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Title: Mismatch between fish landings and market trends: a western European case study

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Abstract

As an island nation, Ireland is connected to and responsible for the seas that surround it. Fishing has historically been one of the major anthropogenic activities linking Irish society to the marine environment. Deriving an approach from historical ecology, we investigated temporal patterns in the diversity of seafood landed, traded and marketed in Ireland by collating long-term datasets acquired from government sources and through conducting contemporary product surveys. Our findings suggest that consumer preferences have not adapted to changes in local resource supply. From the beginning of the 20th century, Irish landings of some of the traditionally most important seafood products have gradually grown, then sharply declined within the most recent 10-20 years, but access to ample supply appears to have been maintained in the Irish marketplace. Our results indicate that this trend has been concealed from consumers through import, aquaculture production and mislabeling. Future intentions of responsible management must incorporate policy implementation and enforcement, consumer education and industry transparency.

Keywords: Fishery landings; Historical ecology; Seafood consumption; Seafood trade

1. Introduction

The world's diverse and interconnected marine habitats are often in close association with human communities from coastal and island nations. The oceans of our planet are, and have been ecologically, economically and socially important to modern and ancient civilizations, contributing significantly to human welfare through both direct and indirect provisions and services (Costanza, 1999). Fishing has historically been one of the major anthropogenic activities directly connecting human societies to the marine environment, frequently to the eventual detriment of the ecosystems exploited (Jackson et al., 2001).

Prior to the development of fast and efficient transportation, isolated coastal and island communities were largely dependent on seafood for survival (Rick and Erlandson, 2008). At present, many communities in developing nations with limited other options still rely on local stocks of fish as an important source of dietary protein (FAO, 2010).

As the globalization of food industries has progressed, particularly developed countries have become more and more disconnected from the production and original sourcing of food (Taylor et al., 2007; Swartz et al., 2010). Advances in transportation have permitted a global seafood market with capabilities of shipping sushi-grade fresh fish nearly anywhere in the world (Bestor, 2001). Additionally, the processing of seafood often occurs in multiple locations, with fish caught in one country, processed in a second, and finally sold and consumed in a third (Mansfield, 2003).

Because of this changing global environment and as a result of other internal and external influences, food cultures have also changed over time, including preferences in both the variety of food consumed and approaches to food preparation (US Department of Commerce, 1992; Harnack et al., 2000; Darmon et al., 2003; Carroll, 2009; Levin and Dufault, 2010). We are no longer limited to consuming locally or even nationally produced food varieties (Mansfield, 2003). Despite these advances, historical patterns of food

consumption restricted by geographic constraints have certainly influenced modern cultures in their current food preferences. In some instances, dominant traditional food preferences have been maintained, even after the local wild availability of these resources has been dramatically reduced (EC, 2010; Katsukawa, 2011). The depletion of local resources could either force domestic markets to adapt by altering the variety of seafood available for purchase and consumption (Schrank, 2004; Scholderer and Trondsen, 2008; Richardson et al., 2009), or encourage a search for other sources of the same or similar varieties of food to import in order to maintain supply in the marketplace (Mansfield, 2003; Kirby, 2004; Hajipieris, 2009). In modern market environments often characterised by consumers seeking 'ready-made' meals and disconnected from the production of food (Park and Capps Jr., 1997; Geeroms et al., 2008), this mismatch of local resource availability and market preferences can perhaps go unnoticed.

The market demand for seafood resources in Europe is high and an oversaturated, unbalanced fishing industry has promoted the expansion of large-scale European Community subsidised fishing efforts in the foreign waters of developing countries (Kaczynski and Fluharty, 2002; Swartz et al., 2010). In addition, Europe is one of the world's largest importers of seafood products, highly dependent on the productivity of marine ecosystems elsewhere in the world to meet Community demand (EC, 2010; Swartz et al., 2010). On their own, six EU member states rank within the top ten importing countries in the world (FAO, 2010). A recently produced report estimated that in 2011, Europeans had hypothetically eaten the total annual quantity of fish locally produced by EU fisheries prior to July 2, relying after this date on fish sourced from foreign waters (Esteban and Crilly, 2011). This date is seven days earlier than that calculated for 2010 and more than one month earlier than for 2000, indicating a growing dependency on foreign fish. The inability of EU fisheries to meet the demand of EU markets is unlikely to improve. As of 2008, 88% of European stocks were

being fished at levels beyond maximum sustainable yield and an estimated 30% of these stocks were considered outside safe biological limits (EC, 2009).

Species produced primarily through aquaculture rank high amongst the seafood products most commonly consumed within the EU (EC, 2010). Although a perception is held by some European consumers that farmed fish is a sustainable alternative to fish captured in the wild (Vanhonacken et al., 2011), farming operations for predatory species such as salmon are not disconnected from wild fisheries and natural marine habitats. Open net-cage salmon farms introduce risks of parasite and disease transfer from contained fish to wild marine animals (Krkošek et al., 2005; Gross, 1998) as well as the escapement of farmed fish into surrounding marine environments which could have significant ecological implications (Gross, 1998). Farmed salmon also currently still require the inclusion of fish meal and fish oil within their diet resulting in a conversion ratio that produces a quantity of farmed fish that is less than the quantity of wild fish which is required for feed (Tacon and Metian, 2008). Although recent improvements have been made in the reduction of wild fish in aquaculture feed, a greater total use of small pelagic forage fish for feed has been observed as global aquaculture production continues to rise (Naylor et al., 2009). As a result, many scientists feel that rather than compensating for declining wild fish production, continued aquaculture development may instead exacerbate this problem (Pauly et al., 2002).

Irish waters provide an important contribution to the overall productivity of European fisheries, supporting the fishing activities of not only the Irish fleet, but both historically and currently also the intensive activities of other European fleets, namely those from France, Spain, the UK, Netherlands and Norway (McArthur, 1959; Marine Institute, 2009). The heavy levels of exploitation that Irish waters have experienced particularly within the last 50 years have not been without consequence. Overfishing has contributed to substantially declining trends in the landings of nearly all commercially exploited demersal species since

the 1970s, leaving some stocks severely depleted and giving national government fisheries scientists serious reason for concern (Marine Institute, 2009, 2010).

Research approaches that integrate long-term data records can potentially provide insight into the cause and scale of fisheries decline. In this study we derived an approach from historical ecology, obtaining and examining long-term data on the landings and market availability of seafood resources in Ireland over the last century. Our objective was to determine whether and how patterns of seafood availability and consumer preference have adapted in response to changes in local patterns of fish landings.

2. Material and methods

Long-term records and survey data relating to the production and market availability of all marine fish produced or consumed in Ireland were acquired through a variety of government sources. Freshwater fish, diadromous fish and shellfish have been excluded from our overall analysis of trends in market availability and production due to inconsistencies in their inclusion within the primary records obtained. Independent datasets containing information on the production and trade of salmon however, were additionally obtained and in consideration of the commercial importance of both salmon and cod in Ireland (BIM, 2011), case study analyses of trends in the domestic supply of these products were separately performed. For all statistical analyses executed within this study, the statistical software program PASW Statistics 18 (SPSS, 2010) was used.

2.1. Fishery Landings:

For the years 1903-2009, annual landing records of all marine fish landed by Irish registered boats at Irish ports were obtained. The following data sources were used to compile this dataset: the International Council for the Exploration of the Sea (ICES, 2010a)

(1903-1918); the 'Sea and Inland Fisheries Reports', produced by various Irish government departments responsible for fisheries (1918-1984); the Irish Central Statistics Office (CSO) (1985-1994); and the Irish Marine Institute (1995-2009). For 1903-1922, total landings included those made in Northern Ireland.

All data have either been recorded as, or converted to landings in tonnes live weight, using conversion values calculated from comparing overlapping data for the same years and species categories but different units, acquired from the Irish Marine Institute (Web Table 1).

Since basking shark (*Cetorhinus maximus*, Cetorhinidae) landings from an Achill Island fishery, Co. Mayo, were not included in the original official landings records, they have been added to the compiled dataset analysed in this study (Kunzlik, 1988).

2.2. Market availability:

Historical data on the market availability of seafood has been challenging to obtain. Given the nonexistence of continuous records containing relevant information, we used a 'snapshot approach', making use of independent and unique datasets from different periods of time. With some unavoidable limitations due to the diverse characteristics of the datasets available, this allowed us to describe and interpret what types of seafood have been historically consumed in Ireland throughout the last century and in most instances, in what relative quantities.

2.2.1. Marketable fish, 1901-1907:

A scientific trawl survey report published in 1909 was obtained, which at the end of each tow record included a summary list of the "marketable fish" caught in each trawl tow (Holt, 1909). This survey was conducted from 1901-1907 and for this time period, a list of all of the species caught during the entire survey which were considered 'marketable' in Ireland

at the time of publication was compiled. Although this information does not provide a quantifiable measure of the market availability of seafood, it does provide an indication of which local varieties of fish were considered desirable for human consumption during this time period. Official landing records may at any time only contain data on the species which are commercially caught in the largest or most valuable quantities and as such, may not contain those species which are caught in less substantial quantities but are still marketable or consumed by Irish people.

2.2.2. Market availability from 1921-1951:

For the years 1921-1951, data from the Dublin fish market was contained within a series of annual government reports entitled 'the Sea and Inland Fisheries Reports'. These were produced by government agencies under different names throughout this time period, including the Department of Agriculture and Technical Instruction for Ireland (1921-1923), the Department of Fisheries (1924-1925), the Department of Lands and Fisheries (1926-1930) and the Department of Agriculture (Fisheries Branch) (1931-1951). Data from the Dublin fish market was present within these reports in a table entitled "Comparative Statement of the Quantities of Sea Fish Dealt with in the Dublin Fish Market". Quantities of different varieties of demersal fish were listed separately from those of pelagic fish, the latter of which were recorded in quantities of 'barrels' and' boxes'. These quantities were converted to values in metric tonnes using information provided by the Department of Scientific and Industrial Research of the Torry Research Station, available through the Food and Agriculture Organisation (FAO) corporate document repository online (Waterman, 2001), and confirmed by experienced Irish government fisheries scientists (John Molloy, personal communication, June, 2011). The following conversion formulas were used:

Quantity in tonnes = (Quantity in boxes (fresh) X 0.0445) (1)

Quantity in tonnes = (Quantity in barrels (fresh) X 0.1451) (2)

Quantity in tonnes = (Quantity in barrels (cured) X 0.1188) (3)

Demersal fish quantities were converted to values in metric tonnes from values in hundredweights (cwts.) using the following formula:

Quantity in tonnes = (Quantity in cwts. X 50.802345) / 1000 (4)

2.2.3. Market availability in 1982:

As part of a market study commissioned by the Irish Sea Fisheries Board, Bord Iascaigh Mhara (BIM), the monthly fish wholesale purchases of one anonymous major seafood retailer in Ireland was recorded and contained within a study summary report document (BIM, 1984). In 1982, the total number of boxes of each species purchased in each month has been summed and converted to the total weight in tonnes of each species that was purchased by the retailer, and therefore made available to consumers purchasing fish from this retailer in 1982. Unfortunately, the anonymous identity of the sampled retailer prevented a determination of the market share and therefore representativeness of this retailer to the Irish market in general. However, the large purchase quantities of some species relative to the total landings of these species, eg. ling (*Molva molva*, Lotidae) and white pollack (*Pollachius pollachius*, Gadidae) and saithe (*Pollachius virens*, Gadidae) (9.2% and 6.8% of total landings purchased, respectively) suggested that this retailer was an important buyer within the Irish market. The quantities of the different species purchased accounted for between 0 – 9.2% of the total national landings quantities of each of these species.

2.2.4. Market availability from 2010-2011:

In both 2010 and 2011, respectively 111 and 110 supermarkets, fresh fish counters, 'fish and chips' shops and restaurants in Dublin, Ireland were visited. During each visit, all seafood products (including marine finfish, shellfish, freshwater fish and diadromous fish) advertised, on display or listed on menus and available for purchase were recorded. Approximately ten vendors were randomly visited within each of ten commercial areas strategically chosen within Dublin to represent a varied range of demographics (Miller and Mariani, 2010). For each seafood product found, the proportion of total vendors sampled where the product was available was calculated for statistical analysis and for use in the graphical presentation of the data. Due to funding and timing constraints, sampling was only permitted during the winter (February) of each survey year. Unfortunately, as some fisheries may be seasonal in nature, we must acknowledge that the results of these surveys may not be entirely representative of the Irish market availability over the course of the whole year. However, the available data does provide an indication of what could be expected as only the presence or absence of varieties was recorded, not relative quantities sold, and seafood in Ireland and the UK is often sold frozen, or previously frozen (Blakeway productions, 2011).

2.3. Statistical Analysis of trends in production and market availability:

To investigate temporal differences in the matching of Irish seafood production in relation to Irish seafood market availability, the significance and magnitude of correlations between the seafood production and availability datasets obtained from each time period were separately tested using Spearman's rank correlation analysis. This analysis was performed twice for each time period, once with all data included and a second time including only the top ten contributing species to either total quantity of landings or market availability.

Notably, the datasets employed differed remarkably in both the time period investigated, and the unit measures used. Thus, prior to statistical analysis, the data associated to each seafood product (expressed either in tonnes or, in the case of the 2010-2011 market availability, as the 'the number of vendors where the product was available') was summed then converted to a proportion of the total, producing a single value for each product that represented the species' proportional relative availability or contribution to total seafood landings during each time period. The Spearman's rank correlation was chosen for all statistical analyses as none of the datasets obtained were normally distributed and transformations were unsuccessful in correcting for this. The information obtained from 1901-1907 was not suitable for statistical analysis and instead has been visually presented in Figure 1, incorporating landings categories from 1903-1907 (the earliest years where landings data was available). Additionally, landings data from 2009 was compared with market availability data from 2010-2011 as 2009 was the last year for which fisheries landings data was available.

2.4. Salmon and Cod:

Together, salmon and cod make up the majority of fresh fish currently available in the Irish market (BIM, 2011). Because of the high commercial importance of these two types of fish, trends in the trade of both salmon and cod were examined along with trends in the production of wild and, only in the case of salmon, farmed production. All data has either been originally recorded as or converted to values in metric tonnes.

The annual quantities of either salmon or cod were obtained from the following sources: wild Atlantic salmon (*Salmo salar*, Salmonidae) caught in Ireland from 1927-2009 through both the Irish CSO (1927-2004), and through the FAO FishStat database (FAO, 2011a) (2005-2009); salmon produced in Ireland through aquaculture from 1974-2009 through both the FAO FishStat database (FAO, 2011a) (1974-2007) and from BIM (2008-

2009); salmon exported from and imported into Ireland from the 'Sea and Inland Fisheries Reports' published by various Irish government agencies responsible for fisheries (exports, 1952-1984) and from the FAO FishStat database (FAO, 2011a) (exports and imports, 1985-2008); Atlantic cod (*Gadus morhua*, Gadidae) landed in Ireland for the years 1903-2009 from the sources listed in section *2.1*.; cod exported from and imported into Ireland from the FAO FishStat database (FAO, 2011a) (exports and imports, 1977-2008).

Trends in the quantities of production and trade data of both salmon and cod were first visually examined, and notable patterns in the data were subsequently tested for correlation through Pearson's product-moment analysis.

3. Results

3.1. Production and market availability:

The data available from the earliest time period does not provide quantitative information on the market availability of seafood due to its source and qualitative nature. However it does provide insight on which species may have been landed, marketed and consumed in Ireland in addition to those major species reported in official landing records. The list of native marine fish species that were considered 'marketable' in the early 1900s was quite extensive and included a large number of species that were not recorded in the official landings records from the same time period (11 out of 22, 50.0%; Fig.1). Only three out of 14 (21.4%; Fig. 1) fish species: herring (*Clupea harengus*, Clupeidae), mackerel (*Scomber scombrus*, Scombridae) and sprat (*Sprattus sprattus*, Clupeidae), were recorded in the official landings records from this time period but were not included on the list of species categorized as 'marketable' by the authors of the trawl survey report. Pelagic species were rarely present within the survey records obtained from this early time period, as the fishing gear used for the survey from which the data was derived was designed for targeting

groundfish, not pelagic species. For this reason, the absence of herring, mackerel and sprat from this 'marketable' list should not be taken as evidence that they were not consumed in Ireland during this early time period.

The relative species composition of fish landed by Irish vessels at Irish ports, totalled for the time period 1921-1951 was significantly positively correlated to the relative species composition of fish available at the Dublin fish market, totalled for the same time period (Fig. 2, $r_s = .673$, $p = .001$). When the analysis was performed only considering the top ten contributing species categories (basking shark, cod, conger eel (*Conger conger*, Congridae), haddock (*Melanogrammus aeglefinus*, Gadidae), hake (*Merluccius merluccius*, Merlucciidae), herring, mackerel, plaice (*Pleuronectes platessa*, Pleuronectidae), ray and skate, whiting (*Merlangius merlangus*, Gadidae), white pollack and saithe and other), the datasets were also significantly positively correlated ($r_s = .825$, $p = .001$). Fig. 2A and Fig. 2B both clearly illustrate a similar trend in the relative species composition of both datasets. Herring and mackerel comprised the largest proportions of total landings during this time period (contributing 35.3% and 24.8%, respectively) and also accounted for large proportions of the total fish dealt with at the Dublin fish market (contributing 26.7% and 9.3%, respectively). Demersal species such as whiting, cod, plaice and ray and skate were also landed and dealt with in substantial quantities, indicating the relative importance of these species.

The relative species composition of fish landed by Irish vessels at Irish ports in 1982 was not significantly correlated to the relative species composition of fish purchased by the sampled Irish retailer, also in 1982 (Fig. 3, $r_s = .241$, $p = .257$). When the analysis was performed only considering the top ten contributing species categories (cod, haddock, hake, herring, ling, mackerel, megrim (*Lepidorhombus whiffiagonis*, Scophthalmidae), plaice, ray and skate, sprat, whiting, witch (*Glyptocephalus cynoglossus*, Pleuronectidae), white pollack

and saithe and other), the datasets were also not significantly positively correlated (r_s = .153, p = .646). The mismatch in patterns of landings and retailer purchases for this particular example is evident when details of the important contributing species are considered. During this year, mackerel was landed in the largest quantity relative to any other species recorded, comprising 60.2% of overall landings. However, mackerel accounted for 4.4% of the fish purchased by the sample retailer. Pollack or saithe comprised the majority of fish purchased by the sample retailer (29.0%) but was caught in quantities that amounted to only 1.4% of total annual marine finfish landings. Both herring and cod each accounted for more than 10% of the total fish purchased by the sample retailer (15.9% and 12.7%, respectively) and although herring comprised over 10% of the landings (16.2%), cod landings only accounted for 5.3% of the total.

The relative species composition of fish landed by Irish vessels at Irish ports in 2009 was significantly positively correlated to the relative species composition of fish available for sale in the Dublin marketplace from 2010-2011 (Fig. 4, r_s = .378, p = .007). However, when the analysis was performed only considering the top ten contributing species categories (blue whiting (Micromesistius poutassou, Gadidae), boarfish (*Capros aper*, Caproidae), cod, haddock, hake, herring, horse mackerel (*Trachurus trachurus*, Carangidae), mackerel, megrim, monkfish (*Lophius spp*., Lophiidae), plaice, ray and skate, sole (*Solea solea*, Soleidae), sprat, tuna and whiting), the datasets were not significantly positively correlated (r_s = -.379, p = .148). During this latest time period, landings of pelagic species such as mackerel, horse mackerel, herring and boarfish were caught in the largest quantities (comprising 29.3%, 27.2%, 7.7% and 5.6% of the total marine finfish landings in 2009, respectively). These species however were not as commonly available for purchase from Irish vendors relative to some demersal species of fish and tuna. Landings of cod, haddock and tuna only contributed 0.7%, 2.9% and 1.5% of total landings, respectively but were available

in 55.2%, 30.8% and 31.7% of the vendors surveyed, respectively. Mackerel, horse mackerel and herring were only found available in 22.2%, 1.4% and 11.3% of the vendors surveyed respectively, and boarfish was not available anywhere as it is most commonly processed into fishmeal and not used for human consumption (Marine Institute, 2009). This latest dataset included a greater diversity of species than the datasets analysed from earlier time periods. The majority of these species both contributed very little to the total amount of marine finfish landings recorded for 2009, and were found available in relatively few of the vendors sampled.

3.2. Salmon and cod:

Trends in the wild production and exports of salmon from 1952-1973 were found to be significantly positively correlated (r = .913, p < 0.001); trends in the farmed production and exports of salmon from 1974-2008 were found to be significantly positively correlated (r = .969, p < 0.001); trends in the wild production and farmed production of salmon from 1974-2009 were found to be significantly negatively correlated (r = -.631, p < 0.001); and trends in the wild production and imports of salmon from 1985-2008 were also found to be significantly negatively correlated (r = -.692, p < 0.001). From these results, if appears as though exports of salmon followed trends in the wild production of salmon until farmed production began, at which point exports followed trends in the farmed production of salmon. Additionally, as wild production of salmon decreased, the farmed production and quantities of imports during the time periods examined increased (Fig. 5A).

Trends in the Irish production and exports of cod from 1977 to 2001 were significantly positively correlated (r = .817, p < 0.001); trends in the imports and exports of cod from 2002 to 2008 were somewhat positively correlated, but not significantly (r = .660, p = .107); and trends in the Irish production and imports of cod from 1977 to 2008 were

significantly negatively correlated (r = -.741, p < 0.001). From these results, it appears as though exports of cod followed trends in the Irish landings of cod until Ireland began importing more cod than it was producing, at which point trends in the exports of cod began to follow trends in the imports of cod, though not significantly. Finally, as the Irish production of cod has decreased, the amount of cod imported into Ireland has increased (Fig. 5B).

4. Discussion

4.1. Production and Market Availability

Comparing results from the time period examined between 1921-1951 to the analysis of data from 1982, the variety of fish available for consumption in Ireland became less correlated to the variety of fish being produced or landed by Irish vessels (Fig. 2-3). Integrating the dataset from the latest time period examined, this pattern did not continue when all species categories were considered in the analysis (Fig. 4). However, though the correlation found in comparing all data from the most recent time period was significant (r_s = .378 p = .007), this correlation was not as strong as that found between market availability and production data from 1921-1951 (r_s = .673, p = .001). Although the fish varieties that were available to the largest extent and that were being landed in the largest quantities did not match well with each other from this latest time period (Fig. 4A), there was a much larger number of species categories recorded in both datasets relative to the earlier time periods (Fig. 2-4) and the large number of species rarely available and produced in small quantities may have contributed to the significant correlation found between datasets. This increased diversity could be attributed to expanding fisheries (Molloy 2004, 2006), improved efficiency of trade promoting access to foreign imports (Swartz et al., 2010) evolving fishing behaviour where less-selective gears are used and more by-catch is retained, and/or improvements in the

detail of data reporting encouraged by tighter management controls (Song, 1995). Additionally, although a non-parametric, rank-based correlation analysis was performed on all datasets, the latest dataset did not enable the use of the same quantitative measure of market availability as the earlier datasets. The applied measure of product presence in vendors sampled within the latest dataset did not permit a reflection of the relative quantity of availability between species in the marketplace, only the relative availability. As such, athough a store may have been found selling, for example, both mackerel and cod, it might have been selling a much larger quantity of cod (which is usually the case, based on personal observation) and this difference would not be reflected within this analysis.

Throughout the last century, the popularity and demand for demersal species such as cod, haddock and pollack or saithe within the Irish marketplace appears to have been maintained despite a decrease in the relative contribution of demersal species to the total Irish fisheries landings. The emergence and development of the 'fish and chips' shop industry in Ireland throughout the 20th century has likely influenced the popularity of whitefish demersal species within Irish society. Introduced during the 1880s by Italian immigrants, fish and chips shops are now commonly found throughout Ireland (La Malfa, 2003; Hegarty, 2009). These shops predominantly sell cod, smoked cod and often but not always a number of other varieties of fish (pers. obs.). Throughout the last 20-30 years, as these businesses continued to thrive, Irish landings of many demersal species including cod dramatically declined (Marine Institute 2009, 2010). In part, decreased landings are a result of increasingly strict EU fisheries management measures including quotas and gear restrictions (Marine Institute, 2009). However, these measures have largely been developed and recommended by fisheries scientists and introduced in response to indications of poor stock status (Marine Institute 2009, 2010). In addition, although small pelagic species have been landed in relatively large quantities during all time periods examined, the data reviewed suggests that in recent years

pelagic species are being retained for human consumption within the Irish market to a much smaller extent relative to earlier years and demersal species. This evidence suggests a mismatch in the trends of local resource production and domestic market demand.

Within all time periods examined, there have been examples of varieties of fish included within official landing records but not present in the market related data (1921-1951, pilchard (*Sardina pilchardus*, Sardina) and sprat; 1982, sprat, whiting, megrim and dab (*Limanda limanda*, Pleuronectidae); 2009-2011, sprat, boarfish, witch, conger, redfish, tusk (*Brosme brosme*, Lotidae), bluemouth, wolffish, forkbeard, sand sole (*Pegusa lascaris*, Soleidae) and pouting (*Trisopterus luscus*, Gadidae)), as well as those present in the market related data but not mentioned in official landings records (1921-1951, dab, saithe, megrim and gurnard; 1982, witch, redfish, gurnard and john dory (*Zeus faber*, Zeidae); 2009-2011, anchovy, snapper, grouper, yellowtail amberjack (*Seriola lalandi*, Carangidae), hoki (*Macruronus novaezelandiae*, Merlucciidae), orange roughy (*Hoplostethus atlanticus*, Trachichthyidae), yellowfin sole (*Limanda aspera*, Pleuronectidae)). These examples appear to have become more common in the latest time periods analysed (Fig 2-4), which is likely a result of a number of factors. In 2009, small pelagic species including blue whiting, boarfish, herring, horse mackerel, mackerel, pilchard and sprat comprised over 80% of the total quantity of all wild marine finfish species landed by the Irish fleet (Fig. 4A). Improvements in fishing technologies, generally experienced by fisheries globally throughout the last 50 years have facilitated the catching of larger and more diverse quantities of small pelagic species, and other types of fish for which consumer demand in Ireland has been low (Caddy and Garibaldi, 2000; Marine Institute, 2009). Concurrently, improvements in transportation permitted the efficient export of these species to external markets where demand for human consumption existed (Taylor et al., 2007). Additionally, a growing global demand for fishmeal helped to develop industrial fisheries in Ireland, such as that for blue whiting and

450 boarfish, caught in large quantities but not consumed to any extent in the Irish market (EP,
451 2004; Tacon, 2005; Marine Institute, 2009).

452 Increased importation of fish has also been facilitated by improvements in
453 transportation (Taylor et al., 2007), allowing for the maintenance of a stable supply of the
454 seafood products demanded by Irish consumers, despite reductions in local production as a
455 result of overexploited and depleted stocks (Marine Institute, 2009, 2010; ICES, 2010b,
456 Swartz et al., 2010). In addition, the Irish market is now able to import foreign varieties of
457 fish not native to Irish waters, increasing the overall diversity of seafood available, though the
458 general availability of diverse products, either from Irish or foreign fisheries still remains low
459 (Fig. 4A). The increasing presence of foreign, imported products within the Irish marketplace
460 could also be a reflection of rising demand by an increasingly well-travelled Irish society.
461 Aided by the advent of low-cost airlines (Francis et al., 2006), Irish consumers may sample
462 foreign seafood products while on holidays abroad and then wish to replicate these dining
463 experiences in Ireland.

464

465 *4.2. Salmon and Cod*

466 When all seafood products surveyed as described in section *2.2.4* were considered,
467 including shellfish, freshwater and diadromous species, salmon and cod were the second and
468 third most commonly available seafood products surveyed (Fig. 6). Salmon and cod were
469 chosen for a further level of investigation within this study both because of their high level of
470 commercial and cultural importance in Ireland (BIM, 2011, de Courcy Ireland, 1981), which
471 somehow embodies the current idiosyncrasies of the Irish seafood industry.

472 In 2007 the drift-net fishery for wild salmon in Ireland was closed based on scientific
473 evidence that local stocks were substantially depleted (DCMNR, 2007). It was estimated that
474 at the time of the fishery closure, there was less than one third of the fish returning annually

475 to Irish coastal waters than had been returning during the 1970s (Collins et al., 2006).
476 Additionally, nearly all of the cod stocks around Ireland are currently severely depleted and
477 recent catches are well below historic levels (Marine Institute, 2009, 2010; ICES 2011a,
478 2011b). In 2009, landings were approximately 10% of the peak levels obtained during the
479 1980s (ICES, 2010b).

480 Based on the knowledge of their severely depleted stock status in local waters, it then
481 seems absurd that salmon and cod are so dominantly available in the Irish market (Fig. 6).
482 Our analysis of trends for these two species reveals that imports of both salmon and cod and
483 farmed production of salmon has been increasing as wild production has been decreasing
484 (Fig. 5). In addition, trends in the exports of these products followed that of wild production
485 until recent years, where trends in exports are now following that of farmed production in
486 salmon and bizarrely, imports in cod (Fig. 5). This suggests that a certain amount of cod
487 imports are not even marketed in Ireland, but are processed to then be exported. Based on
488 these trends, it appears as though the depletion of local wild stocks of these species has been
489 hidden from consumers in the Irish marketplace through the replacement of wild Irish
490 products with farmed salmon and imported salmon and cod. Additionally, there is growing
491 evidence that a large amount of cod sold in Ireland is often mislabelled as 'cod' but is in
492 reality constituted by an entire range of different species (Miller and Mariani, 2010; Miller et
493 al., 2011). These mechanisms contribute to creating a market environment that is completely
494 lacking in transparency, with the potential to have strong negative implications for marine
495 conservation, both on a local and international scale.

496 Wild Atlantic salmon, to a large extent has become irrelevant within global seafood
497 markets. As a result of considerable population declines and extirpations throughout their
498 native range and their high utility in aquaculture, approximately 98% of Atlantic salmon in
499 existence globally, are contained in salmon farms (Parrish et al., 1998). In 1998, for the first

time on record, production of farmed salmon exceeded that of wild salmon and by 2009, annual global production of farmed salmon had reached 1.6 million tonnes, growing from just over 500 tonnes in 1970 (Liu and Sumaila, 2008; FAO, 2011b). However, despite the dominance of farmed salmon within European markets there is some evidence that consumers are not consciously aware that the large majority of salmon available from European retailers is produced through aquaculture (Vanhonacker et al., 2011). Furthermore, consumers interviewed from Belgium, Norway and Spain were found to have an opinion that farmed salmon is generally a sustainable seafood choice (Verbeke et al., 2007; Vanhonacker et al., 2011). Awareness of the environmental issues associated to salmon aquaculture when present however, appear to have negative effects on the consumption of farmed salmon as was found from a survey of consumer attitudes recently conducted in Scotland (Whitmarsh and Palmieri, 2011). This issue is currently controversial, even in considering organic or closed-containment farming operations (Pauly et al., 2002; Liu and Sumaila, 2008; Schlag, 2011). Presently, farmed salmon are still dependent upon wild fish in the production of feed (Naylor et al., 2009) and open-net cage operations introduce risks to the ecosystems occupying the surrounding marine environment (Krkošek et al., 2005; Gross, 1998). Additionally, a recent study has shown that since reaching peak growth in 1966, the global growth rate of farmed salmon production has been decreasing by on average, 1.2% per year (Liu and Sumaila, 2008). Given this and additional calculations, the authors concluded that it is unrealistic to believe that in the future, fish farming will continue to provide a solution to declining global catches from wild fisheries.

5. Conclusions

The industry trends identified and discussed here are the consequences of complex interactions of dynamic biological, cultural and economic influences. Some of these factors, such as the strong cultural traditions and norms within Irish society or financial incentives within the seafood industry must be recognised and acknowledged prior to the planning or instigation of any plans for industry reform, if considered necessary. The vast majority of people living in Ireland consider themselves to be catholic (CSO, 2011), a religion that has in the past required that followers abstain from eating meat on Fridays (Bell, 1968). As such, the strong religious presence in Ireland has likely contributed to shaping attitudes and the customs associated to eating fish, a religiously allowed alternative to 'meat' (Fagan, 2006; Jacquet, 2009). In addition, the development of the Irish aquaculture industry and the fish processing industry have certainly also influenced the varieties of fish available for purchase from Irish retailers. Although these sectors are important components to the seafood industry as a whole, they may operate through different incentives, costs and environmental restrictions relative to the catching sector.

A mismatch within the seafood industry as revealed through this study is potentially harmful to the current and future sustainability of fisheries both in Ireland, and in international locations from which seafood has been imported. Since the reality of what has happened to local resources in Irish waters has been hidden from consumers through imports, aquaculture and mislabelling, Irish consumers are not aware of the problems that local marine ecosystems are currently facing. Consumers that are lacking in awareness or that have a disbelief of the problems facing the fisheries industry are as a result unable, or not willing to make responsible and informed purchasing decisions (Marko et al., 2004; Jacquet and Pauly, 2008; Jacquet et al., 2009). Consumers, to a large extent trust the marketplace and without sensing a problem, they will likely continue 'business as usual' purchasing habits, demanding traditional favourites such as salmon and cod. As a result, this will put more pressure on

549 foreign stocks, remaining local stocks and fragile coastal marine habitats that may experience
550 the damaging effects that expanding aquaculture developments can produce (Greenberg,
551 2010)

552 In order to facilitate the influence consumers can exert through responsible decision-
553 making, which could relieve pressure from overexploited stocks, transparency within seafood
554 and fisheries industries must be established. Conservation interventions of any form are
555 essentially the product of human decision making processes (Mascia et al., 2003) and without
556 transparency, informed consumer decisions cannot be made. As seafood is the world's last
557 major remaining wild food source we must utilise it with respect and restraint.

558

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566

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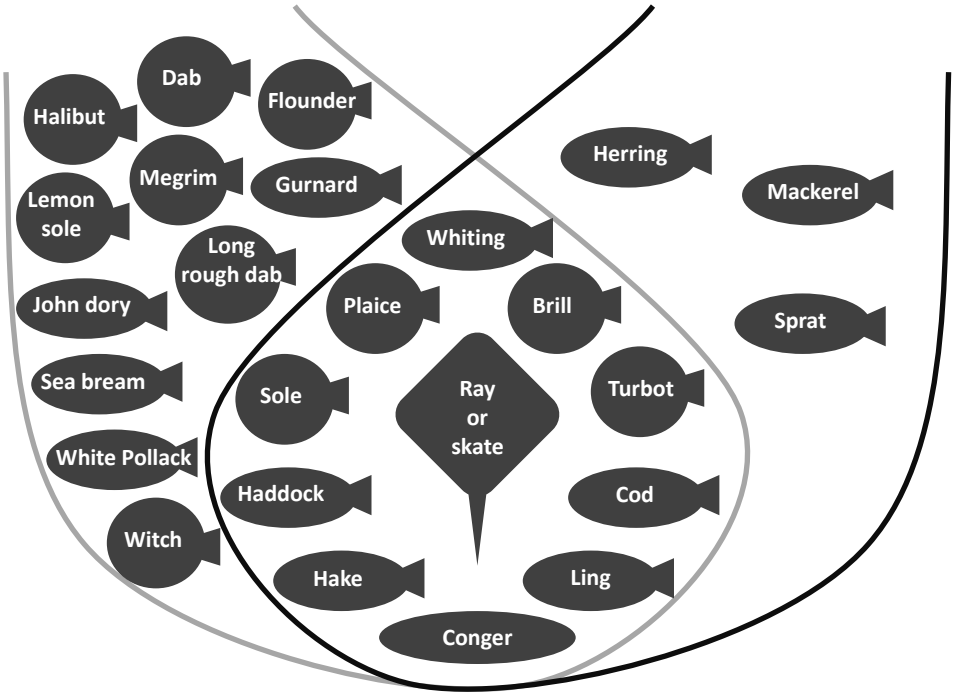
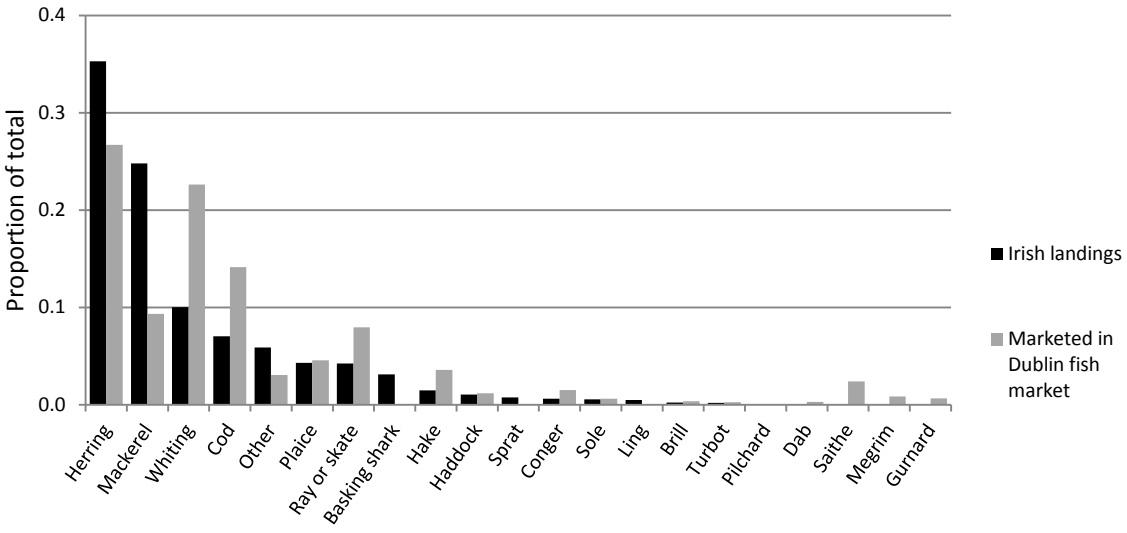


Figure 1



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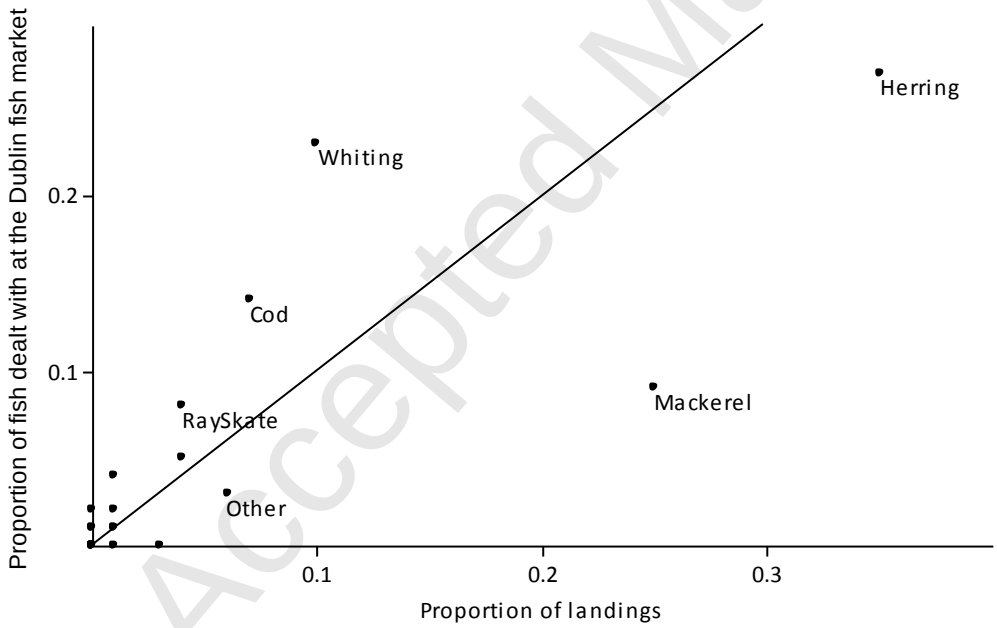

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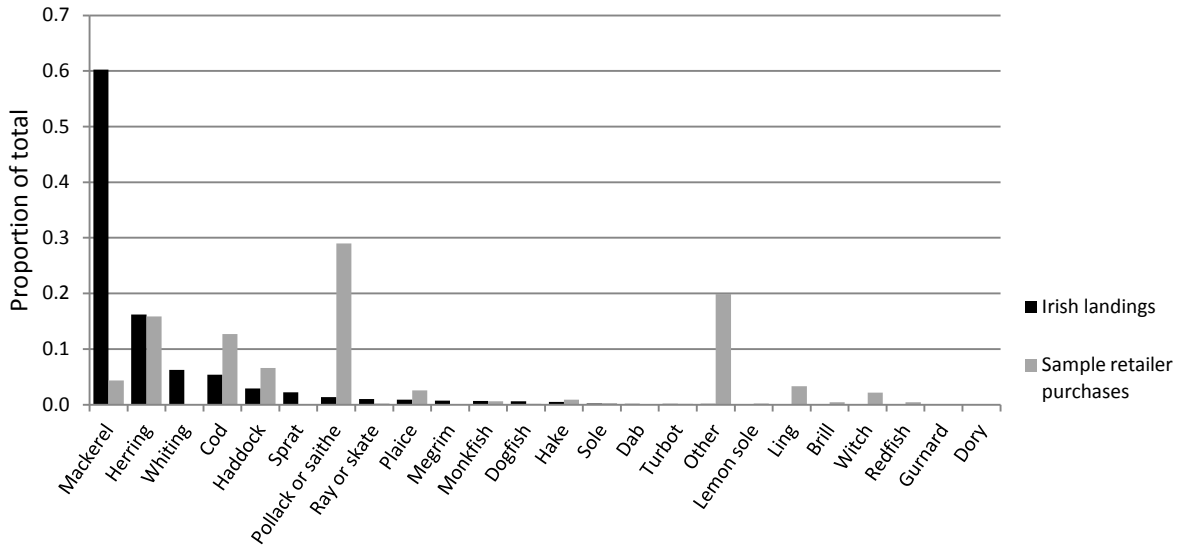

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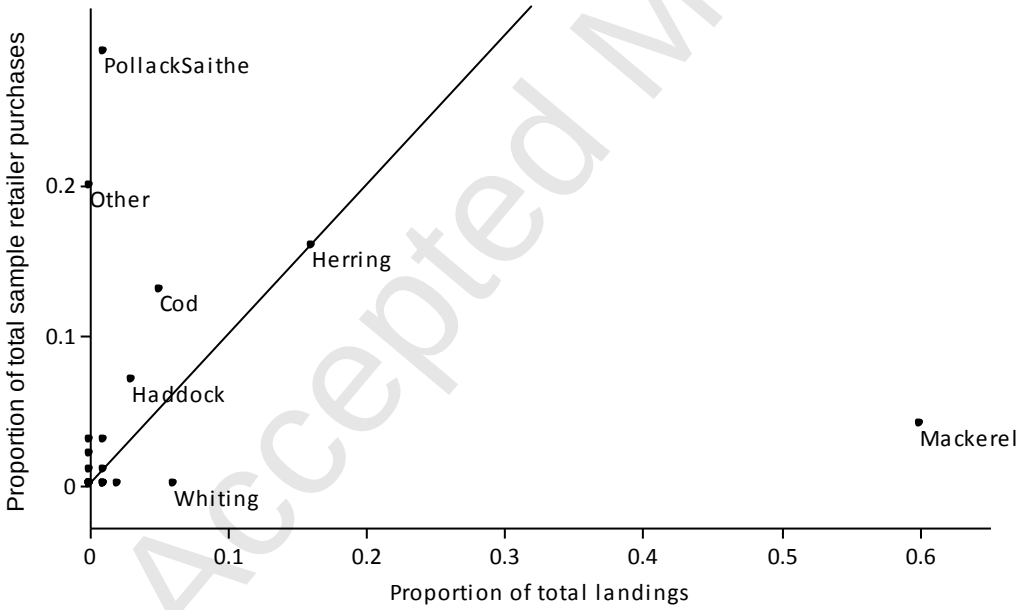

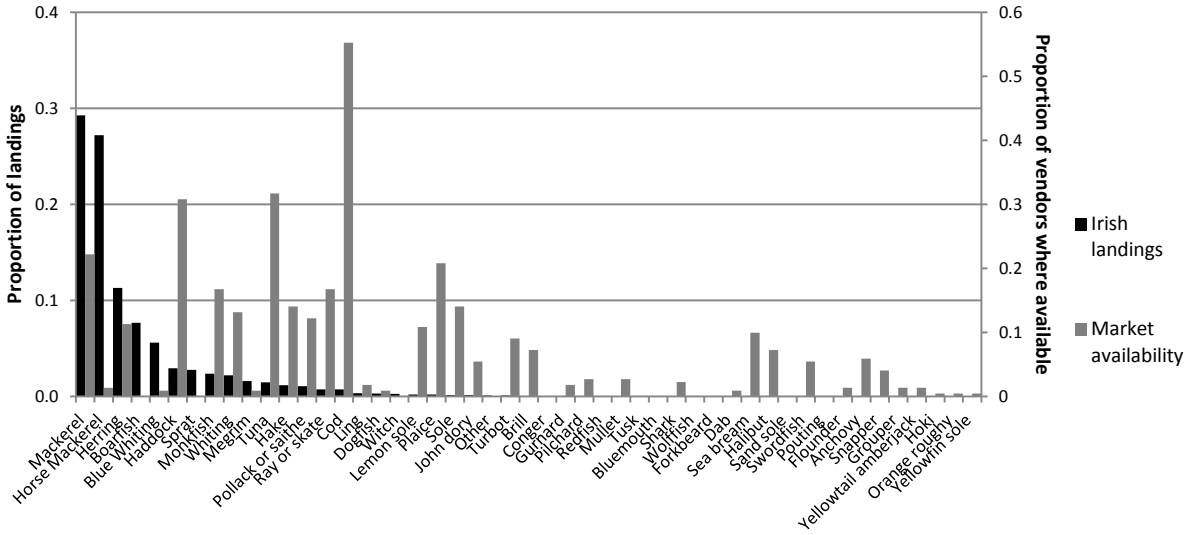

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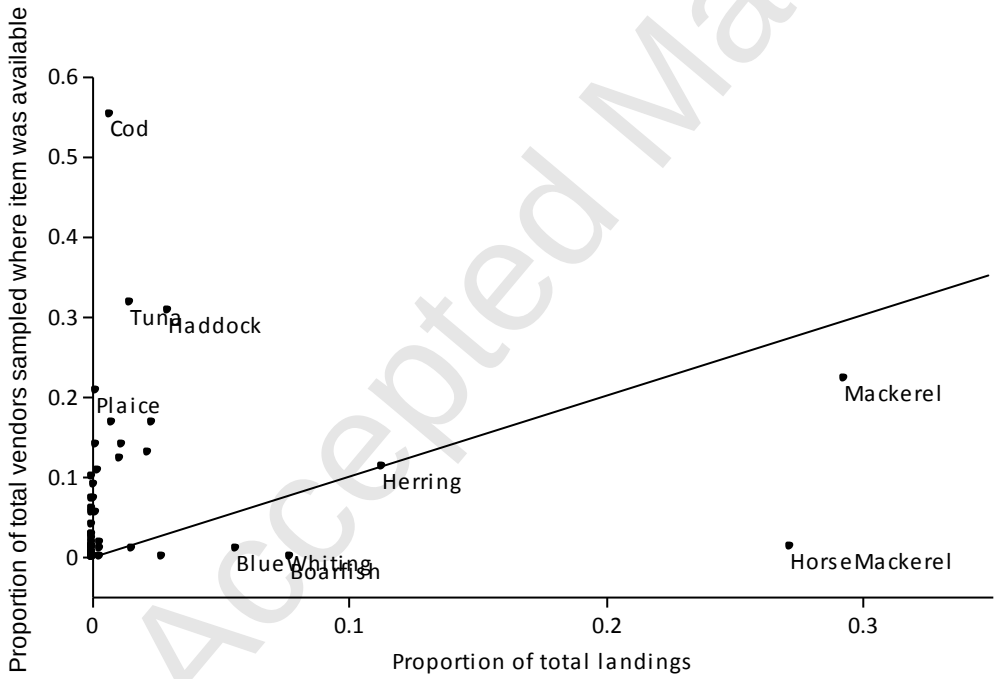

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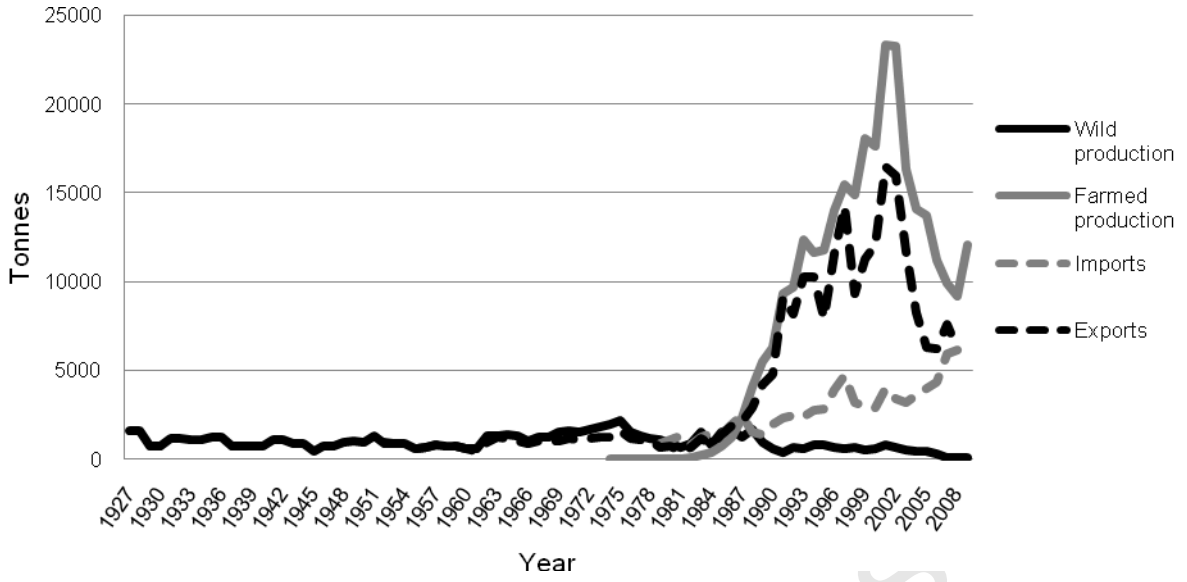

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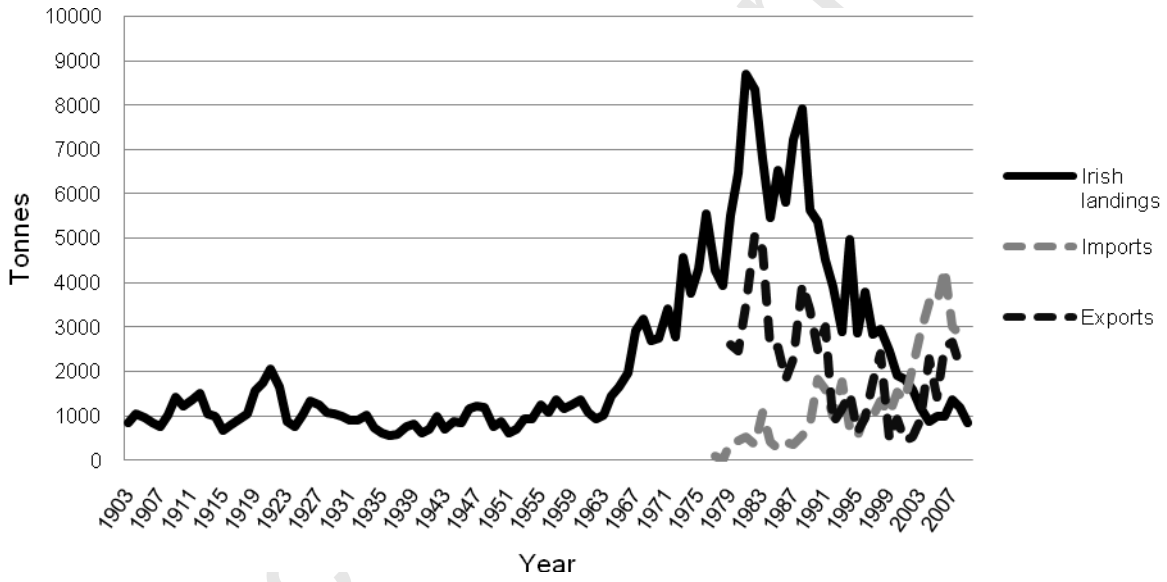

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Figure 5

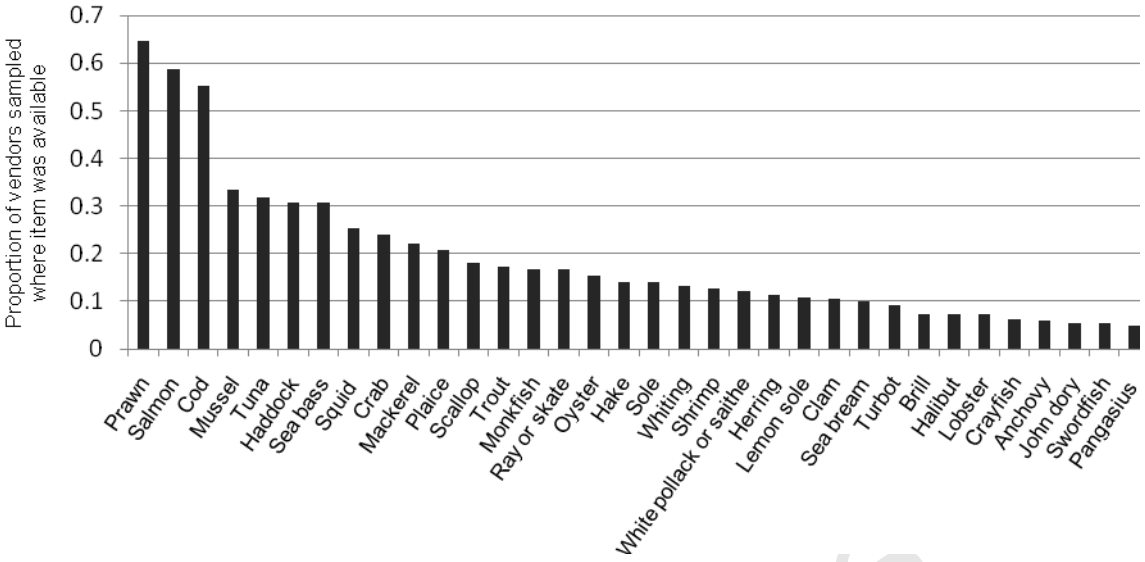

Figure 6

Figure 1. Marketable marine fish varieties and landings in Ireland, 1903-1907. Fish varieties contained within the grey line were those caught through an Irish scientific trawl survey and recorded as 'marketable'. Fish varieties contained within the black line were those recorded in government fisheries landings data records. See text for details on data sources.

Figure 2. The relative proportions of marine fish landed by Irish registered vessels at Irish ports and of fish available for purchase at the Dublin fish market from 1921-1951. A) Data presented by variety as proportions of the total quantity in tonnes landed and marketed during this time period. B) Spearman's rank correlation on proportional data r_s = .673, p = .001. Data points labelled for the top five contributing species to total quantity landed or marketed. Diagonal line represents 1:1 line. See text for details on data sources.

Figure 3. The relative proportions of marine fish landed by Irish registered vessels at Irish ports and of fish purchased by an anonymously sampled retailer in 1982. A) Data presented by variety as proportions of the total quantity landed and purchased in tonnes during this time period. B) Spearman's rank correlation on proportional data r_s = .234, p = .270. Data points labelled for the top five contributing species to total quantity landed or marketed. Diagonal line represents 1:1 line. See text for details on data sources.

Figure 4. The relative proportions of marine fish landed by Irish registered vessels at Irish ports in 2009 (last available year) and the proportions of total sampled vendors from 2010-2011 where each marine fish item was available (n= 221 vendors). A) Data presented by variety as proportions of the total quantity landed in tonnes and as proportions of the total number of vendors sampled where each marine fish variety was available during the stated time periods. B) Spearman's rank correlation on proportional data r_s = .378, p = .007. Data

points labelled for the top five contributing species to total quantity landed or marketed. Diagonal line represents 1:1 line. See text for details on data sources.

Figure 5. Production and trade of salmon (A) and cod (B) products in Ireland. Traded fish may include processed products to varying degrees. See text for details on data sources.

Figure 6. Availability of seafood products commonly sold in Dublin. Availability values are based on the proportion of restaurants or shops sampled that were recorded as selling each product variety, sampled in 2010 and 2011 (n=221 vendors, respectively). Only products that were recorded at least ten times over the two year sampling time period have been included.

Supplementary Data:

Web Table 1. Multiplication factors used for the conversion of quantities from landed weight (tonnes) to live weight (tonnes). Source: Calculated through comparing overlapping data for the same years and species categories but different units, acquired from the Irish Marine Institute.