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The development of the northern European fishery for north Atlantic bluefin tuna *Thunnus thynnus* during 1900-1950

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Abstract:

North Atlantic bluefin tuna, *Thunnus thynnus*, used to migrate to northern European waters (Norwegian Sea, North Sea, Skagerrak, Kattegat, and Øresund) where it supported important commercial and sport fisheries. The species disappeared from the region in the early 1960s and the species is now still extremely rare. The factors which led to the development of the fishery and its subsequent decline remain unclear and poorly documented. This investigation documents the development of the fishery in terms of landings, effort, and gears with focus on the time period from 1900-1950 when landings were increasing. The species was frequently sighted while fishermen were targeting other species (herring, mackerel) and occasionally was caught as bycatch with these and other species. Information from scientifically trained observers demonstrate that tuna schools were common in the North Sea for 2-3 months during the summers of 1923-31. As fishermen realized that the species had market value, new catch methods were developed and employed. These included harpoon-rifle, improved hook and line methods, and hydraulically operated purse seines. Landings rose sharply as did the number of vessels and the capacity of processing facilities for bluefin tuna. Bluefin tuna in this area were generally medium-large (> 50 kg whole weight). The most important countries which participated in bluefin tuna fisheries in this period were Norway, Denmark and Sweden, but bluefin tuna were also exploited by France, Germany, the Netherlands and the United Kingdom. Similarly sportfishing increased in popularity in some of these countries and attracted many foreign participants. The increase in landings between 1900-1950 was driven particularly by an increase in fishing effort and technology. We found no evidence that the increase was due to a temperature-related shift in habitat into the region. Our results demonstrate that the species was an important part of the ecosystem at least back to the early 1900s and that commercial and recreational fisheries were well established in northern European waters before official ICCAT records.

Keywords: bluefin tuna, *Thunnus thynnus*, fishery, North Sea, Norwegian Sea, temperature

Introduction:

High exploitation rates cause many changes in fish populations and marine ecosystems (Pauly et al., 1998; Jackson et al., 2001; Pikitch et al., 2004). The changes include extinctions of local populations of the targeted species, losses of geographical range, changes in size, age and genetic composition of targeted populations, and modifications of trophic pathways and ecosystem functioning. A prerequisite for the documentation of these changes is the availability of fishery and ecosystem data from different time periods which can be compared and interpreted. To provide sufficient contrast in the time series, the fishery-related data (e. g., landings, effort, gears used, mean sizes caught, habitats inhabit) should represent periods when exploitation rates were low and/or when exploitation was increasing, and the ecosystem data (e. g., temperatures, predator/prey abundances) should include a wide range of variability.

Most fishery and environmental data series have been collected only after the exploitation has been high (Jackson et al., 2001; Myers and Worm, 2003; Pikitch et al., 2004). For example, population biomass estimates commonly used for current fishery management decisions (e. g., quotas, closed areas) are based on analytical age or size-structured models and/or fisheries research surveys of species abundances which start only in the 1970s or later, even though the exploitation of the same populations may have started decades or centuries earlier. As a result, perceptions of population and species biology based on these estimates may misrepresent biomass levels and dynamics under scenarios of lower or no exploitation (Pauly et al., 1998; Lotze and Milewski, 2004). These observations suggest that knowledge of fishery and ecosystem dynamics during the early phases of exploitation and during periods when exploitation was much lower could be useful for understanding the causes of long-term fluctuations in population biology (Baumgartner et al., 1992; MacKenzie et al., 2002; Lotze and Milewski 2004).

One fishery for which such a description is presently lacking is the former fishery for northern bluefin tuna in waters of northern Europe (i. e., Norwegian Sea, North Sea, Skagerrak, Kattegat, and Øresund; Figure 1). This species supported a major commercial fishery during the 1940s-1960s but disappeared from the area in the mid-1960s-early 1970s (Tiews, 1978). Many key features of the early development of the fishery (e. g., landings, gears used) for this species have not been documented and quantified. The fishery was supported by annual migrations of bluefin tuna to the area for feeding on species such as herring and mackerel. (Tiews 1978; Cury et al. 1998). Bluefin tuna usually arrived in late June-July before departing again in the autumn (Mather et al., 1995; Fromentin and Powers, 2005). However the species has been extremely rare in the region during the last 20 years and abundances are now too low to support commercial or recreational fishing (Hareide et al., 2000; ICCAT, 2003; Fromentin and Powers 2005).

In this study, we examine the development of the fishery during the early decades of the 1900s. Our objectives are to quantify the total international landings by all countries in northern Europe during 1900-1950 and to describe the fishing fleets and gears used during this period. The synthesis uses published national and historical fishery information which is not presently compiled in the major fishery agencies of the northeast Atlantic (i. e., ICCAT, ICES) and which is not easily available in existing bluefin tuna fishery literature. We also use our data to conduct a preliminary analysis of the role of sea temperature on the development of the fishery.

Methods:

Assembly of fishery data:

Landings of bluefin tuna and descriptions of fishing gears and fleets were extracted from a variety of sources. The main source of landings data was the International Council for the Exploration of the Sea (ICES) which has been compiling fishery statistics in the northeast Atlantic since 1904. The data received and maintained by ICES are provided by individual countries and therefore represent official national statistics. The data provided by the countries are resolved by geographic area where catches were made (e. g, North Sea, Skagerrak).

However, ICES' data are available electronically only from 1972 onwards. Data prior to 1972 are available in annual ICES Statistical Bulletins. Data for the years 1927-1939 were entered manually from these bulletins. Prior to 1927, there are no bluefin tuna landings reported in the ICES Bulletins for the regions of interest by any country. Data from before 1927 were obtained from other sources, such as national fishery yearbooks, fishing industry newspapers or annual reports, and historical accounts based on fishermens' sales records (Svendsen, 1949; Pedersen, 1997; Tangen, 1999). Some catch data were available in published scientific literature. These sources which provided landings data sometimes provided information about the fishing gears used and how bluefin tuna were caught. This information is summarized below. The landings data and sources are described in the Results for each country participating in the fishery at this time (Denmark, France, Germany, Netherlands, Norway, Sweden, United Kingdom).

Fisheries landings data themselves are not necessarily indicative of the biomass of a population. Trends and variability in landings data can differ significantly from trends in biomass because of temporal changes in fishing effort, catchability, migration patterns and fishing technology. In addition, landings data assume reliable reporting; if landings are not reported or misreported (e. g., as a different species, or a different species is reported landed as bluefin tuna), then additional uncertainties and potential biases can occur. It is preferable therefore that analyses of trends in biomass or distribution of fish populations use either true biomass estimates (e. g., as derived from analytical models and calibrated with fishery-independent data such as a research survey), or an effort-standardized landings index (i. e., catch per unit of fishing effort).

For the period of consideration in this study, neither of these options are available. Biomass data only start in 1970 (ICCAT 2003). Effort data (e. g., number of fishers, nets, boats, etc.) during 1900-1950 are either non-existent, unreliable or uncomparable because the fishery at this time was not regulated and the technology to catch bluefin tuna was only starting to be developed (see below for details). In addition, fishers participated in this fishery initially on a part-time basis (e. g., seasonally, between sets of gears for other species), and gears and boats were used for multiple species. The allocation of effort-related resources between species cannot be quantified due to lack of data. As time progressed, the share of full-time bluefin tuna fishermen and dedicated gears is believed to have increased at an unknown rate (Hamre, 1958; Meyer-Waarden, 1959), which further complicates effort to quantify fishing effort. Lastly, fishers increased their skill catching bluefin tuna as time progressed but this is another process which cannot be quantified for this time period.

As a consequence of these limitations, the landings data must be interpreted with caution. In this study they are used in the following ways:

1) the landings are evidence that the species was present in a given area at the given time.
2) the documented presence of only a small number of individuals (even only one) is likely also evidence that many more individuals were present but not caught or seen. This assumption is based on the fact that bluefin tuna are primarily a schooling species (Mather et al., 1995; Block and Stevens, 2001).
3) reports of no landings is not sufficient evidence to document that the species was absent. A year with no landings only means that no bluefin tuna were reported as being caught. This situation could occur if indeed there were no catches, or if there were catches, but fishers did not report the landings (e. g., possibly as bycatch for other species) to authorities. This situation is likely more common in the early years of the 1900s (than after 1930s) because the fishery was not well developed (i. e., little demand or processing capacity) and when official catch monitoring was less comprehensive. The no-catch situation could arise if fishers attempted unsuccessfully to catch bluefin tuna, or if there were no directed bluefin tuna fishing effort (e. g., due to insufficient demand).

These characteristics of the available data limit the scope for quantitative and statistical analysis. However the main objective of this study is only to document with certainty those years when the species was present in northern European waters. The application of landings data for documenting species presence is acceptable for describing long-term changes in species and population dynamics (such as species extinctions or losses of local populations), and how these changes are influenced by human activity (Jackson et al., 2001; Pitcher, 2001; Lotze and Milewski 2004).

Temperature data:

Bluefin tuna are a highly migratory species whose distribution partly depends on temperature (Mather et al., 1995; Fromentin and Powers 2005). In northern Europe, the species is (was) rarely seen outside the months of June-October, which suggests that the seasonal immigration and presence may be temperature-dependent. We compared the presence of bluefin tuna in two areas with local summer sea surface temperatures. The areas are the Norwegian Sea and North Sea, where most of the landings occurred (see below).

Temperature data from the Norwegian Sea (60^o – 65^o N; 0^o E – 10^o E) were obtained from the hydrographic database of the International Council for the Exploration of the Sea (ICES) for July and August. The minimum number of measurements used for estimating averages was set arbitrarily at 15 to reduce potential biases in averaging that could result from temporally and spatially heterogeneous sampling. Temperature data for the North Sea (51-58^o N; 2^o W – 9^o E) were obtained from the HADISST1 dataset maintained by the Hadley Centre for Climate Research (Rayner et al., 2003); a summer average (July, August, September) was calculated using these data. The Hadley Centre dataset is spatially – and temporally interpolated so that all months are represented. We used the temperature data from these two areas to investigate whether bluefin tuna were present in both warm and cold years (i. e., years above and below average). A full interpretation of temperature variability in the area during the last 120 years and based on these data is available elsewhere (MacKenzie and Schiedek, 2007).

Other environmental variables (e. g., atmospheric pressure difference anomalies during summer, wind conditions, North Atlantic Oscillation, zooplankton abundance in the northeast Atlantic; (Rodewald, 1960; Jensen, 1965; Jensen, 1966; Rodewald, 1967; Marsac, 1999)) have also been hypothesized to affect bluefin tuna presence and abundance in northern European waters. These hypotheses, as well as those involving temperature, deserve further study and should include the post-1950 period when landings peaked and subsequently collapsed in this region.

Results and Discussion:

Denmark:

Scattered records of bluefin tuna presence in Danish waters are available from the early 1900s and earlier (Figure 2). The reports are based on fishermen’s bycatches, sightings of schools or individual bluefin tuna swimming at the surface or sometimes jumping above the water surface while chasing prey, and on observations of dead specimens on beaches (Svendsen, 1932; Svendsen, 1949). Because the species was large and rarely captured, these sightings and appearances generated much interest, and captured specimens were often delivered to biologists for identification. Blegvad (1946) reports that there were “unusually many” during 1915-1919. During the mid-late 1800s and early 1900s, garfish (*Belone belone*) fishermen relied on bluefin tuna prey search behaviour to assist with capture of garfish in the Øresund near Helsingør (Mikkelsen, 1986). In autumn when garfish were emigrating from the Baltic through the Øresund, they would be pursued by bluefin tuna towards shore where fishermen would set nets. This fishery became known in Denmark as the “Castle fishery” (Danish: Slottefiskeriet) because it took place in the waters outside Kronborg castle at Helsingør (Mikkelsen, 1986).

In 1919 a bluefin tuna was caught by hook and line by a Danish fisherman (P. Wilhelm Madsen) in the Kattegat, reportedly for the first time (Eli, 1974). Madsen also states that there were 100s of bluefin tuna present that year. Seven more bluefin tuna were caught as bycatch in nearshore herring traps at Skagen, Denmark in 1921 (Pedersen 1997). Further bycatches in these traps were reported in the 1920s and the increasing catches stimulated efforts to develop processing facilities. By 1929, the catches at Skagen were large enough (Figure 2) to motivate construction of the first tuna cannery in Denmark, and within 10 years, three more tuna canneries were built (Pedersen 1997). Bluefin tuna continued to be captured incidentally and intentionally in the 1930s in this area (Pedersen 1997). Landings by commercial vessels also increased (Figure 3) as fishermen began targeting the species and learning the skills to capture it (Svendsen, 1949; Jensen 1965). The size of the bluefin tuna captured in coastal herring traps was generally 50-100 kg (Svendsen, 1949; Pedersen 1997).

Coincident with these developments in the commercial fishery, sportfishermen were also catching bluefin tuna in Danish waters. A Danish sportfishery existed for bluefin tuna near Sjællands Odde, Sjælland, Denmark in the 1920s (Svendsen, 1949; Jensen 1966), although complete annual landings data for this fishery are not available. The landings were relatively low (maximum 100 in both 1926 and 1927), but indicate that the species was present

(Svendsen, 1932). In 1928, one sportfisherman caught 62 bluefin tuna near the Danish island of Anholt (Kattegat) and several more in 1929 (Svendsen, 1932). The appearance of bluefin tuna in Danish waters stimulated English bluefin tuna sport fishermen to visit Denmark and participate in this fishery in 1928 and 1929 (Svendsen, 1949). Additional sportfishing for bluefin tuna occurred in the Øresund and north of Sjælland (Svendsen, 1949; Mather et al., 1995).

Both the commercial and sportfisheries developed in the subsequent decades (Blegvad, 1946; Pedersen 1997). By 1937, Denmark was reporting its official landings to ICES and the species was also being caught using hooks and lines, and rod-reels. In 1949, the Copenhagen bluefin tuna sportfishing community together with a local newspaper (Berlingske Tidende) established the Scandinavian Tuna Club (Svendsen, 1949). This club, which still exists (www.tunaclub.dk), arranged bluefin tuna fishing tournaments every year in the Øresund until the early 1960s (Ekstrøm, 2003) when the species disappeared from the Kattegat and Øresund. Originally the top award was given to the participant catching the largest bluefin tuna in the Øresund; now that bluefin tuna are no longer present, the award is given to the participant catching the largest fish anywhere in the world (Ekstrøm 2003).

France:

The French fishery for bluefin tuna in the North Sea in the early 1900s was based on vessels whose home port was Boulogne (Heldt, 1923; Le Gall, 1927). According to Heldt (1923), the first time a bluefin tuna was ever sold on the Boulogne fish market was in 1907. There is no information about quantities or sizes sold; presumably there was only a small number sold because the data do not appear in the annual government statistical reports (Stat. Pêches Maritimes de la Republique Française). In the following year (1908), one herring boat caught 14 bluefin tuna on a single fishing trip (Le Gall, 1929) and nearly 2 tonnes were reported in official statistics as being sold at Boulogne. Landings based on data for Boulogne from Stat. Pêches Maritimes de la Republique Française increased in the subsequent years (Heldt 1923) and exceeded 100 t by 1924 (Figure 2). The data before 1929 are not listed in the ICES Statistical Bulletins (Figure 3).

Bluefin tuna were initially captured as bycatch by herring fishermen fishing on Dogger Bank. However as it became clear to the fishermen that the species could be caught and sold profitably, they quickly developed fishing methods specifically to catch bluefin tuna (Le Gall 1927). Prior to that time, many fishermen had seen these fish but did not know how to capture them (Le Gall 1929). According to both Heldt (1923) and Le Gall (1927, 1929), the presence of bluefin tuna in the North Sea at that time was not a new phenomenon, although there had been no directed fishery for this species.

Germany:

Official German data in the ICES Statistical Bulletins show that German fishermen caught bluefin tuna in the North Sea in large numbers already in 1928 and during most years up to 1939 (Figure 3). Prior to 1928, information is scarce (Figure 2; (Meyer-Waarden 1959)). A photograph from 1910 (Figure 4) shows 11 bluefin tuna in the Altona (near Hamburg) fish auction hall (Brandenburg, 2003). Given their sizes, these tuna represent a catch of approximately 1 tonne. These landings are not recorded in official German landing statistics submitted to ICES (Figure 3). Duge (1925) states that a herring fishing boat caught 27 bluefin tuna in 1924 (ca. 2.7 t, assuming each tuna weighed 100 kg). During the First World

War, many bluefin tuna caught in the Skagerrak by Swedish fishermen were sold on the German fish markets (Duge, 1925; Thiel, 1938). One large bluefin tuna (2.7 m long) was found on the beach at Warnemuende (western Baltic) in 1903 (Schulze, 1903).

Netherlands:

Dutch fishermen caught bluefin tuna in the years following the Second World War (Figure 3). Official landings were 1-18 tonnes.

Norway:

The Norwegian bluefin tuna fishery started as a bycatch- and sportfishery in the late 1910s and early 1920s (Hamre 1958; Tangen, 1999). It eventually developed into the most important fishery in northern Europe (Mather et al., 1995; Fromentin and Powers 2005). The fishery began along the coast and in fjords of central-northern Norway (Haaland, 1923; Hanson, 1925; Sund, 1925; Hanson, 1927; Sømme, 1942; Hamre 1958; Mather et al., 1995; Tangen, 1999). As in other northern European areas, fishermen had frequently seen the species (e. g., while pursuing prey or as bycatch in fisheries for other species) in previous years but they were unable to capture it effectively using existing fishing gears. Tangen (1999) states that in 1921 fishermen complained that bluefin tuna destroyed herring nets in coastal waters. His historical account of the Norwegian bluefin tuna fishery shows that landings of bluefin tuna varied between 53 and 1200 individuals per year between 1922 and 1930 (Figure 2). These data are based on original fishermen’s and fish company sales and purchase records (Tangen, 1999). However the landings data up to 1927 do not represent the complete landings by all Norwegian fishermen in these years; for example, the 1926 value of 53 tuna was the catch made by a single fisherman (Tangen, 1999). Norwegian tuna landings data first appear in the ICES Statistical Bulletins from 1927 onwards (Figure 3).

The frequent occurrence of bluefin tuna in Norwegian waters during the late 1910s and early 1920s (Figure 2) stimulated Norwegian fishery authorities and the fishing industry to improve catch methods and processing facilities for bluefin tuna. Haaland (1923) describes fishing trials with a new harpoon-rifle (“harpungevær” in Norwegian) developed by Knut Krohnstad. This gear allowed the species to be caught in commercial quantities and Haaland (1923) wrote that “in the latest years, the species appears abundant and seems to be increasing from year to year”. One fisherman caught 20-30 bluefin tuna with this gear in 1923 (Haaland, 1924a). Other authors wrote that the development of efficient fishing gears was the key to the development of this fishery (Hanson 1925; Sund 1925) and that the species which “visits us annually represents substantial value”. Sund (1925) writes that “we know that sometimes bluefin tuna can be seen in the thousands, even 10s of thousands and very frequently in small schools.” These observations and attempts to improve catch technology already in 1923 indicate that the species must have been present in large numbers already several years earlier.

Norwegian fishermen were also experimenting with purse-seine methods to capture groups or small schools of bluefin tuna (Hanson 1925; Hamre 1958; Tangen, 1999). Because the fish were large and powerful, they frequently damaged nets and gears in the early attempts. As a result it took approximately 20 years to develop an operational purse-seine method for capturing bluefin tuna in Norwegian waters (Hamre 1958). The developments included mechanized winches and proved to be very successful.

Fishing effort in terms of number of purse seine vessels participating in the fishery was also increasing in this period (Hamre 1958; Hamre et al., 1966). In 1949 there were 43 boats participating, but in 1950 there were 200 (Hamre et al., 1966). When the methods and effort became fully developed, annual Norwegian catches grew to over 10,000 tonnes in the 1950s (Hamre et al., 1966). These high catches were the highest among all countries of northern Europe (Tiews 1978).

In addition to developing more effective catch methods and increasing overall catch capacity, the Norwegian fishing industry was expanding its expertise and volume for processing bluefin tuna meat (Haaland 1923; Haaland, 1924b; Haaland 1924a; Haaland, 1927; Tangen, 1999). In 1923, one entreprenuer rented a cannery for processing tuna meat and invited Italian tuna canning experts to Trondhjem, Norway to advise on processing methods (Haaland 1924b). The Norwegian Foreign Affairs Department and the Norwegian General Consulate in Genova, Italy also advised the Fiskeridirektorat on marketing, price and quality issues related to the export of canned Norwegian tuna to Italy (Haaland 1924b; Haaland 1927). These developments in both the catch and processing sectors of the fishing industry in the early-mid 1920s suggests that bluefin tuna was and had been abundant for several years.

During these years, sizes varied from 40-50 kg to 600-700 kg, with the most common individuals weighing 50-100 kg (Haaland 1923). The larger individuals (> 150 kg) usually were the first to appear within the year and then smaller individuals (< 150 kg) became more common later in the summer (Hanson 1925). This size pattern among the arrivals of immigrating bluefin tuna would be confirmed later by more extensive size-specific catch and tagging data (Hamre et al., 1966; Mather et al., 1995). In the years after 1950, the size distribution of bluefin tuna in Norway changed over time as smaller fish became proportionally rarer in catches (Pusineri et al., 2002; Fromentin and Powers 2005). This change in size distribution was also evident in the German North Sea bluefin tuna catches and in catches in a fishing trap (Barbate) in southern Spain west of Gibraltar (Pusineri et al., 2002). The change in size and age distribution has been suggested to be due to a change in migration pattern or recruitment but these possibilities have not been extensively evaluated (Fromentin and Powers 2005).

Comparison of the Norwegian landings data (Figure 2, 3) with the Norwegian Sea temperature data (Figure 5) shows that the landings increased in the early 1920s when temperatures were rising, but that landings were still high and increased further even when temperatures decreased or were only at average levels. This comparison shows that bluefin tuna were present in the Norwegian Sea during both cold and warm years. We have not directly and quantitatively compared the landings data with temperature data (e. g. with linear or nonparametric regression analyses) because the fishing effort and technology before 1950 was undergoing major increases and improvements (see above); in this situation functional relationships between landings and temperature could be misleading.

Sweden:

The first official Swedish landings of bluefin data in the ICES Statistical Bulletin is in 1933 (Figure 3). However Sweden made very large catches in several years during 1913-1922 (Figure 2); these were many of the same years that a Danish biologist reported that many bluefin tuna were present in waters around Denmark (Blegvad, 1946). Many of the tuna captured by Swedish fishermen in these years were sold on German fish markets (Duge 1925; Thiel 1938). There are also reports of sightings of tuna schools outside Gothenburg and in the

Bohuslån (western Sweden) area in 1913 (Ekman, 1913). Ekman also states that one bluefin tuna was found dead at Strömstad, western Sweden in August, 1907. The high Swedish catches in 1913-1922 occurred during years when temperatures in the North and Norwegian Seas were both warm and cold (Figure 5).

United Kingdom:

The British zoologist and sea captain D. K. Wolfe Murray frequently observed schools of bluefin tuna while fishing for herring on Dogger Bank during the 1920s and 1930s (Wolfe Murray, 1932). These schools would feed on herring which fell from the herring nets which were being hauled onboard or on herring thrown into the water by the fishermen. Wolfe Murray gives the annual dates of first and last appearance when he saw bluefin tuna schools (Figure 6). These data show that bluefin tuna schools were present in the North Sea for an average of 71 days (standard deviation = 9) during 1923-31.

The seasonality of the presence of bluefin tuna schools near Dogger Bank is consistent with the seasonality of catches made by fishermen elsewhere in other northern European waters (e. g., Norwegian Sea, Skagerrak, eastern North Sea). Wolfe Murray's observations of bluefin tuna schools in the western North Sea are confirmed by the famous British fishery biologist E. S. Russell who states in a footnote in Wolfe Murray's article that English fisheries staff have observed bluefin tuna "on many occasions since 1912". Moreover, the location (Dogger Bank area) of the schools seen by Wolfe Murray is identical to that where the earliest French catches of bluefin tuna in the North Sea were made (see above). The schools seen by Wolfe Murray contained as many as 30 fish. He states that at this time, fishermen called the bluefin tuna "sharks", and that fishermen observed many "sharks" also in 1922. In 1923 while onboard a commercial fishing vessel, he confirmed that the "sharks" were indeed bluefin tuna. Some of these bluefin tuna were large (> 150 cm).

The tuna schools observed by Wolfe Murray were present in years when North Sea temperatures in summer were both cold and warm (Figure 7). The timing and duration of the period when the schools were seen also varied independently of temperature (Figure 7).

An English sportfishery for bluefin tuna caught several tuna in the 1930s (Figure 2). Mather et al. (1995) state that these fish were caught off the Yorkshire coast between Scarborough and Dogger Bank. The English sportfishery however began earlier than 1930, because English bluefin tuna sportfishermen travelled to Denmark already in 1928 and 1929 to participate in Danish sportfisheries (Svendsen, 1949). Landings data for the English sportfishery prior to 1932 are however unknown.

Ecological role of bluefin tuna in northern European waters:

Migration of bluefin tuna to northern European waters is (was) primarily for feeding (Mather et al., 1995; Cury et al., 1998; Fromentin and Powers 2005). While present in these waters, bluefin tuna preyed on several forage species, including herring, mackerel, sprat, garfish, squid and gadoids (Tiews 1978; Mikkelsen, 1986; Mather et al., 1995), and increased their body weight and condition factor (Tiews, 1963a; Tiews, 1963b; Tiews 1978). Tiews (1978) estimated the amount of prey consumed by bluefin tuna while in the North Sea during 1951-1972 for a range of assumed daily ingestion rates, growth efficiencies and fishing mortality rates. According to him, the two most likely consumption rate estimates show that the bluefin tuna population in the North Sea annually consumed ca. 150,000 - 200,000 tonnes of prey in the 1950s (Fig. 8). Most of this prey (ca. 75%) was probably herring (Tiews 1978).

The consumption of herring by bluefin tuna can be compared with contemporary estimates of North Sea herring consumption by other predators as estimated using multi-species virtual population analysis (ICES, 2005). During the overlapping years in the two time series, bluefin tuna consumption of herring is only a very small fraction of that consumed by other predators; by this time the bluefin tuna population had already declined (Tiews 1978). However in the 1950s, bluefin tuna consumption was much higher, and could have been ca. 30% of the predation on herring by all other predators, assuming that their predation rate in the 1950s was similar to the long-term mean consumption rate (660,000 t/year; ICES 2005). Alternatively if one makes the conservative assumption that the record high predation on herring by other predators at the start of the MSVPA time series also occurred in the 1950s, then the tuna consumption would have represented 10-15% of this consumption. These comparisons suggest that bluefin tuna were an important top predator in the North Sea ecosystem, even though they were only present in this system for 2-3 months per year (Figure 7; Tiews 1978; Mather et al. 1995).

Conclusion:

This investigation has documented the presence and exploitation of several tonnes of bluefin tuna per year in the waters of northern Europe in the early decades of the 1900s. These figures likely underestimate the true abundance and catches because many landings and sightings were not likely reported to fishery authorities. In addition, other fishery and archaeological evidence shows that bluefin tuna have been present in northern European waters for 100s of years (Le Gall 1927; Enghoff, 1999). Bluefin tuna were clearly present in large numbers before the industrialized fishery for this species began in the late 1930s and 1940s. Official fishery databases located at ICES and ICCAT do not contain most of these data. Hence studies based on those datasets will not reveal the presence of this species in northern European waters.

Landings increased in these decades primarily due to intensification of effort and the development of more effective fishing methods. These factors were driven and accompanied by increased demand and processing facilities. The multi-annual and –decadal scale development of the fishery can not be attributed to major changes in local temperature conditions because bluefin tuna schools were present in the North and Norwegian Seas in years having widely varying temperatures and the duration of school residency was not affected by temperature. Presence in boreal-temperate waters such as those investigated in this study is facilitated by an efficient thermal regulation ability in this species (Cury et al., 1998; Graham and Dickson, 2001).

This study has established that bluefin tuna was abundant in the early decades of the 1900s in northern Europe. However the species has been rare in this area since the 1970s (Tiews 1978; Mather et al., 1995; Fromentin and Powers 2005). Given that preserving the spatial range of exploited populations is a key for long-term sustainability, the management of bluefin tuna in the Atlantic requires a more precautionary approach, with more concern about re-establishing and maintaining the historical range of the species.

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Figure captions:

Figure 1. Map of northern Europe with main sea regions referred to in the text. Numbers refer to Dogger Bank (1), Sjællands Odde (2) and Skagen (3).

Figure 2. Time series of catches of bluefin tuna by different countries in northern European waters during 1900-1950 as recorded in various historical fishery documents. Note that the vertical scaling and units on the vertical axes are different. The Norwegian landings are based on reports from single or small numbers of fishermen and do not represent entire national landings (Tangen, 1999). The Danish landings only refer to landings at one harbour (Skagen). Also shown on the Danish panel is the number of tuna canneries established in Denmark (squares). The Swedish landings are primarily from Gothenburg.

Figure 3. Official landings of bluefin tuna by by different countries in northern European waters as recorded in annual ICES Statistical Bulletins.

Figure 4. Bluefin tuna caught by German fishermen and for sale at the Altona (near Hamburg) fish market on a single day in 1910 (Brandenburg, 2003). There are 11 tuna in the foreground of the photograph. Photograph reproduced with permission of Sutton Verlag.

Figure 5. Interannual variability in sea surface temperature in the Norwegian Sea (July: black circles) and August (white squares) and in the North Sea (black diamonds) during 1900-1950.

Figure 6. Interannual variability in the timing of first (squares) and last (circles) observations of bluefin tuna schools by scienticially trained observers on herring fishing boats in the Dogger Bank area of the North Sea during 1923-1931 (Wolfe Murray 1932). Tuna schools were also seen by English fishery observers during the years since 1912 (Russell in Wolfe Murray 1932).

Figure 7. The timing (day of first and last sighting, expressed as Julian day number) and duration of sightings of bluefin tuna schools in the North Sea by scienticially trained observers compared with summer (average of July, August and September) sea surface temperature in the North Sea. None of the relationships are statistically significant ($P > 0.10$).

Figure 8. Consumption of prey by bluefin tuna in the North Sea during 1951-1972, as estimated by Tiews (1978); the two estimates (black triangles) considered most likely by Tiews are shown. Most of the prey consumed by bluefin tuna in the North Sea was herring (Tiews 1978). Also shown for comparison (white circles) is the consumption of herring by its most common predators in the North Sea as derived from a multi-species virtual populatoin analysis (ICES 2005); this simulation does not include bluefin tuna.

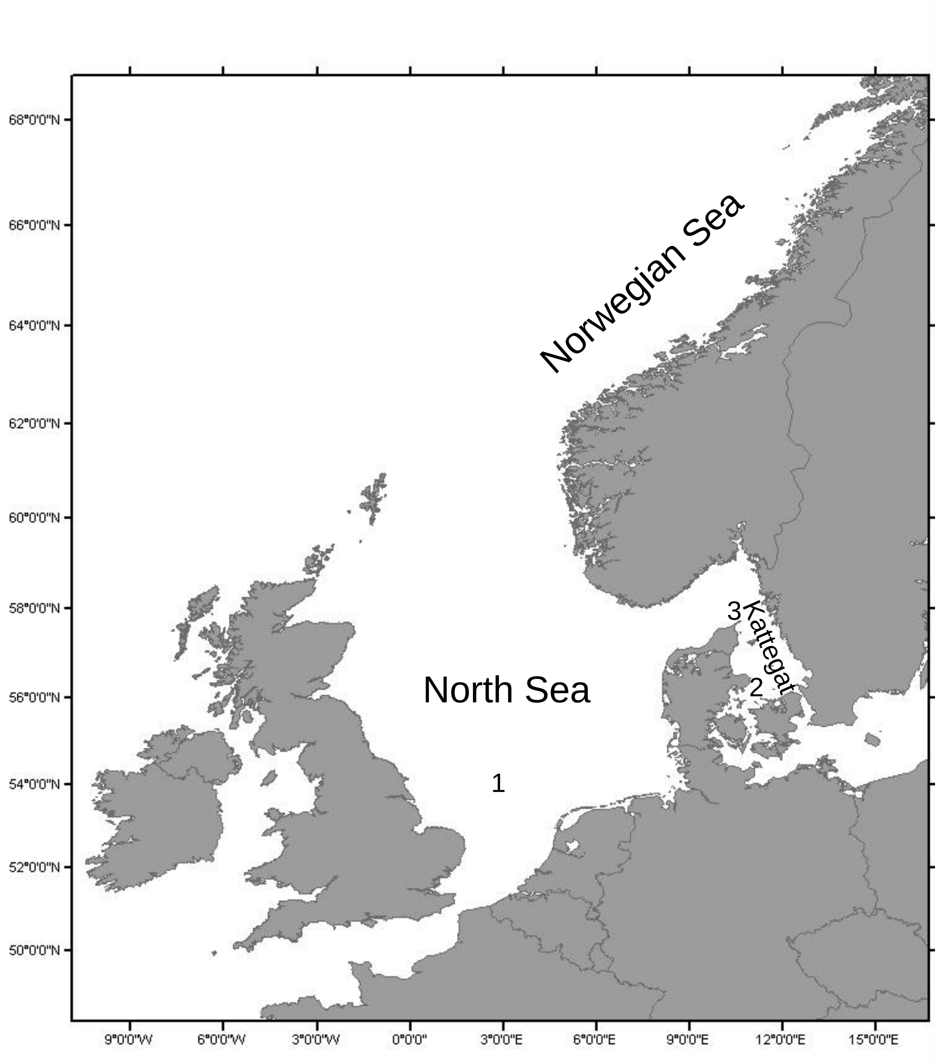
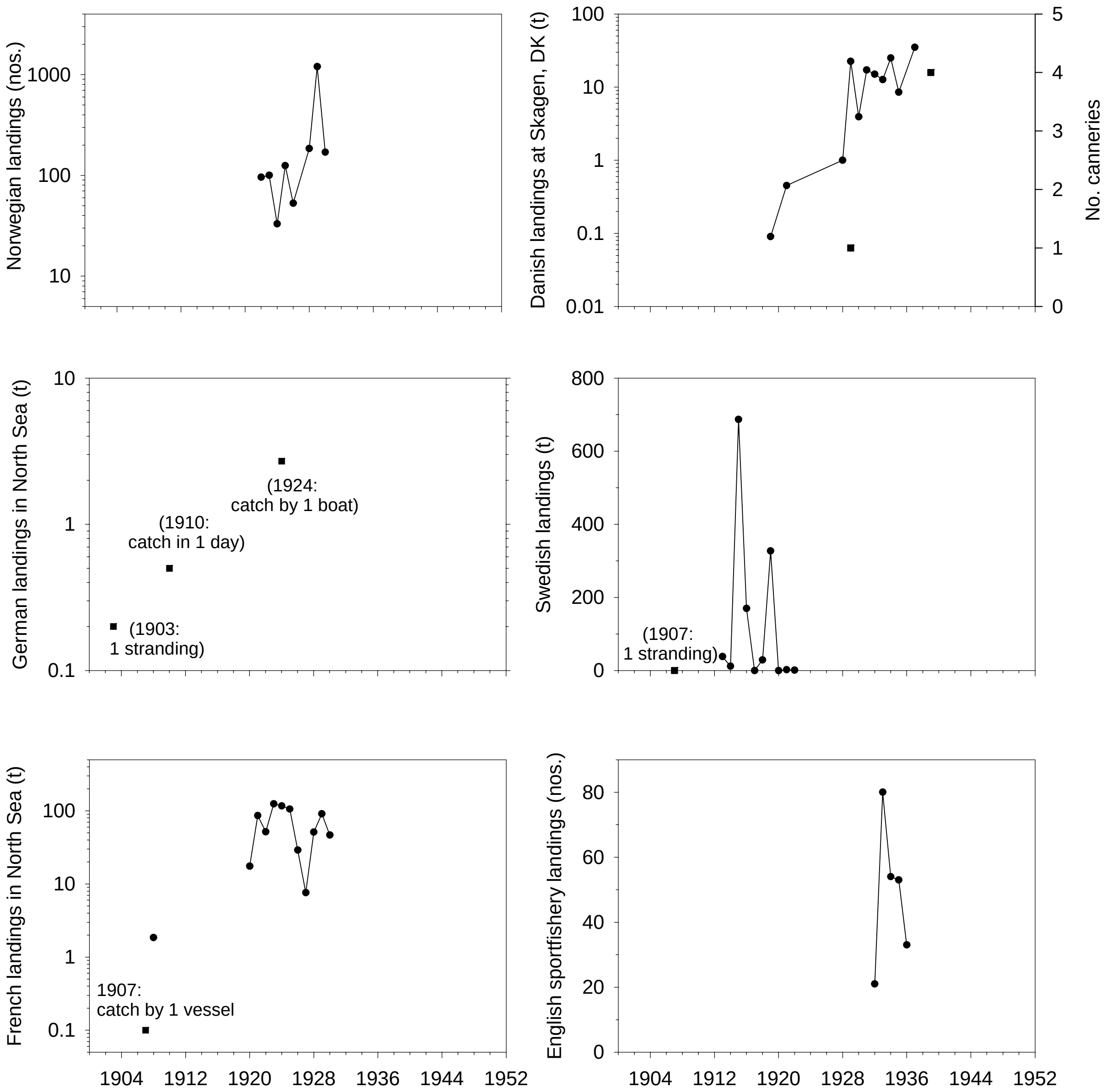

68°0'0"N
66°0'0"N
64°0'0"N
62°0'0"N
60°0'0"N
58°0'0"N
56°0'0"N
54°0'0"N
52°0'0"N
50°0'0"N
9°0'0"W
6°0'0"W
3°0'0"W
0°0'0"
3°0'0"E
6°0'0"E
9°0'0"E
12°0'0"E
15°0'0"E
Norwegian Sea
North Sea
Kattegat
1
2
3

Figure 1



Norwegian landings (nos.)
10
100
1000
Danish landings at Skagen, DK (t)
0.01
0.1
1
10
100
No. canneries
0
1
2
3
4
5
German landings in North Sea (t)
0.1
1
10
(1903:
1 stranding)
(1910:
catch in 1 day)
(1924:
catch by 1 boat)
Swedish landings (t)
0
200
400
600
800
(1907:
1 stranding)
French landings in North Sea (t)
0.1
1
10
100
1907:
catch by 1 vessel
English sportfishery landings (nos.)
0
20
40
60
80
1904
1912
1920
1928
1936
1944
1952

Figure 2

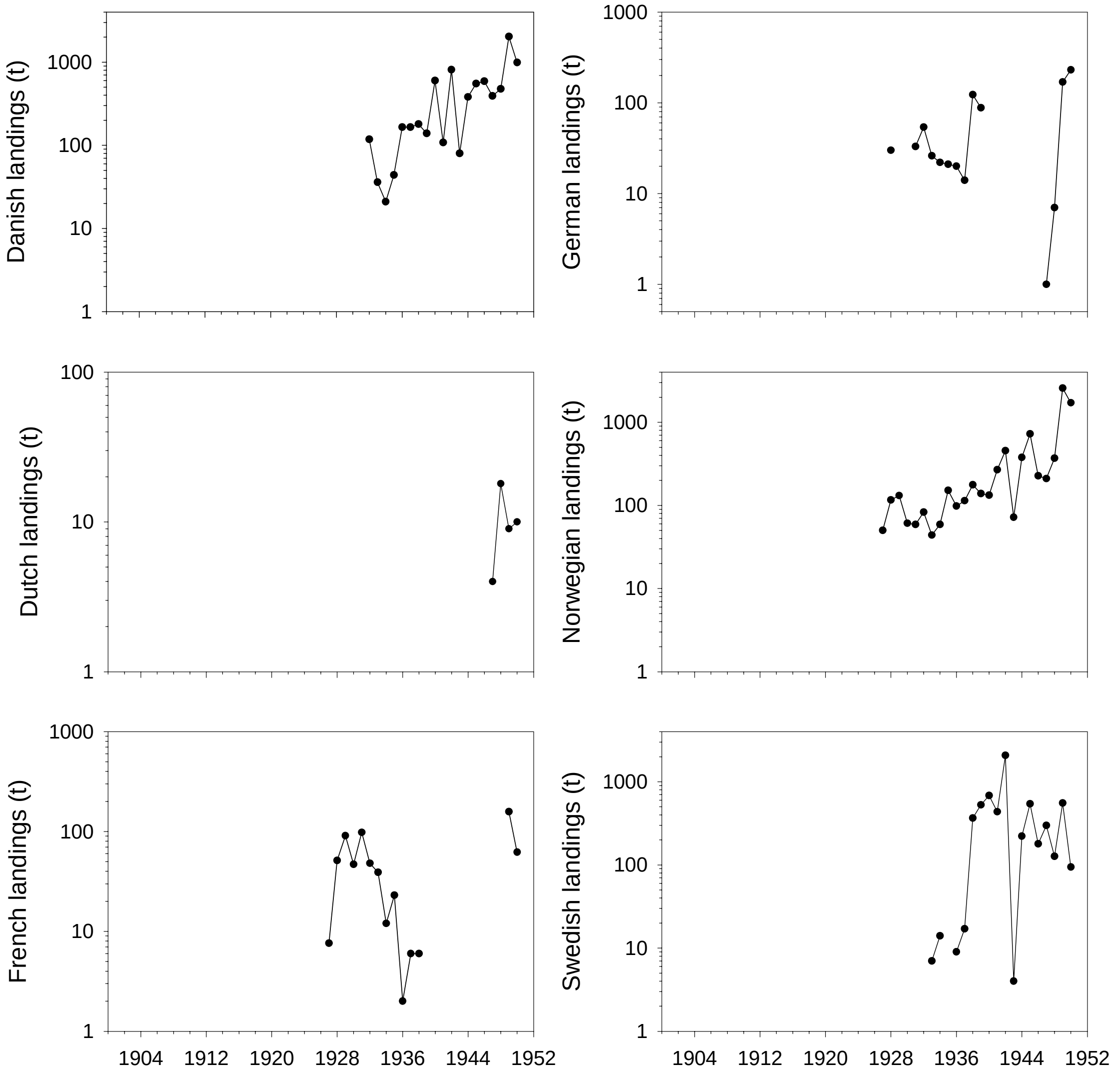

Danish landings (t)
German landings (t)
Dutch landings (t)
Norwegian landings (t)
French landings (t)
Swedish landings (t)
1
10
100
1000
1904
1912
1920
1928
1936
1944
1952

Figure 3

Thunfische vor der Fischauktion, um 1910.

Figure 4

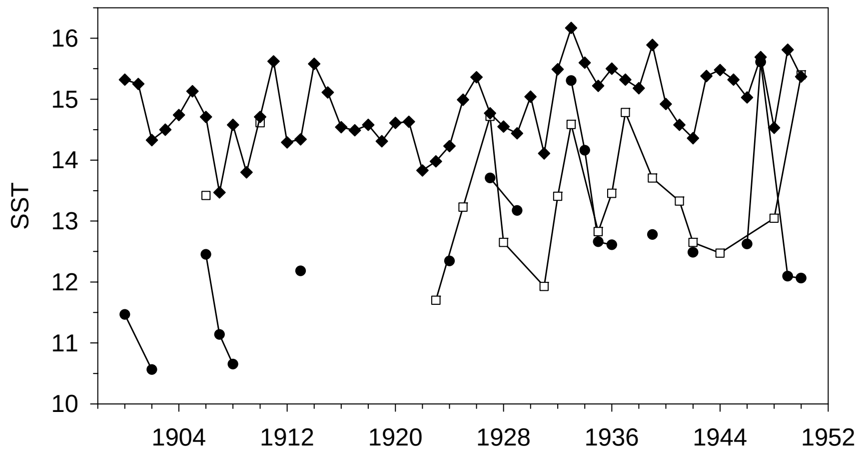


Figure 5

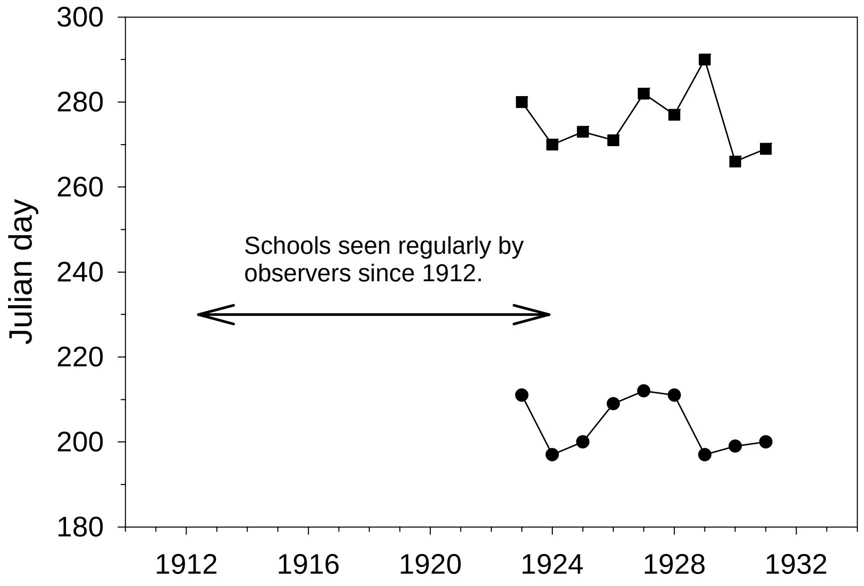

300
280
260
240
220
200
180
Julian day
Schools seen regularly by
observers since 1912.
1912
1916
1920
1924
1928
1932

Figure 6

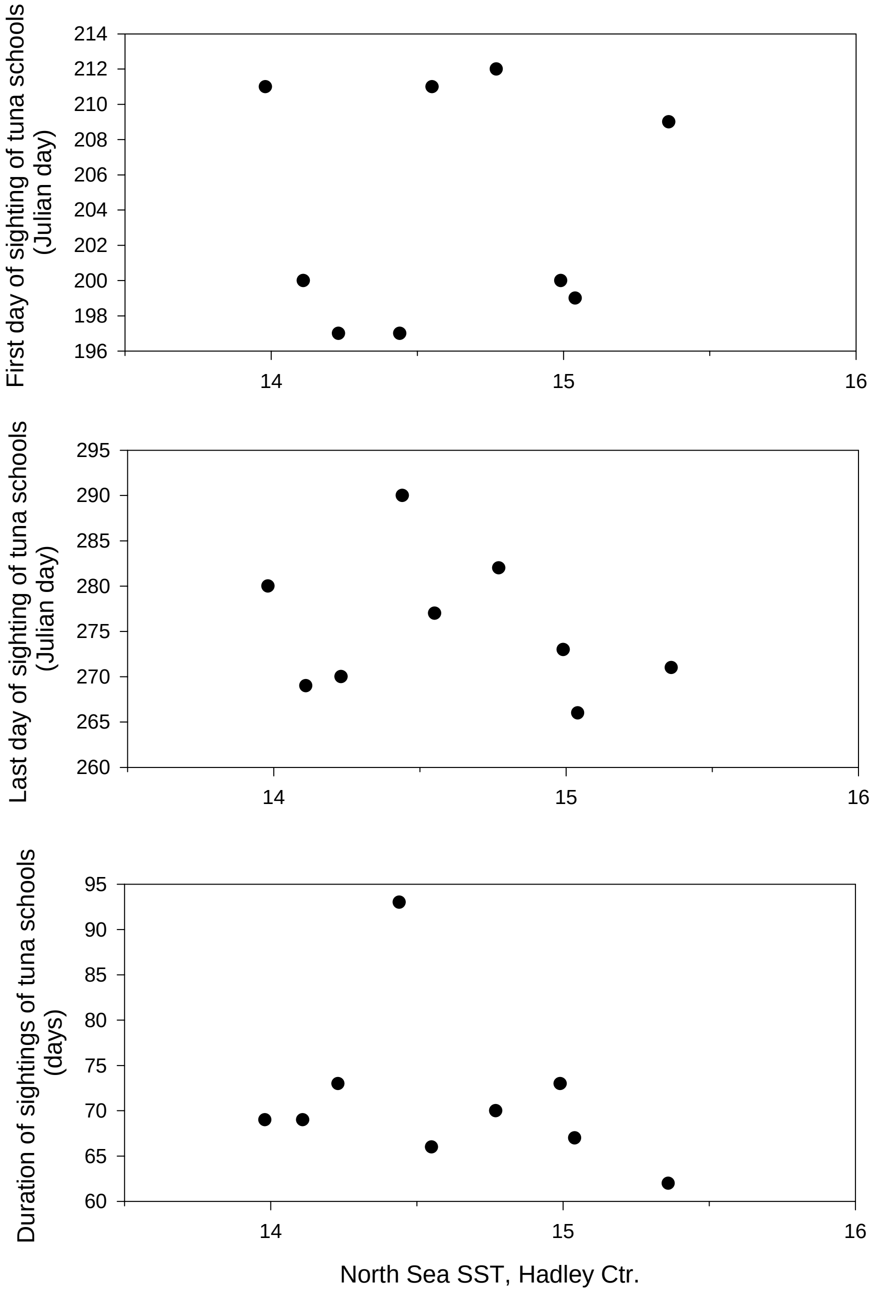

First day of sighting of tuna schools (Julian day)
214
212
210
208
206
204
202
200
198
196
14
15
16
Last day of sighting of tuna schools (Julian day)
295
290
285
280
275
270
265
260
14
15
16
Duration of sightings of tuna schools (days)
95
90
85
80
75
70
65
60
14
15
16
North Sea SST, Hadley Ctr.

Figure 7

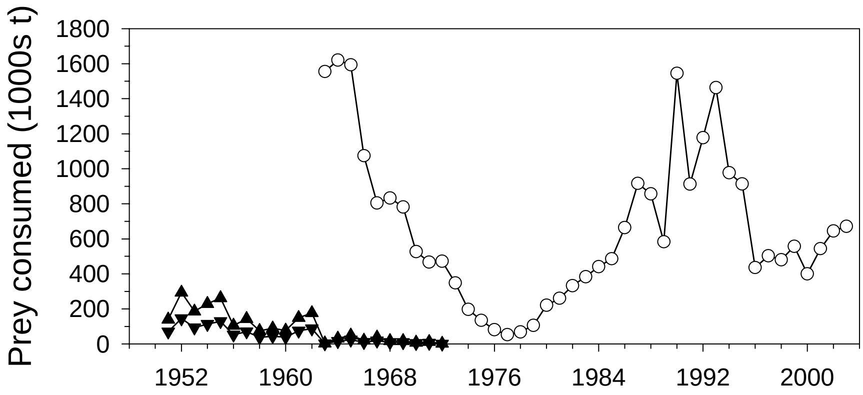

Prey consumed (1000s t)
1800
1600
1400
1200
1000
800
600
400
200
0
1952
1960
1968
1976
1984
1992
2000

Figure 8

Appendix Table 1

Landings and strandings of bluefin tuna in different countries before data began to be reported officially to ICES or ICCAT. These data area also plotted as time series in Figure 2 and Figure 6.

Country	Region, harbour	year	nos.	tonnes	Comments	Reference
Denmark	Kattegat	1919	1	0.09	100s of others seen in Kattegat	Eli 1974
Denmark	Skagen	1921	7	0.45	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1928	10	0.65	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1928		1	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1929	259	22.5	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1930		3.925	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1931		17.131	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1932		15	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1933		12.622	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1934		25	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1935		8.5	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1937		34.927	from fishery and market receipts	Pedersen 1997
Denmark	Skagen	1929			1 cannery	Pedersen 1997
Denmark	Skagen	1939			4 canneries	Pedersen 1997
England	Dogger Bank, North Sea	1912	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1913	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1914	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1915	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1916	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1917	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1918	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1919	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1920	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1921	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1922	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1923	Schools		Sightings by fisheries observers	Wolfe Murray 1932

England	Dogger Bank, North Sea	1924	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1925	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1926	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1927	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1928	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1929	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1930	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Dogger Bank, North Sea	1931	Schools		Sightings by fisheries observers	Wolfe Murray 1932
England	Scarborough-Dogger	1932	21		sportfishery	Mather et al. 1995
England	Scarborough-Dogger	1933	80		sportfishery	Mather et al. 1995
England	Scarborough-Dogger	1934	54		sportfishery	Mather et al. 1995
England	Scarborough-Dogger	1935	53		sportfishery	Mather et al. 1995
England	Scarborough-Dogger	1936	33		sportfishery	Mather et al. 1995
France	Boulogne, Dogger Bank	1906		0		Stat. Peche Marit.
France	Boulogne, Dogger Bank	1907		0.1	bycatch in herring fishery	Stat. Peche Marit.
France	Boulogne, Dogger Bank	1908		1.85	bycatch in herring fishery	Stat. Peche Marit.
France	Dogger Bank	1909		0		Stat. Peche Marit.
France	Dogger Bank	1910		0		Stat. Peche Marit.
France	Dogger Bank	1911		0		Stat. Peche Marit.
France	Dogger Bank	1912		0		Stat. Peche Marit.
France	Dogger Bank	1913		0		Stat. Peche Marit.
France	Dogger Bank	1914		0		Stat. Peche Marit.
France	Dogger Bank	1915		0		Stat. Peche Marit.
France	Dogger Bank	1916		0		Stat. Peche Marit.
France	Dogger Bank	1917		0		Stat. Peche Marit.
France	Dogger Bank	1918		0		Stat. Peche Marit.q
France	Dogger Bank	1919		0		Stat. Peche Marit.
France	Dogger Bank	1920		17.5	commercial fishery	Stat. Peche Marit.
France	Dogger Bank	1921		86	commercial fishery	Stat. Peche Marit.
France	Dogger Bank	1922		51.6	commercial fishery	Stat. Peche Marit.
France	Dogger Bank	1923		124	commercial fishery	Stat. Peche Marit.
France	Dogger Bank	1924		116.6	commercial fishery	Stat. Peche Marit.

France	Dogger Bank	1925		105.5	commercial fishery	Stat. Peche Marit.
France	Dogger Bank	1926		29.1	commercial fishery	Stat. Peche Marit.
France	Dogger Bank	1927		7.6	commercial fishery	Stat. Peche Marit.
France	Dogger Bank	1928		51.2	commercial fishery	Stat. Peche Marit.
France	Dogger Bank	1929		91.2	commercial fishery	Stat. Peche Marit.
France	Dogger Bank	1930		46.5	commercial fishery	Stat. Peche Marit.
Germany	western Baltic Sea	1903	1		stranding at Warnemuende	Schulze 1903
Germany	North Sea	1910	11	0.5	catch in 1 day	Brandenburg 2003
Germany	North Sea	1924	27		caught by one fishing boat	Duge 1925
Norway	several sites	1922	96		from fishery and market receipts	Tangen 1999
Norway	several sites	1923	100		from fishery and market receipts	Tangen 1999
Norway	several sites	1924	33		from fishery and market receipts	Tangen 1999
Norway	several sites	1925	125		from fishery and market receipts	Tangen 1999
Norway	several sites	1926	53		from fishery and market receipts	Tangen 1999
Norway	several sites	1928	185		from fishery and market receipts	Tangen 1999
Norway	several sites	1929	1200		from fishery and market receipts	Tangen 1999
Norway	several sites	1930	170		from fishery and market receipts	Tangen 1999
Sweden	Gothenburg	1913	439	38		Jägerskiöld 1923
Sweden	Gothenburg	1914	132	12		Jägerskiöld 1923
Sweden	Gothenburg	1915	7854	687		Jägerskiöld 1923
Sweden	Gothenburg	1916	1942	170		Jägerskiöld 1923
Sweden	Gothenburg	1917	1	0		Jägerskiöld 1923
Sweden	Gothenburg	1918	327	29		Jägerskiöld 1923
Sweden	Gothenburg	1919	3740	327		Jägerskiöld 1923
Sweden	Gothenburg	1920	0	0		Jägerskiöld 1923
Sweden	Gothenburg	1921	18	2		Jägerskiöld 1923
Sweden	Gothenburg	1922	9	1		Jägerskiöld 1923

Appendix Table 2

Landings of bluefin tuna (tonnes) by country in the North Sea, Norwegian Sea, Skagerrak and Kattegat as reported to ICES and recorded in ICES Statistical Bulletins up to 1950. There were no reported landings before 1927. These data are also plotted as time series in Figure 3.

Year	Denmark	France	Germany	Netherlands	Norway	Sweden
1927		7.6			50	
1928		51.2	30		116	
1929		91			131	
1930		47			61	
1931		98	33		59	
1932	118	48	54		83	
1933	36	39	26		44	7
1934	21	12	22		59	14
1935	44	23	21		152	
1936	165	2	20		98	9
1937	165	6	14		114	17
1938	180	6	123		177	365
1939	139	0	88		139	527
1940	600	0	0		133	681
1941	108	0	0		269	436
1942	810	0	0		455	2068
1943	80	0	0		72	4
1944	380	0	0		377	221
1945	550	0	0		722	542
1946	590	0	0		227	179
1947	392	0	1	4	210	298
1948	475	0	7	18	368	127
1949	2031	158	169	9	2562	556
1950	991	62	230	10	1712	94