**Conservation targets in marine protected area management suffer from shifting baseline syndrome: A case study on the Dogger Bank**

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**Abstract**

The Dogger Bank is a 17,600 km2, subtidal hill in the central southern North Sea and was once renowned for its prolific fisheries. It covers the waters of UK, Netherlands, Germany and Denmark and has been established or proposed in three of them as a Special Area of Conservation under the EU Habitats Directive. Historical records indicate that the Bank has been subject to human exploitation from before the 16th century but conservation objectives have been developed using recent survey data alone. This has the potential to significantly underestimate the alteration this ecosystem has experienced, making the Dogger Bank an example of shifting baseline syndrome in protected area management. We compile quantitative and qualitative descriptions from historical records of change in catch rates, fishing effort, price and fish size to show that there have been steep and prolonged declines in abundance of fish on the Bank since the early 19th Century, especially large-bodied species such as skates, halibut, turbot and cod. Use of present day data to inform conservation has led to inappropriate and unambitious recovery targets, a problem that is endemic to marine conservation efforts across much of Europe. Historical data, we argue, are an essential input to conservation decision making.

**Keywords:** MPA,bottomtrawling, environmental history, fishery exploitation

**Introduction**

Exploitation is considered one of the main threats to marine biodiversity (Jackson *et al.,* 2001; Roberts, 2007). Over the past 300 years, fishing activities have intensified and many once productive ecosystems have suffered severe losses and degradation (Jackson et al., 2006; Roberts, 2007; Thurstan *et al.,* 2010). The decline and disappearance of species caused by hunting and fishing weakens the ocean’s ability to provide ecosystem goods and services and recover from perturbations (Worm *et al.,* 2006).

Modern research often underestimates historical changes to ecosystems as it fails to consider the effects of long-term human exploitation (Jackson *et al.,* 2001). Conservation objectives for marine protected areas are often based on recent ecological data and, therefore, suffer from shifting baseline syndrome. It can be argued that, as a consequence, they lack sufficient ambition and are unlikely to achieve recovery of depleted species and habitats. Historical data predating modern industrial fisheries can help identify 1) the true extent to which a marine ecosystem has been altered by human activity, 2) the underlying causes of this change, and 3) help define more appropriate targets for recovery and restoration (Jackson *et al.,* 2001).

In this paper we examine the case of the Dogger Bank in the south-central North Sea, a shallow underwater hill made up of glacial moraine (Deising *et al.,* 2009). The UK portion of the Dogger Bank is a candidate Special Area of Conservation (SAC) and Site of Community Importance (SCI) under the European Habitats Directive1. In 2012 the UK Joint Nature Conservation Committee (JNCC), assessed the physical and biological condition of the site using data obtained within the last 10 years (JNCC 2012). From this they devised conservation objectives for its future management, which are to maintain natural environmental processes and restore the physical structure, diversity, community structure and typical species representative of the bank’s habitat to ‘favourable conditions’ (JNCC 2012). They predicted the condition of the Bank into the future if these conservation objectives were not met, and used this as the baseline against which to judge the success of management.

Historical records show that the Dogger Bank has been subjected to human exploitation from before the 16th century, and supported significant fisheries over the past 300 years (Beaujon 1884, Oglethorpe 1749). Using recent information on the ecological condition of the bank as a baseline is likely to significantly underestimate the alteration and decline this ecosystem has experienced as a result of human use. Therefore, the Dogger Bank may represent an example of shifting baseline syndrome in protected area management. Conservation objectives set on the basis of shifted baselines will, we contend, lead MPAs to fail on grounds of inadequate ambition.

We examine this conjecture by taking a historical view to identify long-term change in this ecosystem. Few records exist for fisheries that began over three centuries ago. However, witness testimonies from before the era of industrial fishing provide valuable qualitative and semi-quantitative descriptions of the historic state of fish stocks and of fishing effort observed on the Dogger Bank during the 19th century. This information was used to reconstruct the environmental history of the Bank and infer the nature of the ecosystem before the onset of industrial exploitation. Using this reconstructed baseline, we ask whether the present conservation objectives are sufficient to deliver recovery, and discuss management options.

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| **Figure 1:** The location of the Dogger Bank in the North Sea. The bank (outlined in red) is located ~100 km from the northeast coast of England. It is 260 km long from northeast to southwest, and stretches into the exclusive economic zones (demarcated by the dotted redlines) of England, Holland, Germany and Denmark. Information sourced and adapted from Halvala (2010) Wikimedia3. |

**The Dogger Bank**

The Dogger Bank is a large sandbank situated in the North Sea, around 100 km off the north-eastern coast of England (Fig.1). The bank covers 17,600 km2 (Deising *et al*., 2009) and straddles the exclusive economic zones (EEZs) of England, Holland, Germany and Denmark 2. The Bank is a moraine deposit formed by glacial processes ~450,000 years ago (Stride 1959). It rises >20 m higher than the surrounding sea floor and is only 15 m below sea level at its shallowest point (Deising *et al.,* 2009). Today the seabed of the Bank is composed of predominantly fine sand and mud (Krӧnke and Knust 1995).

The Dogger Bank is a highly productive habitat and is unusual in that it exhibits year-round phytoplankton production (Pedersen and Handsen 1993), a result of several hydrographic characteristics. Shallow waters atop the bank do not become stratified during summer as wind-stress and tidal currents maintain vertical mixing of the water column (Reigman *et al.,* 1990). This constant replenishment of nutrients into the photic zone maintains primary production throughout the year (Reigman *et al.,* 1990). On the northern edge of the bank, thermally stratified water from the North Atlantic converges with the isothermal waters of the bank (Pedersen and Handsen 1993). The exchange of nutrients and phytoplankton at this transition zone leads to enhanced primary production along the Bank’s northern edge (Reigman *et al.,* 1990). In turn this attracts an abundance of marine life to feed and breed, and has supported significant fisheries for centuries (Oglethorpe 1749; Beaujon 1884).

**Methods**

We used historical records and eye witness accounts to describe the condition of the Dogger Bank before the onset of industrial exploitation. These accounts were sourced by searching Google Books and the Parliamentary Archives (<http://parlipapers.proquest.com/parlipapers?product=parlipapers>) using the key words ‘Dogger Bank’, and restricting the date from the 1700s through to the present. UK government Royal Commission reports from 1866 to 1893 enquired into the state of fisheries (Royal Commission 1866, 1879, 1884 and 1893) and report verbatim witness statements from thousands of questions put to many hundreds of witnesses. From these, we extracted quantitative and qualitative statements relating to the Dogger Bank fisheries of changes in catch rates, fishing effort, price and fish size to determine the changing state of the ecosystem over time. Where possible we converted statements to percentage change over time in catch or landings per unit effort andin fishing effort. To assess the modern state of the ecosystem, catch statistics for the Dogger Bank between 2006 and 2009 were sourced from JNCC (JNCC 2011). These data show landings from ICES statistical rectangles 39F1-3, 38F1-2, 37F1-2, which cover the UK portion of the bank. There is no landing data specific to the Dogger Bank area, so the UK Marine Management Organisation (MMO) has compiled data on the activity of fishing vessels in UK waters and their landings (JNCC 2011). Data on the distribution of fishing effort on the UK region of the Dogger Bank was obtained using vessel monitoring systems (VMS) on all vessels ≥15m (which constitute the great majority of vessels fishing there). Catch data include information on UK registered vessels landing in UK and non-UK ports, and non-UK registered vessels landing in UK ports, gear used, species caught and the weight of the catch (JNCC 2011). Information on the benthic composition of the Bank was sourced from scientific literature in the 20th Century. Data on benthic conditions prior to this time was unavailable.

**Results**

**The preindustrial fisheries of the Dogger Bank**

In the late 18th century, the Dogger Bank was considered the most extensive and valuable fishing ground in the North Sea for white fish, and supported significant cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*) fisheries (Knox 1789; Wood 1911). The most commonly used method of capture at this time was by hook and line (Beaufoy 1785; Swainson 1839). The high productivity of the fisheries continued into the early 19th century and an account from this time recalls that 8 men fishing on the most productive grounds of the bank could catch 200 cod fish each in 10 hours (Gosse 1845). During this time, the typical weight of cod caught on the Dogger was between 14 and 40lbs (Knox 1789). Therefore, at a conservative estimate, assuming all fish caught weighed 14lbs, 8 men with hand lines could catch 10 tons (10.16 tonnes) of fish a day; that is 1 ton every hour. Dogger Bank cod were said to be so voracious that they would take almost any bait (Swainson 1839), and were renowned for their large size and good quality (Jardine 1861).

The productive and shallow waters of the Bank attracted large numbers of fish which migrated there to spawn and feed (Royal Commission 1879). Throughout the late 18th to early 19th century, a variety of species were caught in abundance there (Knox 1789). Demersal flat fish such as sole (*Solea solea*), turbot (*Scophthalmus maximus*), plaice (*Pleuronectes platessa*) and halibut (*Hippoglossus hippoglossus*) were commonly caught by nets, and static lines (Royal Commission 1866), and elasmobranchs such as the common skate (*Dipturus batis*) and thornback ray (*Raja clavata*) were targeted by line fishermen (Knox 1789). In 1840, a single vessel could take one ton of halibut in a day’s fishing on the Dogger Bank (Royal Commission 1866). This incredible abundance and diversity of fish in turn attracted large populations of predatory species such as porpoise (*Phocoena phocoena*), white beaked dolphin (*Lagenorhynchus albirostris*), seals (*Phoca vitulina*), and dogfish (Squalidae *spp.*), that were said to ‘come to the bank in shoals like all other fish’ (Knox 1789).

Until 1840, the total catch was limited by the quantity of gear and favourable sailing conditions. Salt duties at the time restricted total catch, as the shortage of salt meant fishermen could not preserve the fish and they became rotten and spoiled before they reached market (Vanisttart 1802).

**The growth of the sail trawl fisheries**

Early forms of beam trawling took place in the English Channel throughout the 18th century (Engelhard 2009). However, it was not until the end of the Napoleonic wars in 1815, that British sail trawlers began to explore new grounds in the North Sea (Engelhard 2009). Construction of railway networks in the first half of the 19th century, combined with rapid population growth meant that fish could now be transported to large inland markets fresh (Wood 1911). These two factors greatly increased the demand for fish and encouraged less discriminating methods of fishing to achieve greater catches (Wood 1911). Early bottom trawls were made of a ~36 ft long wooden beam that held open a wide net that was dragged along the seabed by a sail boat (Engelhard 2009; Wood 1911).

In the early years of trawl fishing on the Dogger, immense quantities of fish were taken for relatively little effort (Table 1). In 1863, it was not uncommon for a single trawl vessel to take 2 to 3 tons of fish in a 3 hours’ trawl (Royal Commission 1866). Catches continued to rise as new grounds on the bank were discovered and in 1866, 5 vessels trawling 50 acres of ground caught 17 tons of fish in a night, being the equivalent in weight of 50 cattle or 300 sheep (Royal Commission 1866). At the same time, dogfish were caught in abundance and regularly filled an entire trawl (Royal Commission 1884). Skates of enormous size were also present, often reaching 6ft long, and in 1874, a skate weighing 214lbs, stretching 6ft 10in from nose to tail was caught off the bank (Royal Commission 1879).

**Table 1:** Quotations from witnesses on the catches taken by sail trawl fishermen during early days of their introduction to the Dogger Bank fishing grounds. Statements from witnesses are italicised, quotations not italicised are questions posed to the witness by the Commissioners.

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| **Witness** | **Description** | **Quotation** |
| **1866** Commission |  |  |
| HuxleyCommissioner |  | *“Not only are the fishing vessels constantly being increased in number, but the take of each vessel is increasing, and, from the speedier means of transport, the quality of fish is improving.”* |
| W. Brown, G,Tidman, C.Dossett & W, AthertonSail trawlers |  | *“Within the last six weeks, while fishing on the Dogger Bank, we have frequently seen from 40 to 60 packages, weighing between 2 and 3 tons, taken by a single vessel for 3 hours haul, the most of them being very fine haddocks.”* |
| J. FellowsSail trawler |  | “Do you go to the Dogger Bank? – *No, it would hardly pay to go there. There is too much fish. […] The Dogger Bank literally swarms with haddock and plaice, and if we all fished there we could not get a price for the fish that we should bring in in our boats.”* |
| W.I.Marecrow |  | *“There is a great abundance of fish to be caught there [Dogger Bank] at any time of the year. […] They [trawlers] don’t care to go there. They get so much fish there they are afraid of overstocking the market. […] There are more fish there now than ever and they are in better condition.”**“*Is it really the case that fishermen don’t go there because they are afraid of catching too many fish; is that really so? – *Yes, that does occur. The reason is that they would over supply the market. They could catch as many off the Dogger Bank in 24 hours as would supply all England in 48 hours.”* |
| T. HalfyardSail trawler  |  | *“The haddock is more plentiful than ever. We get in four hours as much as we require at one time of plaice.”*  |
| R.T. VivianSail trawler owner |  | *“I know there have been much larger catches off the Dogger Bank latterly than formerly. Vessels have been bringing 60, 70 or 100 baskets of fish at every catch. Such catches were very unusual 14 or 15 years ago.”*  |
| J.T.MorganSalesman |  | *“There is a great quantity of skate in the months of December, January and February. They come from the Dogger Bank. […] It [the supply of skate], has very greatly increased.”* |
| H. MerchantSmack owner |  | *“Five vessels caught for one night about 17 tons of fish. I was talking to one of the captains about it, and he told me that one of the vessels had been trawling for four hours, and when he came to haul up his net he had so many fish in it that they broke it all in pieces, and out of the fragments he saved 14 baskets of fish.”* |
| J. PotterSail trawler | Expansion of the trawlers | *“Formerly we did not work the Dogger Bank as we have done of late years, 10 years ago I used to be at Brixham, but during the last eight or nine years, since I have come to reside in Hull, I have begun to work on the Dogger.”**“At that time [1855] if we got 2 tons we thought it a great catch; now we don’t consider a Dogger catch under 5 or 6 tons anything of a catch.”* |
| S. Hewett |  | *“They only fish there [Dogger Bank] now and then. […] We have never fished there before this year – at any rate, not so far north. […] They [trawlers] got more there than was ever known or thought possible. […] we go further now than we did in my early days. They go now to the Dogger Bank.”* |

**The diminution of the line fisheries**

From 1840 to 1860 the numbers of trawlers on the Dogger Bank increased considerably as fishermen depleted grounds closer to shore and the sailing fleet expanded (Royal Commission 1866; Engelhard 2009; Thurstan *et al.,* 2013). However, with the increase in landings by the trawlers, longline and handline fishermen began to experience noticeable declines in catches. Complaints regarding trawling as a perceived destructive means of fishing led to a Royal Commission of Enquiry to determine if the supply of fish was decreasing, and whether legislative restrictions on trawling would result in an increase in the supply (Royal Commission 1866). Longline and net fishermen claimed they had seen declines in the abundance of nearly all target species on the Bank, and were only able to catch a quarter of the cod, brill (*Scophthalmus rhombus*) and haddock they had in 1850 (Royal Commission 1866). According to one witness, during 1850 to 1860, catches of haddock declined by 96%, from 1000 haddocks a day to 40 on the same ground on the Dogger (Royal Commission 1866). Catches of cod and ling declined 90%, from 6,000 fish a day to 600 (Royal Commission 1866), and by 1860, 10 times the amount of fishing effort was expended to catch the same quantity of halibut as they had done 20 years prior (Royal Commission 1866). Accounts from witnesses (Table 2) express the changes seen in the productivity of the Dogger Bank line fishery. A fish merchant (D. Crawford), interviewed in 1863 described his experience:

“*Where we used to get 150 stone of halibut in a day, and sometimes 200 stone, we might now fish for six days for 100…”*

If representative, this is equivalent to an 89-92% decline in the catch of halibut per unit effort over the first 20 years after the introduction of the sail trawler to the Bank. Despite better gear, and increased fishing effort, fishers caught less than 20 years previously. Line fishermen attributed the decline to the destructive methods of the trawl and the large number of juvenile fish being removed in this way (Royal Commission 1866; Royal Commission 1879; Blake 1867).

*“In the spring and summer the trawlers work the shallow banks out at sea. Working these areas, the trawlers undoubtedly kill a good many small fish, such as small soles, plaice and haddocks six or seven inches long. Most of the small fish which they thus take are dead when they are brought up to the surface, many of them being suffocated or drowned in the trawl which is frequently down for many hours before it is raised. At the same period of the year the shrimpers work in even shallower places and also catch large quantities of small fish. All kinds of immature fish are thus taken, many as small as a half penny piece.”*

Trawlers would frequently put down nets in areas known for large spawning aggregations to occur, and as a result, take huge quantities of adult fish full of eggs before they were able to spawn (Royal Commission 1866). Gradually from 1840 to 1870 line fishermen were unable to catch enough fish to maintain their businesses and began to decline in number and abandon the ground they once found so prolific (Royal Commission 1866; Royal Commission 1879).

**Table 2**: Quotations from witnesses on the change in productivity on the Dogger Bank since the introduction of the sail trawl. Statements from witnesses are italicised, quotations not italicised are questions posed to the witness by Commissioners.

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| **Witness** | **Description** | **Quotation** |
| **1866** Commission |  |  |
| J. TemplemanLine fisher | Diminution of fish | *“I have found that in the last 10 years there has been a great decrease in the haddock-fishing, and also in the herring-fishing. It has even declined from here to the Dogger Bank […] cod, whiting, haddock, and ling. […] All these kinds of fish […] have greatly declined. […] It [the catch] has declined very much on the Dogger Bank. Not one quarter part can they catch now as compared with what they used to catch”**“They [trawl boats] have increased within these last few years 10 percent. […] They have impoverished all the places they used to fish, and now they have come to impoverish the ground here [the Dogger Bank]. The consequence will be that in a very few years there will be no fish here.”* |
| J. FellLine fisher | Diminution of haddocksIncreased effort | *“*20 years ago what would you consider an average catch of fish for a week? *– I have been going for a week and I have brought 700 or 800 cod ashore, a ton of halibut and a great number of skate and haddocks […] other boats have got the same as mine. Now we can hardly get any fish on the same ground close to the Dogger. The smacks are there now, and they have so trawled over the ground that they have ruined everything about there, where we used to get the most fish […] now we have quite abandoned the ground upon which we got that quantity, as we find we can’t get any at all.”**“Off the Dogger Bank […] I have known them bring 800 to 1000 [haddocks] in the course of an hour’s fishing. […] now they will not get more than 30 or 40 on the same ground. […] At the edge of the Dogger where fish used to be so plentiful there is nothing to catch with the longline now.”**“…our gear is superior to what it used to be, and still we catch less fish.”* |
| W. ThompsonFish merchant | Diminution of halibutDiminution of cod and lingIncreased effort | *“*How have they done there [Dogger Bank]? *– They have got next to nothing. […] There is not a boat that has got 80 stones of halibut this year. When I was young we have caught 12 score of halibut in two days.”**‘They used to get […] 500 or 600 score [of cod or ling] in two or three days. […] Now they can only get 60, 70, or 80, and it is only a very chance boat that gets 5 score.”*“Then you say from your knowledge of the fish brought in by the boats from the Dogger Bank that the takes have greatly fallen off? *– They have almost entirely fallen off, and it was the best fishing ground they had formerly.”**“The total quantity brought to shore has not decreased, but each boat gets less.”* |
| J. TrattlesLine fisher | Diminution of fish | *“50 years ago the Dogger Bank was always our best fishing ground. We used to go there principally to fish off the edge of the Dogger, and we always got an abundance of fish. For 25 years it was our study to get to the Dogger Bank for fishing, but for the last 15 years it has fallen off. During that period it has fallen off more and more every year. We always could get a cargo of fish as soon as we got to the Dogger Bank in my time.”*“When you did go, you found a great difference in the fishing compared with what it had been in the previous times? - *There was a wonderful difference. There was not one third part of the fish to be caught.”* |
| D. CrawfordFish merchant | Diminution of halibut | *“Where we used to get 150 stone of halibut in a day and sometimes 200 stone we might now fish for six days for 100; there is just about that difference.”* |
| W. JenkinsonLine fisher | Diminution of cod | *“The codfish has fallen off. On the Dogger Bank we used to get plenty, and now if we fish there for a week we get very few indeed. The quantity caught there has been falling off ever since the trawlers came upon the bank.”* |

The greatest expansion of the sail trawl fleet occurred between 1850 and 1880, reaching its peak in 1870 (Engelhard 2009). During this period, vessels became larger, increased the capacity of their trawls and carried two masts instead of one (Engelhard 2009). In 1870 steam powered boats were used to transport catches from vessels to the shore so trawlers could stay at sea longer (Engelhard 2009). In some places on the Dogger, 60 to 70 trawlers worked the same ground only a mile wide (Royal Commission 1866). The average daily catch of a trawl vessel on the Dogger increased from 2 tons in the 1850s to 6 tons by 1866 (Royal Commission 1866). However, despite the increase in landings, a noticeable decrease in the number of flatfish brought to market occurred. As their availability dropped, the price of sole increased from 1 shilling 6 pence per stone in 1855 to 23 shillings per stone by 1884 (Royal Commission 1884). The average rate of inflation over the same time frame was -0.4% a year 4, indicating that the rise in price was most likely a result of increasing scarcity relative to demand. Despite the complaints raised in the 1866 Royal Commission of Enquiry, commissioners did not believe the supply of fish to be diminishing as overall landings were still increasing (Royal Commission 1866). They failed to recognise that the decrease in catch per unit effort for longline fishermen was indicative of the declining abundance of fish.

**The introduction of the steam trawler**

Before 1880 the fishing effort for sail trawlers was restricted by favourable tides and weather conditions (Thurstan *et al.,* 2010), but in 1881, the first steam powered trawlers were built in Scarborough and Grimsby (major ports to the Dogger Bank), and revolutionised the fishing industry (Engelhard 2009). Steam trawlers were less subject to weather conditions and could range further and trawl deeper. The first steam trawlers were estimated to be 4 times more efficient at catching demersal fish, and 4.6 times more efficient at catching haddock than the sail trawl (Garstang 1900). In the early years of their introduction, steam trawlers could catch as much fish close to shore as a sail trawler on the Dogger Bank and, therefore, rarely ranged so far (Royal Commission 1884). Longline fishermen’s catches had declined considerably by this time, and it now took a month to catch the same weight of halibut caught in a day 40 years previously (Royal Commission 1884). Sail trawlers began to see catches of sole decline to one or two fish a day, and drop in weight from 6lbs to 2lbs (Royal Commission 1884). Turbot, once regarded as the most prolific fish, had become increasingly scarce. By 1884 flat fish on average had decreased to half their original size, and populations of dogfish had declined to such an extent they were believed extinct (Royal Commission 1884). Catch per unit effort continued to decrease for the sail trawlers;

*“When we first went there [Dogger Bank], we could go and catch several tons of fish in such a time as 18 or 20 hours, or 12 hours. We would get several tons and we would not have a net in the water more than three hours. Now we can have it in the water 24 hours and we would not get half a ton.”* (Royal Commission 1884).

By 1893, the efficiency of the steam trawler had increased to 5 times that of the sail trawl (Garstang 1900), yet they still caught less fish per unit of effort than previously. The quote below is from a steam trawl fisher (C. Jeffs) who was once worked on a sail trawler:

*“Formerly we could go to the Dogger Bank […] tow for two hours in a small vessel, with a small trawl, and we could catch more fish in the two hours or three hours, then towing over something like five or six miles of ground, than we can now catch with a steam trawler, with gear quite as large again, towing over 300 miles of ground. They cannot catch more than one-tenth part of the fish.”* (Royal Commission 1893).

In 1895 the otter trawl was introduced, and by 1898 had been adopted on almost every steam trawler (Engelhard 2009). One steam powered otter trawler was the equivalent in fishing power to 8 sail trawls (Garstang 1900).

**Table 3:** Quotations from witnesses on the continued decline in catches after the introduction of the steam trawl. Statements from witnesses are italicised, quotations not italicised are questions posed to the witness by Commissioners.

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| **Witness** | **Description** | **Quotation** |
| **1879** Commission |  |  |
| W. SawyersLine fisher | Diminution of dog fish | “*The dog fish used to come in large numbers 30 years ago. They have all gone. The fishermen have now to go to the Dogger Bank for herrings. There are no dog fish there.”* |
| D. CrawfordSalesman | Diminution of halibut | *“About 35 or 40 years ago we could catch 200 stone of halibut in a day on the Dogger Bank. It would take a month to catch this quantity now.”* |
| J. Turtles | Diminution of catches | *“40 or 50 years ago they used to carry one third the tackle they do now and yet used to catch more fish. […] The fishermen go to the Dogger Bank now because there are no cod nearer than that, but the cod and ling are falling off even there. The scarcity of fish was not so marked in 1862 when the Huxley Commission was here…”* |
| **1884**Commission |  |  |
| J.J. Hills |  | *“The reason why we want the steam trawlers stopped is for the reasons that I have already given in regards to the sailing trawlers. […] they found that the Dogger Bank has been seriously affected by the trawling going on there; and we have looked upon the Dogger Bank as the principal reservoir of fish.”* |
| A.W. AnsellMerchant | Diminution of solesLarge quantities of haddock caught and the diminution of dog fishDiminution of plaice | *“Since I have been in business soles have gradually become scarcer. In the 10 years 1845 to 1855 they could be bought for from 8d, 10d to 1s6d per stone. According to supply they will now reach from 14s to 23s per stone. I believe the increase in price is owing to the diminishing supply of sole.”**“Our boats catch immense quantities of haddocks which prey on the spawn of herring. […] I examined the contents of the stomach of a haddock caught on the spot of the Dogger when the herrings were there. It contained such an amount of spawn in it that the fish was full to bursting; this was a sample of several tons caught. […] Some years ago our vessels caught an immense number of dog fish, enough to fill a trawl in one haul […], few dog fish are caught now, our vessels have destroyed so many.”**“We found large quantities of plaice on the Dogger Bank long ago. We do not find that now.”* |
| J. AllwardSail trawler | Diminution of solesIncreased trawling on the bank and increased catches | *“On the Dogger you occasionally get a sole […] I do not think it can be said that there is a permanent diminution of fish except soles.[…] I may say turbots also. […] It is very extraordinary with regard to turbots. So far as we are told in natural history, it is one of the most prolific fish that we deal with. Well, now, it is rather singular that they are the scarcest fish.”**“*That is ground [Dogger Bank] that you constantly trawl over? *– We are constantly on it …”**“We caught a very good cargo of fish [plaice and haddock], and from that time [1883] down to the present my experience is that there has been abundant quantities of fish brought from those parts all along the easternmost edge of the Dogger Bank, and from the southmost part of the Dogger…”* |
| J. SellarsSmack owner | Increase in the size and fishing power of vesselsDecrease in catch | *“It all depends on the size of the boats […] Some of them about 35 years ago used to be from 24 to 25 tons, and six and seven tons up to 30. Now we have boats, including smacks, from something like 35 to 38 up to 81 tons.”*“What quantity of fish is caught in the Dogger Bank? *– I have known boats get 25 and 30 score a boat, and now if they get 10 to 15, that is all they will get. […] It has been falling off gradually […] I should say 10 to 14 [years].”* |
| H. ShepherdSail trawler |  | *“When we first went there [Dogger Bank], we could go and catch several tons of fish in such a time as 18 or 20 hours, or 12 hours. We would get several tons and we would not have a net in the water more than three hours. Now we can have it in the water 24 hours and we would not get half a ton.”* |
| **1893**Commission |  |  |
| C. JeffsSail and steam trawler | Increase in fishing effortDecline in sail trawlersDecrease in the size of flat fish | *“Formerly we could go to the Dogger Bank […] tow for two hours in a small vessel, with a small trawl, and we could catch more fish in the two hours or three hours, then towing over something like five or six miles of ground, than we can now catch with a steam trawler, with gear quite as large again, towing over 300 miles of ground. They cannot catch more than one-tenth part of the fish.”**“…the sailing vessels have not paid us for sailing them for several years now. I should say that there are scarcely 10 sailing vessels out of Grimsby that have made their expenses during the last two years; there really has not been the fish to catch.”*“What size of fish is generally caught and landed now as compared with former times? *– Formerly they were all large fish that were caught.”*“Are there any other fish which you wish to specify and contrast between then and now? *– Soles, turbot and brill; all flat fish […] they are decreasing as well.”*“What was the general character of a trunk of fish 10 or 20 years ago? *– There would be then 30 or 40 in a box and now they run from 70 to 90.”* |
| W. C. NormingtonSail trawler | Decline in catches | “Has it been your experience that some of the fishing grounds in the North Sea, which you used to find profitable, have become unprofitable? *– A great many […] The Dogger Bank for instance, up to late years was the most noted fishing ground, now it is almost obsolete, and nearly exhausted of fish. It was the most famous fishing ground of the North Sea.”* |
| J.MurrellSalesman | Decline in plaice | “Have you anything further to say with regard to the diminution of fish as to a cutter which came in on the 9th May (1893) to Billingsgate with 2,700 boxes of fish on board? – *Yes, one of our cutters came to Billingsgate with 2,700 boxes of fish, and according to the average we ought to have had 300 boxes of plaice, and in years gone by we should have had that amount.”*“You mean large plaice do you not? – *Yes; but we had only […] 39 boxes of large plaice. That is a falling-off which every one of you may see is something enormous. Certainly this 39 out of 2,700 boxes is rather exceptional, but lately, as you will observe, from 1889, in four years we have decreased 50,000 to 30,00 – it has been going on decreasing in the same proportion or a little more. In fact, I think I may say, without fear of contradiction that the quantity of place we have landed this year in proportion to the number of boxes we have landed is less a considerable deal than it was before; and in my opinion, unless the sale of immature fish is stopped, or some means are taken to allow an opportunity of recuperating, they will become as the soles are, absolutely obsolete. […] Thirty-two years ago on the Dogger Bank we could fill a vessel in a couple of nights with plaice. This very place on the westerly shoal of the Dogger Bank where this boat came from which I mentioned with only 39 boxes, was one of the most prolific banks for large plaice anywhere in the North Sea, no matter where you went.”*  |

Towards the end of the 19th century, many sail and line fishermen considered the Dogger Bank exhausted of fish. Calculations from witness testimonies in Table 3 indicate that catches of fish such as plaice had declined by nearly 90%. Fishermen concerned with the large numbers of immature fish taken by the trawl appealed to commissioners for the prevention of trawling on important spawning grounds of the Dogger Bank (Table 3).

**Table 4:** Quotations from witnesses regarding the protection of fishing grounds from trawling. Statements from witnesses are italicised, quotations not italicised are questions posed to the witness by Commissioners.

|  |  |
| --- | --- |
| **Fishermen** | **Quotation** |
| **1884**Commission |  |
| J. Allward | *“It is where scientific men determine there are breeding grounds, or nurseries as we might term them, I think it might be judicious to limit the trawling operations.”* |
| M.PeakerSmack owner | *“I am of the opinion that trawling within a limit of three miles off the shore has proved most destructive to the small fry, and it is almost impossible to calculate the amount of harm that has been done to the fishing trade and to the supply of mature fish. […] I take a very strong view that trawling should be made prohibitive within a distance of 10 miles at least from low-water mark […] the great breeding grounds of fish, both round and flat fish, flat fish particularly, and the less these grounds so far as the fry [young fish] is concerned are disturbed the better.”* |
| E.J. Sutton | *“I would shut up parts of the grounds; close them if possible to do it. I do not see any other remedy for it.”**“*If the fish in the protected ground migrated out to the unprotected ground there would not be much use in having a protected ground at all?*- I do not think they all came out. I think they only came out because they were too abundant or crowded. […] I think if it were possible to close the Dogger Bank […] there would be an increase of fish…”**“My fixed opinion, sir, that it [the decline in fish] is chiefly from the over catching, the catching of grown fish. There has been in years past enormous quantities of full roed plaice, and full roed soles caught, which appears to me the most likely thing to decrease the quantity of fish on the ground […] years ago a great quantity was caught on the Dogger Bank.”* |

**The industrial fishing of the 20th Century**

As a result of their enquiries, it became clear that both the supply of flat fish and catch per unit effort had significantly decreased throughout the North Sea since the onset of trawling:

“*Your Committee think that it is proved beyond doubt that there is a very serious diminution of the supply of certain kinds of flat fish, particularly in the North Sea. Of late years the total quantity of such flat fish caught has remained nearly stationary. This fact, when taken along with the enormously increased catching power and the vastly large area of sea subjected to fishing operations, seems to show that the ancient fishing grounds are much depleted. The whole of the local evidence, differing in many other respects, is practically unanimous as to this point. […] Direct remedies lie in either the prohibition of the taking and killing of such small fish, or in the prohibition of fishing within certain areas where small fish more particularly abound*.” (Select Committee 1900)

In response, a Bill was proposed in 1900 to prohibit landing fish below a certain size (Select Committee 1900). Trawl fishermen were in favour of this new legislation, as they believed it would prevent fishermen targeting immature fish on spawning grounds if they were unable to be sold at market (Select Committee 1900). Unfortunately, the Bill was not passed as they were unable to determine appropriate minimum size restrictions.

From 1900 to 1950 steam trawlers landed 80% of Britain’s entire North Sea demersal fish catch. During this time, increases in gear efficiency came with the introduction of tickler chains which stirred up the fish in front of the trawl and Vigneron-Dahl gear, a system of rope bridles between otter boards and nets that allowed the trawl to sweep a wider area without increasing towing power (Wimpenny 1953). By 1930, steam powered trawlers were 10-20 times more efficient at catching cod and 4-5 times more efficient at catching plaice compared to the 1880 sail trawl (Engelhard 2009). Fishing intensity on the Bank remained high throughout this time:

“*Day and night throughout the year, ceaselessly, except when prevented by bad weather from working, the steam-trawlers are at work on the Dogger, gathering its harvest, and so it is with all the other fishing-banks of the North Sea.*” (Wood 1911)

In 1950 the diesel-powered motor trawler was introduced widely and further increased fishing power. Consistent improvements in technology have continued to increase the fishing power of vessels until today.

**Collapse of the Dogger Bank Herring fishery**

Herring fisheries on the Dogger Bank date back to pre-16th century (Beaujon 1884), and were traditionally fished by drift nets until the 20th century (Clover 2006). In the 1900s, drift nets were replaced by pair trawls that greatly increased catching power (Clover 2006). The fishery grew rapidly, from ~1,300 tons caught in 1948, to ~100,000 tons by 1954 (Hodgson 1956). Large, powerful pair trawlers targeted vulnerable spawning aggregations around the Dogger Bank and disturbed spawn on the seabed (Hodgson 1956). By 1957 the spawning stock had fallen from 5 million tons in 1947 to 1.5 million tons (Clover 2006), and by 1975, herring no longer spawned on the Dogger Bank and the fishery had collapsed (Clover 2006).

**Changes in benthic macro-fauna communities**

In 1990 Krӧnke *et al*., analysed and compared five different macro-fauna communities on the Dogger Bank from the 1920s, 1950s and the 1980s. The earliest of these samples post-dates the introduction of intensive trawling on the Bank. However, large changes in the macro-fauna occurred between 1920 and 1950, coinciding with the industrialisation of the North Sea steam trawl fleet (Krӧnke *et al*., 2011). By 1950, large populations of the bivalve species *Spisula subtruncata* and *Mactra* spp. on the north-eastern and central parts of the Bank had disappeared, and in 1980 they were only found as juveniles (Krӧnke *et al.,* 2011). These species were replaced by small, fast growing bivalves such as *Abra prismatica, Tellina fabula* and *Montacuta bidentata* (Krӧnke *et al.,* 2011). By 1985, opportunistic small polychaete species such as *Spiophanes bombyx, Scoloplos armiger* and *Magelona* spp. had increased in abundance and distribution in comparison to 1950 when only a few individuals were found (Krӧnke *et al.,* 1990). By 1987, the total macro-faunal biomass on the Dogger Bank had decreased by 30% from 1950 (Krӧnke *et al.,* 1990).

**The 21st Century**

In 2011, JNCC collated catch statistics for the Dogger Bank area from 2006 to 2009. Between 2006 and 2009, the average catch of cod from the Bank was 114.1 tonnes a year (Table 5). In comparison, the total catch of cod in 1913 was 5287 tonnes (Howell 1921). Therefore, at a conservative estimate, not considering the change in fishing effort, the total weight of cod caught from the bank has declined 98% over the last century. The average weight of halibut caught by a single vessel on the Dogger Bank in 1840 was 1.2 tonnes a day. The average weight of halibut caught per year by all vessels between 2006 to 2009 was 2.1 tonnes (Table 5).

|  |  |  |
| --- | --- | --- |
|  | Average weight (t) | Average as a percentage weight (t) |
| Plaice | 2930.6 | 45.26 |
| Sand eels | 1948.6 | 30.09 |
| *Nephrops* | 397.0 | 6.13 |
| Dabs | 225.6 | 3.48 |
| Sprats | 213.9 | 3.3 |
| Herring | 138.0 | 2.13 |
| Lemon sole | 125.6 | 1.94 |
| Cod | 114.1 | 1.76 |
| Turbot | 66.5 | 1.03 |
| Crabs | 48.9 | 0.76 |
| Sole | 47.0 | 0.73 |
| Haddock | 45.6 | 0.7 |
| Whiting | 29.9 | 0.46 |
| Whelks | 26.6 | 0.41 |
| Gurnard and Latchet (sea robin) | 23.9 | 0.37 |
| Monks and Anglers | 14.7 | 0.23 |
| Skates and Rays | 14.3 | 0.22 |
| Lobster | 11.1 | 0.17 |
| Brill | 9.2 | 0.14 |
| Spurdog | 7.3 | 0.11 |
| Squid | 4.6 | 0.07 |
| Red mullet | 2.7 | 0.04 |
| Halibut | 2.1 | 0.03 |

This means, that in 1840, it would have taken one vessel two days to catch the same weight of halibut, that it now takes the whole fleet, with far greater fishing power, to take in a year.

Between 2006 and 2009, Sand eels contributed 30.1%, and *Nephrops* 6.1% of the total catch by weight. These lower trophic level species now make up a greater percentage of the catch than they did in the in late 19th century where records of their capture are scarce. In comparison, once abundant species such as cod, turbot and halibut now contribute to 1.8 %, 1.0 % and 0.03 % of the catch respectively. Landings of predatory species such as Spurdog (*Squalus* spp), monk and angler fish, and skates and rays are likewise as low.

In 2006 to 2009, 94.2% of species landed were caught using some form of trawl (JNCC 2011), and 5.9% were caught using either Danish seines, pots, gill nets and Scottish seines (JNCC 2011). Longlines were no longer in use on the Bank.

**Table 5:** The average weight of species landed in the ICES squares containing the Dogger Bank SAC from 2006 to 2009. Information sourced and adapted from JNCC (2011)

Table 6 summarises declines in the abundance of species on the Dogger Bank implied by evidence given in testimonies over the past 200 years. The results highlight significant changes very early on as commercial fishing intensified. In some cases, significant declines happened over relatively short periods of time.

**Table 6:** Apparent percentage decline in fish abundance calculated from changing catch per unit effort in witness testimonies.

|  |  |  |
| --- | --- | --- |
| **Time interval** | **Fish** | **Percentage decline in abundance** |
| **1840-1866****1840-1866****1840-1866****1840-1884****1866-1884****1913-2006** | Cod HaddockHalibut Halibut All (trawler)Cod | 90%96%93.7%96.7%99.8%84% |

**Present day protection**

The Dogger Bank is designated as an SAC (Special Area of Conservation) under the European Habitats Directive in German and Dutch waters, and is a candidate SAC in English waters. Table 7 lists conservation objectives for the Dogger Bank SAC for the UK, Germany and Netherlands. There is a considerable disparity among the conservation objectives proposed.

**Table 7**. The conservation objectives as stated by the relevant conservation body for those countries that have designated the Dogger Bank as an SAC.

|  |  |
| --- | --- |
| **Country** | **Conservation Objectives** |
| **UK**(JNCC) | The Conservation Objectives for the Dogger Bank sandbanks which are slightly covered by seawater all the time are:Subject to natural change, restorethe *sandbanks which are slightly covered by seawater all the time* to favourable condition, such that the: * The natural environmental quality is maintained
* The natural environmental processesare maintained
* The extent, physical structure, diversity, community structureand typical speciesrepresentative of *sandbanks which are slightly covered by seawater all the time* in the southern North Sea are restored.
 |
| **Germany**(The German Federal Agency for Nature Conservation - Bundesamt für Naturschutz) | The general conservation objectives have been set out as follows for the sandbank habitat type by which the site is defined, and for harbour porpoise and common seal as species requiring special protection:* Maintenance and restoration of the sites specific ecological functions, biological diversity and natural hydrodynamics and morphodynamics
* Maintenance and restoration at favourable conservation status of habitat type code: 1110 (sandbanks which are slightly covered by sea water all the time) together with its characteristic and endangered ecological communities and species
* Maintenance and restoration at favourable conservation status of the following Habitats Directive species and their natural habitats: Harbour porpoise and common seal
 |
| **Netherlands****(**Ministry of Agriculture, Nature and Food Quality**)** | The Dutch conservation regulatory authority have a set of general conservation objectives that apply to all Natura 2000 sites in the Netherlands, and comprise the maintenance and if applicable the restoration of:* The natural features of the Natura 2000 site, including the coherence of the structure and functions of the habitat types and of the species for which the site has been designated.
* The ecological requirements of the habitat types and species for which the site has been designated

For the Dogger Bank sandbanks habitat, the overall objective is to:Maintain the surface area and improve the quality. |

The above objectives do not provide a clear baseline against which restoration efforts can be measured, and use data from the past few decades to determine the diversity, community structure and typical species ‘representative’ of the Bank. Many of the objectives aim only to ‘maintain’ the conditions of the Bank at current levels.

This limited understanding of the what the preferred target condition of the site should be, has consequences for management. In 2011, the intergovernmental Dogger Bank Steering Group (DBSG) proposed a zoning plan for fisheries management (North Sea Regional Advisory Council 2012). They aimed to establish management measures through the Common Fisheries Policy for the entire SAC complex and encourage cooperative management in order to achieve the conservation objectives of the site (Val Hal *et al*., 2010). They identified that the ecological status of the Bank was unfavourable, but that there was limited information for them to determine the target condition of the Bank;

‘*For offshore sites, there is presently insufficiently detailed information on i) the existing condition of qualifying interest features and ii) the preferred or target condition of interest features. This currently limits identification of measures and associated targets for condition monitoring. It is anticipated that further information on the condition of interest features will be obtained through baseline surveys and monitoring*.’

As a result, recently obtained survey data were used as a baseline measure (Val Hal *et al*., 2010).

**Discussion**

Witness testimonies over the past 300 years confirm that the Dogger Bank ecosystem used to support a great diversity and abundance of species throughout its early history, including high abundances of large-bodied fish such as halibut, skate and turbot. The introduction of the sail trawl in 1840 marked the onset of major ecological changes to the area. Fishermen whose methods had until that time remained consistent for many centuries had appealed for the implementation of legislative restrictions on trawling activity. Despite large catches early on, catch per unit effort of sail trawlers progressively decreased from the mid-19th Century onwards. When steam trawling was introduced in the 1880s, many fishermen already considered the Dogger Bank exhausted of fish. However, the greater fishing power of these boats kept the Bank remunerative and the ongoing further increase in fishing effort was the second pivotal point in the transformation of the ecosystem. Modern data show that even the highly altered and relatively impoverished ecosystem of the late 19th century is now gone; today lower trophic level species dominate catches and many once prolific fish such as halibut are effectively ecologically extinct, while others like large-bodied skates have disappeared completely.

Centuries of trawling have reduced benthic habitat complexity and resulted in macro-faunal communities with low diversity and increased dominance of opportunistic, fast-growing species that can recover from frequent disturbances (Krӧnke *et al*., 2011). Today many predatory species such as Angelshark (*Squatina squatina)*, and several skate and ray species including the Common skate, as well as the dogfish, *Squalus acanthias*, are classified as ‘critically endangered’ in European waters (Neito *et al*., 2015). These predator species have been reduced so significantly that they can no longer exert their former ecological roles (Friedlander and DeMartini, 2002). Removal of higher trophic levels can cause ecosystems to undergo a phase shift where they become dominated by lower trophic guilds as top-down effects are relaxed (Frank *et al*., 2005).

We must consider, of course, the possibility that the initial productivity of the Dogger Bank was overestimated from witness testimonies. The first Royal Commission of Enquiry in 1863-66 was conducted because the traditional line and net fishermen were complaining about declining catches and gear loss when they encountered trawlers. Hence, they had an incentive to exaggerate the declines witnessed in the hope that legislative restrictions on trawling would be implemented. On the other hand, during these enquiries, many people from different geographical locations gave similar testimonies on the subject despite not being able to corroborate with one another. Furthermore, multiple testimonies reported steep early declines in large-bodied species, consistent with theoretical predictions of ecosystem shifts under exploitation pressure, and evidence from numerous ecosystems worldwide (Roberts 2007). A study conducted by Thurstan *et al.,* (2010), on the degradation of the Firth of Clyde ecosystem over a similar timescale, shows comparable losses of biodiversity and ecosystem complexity and demonstrates that steep declines are not unusual.

In addition to the impact of fishing, the Dogger Bank has been subjected to recent anthropogenic activities such as oil exploitation, pollution and climate change. In 1987, high levels of heavy metals such as titanium dioxide and polychlorinated biphenyls (PCBs) were found in Bank sediments (Milne 1987). These pollutants are harmful to marine life, and have been associated with skin tumours on Dab fish (Milne 1987). Perry *et al.,* (2005) studied the change in the distribution of both exploited and non-exploited fish in the North Sea. They found that nearly two-thirds of species sampled had shifted northwards or to deeper depths over the past 25 years in parallel with increased sea surface temperatures. Species that were fast reproducing with smaller body sizes shifted their distribution more readily in response to temperature changes. The synergistic effects of climate change and the exploitation by fisheries will increase the vulnerability of the Bank to environmental perturbations and may result in further phase shifts.

**Conservation policy for the Dogger Bank**

The Dogger Bank represents a case study in the problems of shifting baselines leading to low conservation ambition and flawed management. Our research has demonstrated that the present condition of the Bank is one of ecological degradation and impoverishment as a consequence of over two centuries of intensifying and increasingly destructive fisheries. Conservation objectives are, however, limited to the seabed (except for common seal and porpoise), and fail to consider protection or restoration of fish communities there. Furthermore, even seabed habitats are inadequately catered for in management due to the flawed assumption implicit in recent assessments, that the condition of Bank seabed is ‘favourable’. There are no proposals to protect any of the Bank from mobile fishing gears, so far as we are aware. Nor has there been any consideration of the historical state of the Bank in setting appropriate conservation objectives. More sampling of seabed habitats, fish communities or other wildlife, as proposed by the Dogger Bank Management Group, will get us no closer to assessing baseline conditions. Only historical data can do that.

These problems of shifted baselines and low conservation ambition are not unique to the Dogger Bank, but are endemic to present conservation practice in the UK and much of Europe. They are well illustrated by the recent decision to reopen areas of a large Special Area of Conservation off the Welsh coast to scallop dredging5 . The decision was based on a short-term study that claimed to find that seabed habitats recovered quickly from experimental scallop dredging disturbance ([Lambert](file:///C%3A%5CUsers%5Ccallu%5CDownloads%5CLambert) *et al*., 2015a; 2015b; 2015c). The authors also claimed that scallop dredge impacts were comparable to or less than natural disturbance from wave action and currents. But the seabed in their study area had been commercially dredged only five years before they undertook their research, rendering experimental controls meaningless, and elapsed ‘recovery’ time in the study was only four months. It cannot be surprising that highly disturbed, early successional habitats will recover quickly to their previous state after further disturbance, just as a heavily grazed rangeland might recover quickly after wildfire. What this research cannot demonstrate is what dredging or natural disturbances would do to intact natural habitats. Mid-nineteenth century fishermen spoke of an invertebrate crust that covered the seabed and that was scraped away by the first trawlers and dredgers (Thurstan *et al*. 2013). A few years’ respite from scallop dredging will not regenerate that habitat. But recovery to this rich, diverse and complex state that pre-dates industrial fisheries is surely what nature conservation should strive for, not maintenance of low diversity, low biomass, structurally simple conditions found in areas that have long been commercially dredged and trawled.

Furthermore, it is a significant failing that nature conservation using marine protected areas should focus only on seabed habitats and ignore fish. Decades of fisheries policy have made it clear that fisheries managers have no mandate or desire to conserve anything other than their target species, and they often fail to deliver even this narrow objective (O’Leary *et al.* 2011). The many species that have dwindled to rarity or disappeared altogether over the long history of fishing impact have eliminated themselves as targets for fishery management due to economic insignificance. They represent legitimate, indeed compelling, subjects for conservation intervention, yet are ignored at present. Vulnerable areas of the Dogger Bank fishing grounds were proposed by fishermen for protection over 120 years ago (Royal Commission 1884). Today the Bank is severely depleted and still unprotected.

It is clear from this study that a far greater decline has occurred over the history of the Dogger Bank than was considered in the initial habitat assessments carried out by JNCC. Data that fail to take account of the long-term change and decline, produce a baseline that significantly underestimates the recovery potential of an ecosystem, and in turn encourages management measures that are insufficient to attain any improvement in condition. We argue that historical research into ecosystem states pre-dating the onset of industrial exploitation should be an essential part of determining an appropriate baseline, from which, clear, ambitious, ecosystem-wide conservation objectives can be derived and implemented.

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