessels outside the Irish EEZ.

Maps that visually displayed an approximate distribution of the geographic location of landings by Irish vessels less than 15 meters in length over the period 2006 to 2008 were obtained from the Marine Institute's 'Atlas of the Commercial Fisheries around Ireland' (Figures 2.2.1-2.2.4 in Marine Institute, 2009). These maps were created by linking data from

the Irish Vessel Monitoring System (VMS) to daily logbook recordings of landings for the following species: Atlantic cod, Atlantic herring, Atlantic horse mackerel, Atlantic mackerel, blue whiting, common sole (*Solea solea*), European hake (*Merluccius merluccius*), European plaice, haddock, ling (*Molva molva*), megrim (*Lepidorhombus whiffiagonis*), monkfish (*Lophius* spp.), nephrops, ray and skate (Batoidea), tuna (*Thunnus* spp.) and whiting.

These catch distribution maps were visually inspected, and for each ICES area straddling the Irish EEZ boundary (Sub-areas VIa-b; VIIa; VIIc; and VIIg-k, Figure 1), an estimate was made of the proportion of the landings of each species originating from within and outside the EEZ (Supplementary Table 1). For lCES Sub-area VIIb, which is completely within the Irish EEZ, 100% of landings were designated as being caught within the Irish EEZ.

The estimated proportions of landings originating from inside and outside the Irish EEZ were applied to the entire time series dataset for each species that VMS maps were available for. Proportional EEZ inclusion values were created for all other species recorded within the ICES dataset based on assumptions of similarities in life history traits to species with VMS data. Although some temporal changes in the spatial distribution of catches are likely to have occurred, proportional EEZ inclusion values were assumed constant throughout the entire time period as no other information was available for estimating the extent or direction of possible changes.

Following this process of data separation, ICES Sub-areas where landings were caught were retained within the modified data records and all data, regardless of EEZ classification category, were considered within subsequent reconstruction steps. Thus, no data were moved between statistical areas or sub-areas.

Unreported landings

Unlike data adjustments (modifications for increased accuracy) to official landings records, unreported landings, as their name suggests, have not been accounted for in official landings records. The components that we have included in this category are 'unallocated' landings reported by ICES stock assessment reports, estimates of fish caught and retained through recreational angling activities and landings of a basking shark (*Cetorhinus maximus*) fishery which had previously not been included in national landings records.

ICES unallocated catch

Stock assessment reports prepared by ICES working groups for a number of stocks include a category of landings labelled 'unallocated', but do not specify which countries have contributed to the landings recorded within this category, nor what specifically these values represent and how they have been derived or estimated. Occasionally, values within this category were negative, likely representing suspected over-reporting of landings.

ICES assessment report data relevant to fisheries within Irish waters are included in the Irish Marine Institute's annual 'Stockbook' fisheries advice publication (Marine Institute, 2011a). The proportion of the total 'unallocated' landings for each stock was allocated as being caught by the Irish fleet according to the annual proportion of Ireland's share of the total reported landings for that stock, also calculated using values within these tables originating from ICES stock assessment reports. Thus, we assumed proportionality between reported landings and 'unallocated' catches. 'Unallocated' catches for the Irish fleet were only estimated for the stocks for which ICES data were available (Table 2), and therefore, our estimates of unreported catches in this category are likely a minimal estimate. These catches were allocated within or outside the Irish EEZ according to the stock inclusion rates in Supplementary Table 1. Lastly, estimates for most stocks were not extrapolated backwards in

time to cover years where data were not available as trends within the data were often inconsistent, including estimates of both under-reporting and over-reporting. However, this likely resulted in underestimation of total time series 'unallocated' catches, and hence our data should be considered minimal estimates of this category.

Table 2 Stocks and time periods for which ICES 'unallocated' landings have been estimated for Irish fisheries.

Common name	Scientific name	ICES Sub-area	Time period	Data source
Atlantic cod	*Gadus morhua*	Via	1987-2010	Table 5.4.21.1 (Marine Institute 2011a)
Atlantic cod	*Gadus morhua*	VIIa	1987-1994	Table 5.4.1.1 (Marine Institute 2011a)
Atlantic cod	*Gadus morhua*	VIIa	1995-2010	Table 5.4.1.2 (Marine Institute 2011a)
Atlantic herring	*Clupea harengus*	VIaN	1987-2010	Table 5.4.30.2 (Marine Institute 2011a)
Atlantic herring	*Clupea harengus*	VIaS, VIIb-c	1988-2010	Table 5.4.17.2 (Marine Institute 2011a)
Atlantic herring	*Clupea harengus*	VIIaN	1987 & 1996	Table 5.4.15.2 (Marine Institute 2011a)
Atlantic herring	*Clupea harengus*	VIIaS, VIIg-k	1988-2010	Table 5.4.16.2 (Marine Institute 2011a)
Atl. horse mackerel	*Trachurus trachurus*	VI and VII	1950-1996	Extrapolated backwards from 1997 applying 50% of 1997 'unallocated' rate from Table 9.4.3.7 (Marine Institute 2011a)
Atl. horse mackerel	*Trachurus trachurus*	VI and VII	1997-2010	Table 9.4.3.7 (Marine Institute 2011a)
Atlantic mackerel	*Scomber scombrus*	VI and VII	1950-1987	Extrapolated backwards from 1988 applying 50% of 1988 'unallocated' rate from Table 5.4.2.5 (Marine Institute 2011a)
Atlantic mackerel	*Scomber scombrus*	VI and VII	1988-2010	Table 9.4.2.5 (Marine Institute 2011a)
Common sole	*Solea solea*	VIIa	1973-2010	Table 5.4.12.2 (Marine Institute 2011a)
Common sole	*Solea solea*	VIIf-g	1987-2010	Table 5.4.13.2 (Marine Institute 2011a)
European plaice	*Pleuronectes platessa*	VIIa	1987-1991	Table 5.4.7.1 (Marine Institute 2011a)
European plaice	*Pleuronectes platessa*	VIIa	1992-2010	Table 5.4.7.2 (Marine Institute 2011a)
European plaice	*Pleuronectes platessa*	VIIf-g	1983-2010	Table 5.4.8.2 (Marine Institute 2011a)
Haddock	*Melanogrammus aeglefinus*	Via	1987-2010	Table 5.4.23.1 (Marine Institute 2011a)
Haddock	*Melanogrammus aeglefinus*	VIb	1987-1991	Table 5.4.24.1 (Marine Institute 2011a)
Haddock	*Melanogrammus aeglefinus*	VIb	1992-2010	Table 5.4.24.2 (Marine Institute 2011a)
Haddock	*Melanogrammus aeglefinus*	VIIa	1987-2010	Table 5.4.3.1 (Marine Institute 2011a)
Haddock	*Melanogrammus aeglefinus*	VIIb-k	1987-1992	Table 5.4.4.1 (Marine Institute 2011a)
Haddock	*Melanogrammus aeglefinus*	VIIb-k	1993-2010	Table 5.4.4.2 (Marine Institute 2011a)
Megrim	*Lepidorhombus whiffiagonis*	Via	1950-1989	Extrapolated backwards from 1990 applying 50% of 1990 'unallocated'

				rate from Table 5.4.38.2 (Marine Institute 2011a)
Megrim	*Lepidorhombus whiffiagonis*	Via	1990-2010	Table 5.4.38.2 (Marine Institute 2011a)
Monkfish	*Lophius* spp.	Via	1950-1990	Extrapolated backwards from 1991 applying 50% of 1990 'unallocated' rate from Table 5.4.29.5 (Marine Institute 2011a)
Monkfish	*Lophius* spp.	Via	1991-2010	Table 5.4.29.5 (Marine Institute 2011a)
Monkfish	*Lophius* spp.	VIb	1991-2010	Table 5.4.29.6 (Marine Institute 2011a)
Whiting	*Merlangius merlangus*	Via	1987-2010	Table 5.4.25.1 (Marine Institute 2011a)
Whiting	*Merlangius merlangus*	VIIa	1987-2010	Tables 5.4.5.1 and 5.4.5.2 (Marine Institute 2011a)
Whiting	*Merlangius merlangus*	VIIe-k	1983-2010	Table 5.4.6.2 (Marine Institute 2011a)

Retained recreational catch

In Ireland, there are no reporting requirements for recreational sea angling, either from boat or from shore. In addition, with exception to European seabass (*Dicentrarchus labrax*), there are no regulations to limit catch quantities and no minimum landing size requirements. Sea angling activities in Ireland are currently not monitored and to date, there have been no attempts at estimating the total amount of fish caught through these activities. In order to estimate the likely total amount of fish caught and retained from Irish waters through sea angling for the years 1950 to 2010, a separate reconstruction process was applied to estimate catches made through boat-based and shore-based angling activities.

Estimated values for the total numbers of day trips spent sea angling from boat or shore in Ireland for the years 1996 and 2003 were obtained from a government funded national survey of water-based leisure activities (Marine Institute, 2004). These values were converted into per capita rates using Irish population data (CSO, 2012), and rates for the years 1997 to 2002 were estimated through linear interpolation, assuming a constant decreasing (boat days) and increasing (shore days) trend during this time period. The annual numbers of day trips spent sea angling from boat and shore for this time period were then

calculated by multiplying the rates for each year by the annual Irish population size (CSO, 2012). The estimated total numbers of day trips spent sea angling from boat and shore were extrapolated forward and backwards through applying the per capita day trips rates from 1996 and 2003, respectively to annual Irish population size data (CSO, 2012). To account for technological advances within the last half of the 20th century that have likely led to improved accessibility of vessels for recreational use, we have assumed that the annual per capita rates for days angling from boats have likely increased and the annual per capita rates for days angling from the shore have likely decreased. As such, prior to 1996, the per capita day trip rates were multiplied by a factor of 0.5 in 1950, extrapolated to 1 in 1996 for angling from boats, and by a factor of 2 in 1950, extrapolated to 1 in 1996 for angling from the shore.

Boat-based angling activities

The quantity and diversity of fish caught by boat anglers per year was determined through multiplying the estimated annual effort (boat day trips) by estimated average species-specific weights of fish caught per boat angler per day fishing. These latter values were derived from deep sea angling charter boat logbook data from 1978 to 2002, documented within an annual report published by the Central Fisheries Board (CFB) (now Inland Fisheries Ireland (IFI)) (W. Roche, pers. comm., IFI). Species-specific catch rate data (in fish numbers) was available for Atlantic cod, ling, saithe (*Pollachius virens*), white pollack (*Pollachius pollachius*), conger eel (*Conger conger*), greater spotted dogfish (*Squalus acanthias*) and lesser spotted dogfish (*Scyliorhinus canicula*). We decided to omit conger eel and elasmobranch data from this reconstruction as anecdotal evidence (W. Roche, pers. comm., IFI; A. Hayden, pers. comm., www.anirishanglersworld.com) suggested they are generally not and never have been retained by anglers in large enough quantities to warrant inclusion in retained catch records.

Average catch rates from the first three years (1978-1980) and from the last three years (2000-2002) of this dataset were applied backwards and forwards, respectively, to each of the remaining years of the dataset not covered by the deep sea angling charter logbook records. The total estimated numbers caught of each species were then multiplied by an estimated 'typical' weight of fish, which was conservatively set at 0.25 of the species' specimen weight, as set by the Irish Specimen Fish Committee (ISFC, 2012) to obtain estimated 'typical' species-specific daily catch weights for the year 1950. The specimen weights applied here are 'trophy weights', used by the angling community in Ireland as a threshold measurement for exceptionally large fish that warrant recognition (CSO, 2012). Prior to their application as multiplication factors throughout the dataset, these 'typical' fish weights were extrapolated forwards, declining by 50% for all species from 1950-2010. This conservative estimated trend was applied to account for the decreasing sizes of fish caught over this time period, based on estimates of 50-75% size reductions reported in the North Sea by Jennings (2002). Calculated estimated catch rates by weight were then reduced by 50% for all years, assuming that typical catch rates for all angling activities from boats are not as high as those for angling activities from chartered deep sea angling vessels.

Shore-based angling activities

The quantity of fish caught by shore anglers each year was determined through first assuming that occasionally, due to poor luck and inconsistencies in skill, shore anglers have fishing days where they are unsuccessful in catching anything. Thus, to conservatively account for this, we assumed that on 50% of the estimated days spent angling from the shore, zero fish were caught. For the remaining days, in the absence of any other sources of data, the estimated total daily catch rate by weight for all species combined per angler from a boat was also assumed for anglers from the shore. These annual values were multiplied by the total

estimated number of days spent angling from shore to obtain a total estimated weight of all species of fish caught per year from shore.

Total annual catch weights for sea angling from shore were then disaggregated into species categories based on Scottish angling diversity data (Donnelly, 2009). Scottish data were utilised based on the assumption that the diversity of species caught through angling in Ireland is similar to that in Scotland. The Scottish data were from a national survey where individuals were asked which species they typically fished for. For the purposes of this reconstruction, only the species that were mentioned by at least 25% of the respondents were considered, again excluding elasmobranches (other than rays and skates), and conger eel. The percentage of total respondents that mentioned each species was recorded and these percentage values were used as numerical values, thus approximating the relative catch frequency of each species. These values were converted into proportions of the sum of numerical values for all species mentioned (Atlantic mackerel, Atlantic cod, white pollack, saithe, flatfish, rays and skates, whiting, haddock and European seabass). These proportional values were used to disaggregate the total annual catch weights for all years. In the absence of data suggesting otherwise, it was assumed that the species composition of total shore-based angling catch was consistent throughout the entire time series.

Based on anecdotal quantitative information (W. Roche, pers. comm., IFI; A. Hayden, pers. comm., www.anirishanglersworld.com), it was assumed that in 2010, fishers mostly practiced catch and release, whereas during the 1950s, recreational catches were mostly retained. Thus, linear interpolation was used to calculate the final quantities of recreational catches retained from 1950 to 2010 through both boat-based and shore-based angling activities, assuming a 90% retention rate in 1950 and a 10% retention rate in 2010. Lastly, annual retained catch quantities for both boat-based and shore-based angling activities were

combined, creating a final dataset of estimated retained catch quantities from all angling activities in Ireland from 1950 to 2010.

Basking sharks

Landing records from a localised coastal basking shark fishery on Achill Island, Co. Mayo which had previously not been included within national landings records were added for the years 1950 to 1975 (Kunzlik, 1988). These data were not extrapolated beyond these years as it was known that this fishery closed in 1975 due to a diminished local population of sharks.

Discards

Estimates of the quantity of catch discarded annually by Irish commercial fishing vessels were calculated primarily through data provided in the recently published 'Atlas of Demersal Discarding', produced by the Irish Marine Institute (Marine Institute, 2011b). This Atlas included discarding rates for the ten most commercially important demersal species by weight and also discarded quantities of the ten most highly discarded non-commercial species by weight. In addition, discarding estimates for a number of pelagic and shellfish species were derived from other national sources and were included in the reconstruction. Discard quantities for the Irish fleet were only estimated for the stocks for which stock-specific discarding data were available, listed in Table 3, and are thus likely a minimal estimate of total discarding.

Estimated discards from Irish demersal fisheries

Commercially targeted demersal stocks

Discard estimates for each commercially fished demersal stock listed in Table 3, both within and outside the Irish EEZ, were calculated by applying the stock-specific 'discard' rates

recorded for the combined 2003-2009 time period in the 'Atlas of Demersal Discarding' produced by the Irish Marine Institute (Marine Institute, 2011b) to all baseline and reconstructed data, excluding recreational catch. Discards for each stock for the years prior to the introduction of stock-specific total allowable catch (TAC) regulations have been estimated by applying 50% of the 'discard' rates from the combined 2003-2009 time period. This reduction was made to represent the fact that discarding practices existed prior to the introduction of catch restrictions (see e.g., Roberts, 2007), but TAC regulations likely increased the frequency and volume of discarding.

Non-Commercially targeted stocks caught as by-catch by demersal fisheries

For stocks not targeted by Irish demersal fisheries where recorded discarding rates were 100% (i.e., none was retained), total 'discard' quantities were obtained for all seven years (2003-2009) combined (as opposed to the 'discard' rates given for commercially targeted stocks) (Marine Institute, 2011b). These quantities were apportioned to within EEZ and outside the EEZ following the procedure outlined in the section entitled '**Separation of reconstructed catch by sector**', utilizing discard sampling maps published by the Irish Marine Institute (Figs. 3.13-3.22; Marine Institute, 2011b). These maps indicate the locations of observed discarding of recorded non-commercially targeted species from discard sampling trips carried out by the Marine Institute from 1995 to 2009. Discards were disaggregated into annual quantities within the seven year time period in proportion to annual total estimated landings of all marine species. Total 'discard' quantities for all seven years combined were then converted into 'discard' rates for each recorded non-commercial species, relative to the total estimated landings of all marine species for the same seven year time period. Discard rates for 1950 were assumed to be 50% of the discard rates for the combined years 2003 to 2009, and rates were interpolated between 1950 and 2003. This trend therefore assumes that

discarding rates have gradually increased over the past fifty years (Marine Institute, 2009; Marine Institute, 2011a). Discard rates for 1950 to 2003 were then applied to the total catch volumes of all marine species by Irish vessels caught both within and outside the Irish EEZ to obtain discard estimates for each stock. Discard rates for 2010 were assumed to be the same as the discard rates for the combined years 2003 to 2009.

Table 3 Stocks and time periods for which discard quantities have been estimated.

Common name	Scientific name	Fleet	Time period	Data source
Argentines	*Argentina*	Demersal	1950-2010	Table 3.21 (Marine Institute 2011b)
Atlantic mackerel	*Scomber scombrus*	Pelagic	1950-2010	Table 9.4.2.5 (Marine Institute 2011b)
Atlantic cod	*Gadus morhua*	Demersal	1950-2010	Table 3.8 (Marine Institute 2011b)
Atlantic herring	*Clupea harengus*	Pelagic	1988-1997	Tables 5.4.16.2 & 5.4.17.2 (Marine Institute 2011b)
Atl. horse mackerel	*Trachurus trachurus*	Demersal	1950-2010	Table 3.19 (Marine Institute 2011b)
Blue whiting	*Micromesistius poutassou*	Demersal	1950-2010	Table 3.16 (Marine Institute 2011b)
Boarfish	*Capros aper*	Demersal	1950-2010	Table 3.20 (Marine Institute 2011b)
Common dab	*Limanda limanda*	Demersal	1950-2010	Table 3.15 (Marine Institute 2011b)
European hake	*Merluccius merluccius*	Demersal	1950-2010	Table 3.6 (Marine Institute 2011b)
European plaice	*Pleuronectes platessa*	Demersal	1950-2010	Table 3.9 (Marine Institute 2011b)
Greater forkbeard	*Phycis blennoides*	Demersal	1950-2010	Table 3.17 (Marine Institute 2011b)
Grey gurnard	*Eutrigla gurnardus*	Demersal	1950-2010	Table 3.14 (Marine Institute 2011b)
Haddock	*Melanogrammus aeglefinus*	Demersal	1950-2010	Table 3.3 (Marine Institute 2011b)
Lesser spotted dogfish	*Scyliorhinus canicula*	Demersal	1950-2010	Table 3.13 (Marine Institute 2011b)
Long rough dab	*Hippoglossoides platessoides*	Demersal	1950-2010	Table 3.22 (Marine Institute 2011b)
Megrim	*Lepidorhombus whiffiagonis*	Demersal	1950-2010	Table 3.5 (Marine Institute 2011b)
Monkfish	Lophius	Demersal	1950-2010	Table 3.7 (Marine Institute 2011b)
Nephrops	*Nephrops norvegicus*	Demersal	1950-2010	Table 3.12 (Marine Institute 2011b)
Poor cod	*Trisopterus minutus*	Demersal	1950-2010	Table 3.18 (Marine Institute 2011b)
Razor clam	Euheterodonta	Shellfish	2001-2010	Kelleher *et al.* 2005
Saithe	*Pollachius virens*	Demersal	1950-2010	Table 3.10 (Marine Institute 2011b)
Scallop	*Pecten maximus*	Shellfish	1950-2010	Kelleher *et al.* 2005
White Pollack	*Pollachius pollachius*	Demersal	1950-2010	Table 3.10 (Marine Institute 2011b)
Whiting	*Merlangius merlanngus*	Demersal	1950-2010	Table 3.4 (Marine Institute 2011b)
Witch	*Glyptocephalus cynoglossus*	Demersal	1950-2010	Table 3.11 (Marine Institute 2011b)

Pelagic discarding estimates

Discard estimates for herring and mackerel stocks caught through targeted pelagic fisheries by Irish vessels were calculated through the use of ICES stock assessment report data contained within the Irish Marine Institute's 'Stockbook' (Marine Institute, 2011a). The proportion of the total discards reported for each stock by ICES, but unallocated to any particular fishing fleet was allocated to the Irish fleet in proportion to Ireland's share of the total reported landings for that stock (Marine Institute, 2011a). Thus, in the absence of publically available country-specific information on discarding, we had to assume the same discarding behaviour for all fleet nationalities. Discard quantities of mackerel for the years prior to the introduction of stock-specific total allowable catch (TAC) regulations (1987) have been estimated by applying 50% of the average 'discard' rates from the combined time period 1988-2010 (Marine Institute, 2011a). Estimates for herring stocks were not extrapolated backwards in time to cover years where data was not available as trends within the data were highly inconsistent and relatively small in relation to total catch.

Shellfish discarding estimates

Discard quantities for razor clams (Euheterodonta) and scallops were estimated by applying estimated discarding rates for the year 2001, obtained from Kelleher et al. (2005). This rate was applied to razor clam and scallop catch data from 2001 to 2010 to calculate estimated quantities of discarding for each year during this time period. Razor clam discard estimates were not extrapolated to earlier years of the dataset as there were no recorded razor clam landings prior to this time period and no historical information was found on a pre-existing razor clam fishery. The commercial harvesting of razor clams is currently carried out using relatively modern hydraulic dredging techniques and it is likely that if razor clams were harvested in earlier years a much smaller quantity was gathered using less intensive methods

of extraction. Estimated discard quantities of scallops from 1950 were calculated using 50% of the discarding rate for 2001 and discarding rates from 1951 to 2000 were calculated through linear interpolation.

Separation of reconstructed catch by sector

In an attempt at allocating the final reconstructed catch data to the appropriate sectors from which fish were caught, total reconstructed catch quantities for each species and fishing area were separated into catches by the 'artisanal' (small-scale) fishing sector, the 'industrial' (large-scale) fishing sector, and the 'recreational' (sea angling) fishing sector. All recreational catch quantities were entirely reconstructed and the approach taken has been outlined in the section entitled '***Retained recreational catch'***. All remaining catch data including both reported landings and reconstructed catch were allocated as landings by the artisanal or industrial fishing sector based on comparisons with landings data obtained from the Irish Marine Institute for the years 2003-2010 (M. Clarke, pers. comm., Marine Institute). This dataset contained information on the size of the fishing boats ('under ten meters', or 'ten meters or over') that had caught all reported landing quantities, recorded by species and by port of landing. For the purposes of this catch reconstruction, we interpreted that catches made by vessels 'under ten meters' and within the Irish EEZ were made by the small-scale or artisanal fishing sector. In addition, catches made by vessels 'ten meters or over' or outside the Irish EEZ were made by the large-scale or industrial fishing sector.

Species that were recorded as being caught entirely by only one sector were assigned as being caught by this same sector throughout the entire reconstructed dataset. For species that were recorded as being caught partially by the artisanal sector and partially by the industrial sector, proportional values were calculated for each year from 2003 to 2010,

representing the proportion of the total Irish catch of each species from each sector for each of these years.

For years prior to 2003, the proportion of artisanal vessels catching each species of fish was considered 20% higher in 1950 than in 2003, so the proportional value for 1950 was calculated as the average proportion of catch caught by artisanal vessels in the first three years of the Marine Institute dataset (2003-2005), plus 0.2. Proportional values were then interpolated between 1950 and 2003. These actions were taken following the assumptions that generally, there were smaller vessels in operation earlier in the time series and that throughout the time series, vessels gradually became larger. In cases where the fishery only developed late in the time series, a constant division between artisanal and industrial vessels was assumed throughout. For species that were not specifically included within the Marine Institute dataset, assumptions were made based on similarities with other species and/or on information obtained online from FishBase (www.fishbase.org).

These proportions were then applied to the reconstructed data (the sum of the total landings, IUU and discards for all ICES fishing areas from each year) to calculate the total quantity of catch that originated from each sector for each of these years. The total artisanal catch for each species and each year was quantified only within the catch from the ICES areas bordering on Irish land (ICES areas Via, VIIb, VIIg, VIIj and ICES area (not specified)). This action was taken as it was assumed that it is most likely that artisanal (smaller) vessels catch fish in areas closer to the shore and not in the high seas, or in foreign waters. The Marine Institute dataset supports this assumption as all landings made at foreign ports were caught only by vessels ‘ten meters or over’. Lastly, all catches made by Irish vessels outside of the Irish EEZ were recorded as being caught by the industrial sector as it was decided that having been caught within the Irish EEZ was an appropriate additional classification requirement for catches made by the artisanal sector.

RESULTS

Estimated total Irish removals from all ICES fishing areas within the Northeast Atlantic from 1950 to 2010 as calculated here amounted to approximately 10.96 million tonnes. This is 19.3% higher than the landings of 9.19 million tonnes that are reported in the ICES 'Official Catch Statistics' database.

Catches made within the Irish Exclusive Economic Zone (EEZ)

Our catch reconstruction estimated total Irish catches of approximately 8.69 million tonnes from within the Irish EEZ between 1950 and 2010, a quantity that is 20.9% higher than the 7.19 million tonnes that were assigned to EEZ waters from the ICES 'Official Catch Statistics' database (Figure 2a). Throughout the entire time series, total catches ranged from being 128% higher than reported landings in 1952, to being just under 10% higher than reported landings during the early 1980s. From 2000 to 2010, reconstructed total catches were on average 19.7% higher than reported landings.

Basking shark landings represented the majority of the reconstructed unreported catch additions at the beginning of the time series (1950s), representing 38.1% of total catches and 77% of reconstructed additions to the dataset in 1952. Towards the end of the time series, quantities of both discards and unreported catches increased along with their relative contribution to total annual catches (Figure 2b). From 1990 to 2010, discards and unreported catches represented on average 14.8% and 3.6%, respectively, of the total reconstructed catches. For the entire time period from 1950 to 2010, reconstructed discards and unreported catches represented 12.7% and 2.8%, respectively, of the total reconstructed catches. Reconstructed recreational catch was relatively low and the proportional contribution of this component decreased over time due to increasing catch-and-release behaviour by recreational

fishers. For the entire time period, estimated recreational catches accounted for just under 40 000 tonnes and comprised 0.5% of the total reconstructed catches.

Estimated unreported catches of pelagic species such as Atlantic herring, Atlantic horse mackerel and Atlantic mackerel (in addition to basking shark during earlier years) contributed the most to the unreported component of total reconstructed additions (Figure 2c). Estimated quantities of demersal species such as whiting, haddock and European hake, contributed the most significantly to total estimated discards (Figure 2d). Lastly, although the artisanal component of the total reconstructed catch was dominant at the very begining of the time series in the early 1950s, 86.7% of total catches from 1950 to 2010 were made by the industrial sector (Figure 3).

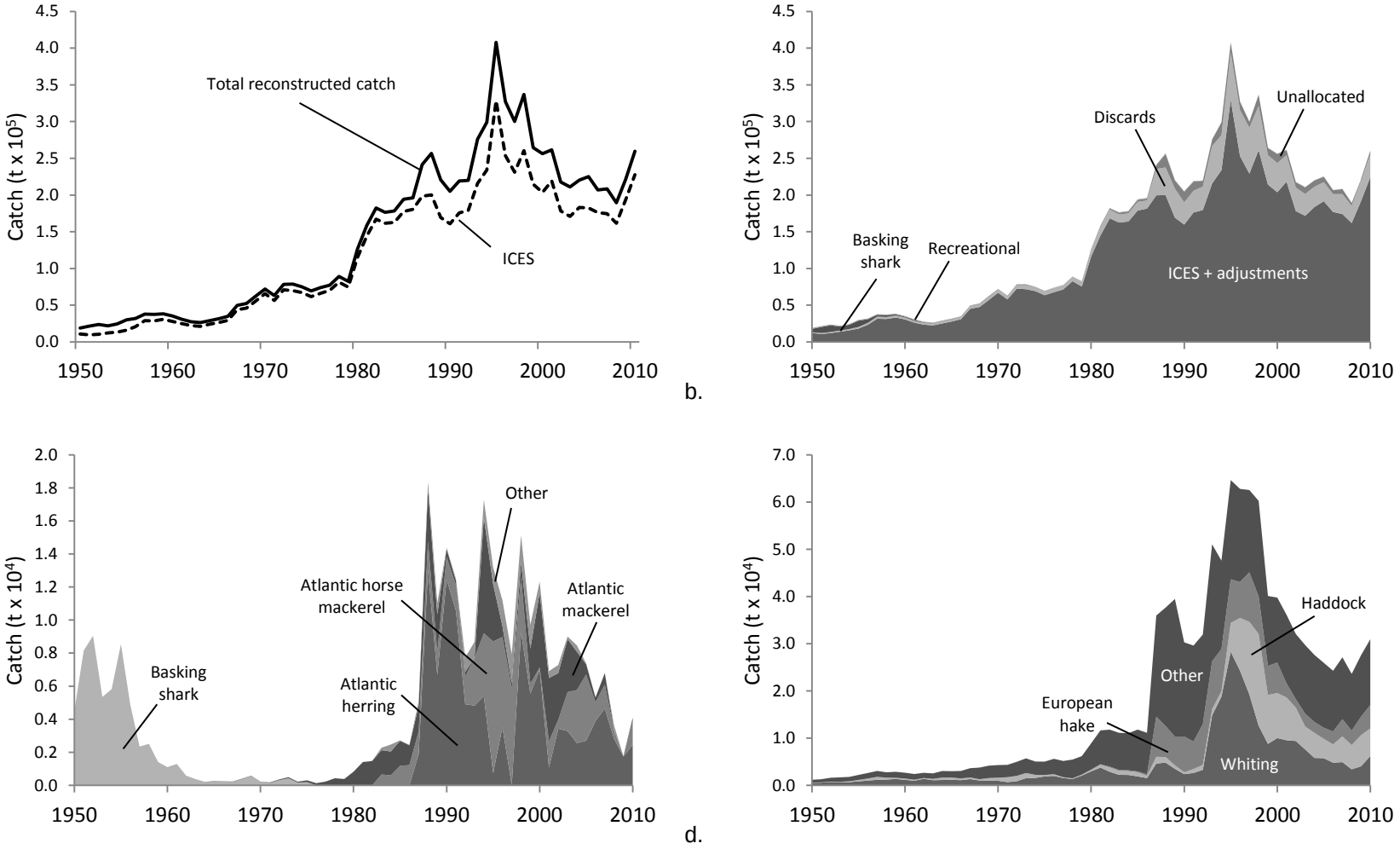

Figure 2 Irish fisheries removals from within the Irish EEZ for the period 1950-2010; (a) total reconstructed removals (solid line) as well as landings reported within the 'Official Catch Statistics' dataset available through ICES (dashed line); (b) total reconstructed removals by category, inclusing ICES + source adjustments, basking shark landings, 'unallocated' landing estimates as reported by ICES, discards and retained recreational catch; (c) total unreported landings by taxon; and (d) total discards by taxon.

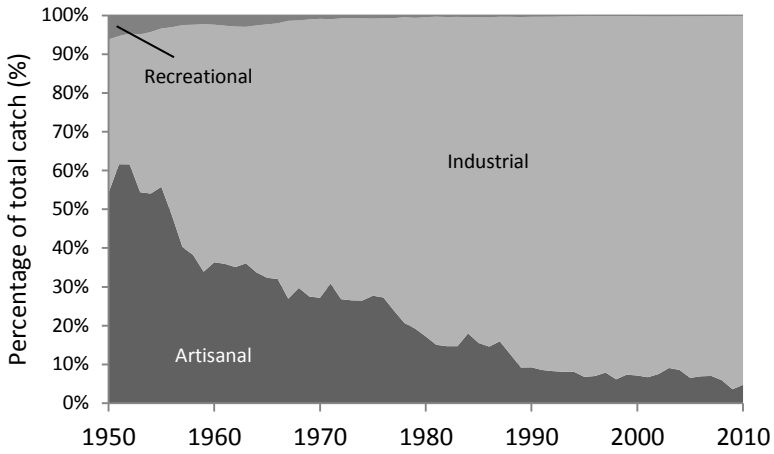

Figure 3 Total Irish reconstructed fisheries removals within the Northeast Atlantic for the period 1950-2010 by sector from within the Irish EEZ.

Catches outside the Irish Exclusive Economic Zone (EEZ)

An estimated 2.27 million tonnes was removed by Irish fishing vessels fishing within the Northeast Atlantic outside the Irish EEZ from 1950 to 2010 (Figure 4a). This is 13.4% higher than the 2 million tonnes that were assigned to non-EEZ waters from the ICES 'Official Catch Statistics' database (Figure 4a). From 1950 to 2010, reconstructed total catches were on average 15.1% higher than reported landings, which was lower than the contribution calculated for catches made within the Irish EEZ, which incorporated both basking shark landings and recreational catch.

Towards the end of the time series, discards and unreported catches increased, along with their relative contribution to total annual catch quantities (Figure 4b). From 1990 to 2010, discards and unreported catches represented on average 9.1% and 3.4%, respectively, of the reconstructed total catches.

Estimated catches of pelagic species such as Atlantic mackerel, Atlantic horse mackerel and Atlantic herring contributed the most to the unreported component (Figure 4c). Estimated catches of demersal species such as whiting, European plaice and haddock contributed the most to total discards (Figure 4d).

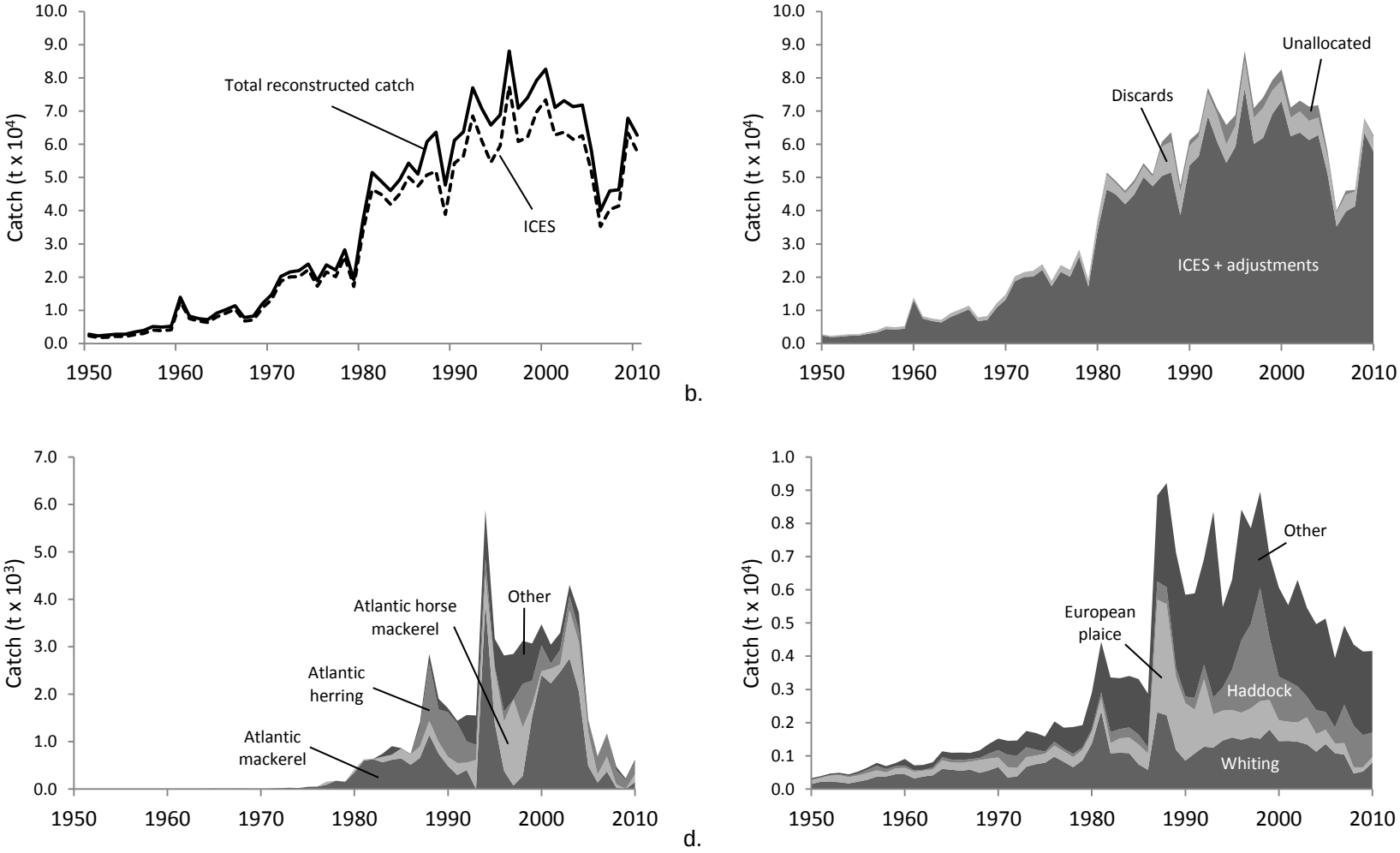

Figure 4 Irish fisheries removals from outside the Irish EEZ but within the Northeast Atlantic for the period 1950-2010; (a) total reconstructed removals (solid line) as well as landings reported within the 'Official Catch Statistics' dataset available through ICES (dashed line); (b) total reconstructed removals by category, inclusing ICES + source adjustments, basking shark landings, 'unallocated' landing estimates as reported by ICES, discards and retained recreational catch; (c) total unreported landings by taxon; and (d) total discards by taxon.

DISCUSSION

Our reconstruction suggests total Irish catches from 1950 to 2010 were approximately 19.3% higher than landings officially reported by ICES for Ireland from the Northeast Atlantic. Total Irish catches were found to be 20.9% higher in Ireland's EEZ than reported landings suggest (Figure 2a). Our reconstruction integrated a decision-making process which favoured the use of lowest quantity or rates being chosen for deriving data anchor points (Rossing et al., 2010). Thus, we consider the total catches estimated here to be conservative and a minimal estimate. Actual total catches for this time period are thus likely even higher than estimated here (Zeller et al., 2011).

ICES does currently consider some estimates of discarded and unreported removals when conducting individual stock assessments (Marine Institute, 2011a). However, what is lacking is a comprehensive and transparent dataset of discarding and 'unallocated' catches by country, year, area and species, incorporating estimates of all catch components for all marine species that face human-induced mortality directly or indirectly through fishing activities. The European public, and the global community, has the right to know exactly how much of these publically owned resources are caught (and discarded) by which country and where. The need for such transparent and comprehensive public accounting, in the face of ongoing overfishing problems in EU waters (Froese & Proelß, 2010; EC, 2011; Villasante et al., 2011), points to the need for 100% observer coverage in all commercial fishing activities (Zeller et al., 2011), and regular survey based estimation of recreational fisheries catches (Zeller et al., 2007, 2008). Complete observer coverage is readily achievable in any fishery that is sustainable and not overcapitalized, as evidenced by the Canadian West Coast groundfish fishery (Branch et al., 2006). Overcapitalized fisheries, such as many EU fleets

will require often substantial reductions in fleet capacity before any notion of sustainability can be achieved (Pauly et al., 2002).

Discarding was identified as the largest contributor to unreported fisheries catches (Figures 2b and 4b). This is disconcerting, as unlike other forms of unreported catches (such as some recreational catches), discarding is nothing more than a wasteful treatment of marine life. Although discards are consumed by the marine food web after they are thrown back (even if ultimately only by the bacterial food-web), this role as a dead and decaying food source has artificially been imposed as a result of fishing activities. In large quantities, discarding may have unpredictable repercussions on ecosystem dynamics (Goñi, 1998; Jennings & Kaiser, 1998).

The EU's Common Fisheries Policy (CFP) incorporates the use of single-stock quotas, which have been widely recognised as perpetuating and even increasing the discarding problem within European fisheries. The CFP's quota system incentivises discarding behaviour through placing limits only on total 'landings' of target stocks, rather than actual 'catches' of all marine species (EC, 2009b; Khalilian et al., 2010; EC, 2011). Change is potentially on the horizon however, as the European Council of Fisheries Ministers recently accepted a proposal to phase out the practice of discarding commercially targeted species (EU, 2012). Such a practise of discard banning, however, requires extremely strict and tight monitoring and enforcement, something only achievable with 100% observer coverage of all fleets (Zeller et al., 2011). Complete observer coverage is readily achievable in fisheries that have addressed over-capacity problems and are fishing sustainably, as evidenced by demersal fisheries off the west coast of Canada (Branch, 2006, Branch et al., 2006). This policy change could potentially bring tremendous improvements to the quality of collected catch records. In the interim, efforts to increase the accessibility of fisheries data relating to discards should be encouraged. Ireland has taken a step towards improving the

transparency of the fishing industry by publically releasing their report on discarding within the Irish demersal fishing fleet which has been utilised as a data source for this reconstruction (Marine Institute, 2011b). Such an approach is highly commendable.

Cumulative 'unallocated' (i.e., unreported) catch, estimated from data reported through ICES stock assessment working groups, was the second highest contributor to this reconstruction of total Irish fisheries catches (Figures 2b and 4b). Considering evidence obtained through various Irish media reports however, we suspect that illegal, unreported and unregulated (IUU) landings, which should be included in this category of 'unallocated' catch, could potentially increase the catch figures estimated through the present reconstruction substantially (Donegal Times, 2004; Fishupdate.com, 2006; Irish Examiner, 2006; The Times Online (UK), 2006a; The Times Online (UK), 2006b; The Times Online (UK), 2006c). Unfortunately, due to insufficient supporting evidence and uncertainties in the reliability of associated original information sources and reported values, we decided to remain conservative. Thus, we refrained from integrating media-reported IUU catch quantities into the reconstruction. However, once suspected IUU activities become known, it should be the responsibility of the authorities processing these charges to report this information publically through the appropriate channels so that additional catch quantities can be incorporated into official catch records. This should be an inherent part of transparency of governance and public resource accounting.

Although the reconstruction presented here only provides an estimate of total catches for the time period 1950 to 2010, this exercise has clearly identified sectors where the quality and coverage of Irish fisheries data should be improved. Inshore catches made by vessels less than ten meters in length are not extracted from logbook records but rather are estimated through the consideration of sales note data. The Irish Department of Defence has reported that in recent years, the inshore sector has grown substantially with many vessels ten meters

or more in length often decommissioned in favour of smaller vessels (Department of Defence and Defence Forces, 2011). Effort displacement after the closure of the salmon drift net fishery in 2007, and the rising costs of fuel have been mentioned as factors contributing to this recent capacity shift (Marine Institute, 2006). The Department of Defence has expressed concerns about this trend, as these smaller vessels are being operated by experienced fishers, now fishing under weaker regulations with less monitoring requirements (Department of Defence and Defence Forces, 2011). Thus, the current ten meter logbook exemption rule needs changing, and all commercial fishing operation will require the same fisheries regulations, reporting and monitoring requirements as other commercial fisheries.

Data on retained recreational catch were the most difficult to obtain. Efforts should be applied to increase the accountability of the recreational fishing sector through, for example, a survey-based monitoring scheme. The complete absence of quantitative data on this sector has left a gap in our understanding of recreational fisheries in Ireland.

CONCLUSIONS

After completing this catch reconstruction, it is noted that the dataset which has been created only accounts for catches made by Irish fishing vessels, neglecting foreign fishing activities within the Irish EEZ. A complete catch reconstruction of all catches in the Irish EEZ, and which would represent total fishing activity within this area would need to incorporate catches of foreign vessels within Irish waters. Such a spatial catch accounting is undertaken by the *Sea Around Us* Project (www.seaaroundus.org), which will be using the present data as one of their input datasets. The reconstructed Irish catch dataset described here represents

a first attempt at estimating total Irish removals from the Northeast Atlantic and the Irish EEZ.

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374 # SUPPLEMENTARY MATERIALS

Table 1 Estimated proportions of Irish landings caught within the Irish EEZ in ICES Sub-areas VIa-b; VIIa; VIIc; and VIIg-k.

Common name	Scientific name	ICES Sub-area	Assumed proportion within Irish EEZ
Atlantic cod	*Gadus morhua*	VIa	0.65
Atlantic cod	*Gadus morhua*	VIb	0.01
Atlantic cod	*Gadus morhua*	VIIa	0.85
Atlantic cod	*Gadus morhua*	VIIc	1.00
Atlantic cod	*Gadus morhua*	VIIg	0.90
Atlantic cod	*Gadus morhua*	VIIg-k	0.95
Atlantic cod	*Gadus morhua*	VIIj	1.00
Atlantic cod	*Gadus morhua*	VIIk	1.00
Atlantic herring	*Clupea harengus*	VIa	0.90
Atlantic herring	*Clupea harengus*	VIb	1.00
Atlantic herring	*Clupea harengus*	VIIa	0.40
Atlantic herring	*Clupea harengus*	VIIc	1.00
Atlantic herring	*Clupea harengus*	VIIg	0.99
Atlantic herring	*Clupea harengus*	VIIg-k	1.00
Atlantic herring	*Clupea harengus*	VIIj	1.00
Atlantic herring	*Clupea harengus*	VIIk	1.00
Atlantic horse mackerel	*Trachurus trachurus*	VIa	0.85
Atlantic horse mackerel	*Trachurus trachurus*	VIb	1.00
Atlantic horse mackerel	*Trachurus trachurus*	VIIa	1.00
Atlantic horse mackerel	*Trachurus trachurus*	VIIc	1.00
Atlantic horse mackerel	*Trachurus trachurus*	VIIg	0.90
Atlantic horse mackerel	*Trachurus trachurus*	VIIg-k	0.99
Atlantic horse mackerel	*Trachurus trachurus*	VIIj	1.00
Atlantic horse mackerel	*Trachurus trachurus*	VIIk	1.00
Atlantic mackerel	*Scomber scombrus*	VI and VII	0.85
Atlantic mackerel	*Scomber scombrus*	VIa	0.70
Atlantic mackerel	*Scomber scombrus*	VIb	0.00
Atlantic mackerel	*Scomber scombrus*	VIIa	0.95
Atlantic mackerel	*Scomber scombrus*	VIIc	1.00
Atlantic mackerel	*Scomber scombrus*	VIIg	0.65
Atlantic mackerel	*Scomber scombrus*	VIIg-k	0.90
Atlantic mackerel	*Scomber scombrus*	VIIj	1.00
Atlantic mackerel	*Scomber scombrus*	VIIk	1.00
Blue whiting	*Micromesistius poutassou*	Via	0.75
Blue whiting	*Micromesistius poutassou*	VIb	1.00
Blue whiting	*Micromesistius poutassou*	VIIa	1.00

Blue whiting	*Micromesistius poutassou*	VIIc	1.00
Blue whiting	*Micromesistius poutassou*	VIIg	1.00
Blue whiting	*Micromesistius poutassou*	VIIg-k	1.00
Blue whiting	*Micromesistius poutassou*	VIIj	1.00
Blue whiting	*Micromesistius poutassou*	VIIk	1.00
Common sole	*Solea solea*	Via	0.60
Common sole	*Solea solea*	VIb	0.00
Common sole	*Solea solea*	VIIa	0.85
Common sole	*Solea solea*	VIIc	1.00
Common sole	*Solea solea*	VIIg	0.80
Common sole	*Solea solea*	VIIg-k	0.85
Common sole	*Solea solea*	VIIj	1.00
Common sole	*Solea solea*	VIIk	1.00
European hake	*Merluccius merluccius*	Via	0.50
European hake	*Merluccius merluccius*	VIb	0.01
European hake	*Merluccius merluccius*	VIIa	0.60
European hake	*Merluccius merluccius*	VIIc	1.00
European hake	*Merluccius merluccius*	VIIg	0.95
European hake	*Merluccius merluccius*	VIIg-k	0.95
European hake	*Merluccius merluccius*	VIIj	1.00
European hake	*Merluccius merluccius*	VIIk	1.00
European plaice	*Pleuronectes platessa*	Via	0.40
European plaice	*Pleuronectes platessa*	VIb	1.00
European plaice	*Pleuronectes platessa*	VIIa	0.70
European plaice	*Pleuronectes platessa*	VIIc	1.00
European plaice	*Pleuronectes platessa*	VIIg	0.85
European plaice	*Pleuronectes platessa*	VIIg-k	0.85
European plaice	*Pleuronectes platessa*	VIIj	1.00
European plaice	*Pleuronectes platessa*	VIIk	1.00
Haddock	*Melanogrammus aeglefinus*	VIa	0.65
Haddock	*Melanogrammus aeglefinus*	VIb	0.01
Haddock	*Melanogrammus aeglefinus*	VIIa	0.80
Haddock	*Melanogrammus aeglefinus*	VIIc	1.00
Haddock	*Melanogrammus aeglefinus*	VIIg	0.90
Haddock	*Melanogrammus aeglefinus*	VIIg-k	0.90
Haddock	*Melanogrammus aeglefinus*	VIIj	1.00
Haddock	*Melanogrammus aeglefinus*	VIIk	1.00
Ling	*Molva molva*	VIa	0.75
Ling	*Molva molva*	VIb	0.01
Ling	*Molva molva*	VIIa	0.80
Ling	*Molva molva*	VIIc	1.00

Ling	*Molva molva*	VIIg	0.80
Ling	*Molva molva*	VIIg-k	0.85
Ling	*Molva molva*	VIIj	1.00
Ling	*Molva molva*	VIIk	1.00
Megrim	*Lepidorhombus whiffiagonis*	VIa	0.30
Megrim	*Lepidorhombus whiffiagonis*	VIb	0.01
Megrim	*Lepidorhombus whiffiagonis*	VIIa	0.90
Megrim	*Lepidorhombus whiffiagonis*	VIIc	1.00
Megrim	*Lepidorhombus whiffiagonis*	VIIg	0.85
Megrim	*Lepidorhombus whiffiagonis*	VIIg-k	0.85
Megrim	*Lepidorhombus whiffiagonis*	VIIj	1.00
Megrim	*Lepidorhombus whiffiagonis*	VIIk	1.00
Monkfish	*Lophius* spp.	VIa	0.50
Monkfish	*Lophius* spp.	VIb	0.01
Monkfish	*Lophius* spp.	VIIa	0.80
Monkfish	*Lophius* spp.	VIIc	1.00
Monkfish	*Lophius* spp.	VIIg	0.75
Monkfish	*Lophius* spp.	VIIg-k	0.90
Monkfish	*Lophius* spp.	VIIj	1.00
Monkfish	*Lophius* spp.	VIIk	1.00
Norway lobster	*Nephrops norvegicus*	VIa	0.30
Norway lobster	*Nephrops norvegicus*	VIb	0.01
Norway lobster	*Nephrops norvegicus*	VIIa	0.80
Norway lobster	*Nephrops norvegicus*	VIIc	1.00
Norway lobster	*Nephrops norvegicus*	VIIg	0.55
Norway lobster	*Nephrops norvegicus*	VIIg-k	0.60
Norway lobster	*Nephrops norvegicus*	VIIj	1.00
Norway lobster	*Nephrops norvegicus*	VIIk	1.00
Rays and skates	Batoidea	VIa	0.50
Rays and skates	Batoidea	VIb	0.01
Rays and skates	Batoidea	VIIa	0.90
Rays and skates	Batoidea	VIIc	1.00
Rays and skates	Batoidea	VIIg	0.85
Rays and skates	Batoidea	VIIg-k	0.90
Rays and skates	Batoidea	VIIj	1.00
Rays and skates	Batoidea	VIIk	1.00
Shellfish	Assorted species	VI and VII	1.00
Tuna	*Thunnus* spp.	VIa	1.00
Tuna	*Thunnus* spp.	VIb	0.00
Tuna	*Thunnus* spp.	VIIa	1.00
Tuna	*Thunnus* spp.	VIIc	1.00

Tuna	*Thunnus* spp.	VIIg	0.85
Tuna	*Thunnus* spp.	VIIj	0.90
Tuna	*Thunnus* spp.	VIIk	0.99
Whiting	*Merlangius merlangus*	VIa	0.40
Whiting	*Merlangius merlangus*	VIb	0.01
Whiting	*Merlangius merlangus*	VIIa	0.75
Whiting	*Merlangius merlangus*	VIIc	1.00
Whiting	*Merlangius merlangus*	VIIg	0.70
Whiting	*Merlangius merlangus*	VIIg-k	0.70
Whiting	*Merlangius merlangus*	VIIj	1.00
Whiting	*Merlangius merlangus*	VIIk	1.00
Other coastal	Assorted species	VIa	1.00
Other coastal	Assorted species	VIb	1.00
Other coastal	Assorted species	VIIa	0.79
Other coastal	Assorted species	VIIc	1.00
Other coastal	Assorted species	VIIg	0.80
Other coastal	Assorted species	VIIg-k	0.84
Other coastal	Assorted species	VIIj	1.00
Other coastal	Assorted species	VIIk	1.00
Other deepwater	Assorted species	VIa	1.00
Other deepwater	Assorted species	VIb	1.00
Other deepwater	Assorted species	VIIa	0.79
Other deepwater	Assorted species	VIIc	1.00
Other deepwater	Assorted species	VIIg	0.80
Other deepwater	Assorted species	VIIg-k	0.84
Other deepwater	Assorted species	VIIj	1.00
Other deepwater	Assorted species	VIIk	1.00
Other demersal & offshore invertebrates	Assorted species	VI and VII	0.85
Other demersal & offshore invertebrates	Assorted species	VIa	0.53
Other demersal & offshore invertebrate species	Assorted species	VIb	0.01
Other demersal & offshore invertebrate species	Assorted species	VIIa	0.79
Other demersal & offshore invertebrate species	Assorted species	VIIc	1.00
Other demersal & offshore invertebrate species	Assorted species	VIIg	0.80
Other demersal & offshore invertebrate species	Assorted species	VIIg-k	0.84
Other demersal & offshore invertebrate species	Assorted species	VIIj	1.00
Other demersal & offshore invertebrate species	Assorted species	VIIk	1.00
Other flatfish	Assorted species	VIa	0.31
Other flatfish	Assorted species	VIb	1.00
Other flatfish	Assorted species	VIIa	0.82
Other flatfish	Assorted species	VIIc	1.00
Other flatfish	Assorted species	VIIg	0.83

Other flatfish	Assorted species	VIIg-k	0.85
Other flatfish	Assorted species	VIIj	1.00
Other flatfish	Assorted species	VIIk	1.00
Other large pelagic	Assorted species	VI and VII	See'Tuna'[a]
Other small pelagic	Assorted species	VI and VII	See 'Herring', 'Horse Mackerel' or Blue whiting'[a]

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376 [a] A large number of individual species were included within the 'Common name' categories referred to as 'Other large pelagic'
377 and 'Other small pelagic'. For each of these species, inclusion values used for either 'Tuna', 'Herring', 'Horse Mackerel' or 'Blue
378 whiting' were applied, based on similarities in life history traits.