Reconstructing Ireland's marine fisheries catches: 1950-2010

Dana D. Miller*[1] and Dirk Zeller[2]

[1]Fisheries Economics Research Unit, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC, Canada, V6T 1Z4

[2]Sea Around Us Project, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC, Canada, V6T 1Z4

*To whom correspondence should be addressed: Tel: +1 604 341 6339. E-mail: d.miller@fisheries.ubc.ca

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

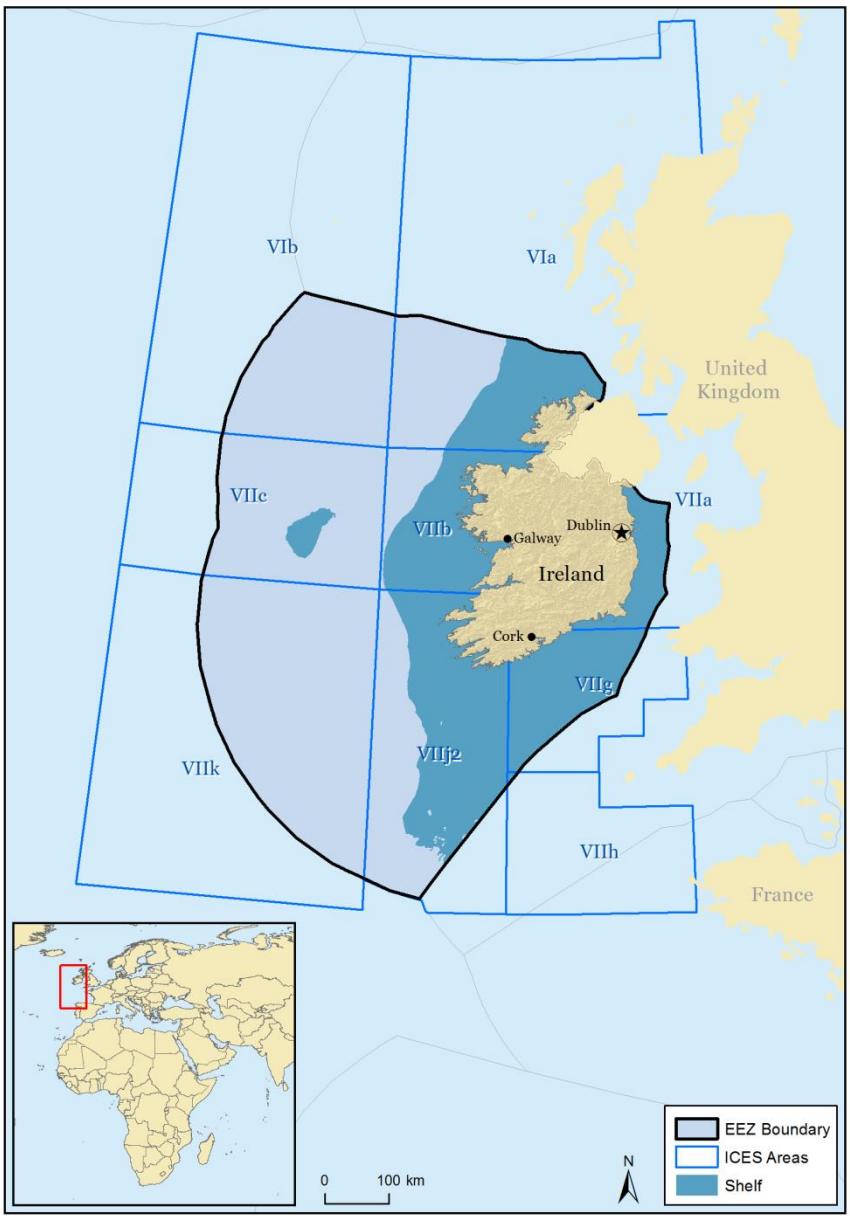


Figure 1 The Irish Exclusive Economic Zone (EEZ) and the ICES Divisions around the Irish Coast. Image generated by the *Sea Around Us* Project, courtesy of Christopher Hoornaert.

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,

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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,

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

197 2007). Vessels under ten meters in length are not required to keep fishing logbooks, and as
198 recently as 2007, a large fraction of the vessels working in the inshore sector were not
199 properly licensed or registered (Connolly et al., 2001; Marine Institute, 2007). Landings made
200 by the inshore sector, which are ultimately reported to ICES, are currently estimated
201 primarily through the examination of sales notes which are required for all transactions
202 involving the sale of over ten kilograms of fish or shellfish (Marine Institute, 2007; C. O
203 Shea, pers. comm., SFPA). This system of data collection has been criticised for not
204 providing a reliable long-term inshore fisheries dataset (Connolly et al., 2001; Marine
205 Institute, 2007; O. Tully, pers. comm., Marine Institute).

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

212

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).

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

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

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

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

252

253

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

279 time to cover years where data were not available as trends within the data were often
280 inconsistent, including estimates of both under-reporting and over-reporting. However, this
281 likely resulted in underestimation of total time series 'unallocated' catches, and hence our
282 data should be considered minimal estimates of this category.
283

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'

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

				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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

376 combined, creating a final dataset of estimated retained catch quantities from all angling
377 activities in Ireland from 1950 to 2010.
378
379 ***Basking sharks***
380 Landing records from a localised coastal basking shark fishery on Achill Island, Co. Mayo
381 which had previously not been included within national landings records were added for the
382 years 1950 to 1975 (Kunzlik, 1988). These data were not extrapolated beyond these years as
383 it was known that this fishery closed in 1975 due to a diminished local population of sharks.
384
385 **Discards**
386 Estimates of the quantity of catch discarded annually by Irish commercial fishing vessels
387 were calculated primarily through data provided in the recently published 'Atlas of Demersal
388 Discarding', produced by the Irish Marine Institute (Marine Institute, 2011b). This Atlas
389 included discarding rates for the ten most commercially important demersal species by
390 weight and also discarded quantities of the ten most highly discarded non-commercial species
391 by weight. In addition, discarding estimates for a number of pelagic and shellfish species
392 were derived from other national sources and were included in the reconstruction. Discard
393 quantities for the Irish fleet were only estimated for the stocks for which stock-specific
394 discarding data were available, listed in Table 3, and are thus likely a minimal estimate of
395 total discarding.
396
397 ***Estimated discards from Irish demersal fisheries***
398 *Commercially targeted demersal stocks*
399 Discard estimates for each commercially fished demersal stock listed in Table 3, both within
400 and outside the Irish EEZ, were calculated by applying the stock-specific 'discard' rates

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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)

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

433 ***Pelagic discarding estimates***

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

447

448 ***Shellfish discarding estimates***

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

458 of extraction. Estimated discard quantities of scallops from 1950 were calculated using 50%
459 of the discarding rate for 2001 and discarding rates from 1951 to 2000 were calculated
460 through linear interpolation.
461
462 **Separation of reconstructed catch by sector**
463 In an attempt at allocating the final reconstructed catch data to the appropriate sectors from
464 which fish were caught, total reconstructed catch quantities for each species and fishing area
465 were separated into catches by the 'artisanal' (small-scale) fishing sector, the 'industrial'
466 (large-scale) fishing sector, and the 'recreational' (sea angling) fishing sector. All recreational
467 catch quantities were entirely reconstructed and the approach taken has been outlined in the
468 section entitled '***Retained recreational catch'***. All remaining catch data including both
469 reported landings and reconstructed catch were allocated as landings by the artisanal or
470 industrial fishing sector based on comparisons with landings data obtained from the Irish
471 Marine Institute for the years 2003-2010 (M. Clarke, pers. comm., Marine Institute). This
472 dataset contained information on the size of the fishing boats ('under ten meters', or 'ten
473 meters or over') that had caught all reported landing quantities, recorded by species and by
474 port of landing. For the purposes of this catch reconstruction, we interpreted that catches
475 made by vessels 'under ten meters' and within the Irish EEZ were made by the small-scale or
476 artisanal fishing sector. In addition, catches made by vessels 'ten meters or over' or outside
477 the Irish EEZ were made by the large-scale or industrial fishing sector.
478 Species that were recorded as being caught entirely by only one sector were assigned
479 as being caught by this same sector throughout the entire reconstructed dataset. For species
480 that were recorded as being caught partially by the artisanal sector and partially by the
481 industrial sector, proportional values were calculated for each year from 2003 to 2010,

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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).

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

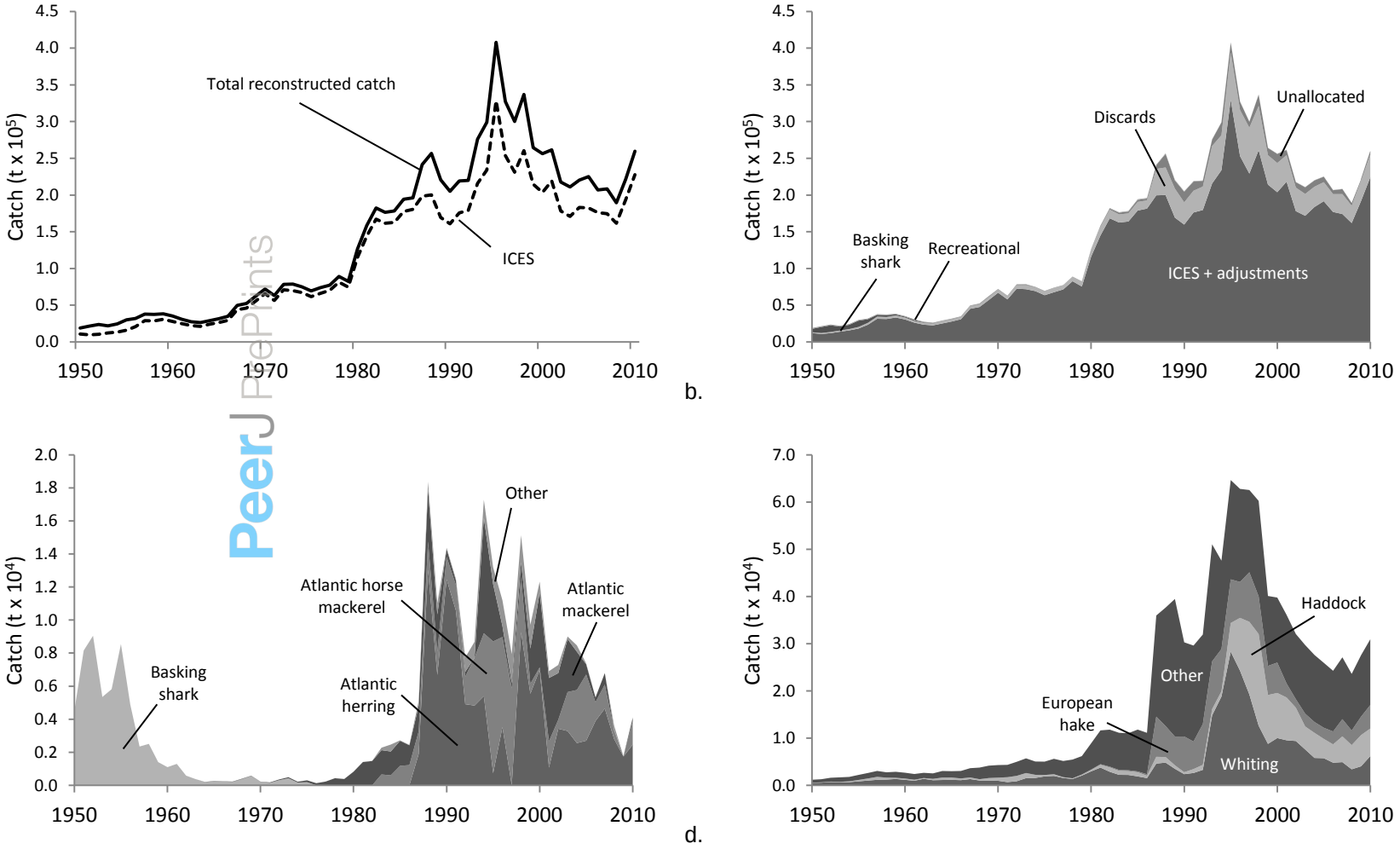
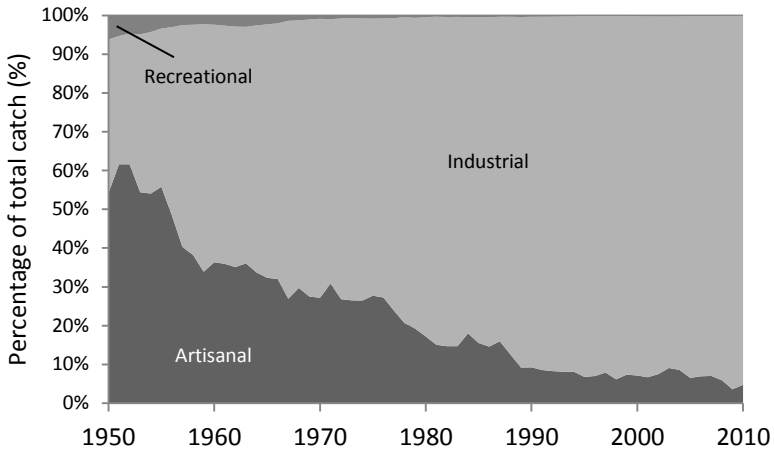


Figure 2 Irish fisheries removals from within the Irish EEZ for the period 1950-2010; (a) total reconstructed removals (solid line) as well as landings reported within the 'Official Catch Statistics' dataset available through ICES (dashed line); (b) total reconstructed removals by category, inclusing 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.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1



549

550 **Figure 3** Total Irish reconstructed fisheries removals within the Northeast Atlantic for the period 1950-
551 2010 by sector from within the Irish EEZ.
552

553 **Catches outside the Irish Exclusive Economic Zone (EEZ)**

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

561 Towards the end of the time series, discards and unreported catches increased, along
562 with their relative contribution to total annual catch quantities (Figure 4b). From 1990 to
563 2010, discards and unreported catches represented on average 9.1% and 3.4%, respectively,
564 of the reconstructed total catches.

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

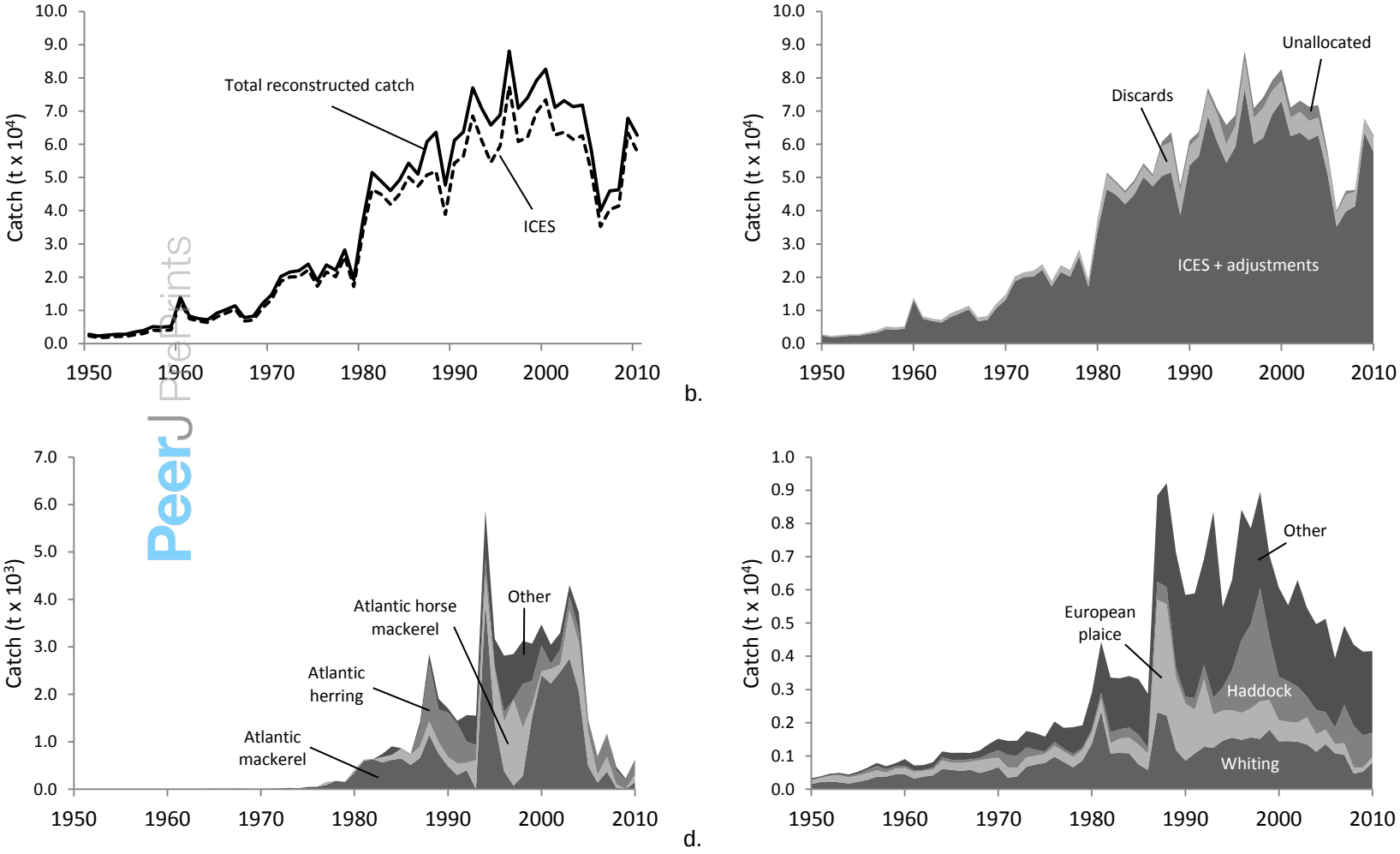


Figure 4 Irish fisheries removals from outside the Irish EEZ but within the Northeast Atlantic for the period 1950-2010; (a) total reconstructed removals (solid line) as well as landings reported within the 'Official Catch Statistics' dataset available through ICES (dashed line); (b) total reconstructed 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.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

575 **DISCUSSION**

576

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

585 ICES does currently consider some estimates of discarded and unreported removals
586 when conducting individual stock assessments (Marine Institute, 2011a). However, what is
587 lacking is a comprehensive and transparent dataset of discarding and 'unallocated' catches by
588 country, year, area and species, incorporating estimates of all catch components for all marine
589 species that face human-induced mortality directly or indirectly through fishing activities.
590 The European public, and the global community, has the right to know exactly how much of
591 these publically owned resources are caught (and discarded) by which country and where.
592 The need for such transparent and comprehensive public accounting, in the face of ongoing
593 overfishing problems in EU waters (Froese & Proelß, 2010; EC, 2011; Villasante et al.,
594 2011), points to the need for 100% observer coverage in all commercial fishing activities
595 (Zeller et al., 2011), and regular survey based estimation of recreational fisheries catches
596 (Zeller et al., 2007, 2008). Complete observer coverage is readily achievable in any fishery
597 that is sustainable and not overcapitalized, as evidenced by the Canadian West Coast
598 groundfish fishery (Branch et al., 2006). Overcapitalized fisheries, such as many EU fleets

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

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

609 The EU's Common Fisheries Policy (CFP) incorporates the use of single-stock
610 quotas, which have been widely recognised as perpetuating and even increasing the
611 discarding problem within European fisheries. The CFP's quota system incentivises
612 discarding behaviour through placing limits only on total 'landings' of target stocks, rather
613 than actual 'catches' of all marine species (EC, 2009b; Khalilian et al., 2010; EC, 2011).
614 Change is potentially on the horizon however, as the European Council of Fisheries Ministers
615 recently accepted a proposal to phase out the practice of discarding commercially targeted
616 species (EU, 2012). Such a practise of discard banning, however, requires extremely strict
617 and tight monitoring and enforcement, something only achievable with 100% observer
618 coverage of all fleets (Zeller et al., 2011). Complete observer coverage is readily achievable
619 in fisheries that have addressed over-capacity problems and are fishing sustainably, as
620 evidenced by demersal fisheries off the west coast of Canada (Branch, 2006, Branch et al.,
621 2006). This policy change could potentially bring tremendous improvements to the quality of
622 collected catch records. In the interim, efforts to increase the accessibility of fisheries data
623 relating to discards should be encouraged. Ireland has taken a step towards improving the

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

673 a first attempt at estimating total Irish removals from the Northeast Atlantic and the Irish
674 EEZ.
675
676 **ACKNOWLEDGEMENTS**
677
678 The authors would like to thank Oliver Tully, Edward Fahy, Maurice Clarke and Stefano
679 Mariani for information and/or advice provided throughout the reconstruction process. In
680 addition, Ashley Hayden, Willie Roche and Johnny Woodlock are to be thanked for
681 providing information and/or guidance that was useful for the recreational component of this
682 project. The contributions of Ciaran Kelly and Sarah Harper in providing comments on
683 earlier drafts of the manuscript are appreciated. Lastly, many thanks to Daniel Pauly and
684 others within UBC's Fisheries Centre for their support and insightful discussions throughout
685 the duration of this project. This is a contribution of the *Sea Around Us* project, a scientific
686 collaboration between The University of British Columbia and The Pew Charitable Trust.
687
688
689 **REFERENCES**
690
691 Borges L, Rogan E, Officer R. 2005. Discarding by the demersal fishery in the waters
692 around Ireland. *Fisheries Research* 76: 1-13.
693
694 Branch T. 2006. Discards and revenues in multispecies groundfish trawl fisheries managed
695 by trip limits on the U.S. West Coast and by ITQs in British Columbia. *Bulletin of*
696 *Marine Science* 78(3): 669-690.
697

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

698 Branch T, Rutherford K, Hilborn R. 2006. Replacing trip limits with individual
699 transferable quotas: implications for discarding. *Marine Policy* 30: 281-292.
700
701 Connolly N, Buchanan C, O'Connell M, Cronin M, O'Mahony C, Sealy H, Kay D,
702 Buckley S. 2001. Assessment of Human Activity in the Coastal Zone: a research
703 project linking Ireland and Wales. Maritime Ireland/Wales INTERREG Report NO.9.
704 Measure 1.3: Protection of the Marine and Coastal Environment and Marine
705 Emergency Planning, 136 p.
706
707 CSO (Central Statistics Office). 2012. Population Estimates by Sex, Age Group and Year
708 (1950-2011). Statistical Product – Population Estimates. Central Statistics Office,
709 Ireland. *Available at*
710 http://www.cso.ie/px/pxeirestat/database/eirestat/Population%20Estimates/Population
711 %20Estimates_statbank.asp (accessed 29 July 2012).
712
713 Cummins V, Coughlan S, McClean O, Connolly N, Mercer J, Burnell G. 2002. An
714 assessment of the potential for the sustainable development of the edible periwinkle,
715 *Littorina littorea*, industry in Ireland. Coastal and Marine Resources Centre,
716 Environmental Research Institute, University College Cork, Ireland, 82 p.
717
718 de Courcy Ireland J. 1981. Ireland's Sea Fisheries: a History. The Glendale Press, Dublin.
719
720 Department of Defence and the Defence Forces. 2011. Dept of Defence submission CFP
721 Dec 11. Common fisheries policy review, submissions received on CFP proposals
722 2011. FishingNET, the Irish Government's commercial sea fishing network portal, 5

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

p. *Available at* http://www.fishingnet.ie/media/fishingnet/content/commonfisheriespolicyreview/submissionsreceivedoncfpproposals2011/Dept_of_Defence_submisssion_CFP_dec_11.pdf (accessed 29 July 2012).

Donegal Times. 2004. Fraud squad target Killybegs, 24 November 2004. *Available at* http://www.donegaltimes.com/2004/11_2/other.html (accessed 29 July 2012).

Donnelley RR. 2009. Technical Report: Economic Impact of Recreational Sea Angling in Scotland. The Scottish Government, Edinburgh, 263 p.

EC (European Commission). 2009a. The Common Fisheries Policy - a user‟s guide. Office for Official Publications of the European Communities, Luxembourg.

EC (European Commission). 2009b. Green Paper: Reform of the Common Fisheries Policy. Com (2009) 163 final. Commission of the European Communities, Brussels.

EC (European Commission). 2011. Proposal for a Regulation of the European Parliament and of the Council on the Common Fisheries Policy. Com (2011) 425 final. Commission of the European Communities, Brussels.

EU (European Union). 2011. Press Release - 3174th Agriculture and Fisheries Council meeting - Luxembourg, 12 June 2012. EN 1111/12 Presse 258 PR CO 36. Council of the European Union, Brussels, 9 p. *Available at*

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/agricult/130884.pdf (accessed 29 July 2012).

Fahy E, Carroll J, O'Toole M, Barry C, Hother-Parkes L. 2004. Fishery-associated changes in the whelk *Buccinum undatum* stock in the Southwest Irish Sea, 1995-2003. Irish Fisheries Investigations Number 15. Fisheries Science Services, Marine Institute, Dublin, Ireland, 32 p.

FAO (Food and Agriculture Organization of the United Nations). 2012. Coordinating Working Party on Fishery Statistics (CWP) Handbook of Fishery Statistical Standards. Section I: Conversion factors from landed to nominal weight. FAO, Fisheries and Aquaculture Department, Rome. *Available at* http://www.fao.org/fishery/cwp/handbook/I/en (accessed 29 July 2012).

Fishupdate.com. 2006. Moves to tackle illegal mackerel landings by the Irish fleet into Scotland are being tackled. *Available at* http://www.illegal-fishing.info/item_single.php?item=news&item_id=862&approach_id=21 (accessed 29 July 2012).

Froese R, Proelß A. 2010. Rebuilding fish stocks no later than 2015: will Europe meet the deadline? *Fish and Fisheries* 11: 194-202.

Goñi R. 1998. Ecosystem effects of marine fisheries: an overview. *Ocean and Coastal Management* 40(1): 37-64.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

772 ICES (International Council for the Exploration of the Sea). 2011. ICES Catch Statistics
773 1950-2010. Eurostat/ICES database on catch statistics, ICES 2011, Copenhagen.
774 *Available at* http://www.ices.dk/fish/CATCHSTATISTICS.asp (accessed 15 July
775 2012).
776
777 ICES (International Council for the Exploration of the Sea). 2012. The Data Centre:
778 Submitting Data. ICES, Copenhagen. *Available at*
779 http://www.ices.dk/datacentre/Submissions/index.aspx?t=1 (accessed 29 July 2012).
780
781 Irish Examiner. 2006. Gallagher future – fishing industry needs reform, 14 February, 2006.
782 *Available at* http://www.illegal-
783 fishing.info/item_single.php?item=news&item_id=41&approach_id=21 (accessed 29
784 July 2012).
785
786 ISFC (Irish Specimen Fish Committee). 2012. List of specimen weights for marine fish
787 species. ISFC, Ireland. *Available at* http://www.irish-trophy-
788 fish.com/trophies/marine.htm (accessed 29 July 2012).
789
790 Jennings S, Kaiser MJ. 1998. The effects of fishing on marine ecosystems. *Advances in*
791 *Marine Biology* 34: 201-212.
792
793 Jennings S, Greenstreet SPR, Hill L, Piet GJ, Pinnegar JK, Warr KJ. 2002.
794 Long-term trends in the trophic structure of the North Sea fish community: evidence
795 from stable-isotope analysis, size-spectra and community metrics. *Marine Biology*
796 141: 1085-1097.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

797

798 Kelleher K. 2005. Discards in the world's marine fisheries: an update. FAO Fisheries
799 Technical Paper 470. FAO Fisheries Department, Rome.

800

801 Khalilian S, Froese R, Proelss A, Requate T. 2010. Designed for failure: a critique
802 of the Common Fisheries Policy of the European Union. *Marine Policy* 34(6): 1178-
803 1182.

804

805 Kunzlik PA. 1988. The Basking Shark. Department of Agriculture and Fisheries for
806 Scotland. Scottish Fisheries Information Pamphlet No. 14.

807

808 Marine Institute. 2004. A National Survey of Water-Based Leisure Activities in Ireland 2003.
809 Marine Institute, Co. Galway, Ireland, 62 p.

810

811 Marine Institute. 2006. The Stock Book: Annual Review of Fish Stocks in 2006 with
812 Management Advice for 2007. Marine Institute Fisheries Science Services, Co.
813 Galway, Ireland, 425 p.

814

815 Marine Institute. 2007. The Stock Book: Annual Review of Fish Stocks in 2007 with
816 Management Advice for 2008. Marine Institute Fisheries Science Services, Co.
817 Galway, Ireland, 424 p.

818

819 Marine Institute. 2009. Atlas of the Commercial Fisheries around Ireland: 2009 review of
820 the fisheries of relevance around Ireland. Marine Institute Fisheries Science Services,
821 Co. Galway, Ireland, 64 p.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

822

823 Marine Institute. 2011a. The Stock Book: Annual Review of Fish Stocks in 2011 with
824 Management Advice for 2012. Marine Institute Fisheries Science Services, Co.
825 Galway, Ireland, 502 p.

826

827 Marine Institute. 2011b. Atlas of Demersal Discarding: Scientific Observations and Potential
828 Solutions. Marine Institute Fisheries Science Services, Co. Galway, Ireland, 93 p.

829

830 Marine Institute. 2011c. Shellfish Stocks and Fisheries Review, December, 2011. Shellfish
831 stocks and fisheries review 2011: an assessment of selected stocks. The Marine
832 Institute and Bord Iascaigh Mhara, Ireland, 67 p.

833

834 Marine Institute. 2012. The Stock Book: Annual 2012 Review of Fish Stocks with
835 Management Advice for 2013. Marine Institute Fisheries Ecosystems Advisory
836 Services, Co. Galway, Ireland, 606 p.

837

838 McArthur IS. 1959. Report to the Government of Ireland on the Development of the Sea
839 Fisheries Industries. Food and Agriculture Organisation of the United Nations, Rome.

840

841 Miller D, Clarke M, Mariani S. 2012. Mismatch between fish landings and market
842 trends: A western European case study. *Fisheries Research* 121: 104-114.

843

844 Molloy J. 2004. The Irish Mackerel Fishery and the Making of an Industry. Killybegs
845 Fishermens Organisation Ltd. and the Marine Institute, Killarney Printing Works,
846 Ireland.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

Österblom H, Sissenwine M, Symes D, Kadin M, Daw T, Folke C. 2011. Incentives, social-ecological feedbacks and European fisheries. *Marine Policy* 35: 568-574.

Pauly D. 1998. Rationale for reconstructing catch time series. *EC Fisheries Cooperation Bulletin* 11: 4-10.

Pauly D, Christensen V, Dalsgaard J, Froese R, Torres Jr. F. 1998. Fishing down marine food webs. *Science* 279: 860-863.

Pauly D, Christensen V, Guénette S, Pitcher TJ, Sumaila UR, Walters CJ, Watson R, Zeller D. 2002. Towards sustainability in world fisheries. *Nature* 418: 689-695.

Pikitch EK, Santora C, Babcock EA, Bakun A, Bonfil R, Conover DO, Dayton P, Doukakis P, Fluharty D, Heneman B, Houde ED, Link J, Livingston PA, Mangel M, McAllister MK, Pope J, Sainsbury KJ. 2004. Ecosystem-based fishery management. *Science* 305: 346-347.

Pinnegar JK, Polunin NVV, Badalamenti F. 2003. Long-term changes in the trophic level of western Mediterranean fishery and aquaculture landings. *Canadian Journal of Fisheries and Aquatic Sciences* 60(2): 222-235.

Pooley SG. 1993. Hawaii's marine fisheries: some history, long-term trends, and recent developments. *Marine Fisheries Review* 55(2): 7-19.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

872

873 Roberts C. 2007. Unnatural history of the sea. Island Press/Shearwater Books,
874 Washington D.C. XVII + 435 p.

875

876 Rossing P, Booth S, Zeller D. (Eds.). 2010. Total marine fisheries extractions by
877 country in the Baltic Sea: 1950-present. Fisheries Centre Research Report 18(1),
878 Fisheries Centre, University of British Columbia, Vancouver.

879

880 The Times Online (UK). 2006a. 140m EU fine over illegal fish, 5 February 2006. *Available*
881 *at* http://www.illegal-
882 fishing.info/item_single.php?item=news&item_id=37&approach_id=21 (accessed 29
883 July 2012).

884

885 The Times Online (UK). 2006b. A Fishy business, 12 February 2006. *Available at*
886 http://www.illegal-
887 fishing.info/item_single.php?item=news&item_id=58&approach_id=21 (accessed 29
888 July 2012).

889

890 The Times Online (UK). 2006c. Illegal fish haul in Rossaveal, 12 February 2006.
891 *Available at* http://www.illegal-
892 fishing.info/item_single.php?item=news&item_id=59&approach_id=21 (accessed 29
893 July 2012).

894

895 Villasante S, do Carme García-Negro M, González-Laxe F, Rodríguez GR. 2011.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

Overfishing and the Common Fisheries Policy: (un)successful results from TAC regulation? *Fish and Fisheries* 12: 34-50.

Zeller D, Booth S, Craig P, Pauly D. 2007. Re-estimation of small-scale fisheries catches for U.S. flag island areas in the Western Pacific: the last 50 years. *Fisheries Bulletin* 105: 266-277.

Zeller D, Darcy M, Booth S, Lowe MK, Martell SJ. 2008. What about recreational catch? Potential impact on stock assessment for Hawaii's bottomfish fisheries. *Fisheries Research* 91:88-97.

Zeller D, Cheung WWL, Close C, Pauly D. 2009. Trends in global marine fisheries – a critical view. In: Wrammer, P., Ackefors, H., Cullberg, M.s. (Eds.), Fisheries, Sustainability and Development. Royal Swedish Academy of Agriculture and Forestry, Stockholm, pp. 87-107.

Zeller D, Rossing P, Harper S, Persson L, Booth S, Pauly D. 2011. The Baltic Sea: Estimates of total fisheries removals 1950-2007. *Fisheries Research* 108: 356-363.

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

916 **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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1

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]

917

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

PeerJ PrePrints | https://peerj.com/preprints/150v1/ | v1 received: 11 Dec 2013, published: 11 Dec 2013, doi: 10.7287/peerj.preprints.150v1