One hundred and twenty years of change in fishing power of English North Sea trawlers

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ABSTRACT: Fishing vessels differ in fishing power—that is, in the quantity of fish they would catch per unit time if they were fishing at the same time and location—and there is a general trend of increasing fishing power over time. Typically, fishing power studies are limited to comparisons over 1–2 decades, but here I attempt to quantify this trend for English North Sea trawlers over the past 120 years. A review of fishing history shows how sailing trawlers, steam trawlers, and currently both motor otter trawlers and twin-beam trawlers have in turn dominated the trawl fisheries. A huge, overall increase in fishing power has occurred but the trend has been all but linear: fishing power has sometimes "leapt" forward within a few years, but at times has also stagnated for decades. Compared with historical sailing trawlers, motor otter trawlers around the Millennium are estimated to have 50 times higher cod fishing power, and twin-beam trawlers to have 100 times higher plaice fishing power. However, this does not mean that fisheries have become more profitable, because increases in catch rates have lagged far behind those in fishing power, and everything points in the direction of great overcapacity of the current international North Sea trawling fleet.

Keywords: fishing power, fleet dynamics, gear changes, (over)capacity, propulsion method, technological creep

INTRODUCTION

About a decade ago, some brave fisheries scientists in Lowestoft went on board an old sailing trawler, the *Excelsior*, and using a replica of a traditional 1880s beam trawl, fished on plaice (*Pleuronectes platessa*) grounds in the southern North Sea for a week. The aim was to gain insight into the fishing power of the type of vessel that, 120 years ago, was responsible for thousands of tonnes of fish being landed in Britain. The experiment was not considered to be successful because virtually no fish were caught despite the scientists' hard labour (Millner *et al*., 1997). Why was that? Did the crew or the scientists simply lack the fishing skills? Or was the sea a hundred years ago so much richer in fish resources that even a sailing trawler could easily catch sufficient to sustain a fisher's family? In other words: was the zero catch a consequence of a lack of fishing power or reduced abundance of fish?

Clearly, fishing power (sometimes referred to as catching power) has improved steadily over the past century, but very little is known about the speed or the magnitude of the change. Fisheries scientists have addressed this issue since the early days of this field of research: see, for example, Garstang (1900) on the dramatic increase in fishing power when the era of steam-powered propulsion followed that of wind-powered. The continuous improvement in fishing power is also a question that will intrigue a fisher,

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not the least those senior fishers who have witnessed technological improvements themselves (and who may not always have seen these reflected in better catches, e.g. when stocks began to shrink).

Beverton and Holt (1957a) provide a range of calculations of fishing power. Their book appeared in the period when steam trawling was gradually giving way to motor trawling (with diesel engines), and they made several comparisons of fishing power between the two. Although more refined, their methods used the same principle as Garstang's half a century before, namely to compare the catch per unit effort (cpue) of a base vessel (base fleet) with data available over a number of years, with the cpue of other vessels (fleet or fleets) that are newly developing. They stressed the importance of standardizing the comparison – ideally, vessels need to operate at the same time and in the same location in order to attempt to standardize for local differences in abundance (note that although straightforward theoretically, such data are in practice often difficult to obtain). Beverton and Holt also provide an early attempt to account for vessel characteristics, such as gross tonnage, and their effects upon fishing power. This makes it easier to distinguish between changes in the fishing power of a fleet caused by changes in gear and fishing technology, and those attributable to increases in the size or engine power of vessels. Such an approach requires the availability of data on the characteristics of individual vessels, which is not often available in historical datasets.

Standing on the shoulders of these giants of fisheries science, and using their basic methodology, I here make a rather bold attempt to address the question: to what extent has fishing power changed over 120 years of English trawling in the North Sea? The period is divided for the purpose into five principal eras, for which I describe the main changes in the fishing fleets, and the changes in their fishing power from one era to another using available cpue data. I conclude by making a standardized comparison across the full time-span.

ERA 1 – 14TH TO 19TH CENTURY: FROM SAILING TO EARLY STEAM TRAWLING

References to some form of trawl fishing in England date back to the 14th century: in 1376/77, a royal commission under King Edward III prohibited the use of a controversial new fishing gear called the "wondyrchoun" that had then been in use in the Thames Estuary for about 7 years. This early, 10-feet-wide beam trawl was already accused by traditional line and net fishers of catching large quantities of small fish in the estuary and destroying "the spat of oysters, mussels and other fish upon which the great fish are accustomed to be fed and nourished" (Graham, 1956; Kennelly and Broadhurst, 2002). Opposition against the trawl continued throughout history, but never halted its development.

There is confusion about how trawling was extended to the open sea, as carried out from wooden sailing vessels. There are claims that the step was taken contemporaneously by fishers from Barking (Thames Estuary) and Brixham (Devon) (Holt, 1895). According to Alward (1911), this means of fishing originated along the shallow sandy coast of Holland, seabed ideally suited to trawling, and was brought to England by Dutch seamen who settled in Brixham after the armada of Prince William of Orange landed there in 1688. However accurate this statement may be, it is clear that Brixham fishers used light beam trawls in the western English Channel well before the French Revolution. The fishery began to expand during the Napoleonic wars, apparently benefiting from provisioning problems associated with high fish prices (Robinson, 2000a). When Anglo–French hostilities ended in 1815, Brixham trawlermen gradually began to explore fishing grounds farther east in the Channel, and settled in fishing towns close to these new grounds. Working from Ramsgate, they reached the southern North Sea in 1821. During the following decades, these fishers gradually advanced farther north in the North Sea, and settled in a number of east coast ports, including Lowestoft, Scarborough, Hull and Grimsby, which developed as important trawling stations (Wimpenny, 1953; Robinson, 1996, 2000a).

Driven by the industrial revolution, subsequent population growth and increasing food demands, especially in newly developing industrial centres, the British sailing trawl industry in the North Sea expanded greatly during much of the 19th century (Robinson, 2000a). Of crucial importance was the construction of the railway network, which opened up the industrial centres as inland markets for selling fish products in a fresh state: fish brought ashore during the late afternoon were transported by rail overnight to reach the inland markets as early as the next morning. There was significant innovation in the design of sailing trawlers between about 1850 and 1880, the period of most marked expansion of the sailing trawl fleet (Figure 1): vessels became larger, carried two masts instead of one and used larger beam trawls with greater catching capacity. During the 1870s when trawling by sail in the North Sea reached its peak, auxiliary steam engines were installed to haul the trawls, and there was widespread use of a "boxing fleet" system, allowing sailing trawlers to stay at sea for longer while their catches were taken ashore by steam cutters – fast, steam-powered vessels that on an almost daily basis travelled between the ports and the fishing grounds until the 1890s (Robinson, 2000a, b). However, despite these developments, it was steam power that caused the decline in trawling by sail from about 1880 on.

Figure 1. Sailing trawler LT337 *Fern* being towed out of Lowestoft harbour by a paddle steamer. Painting by Joe Crowfoot. © Crown Copyright.

Steam had first been used in British sea fisheries in the 1850s, in the form of paddle vessels, such as two paddle steamers introduced in 1856 to Grimsby. However, these initial attempts could not cover the working expenses, and died out (Alward, 1911, 1932). The first commercially successful steam trawlers were converted paddle tugs that during the late 1870s worked out of northeastern English ports (Robinson, 2000b). It was, however, during the 1880s that the steam trawling industry really took off, with the arrival of the first purpose-built steam screw trawlers in Scarborough and Grimsby (1881), Hull (1885), and within a few years each of the other major fishing ports. Steam trawlers had a range of advantages over sailing trawlers. They were not subject to the mercies of the wind, could range further, trawl at considerably greater depths and tow fast enough to encourage the switch to the otter trawl, which was a more effective gear for many fish species than the beam trawl. Further, the supremacy of the steam trawler was ensured by the combination of iron hulls, and later steel hulls, and compound, then triple-expansion, steam engines. This was coupled with a change in vessel ownership structure, from skipper ownership to the development of limited liability steam trawling companies (Alward, 1932; Robinson, 2000b).

Garstang (1900) quantified this first, major change in fishing power of North Sea trawlers. Observing that in the sailing trawl fleet virtually no change in vessel design and only limited change in fishing practice had taken place since about 1880, he adopted the sailing trawler or "smack" as a standard unit of fishing power, and expressed the average fishing power of steam trawlers in terms of smack units. Based on the average annual catches of vessels fishing on the same grounds during the period 1883–1885, he estimated that compared with sailing trawlers, the first steam trawlers were about 2.6 and 4.6 times as efficient at catching plaice and haddock (*Melanogrammus aeglefinus*), respectively, and that the combined fishing power for all demersal species was four times higher.

Newly built steam trawlers gradually increased in size, and Garstang (1900), assuming that tonnage was equivalent to fishing power, estimated that by 1889 the steam trawler had become five times as efficient as the smack, and 5.5 times by 1893. The fishing gear on these earliest steam trawlers was the beam trawl, which had been adopted from the sailing trawler. There was a further increase in fishing power from 1895 to 1898 with the introduction and widespread use of the Granton otter trawl on steam trawlers. In an otter trawl, two comparatively small otter boards or doors, functioning as underwater kites, generated and maintained the spread of the net, making the large and cumbersome beam of the old beam trawl obsolete. Not only was the otter trawl more efficient at catching large aggregations of fish than the beam trawl in use then (by a factor of 1.37 according to Garstang, 1900; see also Lee, 1915), but it could also more conveniently be stowed aboard ship. By 1898, otter trawls were adopted on virtually all steam trawlers. Garstang (1900) concluded that the resulting total fishing power of a single steam trawler by 1898 had become equivalent to eight smack units, or twice that of the 1884 steam-propelled beam trawler.

ERA 2 – FIRST HALF OF THE 20TH CENTURY: DOMINATION OF STEAM TRAWLING

Around the turn of the 20th century, steam trawlers were being built rapidly in Great Britain, and by 1900 their combined number in English and Scottish east coast ports was no less than 1 251, according to official statistics. There was also a continued expansion of the fishing grounds worked by British steam trawlers, which by 1900 included the entire southern and central North Sea (ICES Divisions IVb and IVc), and by the 1920s, also almost the entire northern part (Division IVa; Alward, 1911, 1932; Engelhard, 2005). Before that, steam trawlers had already begun fishing in distant waters, such as off Iceland (1891) and in the Barents Sea (1905). From about 1900 to the late 1950s, steam trawlers (Figure 2) were by far the most important component of the British fishing fleet, and in most of those years landed at least 80% of Britain's entire North Sea demersal catch. However, there was a general decline in steam trawl effort over much of this period. Moreover, both World Wars caused significant reductions in steam trawl effort and landings, partly because vessel movements were restricted or the vessels themselves were lost in the hostilities, and partly because many vessels were requisitioned by the Royal Navy to be employed on war service, especially as minesweepers. As a result of these temporary, substantial reductions in fishing pressure, however, catch rates of many fish species in the North Sea in the immediate post-war years recovered to record high levels. This may have encouraged the rapid recovery in steam trawl fishing effort following both World Wars.

Meanwhile, the sailing trawl fleet only survived into the 20th century in the relatively shallow, southern North Sea (Division IVc), where it was almost entirely based at Lowestoft. The last sailing trawlers especially targeted flatfish including sole (*Solea solea*), brill (*Scophthalmus rhombus*), turbot (*Psetta maxima*) and plaice, which have relatively high market value and for which a beam trawl is a particularly appropriate capture gear, when compared with the otter trawl used on steam trawlers. This, combined with low running costs, to some extent allowed sailing trawlers to compete with steam trawlers at a time when coal prices were often high. It could, however, not stop the

*Figure 2***.** Great Yarmouth docks in the 1930s when steam drifters, along with steam trawlers, dominated British fisheries. Note YH89 *Lydia Eva* (right), England's sole surviving steam drifter and currently in the nation's "Core Collection of Historic Vessels". © Crown Copyright.

demise of the sailing trawl fleet, which was accelerated by the two World Wars. The total number of British first-class (>15 ton net) sailing trawlers (including all coasts) declined from 925 in 1900 to 380 in 1920. Then, from 41 vessels still fishing in 1937, only one remained active in 1946 (Engelhard, 2005).

Wimpenny (1953) reviewed the main gear developments during the first half of the 20th century, the so-called golden age of steam trawling. The original Granton otter trawls which had been introduced to steamers in 1894 were in general use until the First World War, but thereafter it became practice to strengthen the groundrope with rollers so that trawlers could work grounds that were previously too rough and which had been estimated to occupy about 17% of the North Sea floor. The gear was further improved by tickler chains spread across the mouth of the trawl in front of the groundrope, which stirred up the fish in front of the trawl that would otherwise have stayed too low to be captured. A further modification was the Vigneron–Dahl gear, first introduced in 1923 and in general use by 1926. This consisted of lengths of cable introduced between each otter board and the net, with the effect of sweeping a wider area than the normal trawl opening, and causing more fish to be herded into the mouth of the net. It also allowed a reduction in the size and hence the resistance of the net (Graham, 1956). The Vigneron–Dahl gear, compared with the standard otter trawl, was estimated to have improved the fishing power of steam trawlers by a factor of 1.5 for haddock (Bowman, 1932) and 1.25 for plaice (Wimpenny, 1953).

Based on the co-occurrence for many decades of both sailing and steam trawlers in the southern North Sea, and following Garstang's (1900) approach, I have attempted to quantify the fishing power of North Sea steam trawlers in terms of contemporary smack units (Figure 3). Note that Lowestoft sailing beam trawlers are here designated as the base fleet (*sensu* Beverton and Holt, 1957a), given that their fishing methods appeared to have remained practically unchanged since the late 19th century, and it is against those that the cpue of steam trawlers is being compared. Calculations were based on the cpue of cod (*Gadus morhua*) and plaice by sailing and steam trawlers, matched by year and by area or rectangle, for two periods where sufficient data were available: 1906–1914 (based on Board of Agriculture and Fisheries, 1908, ff.) and 1924–1932 (based on Ministry of Agriculture and Fisheries, 1921, ff. and Defra Statistical Charts, catalogued in Engelhard, 2005). The effect of vessel tonnage was not taken into account in this comparison, which instead shows how fishing power differed between a typical sailing trawler and a steam trawler at that time.

It appears that, in both periods, the typical steam otter trawler caught about four times more plaice, and about 10–20 times more cod per hour fished than the contemporary sailing beam trawler. The greater difference in fishing power for cod than for plaice relates to the otter trawl being better suited to catching roundfish and the beam trawl to catching flatfish; in addition, the faster towing speed of steam trawlers gave extra advantage when relatively fast-swimming fish such as cod were being caught (cf. Main and Sangster, 1983).

Surprisingly, these values do not suggest that the fishing power of the typical steam trawler operating in the southern North Sea during the inter-war years was better than during immediate pre-WWI years. In fact, it even appears that their relative fishing power for cod (compared with sailing trawlers) decreased from 1924 to 1932, albeit from a likely peak just after WWI. This was despite the several gear developments mentioned above, and notwithstanding a number of new, large steam trawlers being built then. However, almost all new steam trawlers became employed in trawl fisheries beyond the North Sea,

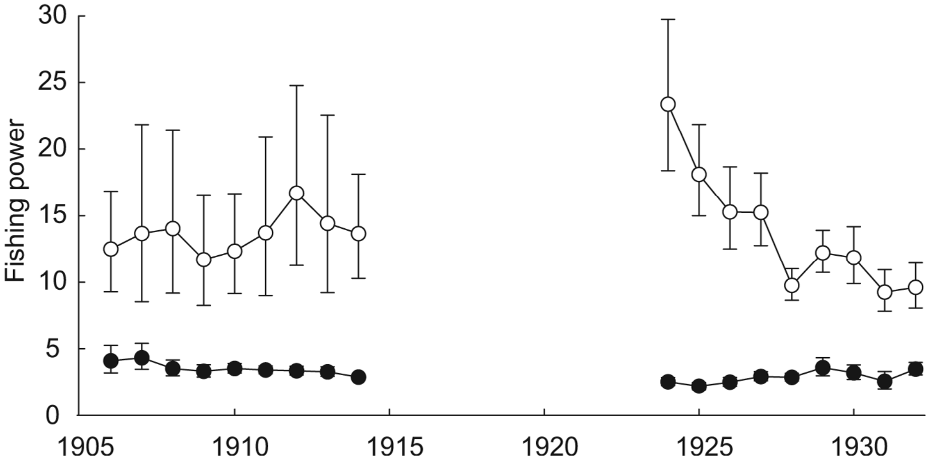

Figure 3. The relative fishing power of the steam otter trawler fleet compared with the sailing beam trawler fleet in the southern North Sea during the periods 1906–1914 and 1924–1932, catching cod (open symbols) and plaice (closed symbols). Fishing power is defined as the ratio between steam and sailing trawler cpue for the same year and within the same area. For each year, symbols indicate the geometric means (with standard error) by area, but note that the data for the two periods may not be strictly comparable. First, in 1906–1914 effort was quantified as days absent from port, and in 1924–1932 as number of hours fished. Second, in 1906–1914 fisheries statistics were aggregated spatially into four so-called regions based on depth contours (regions A1, B2, B3 and C3 in Board of Agriculture and Fisheries, 1908), whereas in 1924–1932 the data are by statistical rectangle. Nevertheless, the figure is considered representative of general trends in fishing power.

such as around Iceland (Robinson, 2000b) and in the northern North Sea, where cod and haddock are more abundant. Although it is probable that there was some size increase in trawlers operating in the southern North Sea, no precise information on this is available (Wimpenny, 1953). Moreover, those steam trawlers that were employed on War Service during WWI had often been the largest and most modern vessels then available; hence, during the inter-war years a relatively large proportion of old vessels was employed in fishing. This was also generally a period of stagnation or decline for many trawling ports (e.g. Boston, having lost half its trawlers during WWI, ceased to exist as a major trawling port in the 1920s), and only the distant-water trawl fisheries (especially Hull) expanded markedly in those years (Robinson, 2000b). Finally, one of the assumptions in these fishing power calculations, the consistency of the fishing power of the base fleet of sailing trawlers, may have been compromised to some extent. First, there might have been some efficiency increase, for example if only the most successful sailing trawlers remained in the declining fleet while less successful ones were decommissioned; second, vessels might have altered their species-targeting strategies; third, owing to the strong decrease in the total number of sailing trawlers over those years, the remaining vessels in this fleet may well have benefited from better catch rates through the concurrent release of competitive interactions with other sailing trawlers (cf. Rijnsdorp *et al.*, 2000).

The overall pattern, however, suggests that at least within the southern North Sea, the fishing power of steam trawlers changed very little between the pre-WWI and inter-war years. Nevertheless, it is likely that the northern North Sea witnessed a more robust increase in the fishing power of steam trawlers (cf. Wimpenny, 1953).

ERA 3 – 1950s AND 1960s: STEAM GIVING WAY TO DIESEL

I consider it again likely that from 1930 to the early 1950s, there was little change in the average fishing power of British steam trawlers fishing the North Sea. In particular, the fleet of the 1950s was mostly old: as late as 1952 no fewer than 637 vessels of the British near- and middle-water fleet[a] of 817 vessels >70 feet long had been built before 1921 (Robinson, 1996). This resulted partly from under-investment in near-water fisheries during the difficult inter-war years (Robinson, 1996, 2000b), and partly from the fact that as in WWI, those trawlers requisitioned by the Navy to serve in WWII as minesweepers were usually the larger and newer ones of the fishing fleet. During warfare many of those vessels were lost, often with their crews. Then, after the war, surviving Admiralty trawlers were only gradually released from naval service. Finally, large new steam trawlers built immediately after WWII were mainly destined to fish the distant grounds, so older vessels dominated the steam trawl fleet working the North Sea.

Nevertheless, a number of important changes did take place in steam trawlers during the decades post-WWII. Originally, all steam trawlers burned coal, but in 1946 the first oil-fired steam trawlers were introduced. Still driven by steam, those vessels replaced coal with a fuel much easier and cleaner to handle, less bulky and at the time still relatively cheap. Soon thereafter, all new steam trawlers were built as oil burners, and many old coal burners were converted (King and Pulfrey, 1991; Robinson, 2000b). Generally, though, oil-fired steam trawlers had a short life-span because of competition with a segment of the trawling fleet that, although it had already existed before the war, now underwent rapid technological innovations – motor trawlers.

The internal combustion engine had already been used in trawl fisheries before WWI, mainly in Devon and Cornwall; the English fleet in 1912, the first year for which data are available, included six motor trawlers. England's motor-trawl fleet remained small throughout the inter-war years and, within the North Sea, was limited to some 30–40 vessels active in the southernmost and westernmost parts (there was more extensive motor trawling in the English Channel; Engelhard, 2005). Early motor trawlers were often converted sailing craft with a small petrol or paraffin combustion engine, so were about equal in average tonnage. During the period 1924–1932, the fishing power of motor trawlers, in terms of cod or plaice caught per hour fished, appears to have been about 1.2–2.0 times that of contemporary sailing trawlers (Figure 4). In addition to better catch rates attributable to motive power, motor trawlers shared the advantage of steam trawlers of being able to move quickly to and from the fishing grounds, although they could not operate as far from port as steam trawlers. A significant issue in early years, especially with large trawls, was that it proved particularly problematic to adapt the

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[a] *In British fisheries statistics, "Near and Middle Waters" comprise the North Sea, Irish Sea, English Channel and Bristol Channel, and waters adjacent to the Faroes, Rockall, the West of Scotland and Ireland. "Distant Waters" include, historically most importantly, Iceland, the Barents Sea and waters adjacent to Bear Island, Spitzbergen, Norway, Greenland, Labrador, Newfoundland and Portugal.*

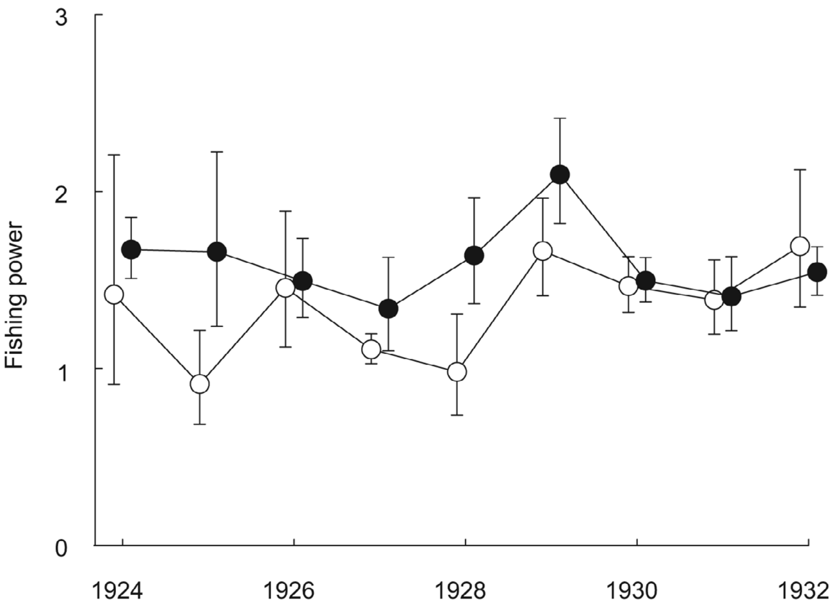

Figure 4. Relative fishing power of early motor trawlers compared with sailing beam trawlers in the southern North Sea during the period 1924–1932, when catching cod (open symbols) and plaice (closed symbols). Fishing power is defined as the ratio between motor and sailing trawler cpue for the same year and within the same rectangle. For each year, symbols indicate the geometric means (with standard error) across rectangles. Data from Defra Statistical Charts (reviewed in Engelhard, 2005).

internal combustion engine to hauling the fishing gear, because the engine could not withstand the sudden, irregular strains in the gear that are typical at sea. Hence, hauling still had to be done either by hand, which was slow and laborious, or by an auxiliary steam engine or capstan (Board of Agriculture and Fisheries, 1914). With this major setback, the development of motor trawlers lagged behind that of steam trawlers for many years, and motor trawlers remained small in average size.

The size of the British motor trawl fleet was fairly stable throughout the inter-war years, but it increased rapidly in the three decades following WWII. This was, most importantly, attributable to the introduction of marine diesel engines from the late 1940s, and the subsequent construction of larger purpose-built, diesel-driven motor trawlers. Compared with steam engines, diesel engines were more efficient and compact, allowing significant savings on both fuel use and space. Diesel engines were, however, initially more expensive to install, and driving the trawling and steering gear still required auxiliary systems (Robinson, 2000b). The first diesel-electric trawlers, with engines capable of driving both propulsion and auxiliary systems, appeared during the 1950s. The various technical innovations led to the motor trawl fleet gradually replacing the steam trawl fleet, operating in an increasingly large part of the North Sea as well as in distant waters (Engelhard, 2005).

Several fisheries scientists, including Beverton and Holt (1957a) and Gulland (1956) working simultaneously in Lowestoft, compared the fishing power of steam and motor trawlers in the North Sea. Beverton and Holt (1957a) reported that in the southern North Sea during the years 1946 and 1947, fishing power calculated from total demersal cpue was approximately proportional to gross tonnage in both steam and motor trawlers. They found moreover that in motor trawlers, fishing power per ton of vessel was greater than that of steam trawlers by a factor of 1.4. A similar factor was found by Gulland (1956) for Lowestoft steam and motor trawlers in 1951: ton for ton, motor trawlers were 1.32 times as powerful (again in terms of the cpue of total demersal fish). However, Gulland found that Beverton and Holt's proportionality assumption of fishing power to tonnage only held true for steam trawlers >150 ton gross, whereas smaller steam trawlers, ton for ton, tended to have greater fishing power. Therefore, the above factors somewhat overstated the catching power of the, typically, much smaller motor trawlers. For example, at 95 ton (the size of the smallest steam trawler), the fishing power of motor trawlers was 1.12 × that of steam trawlers, whereas at 160 ton (the largest motor trawler then) this factor was 1.22. Interestingly, Gulland found no effect of the age of steam trawlers on their fishing power.

For the period 1957–1965 where steam and motor trawl catch and effort data by ICES rectangle are easily available for the North Sea (Engelhard, 2005), I compared the fishing power of motor trawlers with that of steam trawlers (Figure 5). Unlike Gulland (1956) and Beverton and Holt (1957a), I could not take into account vessel tonnage in these, or earlier, calculations owing to the lack of disaggregated tonnage data for individual vessels, although in those years the average tonnage of steam trawlers fishing in the North Sea was no less than 2–3 times that of motor trawlers (Figure 5a, based on a published aggregated average tonnage). Despite this limitation, fishing power in the two classes of vessels was about equal in terms of cod cpue (Figure 5b: note that relative cod fishing power of motor trawlers, here expressed in terms of 'steam trawler units', was generally close to unity for all years). In terms of plaice cpue, fishing power was generally better for motor trawlers (by a factor of 1–1.5), and it tended to become increasingly better over time. This is despite the marked size difference of vessels, and despite only the largest steam trawlers surviving into the mid-1960s. Overall this illustrates the particular usefulness of compact and powerful diesel engines at a time when the North Sea became increasingly intensively fished by a growing international fleet.

By 1960, the British motor trawl fleet had outgrown the steam trawl fleet both in total number of vessels and the total catch landed from the North Sea. Steam trawling thereafter declined ever more rapidly, and the last landings from the North Sea by steam-propelled vessels, fishing from Hull and Grimsby, were in 1976.

Within the motor trawl fleet, two major innovations were the introduction of the stern trawler, and that of onboard freezing facilities. The world's first purpose-built stern freezer trawler was the *Fairtry*, built in 1953 in Aberdeen to an Icelandic plan and thereafter mainly landing in Hull. As a stern trawler, it shot its net down a stern ramp at the rear of the ship, rather than over the side as had been the case in traditional, so-called side (or sidewinder) trawlers. The fully mechanized retrieval system did not only take away the need for manually hauling the net, so increasing safety, but also allowed for much larger nets to be used. Further, the net could be hauled and the catch processed while the vessel was steaming, in contrast to traditional side trawlers that had to lay still to haul the net (Robinson, 2000b). The ability to freeze the catch was especially advantageous in the distant-water fisheries, in which conventional vessels only iced rather than froze

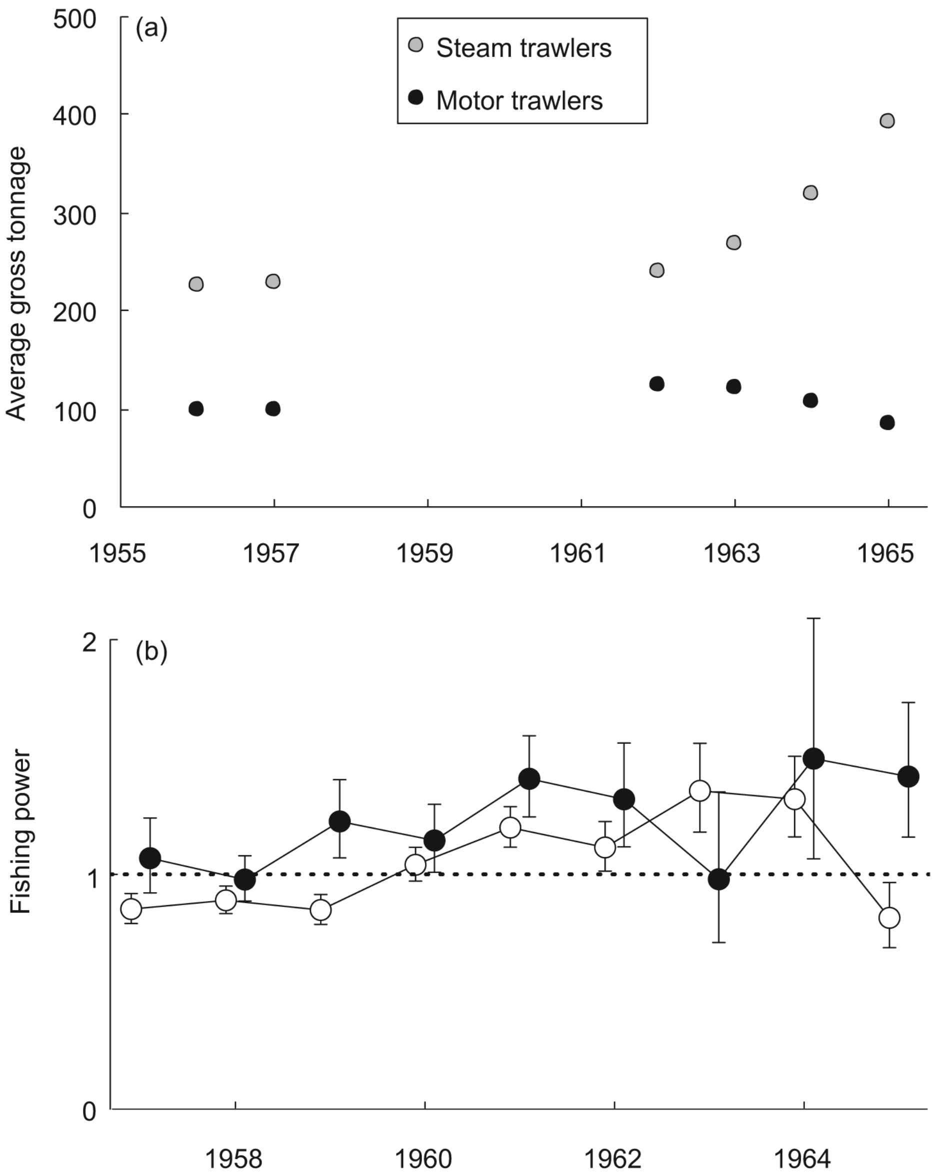

Figure 5. (a) Average gross tonnage per voyage of steam trawlers (grey) and motor trawlers (black) in the North Sea during the period 1956–1965 (where data were available). (b) Relative fishing power of motor trawlers, in comparison with steam trawlers, in the North Sea, when catching cod (open symbols) and plaice (closed symbols). Symbols indicate geometric means and standard errors. Note the approximately similar fishing power of steam and motor trawlers despite substantial differences in the average size of vessels. Data in (a) are taken from ICES Bulletins Statistiques, and in (b) from Defra Statistical Charts (reviewed in Engelhard, 2005).

their catch, so that the total duration of a fishing trip was restricted to about three weeks before deterioration would set in. The *Fairtry* could stay out for 70 days, although it usually returned from the Grand Banks within 40 days (Robinson, 2000b). However, stern trawling and onboard freezing initially only developed in distant-water fisheries, without playing a prominent role in the North Sea. There, compact stern trawlers began fishing in the early 1960s, although hauling the gear was only partly mechanized in the early days and hence could require more time than in the case of a side trawler. In near-waters there was no direct need to freeze the catch, which actually fetched a better price if landed chilled. Ice taken onboard when the vessel left port would usually suffice for the fishing trip except during very warm weather, and it was only by the 1980s that vessels with controlled, refrigerated fish holds at around 0°C were in wide use in the North Sea (J. Deacon, pers. comm.).

ERA 4 – 1960s TO 1980s: RISE OF MODERN TWIN-BEAM TRAWLING

Although this chapter is mainly concerned with the fishing power of English trawlers, a major development that was principally outside British fisheries – the rise of modern twin-beam trawling – needs to be mentioned here because it is now so prominent in North Sea trawl fisheries (Jennings *et al*., 1999). Moreover, modern beam trawling is also considered to be one of the most invasive fishing methods, with a range of ecosystem consequences (Jennings and Kaiser, 1998; Callaway *et al*., 2002; Hiddink *et al*., 2006). With this fishing method, two large beam trawls are lowered mechanically, one from each side of the vessel. The mouth of each trawl is held open by a metal beam up to 12 m long, and several tons of tickler chains are usually rigged ahead of the ground rope to raise fish that may otherwise be passed over.

Introduced around 1961, the twin-beam trawl has been extensively used by the Netherlands and Belgium to catch plaice, sole and other species closely associated with the seafloor (Rijnsdorp and Millner, 1996). Sole played a particularly important role in the development of this fishery, and the recruitment of 2- and 3-year-old sole of the very strong year classes of 1958, 1963 and 1969 triggered waves of construction of new and increasingly powerful beam trawlers, and of upgrading existing vessels with stronger engines (de Veen, 1979). Ironically, by the time newly constructed vessels began fishing, strong year classes were often already past their peaks in biomass (de Veen, 1979). The average horsepower of Dutch trawlers rose from 194 in 1960 to 767 in 1975 (de Veen and Arena, 1975). Fishing power increased accordingly, following a power relationship according to Sichone and de Veen (1973). The trend has continued to the present, mean engine power rising from 1996 hp in 1990 to 2277 hp in 2003 (Rijnsdorp *et al*., 2006). Meanwhile, there is anecdotal evidence that beam trawler efficiency was also increased by the appropriate matching of propeller size to engine power rating, so improving pull and towing speed (de Boer, 1975; R. C. A. Bannister, pers. comm.). This included the introduction of ducted propellers (which are surrounded by a ring or nozzle), resulting in an increase in pull at the same engine power and tow speed, reportedly of about 12–18% compared with an unducted propeller (de Boer, 1975; de Boer and de Veen, 1975).

Tonnage and relative fishing power of Dutch beam trawlers and English motor trawlers in the southern North Sea from the 1960s to mid-1970s are compared in Figure 6. Fishing power was here calculated using the aggregate cpue for the entire division, so it does not account for rectangle effects as in earlier figures, and confidence limits could not be

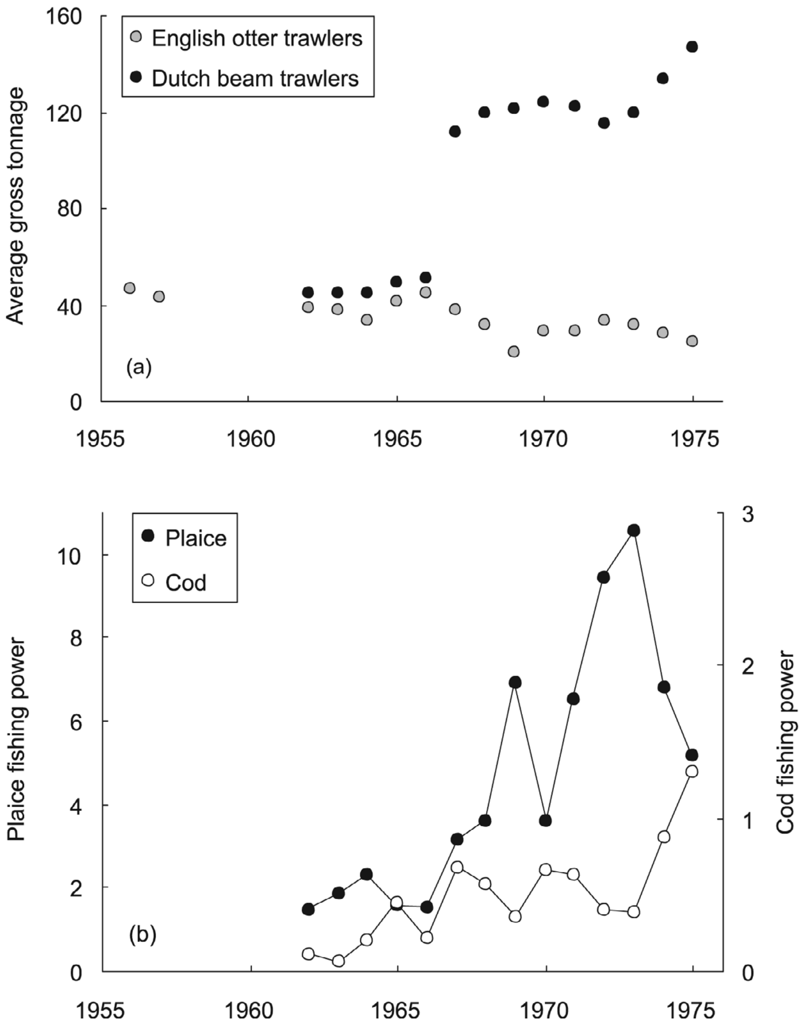

Figure 6. (a) Average gross tonnage per voyage of English otter trawlers (grey) and Dutch beam trawlers (black) fishing the southern North Sea (ICES Division IVc) during the period 1956–1975 (where data were available). (b) Relative fishing power of Dutch beam trawlers compared with that of English motor trawlers, in the same period and area, when catching cod (open symbols) and plaice (closed symbols). Note that the vertical axes for cod and plaice fishing power differ. Fishing power is here, unlike in the figures earlier where data by rectangle were available, expressed as the ratio between the aggregate Dutch and English cpue for the entire southern North Sea (based on ICES Bulletins Statistiques), so confidence limits could not be calculated. Cpue only includes the part of catches actually landed; some discarding of plaice and cod did, however, likely take place. Further, although the figures are likely biased by differences in catch and effort per rectangle between the two fleets, they are considered likely to illustrate the general trends.

estimated. Nevertheless, from 1962 to 1966, Dutch beamers seem to be about twice as efficient in catching plaice as English otter trawlers of similar size, although the former performed less well (by a factor 0.2) at catching cod. Following the Dutch construction wave of the mid-1960s, there was a marked increase in mean tonnage (and engine power) in this fleet, but relative consistency in those English otter trawlers fishing in the southern North Sea. Relative fishing power of Dutch beamers compared with English otter trawlers therefore increased rapidly, and around the mid-1970s was 5–10 times greater for plaice fishing. Even though the otter trawlers generally remained more efficient at catching cod, beam trawl efficiency for cod did increase, and by 1975 was about equal to that of otter trawlers. It should be borne in mind that Dutch beam trawlers relied most heavily on sole catches in the southern North Sea, with plaice and cod being merely important additional species (de Veen, 1979); to some extent, the discarding of especially plaice may have confounded the fishing power estimates based on landings only. Moreover, the southern North Sea was no longer a major fishing ground for British trawl fisheries in those years (Bannister, 1978).

Somewhat surprisingly, it was not until the 1980s that beam trawling was introduced to English North Sea trawl fisheries. A combination of factors may have played a role in this elapse of about two decades. Up to the mid-1970s, British trawl fisheries still relied heavily upon the distant grounds, and within the North Sea on roundfish species (partly related to the "fish and chips" market) that are optimally fished with an otter trawl. Nevertheless, the English plaice fishery was locally important to ports such as Lowestoft, although by that time the English fleet had largely left, and become unfamiliar with, the southern and southeastern parts of the North Sea, where the Dutch and Belgians were so successful in beam trawling for sole and small to medium-sized plaice. Rather, the English plaice fishery was distributed over a wide belt in the central, central-eastern and northern North Sea (Bannister, 1978). This is to the north and northwest of the main sole grounds, but medium to large plaice are more abundant there, and were targeted for the English plaice market by the motorized side otter trawlers that made up the English fleet in the 1960s. Although the total number of vessels declined, this was probably offset, especially at Lowestoft, by increases in engine power, the use of heavy gear with synthetic nets and chains, and more targeted fishing by means of precision Decca-fixing (Bannister, 1978). In Lowestoft, the average horsepower of otter trawlers changed from 328 in 1960 to 831 in 1975, and this appears to have coincided with a three- to fourfold increase in their fishing power for plaice (Bannister and Vince, 1976). The lag of about two decades before English beam trawling commenced therefore appears to relate to differences between the Dutch and the English fishing fleets in the main flatfish fishing grounds and species targeted, as well as to continuous improvement in the efficiency of both English otter and Dutch beam trawlers, and also perhaps to such factors as home market demand, and the individuality of fishers and fishing companies (R. C. A. Bannister, pers. comm.).

This situation changed notably from the 1970s to the early 1980s. With the 1973/74 oil crisis and resultant high fuel prices, the trend towards stronger, increasingly powerful vessels was dampened, and many older vessels (especially side otter trawlers) left the fleet. Nevertheless, during the mid-1970s, powerful side and stern otter trawlers were still considered the way forward for English plaice fisheries, and several new vessels of both types were purchased for Lowestoft. Nevertheless, opinions changed with the second, 1979 oil crisis, when high fuel prices coincided with depressed quayside fish prices, and only modest catch rates for plaice. During the early 1980s the first beam trawlers to be registered at English east coast ports arrived in Lowestoft and Grimsby, at a time when the otter trawl fleets of those and other traditional trawling ports became more reduced than they had probably ever been since the end of WWII (Large and Bannister, 1986; R. C. A. Bannister, pers. comm.).

Since its introduction, modern beam trawling has not played the same, substantial role in British North Sea fisheries as it did for some other European countries. The number of hours fished in the North Sea by British beam trawlers landing in England and Wales increased from 9 528 in 1982 to a peak of 113 380 in 1993, but has since declined, to a level of just 1 317 in 2005 (Defra Fisheries Activity Database). The number of beam trawlers in Lowestoft was highest in the mid-1990s, but only seven remained by 2001, and the last was sold in 2004. It should be mentioned that several dozens of Dutch "flagship" beam trawlers, registered as British-owned and fishing against UK quota, are currently administered from Lowestoft and Grimsby (Pawson *et al*., 2002; Cotter *et al*., 2006).

ERA 5 – 1980s TO PRESENT: RECENT CHANGES IN FISHING POWER

To what extent has average fishing power of English trawlers in the North Sea further changed in the past few decades? For the period from the mid-1980s or 1990s to the present, several studies on fishing power changes are available for various European fleets fishing in the Northeast Atlantic (e.g. Gascuel *et al*., 1993; Millischer *et al*., 1999; Marchal *et al*., 2007), including the North Sea (Marchal *et al.*, 2002, 2003). Often, different methods have been used to calculate fishing power. For example, for the Brittany offshore trawling fleets fishing in the Celtic Sea and West of Scotland, Millischer *et al*. (1999) modelled fishing power based on VPA estimates of annual fishing mortality (F), and the total fishing effort by these fleets. For North Sea demersal fleets of four European countries, Marchal *et al*. (2002) compared three indices of fishing power. The first was based on the relationship between F and effort (as in Millischer *et al*., 1999); the second compared the cpue of a set of relatively unchanged reference or base vessels with the cpue for the fleet as a whole (akin to Beverton and Holt's [1957a] method); and the third index compared commercial cpue with abundance indices derived from external research surveys. Fishing power estimated by all three indices increased with engine power, particularly in relation to target species. The study suggested that in English otter and beam trawlers fishing for cod and plaice during the years 1989–1999, there was little increase in fishing power, except for beam trawlers fishing for plaice. Conversely, a different study for the period 1980–1998 suggested that in English otter trawlers, catchability-at-age for 2- to 4-year-old cod increased annually by between 9 and 15%, and plaice catchability in English beam trawlers increased annually by about 6–13% (Marchal *et al*., 2003). If it is assumed that trends in catchability mainly reflect changes in fishing power, these high levels of *annual* increases in catchability would suggest that, accumulated over a number of years, there were substantial changes in fishing power, of the order of magnitude of a doubling every 5–12 years. Note that these figures are only valid for the period examined – great caution is required when extrapolating any models on fishing power beyond the time-spans represented in the data (Bishop, 2006), given that fishing power may also stagnate or even decrease over time. A decrease in fishing power could result from a shift in fishing tactics away from a previously targeted species (Marchal *et al*., 2003).

From about the 1970s, analyses of fishing power changes can make use of the availability of several external survey indices of fish abundance in the North Sea, generally collected in a reasonably consistent way, against which commercial catch and effort data can be compared. Consistent survey data up to the 1960s are extremely limited, although a few valuable datasets do exist (Greenstreet and Hall, 1996). Current ongoing surveys in the North Sea include International Bottom Trawl Surveys (Heessen *et al*., 1997) and International Beam Trawl Surveys (Rogers *et al*., 1997), which commenced in the 1970s and 1980s, respectively.

By comparing commercial and survey cpue for the period 1982–2005, I examined changes in cod and plaice fishing power of British otter trawlers and beam trawlers fishing in the North Sea and landing in England and Wales. Relative fishing power was expressed as the ratio between commercial cpue (from Defra's Fisheries Activity Database; only August–September) and survey cpue (both in kg h^{-1}) collected during the summer English groundfish survey (EGFS). This is akin to the third index of fishing power in Marchal *et al*. (2002). The EGFS is carried out annually in August–September, and about half of all statistical rectangles in the North Sea are sampled for demersal fish using an otter trawl with a small-mesh codend. The survey protocol is standardized, but there was a change in gear from 1991 to 1992, when the Granton otter trawl previously in use was exchanged for a grande ouverture verticale (GOV) trawl. To account for the gear change, pre-1992 survey cpue was multiplied by the estimated correction factors of 1.64 for cod and 0.27 for plaice (Cotter, 2001).

Over this period, there were notable changes in the fishing effort expended by these fleets in the North Sea. As stated above, effort by English beam trawlers expanded from the early 1980s to a peak in the early 1990s, but plummeted in recent years. As a result, overlapping commercial and survey cpue data pre-1987 and post-2000 (for August–September) were so limited that the analysis was restricted to the years 1987–2000. English otter trawlers have shown a dramatic reduction in hours fished in the North Sea, from 454 898 in 1982 to 90 676 in 2005. Owing to this and to the extremely low (and localized) cod abundance in recent years, matching commercial and survey cpue for cod became limited to only 4–7 rectangles from 1998 on, and estimates of cod fishing power from that year on may be unreliable.

Despite these shortcomings, one interesting finding (Figure 7a, c) was that in many years there was no large difference in cod or plaice cpue (both expressed in kg h^{-1} fished) between the commercial otter trawl fleet and the research survey (in agreement with Cotter *et al*., 2004), so the relative fishing power in terms of EGFS units is often reasonably close to unity. Admittedly, commercial cpue only includes the landed, and reported, part of the catch, whereas the EGFS, with a small mesh covering the codend of the trawl, also includes small fish below the minimum landing size. On the other hand, the survey design eliminates targeted fishing on high abundance patches, in contrast to commercial vessels. These results suggest that the groundfish survey cpue provides a realistic indication, of comparable magnitude, of the catch rates that commercial otter trawlers encounter. In contrast, the fishing power of beam trawlers for plaice was very many times higher (by a factor 20–80) than that of the survey (and unsurprisingly, lower for cod; Figure 7b, d). The former underlines the extreme efficiency with which the modern beam trawl fleet is capable of catching plaice.

Most notably, the figures are not indicative of clearly increasing trends in fishing power over the period examined. Rather, it appears that plaice fishing power in both beam and otter trawlers decreased markedly from 1982 to about 1995. This may not only relate to

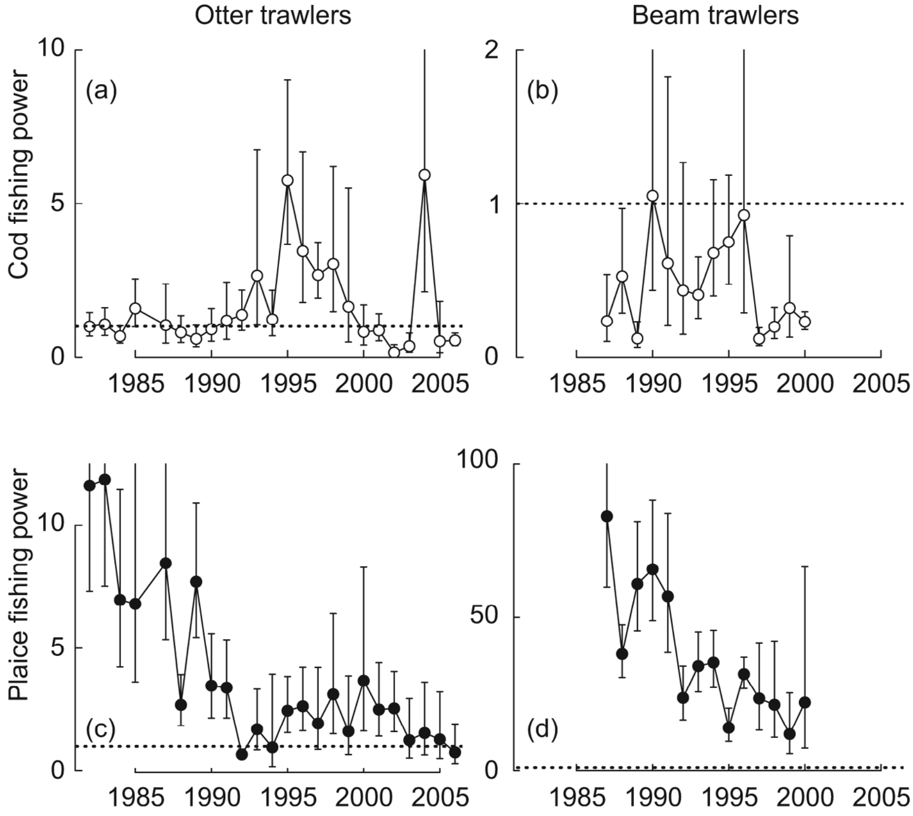

Figure 7. Relative fishing power of commercial otter trawlers (a, c) and beam trawlers (b, d) fishing the North Sea and landing in England and Wales, compared with the English Summer Groundfish Survey cpue for (a, b) cod and (c, d) plaice. Relative fishing power is expressed as the ratio between commercial and survey cpue (kg h^{-1}), matched by rectangle, year and month (excluding any cases where commercial cpue was based on <100 h fished). Symbols show, by year, the geometric means of fishing power (with the standard error) averaged over all rectangles where data were available. Note the differences in the scales of the vertical axes. Commercial data from Defra's Fisheries Activity Database (FAD); survey data collected by Cefas.

less targeted fishing for plaice in favour of other species (which could have resulted from the demise in Lowestoft's plaice-directed fishery), but also to increased discarding or high-grading of the catch. In the North Sea, both plaice and sole are caught by a mixed flatfish fishery, but the former have been, and are being, discarded at sea at increasing levels, to allow higher and more profitable landings of the latter, higher-valued species (ICES, 2006). A reduction in fishing power can also result from restrictions imposed on the fishery through management constraints (Gillis *et al*., 1995a, b). For example, the apparent decrease in cod fishing power of otter trawlers since about 1995 may well have resulted from strict quota regulations, combined with a switch of the northern English trawl fisheries towards Norway lobster (*Nephrops norvegicus*) and away from traditional roundfish species (Pawson *et al*., 2002; Cotter *et al*., 2006).

The figures mentioned above rely heavily upon the assumption of consistency of survey index. In the case of the EGFS, the change in trawl gear from 1991 to 1992 is of note and has required the application of catchability correction factors (Cotter, 2001), whereas the survey vessel has changed twice. As well as such stepwise, and perhaps quantifiable, changes, there may also exist a survey creep, whereby over the lifetime of a survey, slight modifications of the gear may accumulate, and both crew and scientists may gradually improve their knowledge of the sampling stations, gear used, identification skills and work routine, and so unwittingly change the catchability (ICES, 2005; A. J. R. Cotter and B. Harley, pers. comm.). Survey creep would result in an increase in survey catchability over time, and Marchal *et al*. (2003) reported an increase in saithe (*Pollachius virens*) catchability (although not cod or plaice) by the EGFS during the period 1990–1998. If survey creep is a reality, it would confound the commercial fishing power estimates (leading to underestimates for more recent years), but it has not been possible to investigate this issue further.

CONCLUSIONS

The aim of this paper was to compile the major changes in fishing power measured in the different eras in order to obtain a reasonable estimate of the total change in fishing power that may have taken place since the late 1800s. The rather diverse pieces of information on fishing power described above are collated in Table 1 where, inspired by Garstang's (1900) landmark paper, these are referred back to his original "sailing smack unit". I emphasize that the exercise has considerable uncertainty especially after 1946 when sailing trawlers simply left the stage, and Bishop (2006) comments on some of the issues when interpreting long-term trends in fishing power. However, although caution is required in interpreting the estimates, I consider that the table broadly illustrates the overall magnitude of change.

The most significant, single leap in fishing power was probably that of 120 years ago when steam trawling was introduced, leading to an increase in its very first year by a factor 4.6 (cod) or 2.6 (plaice; Garstang, 1900) compared with sailing trawlers. Rapid improvements in steam trawler technology followed and, by the 1930s, their fishing power had become equivalent to 10–25 (cod) or 4–5 (plaice) smack units (Table 1). However, the most significant increase had already occurred before WWI, so Alward (1911) rightly characterized the steam trawler of his time as "a machine for catching fish such as never existed before". Probably because of both World Wars and the Depression, this was followed by a stagnation in fishing power of English steam trawlers fishing in the North Sea, which apparently lasted throughout the inter-war and immediate post-WWII years, so that by about 1950, steam trawl fishing power may still have been close to what it was in 1930 (though there was significant change in fishing power in distant-water steam trawlers).

Although the change from sail to steam was massive, the replacement of steam by motor otter trawlers in the 1950s and 1960s incurred a far more subtle change in fishing power. Large steam trawlers were now being outfished by, on average, far smaller motor trawlers that nevertheless had roughly the same, or marginally higher, fishing power. Hence, by 1965, the fishing power of typical motor trawlers may have been comparable with that of the larger steam trawlers of the 1930s, i.e. about 20 (cod) or 7.5 (plaice)

Table 1. Synopsis of 120 years of change in fishing power in British North Sea trawlers. For the various trawling fleets that were prominent during different periods, relative cod and plaice fishing power is compared with that of the original sailing beam trawler, and hence expressed in terms of Garstang's (1900) smack units. The pre-WWII figures are based on direct comparisons with sailing trawlers, but those for more recent years have been established indirectly and are considerably less reliable. The main assumptions are that: (i) fishing power in sailing trawlers stayed constant between the 1880s and 1930s; (ii) there was no appreciable change in fishing power of steam trawlers between 1924–1932 and 1957 (this is likely to be true up to about 1950, see text, but perhaps not so thereafter); (iii) the increase in cod fishing power of motor otter trawlers from 1965 to 1979 was proportional to the increase in engine power; (iv) there was no appreciable change in fishing power of motor otter trawlers between 1975–1979 and 1982, the first year where their fishing power could be calibrated against that of the English summer groundfish survey; and (v) fishing power in the English summer groundfish survey remained constant.

Period	Fleet	Estimated fishing power, converted to smack units		Comments
		Cod	Plaice	
19th century				
1880s–1890s	Sailing beam trawlers	1	1	Fishing methods unchanged since ~1880 (Garstang, 1900)
1883–1885	Steam beam trawlers	4.6	2.6	Garstang (1900)
1898	Steam otter trawlers	12.8	6.6	Garstang (1900)
1900 to WWI				
1900–1914	Sailing beam trawlers	1	1	Assuming no change in fishing power
1906–1914	Steam otter trawlers	~10–15	~4–5	This study (Figure 3)
Inter-war years				
1924–1932	Sailing beam trawlers	1	1	Assuming no change in fishing power
1924–1932	Steam otter trawlers	~10–25	~4–5	This study (Figure 3)
1924–1932	Early motor trawlers	~1–2	~1.5–2	This study (Figure 4)
1950s–1970s				
1957–1965	Steam otter trawlers	~20	~5	Conservative assumption of no change since 1930s
1957–1965	Motor otter trawlers	~20	~5–7.5	This study (Figure 5), and assuming no change in steam trawlers since 1930s
1975	Motor otter trawlers	~50	~22	Cod: very approximate, based on ratio of mean engine power 1965 (328 hp) and 1975 (831 hp); plaice: ~3 times the 1965 plaice fishing power in Lowestoft (Bannister and Vince, 1976)

Table 1. continued

Period	Fleet	Estimated fishing power, converted to smack units		Comments
		Cod	Plaice	
1950s–1970s continued				
1979	Motor otter trawlers	~50	~23	Cod: very approximate, based on ratio of mean engine power 1965 (328 hp) and 1979 (878 hp); plaice: ~1.03 times 1975 plaice fishing power (Large and Bannister, 1986)
1980s–2000s				
1982	Motor otter trawlers	~50	~23	Conservative assumption of no change since 1979
1982–2006	Summer English Groundfish Survey	~50	~4	Comparing EGFS results with commercial otter trawlers (Figures 7a, c) for 1980s. Cod, about equal fishing power; plaice, survey about one-sixth of commercial fishing power
1986	Twin-beam trawlers	~10	200	Comparing with EGFS, assuming no change in survey fishing power (Figures 7b, d); cod, about 20% of survey; plaice, about 50 times higher than survey
2000	Twin-beam trawlers	~10	100	Comparing with EGFS, assuming no change in survey fishing power (Figures 7b, d); cod, about 20% of survey; plaice, about 25 times higher than survey
2005	Motor otter trawlers	~50	~4	Comparing with EGFS, assuming no change in survey fishing power (Figures 7a, c); cod and plaice fishing power appear roughly equal in survey and commercial otter trawlers

smack units (Table 1), even though these estimates rely on the conservative assumption that there was no change in steam trawl fishing power, which may not be true after about 1950. With the newly developing motor trawl fleet now dominating North Sea otter trawl fisheries, the creep in fishing power that had halted for some decades again gained momentum. Bannister and Vince (1976) reported that Lowestoft motor otter trawlers tripled their plaice fishing power from 1965 to 1975, and Large and Bannister (1986) reported a more marginal increase in the following few years. This brings my estimate of motor trawl plaice fishing power in 1979 to about 23 smack units (Table 1). Unfortunately, similar data on cod are not available, so post-1965 estimates of cod fishing power incur much uncertainty. However, assuming that from 1957 to 1979 cod fishing power increased in proportion to engine power, cod fishing power was estimated to have increased from 20 to 50 smack units over those years (Table 1).

Between the 1980s and 2000s there was again some stagnation, or at least a lesser rate of increase, in the average fishing power of the English otter trawl fleet fishing the North Sea. This is suggested by the comparison between commercial cpue and the summer EGFS cpue, under the assumption that survey catchability remained constant (Figure 7; see also Marchal *et al*., 2003). Average cod fishing power in otter trawlers peaked from

1995 to 1998, but it has now returned to the level assessed for the years 1982–1994, and therefore might well be close to the estimated 1979 level of 50 smack units (Table 1). By contrast, the average plaice fishing power in otter trawlers appears to have decreased markedly between 1982 and 1992, and may now be as low as 4 smack units, a decrease that very likely relates to the demise of Lowestoft's plaice-directed otter trawl fleet. In contrast, twin-beam trawlers have now taken over the plaice fisheries. Indeed, the modern twin-beam trawler is, according to these calculations, characterized by an exceptionally high fishing power for plaice, about 200 and 100 original sailing smack units in 1986 and 2000, respectively (the less impressive figure for 2000 likely relating more to increased discard rates than to an actual decrease in catching power).

One interesting question that does arise, in view of current concerns about overcapacity in fishing fleets, is: do the major increases in fishing power scale up to similar increases in catch rates? A comparison of historical and contemporary cpue data for trawlers, fishing for plaice at the same grounds in the southern North Sea (Table 2), indicates that it does not. During April–December of the years 1903–1906, three Lowestoft sailing trawlers on average caught 1.09 cwt of plaice per 6 h fishing (Lee, 1915), which translates to 9.23 kg h^{-1}; from 1924 to 1927 the annual catch rates for the entire sailing trawl fleet in the southern North Sea averaged 5.50 kg h^{-1}. On the same grounds, the modern twin-beam trawl fleet during the period 1999–2001 caught an annual average of 29.19 kg h^{-1}, implying that despite an estimated 100 times greater fishing power, they caught only about 3 and 5 times more per hour than sailing trawlers of the 1900s and 1920s, respectively (Table 2). Modern otter trawlers fare even worse in the estimates of plaice capture (although admittedly their targeted plaice fishing in the southern North Sea is limited), catch rates in the years 1999–2001 (2.79 kg h^{-1}) being decidedly lower than those of historical sailing trawlers. This value should be compared with the plaice cpue of a steam-powered otter trawler of the 1920s (14.25 kg h^{-1}).

Table 2. Historical and contemporary English trawlers fishing approximately the same grounds in the southern North Sea (ICES Division IVc): comparison of cpue (kg h^{-1}), relative cpue (base: sailing trawlers during the period 1924–1927) and relative fishing power (in smack units, compare with Table 1). Note that changes in cpue do not scale up to improvements in fishing power. Cpue was calculated as the grand mean of annual averages by rectangle (excluding cases where effort was <100 h), except for the years 1903–1906 where only April–December data were included. Data for the period 1903–1906 from Lee (1915); for 1924–1927 from Defra Statistical Charts (Engelhard, 2005); for 1999–2001 from FAD.

Period	Fleet	Plaice cpue	Relative cpue	Fishing power
1903–1906	Sailing beam trawlers	9.73	1.77	1
1924–1927	Sailing beam trawlers	5.50	1	1
1924–1927	Steam otter trawlers	14.25	2.59	3–4
1999–2001	Twin-beam trawlers	29.19	5.31	100
1999–2001	Motor otter trawlers	2.79	0.51	4

Differences in cpue relate to both fishing power and stock abundance. Paradoxically, the North Sea plaice stock was considered to be *depressed* during the inter-war years, a state ascribed to overfishing (Beverton and Holt, 1957b), and was then probably at a low level similar to that around the turn of the 21st century (Rijnsdorp and Millner, 1996; ICES, 2006). Clearly, the discrepancies in trends in plaice stock abundance, commercial cpue and fishing power are in accord with the current view that the international North Sea trawling fleet has marked overcapacity. Given the limited nature of marine living resources, this leads me to conclude that a much reduced international fleet would be capable of catching the same quantities of fish.

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