FISH and FISHERIES

Origins of the bottom trawling controversy in the British Isles: 19th century witness testimonies reveal evidence of early fishery declines

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Abstract

Bottom trawling (nets towed along the seabed) spread around the British Isles from the 1820s, yet the collection of national fisheries statistics did not begin until 1886. Consequently, analysis of the impacts of trawling on fish stocks and habitats during this early period is difficult, yet without this information, we risk underestimating the extent of changes that have occurred as a result of trawling activities. We examined witness testimonies recorded during two Royal Commissions of Enquiry (1863–66 and 1883–85). These enquiries interviewed hundreds of fishers about the early effects of sail trawling and the changes they were witnessing to fish stocks, habitats and fishing practises during this time. We converted all quantitative statements of perceived change in fish stocks and fishing practices to relative change. Witnesses from the north-east of England interviewed during 1863 revealed an average perceived decline in whitefish of 64% during their careers, which many blamed upon trawling. Between 1867 and 1892, trawl-landing records from the same location suggest that this trajectory continued, with fish availability declining by 66% during the period. Fishers adapted to these declines by increasing distances travelled to fishing grounds and increasing gear size and quantity. However, inshore declines continued and by the early 1880s even trawl owners were calling for closures of territorial waters to trawling in order to protect fish nursery and spawning grounds. Until now, these testimonies have been largely forgotten, yet they reveal that alterations to near-shore habitats as a result of trawling began long before official data collection was initiated.

Keywords bottom trawling, British fisheries, environmental history, historical ecology

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Introduction

Sea fishing has occurred along the coasts of Europe for centuries (Barrett *et al.* 2004), yet until recently a lack of temporal context has led us to underestimate the changes that have occurred as a result of exploitation (Roberts 2007). Seminal papers by Jackson *et al.* (2001), Pandolfi *et al.* (2003) and Myers and Worm (2003), for example, have helped to stimulate important debate about the long-term effects of fishing. Whilst it is generally agreed that the adoption of steam by fishing vessels during the 1880s led to dramatic increases in fishing power and consequently increased impacts upon fish stocks (Garstang 1900; Engelhard 2009), it is likely that pre-industrial fisheries also significantly impacted fish abundance (Pinnegar and Engelhard 2008).

However, for fisheries that began many decades ago, limited records exist to evaluate the scale of early impacts and thus quantify the magnitude of departure from pre-fishery conditions. Research into pre-industrial fisheries includes work by MacKenzie *et al.* (2007) who uncovered data describing the scale of 16th century Baltic cod fisheries; Poulsen *et al.* (2007a) who showed that both intensive fishing activities and environmental variability were important drivers of change in fish stock abundance in the Limfjord Estuary, Denmark between 1667 and 1860; and Poulsen *et al.* (2007b) who were able to reconstruct abundance estimates for ling and cod in the Skagerrak and north-eastern North Sea prior to the onset of bottom trawling using historical catch per unit effort data. Further examples include Eero *et al.* (2007), Lajus *et al.* (2007) and Grasso (2008). Our research adds to this literature by investigating the initial impacts of bottom trawling as it expanded into the North Sea (Engelhard 2009; Kerby *et al.* 2012). This research is novel in that it uses 19th century fisher perceptions to quantitatively describe the changes in catch rates that were witnessed by fishers during the earliest years of the expansion of trawl fishing.

Bottom trawling in the British Isles has been documented as far back as the 14th century (Jones 1992; Roberts 2007); however, until the mid-19th century, this activity was limited to a few localities along the south coast of England (Alward 1932). Early bottom trawls consisted of a wooden beam from 3 m long that held open a bag net that was towed across the seabed by sail-powered fishing smacks (Alward 1932). From about the 1820s, improved transport networks (mainly railways) opened up large markets in inland cities for cheap supplies of fish, thus stimulating the rapid spread of trawling (Robinson and Starkey 1996; Fig. 1). Despite the trawl's long history, little information exists to describe the early impacts that trawling had on marine fish stocks and habitats. Statistical information on British fisheries did not begin to be gathered on a national scale until the 1880s, by which time trawling was widespread (Russell and Edser 1925). Hence, whilst these statistical data provide valuable insights into the changing fortunes of the fishing industry (Thurstan *et al.* 2010; Kerby *et al.* 2012), they do not incorporate the earliest years of industrialized fishing.

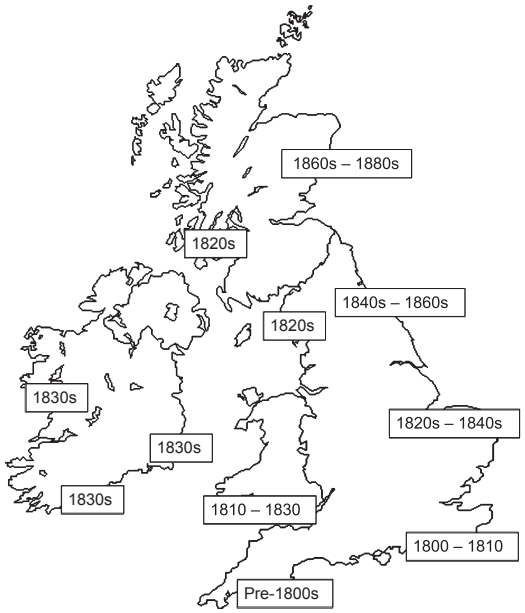

Figure 1 Approximate dates that sail trawling began around coasts of the British Isles in the areas indicated. Dates for the North Sea were sourced from Alward (1932), and dates for the rest of the British Isles and Ireland were sourced directly from the 1866 Royal Commission.

Important exceptions to the lack of data from this period include the Minutes of Evidence of Royal Commissions, who periodically undertook enquiries into British fisheries to gain a deeper understanding of what was then a rapidly growing and increasingly profitable industry. The rapid spread of the trawl meant that by the 1860s trawlers were resident at major ports upon the north-east coast of England and were exploring grounds throughout the North Sea, often coming into direct competition with other classes of fishers. Many fishers opposed trawling as they perceived it to be a wasteful and destructive method of fishing (Report of the Commissioners 1866). The outcry that ensued resulted in a 3-year Royal Commission of Enquiry beginning in 1863 that investigated complaints made against trawlers and allegations of overfishing (Report of the Commissioners 1866). Throughout this period, the Commissioners visited 86 ports (see Fig. S1, Supporting Information for the main towns visited by the Commissioners), posing nearly 62 000 questions to 700 witnesses drawn from all parts of the fishing industry including fishers, auctioneers, traders, carriers, boat owners and harbour authorities. These Minutes of Evidence record, word for word, the testimony of people who were intimately acquainted with the fishing industry during the early days of trawling and prior to the era of fishery statistics.

Despite the scale of this enquiry, its final recommendations were controversial. The interpretation of the information was confounded by the conflicting interests between different classes of fishers, a rapidly expanding industry and a lack of fishery statistics, all of which prevented firm conclusions. In addition, the influx of fish to inland cities and towns provided a cheap source of protein, the importance of which was not lost on the Commissioners. Despite much evidence recorded that trawling destroyed young fish and damaged the seabed, the Commissioners concluded in their report that

> 'The allegations that trawling in the open sea has exhausted any trawling grounds, and that trawlers have been obliged permanently to leave any trawling ground on account of such exhaustion, are […] devoid of foundation'.

They also stated,

> '…fishing by the use of the beam-trawl is the of by far the greatest and most progressive supply of fish, other than herring, to the principal markets of this country; that certain descriptions of fish, such as soles and plaice, could not be largely supplied by any other mode of fishing; that it engages the largest capital, employs the most numerous body of hardy fishermen, is the least under the control of the weather, and obtains the greatest returns of fish for the labour and capital employed'.

They then recommended 'unrestricted freedom of fishing to be permitted' to the entire British fishing industry (Report of the Commissioners 1866).

However, the findings of the 1866 Commission did not end the problems of declining coastal fish stocks or conflict between trawl and line fishermen. Consequently in 1883, another enquiry was called to further investigate the effects of trawling. By this time, sail trawling was well established in most parts of England but was relatively new to the east coast of Scotland. Steam trawling had also begun but was in its infancy. During the second enquiry, which posed nearly 13 000 questions to 224 witnesses, much testimony was given that trawling affected local inshore fish stocks, but at the same time, trawling had established itself as an important supply of cheap fish to the growing population (Report of the Commissioners 1885). The recommendations of these Commissioners

paved the way for the national collection of fishery statistics.

These two Commissions of Enquiry hold vital clues to how our marine environment looked before widespread trawling commenced. The detailed testimonies compiled in the Minutes of Evidence have been largely overlooked until now, yet they provide some of the earliest evidence of the influence of intensive fishing. Our research uses these witness statements to quantify (i) the early changes in catch rates during the nineteenth century as stated by contemporary fishers and documented in the Commissions of Enquiry and; (ii) the perceived early impacts of trawling on habitats, juvenile fish and spawn as reported by contemporary fishers. These results will be interpreted in the context of the initial expansion and intensification of trawl fisheries around the British Isles.

Methods

Quantifying perceptions of changes in catch rate

The report of the Royal Commission of 1866 contains 1379 pages of evidence from interviews with over 700 witnesses. We scanned this evidence and extracted all quantitative statements – that is, those in which witnesses compared their present to past experiences of fishing in a quantitative way – which related to beam trawling. Statements that spoke of general declines or increases but did not provide a quantitative measure were not used unless the witness stated that a previous fishery no longer existed or that no fish were caught. In such circumstances, we used these and assumed catches to have declined by 95%. No information was used if witnesses contradicted themselves during the interview or if they spoke of changes in catch rate as they moved to unexplored fishing grounds. Where a statement included a range of values, for example, '20 years ago an average take was 20–30 stone, today it is 2–3 stone', we took the mean value. In total, we found quantitative statements of change for catch rate (119), fishing effort (74), price (17) and fish size (11) (Table 1). We then grouped statements according to species and also used a general 'whitefish' category because many witnesses used this term rather than giving a specific species name. As the whitefish category was by far the most commonly used

Table 1 Examples of witness statements used for perceptions of change.

Fisher	Location	Description
1866 Royal Commission		
B. Simpson, ex-line fisher	North-east England	*'[Off Spurn Point] twenty years ago we used to get 600 or 700 head of fish a day there; now they cannot get above 20 head, or 3 or 4 score at the outside'.*
T. Fell, line fisher	North-east England	*'[20 years ago] a boat would get 58 or 60 stone of cod, haddock, and other fish. They would average that each boat. [Today they average] sometimes 12 or 15 stone [...] sometimes a boat will go out and only get 2 or 3 stone'.*
T. Bulmer, line fisher	North-east England	*'On the average, we brought ashore 3 quarters or a ton of fish in a boat [...]. Now, on the average, 15 or 16 stones will be the outside'.*
R. Stibbs, ex-trawler	South-west England	*'40 years ago there were 30 trawl vessels, now there are 64'.*
C. Abbs, council member	North-east England	*'I could buy haddocks formerly at 3d. and I have now to pay 6d. Cod [...] I could formerly get for 1s. and 1s.8d. I am now obliged to pay 2s.6d. and 3s.6d'.*
1885 Royal Commission		
G. Morrice, line/net fisher	North-east Scotland	*'[7 years ago] boats here can say they have got half a ton, 12 cwt, and as high as 14 and 15 cwt [haddocks], but the highest catch we had last year was 5.5 cwt, at about, I may say, 6 miles farther offshore than formerly'.*
G. Milne, line fisher	North-east Scotland	*'We have landed at Port Erroll as 1000 to 1100 cod in the winter season [5 years ago]. [Last year we landed] 150'.*
R. Rowntree, line fisher	North-east England	*'I have been going [to sea] 34 years [...] and when I commenced we would get from 40 to 50 stone of fish, and now [...] we cannot get over 4 or 5'.*
A.W. Ansell, trawl fisher and owner	North-east England	*'Up to 1855, a vessel would capture as much as 60 stones in a night from the Silver pits [...] it is unusual now to get more than 6 or 8 stone, which is a good haul'.*
D. Cole, line/net fisher	North-east England	*'[When first began fishing, we went] 25 to 30 miles, and now we have to go 60 and 70'.*

by witnesses, these alone were used for further analysis.

Two regions, the south and north-east coasts of England, were selected to compare perceived changes in the catch rate of whitefish and adaptation by fishers to inshore declines, for example, increased distance travelled offshore to reach productive fishing grounds and greater size or quantity of fishing gear. The regions were chosen because by the 1860s, a number of ports in the south of England had had resident beam trawlers working off the coast for over 60 years; therefore, residents and fishers had experienced this form of fishing for their entire lives. However, in the north-east of England, trawling had only recently become established; hence, any differences between witness perceptions from the two areas may provide evidence of shifting environmental baselines. Also, the bottom trawl was not yet a regular feature around other parts of the British Isles. For the two regions, each quantitative statement made by a witness was converted to relative change over the period of time that the witness could recollect. Perceived changes for all witnesses from each region were then plotted graphically to determine whether any overall trends existed in witnesses' perceptions of change. The same method was used to interpret perceptions of change in fishing effort, but was compared across the whole of the British Isles because of a lack of data from the south and north-east coasts alone.

The procedures described previously were also applied to the Government enquiry that took place in 1883–84 (Report of the Commissioners 1885). This was more limited than the 1866 enquiry and focused upon places where numerous and persistent complaints were being made about the effects of trawling. In particular, the Commissioners concentrated on the north-east of England and the east coast of Scotland. Trawling had been established for a number of years on the north-east coast of England by this time, but was still a recent phenomenon in Scotland. The Commissioners also interviewed a number of witnesses from London and Brixham (on the south coast of England) where trawling was well established. They also took statements from related occupations such as fishery inspectors, scientists, local magistrates and fish merchants. From this report, we found quantitative statements of change for catch rate (48), fishing effort (18) and price of fish (14).

Quantifying perceived effects of bottom trawling

Witnesses' perceptions of bottom trawling were collated from the 1866 and 1885 enquiries. A Likert Scale was used to categorize people's perceptions of trawling, from very positive through to very negative (see Table S1 in Supporting Information for descriptions used). Occupations of the witnesses were split into: trawlers (included full-time, part-time and ex-trawlers, also owners of trawls), other fishers (fishers not connected with trawling e.g. net or line fisher) or other (e.g. fish buyer, seller or non-fisher). Where witnesses expressed a negative view of trawling, the reasons for their negativity were logged. These fell into the following categories: destruction of young fish, destruction of fish (e.g. over-fishing of an area or wasteful destruction of adult fish), habitat destruction, destruction of spawn, competition with other fishers and loss of gear. If a witness detailed more than one trigger for unhappiness against trawling, these were all recorded.

Perceptions of early habitat impacts

Quotes from witnesses' about the impact of trawling upon the seabed and its associated fauna were tabulated to gain insights into the impacts of early trawling activities upon the seabed. Perceptions were placed into the following categories: increased production, decreased production, destruction of spawning grounds and destruction of feeding grounds or habitat.

Results

Perceptions of changes to catch rate

Eleven of the 35 witnesses interviewed who provided quantitative statements of change during the 1866 enquiry included fishers who were old enough to recollect fishing prior to 1830. On the south coast, one witness recollected back 60 years, whilst the earliest recollection stated to the Commissioners on the north-east coast was 55 years prior to the enquiry. People's perceptions of relative changes to catch rates of whitefish over the course of their careers are shown for north-east England (Fig. 2a) and south England (Fig. 2b). Twenty-one fishers (60%) on both coasts perceived declines of fish to have occurred during the course of their careers. However, declines were

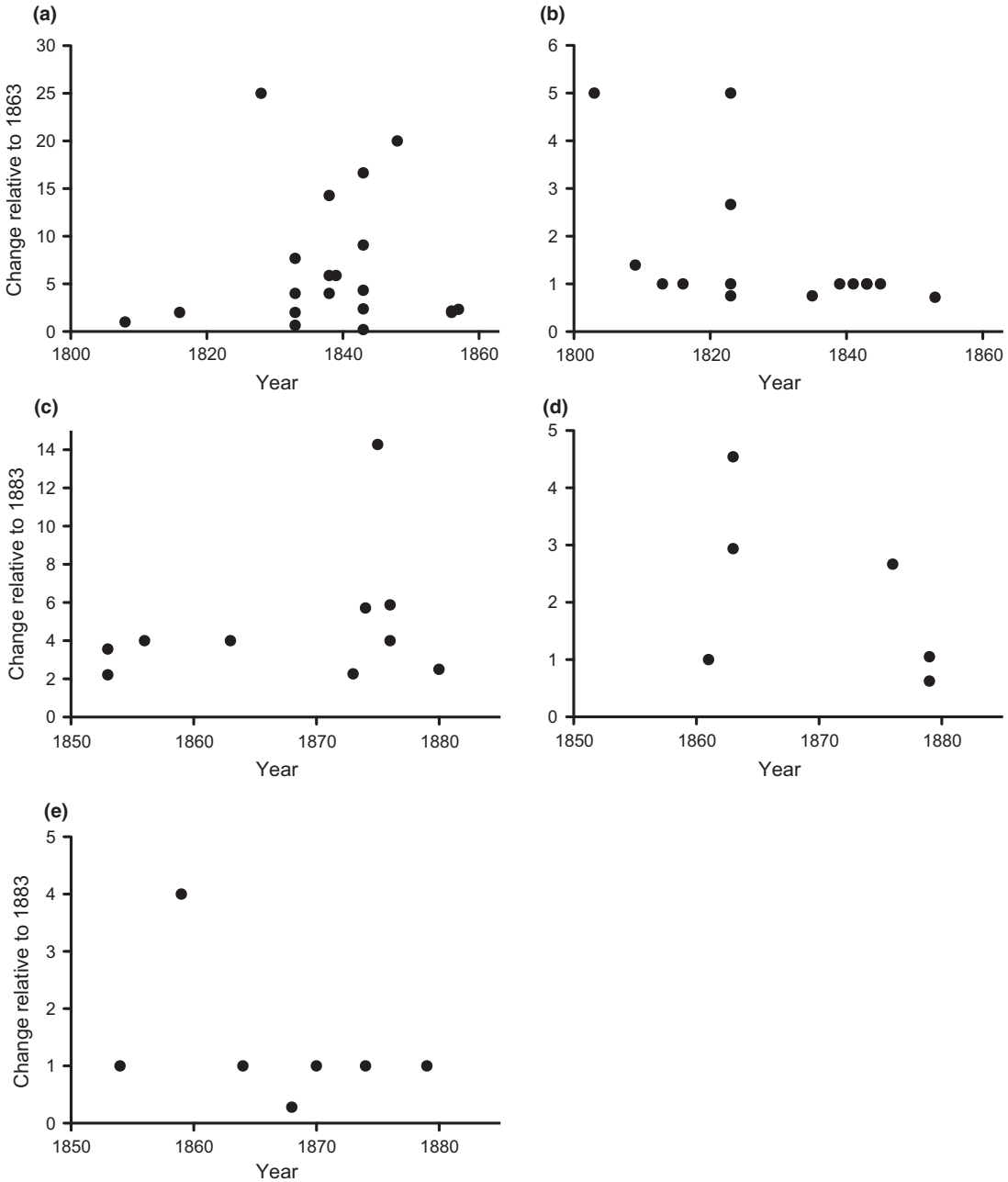

Figure 2 Witness perceptions of changes to catch rate of whitefish relative to 1863 and 1883; (a) north-east England, 1866 enquiry (n = 20); (b) south England, 1866 enquiry (n = 15); (c) east Scotland, 1885 enquiry (n = 10); (d) north-east England; 1885 enquiry (n = 6); (e) south England, 1885 enquiry (n = 7). Each datum point represents an interviewed fisher's perception of change from the earliest year they can recall. Relative catch rates >1 show a perceived decline during the individual's experience. Relative catch rates <1 show a perceived increase.

more commonly perceived in the north-east, where 85% of witnesses who made quantitative statements of change perceived declines in whitefish, compared with only 27% of witnesses on the south coast.

Perceptions of the extent of decline by witnesses from the north-east coast of England, where trawling was a new activity (witnesses stated that local trawling vessels had only become established up to 20 years prior to the enquiry, although visiting

trawl vessels would have fished these waters earlier than this), were also greater than on the south coast, which had been a hub of trawling activity since the late 1700s (Fig. 1). On average, south coast fishers interviewed believed that whitefish had declined by only 9.8% in the past 60 years (SE 9.7%, $n = 15$), whilst north-east fishers interviewed perceived a 64% decline (SE 8.4%, $n = 20$) throughout the past 55 years. The maximum perceived decline on the south coast was a 5-fold decrease in catch rate, stated by two fishers who had been fishing for 60 and 40 years (Fig. 2a; T. Hodder, trawl fisher from Brixham; H. Niaass, line/net fisher from Torquay), although three (all trawl fishers) stated they had seen a 0.75-fold increase in catch rate during their careers (W. Clapp and P. Bartlett from Ramsgate; J. Bowden from Brixham). In contrast, the only witnesses who expressed measurable increases in catch rate from the north-east of England (Fig. 2a) included a trawl fisher who was able to transport fish he previously threw overboard to other markets using the railway network and a fish curer who was dealing with greater quantities of fish than he did in the past (S. Decent, trawl fisher from Hull; H. Wyrill, fish merchant from Scarborough). In contrast to these two witnesses, the majority of fishers (85%) on the north-east coast of England complained of declines in whitefish. One line fisher complained of a 20-fold decline over a 15-year period (E. Clarke, from Cullercoats), whilst another line fisher stated he had experienced a 25-fold decline in catch rates of whitefish over a period of 35 years (P. Jefferson, from Cullercoats).

From the 1885 enquiry, three regions were compared, the east of Scotland (Fig. 2c), the north-east of England (Fig. 2d) and south England (Fig. 2e). Fewer witnesses were interviewed during the course of the 1885 Commission of Enquiry, and of them, fewer still provided quantitative recollections. Within Scotland ($n = 10$) (Fig. 2c), all interviewees believed their catch rates had declined (an average decline of 73%, SE 3.9%), with many perceiving declines on a similar scale to fishers in north-east England 20 years before. Of those interviewed in the north-east of England who expressed an opinion of quantifiable change (Fig. 2d; $n = 6$), only one interviewee, a fish buyer, described an increase in fish within his recollection. However, the extent of decline was smaller compared with the 1866 enquiry; two fishers expressed the opinion that no change had taken place, whilst three stated that they had seen declines. The greatest measure of decline came from a trawl fisher (J. Reynolds, from Scarborough), who had perceived a nearly 5-fold decrease in fish catch over a 20-year period. Five fishers of 7 witnesses from the south-west of England stated that there had been no change in fish stocks (Fig. 2e).

Adaptations of fishing methods

Adaptations to gear

Fishers described the changes they had made to their gear over the years to compensate for declines in fish stocks or to meet increased demand. R. Nicholson, a line and net fisher for 50 years from Cullercoats stated that cobles (small oar/sail-powered open boats) now set 'lengths of 20 nets', yet used to set no more than '6 lengths' 30 years previously. A similar pattern occurred with hook and line fishing. J. Patterson from North Sunderland stated that 21 years before, lines would have '400–500 hooks' but that fishers now used '800–1000 hooks per line'. Trawls also got larger as boats increased in size.

Reported change in distance travelled

Whilst only six quantitative statements showing distance from shore travelled were found within the 1866 enquiry, many other witnesses stated qualitatively that they also travelled further offshore to fish. Figure 3(a) shows a clear trend in increasing distance travelled over time. During the 1885 enquiry, distance travelled from port was the most frequently mentioned change in fishing effort, although only nine quantitative statements could be found. Figure 3(b) shows that witnesses' experiences varied substantially, with no trend seen over time. However, all witnesses perceived an increase in the distance they had to travel to fish. J.L. Potter, a trawl owner at Hull, spoke of the trend,

> 'When I first went to sea the nearest fishing grounds to the mouth of the river Humber were distant from between 30 and 40 miles in an E.N.E. direction. Since that time they have gradually moved into a more northerly direction, and the nearest fishing grounds of any note are now distant from the Humber 170 miles'.

Reported motivation for change

The increase in travel time and adoption of larger gear appear to be a consequence of the declining productivity of fishing grounds closer to shore.

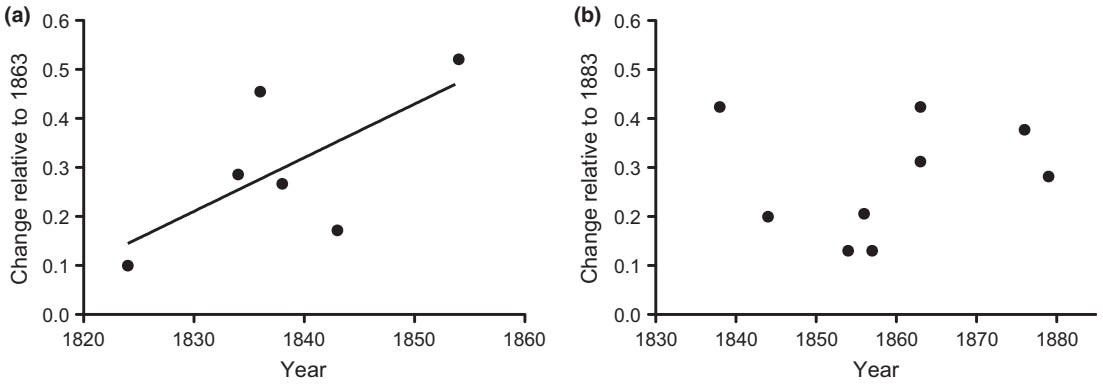

Figure 3 Witness perceptions of relative changes in distance travelled to fishing grounds in (a) 1866 enquiry (n = 6) (y = 0.0109x−19.824. R^2 = 0.46) and (b) 1885 enquiry (n = 9). Relative changes of <1 show a perceived increase in the distance travelled offshore.

For example, during the 1885 enquiry, A.W. Ansell, a trawl owner from Hull, showed from his record books that flatfish and soles had greatly diminished in the traditional fishing grounds of the North Sea between 1855 and 1883 and that smacks had to travel further for roundfish. He also stated that from 1845 to 1855, soles could be brought from between 8d to 1s.6d per stone (equivalent to £2.80–£6.30 today using the Retail Price Index) (Measuring Worth 2011). By the time of the 1885 enquiry, they reached from 14 to 23 s per stone (equivalent to £55.00–£90.00 today). These records are supported by other witnesses' testimony, for example, M. Peaker, a trawl owner from Hull stated that 'The southern part of the North Sea is fished out in my opinion'.

'Time heals all wounds': changes to perceptions of trawling over time

During the 1866 enquiry, many line and net fishers from the north-east of England vehemently condemned the trawl, and in response, most trawl fishers vigorously leapt to its defence (Fig. 4a). Opinions on the south coast reflected the less controversial nature of the trawl there (Fig. 4b): many pot or line fishers were negative about the effects of trawling upon some fisheries, but in being so did not show the same vehemence that a number of north-east fishermen did. By the 1880s, sail and small steam trawlers had reached the east coast of Scotland. This led to a similar outcry during the 1885 enquiry to the one 20 years earlier on the north-east coast of England (Fig. 4c). However, during the 1885 enquiry, it was noticeable that fishers, both trawl and non-trawl, from the north-east coast of England were less vehement in their statements about trawling compared with in the 1866 enquiry (Fig. 4d).

Negative perceptions of trawls were triggered by a variety of causes. The major reasons stated during the 1866 enquiry were destruction of young fish and spawn or wasteful destruction of adult fish, but the loss of pots, lines and nets by trawling was also of concern for many fishers (Fig. 5a). Reasons for negative perceptions were similar for both the north-east and the south of England. The same triggers were also found for the 1885 enquiry (Fig. 5b), except that destruction of spawn was less of a concern and competition with other fishers, either within markets or at sea was of heightened concern for fishers from Scotland.

Perceptions of early habitat impacts

Quotes from the 1866 and 1885 Minutes of Evidence provide early insights into the perception of changes to seabed habitats as a result of trawling activity. Table 2 presents a selection of quotations that typified the range of comments associated with the impacts of trawling upon the seabed (see Table S2 in Supporting Information for further quotations). During both the 1866 and 1885 enquiries, some fishers compared trawling the seabed with ploughing the fields on land or stated that trawling increased food availability for commercial fish by stirring the seabed. One line fisher (J. Hill, 1866 enquiry, Table S2) said that his fishing

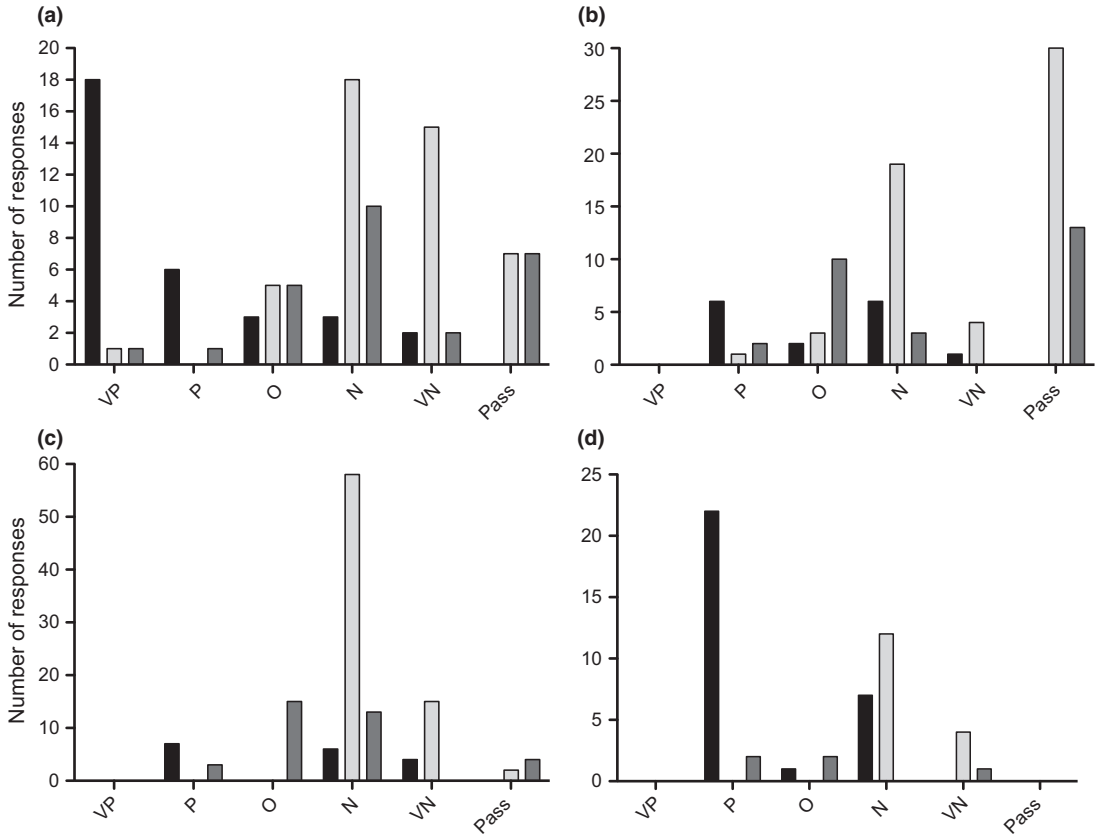

Figure 4 Perception of trawling from witnesses interviewed during the 1866 and 1885 enquiries. Reponses were classified according to the Likert scale (VP = very positive, P = positive, O = neutral, N = negative, VN = very negative, Pass = trawling not mentioned). Black bars = trawlers, light grey bars = other fisher, dark grey bars = non-fishers. (a) North-east of England, 1866 enquiry (n = 104). (b) South-west of England, 1866 enquiry (n = 100). (c) Scotland, 1885 enquiry (n = 127). (d) North-east of England, 1885 enquiry (n = 52).

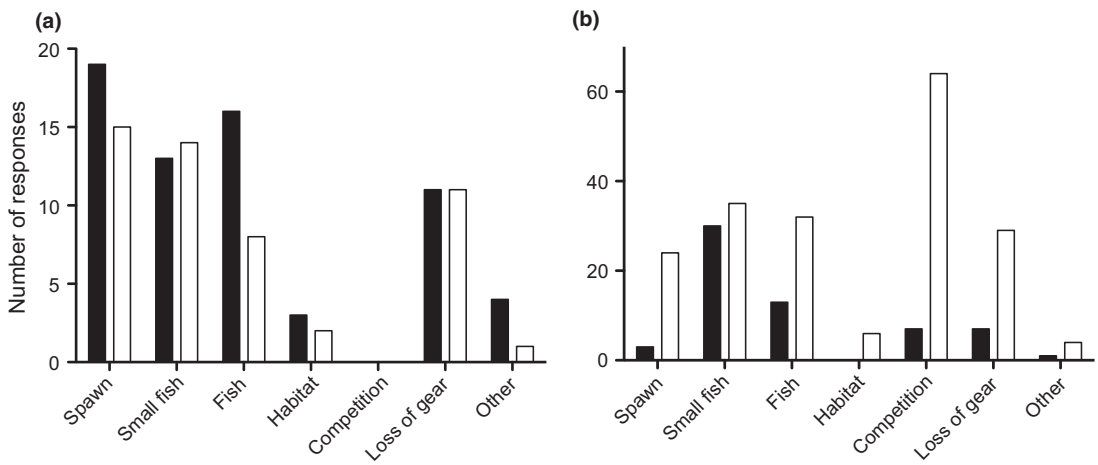

Figure 5 Reasons provided for negative perceptions of trawling. (a) Numbers of responses for each category as recorded from witnesses from the north-east of England (black bars) and south-west of England (white bars) during the 1866 enquiry (n = 117); (b) Numbers of responses for each category as recorded from witnesses from the north-east of England (black bars) and Scotland (white bars) during the 1885 enquiry (n = 75). Categories are listed in full in the methods section.

Table 2 Selected quotations from witnesses at the Royal Commissions of 1866 and 1885 on the effects of bottom trawling on the seabed and its associated fauna (see Table S2 for a more extensive list of quotations).

Description	Quotations
1866 Royal Commission	
Increased production	*'...the oftener the smacks and the trawls go there the more fish they get. And for this reason [...], the farmer in the field ploughs the ground, and the birds in the air follow after to pick up the worms, and we can say safely too that wherever we go with our trawls we plough the ground at the bottom of the sea'. W. Bartlett, trawl fisher from Hartlepool.*
Decreased production	*'I have no doubt that [trawling] does destroy the fish, and it also bares the soil so that it has no food upon it for the fish'. M. King, ex-trawler from Galway.*
Destruction of spawning grounds	*'This ground-rope weighing with the pair of irons to keep it down 250 lbs is dragged over the ground; it goes over the ground at the rate of a tide, and for 20 miles it will scour the ground wherever it goes, and that, in my opinion, is where the destruction is caused. It destroys all the eggs'. T. Hodder, trawl fisher from Brixham.*
Destruction of feeding grounds or habitat	*'I believe there is not a portion of the ground but what the trawl destroys. [...] I have dragged 50 miles off Aberdeen. I have got fast there, and brought up coral about 2.5 feet in circumference, lumps of soft coral, and I am prepared to say that whatever is in the way of the beam trawler will not escape'. G. Cormack, ex-trawler from Torry.*
1885 Royal Commission	
Increased production	*'As the crow follows the plough for the worm, so the stirring of the ground brought the fish, and made our fishing ground really prolific, a beautiful provision of nature' J. Bartlett, chairman of the local fishery board, Brixham.*
Decreased production	*'They trawl along the bottom and tear everything that is before them'. J. MacDonald, line fisher from Golspie.*
Destruction of spawning grounds	*'The spawn and the small fry are all turned away, you know, and killed entirely' J. Gourley, line fisher from St Andrews*
Destruction of feeding grounds or habitat	*'[50 years ago] we used to go to the back of west rock, that is abreast of Filey, very often, and at that time we could not trawl more than an hour and a half or two hours in consequence of the shells, what we call the clam shells, some dead ones and others alive. Those dead shells had at that time white and brown thusks in them, and all among these shells the soles inhabited; and we by this small beam net [...] could get 40 and 50 pair of soles in a tide [...]. Well now, you could take the same coble, the same net, the same everything, and trawl over the same ground and where there are no shells, and I would think we would not get five pair of soles in a tide [...]. They have trawled [the shell fish] away...' W. Appleby, line fisher and ex-trawler from Scarborough.*

grounds had expanded as a result of trawlers working their nets; other fishers, however, were adamant that trawling decreased the productivity of the fishing grounds and described the trawl as 'tearing up' the seabed (Table S2).

By far, the most common complaint among fishers during the 1866 enquiry was that trawling destroyed the spawning grounds or eggs of fishes. Many witnesses testified to seeing 'spawn' dragged up in trawl nets (Table S2). During the 1885 enquiry, this view was not so prevalent. Destruction of feeding grounds or associated habitat was also of concern during both enquiries, and both trawlers and other types of fishers described the large quantities of benthic fauna brought up by the trawl (Table S2).

Quantitative records

Analysis of long-term fisheries statistics shows us that there has been a dramatic decline in the availability of fish between 1889 and the present day (Thurstan *et al.* 2010). However, the witness testimony examined here indicates that fishing had already caused significant declines in stocks and impacts on the seabed by the 1880s. Early fishery statistics clearly do not reflect a pristine environment. The question is, to what extent had our marine environment already been altered by this time? Two trawl owners provide documented evidence of catches prior to the collation of national fishery statistics, one collected during the 1866 enquiry and another whose data were recorded by Gars-

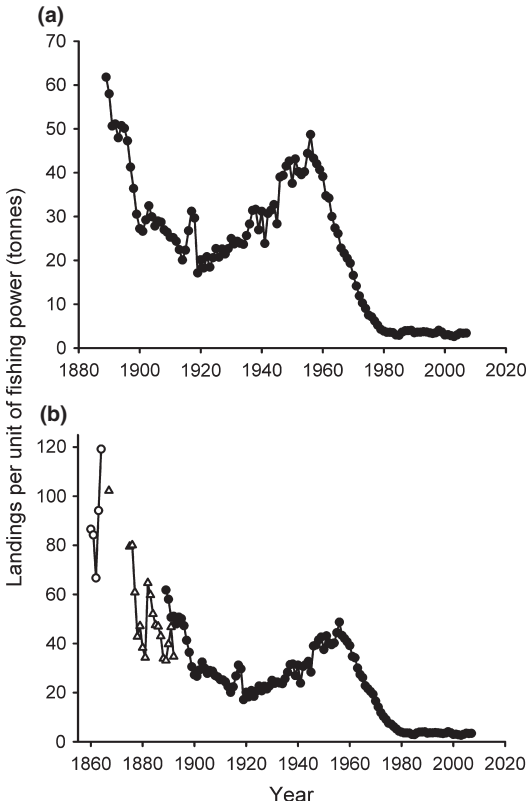

Figure 6 Landings of bottom-living fish into England and Wales per unit of fishing power of large British trawlers (LPUP). (a) Closed circles show data adapted from Thurstan *et al.* (2010) which used annual national fishing statistics from 1889 to 2007; (b) Closed circles show trawl landings data provided by H. Knott during the 1866 Commission of Enquiry, open triangles show trawl landings data provided by G. Alward for reproduction by Garstang (1900). Closed circles show the same data as in a) but in the context of longer-term change in LPUP.

tang (1900). Both provided average annual catches of their sailing trawlers over a period of years out of Grimsby and Hull, the location of the majority of 19th century trawl landings. It is therefore reasonable to assume that these catches could be representative of other English trawlers operating throughout the North Sea during this period.

Thurstan *et al.* (2010) demonstrated that the trawlers of today catch 17 times less fish than those of the 1880s once the masking effect of technological improvements and increases in the number of vessels is removed (Fig. 6a). If we assume (conservatively) that the sailing trawlers of the 1860s and 1870s had the same fishing power as 1880s sail trawlers, we can extend this picture of change back another 29 years based on data from the two witnesses (Fig. 6b). The data provided by Alward showed a 66% decline in annual demersal fish landings per vessel (averaged from four vessels) over a period of 25 years from 1867 to 1892.

Discussion

Witness statements from the Royal Commissions of 1866 and 1885 cover much of the 19th century, providing a window into the changes that took place long before fisheries statistics began to be collected. Our objectives were to quantify the early changes in catch rates of 19th century fishers, quantify the adaptations in gear and behaviour of fishers and record early statements of changes to the seabed as a result of trawling within the context of the expansion of trawl fisheries around the British Isles.

In analysing these fisher testimonies, we make the important assumption that fishers were able to accurately recall past catch rates. Whilst some studies have provided convincing arguments for using fisher knowledge to help reconstruct past environments (Sáenz-Arroyo *et al.* 2005; Eddy *et al.* 2010; Maynou *et al.* 2011), memory recall can be distorted over time (Daw 2008). Because we have little way of knowing how accurate these witness testimonies are, we took care to draw our conclusions in the light of the qualitative context provided by the enquiries. We also had to assume that fishers had no reasons to provide the Commissioners with biased or incorrect information. However, fishers may have felt under pressure to provide incorrect data to the Commissioners because they wished to bias the Commissioners findings against (or for) trawling, or because they felt under pressure from their peers to provide particular information. Again, it is difficult to know the extent to which this occurred and thus is difficult to accurately correct for. We attempted to overcome major biases by including information from all witnesses (i.e. trawl fishers, non-trawl fishers and non-fishers) and by comparing locations with contrasting trawl histories. Whilst only small samples of quantitative data existed, these were supported by more numerous qualitative descriptions; for example, many eloquent descriptions of degradation came from long-time trawl fishers during the 1885 enquiry, but not all of these contained quantitative data.

Perceptions of changes to catch rates

During the 1866 enquiry, witnesses in the north-east of England, where trawling was a relatively new activity, perceived greater declines than witnesses in the south, where trawling had taken place for generations. The 1885 enquiry showed similar trends; perceptions of decline were greater again in Scotland where trawls had only recently started to work, compared with north-east England, where sail trawling was firmly established by the 1880s. Despite the low sample sizes, these data support the interpretation that when a new fishery enters a region, the strongest rate of decline is expected during its early years (Pinnegar and Engelhard 2008). The declines shown by the data in Fig. 6(b) provide additional evidence to this effect.

Witness testimonies from the two enquiries provide little indication that fishers with longer experience perceived greater declines in fish stocks than fishers who had fished for less time. This may be a result of the small number of witnesses that were able to provide quantitative measures of change, coupled with the variety of gears used and number of different fishing grounds and species targeted. Or, it may reflect how fishers were influenced by other fishers' opinions during the interviews, which were conducted in public.

These perceptions of general perceptions of decline reported by fishers presented a complex picture for the Commissioners. On the one hand, many line and net fishers and some trawlers stated they were struggling to maintain catches, yet the limited official data – tonnage of fish transported by rail – showed an increased quantity of fish transported (Robinson 1996; Fig. S2). In addition, the size of the trawl fleet was rapidly expanding (Report of the Commissioners 1866).

Adaptations of fishing methods

Witness testimonies from the two enquiries provide much evidence that fishers were increasing the number and size of their gear and moving further offshore, although the extent of change over time varied between individuals. Witness statements show that, for some, the motivation for these changes was due to declines in traditional fishing areas. In reality, the reasons for these changes in fishing methods and movements offshore were most likely effected through a combination of declines in traditional fishing grounds, improved technology and competition between fishers. For example, improvements in technology provided a competitive advantage to those fishers who were able to invest in such technology, whilst at the same time, these improvements enabled fishers to exploit the more productive grounds further offshore (Rijnsdorp *et al.* 2008).

Changes to perceptions of trawling

At the time of the 1866 enquiry, trawling was a relatively new phenomenon for fishers located on the north-east coast of England, and hence, trawling was an emotive subject. Increased competition and the perceived destruction of young fish led to a distinct polarization of views among the different classes of fishers, with line and net fishers demanding a halt to trawling, whilst trawl fishers vigorously defended their trade;

> 'If this trawling is not done away with there will be no haddocks at all […]. Now, when these trawls go over the ground, if there was a shilling lying on the ground they would take it from the bottom. The consequence is that they take all the spawn away, and there is nothing left at all to breed from'. R. Nicholson, line fisher from Cullercoats.

> '…I think trawl-fishing does us good. […] The trawl as it goes over the ground disturbs it, and things come up so that the cods can follow and obtain good food'. B. Bulpit, an ex-trawler from Grimsby.

Fishers on the south coast also had different views of trawling, but their views were generally less polarized, probably because trawling had a much longer history on the south coast of England (Bellamy 1843). J. Couch, a resident of Polperro (south-west England), summed up the local importance of trawlers in maintaining supplies of fish,

> 'I think that the trawling has now become far too wide an interest to be interfered with unnecessarily. They catch an abundance of fish which no one else would catch; they therefore form a very valuable interest, and one which ought to be supported'.

Fishers on both coasts, however, had similar reasons for their negativity towards trawlers during the 1866 enquiry. This was mainly manifested in the common belief that fish spawn adhered to the seabed. In reality, with a few exceptions like herring whose spawn does attach to the seabed, this 'spawn' was most likely bottom-living fauna

such as ascidians. Trawls were also commonly blamed for destroying young (unmarketable) fish and wasting marketable fish.

During the 1885 enquiry, non-trawlers based in Scotland displayed emotive responses to trawling, mainly triggered by concerns about increased competition between fishers, destruction of young and marketable fish and loss of gear. However, by this time, it had become clear to fishers in the north-east of England that the trawl was here to stay. Hence, whilst many of these fishers were still negative about trawling, rather than call for the trawl to be stopped completely, many requested that a limit be put on trawling inshore to protect their fishing grounds and fish nursery areas. Notably, this same request also came from a number of trawl owners, many of whom spoke of falling catches in traditional fishing grounds and who believed a limit should be put on trawling along the shores to protect breeding grounds within the 3 mile territorial limit,

> 'This decrease I attribute to trawling as carried on within these territorial waters and within the rivers and bays. I am of opinion that trawling of all kinds within those limits should be put a stop to entirely. I am also of opinion that the practise of steam trawling within the territorial limits has contributed to the deficiency of the supply of fish […]. I think that the best legislative remedy would be the prevention of such trawling by an Act of Parliament stopping all trawling within a limit of 3 miles. I should, were it not for the difficulties in the way, prefer a limit of 10 miles'. W.L. Robins, trawl owner from Hull.

> '…where scientific men determine that there are breeding grounds, or nurseries as we might term them, I think it might be judicious to limit the trawling operations'. J. Alward, trawl owner from Grimsby.

This shows a distinct shift in attitude of fishers from the north-east of England since the previous enquiry. The realization that trawling could affect fish stocks and their habitats was increasingly accepted, including by those who had long-term vested interests in trawling,

> 'Some years ago our vessels caught an immense number of dogfish, enough to fill a trawl in one haul; when caught they contained herring, showing what food they got; few dogfish are caught now, our vessels having destroyed so many'. A.W. Ansell, trawl owner from Hull.

> 'I am directly opposed to trawling within the territorial waters, and I am convinced that if such trawling were prohibited in a very short time the supply of fish would increase, and that a plentiful supply could be caught nearer home'. P. Bates, trawl owner from Hull.

Perceptions of early habitat impacts

Around the British Isles today, it is difficult to study how the seabed may have looked prior to intensive fishing activities. Quotes from the 1866 and 1885 enquiries provide evidence that sail trawlers almost certainly affected habitats in similar ways to steam trawlers (Table 2 and Table S2, Supporting Information). Testimony from witnesses' shows that during the 19th century, the extent of trawling impacts upon the seabed was widespread in inshore areas. These initial impacts were severe and appear to have taken place within a short period of time. However, conflicting testimonies and a lack of statistics made it difficult for the Commissioners from either enquiry to determine whether the declines perceived by fishers in the north-east of England and Scotland were the result of trawling alone. During the 1885 enquiry, the Commissioners sent Professor McIntosh, a prominent fisheries scientist of the time, to conduct trawling experiments off the east coast of Scotland. His results are recorded in the appendices of the Royal Commission (1885),

> 'The effect of the trawl on the bottom fauna of the [Firth of] Forth […] appears to be as follows. – The sponges and hydroid zoophytes seem to suffer little. The ground rope sweeps through the coralline forests, picking off here and there a tuft of Hydrallmania or other zoophyte attached to a yielding surface, or which is comparatively free (e.g., attached to a shell.). Generally, however, zoophytes grow rapidly, so that even though extensive injury were done to any submarine surface in this respect the loss would be rapidly repaired […]. To sum up, therefore, a certain amount of damage is inflicted by the trawl on the invertebrate inhabitants of the fishing banks, but the nature of the fauna and their surroundings is such that this injury occurs rather in the net and on the deck of the vessel than on the sea bed. No evidence has been obtained that fishes will not frequent a bank that has been trawled over'.

Whilst McIntosh admitted that some damage to seabed inhabitants occurred, his conclusions probably underestimated the extent of the damage. His

report describes an abundance of species such as echinoderms, starfish, anemones, hydroids, horse mussels and crustaceans brought up in the trawl, many of which were thrown back overboard. Yet he did not account for delayed mortality to organisms as a result of crushing in the net or being thrown back onto unsuitable ground. He also did not take into account animals left injured or killed in the path of the trawl but which were not brought up in the nets and hence were not recorded. In addition, McIntosh trawled in areas that were already worked as fishing grounds and so these would have already sustained trawling damage prior to his investigation.

Conclusions of the Commissioners

The 1866 and 1885 Royal Commissions of Enquiry took placed at a time of great change in the fishing industry: the 1820s to 1860s saw the opening up of inland markets for fish via the spreading of the national rail network (Fig. S2, Supporting Information), whilst the 1880s heralded the arrival of the steam trawler and the beginning of industrial fishing. The Commissioners of the 1866 enquiry were unconvinced that the trawl could be responsible for depletion of fish stocks in the open sea. Yet just 20 years later, testimonies of localized depletions from experienced trawl fishers and scientists encouraged the Commissioners of the 1885 enquiry to accept that exhaustion of fishing grounds could occur. However, this was not enough for them to recommend restrictive management measures upon what was rapidly becoming a vast industry. In addition, the Commissioners felt that other methods of fishing also had to bear some of the responsibility for declining stocks,

> 'Without accurate statistical information extending over many years it is impossible to form any satisfactory conclusion […]. We are, therefore, unable to come to the conclusion that trawling is the sole cause of the decrease of fish in inshore waters. In so far as it may contribute to that decrease, we think it can only be as part of a system of over-fishing, and not because of any wasteful destruction of spawn, fish-food, or immature fish'.

Whilst the Commissioners of 1885 recognized that overfishing was taking place in some inshore areas and traditional North Sea fishing grounds, they did not feel that the witness testimonies they received were sufficient to justify reform of fisheries management. Instead, they championed the need for scientific study and the collection of national statistics. Whilst both of these measures occurred over the next few decades, the process of shifting environmental baselines was already well underway, such that of the limited trawling studies undertaken in the decades after these enquiries, most did not take into account, or did not feel it worth considering, the great changes to habitats that had already occurred during the early days of trawling (Graham 1955). By contrast, the destruction of young fish was considered at length (Davies 1929; Borowik 1930). The era prior to statistical collection was effectively forgotten.

Other factors influencing fish stock abundance

The testimonies from the Royal Commissions of Enquiry provide a strong argument that trawling was, at least in part, responsible for the perceived declines in inshore fish stocks. However, environmental factors affecting fish stock abundance, such as changing sea surface temperatures, may also have been at play during this period. For example, it is possible that the early expansion of trawling coincided with a period of increased productivity in cod and haddock stocks, similar to the 'gadoid outburst' that occurred during the 20th century in the North and Baltic seas (Cushing 1984). This would have influenced the initial success of trawling, but catches would not have been maintained in later years. Long-term sea surface temperature series for the North Sea do exist from 1870 (MacKenzie and Schiedek 2007), but there is little to suggest that major changes in sea surface temperature occurred during the early period of trawling. However, we do not know what changes occurred prior to this or how seasonal shifts in sea surface temperature may have influenced prey availability during the mid-19th century. Whilst the potential influence of environmental factors should not be ruled out, the maintaining of catches by movement of vessels further offshore alongside the documented depletion of traditional fishing grounds, in addition to perceived declines in the size of fish in some local fishing grounds (e.g. J. Morton, T. Bulmer and T. Davison, line fishers from Hartlepool, 1866 enquiry) indicate that serial depletion was occurring during the early expansion of trawling.

Conclusions

This study provides evidence of the large-scale destruction that occurred to seabed habitats and inshore fish populations long before collection of fisheries statistics commenced and even longer before regular scientific monitoring began. Scientific research on the impacts of bottom trawling (with the exception of McIntosh, Report of the Commissioners 1885) only began during the 20th century, when Graham (1955) undertook a study in 1938 on the plaice fishing grounds of the North Sea. This study concluded that trawling did not have a serious effect on the benthos. Other studies have since been undertaken, many of which produced conflicting results or suggested that the damage done by trawling was not very great (see reviews by Gibbs *et al.* 1980; De Groot 1984; Bergman and Hup 1992; but see Kaiser *et al.* 2000). Exceptions include Collie *et al.* (2000), who found that fauna in more stable sediments are more adversely affected by trawling and dredging than those in unstable sediments and Hall-Spencer and Moore (2000), who showed that unfished maerl beds that were subsequently trawled failed to recover after 4 years of monitoring. Witness testimony from the two Royal Commissions suggests that vulnerable habitats were heavily impacted during the early years of trawling expansion, leaving more resilient systems to be studied in later years without suitable controls (Kaiser 1998).

Whilst these 19th century witness testimonies cannot replace quantitative data collection, they are of great significance today. They provide evidence of the swift and dramatic transformations that took place as a result of early trawling activities, a turning point in British fisheries that is otherwise mostly undocumented. Today, a similar transformation is taking place in the deep sea, as our fishing activities reach further into previously untouched marine environments (Koslow *et al.* 2000, 2001; Clark and O'Driscoll 2003; Devine *et al.* 2006). Unlike today, the Commissioners of these 19th century reports did not have the ability to directly survey underwater habitats, nor could they easily anticipate the improvements in technology that were to come. By judging the status of today's marine environment in the context of long-term change, we can better understand the true extent of alteration that we have effected upon marine communities. This knowledge should aid effective management of marine ecosystems for the future.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Locations of the major towns and ports around the British Isles and Ireland visited by the Royal Commission of Enquiry (1866).

Figure S2. Fish (i.e. finfish and shellfish) transported from coastal ports by three 19th century rail companies.

Table S1. Likert Scale descriptions of perceptions of trawling.

Table S2. Quotations from witnesses at the Royal Commissions of 1866 and 1885 on the effects of bottom trawling on the seabed.