
The North Atlantic Fish Revolution (ca. AD 1500)

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Abstract

We propose the concept of the “Fish Revolution” to demarcate the dramatic increase in North Atlantic fisheries after AD 1500, which led to a 15-fold increase of cod (*Gadus morhua*) catch volumes and likely a tripling of fish protein to the European market. We consider three key questions: (1) What were the environmental parameters of the Fish Revolution? (2) What were the globalising effects of the Fish Revolution? (3) What were the consequences of the Fish Revolution for fishing communities? While these questions would have been considered unknowable a decade or two ago, methodological developments in marine environmental history and historical ecology have moved information about both supply and demand into the realm of the discernible. Although much research remains to be done, we conclude that this was a major event in the history of resource extraction from the sea, mediated by forces of climate change and globalisation, and is likely to provide a fruitful agenda for future multidisciplinary research.

Keywords: North Atlantic; Fish Revolution; Climate change; Settlements; Market integration; Early modern history

INTRODUCTION

Throughout the past five centuries, cod (*Gadus morhua*) on the Grand Banks in the Northwest Atlantic off Newfoundland sustained the largest single fishery on the planet. When this cod stock collapsed in 1991, it was an indictment of human environmental management practices and a salutary warning regarding the human impact on marine life. The rise of the fishery in the early decades of the sixteenth century was similarly of momentous consequence for peoples on both sides of the North Atlantic. We propose the concept of the “Fish Revolution” as a means of representing both the known and as yet only dimly perceived or hypothetical societal impacts wrought by the opening of this fishery. The Fish Revolution dramatically increased fish supplies, primarily cod (*Gadus morhua*), to the European market shortly after AD 1500, a period also marked by great societal and environmental upheaval (e.g., Parker, 2013; Campbell, 2016).

In this article, we argue that the Fish Revolution must be understood in the context of climate change and market

globalisation. We present preliminary estimates of supplies from the main catch areas of North Norway, Iceland, and Newfoundland/Grand Banks; map changing fishing effort; and discuss drivers and effects of a globalising seafood market. We identify basic ecological and anthropogenic parameters of the Fish Revolution and propose ways forward to understand the Fish Revolution as it related to climate-driven changes to the natural system and globalisation of the human system. The Fish Revolution should be recognised as a major event in global human history, and we call for collaborative multi- and interdisciplinary research to understand (1) the natural abundance and dynamics of the resource, (2) the shock to and long-term impact on the dynamics of the European food system, and (3) the consequences for human landscapes and migration patterns on both sides of the North Atlantic.

THE NORTH ATLANTIC FISH REVOLUTION

In the late Middle Ages (ca. AD 1300–1500), fish was a high-priced, limited resource. Returns on fishing efforts in Europe were so lucrative that historians have identified the period as the second phase of commercialisation of the fisheries (Kowaleski, 2003; Gardiner, 2016) (following the first breakthrough of intensified sea fishing in the eleventh century;

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Barrett, 2004). The most important species were herring (*Clupea harengus*) and cod (Barrett and Orton, 2016). Fresh marine fish was only used for local consumption while markets farther than 30–50 km from the coast depended on dried and salted goods (Hoffman, 2005; Amorim, 2009).

In the latter half of the fifteenth century, fishers and explorers from many countries were pushing into the North Atlantic, but it is Giovanni Caboto (a Venetian navigator, also known as John Cabot) who is generally credited with the European discovery of the Grand Banks. In 1497, he returned to Bristol from a voyage commissioned by Henry VII of England in a vain search for a westerly seaway to China. He told of waters so “full of fish that [they] can be taken not only with nets but with fishing-baskets” (Lawrence and Young, 1931, p. 274; Jones and Condon, 2016). Within a few years, fishers, primarily from the Iberian Peninsula, had journeyed to the waters of which Cabot spoke. Spanish and Portuguese fishers benefitted from easy access to domestic salt, an essential substance for long-distance fisheries. They soon found that the climate was ideal for drying the cod and producing a staple food that would keep for years. The Grand Banks fishery, thus exploited, offered abundant, high-quality, low-priced catches to the European market. This signalled the third and most dramatic phase in the development of North Atlantic fisheries, the Fish Revolution.

In order to assess the importance of this discovery, we present quantitative estimates of the long-term trends in the European fish market. In his overview of early modern (ca. 1500–1750) fisheries, A.R. Michell (1977, p.134) observed that “one reason why the definitive history of European fishing has yet to be written is that quantitative records concerning fishing pre-1750 are few.” A recent survey of European fisheries refrained from making quantitative estimates (Starkey et al., 2009). Nevertheless, historians and fisheries scientists have identified and published a significant number of quantitative records in the last 40 yr (reviewed by Poulsen 2016a). Much of this recent research is, however, confined to particular national contexts. We have assembled the evidence for the major exporters—Iceland, Norway, Denmark, and the Netherlands—of herring and cod for the continental European market, as well as estimates of total production of Newfoundland cod. All figures have been converted from medieval weights to modern metric tonne live weight fish (including heads and guts).

There are important limitations to the picture presented. First, we have refrained from assessing the British market as it was predominantly served by the domestic fishing industry and figures are hence mostly for total landings (local consumption + marketed volume) and therefore not compatible with those for the Continent (marketed values only). The English East Anglian fishery was much reduced by the fifteenth century because of Dutch competition (Childs, 2000). The English cod fishery off Iceland was substantial and is estimated to have peaked at about 10,000 metric tonnes by the 1520s. Thirty years later, the fishery was much reduced, but it recovered somewhat by the end of the century and still exceeded English Newfoundland catches until the 1630s (Jones, 2000). Second, we lack information about

some exporters. There was a British and Irish export of herring and cod to the Continent, though we presently estimate that the volumes would have been insignificant for the broad-brush picture we are painting. French fisheries in the North and Celtic Seas would have been significant for the domestic market, and there was a sizable but unknown export of hake (*Merluccius merluccius*) and cod to Mediterranean countries. Third, we have not considered the southern European market where hake, tuna (*Thunnini*), and smaller pelagic species dominated.

Figure 1 documents the dramatic increase of fish supplies for the sixteenth-century continental European market. This rise was exclusively because of cod. Around AD 1500, the ratio of herring to cod volumes was about 5:1; by 1600, it was 1:4. Although herring supplies were relatively stagnant, the cod market boomed. In the medieval period, cod was primarily produced as dried fish—so-called stockfish—by Norwegian and Icelandic fishers. Around AD 1400, total Norwegian cod exports were about 6250 metric tonnes, while we estimate Icelandic supplies to have been about 2000–3000 tonnes. By 1550, Norwegian and Icelandic exports had risen to about 15,000 tonnes (Jónsson, 1994; Nedkvitne, 2014; Nielssen et al., 2014), but Newfoundland catches provided the true step change. By 1580, Newfoundland output is estimated to have reached about 200,000 tonnes of cod (Pope, 2004a). This was a 15-fold increase in cod supplies, and it tripled overall supplies of fish (herring and cod) protein to the European market. Average annual consumption of imported fish per capita rose from the very low figure of 0.75 kg in 1500 to 3.2 kg in 1650, employing the demographic data of Maddison (2008).

The Fish Revolution begs simple but challenging questions. An immediate question may be: Why would European fishers want to cross the North Atlantic to fish? This was a dangerous journey. An abundance of French notarial records attests to the diverse range of hazards such as storms and pirates faced by mariners. Based on sixteenth-century records, we estimate that an average of 5% of vessels in the French fleet were lost in the crossing because of wreckage, capture, and so forth (Archives départementales de Seine Maritime, Rouen, 2E-70). Portuguese inventories document hundreds of ships captured by pirates in the middle sixteenth century (Russell-Wood, 1998), but no average estimate is yet possible. What were the rewards that justified these perils? One way to answer this question is to reconstruct the set of push and pull factors that influenced the decision making by merchants and fishers.

One likely pull (attraction) was economic gain. In 1502, the first recorded landing of 36 metric tonnes of cod (saltfish) from Northwest (NW) Atlantic waters fetched a price of £180 (Pope 2004a, p. 15). It is difficult to assess the actual financial reward of such an endeavour in the absence of business records, but we can gain some insight by simply converting to modern prices. Using the MeasuringWorth calculator, the relative value of £180 from 1500 equals labour earnings of £1.2 million in 2016 prices (Officer and Williamson, 2018). The economic power (wealth relative to total GDP) would be a staggering £75.9 million in modern value. These

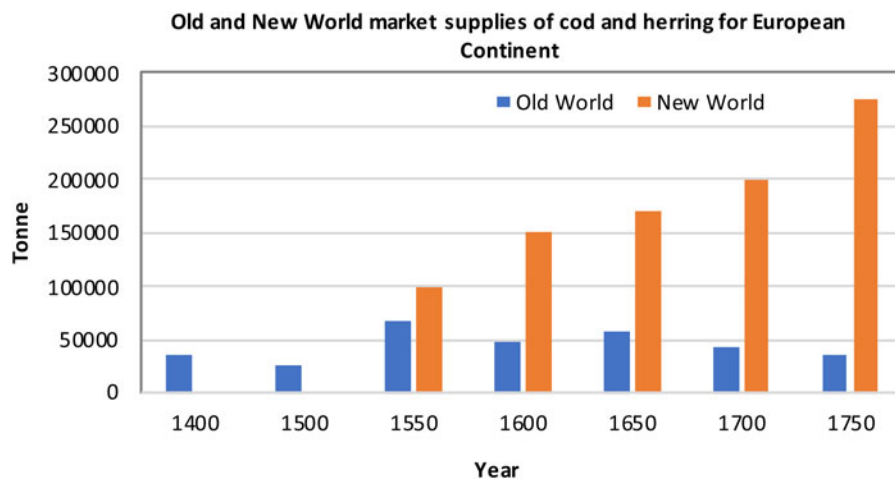


Figure 1. (colour online) Old and New World market supplies of cod and herring for the European continent, in metric tonnes. Based on published studies for the exports from Iceland (Jónsson, 1994), Norway (Nedkvitne, 2014; Nielssen, 2014), Denmark (Holm, 2016), the Netherlands (Poulsen, 2008), and Newfoundland landings (Pope, 2006). The figures prior to 1600 are best estimates. For the Grand Banks, the 1550 assessment is based on the number of ships active in the fishery. For Norway, the known export in 1577 has been used as a proxy for 1550. For Iceland, we have used the known exports in 1624 as a proxy for 1600, 1655 for 1650, 1733 for 1700, 1753 for 1750, and 1796 for 1800; Icelandic exports in 1300, 1400, and 1550 are calculated as a ratio of Norwegian exports in 1600. The figure for 1500 is an estimate.

estimates, however crude, are sufficient to make the economic pull of Newfoundland cod stocks seem obvious. Indeed, in the past we have grossly underestimated the historical economic significance of the fish trade, which may have been equal to the much more famed rush to exploit the silver mines of the Incas (Pope, 2004a).

MULTIDISCIPLINARY WAYS FORWARD

As momentous as this development was, the challenges to model and understand the ecological, economic, and wider social and cultural ramifications of the Fish Revolution are significant. In the words of the eminent historian Peter Pope (2004a, p. 21): “Like most early modern industries, the migratory cod fishery at Newfoundland was constrained by natural forces to an annual cycle no less than to long-term change in the climatic, economic, and diplomatic environments. This web is too complex to untangle with one tug.” We agree and believe that a full understanding of this complex web of marine ecosystems and human societies can only be obtained by multidisciplinary collaboration involving climate and marine science, as well as history and archaeology.

A satisfactory interpretation of the Fish Revolution must assess the relative importance of abiotic, biotic, and human variables. Although most of these factors would have been considered unknowable 10 or 15 years ago, ongoing breakthroughs in marine environmental history and historical ecology have moved information about both supply and demand sides of the equation into the realm of the discernible. Our knowledge of abiotic factors, such as temperature, wind, and currents, has increased tremendously in recent decades (e.g., Wang et al., 2017). In addition, biotic factors such as primary production, fish abundance, and distribution can now be mapped, visualised, and analysed in tandem with social, cultural, political, and economic variables. On the human side, there is a long tradition of research and recently renewed interest in factors such as settlement, demography, capital, labour, and technology. Recent interest in consumption history has, moreover, sparked research into social and cultural food preferences and the factors of politics, strategy, and subsidies. A multidisciplinary approach facilitates reappraisal of major historical phenomena. Table 1 identifies variables in the complex web of the Fish Revolution that need untangling and call for a multifaceted approach.

Table 1. The web of factors and variables of the Fish Revolution.

	Abiotic	Biotic	Economic	Social	Cultural	Political
Supply:	Temperature, wind, currents, salinity, nutrients	Primary production, target fish abundance and distribution	Capital, technology, labour	Distribution of settlements	Esteem, migrant cultures	Subsidies, tariffs, war
Demand:	Climate, shocks, hazards	Diseases	Integration, information flows	Human population	Preferences, religious prescriptions	Strategies (economy, settlement, navy), war

WHAT WERE THE ENVIRONMENTAL PARAMETERS OF THE FISH REVOLUTION?

Ecological forces may have been just as important as economic ones. Sixteenth-century explorers remarked on the abundance of marine life in Newfoundland relative to home waters (e.g., Pope, 2009), and indeed similar observations are made by seventeenth-century New England writers (Cronon, 2013). Bolster (2013) argues that these observations indicate an already-severe depletion of European waters. He cites medieval evidence for population decline of right whales (*Eubalaena glacialis*) and grey whales (*Eschrichtius robustus*) in the Bay of Biscay and the English Channel, decline of grey seals (*Halichoerus grypus*) and eider ducks (*Somateria molissima*) in the North Sea, and the depletion of sturgeon (*Acipenser oxyrinchus oxyrinchus*) and salmon (*Salmo salar*) from European rivers and estuaries. Indeed, similar pressure was soon put on the NW Atlantic region. Between 1530 and 1620, Basque whalers in the Straits of Belle Isle between Newfoundland and Labrador decimated right whale and bowhead (*Balaena mysticetus*) populations by killing tens of thousands of whales (Barkham, 1984). Later, between 1660 and 1701, Dutch and Basque whalers killed 35,000 to 40,000 whales in the western Arctic Ocean, causing considerable depletions of stocks and altering the whales' migratory patterns (Reeves et al., 1999). By contrast, the impact of pre-Columbian human pressure on marine life was considerably less. Although Native American Beothuk and Mi'kmaq communities in Newfoundland did prey on seals, porpoises (*Phocoena*), and gannets (*Morus bassanus*), it seems that cod fishing was minimal and that harvest rates were low relative to the scale of these marine resources, due to the available technologies and the comparatively limited level of access to offshore fishing grounds (Gilbert, 2011). Farther south, along the shores and estuaries of present-day New England, there is much evidence of the consumption of shellfish and riverine and marine fish (McKenzie, 2011, pp. 13–14). Cod was fished in some quantities as early as 2000–1200 years ago in East Penobscot Bay, Maine (Belcher, 1989), and analysis of human collagen indicates a substantial consumption of marine food, primarily shellfish (Little and Schoeninger, 1995). On balance, we agree with Bolster that European marine life in nearshore waters had been affected by AD 1500 to a degree that NW Atlantic shores had not.

However, in order to understand the choices confronting European fishers, the question must be whether human extractions had depleted major commercial fish species such as cod and herring in European waters to a degree sufficient to push fishers across the Atlantic. This seems highly unlikely. The largest and best-documented fishery of all is the Dutch North Sea herring fishery, which at a peak in AD 1602 extracted an exceptional 79,000 metric tonnes (Poulsen, 2008). This was the single most closely managed and technologically advanced fishery of the world at this time. Other nations' catches in the North Sea may be estimated at no more than half the Dutch based on preliminary investigations. To assess the impact of historical extractions, we can compare

them with modern recommended total allowable catches (TACs). Through the 1990s and 2000s, the TAC of North Sea herring was in the interval of 180,000 to 300,000 metric tonnes (Simmonds, 2007). Thus, total catches in the early modern period were consistently and considerably below those of the present day (Fig. 2). Indeed, 1602 was an exceptional year, and annual catches in the seventeenth century were mostly in the range of 20,000–50,000 tonnes, or at most 25% of today's recommended sustainable catch. The point is not that European catches were insignificant—certainly by the standards of the day the Dutch fishery was magnificent—but that their sustained efforts were likely insufficient to fish down the North Sea herring population according to present understandings.

Although European waters were not necessarily overfished, the waters of America still presented a bonanza—a pull to attract fishers across the Atlantic. But what exactly caused the attraction: Were NW Atlantic waters simply that much more productive than the European waters, even if their own status had not been markedly degraded, whether because of the intrinsic features of the NW Atlantic environment or the relatively lesser human extraction from these waters? The evidence as we currently have it indicates both. Seventeenth-century New Englanders did rave about the richness of the New World waters. Here they found an abundance and diversity of fish and specimens of a size that they had never seen before. The NW Atlantic is likely to have been more abundant than today because the ecosystem was relatively untouched. Global historical averages indicate that top predators were roughly 10 times more abundant in unimpacted ecosystems than what we observe today (Lotze and Worm, 2009). In a study of cod in the Gulf of Maine, Rosenberg et al. (2005) found a 12-fold higher abundance of cod spawning stock biomass around 1852 relative to the average of the late twentieth century. Such superabundance may explain why in the late sixteenth century the combined efforts of French, Spanish, and Portuguese hook-and-line fishers were enough to extract a staggering 200,000 metric tonnes of cod from Newfoundland waters (Pope, 2004a, 2004b).

What were the ecological implications of this scale of extraction? Clearly, the ecosystem was productive enough to sustain large-scale fishery right up to the fatal collapse of the cod by the last decades of the twentieth century. On the other hand, the removal of biomass during the Fish Revolution will have had direct repercussions on top predators and longer-term impacts on the ecosystem that we are only beginning to understand. One previously ignored consequence of the fishery was the use of marine seabirds as bait as well as diet for resident fishing communities. It is estimated that as many as 70,000–80,000 birds were culled every year. Pope (2009) argues that the ecological side effects of the cod fishery included the demise of the Great Auk (*Pinguinus impennis*) and a substantial reduction of nesting places and populations of Atlantic Puffin (*Fratercula arctica*), Common Murre also known as Guillemot (*Uria aalge*), and Northern Gannet (*Morus bassanus*). Woodland contraction was another ecological side effect (Pope, 2008). On the other

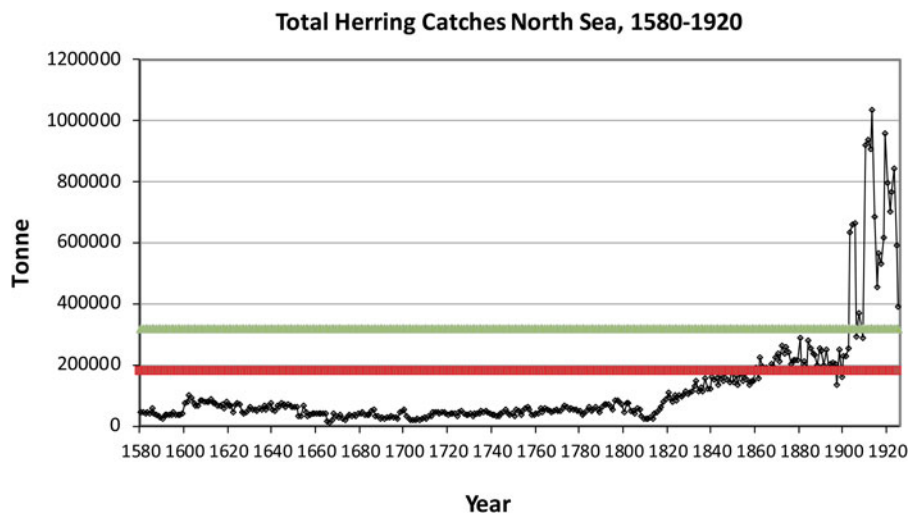


Figure 2. Herring catch data in the North Sea by Dutch fishers, 1580–1920, including total allowable catches (TACs) range 1997–2007. Based on van Bochove (2004) and Poulsen (2008), International Council for the Exploration of the Seas recommended TAC. The y-axis units are in metric tonnes. Red line indicates lower TAC range; green line indicates upper TAC range. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

hand, the removal of substantial whale populations could have left much more food for top predator fish such as cod. Considerable work remains to understand the ecological consequences of the Fish Revolution.

The contraction of Newfoundland and Grand Banks fishing areas between the time of the Fish Revolution and the present may be illustrated by comparing and contrasting

historical and contemporary map data. Figure 3 shows the extent of the modern-day cod fishery and how it contrasts with the extent of early modern fishing activities based on 51 georectified historical maps dating between 1504 and 1787. Cod fishing expanded far and wide off the Newfoundland coasts in the early modern period, encompassing the riches of the Grand Banks, which were widely fished (see

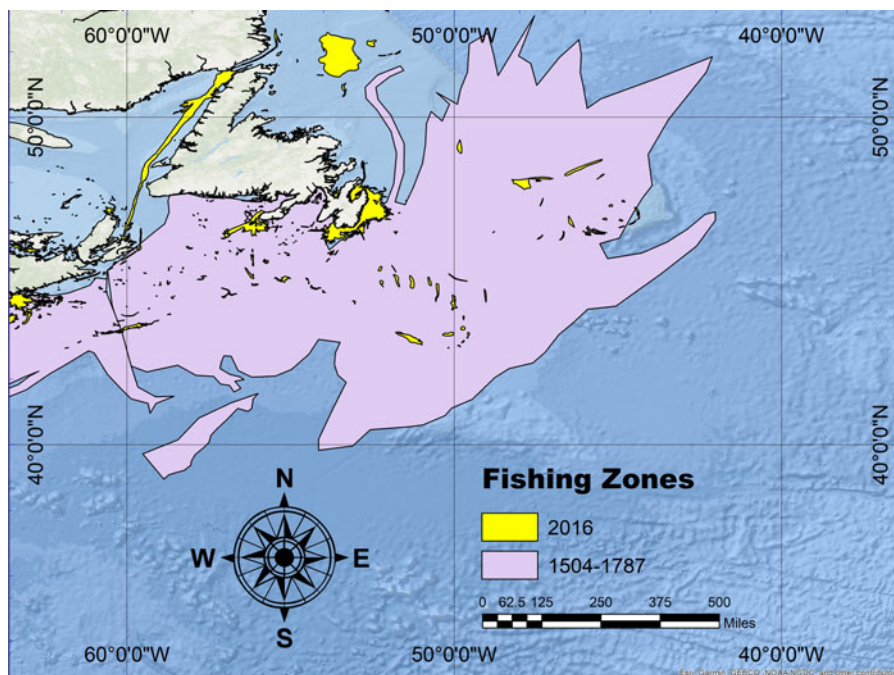


Figure 3. Contraction of Northwest Atlantic fishery, 1504–1787 versus 2016. Conglomerated historic fishing areas are indicated by purple. Yellow indicates a snapshot of 2016 fishing areas. Sources: MarineTraffic, Advanced Vessel Filters (<https://www.marinetraffic.com/en/ais/home/> [accessed 2017]); Kroodsmas et al. (2018) and Global Fishing Watch (<https://globalfishingwatch.org/our-map/> [accessed 2018]); Holm, P., Travis, C., Loughheed, K., Ludlow, F., Rankin, K.J., Legg, R., unpublished data [NorFish Historical Cartography & Fishery Data], 2018. Map by C. Travis, 2018. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

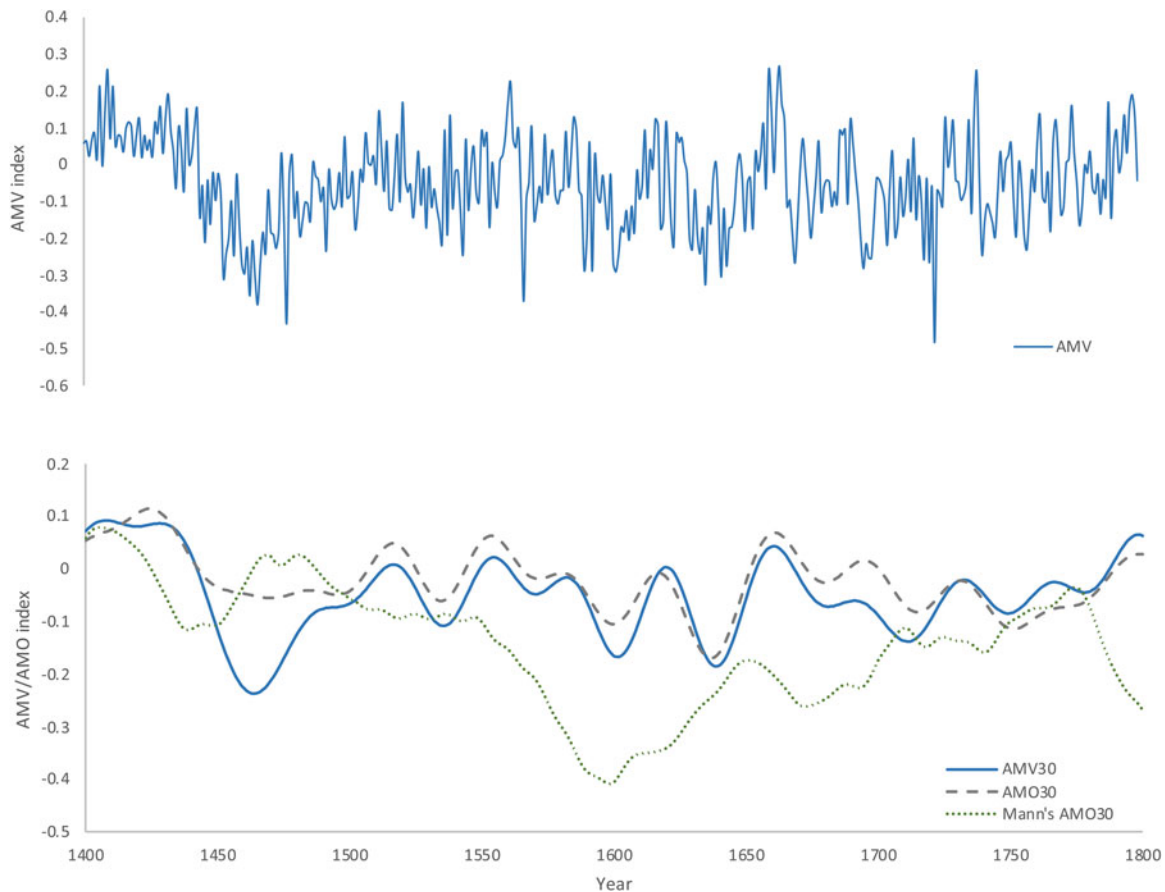


Figure 4. (colour online) The Atlantic Multidecadal Variability (AMV) and the Atlantic Multidecadal Oscillation (AMO) as indicators for environmental change, 1400–1800. Available reconstructions are increasing in number and sophistication but still exhibit disagreements, as shown here in the available reconstructions of the AMO. Sources: Top panel, AMV from Wang et al. (2017). Bottom panel, AMV with 30-yr smoothing from Wang et al. (2017), and AMO from Wang et al. (2017) and Mann et al. (2009).

Fig. 3). Even assuming uncertainty in the accuracy of the available historical maps and the challenges inherent in the process of their georeferencing and visualization that may inflate the area apparently fished, it is abundantly clear that the geographic extent of the modern fishery in the region has contracted markedly.

To better understand the attraction of the NW Atlantic, we additionally need to understand how ocean productivity varied through time and, in particular, to elucidate the likely role of climate variability such as the Little Ice Age (LIA), the spatially variable downturn of Northern Hemisphere temperatures roughly between the fifteenth and nineteenth centuries. Much more is currently known about climatic changes and their underlying dynamics during this period than the marine palaeoenvironment per se. However, we can expect that the climatic volatility of the LIA (Matthews and Briffa, 2005; Bradley, 2015) affected marine ecosystems. We know that modern ocean productivity can be highly regionalised (Prasad and Haedrich, 1993; Moll, 1998). But how did the LIA affect regional productivity? Ólafsdóttir et al. (2014) found historical DNA indications of a decline of the coastal cod population around Iceland around AD 1500, possibly related to climate change. Greene et al. (2003) have shown that

warmer waters are (at least for the Gulf of Maine) associated with greater primary biological productivity, whereas in the North Sea warmer waters are known to have the opposite effect. If the LIA acted to drive down temperatures across the Atlantic (e.g., Mann et al., 2009; Wang et al., 2017; Fig. 4), we might infer that this exerted a downward pressure on potential biological productivity in the New World while having the opposite effect in Old World waters. This observation appears initially counterintuitive to the observed attraction of the Newfoundland waters to sixteenth-century fishers. We might thus further infer, at least provisionally, that whatever the influence of climate on the relative productivities of New and Old World waters, it was not of sufficient magnitude to meaningfully rebalance the suite of push and pull factors governing the decisions of European fishers. Future challenges lie, therefore, in testing the physical reality of the assumptions underlying the previous inferences and, ultimately, in reconstructing ocean productivity across the North Atlantic to better understand the role of total and relative biological production in the Fish Revolution.

The challenges of reconstructing the marine palaeoenvironment are considerable. Climate dynamics are driven by

an interaction between internal variability and external (e.g., volcanic and solar) forcing, all having implications for marine conditions. Major explosive volcanic eruptions may, for example, influence North Atlantic productivity by multiple interacting mechanisms, including by directly cooling surface waters as well as altering ocean currents (location, velocity, mixing) and available light levels, both direct and diffuse (e.g., Robock, 2000; Pausata et al., 2015). All of these variables influence ocean productivity, beginning with the foundation of the food web in the abundance of light- and temperature-sensitive lower-trophic-level organisms such as phytoplankton and zooplankton (e.g., Legendre and Rassoulzadegan, 1995), with influences here cascading to successively higher trophic levels up to and including commercially valuable fish species such as cod and herring (Alheit et al., 2014; Alexander et al., 2017). Only by resolving questions of the long- and short-term variability of ocean productivity, and understanding whether meaningful differences existed between the total productivities and relative trajectories of Northeast (NE) and NW Atlantic waters, will we be able to fully address the questions of how LIA climates mediated marine biomass production and ultimately untangle the ecological drivers of the Fish Revolution. Although such questions would have seemed unanswerable only a couple of decades ago, we are at the cusp of a breakthrough in marine palaeoscience that calls for a sustained inquiry with marine and climate scientists in dialogue with historians and archaeologists.

WHAT WERE THE GLOBALISING EFFECTS OF THE FISH REVOLUTION?

In this article, we use the concept of globalisation in a narrow definition to denote the integration between two continents—America and Europe—as driven by trade, human migration, knowledge and cultural exchange, and financial flows (International Monetary Fund, 2000). The environmental and ecological ramifications of globalisation (Worster, 1988; Peters, 2008)—such as biodiversity change, invasive species, evolving disease environments, and other health issues—may eventually be analysed in the context of the Fish Revolution. The rise of the NW Atlantic fishery had dramatic repercussions for the European fish market, which experienced a tripling of supplies of fish protein. Consumers had the choice of buying protein as meat or fish, as depicted in Figure 5, and the aggregated effect of their preferences would have ultimately driven fishing effort. To consumers in Europe, Newfoundland cod represented a novelty. The fish was large—up to 2 m in length—and the Newfoundland climate dried the fish well.

The abundance of Newfoundland cod drove down the overall price of fish, but it still claimed a premium relative to unbranded or inferior products. We can trace the overall decline of the cod price in the purchasing power of the fishers. In AD 1500, 1 kg of Norwegian cod bought the fisher 8 kg of rye in the Bergen market. Only 50 years later, the same amount of fish bought just half this amount (Nedkvitne, 1988). This



Figure 5. (colour online) Lucas van Valckenborch (1535–1597), *Meat and Fish Market (Winter)*, ca. 1595. Oil on canvas, 123.3 x 188 cm. Montreal Museum of Fine Arts. Image used under Creative Commons.

decline continued relentlessly, as shown in Figure 6. To survive in such a market, you needed bulk, and bulk was what the Grand Banks offered.

Not only was Newfoundland fish abundant, but consumers were willing to pay a premium for it, up to twice the price of locally sourced cod (Turgeon, 2009). Regional control was enforced in the European markets, enabling customers to be confident in the uniform quality of the main commercial fish species (Unger, 1978; Vickers, 1988; Wubs-Mrozewicz, 2009; Grafe, 2012). At a time of relative price decline, producers of better quality, volume, and durability stood to gain, but exactly how did the competition between Norwegian, Icelandic, and Newfoundland cod play out? The question raises a contested subject in understanding early modern markets: How efficient—or how integrated—were markets in early modern Europe? In other words, did Newfoundland and Norwegian cod compete in the same market, or did privileged access and consumer preference stall or indeed obviate the emergence of a common seafood market? The question of integration is important for understanding the full impact of the Fish Revolution—and indeed for understanding early modern economic growth (Persson, 1999; Bateman, 2011).

The early modern European fish market operated under the influence of diverse factors, and a regional perspective does indicate that market integration was not a given. Norwegian producers had long-established contacts with the Hanseatic trading network that gave them easy access to the German and other continental markets (Wubs-Mrozewicz, 2009). French fishers developed a special commodity, the green or light-salted cod, which was preferred in France, while the Spanish fishers opened new markets in southern Europe for a heavily dried Newfoundland cod. The dried cod was ideal for the hot interior of Spain as it would endure long overland transportation (Grafe, 2012). Between 1580 and 1630, English suppliers eventually took over this market as they

forced Iberian fishers from Newfoundland by means of competition and piracy.

When possible, fish merchants took opportunities to sell at different ports in pursuit of higher demand, though the gain of doing so was mediated by variable distances and transport costs (Grafe, 2012). Such behaviour acted to promote a greater integration of the European market and a convergence of prices between regions. Yet any evolving integration also contended with factors such as customs barriers, preferential treatment, and indeed politics and war that would have pushed the market towards fragmentation (Volckardt and Wolf, 2004; Grafe, 2012). Questions about the resilience of contemporary globalized markets are now high on research agendas, notably focusing on how these markets may perform under exogenous shocks, whether from sudden moves towards protectionism, warfare, climate, or disease (e.g., Puma et al., 2015; Gephart et al., 2016; Marchand et al., 2016). It is often held that integrated markets should “perform” better by efficiently distributing food supplies from areas with surpluses to deficits, to prevent subsistence crises (van der Spek et al., 2015). However, political, environmental, economic, and ideological complexities often interfere with the system-functional expectations of macroeconomic theory. Historical tests of the functioning of integrated markets are, therefore, urgently needed (Persson, 1999; Bateman, 2011; Grafe, 2012). Cod is a suitable candidate commodity for testing these questions, as it originated from a few producers and traded as a well-defined quality product. Such research may focus on a concerted effort to map and assess the extent of market integration (in its rapidity, geography, and depth), how it was promoted or constrained by factors external to the market, how the market performed under shocks such as war or climate extremes, and how much this integration influenced the fortunes of European fishers and associated settlements.

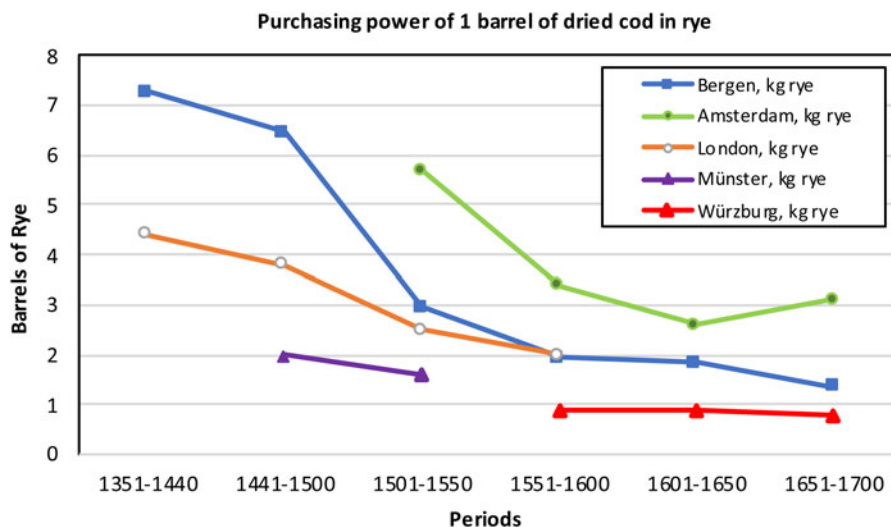


Figure 6. (colour online) Purchasing power of dried cod for rye in Bergen, Amsterdam, London, Münster, and Würzburg, 1270–1730. The y-axis units are kilograms of rye in exchange for 1 kg of dried cod. After Nedkvitne (1988, pp. 38, 42).

WHAT WERE THE CONSEQUENCES OF THE FISH REVOLUTION FOR FISHING COMMUNITIES?

The Fish Revolution affected fishing societies on both sides of the North Atlantic in opposite ways. In the NW Atlantic, new landscapes of at first migratory and later permanent mixed-ethnic settlements emerged in a landscape that had previously borne only a small indigenous population. In the NE Atlantic, the coastal landscape around 1500 was dotted with settlements, which by the seventeenth century were in decline. Distinct migratory pathways developed as a result, which conditioned the landscapes for the next couple of hundred years and in many ways are discernible even today.

Prior to the Fish Revolution, the late medieval commercial boom led to a rapid development of European fishing communities in both urban and rural contexts. A comprehensive review of the settlements remains to be undertaken, but it seems that urban fishing communities thrived on providing fresh fish for the town and local elites while also attracting merchant and estate capital to fit out vessels for long-distance operations. Urban fishing communities flourished in Ribe in Denmark (Holm, 1999) and in Great Yarmouth, Scarborough, and Hull in England (Childs, 2000), but nowhere more so than in the Low Countries in towns such as Dunkirk, Nieuwpoort and Ostend, Rotterdam, Schiedam, Vlaardingen, Maassluis, Brielle, and Enkhuizen (Sicking, 2002; van Bochove, 2004). The Dutch developed a technological lead in North Sea herring fisheries that was begrudged but never successfully copied through this period by their competitors (Poulsen, 2016b). Although the English herring fishery seems to have succumbed to Dutch competition by the fifteenth century, Hull developed a longline fishery off Iceland that lasted well into the seventeenth century (Childs, 2000; Jones, 2000).

Rural coastal settlements—lacking a ready market—concentrated on nearshore fishing and produced dried and salted fish for sale at seasonal fairs in combination with other maritime activities such as trade, privateering (essentially piracy), and other coastal trades. The coastal settlements differed from the rural hinterland by including households of fishermerchants with international contacts. They stand out in the archaeological record as particularly rich in imported goods and show a wealth in some households that make the settlements more akin to an urban than a rural context. The rural coastal settlements may be found all around northern European coasts of the Atlantic and (western) Baltic. They were clearly linked to the late medieval rise in income that was conditioned by the high fish prices of the fourteenth and fifteenth centuries. Settlement took place on open lands, dunes, rocks, and moors, in close proximity to the sea and sometimes right by the beach. Although settlers cultivated small garden plots, the land was often largely unfit for agriculture. The settlers themselves are likely to have come from impoverished landless origins. The settlements often depended on capital provided by urban merchants and landed nobility who took an interest in developing maritime trade and even piracy out of

barren soil (Berg et al., 1981; Holm, 1999; Fox, 2001; Kowaleski, 2003).

The rural coastal settlements are significant for our understanding of the second phase of commercialisation of the fisheries. Fox (2001, pp. 186–187) interpreted the late-medieval settlements as “marginal economically because Acts of God (like storms and the disappearance of shoals from the inshore waters) could take away their inhabitants’ main means of making a living; and because they were especially prone to destruction by fire (closely huddled houses) and their people especially prone to plague.” A very different view is proposed by Goddard (2011) who argues that thirteenth- and fourteenth-century small boroughs may be seen as “enterprise zones” within the English manorial economy. Goddard is not particularly concerned with coastal locations, but his considerations may be very pertinent to an understanding of their economic role. His model would fit an interpretation of the many rural ports of southwest England as a major factor in the English expansion into the Atlantic (Kowaleski, 2000).

Many of the marginal settlements were deserted or much reduced by the seventeenth century (i.e., after the onset of the Fish Revolution). We can identify local contraction and even abandonment of fishing in Norway, Denmark, Iceland, the Faroes, and Ireland. Archaeological and historical evidence shows that the Danish North Sea coast experienced a retraction of settlements to the inland (Holm, 2002). In northern Norway, specialised coastal fishing settlements were abandoned, and people moved inland to pursue a multiplurality economic subsistence that mixed farming and marine exploitation (Nielssen, 2016). In Iceland, fishing changed from being market led to being primarily for subsistence (Krivogorskaya et al., 2005; Edvardsson, 2010; Vésteinnsson, 2016), and the primary export commodity shifted from fish to wool as was the case also on the Faroes (Gunnarsson, 1983; Stoklund, 1992). Urban fishing communities beyond the still-prospering Netherlands similarly seem to have declined.

This decline may be explained by multiple factors that are likely to have interacted in complex ways. Settlements in the Old World suffered from the Atlantic Fish Revolution (declining real prices of fish, increased fish supplies, and changing consumer demands), increased trade competition and piracy, and the global shipping revolution (increasing focus on port cities and long-distance trade). Others suffered dramatic flooding with coastal erosion and loss of settlements during the LIA (e.g., Lamb and Frydendahl, 1991; Soens, 2013). Their demise or transformation is indicative of a larger economic, social, and environmental pattern that remains to be fully researched.

At the same time, settlements increased in Newfoundland. Archaeological traces of French settlers in the Petit Nord, and in southern Newfoundland, in addition to emerging English settlements in the southeast, showed a significant increase when seasonal return voyages of the labour force, typical of the sixteenth century, gave way to permanent settlements in the seventeenth and eighteenth centuries (see Fig. 7). The process was entangled with the differing political fortunes

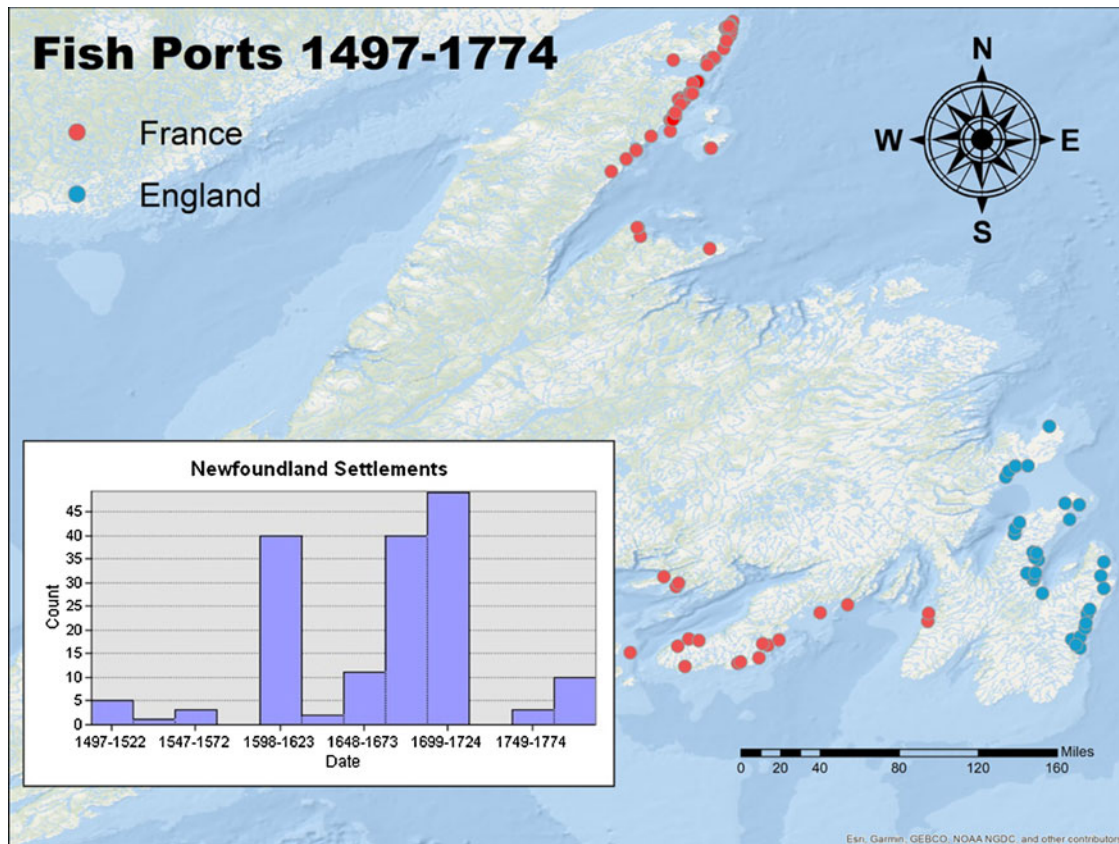


Figure 7. (colour online) Evidence of French fishing “rooms” in the northernmost peninsula (the Petit Nord) and in southern Newfoundland, in addition to English settlement in the southeast, 1497–1774. Sources: Tapper (2014); P. Pope, personal communication 2016. Redrawn by C. Travis.

of the nations and peoples in question. Portuguese, Spanish, Basque, and French fishers had pioneered the Atlantic trade route as is evidenced by the surviving place names of the landscape and early cartography. Unfortunately, the details of this process are still obscure despite some pioneering research (Turgeon, 2009; Grafe, 2013; Barros, 2015). However, by the end of the sixteenth century, English fishermen and privateers succeeded in ousting the Iberian fishers, while the French succeeded in keeping the Petit Nord and southern coasts of Newfoundland into the mid-eighteenth century. Figure 7 shows the locations of French and British settlements and highlights that permanent migration took place most heavily in two distinct phases, 1598–1623 and 1699–1724.

These changes in settlement patterns raise fundamental questions about the broader social and cultural impact of the Fish Revolution. Regions, such as Scandinavia, the NE Atlantic islands, and Germany, which failed to obtain access to the new fishing grounds in the NW Atlantic, saw a decline of home fisheries and a rise of an itinerant labour force as the European fisheries went into decline (Holm, 2002; van Lotum, 2007). Regions such as southwest England that did have access to Newfoundland saw a wave of emigration across the Atlantic (Matthews, 1968). In other words, we may be looking at two distinct patterns of labour migration

as a result of the Fish Revolution. A full resolution of this picture will be of importance for understanding how coastal societies responded and adapted to the challenges of climate change and globalisation.

The Atlantic pathway points to the importance of overarching political rivalries and colonial contexts as the commercial interests of the Fish Revolution intensified. As a consequence of the Fish Revolution, perceptions of the North Atlantic changed, not only among fishers themselves but also within the European political, cultural, and economic hierarchy. Fishers were key witnesses for adventurers searching for both the Northwest and Northeast Passages and for prospectors searching for precious metals and valued commodities in the New World. Their information was filtered into the contemporaneous cartographic records, which now yield significant insights into what was known about fisheries and the related marine environment, while also reflecting the political and technological contexts underlying the production of maps. Through maps we can survey how evolving representations of Newfoundland reflected changing political and economic contexts over time, from early renderings by the Portuguese (e.g., Pedro Reinel’s map, ca. 1504; Fig. 8) to maps reflecting the English/French rivalry over the fishery in the late seventeenth century, such as the 1693 chart of



Figure 8. (colour online) Pedro Reinel (ca. 1462–1542), Portulan (Atlantic) (Portugal, ca. 1504). 62.0 x 89.3 cm. Bayerische Staatsbibliothek, Munich. (Digital copy is licensed under: CC BY-NC-SA 4.0.)



Figure 9. (colour online) Augustine Fitzhugh, *A Chart of the Coasts of Newfoundland, with the Fishing Districts Marked...*, 1693, London. Original 122 x 69 cm. © British Library Board (Additional MS. 5414.30).

the coasts of Newfoundland and the Grand Banks by Augustine Fitzhugh (Fig. 9). While Fitzhugh shows the Grand Banks teeming with large French vessels, he depicts the small British boats in the inshore waters as literally besieged. The tensions underlying the political propaganda inherent in this map were eventually resolved with military confrontation and ultimately the Treaty of Utrecht of 1713 (Ames, 2008), which gave the British the undisputed upper hand in that most valuable asset of the “New World”, the Grand Banks.

CONCLUSION

The Fish Revolution is under-researched and indeed little appreciated as a major event in the history of resource utilisation and globalisation. Open research questions abound, especially those that pertain to the natural productivity and variability of fish stocks, the impact of changes in fisheries on coastal societies in Europe, and the relationship between changing fisheries and the politics and culture of European states. The challenge is finding effective ways to coordinate and integrate research into natural environmental variability, social science, and historical analysis. It involves working with very different kinds of data, each with its own appropriate scales, uncertainties, and relevance. It requires multidisciplinary teams that are motivated to collaborate and work towards finding the answers to common questions and problems, and it requires the development of theoretical frameworks capable of addressing complexity and multicausality.

By identifying the Fish Revolution as a major event in the history of resource extraction and consumption, bounded by climate change and globalisation, and by engaging in multidisciplinary research, we have highlighted and begun to address three key questions: (1) What were the environmental parameters of the Fish Revolution? (2) What were the globalising effects of the Fish Revolution? (3) What were the consequences of the Fish Revolution for fishing communities?

Much remains to be done, but we hope here to have identified a research agenda that will stimulate future multidisciplinary endeavours. Further and larger questions wait to be explored and answered in future work. For example: How was the change in fish consumption related to other changes, material and cultural, such as the access to other new foods (potatoes, maize, etc.) coming from the New World, and how significant were the fishing operations to the development of capital, politics, and cultural values of the period?

Fishing was not a glamorous activity; it was dangerous and dirty work. The industry developed between ca.1500 and 1700 with a transatlantic thrust of momentous economic, cultural, and political significance. Indeed, the Fish Revolution around 1500 permanently changed human and animal life in the North Atlantic region. The wider seafood market was transformed in the process, and the marine expansion of humans across the North Atlantic was conditioned by significant climatic and environmental parameters. The Fish

Revolution is one of the clearest early examples of how humans can affect marine life on our planet and of how marine life can in return influence and become, in essence, a part of a globalising human world.

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REFERENCES

- Alexander, K.E., Bittner, S.M., Bryan, A., Carr, B.H., Hall, C., Jordaan, A., Klein, E., *et al.*, 2017. Tabora and the mackerel year: phenology and fisheries during an extreme climate event. *Science Advances* 3, e1601635.
- Alheit, J., Licandro, P., Coombs, S., Garcia, A., Giráldez, A., Garcia Santamaría, M.T., Slotte, A., Tsiakirias, A.C., 2014. Atlantic Multidecadal Oscillation (AMO) modulates dynamics of small pelagic fishes and ecosystem regime shifts in the eastern North and Central Atlantic. *Journal of Marine Systems* 131, 21–35.
- Ames, G.J., 2008. *The Globe Encompassed: The Age of European Discovery, 1500–1700*. Pearson, Upper Saddle River, NJ.
- Amorim, I., 2009. Portuguese fisheries, c. 1100–1830. In: David, J., Starkey, J. (Ed.), *A History of the North Atlantic Fisheries*. Vol. 1, From Early Times to the Mid-Nineteenth Century. Verlag H.M. Hauschild, Bremen, Germany, pp. 279–298.
- Barkham, S. H., 1984. The Basque whaling establishments in Labrador 1536–1632—a summary. *Arctic* 37, 515–519.
- Barrett, J., Locker, A.M., Roberts, C.M. 2004. The origin of intensive marine fishing in medieval Europe: The English evidence. *Proceedings of the Royal Society B* 271: 2417–2421.
- Barrett, J., Orton, D., 2016. *Cod and Herring: The Archaeology and History of Medieval Sea Fishing*. Oxbow Books, Oxford, UK.
- Barros, A.J.M., 2015. Cod fishery and global trade: Porto’s ships in Newfoundland in the sixteenth century. In: Robinson, R., Wilcox, M., McCarthy, M. (Eds.), *Human and Environmental Interactions in the Development of the North Atlantic Fisheries*. North Atlantic Fisheries History Association, Hull, UK, pp. 7–22.
- Bateman, V., 2011. The evolution of markets in early modern Europe, 1350–1800: a study of wheat prices. *Economic History Review* 64, 447–471.
- Belcher, W.R., 1989. Prehistoric fish exploitation in east Penobscot Bay, Maine: the Knox site and sea-level rise. *Archaeology of Eastern North America* 17, 175–191.
- Berg, H., Jørgensen, L.B., Mortensøn, O., 1981. *Sandhagen: Et langlandsk fiskerleje fra renaissancen*. Langelands Museum, Rudkøbing, Denmark.
- Bolster, W.J., 2013. *The Mortal Sea: Fishing the Atlantic in the Age of Sail*. Harvard University Press, Cambridge, MA.
- Bradley, R.S., 2015. *Paleoclimatology: Reconstructing Climates of the Quaternary*. 3rd ed. Elsevier, Amsterdam.

- Campbell, B.M.S., 2016. *The Great Transition: Climate, Disease and Society in the Late-Medieval World*. Cambridge University Press, Cambridge.
- Childs, W.R., 2000. Irish merchants and seamen in late medieval England. *Irish Historical Studies* 32, 22–43.
- Cronon, W., 2013. *Changes in the Land: Indians, Colonists, and the Ecology of New England*. Farrar, Straus and Giroux, New York.
- Edvardsson, R., 2010. The Role of Marine Resources in the Medieval Economy of Vestfirðir, Iceland. PhD dissertation, Graduate Center, City University of New York, New York. https://www.geos.ed.ac.uk/~nabo/postgraduates/theses/ragnar/Dissertation_ragnar_Finalvers_bw.pdf.
- Fox, H., 2001. *The Evolution of the Fishing Village: Landscape and Society along the South Coast, 1086–1550*. Leopard's Head Press, Oxford, UK.
- Gardiner, M., 2016. The character of commercial fishing in Icelandic waters in the fifteenth century. In: Barrett, J.H., Orton, D.C. (Eds.), *Cod and Herring: The Archaeology and History of Medieval Sea Fishing*. Oxbow, Oxford, UK, pp. 80–90.
- Gephart, J.A., Rovenskaya, E., Dieckmann, U., Pace, M.L., Brännström, A., 2016. Vulnerability to shocks in the global seafood trade network. *Environmental Research Letters* 11, 035008.
- Gilbert, W., 2011. Beothuk-European contact in the 16th century: a re-evaluation of the documentary evidence. *Acadiensis* 40, 24–44.
- Goddard, R., 2011. Small Boroughs and the Manorial Economy: Enterprise Zones or Urban Failures? *Past & Present* 210(1): 3–31.
- Grafe, R., 2012. *Distant Tyranny: Markets, Power, and Backwardness in Spain, 1650–1800*. Princeton University Press, Princeton, NJ.
- Grafe, R., 2013. Polycentric states: the Spanish reigns and the “failures” of mercantilism. In: Stern, P., Wennerlind, C. (Eds.), *Mercantilism Reimagined: Political Economy in Early Modern Britain and Its Empire*. Oxford University Press, Oxford, 241–262.
- Greene, C.H., Pershing, A.J., Conversi, A., Planque, B., Hannah, C., Sameoto, D., Head, E., Smith, P.C., Reid, P.C., Jossi, J., Mountain, D., Benfield, M.C., Wiebe, P.H., Durbin, E. (2003) Trans-atlantic responses of *Calanus finmarchicus* populations to basin-scale forcing associated with the North Atlantic Oscillation. *Progress in Oceanography*, 58, 301–312.
- Gunnarsson, G., 1983. *Monopoly Trade and Economic Stagnation: Studies in the Foreign Trade of Iceland 1602–1787*. Ekonomisk-historiska foreningen, Lund, Sweden.
- Hoffmann, R., 2005. A brief history of aquatic resource use in medieval Europe. *Helgoland Marine Research* 59, 22–30.
- Holm, P., 1999. Fiskeriets økonomiske betydning i Danmark, 1350–1650. *Sjæk'len* 1998, 9–42.
- Holm, P., 2002. Maritime dependency in Ribe and Aalborg, 1450–1800. In: Starkey, D.J., Hahn-Pedersen, M. (Eds.), *Concentration and Dependency: The Role of Maritime Activities in North Sea Communities, 1299–1999*. Fiskeri- og Søfartsmuseet, Esbjerg, Denmark, pp. 47–68.
- Holm, P., 2016. Commercial sea fisheries in the Baltic region c. AD 1000–1600. In: Barrett, J., Orton, D. (Eds.), *Cod and Herring: The Archaeology and History of Medieval Sea Fishing*. Oxbow Books, Oxford, UK, pp. 13–22.
- International Monetary Fund (IMF), 2000. *Globalization: Threat or Opportunity?* IMF, Washington, DC. <https://www.imf.org/external/np/exr/ib/2000/041200to.htm#II>.
- Jones, E.T., 2000. England's Icelandic fishery in the early modern period. In: Starkey, D.J. (Ed.), *England's Sea Fisheries: The Commercial Sea Fisheries of England and Wales since 1300*. Chatham, London, pp. 105–110.
- Jones, E.T., Condon, M.M., 2016. *Cabot and Bristol's Age of Discovery: The Bristol Discovery Voyages 1480–1508*. University of Bristol, Bristol, UK.
- Jónsson, J., 1994. Fisheries off Iceland, 1600–1900. *ICES Marine Science Symposia* 198, 3–16.
- Kowaleski, M., 2000. The expansion of the south-western fisheries in late medieval England. *Economic History Review* 3, 429–454.
- Kowaleski, M., 2003. The commercialization of the sea fisheries in medieval England and Wales. *International Journal of Maritime History* 15, 177–231.
- Krivogorskaya, Y., Perdikaris, S., McGovern, T.H., 2005. Fish bones and fishermen: the potential of zooarchaeology in the Westfjords. *Archaeologica Islandica* 4, 31–51.
- Kroodsmá, D.A., Hochberg, T., Mayorga, J., Miller, N.A., Boerder, K., Ferretti, F., Wilson, A., et al., 2018. Tracking the global footprint of fisheries. *Science* 359, 904–908.
- Lamb, H.H., Frydendahl, K., 1991. *Historic Storms of the North Sea, British Isles and Northwest Europe*. Cambridge University Press, Cambridge.
- Lawrence, A.W., Young, J. (Eds.), 1931. *Narratives of the Discovery of America*. J. Cape and H. Smith, New York.
- Legendre, L., Rassoulzadegan, F., 1995. Plankton and nutrient dynamics in marine waters. *Ophelia* 41, 153–172.
- Little, E.A., Schoeninger, M.J., 1995. The Late Woodland diet on Nantucket Island and the problem of maize in coastal New England. *American Antiquity* 60, 351–368.
- Lotze, H.K., Worm, B., 2009. Historical baselines for large marine animals. *Trends in Ecology and Evolution* 24, 254–262.
- Maddison, A., 2008. *Statistics on World Population, GDP and Per Capita GDP, 1–2008 AD*. Groningen Growth & Development Centre, University of Groningen, Groningen, the Netherlands. <http://www.ggd.net/maddison/oriindex.htm>.
- Mann, M., Zhang, Z., Rutherford, S., Bradley, R.S., Hughes, M.K., Shindell, D., Ammann, C., Faluvegi, G., Ni, F., 2009. Global signature and dynamical origins of the Little Ice Age and Medieval Climate Anomaly. *Science* 326, 1256–1260.
- Marchand, P., Carr, J.A., Dell'Angelo, J., Fader, M., Gephart, J.A., Kumm, M., Magliocca, N.R., et al., 2016. Reserves and trade jointly determine exposure to food supply shocks. *Environmental Research Letters* 11, 095009.
- Matthews, J.A., Briffa, K.R., 2005. The ‘Little Ice Age’: re-evaluation of an evolving concept. *Geografiska Annaler Series A: Physical Geography* 87, 17–36.
- Matthews, K., 1968. *A History of the West of England-Newfoundland Fishery*. PhD dissertation, Oxford University, Oxford.
- McKenzie, M., 2011. *Clearing the Coastline: The Nineteenth-Century Ecological and Cultural Transformation of Cape Cod*. University Press of New England, Hanover, NH.
- Michell, A.R., 1977. The European fisheries in early modern history. In: Rich, E.E., Wilson, C.H. (Eds.), *The Cambridge Economic History of Europe*. Vol. 5, The Economic Organization of Early Modern Europe. Cambridge University Press, Cambridge, pp. 133–184.
- Moll, A., 1998. Regional distribution of primary production in the North Sea simulated by a three-dimensional model. *Journal of Marine Systems* 16, 151–170.
- Nedkvitne, A., 1988. “Mens Bønderne seilte og Jægterne for”: *Nordnorsk og vestnorsk kystøkonomi 1500–1730*. Universitetsforlaget, Oslo.

- Nedkvitne, A., 2014. *The German Hansa and Bergen 1100–1600*. Böhlau-Verlag, Vienna.
- Nielsen, A.R., 2016. Early commercial fisheries and the interplay among farm, fishing station and fishing village in North Norway. In: Barrett, J., Orton, D. (Eds.), *Cod and Herring: The Archaeology and History of Medieval Sea Fishing*. Oxbow Books, Oxford, UK, pp. 42–49
- Nielsen, A.R., Bjerck, H.B., Hutchison, A., Kolle, N., Larsen, M.F. (Eds.), 2014. *Fangstmenn, fiskerbønder og værfolk, Fram til 1720*. Fagbokforlaget, Bergen, Norway.
- Officer, L.H., Williamson, S.H., 2018. Five Ways to Compute the Relative Value of a UK Pound Amount, 1270 to Present (accessed November 22, 2018). MeasuringWorth. <https://www.measuring-worth.com/calculators/ukcompare>.
- Ólafsdóttir, G.Á., Westfall, K.M., Edvardsson, R., Pálsson, S., 2014. Historical DNA reveals the demographic history of Atlantic cod (*Gadus morhua*) in medieval and early modern Iceland. *Proceedings of the Royal Society B: Biological Sciences* 281, 20132976.
- Parker, G., 2013. *Global Crisis: War, Climate Change and Catastrophe in the Seventeenth Century*. Yale University Press, New Haven, CT.
- Pausata, F.S.R., Chafik, L., Caballero, R., Battisti, D.S., 2015. Impacts of high-latitude volcanic eruptions on ENSO and AMOC. *Proceedings of the National Academy of Sciences of the United States of America* 112, 13784–13788.
- Persson, K.G., 1999. *Grain Markets in Europe, 1500–1900: Integration and Deregulation*. Cambridge University Press, Cambridge.
- Peters, D.C., 2008. Ecology in a connected world: a vision for a “network of networks.” *Frontiers in Ecology and the Environment* 6, 227.
- Pope, P.E., 2004a. *Fish into wine the Newfoundland plantation in the seventeenth century*. University of North Carolina Press, Chapel Hill.
- Pope, P.E., 2004b. HMAP Dataset 6: Newfoundland 1675–1698 (accessed November 22, 2018). <https://hydra.hull.ac.uk/resources/hull:2157>.
- Pope, P.E., 2006. The scale of the early modern Newfoundland cod fishery. In: Starkey, D., Candow, J.E. (Eds.), *The North Atlantic Fisheries: Supply, Marketing and Consumption, 1560–1990*. North Atlantic Fisheries History Association, Hull, UK, pp. 9–28.
- Pope, P.E., 2008. Transformation of the maritime cultural landscape of Atlantic Canada by migratory European fishers, 1500–1800. In: Sicking, L., Abreu-Ferreira, D. (Eds.), *Beyond the Catch: Fisheries of the North Atlantic, the North Sea, and the Baltic, 900–1850*. Brill, The Hague, the Netherlands, pp. 123–154.
- Pope, P.E., 2009. Early migratory fishermen and Newfoundland’s seabird colonies. *Journal of the North Atlantic* 1, 57–70.
- Poulsen, B., 2008. *Dutch Herring: An Environmental History, c. 1600–1860*. Amsterdam University Press, Amsterdam.
- Poulsen, B., 2016a. Human archives: historians’ methodologies and past marine resource use. In: Schwerdtner Mániz, K. Poulsen, B. (Eds.), *Perspectives on Oceans Past: A Handbook of Marine Environmental History*. Springer, Dordrecht, the Netherlands, pp. 71–87.
- Poulsen, B., 2016b. Imitation in European herring fisheries, c. 1550–1860. *Scandinavian Journal of History* 41, 185–207.
- Prasad, K.S., Haedrich, R.L., 1993. Primary production estimates on the Grand Banks of Newfoundland, north-west Atlantic Ocean, derived from remotely-sensed chlorophyll. *International Journal of Remote Sensing* 14, 3299–3304.
- Puma, M.J., Bose, S., Chon, S.Y., Cook, B.I., 2015. Assessing the evolving fragility of the global food system. *Environmental Research Letters* 10, 024007.
- Reeves, R.R., Jeffrey, M.B., Mitchell, E.D., 1999. History of whaling and estimated kill of right whales, *Balaena glacialis*, in the northeastern United States, 1620–1924. *Marine Fisheries Review* 61, 1–36.
- Robock, A., 2000. Volcanic eruptions and climate. *Reviews of Geophysics* 38, 191–219.
- Rosenberg, A., Bolster, W.J., Alexander, K.E., Leavenworth, W.B., Cooper, A.B., McKenzie, M.G., 2005. The history of ocean resources: modeling cod biomass using historical records. *Frontiers in Ecology and the Environment* 3, 78–84.
- Russel-Wood, A.J.R., 1998. *The Portuguese Empire, 1415–1808: A World on the Move*. Johns Hopkins University Press, Baltimore, MD.
- Sicking, L., 2002. The fishing lobby of Flanders, 1485–1559. *Studia Atlantica* 5, 1–12.
- Simmonds, E.J., 2007. Comparison of two periods of North Sea herring stock management: success, failure, and monetary value. *ICES Journal of Marine Science* 64, 686–692.
- Soens, T., 2013. Flood security in the medieval and early modern North Sea area: a question of entitlement? *Environment and History* 19, 209–232.
- Starkey, D.J., Thor, J.Th., Heidbrink, I., (Eds.), 2009. *A History of the North Atlantic Fisheries*. Vol. 1, From Early Times to the Mid-Nineteenth Century. H.M. Hauschild, Bremen, Germany.
- Stoklund, B., 1992. From centre to periphery: main lines of North Atlantic cultural development from medieval to modern times. *Ethnologia Europaea: Journal of European Technology* 22, 51–65.
- Tapper, B., 2014. *An Archaeological Analysis of the Distribution of French Fishing Rooms on the Petit Nord, Newfoundland*. Master’s thesis, Memorial University of Newfoundland, St. John’s.
- Turgeon, L., 2009. Codfish, consumption, and colonization: the creation of the French Atlantic world during the sixteenth century. In: Williams, C.A. (Ed.), *Bridging the Early Modern Atlantic World: People, Products, and Practices on the Move*. Ashgate, Aldershot, UK, pp. 33–56
- Unger, R.W., 1978. The Netherlands herring fishery in the late Middle Ages: the false legend of Willem Beukels of Biervliet. *Viator: Medieval and Renaissance Studies* 9, 335–356.
- van Bochove, C., 2004. De Hollandse haringvisserij tijdens de vroegmoderne tijd. *Tijdschrift voor sociale en economische geschiedenis* 1, 3–27.
- van der Spek, R.J., van Leeuwen, R.J., van Zanden, J.L. (Eds.), 2015. *A History of Market Performance: From Ancient Babylonia to the Modern World*. Routledge, London.
- van Lottum, J.J., 2007. *Across the North Sea: The Impact of the Dutch Republic on International Labour Migration, c. 1550–1850*. Amsterdam University Press, Amsterdam.
- Vésteinsson, O., 2016. Commercial fishing and the political economy of medieval Iceland. In: Barrett, J., Orton, D. (Eds.), *Cod and Herring: The Archaeology and History of Medieval Sea Fishing*. Oxbow Books, Oxford, UK, pp. 178–195.
- Vickers, D. 1988. “A known and staple commodity”: codfish prices in Essex County, Massachusetts, 1640–1775. *Essex Institute Historical Collections* 124, 186–203.

- Volckart, O., Wolf, N., 2004. *Estimating Medieval Market Integration: Evidence from Exchange Rates. Discussion Papers 2004/21*. School of Business and Economics, Free University of Berlin, Berlin.
- Wang, J., Yang, B., Ljungqvist, F.C., Luterbacher, J., Osborn, T.J., Briffa, K.R., Zorita, E., 2017. Internal and external forcing of multidecadal Atlantic climate variability over the past 1,200 years. *Nature Geoscience* 10, 512–518.
- Worster, D. (Ed.), 1988. *The Ends of the Earth. Perspectives on Modern Environmental History*. Cambridge University Press, Cambridge.
- Wubs-Mrozewicz, J., 2009. Fish, stock and barrel: changes in the stockfish trade in Northern Europe, c. 1360–1560. In: Sicking, L., Abreu-Ferreira, D. (Eds.), *Beyond the Catch*. Brill, Leiden, the Netherlands, pp. 187–208