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Report:

''Common dab (*Limanda limanda*) fisheries biology in the Northumberland coast (NE, England); Preliminary age and growth study in order to introduce a Minimum Landing Size (MLS) restriction for the future''

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Common dab (*Limanda limanda*) fisheries biology in the Northumberland coast (NE, England); Preliminary age and growth study in order to introduce a Minimum Landing Size (MLS) restriction for the future.

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Abstract

In this study, a possible MLS restriction was proposed for common dab (*Limanda limanda*) by determining age at length, and estimating growth parameters and length at first maturity. Individuals were collected in the Northumberland coastal waters, within the Northumberland Inshore Fisheries and Conservation Authority (NIFCA) area of jurisdiction (<6 nm offshore), from May 2014 to June 2014. Specimens were collected using three different fishing gears including demersal otter trawl, beam trawl and trammel nets, and ranged from 55 to 335 mm in total length. Otoliths were extracted for age determination with age distribution ranging from 1 to 7 years. Growth was described by applying the standard form of the von Bertalanffy growth equation to the mean lengths at age and the estimated parameters were L_∞ = 406 mm, K = 0.237 and t_0 = -0.022. Sexual maturity was found to occur at 184 mm (2.56 years). Thus, the suggested MLS was 185 mm, in order to maintain dab population in a sustainable way, and prevent the stock of being overexploited when its market value peaks.

Keywords: Common dab, age, growth, maturity, MLS, Northumberland coast, North Sea.

Introduction

Age and growth data of fish are crucial information for any species stock assessment. Information on age is fundamental as it lays the core for the estimations of important parameters such as productivity, growth and mortality rates (Campana, 2001). Thus, age information is necessary for fisheries management (Cailliet *et al.*, 2001). Age of fish can be determined by using otoliths or scales (Campana, 2001). However, in recent years otoliths are preferred (Fossum *et al.*, 2000) as they are more reliable for long-lived species, whereas scales underestimate the age of slow-growing species (Summerfelt and Hall, 1987).

Growth is also an important life history process of a fish and is strongly correlated with the dynamics of its population (Cengiz *et al.*, 2013). Specifically, von Bertalanffy growth parameters set the basis of fisheries biology (Apostolidis and Stergiou, 2014), as they are required for stock assessment models (Hilborn and Walters, 1992), maximum sustainable yield predictions (Beddington and Kirkwood, 2005) and estimations of empirical equations to calculate other biological parameters such as size at maturity (Froese and Binohlan, 2000).

Length at first maturity (L_M) is one of the most important population parameters in the fisheries management of exploited stocks (Jennings *et al.*, 2001). Fish should be allowed to spawn at least once over their lifetime before being caught, in order to maintain a stock biomass (Beverton and Holt, 1957), which premises that their catch size should exceed their size of maturation (Trippel, 1995). Hence, L_M lays the core for setting the Minimum Landing Size (MLS) restriction of exploited stocks, which is one of the most significant management measures as it prohibits the capture and landing of fish below the legal size (Tsikliras and Stergiou, 2014). The continuous removal of immature fish may lead to growth overfishing (Lleonart, 1999), which could be detrimental for slow-maturing, slow-growing and long-lived fish stocks (Froese *et al.*, 2008).

Common dab (*Limanda limanda*), is the most abundant flatfish species in the North Sea (Rijnsdorp *et al*., 1992) and Northeast Atlantic (Beggs and Nash, 2007) and the third most abundant fish in the North Sea (Sparholt,

1990) after sprat (*Sprattus sprattus*) and sand eel (*Ammodytes marinus*). Dab is an edible widespread demersal Pleuronectid (*DEFRA*, 2013) distributed in the northeastern Atlantic shelf living in coastal waters from the Bay of Biscay in the south, to as far north and east as Iceland and Norway respectively, including the Barents, White and Baltic Seas (Henderson, 1998). It inhabits mostly in sandy or muddy sediments (Green and Lart, 2014) and is frequently caught down to depths of 100 m (Bohl, 1957), although it can occasionally be found in deeper waters of 150 m (Daan *et al.*, 1990). Like most flatfish, dab is a long-lived and slow-growing species with a life expectancy of 11 years (Henderson, 1998) and can reach to a total length and weight up to 33 cm and 400 g respectively (Jennings *et al.*, 2001a). However, sexual maturity occurs relatively quickly, usually after their second year of age (Bohl, 1957).

Dab is generally caught as bycatch in the fishery directed at other demersal species, mainly in the beam trawl and bottom otter trawl fisheries, and is often discarded based on the availability of target species and market price (ICES, 2013). Dab is among the species which suffer the highest discard mortality (Depestele *et al.*, 2014) with a low survival rate upon discarding of 24% (Kaiser and Spencer, 1995). Despite high rates of exploitation mainly as bycatch, in June 2013 North Sea abundance indices indicate a stable and increasing stock for subarea IV (North Sea) and division IIIa respectively, over the past 20 years. These indicators suggest that the North Sea dab populations are currently stable or increasing, and at low risk that current exploitation is unsustainable (Green and Lart, 2014). Dab is landed mainly as bycatch, mostly by UK, Dutch, German and Danish fishing fleets and according to landing statistics the annual catch of dab in the Northeast Atlantic has been above 11,000 tonnes since the 1950's. Catches peaked at 22,000 tonnes in 1998 but have since declined to just over 10,000 tonnes (*ICES*, 2011).

However, despite its key role in the food web, because of its great abundance, as both predator and prey, comprehensive studies on the biology and age and growth of dab from the North Sea are limited, and mainly focused in the southeastern part (Bohl, 1957; Rijnsdorp *et al.*, 1992). In contrast, spatial and temporal recruitment variability has been thoroughly studied in the Irish (Henderson, 1998; Lee *et al.*, 2006; Lee *et al.*, 2007; Beggs and Nash, 2007) and the North Sea (Bolle *et al.*, 2001). In addition, dab has been used as an eco-toxicological indicator in many pollution monitoring programmes (Dethlefsen *et al.*, 1987; Cameron *et al.*, 1992; Vethaak and ap Rheinallt, 1992).

The aim of the present study is to suggest a possible MLS for common dab in the Northumberland coast. To do so this study will address three objectives: (1) determination of age at length, and estimation of (2) growth parameters and (3) length at first maturity.

Materials and methods

Study Area

Dab were collected between 30 May and 12 June 2014 from ten different sites along the Northumberland coastline (Figure 1). All sites were located within the Northumberland Inshore Fisheries and Conservation Authority (NIFCA) area of jurisdiction (<6 nm offshore). Sampling, ranged from offshore of Blyth port in the south to as far north as the Farne Islands, in depths ranging from 6 m offshore of Amble to 47.5 m in the National Renewable Energy Centre (NAREC) offshore wind farm area.

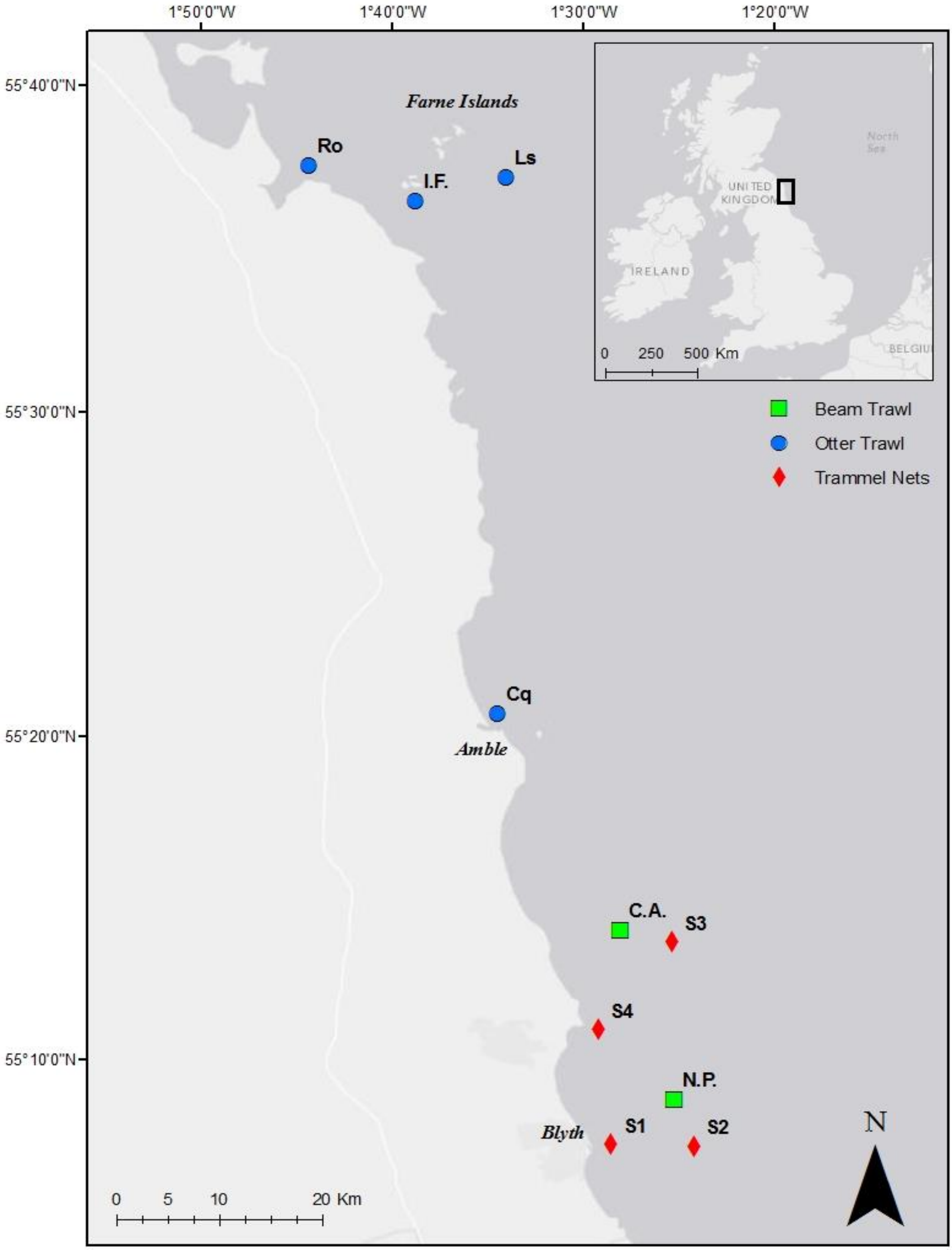

Figure 1. Map of all sampling locations of present study for dab fishery along Northumberland coastline showing with different colour all fishing gears that had been used (May-June 2014). Lo: Longstone; I.F.: Inner Farnes; Ro: Ross; N.P.: NAREC platform; C.A.: Control area; S1-4: Sites 1-4.

Sample collection

Sampling was conducted in collaboration with other ongoing studies. Thus, three different fishing gears were deployed by the Newcastle University Research Vessel "The Princess Royal" including demersal otter trawl, beam trawl and trammel nets. By the use of diverse gears different components of the population could be examined and specific biases of gears could be overcome.

The otter trawl was used in three sites in proximity of the Farne Islands (Longstone, Inner Farnes and Ross) and in a single site offshore of Amble near Coquet Island, in depths ranging from 6 to 30 m. Three hauls were conducted in each site. The demersal otter trawl consisted of a 30 mm squared mesh net with a 5 mm cod end liner. The net had an average 9.8 m wing spread and a 14.4 m circumference fishing circle. Gear specific trawl doors were also used (Sweeting *et al.*, 2011). Each haul was carried out for 10 minutes at approximately 2.4 knots. Trawl start time was defined as the point at which the trawl line became taught, and end time was the point at which hauling began. Catch was recorded and measured once the gear was retrieved on deck.

Beam trawl was used in two sites (NAREC platform and Control area). Each site consisted of three concentric circles (zones) with the radius distance to change every 500 m. One site (N.P.) had the concentric rings centered on the anemometry hob and the second (C.A.) was centered on an area near the NAREC anemometry platform area. 18 hauls were conducted in total (3 hauls per zone). The beam trawl consisted of a 2.2 m wide steel beam with a 25 mm mesh throughout the net. Each haul was carried out for 10 minutes at circa 2.4 knots. Trawl start time was defined as the point at which the trawl line became taught, and end time was the point at which hauling began. Catch was recorded and measured once the gear was retrieved on deck (Polunin *et al.*, 2012).

Trammel nets were deployed in four different sites (Site1-Site4) in depths from 14.9 to 47.5 m, within the NAREC offshore wind farm area and left soak for 24 hours. The trammel nets were comprised of two panels of 100 yards with inner meshes of 55 mm and 120 mm, and an outer mesh of 305 mm stretching across the entire length of the two panels. Nets were cleared immediately after retrieval and recording and measuring were followed on deck.

Sample processing

All individuals were measured on board to the nearest 1 mm (Total Length-TL, mm). Both otoliths were extracted from 50% of individuals and stored in eppendorf storing tubes for age determination. In the laboratory otoliths were soaked in 20% EtOH (ethyl alcohol) solution, washed in distilled water, and subsequently dried in order to be cleaned. Otoliths were then placed in a petri dish with water for annuli reading. Age determination was conducted using a stereoscopic zoom microscope under reflected light, in x12 enlargement, against a black background. The left otoliths from each pair were used for age determination and observed from their concave side, as the nucleus was more central here and it was easier to detect the annuli. Hyaline and opaque zones were observed and each hyaline ring plus one opaque ring was assumed to be one age mark (Figure 2) (ICES, 2010).

Statistical analysis

According to the observed annuli from the otoliths' age determination, an age-length key was created with the mean lengths being given corresponding to each age class. The precision's error in age reading was tested by the estimation of the Coefficient of Variation (CV) by age group (ICES, 2010), which is less dependent of the closeness to the true age than the Standard Deviation (SD), and is therefore a better index of precision in age reading (ICES, 2007). The statistical dependence between age and length was also examined using the Spearman rank correlation coefficient (rho) in R statistical software (*R Core Team*, 2014).

The Von Bertalanffy Growth Equation (VBGE) was calculated according to:

$$L_t = L_\infty \left[1 - e^{-K(t - t_0)}\right],$$

where L_t (mm) represents the fish TL (mm) at age t (y), L_∞ (mm) is the asymptotic fish length (the length a fish would have if it lived infinitely), t (y) is the fish age, t_0 (y) is the hypothetical time at which the fish length is zero, and K (y^{-1}) represents the growth coefficient (the rate in which the fish approaches the L_∞) (von Bertalanffy, 1938). Using mean TLs for each age class the VBGE parameters were computed through non-linear regression analysis using Statgraphics statistical software. In order to validate the estimates, the maximum observed length to asymptotic length ratio (L_{MAX} / L_∞) was calculated. When the ratio is higher than 0.7 the estimates can be classified as trustful (Froese and Binohlan, 2000).

Length at first maturity (L_M) (the length at which the 50% of individuals of a stock become mature) was calculated according to an empirical equation for Actinopterygii (Froese and Binohlan, 2000):

$$\log(L_M) = 0.8979 \times \log(L_\infty) - 0.0782.$$

In addition, the age at first maturity (t_M) was estimated by using the inverse of the VBGE. The dimensionless ratio L_M/ L_∞, which expresses the proportion of the potential growth span of the species covered before maturation (Beverton, 1992), was also included in the analysis as an alternative way to express the reproductive load (Tsikliras and Stergiou, 2014). In general, the L_M/ L_∞ ratio is larger for small sized species and smaller for large size species (Longhurst and Pauly, 1987), and constant among different populations of the same species and similar between closely related species (Beverton, 1992).

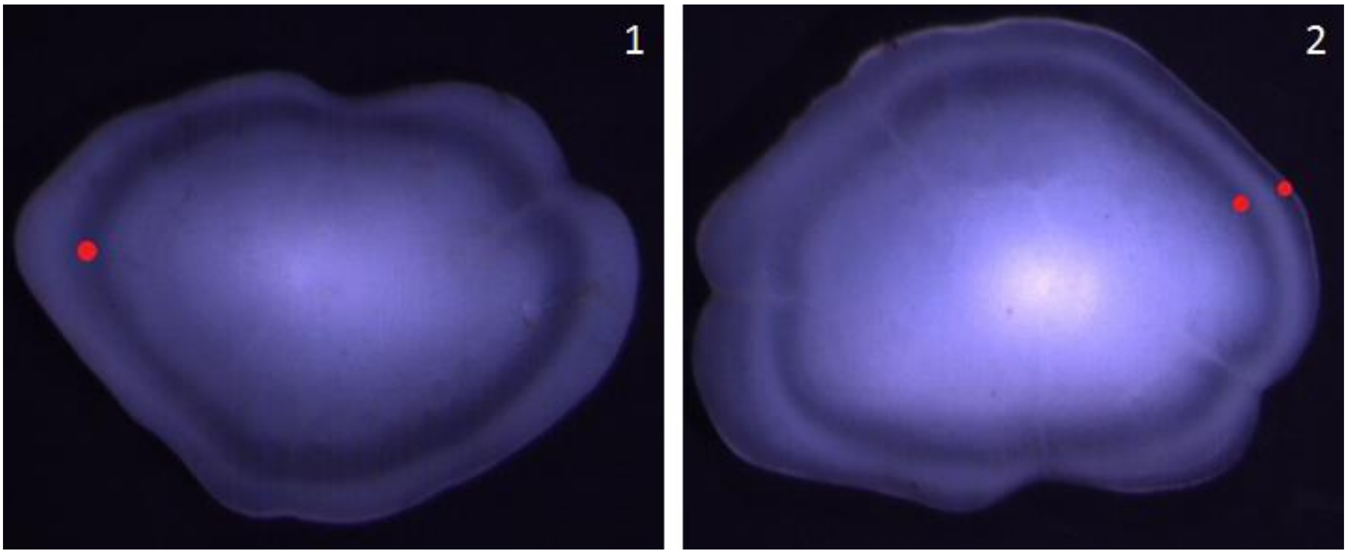

Figure 2. Common dab (*L. limanda*) otoliths with 1 (Total Length=61 mm, x12) and 2 (Total Length=115 mm, x12) annuli (images not in scale, magnification is given).

Results

A total of 208 individuals were sampled for this project during the study period. The smallest and the largest individuals caught were 55 and 335 mm long respectively. The length-frequency distribution of the common dab (*L. limanda*) caught is displayed in Figure 3.

The otoliths of 112 individuals ranging from 55 to 335 mm in total length were successfully extracted and prepared for age determination. Age distribution ranged from 1 to 7 years. Assuming that 1 January is the birth date of *L. limanda*, the age – length key with the mean TLs corresponding to each class age is given in Table 1. Mean CV of age estimation was 7.1% which means that the age reading process was significantly precise. Length and age were strongly positively correlated (Spearman rho=0.95, $p<0.05$).

Table 1. Number of individuals and age-length key of common dab (*L. limanda*) used for growth analysis (Northumberland coast, May-June 2014).

Length class (mm)	**Age**							**N**
	1	**2**	**3**	**4**	**5**	**6**	**7**	
50-59	2							2
60-69	4							4
70-79	2							2
80-89	12							12
90-99	9							9
100-109								-
110-119	2	1						3
120-129		2						2
130-139		7						7
140-149		7						7
150-159		6						6
160-169		5						5
170-179		6	4					10
180-189		3	1					4
190-199			6					6
200-209			9					9
210-219			7					7
220-229			2					2
230-239				2				2
240-249				2				2
250-259				2				2
260-269				2				2
270-279				2	1			3
280-289					1			1
290-299								-
300-309						2		2
310-319								-
320-329								-
330-329							1	1
N	31	37	29	10	2	2	1	112
Mean	84.7	162.5	201.8	255	281.5	303	335	161.7
Min	55	115	174	230	278	301	335	55
Max	111	185	229	271	285	305	335	335
SD	14.3	18.0	13.6	14.8	4.9	2.8	-	11.4
CV	16.9	11.1	6.8	5.8	1.8	0.9	-	7.1
%	27.7	33.0	25.9	8.9	1.8	1.8	0.9	100.0

N=Sample size; Min=Minimum (mm); Max=Maximum (mm); SD=Standard Deviation; CV=Coefficient of Variation (%).

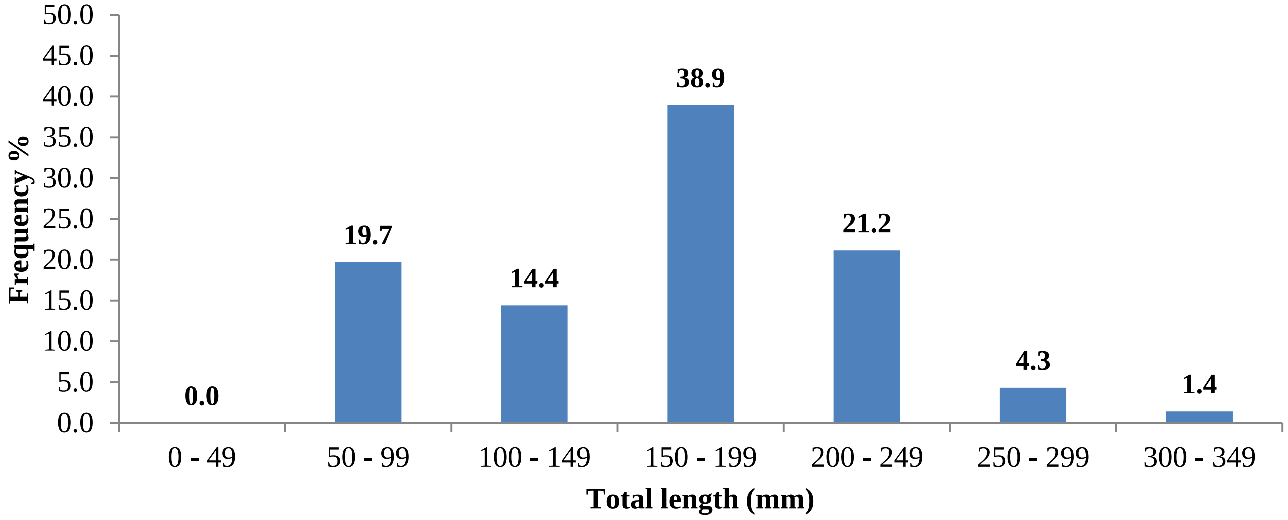

Figure 3. Length-frequency distribution of common dab (*L. limanda*), Northumberland coast (May-June 2014).

The estimated von Bertalanffy growth parameters are presented in Table 2. The maximum observed length to asymptotic length ratio (L_{MAX} / L_∞) was calculated as 0.82, which makes them trustful. Thus, the VBGE curve is given in Figure 4.

Table 2. VBGE parameter estimations after non-linear regression analysis in Statgraphics, showing standard errors and the lower and upper confidence intervals.

Parameter		Estimate	Asymptotic Standard Error	Asymptotic 95% Confidence Interval Lower	Upper
L_∞	(mm)	406.778	29.099	325.986	487.569
K	(y^{-1})	0.237	0.041	0.125	0.350
t_0	(y)	-0.022	0.163	-0.479	0.435

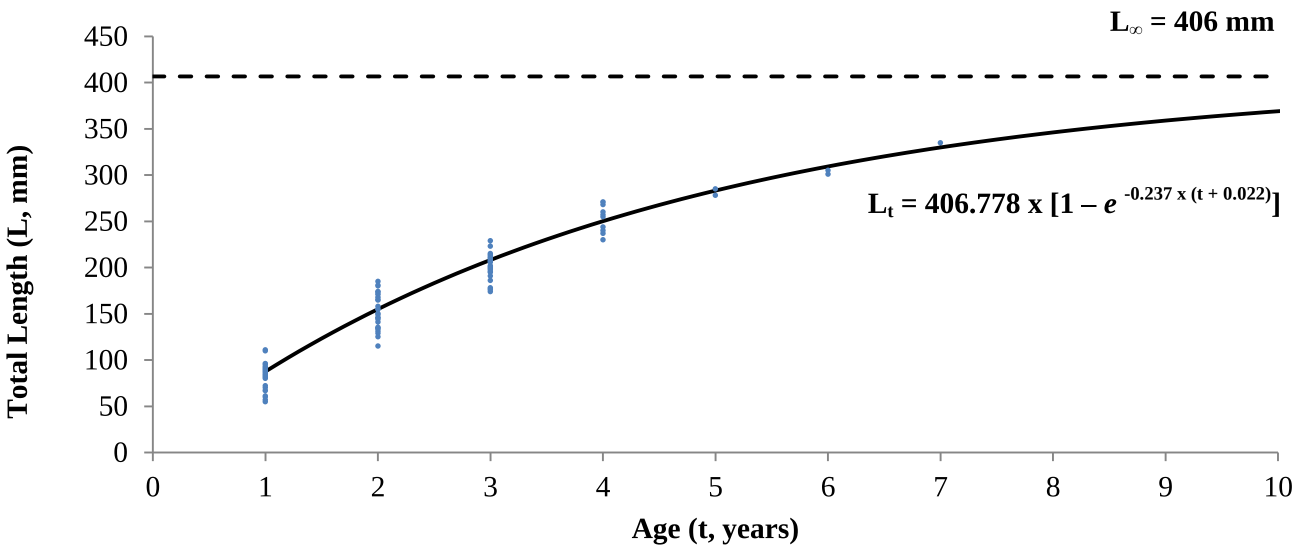

Figure 4. VBGE curve (solid line) and hypothetical asymptotic length (dashed line) for common dab (*L. limanda*), Northumberland coast (May-June 2014).

According to the empirical length at maturity equations (Froese and Binohlan, 2000), L_M for dab was calculated as 184 mm. Thus, the present study suggests that the legal MLS for dab should exceed that length. 128 individuals (60% of total catch) of dab were caught below L_M (Figure 5). Based on the derived von Bertalanffy growth parameters above of the species, and using the inverse of the VBGE, the age at first maturity (t_M) was calculated as 2.56 years. Finally, the L_M / L_∞ ratio was 0.45.

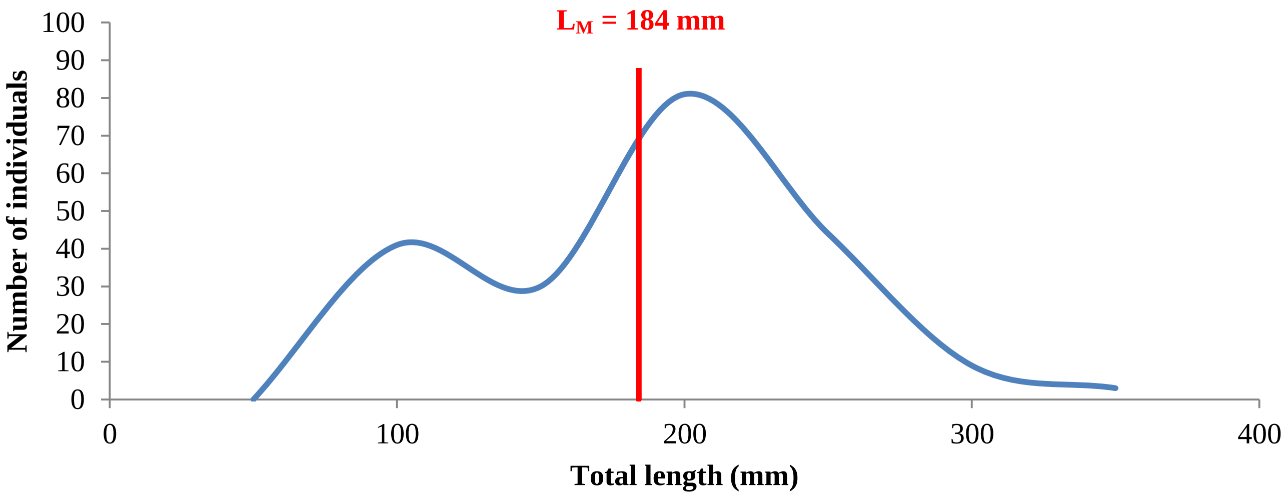

Figure 5. Length distribution (blue line) per caught individual and L_M limit (red line) of common dab (*L. limanda*), Northumberland coast (May-June 2014).

Discussion

The use of otoliths is considered as an appropriate method for age determination of slow-growing and long-lived species such as dab. In the present study, age distribution of dab ranged from 1 to 7 years after the reading of 112 otoliths from individuals ranging from 55 mm to 335 mm total length. The age composition of dab was dominated mostly by 2 (33%) and 3 (25.9%) years old fish. After the analysis of 1521 otoliths the age distribution of dab caught in the southeastern North Sea ranged from 1 to 12 years from individuals with a mean length at age ranging from 90 mm to 320 mm (Rijnsdorp *et al.*, 1992). However, the age composition was dominated by 4 and 5 years old fish, whereas only 6 individuals were older than 10 years and two were 1 year old. The length ranges of the two studies differ in the absence of small dab, probably due to the different sampling gear and period. In addition, despite the almost same largest recorded fish length, the age classes seem to differ considerably. The reasons of the difference between the age ranges could be attributed to the different latitudes of the sampling areas and the sampling sizes (Nash and Geffen, 2000), or to uncertainties during the age determination process.

For dab the main difficulty in ageing is the discrimination of the first annual ring from the false ring (ICES, 2010). Other difficulties are the misinterpretation of the occurrence of thinner split rings (which leads to overestimation of the age) and the identification of annual rings close to the edge of the otolith (which leads to underestimation of the age) (personal observation). Recently, an ageing workshop based on dab otoliths took place in order to improve and evaluate the age determination (ICES, 2010), where otoliths from 160 individuals of the North Sea ranging from 110 mm to 300 mm were analyzed, and the age distribution ranged from 1 to 8 years. These results are very similar to those of the present study.

The estimated growth parameters of the present study are similar to those of the Rijnsdorp *et al.* (1992) study. The growth coefficient ($K=0.237\ y^{-1}$) of the present study is relatively slow which comes to an agreement with other studies (Rijnsdorp *et al.*, 1992). In addition, t_0 found as -0.022 y, which indicates that the early stages of the fish life are well described by the VBGE. However, L_∞ was found to be 406 mm and considerably higher than gender dimorphic estimations of 334 mm (males) and 231 mm (females) from the southeastern North Sea (Rijnsdorp *et al.*, 1992). In general, differences in growth parameters between different areas could be related to geographical attributes, water temperature, food availability (Santic *et al.*, 2002), as well as to sampling gear selectivity (Potts *et al.*, 1998). Correspondingly, differences in L_M can also affect the growth parameter estimations (Cengiz *et al.*, 2012). The maximum observed length to asymptotic length ratio (L_{MAX} / L_∞) was calculated as 0.82, which shows that the species reaches the 99% of its potential growth over its lifespan (Beverton, 1963).

In the present study, dab was found to reach sexual maturity after its second year of life (t_M=2.56 y) at a length of 184 mm. In contrast, dab in the southeastern North Sea were found to reach sexual maturity at a length of 110 mm and 140 mm for males and females respectively but at the same age of the present study (Rijnsdorp *et al.*, 1992). This difference can be attributed to the higher exploitation rates in the northeastern North Sea or to environmental issues, as L_M reduces in stocks with high mortality rates (Wootton, 1990). The dimensionless ratio L_M/ L_∞, which expresses the proportion of the potential growth span of the species covered before maturation was estimated as 0.45. In general, the L_M/ L_∞ ratio is larger for small sized species and smaller for large size species (Longhurst and Pauly, 1987).

The 60% of the total catch in the present study was caught before dab spawns at least once over its lifespan. However, all gears that had been used had a scientific mesh size. Comparing to the catch data of a commercial vessel the rate of the present study was considerably higher (Figure 6). Specifically, only the 20% of a commercial catch was found to be undersized in the same area (Sweeting *et al*., 2011). The difference is attributed to the different mesh sizes that had been used, as commercial mesh sizes are larger than scientific ones.

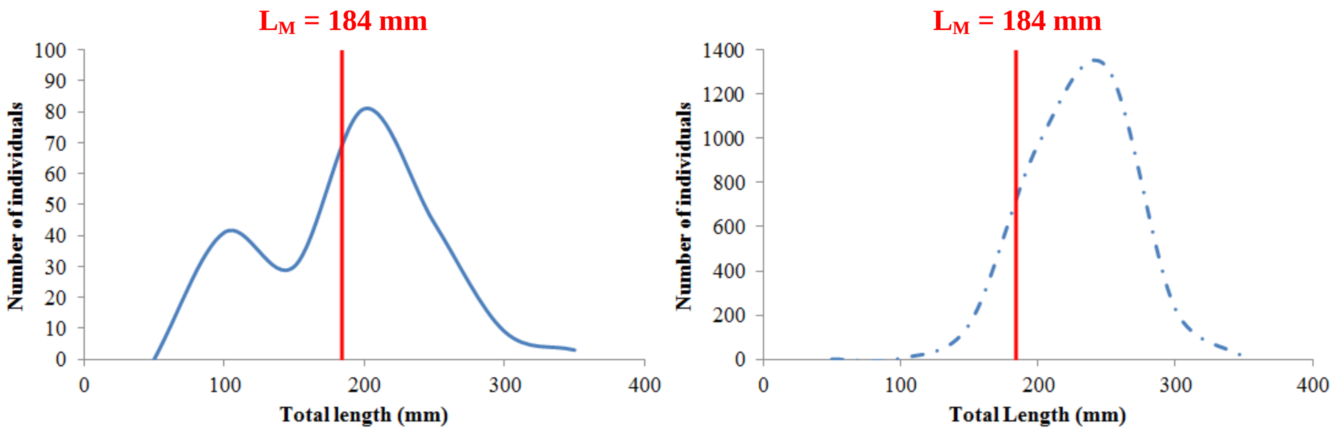

Figure 6. Comparison between common dab (*L. limanda*) catch composition of the present study (solid blue line) and the local commercial fishery (dashed blue line). The L_M (red line) is also given.

The overexploitation of immature individuals may have severe consequences for future recruitment and stock conservation (Myers *et al.*, 1997). In European fisheries, legal MLSs are set for most commercial species, creating a commercial precaution from catching undersized fish (Catchpole *et al.*, 2005). The MLS should always exceed the L_M giving the opportunity to every species in every stock to spawn at least once over their lifetime before being caught (Tsikliras and Stergiou, 2014), preventing as well recruitment overfishing of being occurred.

For the Northumberland Inshore Fisheries and Conservation Authority (NIFCA) area of jurisdiction 13 MLSs are set for commonly caught species. However, the only flatfish species that are protected under a MLS restriction are megrim (*Lebidorhombus whiffiagonis*), sole (*Solea solea*) and plaice (*Pleuronectes platessa*).

Despite its key role in the food web, because of its great abundance, as both predator and prey, no MLS restriction is set for dab (*NIFCA*, 2014). According to ICES, no specific management objectives for dab sustainability are known and no analytical assessment can be presented due to the lack of reliable catch data either (ICES, 2013a). The only existing regulation is a Total Allowable Catch (TAC), set for the combined catch of dab and flounder (*Platichthys flesus*) in the North Sea (*Council Regulation 43/2014*, 2014). This mixed TAC is lacking in accuracy of catch statistics for dab though, as it does not segregate the two species. Moreover, TACs do not seem very helpful for bycatch species, as many surveys of discarding practices indicate that a very high proportion of dab caught were discarded (ICES, 2013).

Conclusions

The highly and rapidly increased commercial value of dab in combination with the landing obligation of the new Common Fisheries Policy (CFP), which will be introduced gradually between 2015 and 2019 for all commercial fisheries in European waters, will lead to the creation of a new market for dab, as fisheries will be obliged to land it rather than to discard it. Therefore, a MLS restriction is required to be applied and exceed the length at which dab reach sexual maturity. Thus, the present study suggests that the MLS for dab in the NIFCA district should be 185 mm in order to maintain its population in a sustainable way, and prevent the stock of being overexploited when its market value peaks. However, in order to have a more reliable estimate for the North Sea, a further and more comprehensive study should be undertaken that will consider all the biological and population characteristics of the species.

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Appendices

LITERATURE REVIEW

Common dab (*Limanda limanda*) fishery in the North Sea; How did it change and what we might need to do in the next 10 years.

In response to a request from Dr Chris Sweeting this review describes the biology of common dab (*Limanda limanda*) and its fishery in the North Sea. Specifically, information for its geographical distribution, habitat, trophic biology, age and growth, reproduction, stock state and its role as a main bycatch species in the North Sea fisheries is being given. In addition, all existing and future management considerations are presented in order to maintain its population in a sustainable way, and prevent the stock to be overexploited.

Geographical distribution

The common dab (*Limanda limanda*) is the most abundant flatfish species in the North Sea (Rijnsdorp *et al.*, 1992) and northeastern Atlantic (Beggs and Nash, 2007) and the third most abundant fish in the North Sea (Sparholt, 1990) after sprat (*Sprattus sprattus*) and sand eel (*Ammodytes marinus*).

Dab is an edible widespread demersal Pleuronectid (*DEFRA*, 2013) distributed in the northeast Atlantic shelf (Figure 1) living in coastal waters from the Bay of Biscay in the south, to as far north and east as Iceland and Norway respectively, including the Barents, White and Baltic Seas (Henderson, 1998).

Figure 1. Geographical distribution of common dab (*L. limanda*) over the northeast Atlantic region (*FAO*, 2011).

Habitat and identification characteristics

Dab inhabits mostly in sandy or muddy sediments (Green and Lart, 2014) and is frequently caught down to depths of 100 m (Bohl, 1957), although it can occasionally be found in deeper waters of 150 m (Daan *et al.*, 1990). The main identification differences between dab and other flatfish are that its body scales are finely toothed on the free edge and the eyed side has a distinctively rough feel, which on the blind side is noticeable only along the edges of the body. In addition, its lateral line is strongly curved the pectoral fin.

Trophic biology

Feeding strategy

According to their morphology, dab can be classified as visual feeder with relatively large eyes, small jaw and the ability for fast acceleration comparing to other common flatfish species in the North Sea (Piet *et al.*, 1998). Dab has a relatively wide prey spectrum (Hinz *et al.*, 2005) feeding mainly on benthic organisms such as crustaceans, polychaetes, molluscs and occasionally on small fish. Juvenile dab consume mainly harpacticoid copepods, bivalvia (*Mysella bidentata*) and polychaetes (palps of *Magelona mirabilis* and Spionidae sp.) (Amara *et al.*, 2001). Larger individuals consume also Hydrozoa and amphipods. On the other hand, the major predators for juvenile dab are grey gurnard (*Eutrigla gurnardus*), poor cod (*Trisopterus minutus*) and whiting (*Merlangius merlangus*), while cod (*Gadus morhua*) predates also larger individuals (Henderson, 1998). In the North Sea dab tend to aggregate in recently trawled areas to feed (Kaiser and Spencer, 1994). This is occurring because dab are classified as opportunistic consumers (Knust, 1991). Hence dab follow the trawled paths and feed on any disturbed, damaged, dead or discarded benthic organism (Groenewold and Fonds, 2000).

Trophic level

Two main techniques in order to estimate the trophic level of an organism are mostly used. Carbon and Nitrogen stable isotope data are commonly used to describe the trophic level of individuals and to understand their trophic dynamics (Barnes *et al.*, 2007). Hence a reliable analysis of stable isotope data is requiring well knowledge of the isotopic fractionation between prey and predator. The other way to describe the trophic level of a fish is through the relation of their productivity level and their food consumption (Yang, 1982). Although it is not absolutely accepted that organisms with higher body mass feed always on higher trophic levels (Jennings *et al.*, 2001a), dab has a significant and positive correlation between its body size and its trophic level (Jennings *et al.*, 2002b). Dab has a relatively high trophic level (4.2) despite the fact that it mainly feeds on benthic invertebrates (Pinnegar *et al.*, 2002). An explanation for this high trophic level is that many polychaetes feed exclusively on other polychaetes, which gives them and their predators also a high trophic level (Jennings *et al.*, 2001b). Thus, due to invertebrates' large contribution to production and biomass in general, a change of their abundance may have a significant influence on the trophic level of species in an ecosystem (Jennings *et al.*, 2002a).

Age and growth

Dab has a relatively slow growth, while female grow slightly quicker than male and attain a longer total length at age, especially after their third year of life (Rijnsdorp *et al.*, 1992). Like most flatfish, dab is a long lived species with a life expectancy of 11 years (Henderson, 1998) and can reach to a total length and weight up to 33 cm and 400 g respectively (Jennings *et al.*, 2001a).

Sexual maturity occurs in males at the second year of their age and 11 cm, while in females at the second or third year and 14 cm (Bohl, 1957).

Reproduction biology

In the North Sea, dab is spawning its planktonic eggs (Munk and Nielsen, 2005) between January and September with a peak spawning starting in May to June (van der Land, 1991). It is a high-fecundity batch spawner (Murhua and Seborido-Rey, 2003) that releases its eggs over a prolonged period of time. This spawning strategy may be the reason for the presence of dab eggs for a longer period of time (Daan *et al*., 1990). Dab spawning grounds are offshore in fine sediment types (mainly sand and gravel), typically in shallow waters with intermediate depth of 30-50 m deep (Henderson, 1998). Dab eggs hatch after three to twelve days of incubation (Martin *et al*., 2010) and larval stages remain pelagic until stage 5 individuals metamorphose into demersal juveniles (Rijnsdorp *et al*., 1995).

Other uses of dab

Because of its sedentary nature, and its high abundance, wide distribution and high disease frequency, dab has proved to be a valuable eco-toxicological indicator (ICES, 2013). In addition, dab is an important species in pollution monitoring programmes in the North Sea (Rijnsdorp *et al.*, 1992) such as occurrence of embryonic deformities (Cameron *et al.*, 1992), analysis of tissue residues (Dethlefsen *et al.*, 1987) and epidemiological surveys (Vethaak and ap Rheinallt, 1992). In addition, dab is often used as bait in pots of lobster fisheries or as an angling fish, due to its delicious flavor.

Dab fishery

<u>Discards</u>

Dab is generally caught as bycatch in the fishery directed at other flatfish (e.g. plaice and sole), brown shrimp and other demersal species, mainly in the beam trawl and bottom otter trawl fisheries, and is often discarded based on the availability of target species and market price (ICES, 2013). Dab is among the species which suffer the highest discard mortality (Depestele *et al.*, 2014) with a low survival rate upon discarding of 24% (Kaiser and Spencer, 1995). Specifically, in a flatfish targeting beam trawl fishery, almost 90% (42 tonnes, 750,000 individuals) of the caught dab were discarded, while the percentage reached its maximum when the beam trawl fishery was targeting in brown shrimp (*Crangon crangon*) (246 kg, 26,600 individuals). In addition, the discard rate of dab was almost 60% (494 kg, 4,500 individuals) in a demersal fish targeting otter trawl fishery using a 120 mm codend, while the rate rise to 82% (48.6 tonnes, 670,000 individuals) with a 80-100 mm codend (Ulleweit *et al.*, 2010). In 1998, the annual mass of dab discards produced by beam trawls in the southern North Sea was estimated at about 180,000 tonnes dead dab (Groenewold and Fonds, 2000).

<u>Stock state</u>

Relative abundance of dab has increased almost 40% from the early 1900's to the late of the same century (Rijnsdorp *et al.*, 1995). Despite high rates of exploitation mainly as a bycatch, in June 2013 North Sea abundance indices indicate a stable and an increasing stock for subarea IV and division IIIa respectively, over the past 20 years. These indicators suggest that the North Sea dab populations are currently stable or increasing, and at low risk that current exploitation is unsustainable (Green and Lart, 2014). Specifically, the stock size indicator (number/hour) in the North Sea is 7% higher in recent years 2010-2012, compering to the average of the five previous years (2005-2009) (Green and Lart, 2014).

The factors leading to dab's resilience to fishing pressure are not fully understood as exploitation levels are similar to other flatfish species (Hinz *et al.*, 2005). Many alternative explanations have been given to clarify this phenomenon, such as the reduction of dab predators (Greenstreet and Hall, 1996). Other explanations of this resilience are that, eutrophication and the effects of trawling disturbance increase prey availability and accessibility for dab (Kaiser and Ramsay, 1997), or that the early maturity of dab allow them to spawn before they recruit to the fishery (Pope *et al.*, 2000).

Catches and landings

Dab is landed mostly by UK, Dutch, German and Danish fishing fleets and according to landing statistics the annual catch of dab in the North East Atlantic (Figure 2) has been above 11,000 tonnes since the 1950's. Catches peaked at 22,000 tonnes in 1998 but have since declined to just over 10,000 tonnes (*ICES*, 2011). A decline in catches and size of dab has also been reported in the early 1970's in the Humber and Thames estuaries and it was suggested that increased predation by cod was partly responsible for the decline (Clark, 1971). In addition, landings decreased in subarea IV and division IIIa since 2000 (ICES, 2013). The value and quantity of landings by UK vessels into the UK and abroad, and by foreign vessels into the UK, were £637,645 and 964 tonnes respectively in 2013 and have decreased by 50% and 58% respectively since 2001 (£1,280,500 and 1,640 tonnes) (Figure 3). Based on the ICES approach for data limited stocks, ICES advises that dab landings should not be more than 7,795 tonnes. Despite the fact that discards are known to take place, the data are insufficient to estimate a discard proportion that could be applied to give catch advice, and therefore total catches cannot be estimated (ICES, 2013).

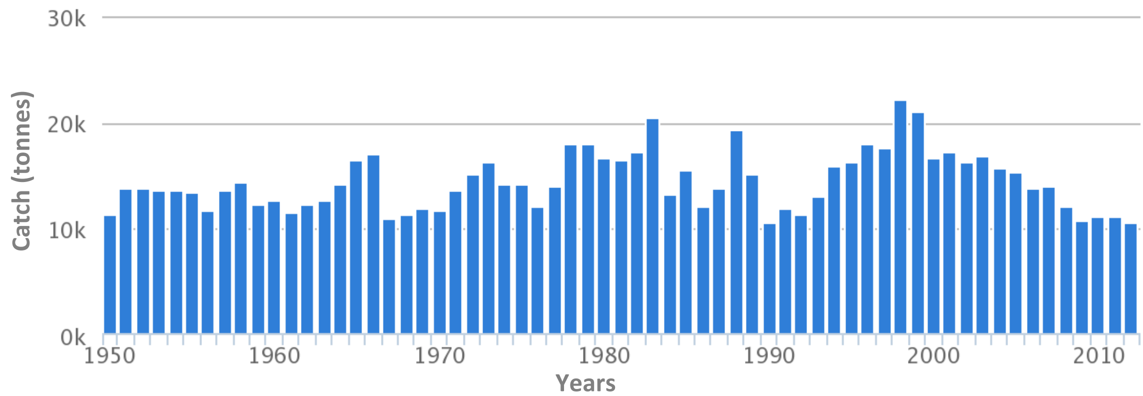

Figure 2. Annual reported catches of dab (*L. limanda*) for the northeast Atlantic region from 1950 to 2010 (*FAO*, 2011).

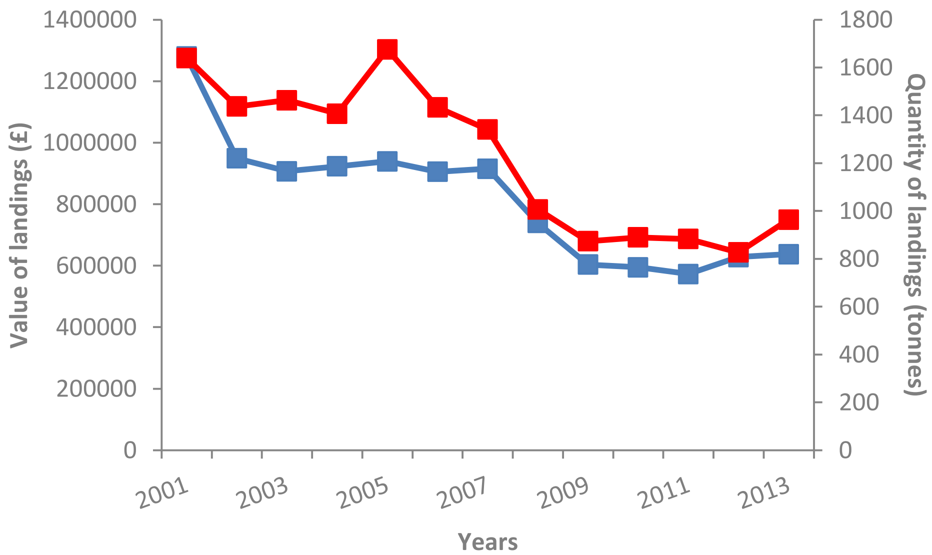

Figure 3. Value (blue line) and quantity (red line) of landings by UK vessels into the UK and abroad, and by foreign vessels into the UK for common dab (*L. limanda*) from 2001 to 2013 (*The Scottish Government*, 2014).

Current consumption

In previous years dab was not highly rated as a commercial fish and had been overlooked in favour of other flatfish. However, campaigns to reform the ineffective commercial fishing policies of Europe urge people to become more willing to try other species (*Marine Conservation Society*, 2014). Thus, dab became more popular and consumers choose it more often as a food fish. In fact, Retail sales of dab for the year ending September 2008 were £1,943,000, compared with £1,325,000 the year before (Gillan, 2008). Dab's growing reputation is also helped by its cheap price (£8.5/kg) comparing to other more expensive flatfish such as Dover sole (*Solea solea*) (£33/kg), brill (*Scophthalmus rhombus*) (£16.5/kg) and plaice (*Pleuronectes platessa*) (£15.2/kg) (*Fish in a box*, 2014).

Existing and future management considerations

However, despite its key role in the food web, because of its great abundance, as both predator and prey, there are neither conventional stock assessments nor information on the stock identity for this species. According to ICES, no specific management objectives for dab sustainability are known and no analytical assessment can be presented due to the lack of reliable catch data (ICES, 2013a). The only existing regulation is a Total Allowable Catch (TAC), set for the combined catch of dab and flounder (*Platichthys flesus*) in the North Sea (*Council Regulation 43/2014*, 2014). This mixed TAC is lacking in accuracy of catch statistics for dab though, as it does not segregate the two species. Moreover, TACs do not seem very helpful for bycatch species, as many surveys of discarding practices indicate that a very high proportion of dab caught were discarded (ICES, 2013).

According to the landing obligation of the new Common Fisheries Policy (CFP), which will be introduced gradually between 2015 and 2019 for all commercial fisheries in European waters, all catches have to be kept on board, landed and counted against the quotas. Undersized fish cannot be marketed for human consumption purposes. This fact will lead to the creation of a new market for this species with multiple benefits. On the one hand this will take pressure off the already overfished stocks such as cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*), and on the other hand the value of this species will increase, making commercial fisheries to land dab, rather than treating it as an unwanted bycatch. This change in regime serves as a driver for more selectivity, and provides more reliable catch data.

Thus, due to the future highly and rapidly increased commercial value of dab, which will obligate fisheries to land it rather than to discard it, a Minimum Landing Size (MLS) restriction is required to be introduced. There is no existing MLS restriction for dab (*NIFCA*, 2014) and this will help to maintain its population in a sustainable way, and prevent the stock to be overexploited when its market value peaks.

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