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Biology of anglerfish *Lophius piscatorius* in Faroese waters

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ABSTRACT

Anglerfish in Faroese waters are exploited in Faroese gillnet and trawl fisheries. The age, growth, and reproduction of anglerfish are studied using data from 2001-2006. Age was determined by counting the growth rings in sectioned illicia, sampled from anglerfish caught by the commercial fleet and in fisheries research surveys. The gonad maturity was visually classified into five stages where stage one is immature through to stage four being ripe or spawning and stage five being spent.

Female anglerfish grow larger and reach older ages than males. Significant differences between sexes were found when comparing growth in weight related to length and mean length at age for fish older than six years. Growth until maturation was around 9 cm per year and around 5 cm per year after maturation for both sexes. The conversion factor for gutted weight to round weight (g) for all sampled anglerfish was 1.27. Females had a higher conversion factor than males. Proportion of females and males analysed by length was roughly equal in the length interval up to around 60 cm, between 60-75 cm males were slightly more numerous, and over 75 cm females were predominant. Fish larger than 110 cm were all female. Length at first maturity ($L_{50\%}$) was calculated to be 83 cm for females and 57 cm for males. This corresponds to an age at maturity of around eight years for females and five years for males. Gonadosomatic index (GSI) values higher than 10% were taken to indicate signs of maturation and were found in females larger than 90 cm. Male GSI increased after a length of about 55 cm, which confirms male length at first maturity. Based on observations of ripe females and GSI data, the spawning season is suggested to be in late winter and early spring. Findings of egg ribbons and pelagic anglerfish larvae, together with other observations, suggest that there is some spawning activity of anglerfish in Faroese waters. The results of the present anglerfish study are comparable with those reported from other areas of the north Atlantic.

Keywords: Faroe Islands, *Lophius piscatorius*, anglerfish, age, growth, sex ratio, reproduction, maturity ogive.

INTRODUCTION

The Faroe Islands are located in the northeast Atlantic at 62°N and 7°W, where the North Atlantic Current and the East Icelandic current meet in the Polar Front (Hansen *et al*., 1998) (Figure 1). This highly productive marine environment contains several fish species that have their feeding and spawning grounds in Faroese waters, as well as several migratory species.

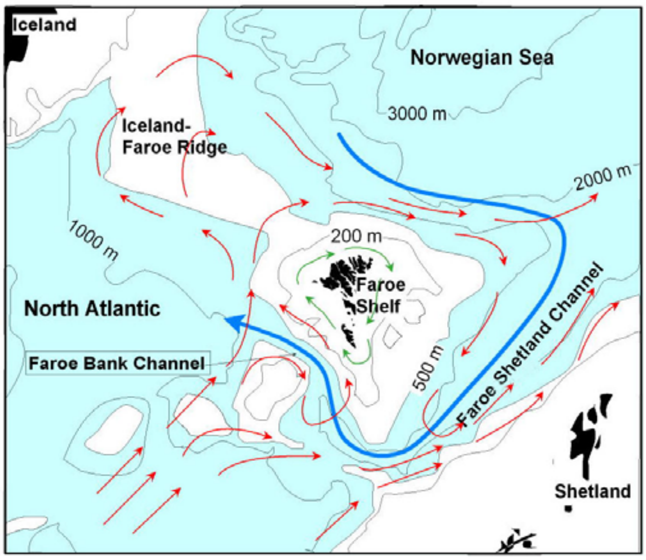

Figure 1. Topography and the current system around the Faroe Islands. Red arrows: warm currents in upper layers, blue arrow: main cold flow in deep layer, green arrows: currents on Faroe Shelf.

Anglerfish (*Lophius piscatorius* Linnaeus, 1758) in Faroese waters (ICES area Vb) have in recent years become a highly exploited resource and also one of the most valuable fish species in Faroese fisheries. The direct fishery for anglerfish started in the early 1990s (Reinert, 1995), and has increased to reach 5500 tonnes in 2006. The annual increase in landings of more than 1000 tonnes per year from 2003 - 2005 may be due to a more directed fishery and is a consequence of the availability of more traditional stocks. Landings have historically been from demersal trawl but a direct gillnet fishery started in 1993 and now accounts for 42 % of anglerfish landings. There is no ICES assessment of anglerfish around the Faroes.

Anglerfish in Faroese waters is probably part of a wider stock since no genetic differences were detected between anglerfish in Nordic areas (O'Sullivan, 2005). Tagging studies in Shetland demonstrated that anglerfish migrated to Iceland and Faroes (Laurenson *et al*., 2005) and also to Norway (Laurenson *unpub. data*). And a reciprocal migration from Norway to Shetland was also demonstrated (Bjelland *unpub. data*). Tagging in Faroese waters have demonstrated migration of anglerfish from Faroes to Iceland (Ofstad *unpub*. data). A particle tracking model presented by Hislop *et al*. (2001) indicated that anglerfish spawned at Rockall could be transported to Faroese waters as well as towards the northern North Sea. This may imply that anglerfish over a large area of the northeastern Atlantic could belong to one stock.

Even though anglerfish in Faroese waters may be part of a much wider stock, biological parameters, such as growth, may vary over the wider distribution area. The present study is a first attempt to describe the biology of anglerfish in Faroese waters. The aim of this paper is to present results from a study on age, growth and reproductive biology of anglerfish (*Lophius piscatorius*) around the Faroe Islands using data collected between 2001 and 2006. The results are compared to studies from other regions.

MATERIAL AND METHODS

All the material was sampled from anglerfish caught by the commercial fleet (demersal trawl and gillnet) and in fisheries research surveys (using demersal trawl) around the Faroe Islands in the period 2001-2006. The length range in the anglerfish samples is from 11 cm to 142 cm. The commercial samples are mainly from an area called Skeivibanki south-west of the Faroe Islands at a depth of about 300-400 m and from an area to the north of the Islands at a depth of around 250 m. The anglerfish samples from the annual surveys cover the entire Faroe Plateau and the depths are usually less than 500 m. A few anglerfish samples were obtained from deep-sea surveys that cover depths down to 800 m. Data on *Lophius* juveniles (length range 7-130 mm) are recorded during the regular Faroese 0-group surveys. This survey is during the months June and July and pelagic samples are taken in depths less than 100 m, with a few stations from 100-200 m (Gaard & Reinert, 2002).

The programs used for data treatment were Excel and R.

Length-weight relationship and conversion factor

The length-weight relationship was described using round weight (W_r), gutted weight (W_g) (g) and total length (L) (cm) using multiplicative functions.

Conversion factors for gutted weight to total weight relationships were calculated by forcing the linear relationship through the co-ordinates origin.

The length-weight relationship data were first log transformed for normality. Anova analysis was used to test the differences between the two regression lines (females and males) (Fowler *et al*., 1998).

Age and growth

Age was determined by counting the growth rings in sectioned illicia in the same way as described in the report from ageing workshop in Lisbon 2004 (Duarte *et al*., 2005).

For growth, the von Bertalanffy growth equation was fitted, calculated as

$L_t = L_\infty (1 - e^{-K(t-t0)})$
where L_t = total length (cm) at age t, L_∞ = average maximum asymptotic length, K = instantaneous growth coefficient, t_0 = the point where the fish has zero length.

An overall test of coincident curves was performed using the method proposed by Chen *et al*. (1992), in Haddon (2001), called analysis of the residual sum of squares (ARSS), to test the difference between female and male growth.

Reproduction

Sex was determined by macroscopic examination of the gonad. Males have a white tube-shaped gonad, while females have a band-shaped gonad (Duarte *et al*., 2001, Thangstad *et al*., 2006). The gonad maturity was visually/ macroscopically classified into five maturity stages where one is immature through to stage four being ripe or spawning and five being spent (Thangstad *et al*., 2006). Maturity stage one and two was treated as immature and stages three to five as mature fish. A few fish were not sexed due to that they were gutted or the sex was not recorded.

Length/weight/age at maturity were calculated by determining the proportion of reproductively active fish (maturity stages three to five) per size/weight/age class by fitting a logistic ogive of the form

$Y_i = 1/(1+ e^{(-a-bXi)})$
where Y_i is the proportion of mature fish in class i, X_i is length, weight, or age, respectively, and a and b are the function parameters.

The gonadosomatic index (GSI) was calculated as:

$GSI= W_{gon}/W_t *100$
where W_{gon} is the weight of gonad mass (g) and W_t is the total fish weight (g).

RESULTS

Length-weight relationship and conversion factor

Relationship between length and weight (round and gutted) split by sex are shown in Figure 2-3. Fitted relationships by sex and total (female + male + unsexed fish) are given in Table 1-2. The data illustrate that females grow larger than males. There are significant differences ($F_{3\ 4067}= 9.508e^{+4}$, $P<<0.01$) in both length-round weight and length-gutted weight relationship between females and males. The largest male in the samples was 107 cm while the largest female was 142 cm.

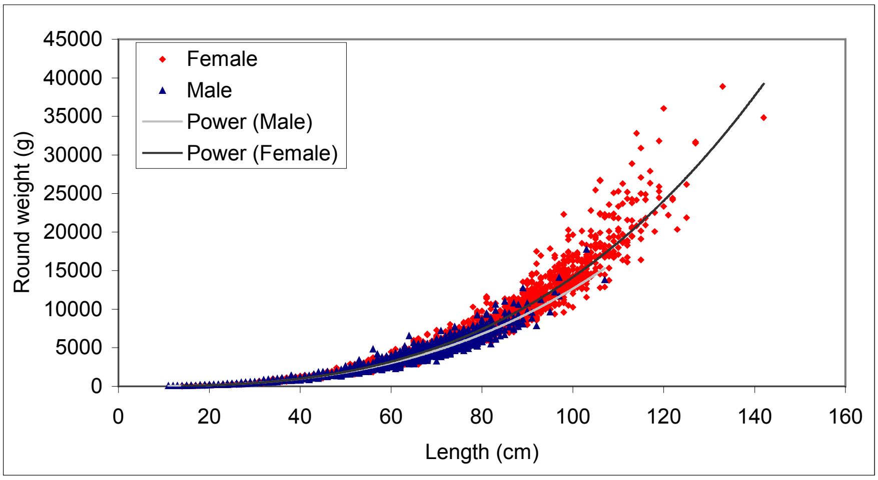

Figure 2. Length-round weight relationship for female and male anglerfish.

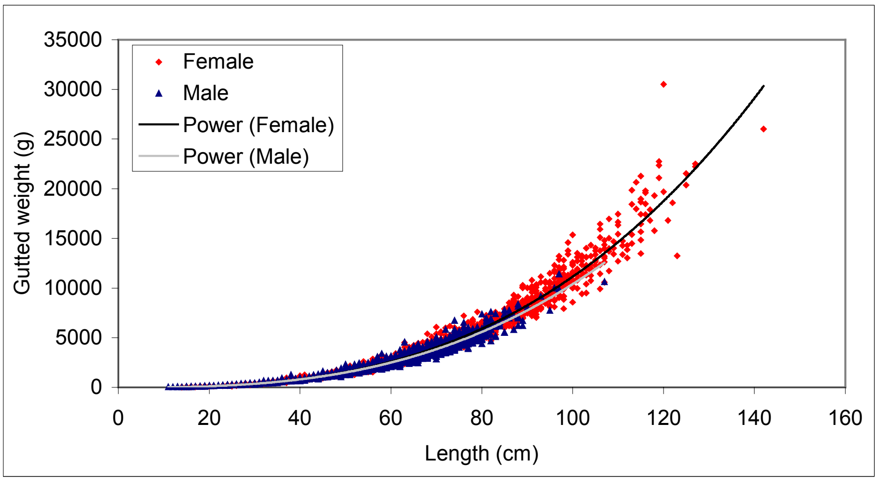

Figure 3. Length-gutted weight relationship for female and male anglerfish.

Table 1. Length-round weight relationship fitted with power equation for females, males and total (females + males + unsexed fish).

	Function	R^2	N	Length range (cm)	Weight range (g)
Female	$W_r = 0.0216 * L^{2.9079}$	0.987	2171	14 - 142	37 - 38900
Male	$W_r = 0.0319 * L^{2.7992}$	0.982	1900	11 - 107	26 - 17720
Total	$W_r = 0.0232 * L^{2.8861}$	0.984	4565	11 - 142	26 - 38900

Table 2. Length-gutted weight relationship fitted with power equation for females, males and total (females + males + unsexed fish).

	Function	R^2	N	Length range (cm)	Weight range (g)
Female	$W_g = 0.0219 * L^{2.8538}$	0.991	1701	14 - 120	32 - 30500
Male	$W_g = 0.0272 * L^{2.7909}$	0.986	1623	11 - 107	20 - 11390
Total	$W_g = 0.0230 * L^{2.8371}$	0.989	3407	11 - 142	20 - 30500

Conversion factors between weights (g) are shown by sex in Table 3 and Figure 4. There are significant differences ($F_{1\ 1699}$= 3.876e^{+5}, P<<0.01) in the conversion factor between females and males if all data are in the model. If only data with gutted weights less than 8 kg is taken into account is there no statistical difference between the sexes ($F_{3\ 3001}$= 2.31e^{+5}, t=-1.628, P=0.104).

Table 3. Conversion factor for gutted weight (W_g) to round weight (W_r) of females, males and total (females + males + unsexed fish).

	Conversion factor function	R^2	N	Length range (cm)
Female	$W_r = 1.2838 * W_g$	0.979	1701	14 - 142
Male	$W_r = 1.2154 * W_g$	0.988	1623	11 - 107
Total	$W_r = 1.2671 * W_g$	0.981	3407	11 - 142

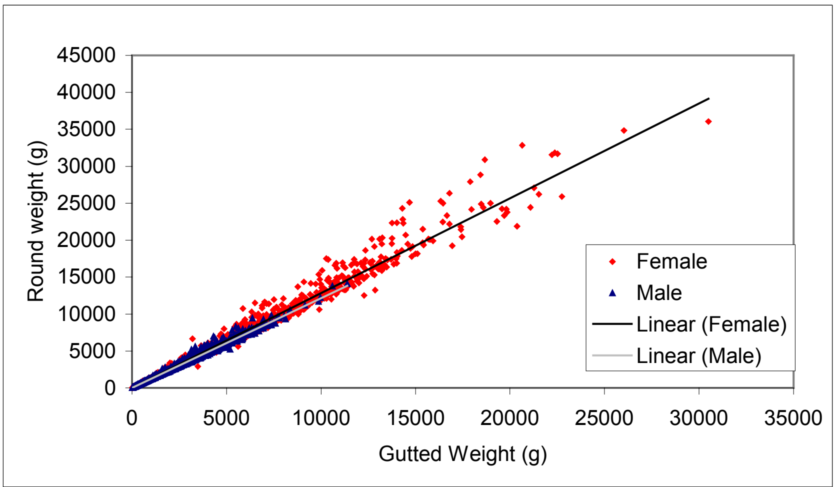

Figure 4. Conversion factor between gutted weight and round weight for female and male anglerfish.

<u>Age and growth</u>

Mean lengths at age were calculated from age readings of illicia. Mean length at age for females, males, and total (females + males + unsexed fish) are given in Table 4. There were no males older than 11 years in the samples and no female older than 15 years. T-tests show that there are no significant differences between females and males in mean length at age up to age three (P>0.2 in each case) and fish older than seven years have significant differences between sexes (P<0.05 in each case) (Table 4). For fish older than five years is there significant difference between the sexes in mean round weight at age (Table 5). The females become larger than males after around age five. The average growth until maturation was around 9 cm per year and around 5 cm per year afterwards for both sexes.

The L_∞ parameter of the fitted von Bertalanffy growth curves show that female anglerfish grow larger than males. There is a divergence between the fitted curves from around age 7 (Table 6 and Figure 5). The overall test of coincident curves between females and males show that there is a significant difference between the sexes ($F_{3\ 21}$= 5.222, P=0.007).

Table 4. Mean length at age and number for females, males, and total (females + males + unsexed fish). The P-value is the results of the t-test between females and males per age.

	Female		Male		Total		F-M
Age	Length (cm)	N	Length (cm)	N	Length (cm)	N	P-value
0	17.0	12	16.2	5	16.7	18	0.548
1	25.3	40	25.0	44	25.2	87	0.703
2	31.7	108	32.3	103	32.5	256	0.273
3	41.9	136	41.7	159	41.6	416	0.704
4	51.4	244	52.8	286	51.0	750	<0.01
5	59.2	228	60.2	361	59.1	940	0.019
6	68.0	221	67.3	324	66.5	1104	0.074
7	76.1	197	73.7	165	74.2	844	<0.01
8	85.0	180	79.6	67	82.1	584	<0.01
9	92.8	144	86.0	12	89.9	335	<0.01
10	98.1	146	87.5	6	96.1	230	0.012
11	103.4	96	88.0	1	101.2	132	
12	109.1	61			108.6	64	
13	111.5	26			111.5	26	
14	115.3	7			115.3	7	
15	119.0	1			119.0	1	

Table 5. Mean round weight at age and number for females, males, and total (females + males + unsexed fish). The P-value is the results of the t-test between females and males per age.

	Female		Male		Total		F-M
Age	Weight (g)	N	Weight (g)	N	Weight (g)	N	P-value
0	87	12	73	5	83	18	0.377
1	278	40	272	44	275	87	0.758
2	538	108	575	103	553	256	0.167
3	1197	136	1145	159	1064	416	0.346
4	2078	244	2173	286	1893	750	0.128
5	3085	228	3120	361	2763	940	0.649
6	4671	221	4239	324	3759	1104	<0.01
7	6385	197	5473	165	5096	844	<0.01
8	8759	179	6777	67	6859	584	<0.01
9	11440	135	8530	12	9242	335	<0.01
10	13885	118	8461	6	11794	230	<0.01
11	16232	66	8400	1	13455	132	
12	21584	25			16498	64	
13	21835	13			17814	26	
14	32180	2			21677	7	

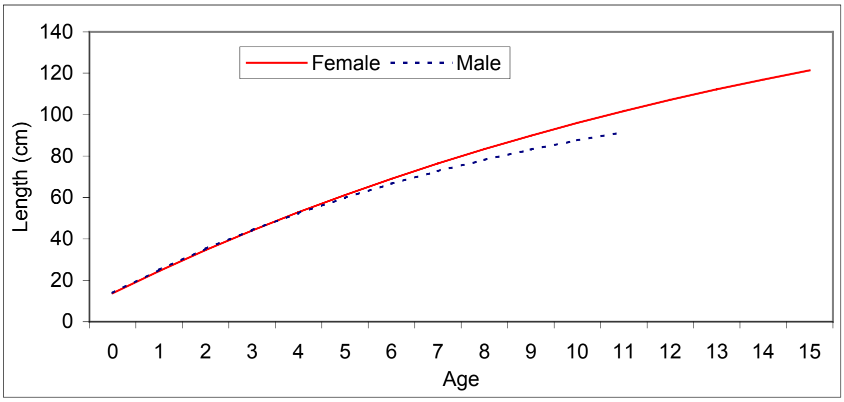

Figure 5. Mean length at age for female and male anglerfish.

Table 6. Parameters estimated in von Bertalanffy growth curve for females, males, and total (females + males + unsexed fish).

	Female	Male	Total
L_∞	191.38	129.38	210.73
K	0.06	0.10	0.05
t_0	-0.70	-0.62	-0.88
No. of ind.	1847	1546	5794

Sex composition

There were 14 % more females than males recorded (2186 females:1921 males). The proportion of females by length and age is shown in Figure 6. The percentage of females for lengths between 10 and 60 cm and in age between 0 and 4 years was approximately 50 %, except when there were few anglerfish samples. The proportion of males was highest between lengths of 60 and 75 cm and ages of 5 and 6 years. Afterwards the females dominate, and at lengths greater than 110 cm and 11 years, 100 % are females, with no males being recorded greater than 107 cm.

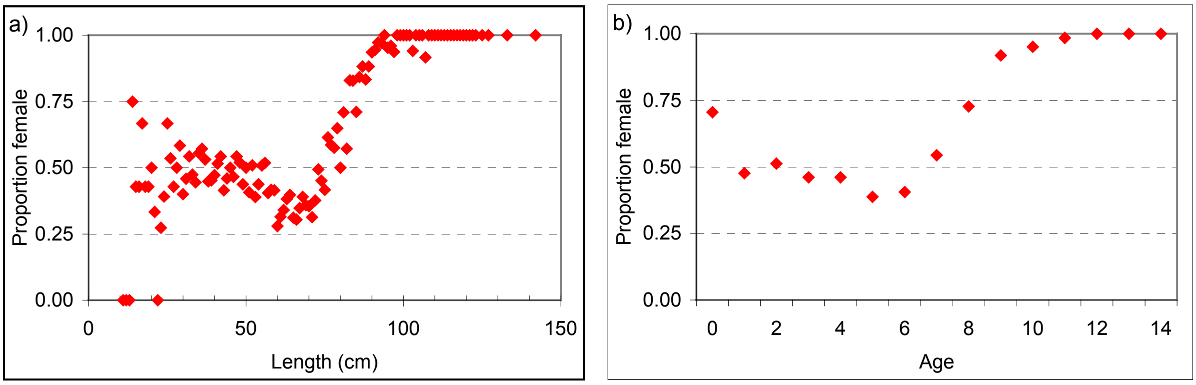

Figure 6. Proportion of females in each cm length group (a) and in each age group (b) for anglerfish in Faroese waters.

Reproduction

The maturity ogive for anglerfish was estimated using all data where maturity stages were three to five. The graphic analysis (Figures 7-9) shows that the length, weight and age of first maturity for females were 83 cm, 8 kg (round weight), and 7.8 years respectively. The percentage of mature females reaches 100 percent at lengths >110 cm, round weights >12 kg, and age >11 years. The length, weight and age of first maturity for males were 57 cm, 2.6 kg (round weight), and 4.7 years respectively. The calculated length, age, and weights of 25%, 50%, and 75% maturity for female and male anglerfish are showed in Table 7.

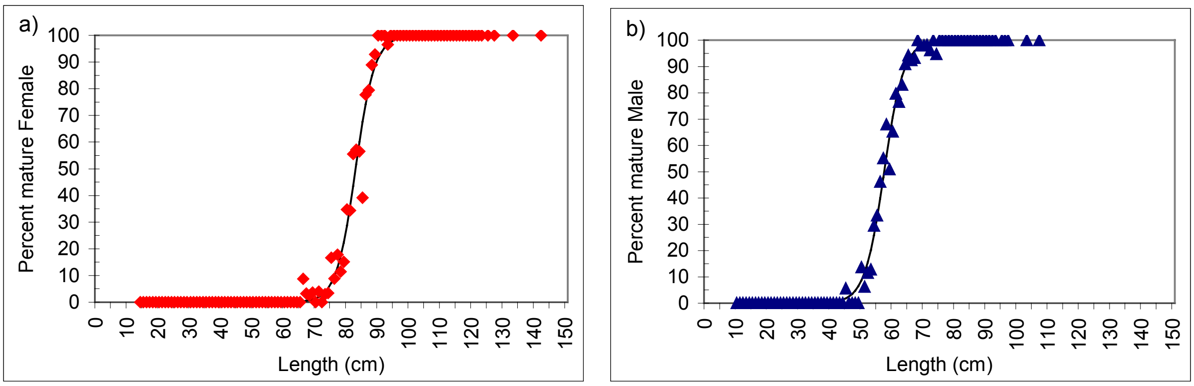

Figure 7. Maturity ogives for female (a) and male (b) anglerfish in Faroese waters as a function of length (female n=2080, male n=1882).

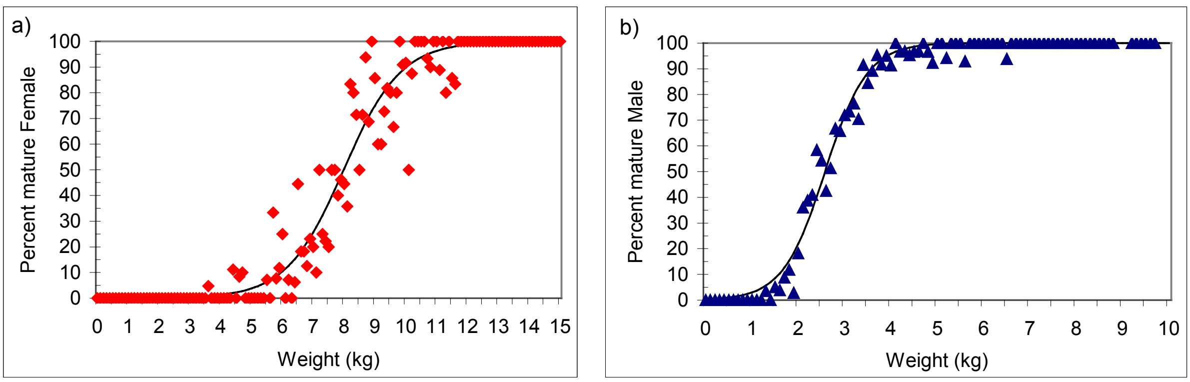

Figure 8. Maturity ogives for female (a) and male (b) anglerfish in Faroese waters as a function of round weight (female n=1905, male n=1869).

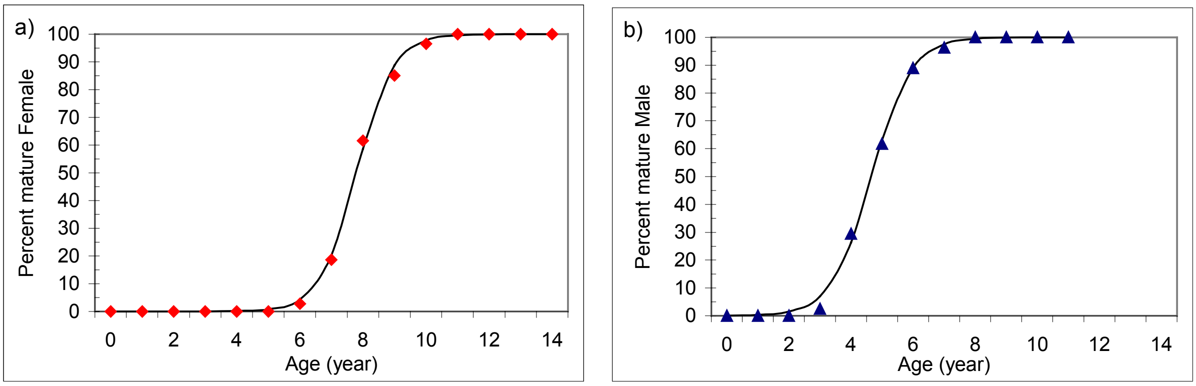

Figure 9. Maturity ogives for female (a) and male (b) anglerfish in Faroese waters as a function of age (female n=1700, male n=1505).

Table 7. Length, age, and weights of 25%, 50%, and 75% maturity for female and male anglerfish.

	Length (cm)		Age (years)		Round weight (kg)	
Female	L_{25}	79.45	A_{25}	7.16	W_{25}	6.97
	L_{50}	82.80	A_{50}	7.80	W_{50}	7.99
	L_{75}	86.15	A_{75}	8.44	W_{75}	9.00
Male	L_{25}	53.88	A_{25}	3.96	W_{25}	2.08
	L_{50}	57.30	A_{50}	4.66	W_{50}	2.58
	L_{75}	60.70	A_{75}	5.37	W_{75}	3.08

The gonadosomatic indices for all data grouped into females and males are presented in Figure 10-12. An increase in length, weight and age GSI occurs when the lengths are above 90 cm, round weights above 10-15 kg, and age above 9 years. For males a similar pattern occurs with lower values: lengths above 50 cm, round weights above 2 kg and age above 4 years.

Gonadosomatic index per month (Figure 13) for females and males show that the GSI is highest in the months from January- April for females and December to April for males. However, spawning males were observed year round. No GSI data were available for anglerfish in the months of May and July.

Average GSI per length for immature and mature female and male anglerfish show that mature fish have a higher GSI than immature fish (Figure 14).

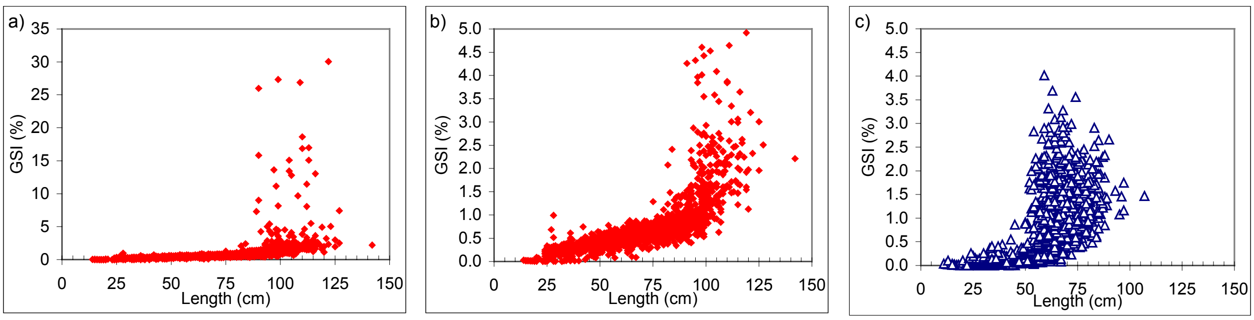

Figure 10. Gonadosomatic indices (GSI, %) of female (a, b) and male (c) anglerfish by length. Female n=1705 and male n=1424. For clarity, GSI values for females are shown both in full scale (a) and in reduced scale (b).

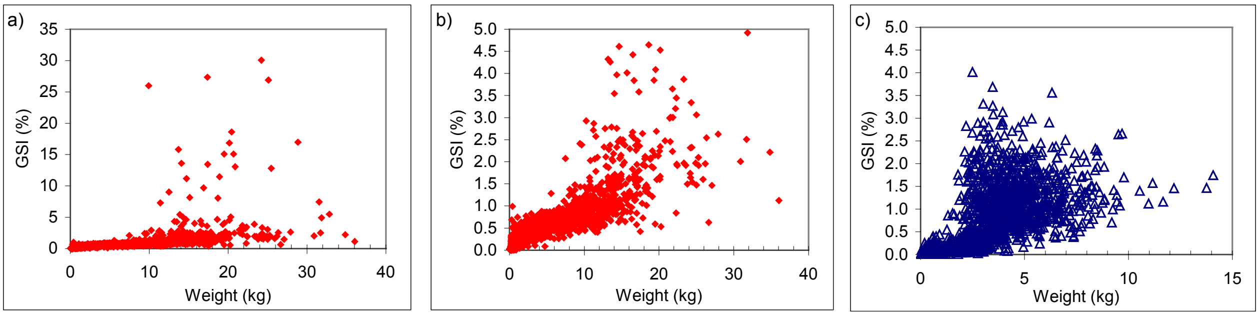

Figure 11. Gonadosomatic indices (GSI, %) of female (a, b) and male (c) anglerfish by round weight. For clarity, GSI values for females are shown both in full scale (a) and in reduced scale (b).

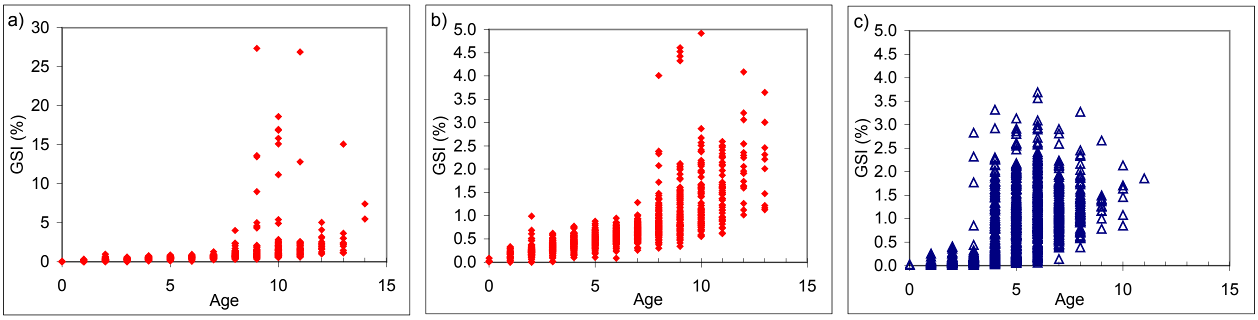

Figure 12. Gonadosomatic indices (GSI, %) of female (a, b) and male (c) anglerfish by age. For clarity, GSI values for females are shown both in full scale (a) and in reduced scale (b).

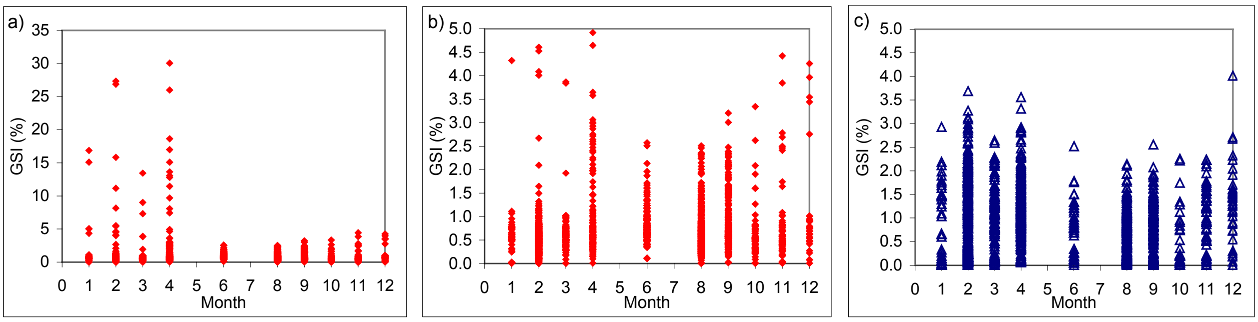

Figure 13. GSI per month for female (a, b) and male (c) anglerfish. For clarity, GSI values for females are shown both in full scale (a) and in reduced scale (b).

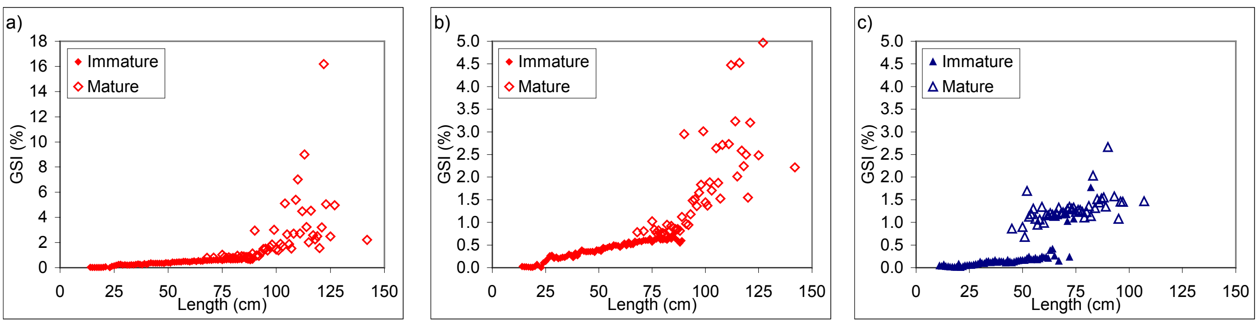

Figure 14. Average GSI per length for immature and mature female (a, b) and male (c) anglerfish. For clarity, GSI values for females are shown both in full scale (a) and in reduced scale (b).

During the period from 1984 to 2004 a total of only 73 *Lophius* larvae were recorded during the pelagic 0-group survey in June-July (Figure 15) and the length range was between 7-130 mm (Figure 16). Most of the pelagic larval stages were caught on the Faroe Bank, while the remainder were mainly recorded west of the Faroes.

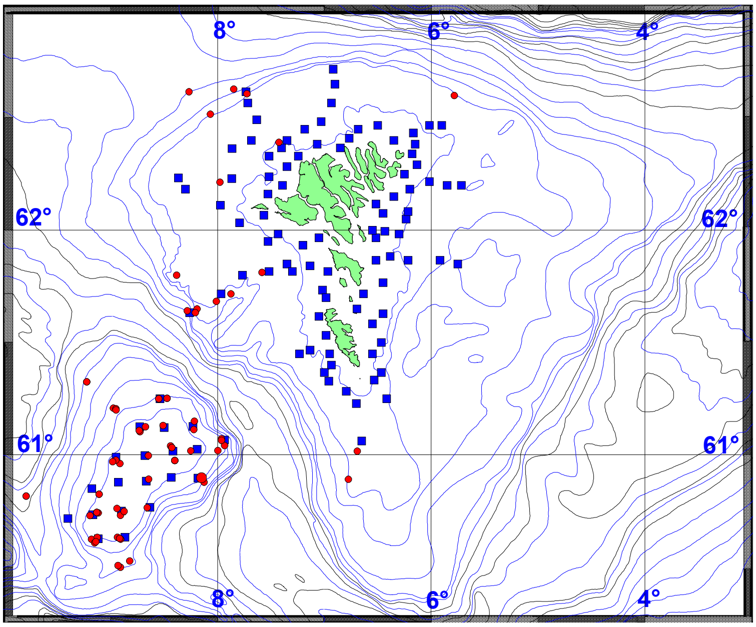

Figure 15. Observations of anglerfish larvae (n = 73) (red circles) from the pelagic 0-group survey in Faroese waters in June-July 1984-2004. The blue rectangles show positions of all stations in the survey. Depth contours are per 100 m.

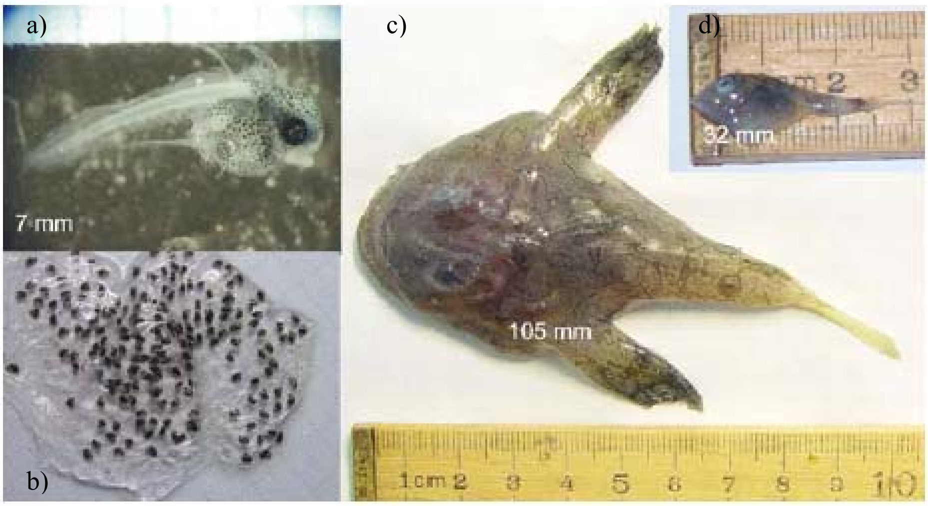

Figure 16. Examples of anglerfish larval stages caught during pelagic 0-group surveys in Faroese waters. (a) 7 mm long larvae from spawn jelly under light microscope, (b) larvae in spawn jelly, (c) 105 mm long fish in late larval stage and, (d) 32 mm long larvae.

DISCUSSION

Growth

The relationship between length-round weight and length-gutted weight of anglerfish in the present study are comparable with those published from other areas (e.g. Laurenson, 2003, Dyb, 2003, Quincoces *et al*., 1998, Alfonso-Dias, 1997, Crozier, 1989). In Faroese waters growth in weight related to length was significantly different for females and males. A significant difference by sex was also found in Norway (Dyb, 2003) and in the area west of Scotland (Alfonso-Dias, 1997). At Shetland (Laurenson, 2003) and in the Bay of Biscay (Quincoces *et al*., 1998), no significant differences between sexes for this relationship were found. One reason for this could be that in the Faroese, Norwegian and Scottish materials a larger proportion of large females were present. This will give a larger probability of differences between males and females because the sexes have a different growth pattern.

The conversion factor for all anglerfish data from Faroese waters is numerically higher than in other areas (Table 8), but there does not appear to be a latitudinal trend. The differences in conversion factor values are, in real terms, small and if uncertainty is taken into account, the conversion factors can be considered similar between the available studies. There was a significant difference between the conversion factor of females and males in the Faroese area when using all the data in the size range. But at sizes less than 8 kg gutted weight, no statistical differences were found between sexes. This is due to the large females that reach a much higher round weight than males. The conversion factor used by the Faroese authorities is 1.2 (Anon., 2003), somewhat lower than what is found in the present study, so estimated landings in round weight from the Faroese area may be underestimated.

Table 8. Conversion factor of anglerfish (*Lophius piscatorius*) from various North Atlantic areas.

Area	Conversion factor	Reference
Faroe Islands	$W_r = 1.267\ (\pm 0.09) * W_g$	This study
Norway	$W_r = 1.258 * W_g$	Dyb, 2003
Norway	$W_r = 1.23 * W_g$	Staalesen, 1995
Shetland	$W_r = 1.224 * W_g$	Laurenson, 2003
West of Scotland	$W_r = 1.207 * W_g$	Alfonso-Dias, 1997
Bay of Biscay	$W_r = 1.248 * W_g$	Quincices *et al*., 1998

The mean length at age estimate in this study seems to fit very well with the results from Norway (Staalesen 1995), Shetland (Laurenson, 2003) and the area west of Scotland (Alfonso-Dias, 1997) for the smaller ages (Figure 17). The mean length at age zero obtained from illicia readings in this study are equivalent to the lengths at age 1, also obtained from illicia readings, that were presented for the Bay of Biscay (Quincoces *et al*., 1998), and Spanish/Portuguese waters (Duarte *et al*., 1997, Landa *et al*., 2001) and for Greek waters, based on otolith readings (Tseminidis & Ondrias, 1980). This difference most likely is due to the difficulty in determining the first annulus. It has been shown that different age readers can assign ages differently on the same illicia (Duarte *et al*. 2005), so differences in mean length at age could be due to difficulties in the age reading of anglerfish.

The growth, based on illicia readings, in Faroese waters was around 9 cm per year until maturation and around 5 cm per year after maturation for both sexes. This growth corresponds with the growth from the tagging study in Shetland where recaptured fish had an average growth of 9.4 cm per year (Laurenson *et al*., 2005)

A method of using microincrements on lapilli to investigate ages of small anglerfish was used by Wright *et al*. (2002). They found that differences in age assignments between illicia and otolith could be because the translucent zones were formed at different times in different structures. They showed that an anglerfish could be 27 cm in length in September in its first year, but a fish with similar length in the spring would be a 1-group fish. In the present study, mean length at age for 1-group anglerfish was 26 cm. There can be false annuli in ageing because of stress caused for example by inadequate feeding or, at later stages, during reproduction. Another problem is that as the fish get older, their growth rate slows and in old fish successive annuli in the age reading structure become difficult or impossible to recognise so the age of the fish is under-estimated (Wootton, 1990).

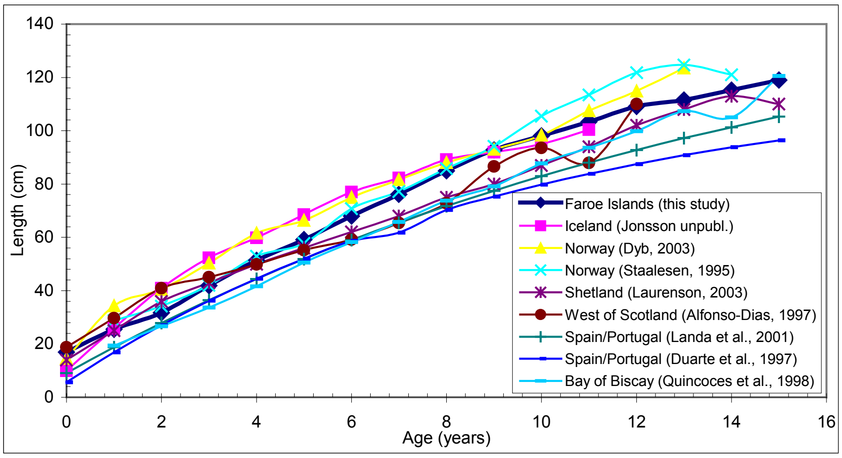

Figure 17. Length at age of *L. piscatorius* from various North Atlantic areas. All age readings are based on illicia, except Laurenson (2003) and Alfonso-Dias (1997), which were based on otolith readings.

In the present study, there is a significant difference in mean length at age between sexes for larger fish. Mean length at age was the same for females and males until age four (52 cm) and females started to be much larger than males after age six (68 cm). The same is found in Norwegian waters, were females had a significantly higher growth rate after age six/seven (71 cm) (Staalesen, 1995). West of Scotland, mean length at age for females was less than for males up to an age of four (50 cm) and from age five it was opposite (Alfonso-Dias, 1997). In the Bay of Biscay, mean length at age were similar for both sexes until age five (50 cm) and above this age, females were consistently larger and longer lived than males (Quincoces *et al.*, 1998). Similarly, in Greek waters most of the larger fish were females and the age reading showed that they were also older than the males (Tsimenidis & Ondrias, 1980). In this study, differences in mean round weight at age between sexes are also shown. One reason for this could be development of female gonad at maturity, since gonads of mature females are much larger than of males. Another reason could be the observed difference in growth pattern between sexes.

The L_∞ values that were obtained from the fitted von Bertalanffy growth equation are considered by the authors to be realistic values. This equation is frequently used to describe fish growth and in Table 9 results from von Bertalanffy growth equation from different areas are given. The estimated growth rate (K) in this study was also close to that reported for Shetland waters, while those determined for other areas were higher (Table 9). It is important to keep in mind that this growth equation is solved in different ways, due to among other factors, unrealistic results in L_∞ (e.g. Alfonso-Dias, 1997, Quincoces *et al.*, 1998, Landa *et al.*, 1998, Duarte *et al.*, 1997, Dyb, 2003, Staalesen, 1995). These make comparisons of growth between different areas complicated. Fish growth is characterised by its variability and individuals in the same species can show different growth rates. The factors causing this variability are many and may be exogenic (i.e. environmental, density-dependent) or endogenic (i.e. genetic) (Wootton, 1990). According to Beverton & Holt (1959), fish of the same species initially tend to grow faster in warmer waters but the maximum theoretically attainable length (L_∞) tends to be smaller in warmer than colder waters. Other factors that can account for the differences between areas could be how the various materials are collected (e.g. depth ranges, gear type).

Table 9. Results from von Bertalanffy growth equation for *L. piscatorius* in various North Atlantic areas.

Area	L_∞	K	t_0	Reference
Faroe Islands	210.7	0.05	-0.88	This study
Norway	148.1	0.102	-0.067	Staalesen, 1995
Norway	146	0.120	-0.34	Dyb, 2003
Shetland	205.7	0.046	-1.99	Laurenson, 2003
Irish Sea	105.6	0.176	-0.38	Crozier, 1989
West of Scotland	140.43	0.079	-1.34	Alfonso-Dias, 1997
Spanish & Portugese waters	121.54	0.102	0.03	Duarte *et al.*, 1997
Spanish & Portugese waters	140.5	0.080	0.23	Landa *et al.*, 1998
Spanish & Portugese waters	165.5	0.065	-0.38	Landa *et al.*, 2001
ICES area VII & VIII	140	0.102	0.52	Dupouy *et al.*, 1986
Bay of Biscay	150	0.09	-0.24	Quincoces *et al.*, 1998

Females were found to reach older ages and greater lengths than males (Table 10), but the von Bertalanffy growth rate (K) were higher in males than in females in this study. Similar findings were reported in Norwegian waters (Staalesen, 1995) and in Spanish and Portuguese waters (Landa *et al*., 1998, 2001). However the differences in growth rate between sexes become most apparent at lengths beyond those at which males have reached maturity. Change in growth is usually connected to time at maturity. But growth differences between the sexes may also be due to that, as fish is getting older, natural mortality of males increases more than the females, and the oldest fishes will all be females (Pitcher & Hart, 1982).

Table 10. Results from von Bertalanffy growth equation for *L. piscatorius* females and males, in various North Atlantic areas.

	Female			Male			
Area	L_∞	K	t_0	L_∞	K	t_0	Reference
Faroe Islands	191.4	0.06	-0.70	129.4	0.10	-0.62	This study
Norway	320	0.038	-0.342	148	0.102	-0.067	Staalesen, 1995
Norway	146	0.118	-0.292	98	0.192	-0.161	Dyb, 2003
Spanish & Portuguese waters	140.5	0.08	0.09	110.5	0.11	0.26	Landa *et al*., 1998,2001
ICES area VII & VIII	149.1	0.09	0.467	117.2	0.131	0.65	Dupouy *et al*., 1986
Bay of Biscay	150	0.085	-0.296	100	0.152	0.105	Quincoces *et al*., 1998

In this study, the proportion of females and males was roughly equal in the length interval up to about 60 cm. In the 60 to 75 cm length interval, males were slightly more numerous, but after about 75 cm, females outnumbered males, and above 107 cm, all fish were females. This is similar to that reported in the Bay of Biscay where males appeared in a rather similar abundance to females in length classes until 75-80 cm while females started to be clearly dominant for greater lengths (Quincoces *et al*., 1998). In Shetland (Laurenson, 2003) and in Spanish and Portuguese waters (Duarte *et al*., 1998, 2001), the sex ratio was about 1:1 up to lengths of 58 and 60 cm, respectively, after which females outnumbered males and above about 100 cm all fish were females. The same pattern in sex ratio by length is observed by age, with approximately equal proportions in ages up to four years, males slightly outnumbering females at ages five, and above age 12, all fish were females. Male growth slows down after maturation is reached, causing an accumulation of males in these length groups before females outnumber them at the largest sizes as they outgrow and outlive the males. An uneven sex ratio most likely is explained by sexual differences in growth and maturation.

Reproduction

In the present study, females were found to mature at greater size and age than males and this pattern has been reported for anglerfish in other areas (Table 11). The values given in this study are within the range given for the species. There is a larger range in values for females than for males. This may in part be due to the relatively low numbers of mature females recorded in some of those studies or because maturity scales were not standardized for all areas. Differences in ageing may have accounted for some of the difference found between these studies. There is a difference of three years in sexual maturation between sexes. The variations of maturation with length and weight are consistent with this. The data from Faroese waters show that females have a round weight at first maturity more than twice that of males, 8.0 kg and 2.6 kg, respectively.

Table 11. Length- and age at first maturity for female and male *L. piscatorius* in various North Atlantic areas.

	Length (cm) at first maturity		Age (years) at first maturity		
Area	Female	Male	Female	Male	Reference
Faroe Islands	82.8	57.3	7.8	4.7	This study
Norway	61.0	57.6			Dyb, 2003
Shetland	98	58			Laurenson, 2003
West of Scotland	73.5	48.9	8.0	5.0	Alfonso-Dias & Hislop, 1996
Spanish & Portuguese waters	93.9	50.3	14	6	Duarte *et al*., 1998, 2001
Bay of Biscay	83.6	54.6	10.7	4.7	Quincoces *et al*., 1998

Estimated length-, weight-, and age at first maturity of anglerfish in Faroese waters correspond fairly well with length-, weight-, and age at which an increase in gonadosomatic indices (GSI) is observed, although the GSI, as a function of length-, age-, and weight for females, is somewhat higher. The increase in female GSI occurs in late stage 3 when gonads become gelatinous and increase in volume and weight. As all stage 3 individuals are included in calculating the $L_{50\%}$ value, the relatively high proportion of smaller early stage 3 individuals has reduced the $L_{50\%}$ value compared to the length at which the increase in GSI is observed. For males, GSI, as a function of length-, age-, and weight, fits with the determined results on first maturity values.

Knowledge on where and when anglerfish spawn in northern European waters is limited (Hislop *et al*., 2001). The spawning period seems to be from late winter to summer for various North Atlantic areas (see Table 12). This is the period were the GSI indicates reproductive activity of anglerfish, in terms of the presence of ripe females and males, in Faroese waters. There were a relatively high proportion of mature males throughout the year in this study, and this is also found in Spanish and Portuguese waters, and in Bay of Biscay (Duarte *et al*., 2001, Quincoces *et al*., 1998).

Table 12. Spawning period for *L. piscatorius* in various North Atlantic areas.

Area	Spawning period	Reference
Faroe Islands	January - April	This study
Iceland	April - June	Jónsson unpubl. in Tangstad *et al*., 2006
Norwegian waters	May - June	Staalesen, 1995
Shetland	December - May	Laurenson, 2003
West of Scotland	November - May	Afonso-Dias & Hislop, 1996
Spanish/Portuguese waters	January - June	Duarte *et al*., 2001
Bay of Biscay	May - July/August	Quincoces *et al*., 1998

The main spawning ground of anglerfish is believed to be south west and south of the Faroes and along the European coasts around the 1000 m contour line, as well as oceanic (Joensen & Tåning, 1970). The observation of ripe females, four of which had GSI higher that 25%, followed by the later observation and collection of egg ribbons, pelagic larvae and newly settled juveniles suggests that there are spawning locations in Faroese waters but the exact locations are yet to be determined. Two of the females with GSI >25% were caught in February, one in 350 m south west of the Faroes, and one in 200 m depth on the Faroe Bank. The other two were caught in April north of Faroes in water around 250 m deep. However the apparent rarity of spawning females in the material may suggest that anglerfish perform spawning migrations to areas or depths not sampled in the present study. Floating egg masses and fry have been observed in the Faroe-Shetland Channel and east of Shetland and northeast of Scotland (Joensen & Tåning, 1970). There is a possibility that the anglerfish females do not spawn each year, only a proportion of the large females, of the size at maturity, showed evidence of maturing gonads at the times of year when this would have been expected. Each kind of growth has costs and benefits, which are intimately related to fitness. Bigger females have more eggs so there is sense in a fish delaying reproduction for a year or two, putting all available energy into somatic growth (Pitcher & Hart, 1982).

Anglerfish larvae with a length range from 7-130 mm are caught in the regular Faroese pelagic 0-group survey in the upper depths in June and July (Thangstad *et al*., 2006, Ofstad unpubl. data). These individuals are most likely to have been spawned between late winter and spring. Hislop *et al.* (2001) also recorded individuals of a similar length in Scottish waters between 6 and 112 mm and daily aging of lapilli suggested that those were between 21 and 124 days old. Most of the pelagic anglerfish larvae were caught on the Faroe Bank, while the remainder was caught on the shelf west of the Faroes. The upper layers, in these areas are dominated by the warm northward-bound North Atlantic Current, which forms anticyclonic circulation cells around the shallow bank and shelf areas surrounding the Faroes (Hansen *et al*., 1998). This results in large retention times in the shallow areas. Some of the recruits may aggregate by advection in these areas from local spawning grounds, but a number of juveniles may also have drifted northward with the Atlantic current from southern spawning areas. Further research is required in this area. At present, it is difficult to reflect upon these circumstances because of the lack in knowledge about spawning areas of anglerfish in North Atlantic.

Conclusion

The presented study has provided new knowledge on biological parameters for the proportion of the *Lophius piscatorius* stock that occurs in Faroese waters. The patterns in age and growth that were observed are comparable to those reported for other areas. Patterns of sex ratio with length are also similar to those reported in other areas and lengths at maturity are within previously published ranges, suggesting that there is no latitudinal gradient in biological parameters. As is common with other studies, very few ripe females were recorded. However, this recording, together with observation of egg ribbons and pelagic anglerfish larvae, suggests that there is some spawning activity of anglerfish in Faroese waters.

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