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Condition and Feeding of Greenland Halibut (*Reinhardtius hippoglossoides*) in the North Atlantic with Emphasis on the Flemish Cap

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Abstract

The Relative Condition Factor of Greenland halibut (*Reinhardtius hippoglossoides*) was analysed for seasonal, annual and geographical variability. Sampling covered commercial fishing and scientific surveys in three areas of the North Atlantic (NAFO Divisions 3M and 3LNO, and ICES Division IIb), comprising a total of 64 984 individuals from 1992 to 2003. Several data sets were established in order to carry out the comparisons: individuals as a whole; by sex - females and males separately; and by areas - each area independently. Condition showed significant differences with regard to the area, season, size range and sex, but it was not always significant among interactions of these factors. Individuals from the Northeast Atlantic had better condition, while those in the Northwest Atlantic suffered a notable fall in condition throughout the studied period, mainly in Flemish Cap. Condition was lightly superior in females, regarding size. A clear increment in the feeding intensity appeared when the condition diminished. When the total weight is used to calculate the condition, more remarkable differences could be expected because this index is sensitive to the gonad weight; in this respect, adult females showed more marked differences. Moreover, the complex maturity schedule and variable maturity at size would contribute to find misleading differences. Feeding habits of Greenland halibut were studied in the same areas based on a sample of 19 001 fish. Feeding intensity was the higher on the Flemish Cap, where the main preys were *Pandalus borealis*, *Sebastes* spp. and *Serrivomer beani. P. borealis* predation increased in the late 1990s. Diet was piscivorous in Div. 3LNO and Div. IIb as well, mainly based on *Mallotus villosus* and *Micromesistius poutassou*, respectively. Cannibalism and offal consumption was remarkable in Svalbard (ICES Div. IIb). Fish predation increased when predator size increased. Molluscs took an important place in the diet of intermediate sizes in Div. 3LNO and IIb. Similar diet pattern for both sexes was observed.

Key words: condition factor, Flemish Cap, Greenland halibut, North Atlantic, *Reinhardtius hippoglossoides*

Introduction

Greenland halibut (*Reinhardtius hippoglossoides*) is an economically and ecologically important flatfish that inhabits both sides in the North Atlantic. The Greenland halibut in NAFO Subareas 0, 1, 2 and Div. 3KLMNO is considered the same complex stock. The exploitable biomass was reduced to low levels in 1995–97. It increased during 1998–2000 due to the decrease in catches and the improvement of the recruitment, and then fell again during the period 2003–2004 to the lowest values in the series (NAFO, MS 2005). Survey biomass indices in the Flemish Cap (NAFO Div. 3M) maintained a continuous increase to a peak in 1998 and decreased since then (Casas, MS 2004). The stock in the Svalbard area (ICES Div. IIb) is below historical levels (ICES, MS 2004; Paz *et al*., MS 2004).

Condition indices provide a useful assessment of the physiological well-being of fishes and provide an indirect means to evaluate ecological relations and the effects of management strategies (Murphy *et al*., 1991). Studies have demonstrated that these indices are a measure of the energy reserves of fishes and their relationships with the environmental, maturity, feeding or parasitic conditions (Costopoulos and Fonds, 1989).

The relationships among condition, biomass and natural mortality has been analysed in Atlantic cod (*Gadus morhua*) (Lambert and Dutil, 1997a, b). Also the decrease of the reproductive investment could affect the reproductive potential and recruitment (Lambert and Dutil, 2000). Junquera *et al*. (1999) analysed the possible compensatory effect on the reproductive and growth of the Greenland halibut in Northwest Atlantic observing that the condition factor had remained almost invariable throughout the period 1991–1997, in spite of being subjected to a strong exploitation.

The condition and feeding habits of Greenland halibut in three areas of the North Atlantic, NAFO Divs. 3M and 3LNO, and Svalbard Area (ICES Div. IIb), from 1992 to 2003 were examined in this study.

Material and Methods

A total of 64 984 individual Greenland halibut (*Reinhardtius hippoglossoides*) from the Northwest Atlantic were analysed from scientific and commercial surveys during the period 1992–2003 (Tables 1 and 2). The surveys were: the summer EU Bottom Trawl Survey of Flemish Cap (NAFO Div. 3M) (Casas, MS 2004), the spring Spanish Survey "*Platuxa*" in NAFO Div. 3NO (González Troncoso *et al.,* MS 2004), the summer Spanish Survey "*3L-Fletán Negro*" in the Flemish Pass; and the

TABLE 1. Number of individuals of *R. hippoglossoides* sampled for relative condition factor study by area (NAFO Divs. 3LNO and 3M; ICES Div. IIb), year (1992–2003) and size range.

Area	Size range (cm)	Year												Total
		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	
3M	10–19		12	31	56	80	123	106	25	171	113	119	127	963
	20–29	53	134	109	101	135	227	176	85	53	129	138	108	1 448
	30–39	59	159	306	146	168	341	669	278	278	464	475	208	3 551
	40–49	429	379	475	250	308	357	679	295	432	1 977	1 866	673	8 120
	50–59	252	222	184	112	143	175	258	129	199	1 403	1 379	591	5 047
	60–69	33	17	24	26	12	22	16	12	13	284	373	97	929
	70–79	4	1		1	2	2	1	1		80	98	41	231
	80–89										35	24	12	71
	Total	830	924	1 129	692	848	1247	1 905	825	1 146	4 485	4 472	1 857	20 360
3LNO	10–19				3	16	101	35	78	49	133	167	329	911
	20–29				47	187	782	344	172	99	238	249	425	2 543
	30–39				26	164	697	254	110	155	1 847	1 306	957	5 516
	40–49				2	152	452	148	87	226	3 796	3 081	1 119	9 063
	50–59					88	249	159	70	149	1 889	2 208	800	5 612
	60–69					39	135	123	61	136	519	775	147	1 935
	70–79					10	51	69	39	80	183	184	52	668
	80–89					8	11	28	17	31	97	46	11	249
	Total				78	664	2 478	1 160	634	925	8 702	8 016	3 840	26 497
IIb	20–29				2		10	28	19	17	39	44	35	194
	30–39				92		496	159	421	197	419	419	351	2 554
	40–49				2 103		830	278	736	233	541	571	405	5 697
	50–59				1 185		689	273	709	230	531	608	408	4 633
	60–69				540		381	159	358	150	379	510	336	2 813
	70–79				202		248	118	126	106	186	237	201	1 424
	80–89				16		76	45	39	94	114	130	166	680
	90–99				2		13	10	4	21	19	30	33	132
	Total				4 142	0	2 743	1 070	2 412	1 048	2 228	2 549	1 935	18 127
	Total	830	924	1 129	4 912	1 512	6 468	4 135	3 871	3 119	15 415	15 037	7 632	64 984

TABLE 2. Number of individuals of *R. hippoglossoides* sampled by area (NAFO Divs. 3LNO and 3M; ICES Div. IIb), year (1992–2003) and season.

		Year												
Area	Season	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
3M	Spring										696	629	935	2 260
	Summer	830	924	1 129	692	848	1 247	1 905	825	1 146	1 203	2 741	922	14 412
	Autumn										1 441	561		2 002
	Winter										1 145	541		1 686
3 LNO	Spring				78	664	2 478	1 160	634	925	1 699	1 338	1 803	10 779
	Summer										1 659	1 604	2 037	5 300
	Autumn										2 706	2 470		5 176
	Winter										2 638	2 604		5 242
IIb	Summer				4 142							6		4 148
	Autumn						2 743	1 070	2 412	1 048	2228	2 352	1 758	13 611
	Winter											191	177	368

autumn Spanish Survey "*Fletán Ártico*" in Svalbard ICES Div. IIb (Paz *et al*, MS 2004). Commercial data were available for the Spanish bottom trawl fishery for Greenland halibut in NAFO (1992–2003), the Spanish pair trawl fishery for Atlantic cod in the Svalvard area, and the Spanish bottom trawl fishery for northern shrimp (*Pandalus borealis*) also in Svalvard area. Data from the Pilot Action of Experimental Fishing carried out in the Sea of Barents-Svalbard (ICES, Divs. I and IIb) targeting American plaice (*Hippoglossoides platessoides*) in 1995 were also included (Durán and Román, MS 2000). The same biological data were used to calculate the condition as well as the parameters of the length-weight relationship.

The biological sampling was carried out onboard, and the data collected for each individual fish were: length (TL to the nearest cm below), sex, maturity stage (immature, maturing, spawning and post-spawning), weight (g) and stomach repletion (empty, fullness). The individuals were compiled in size ranges of 10 cm each (starting with the 10–19 cm group) (Table 1). Maturity stages were determined by macroscopic analysis. In some cases, individuals bigger than 100 cm were not considered due to low sample size.

Data were grouped by seasons (Table 2). Data from March to May are referred as spring; June–August as summer; September–November as autumn; and December–February as winter. The annual cycle was incomplete in ICES Div. IIb because of scarce data. The inter-annual comparisons were only made when at least, a two year series for the same season was available. Data from Divisions 3LNO were studied as a whole and separated from those of Div. 3M.

The condition index provides a useful assessment of the 'plumpness' and physiological well-being of fishes. Relative Condition Factor (K_r) is calculated to compare fishes of the same species of different lengths, sex, locations and years (Le Cren, 1951), from

$$K_r = W_i / W_i'$$

where W_i and W_i' are, respectively, the observed and expected weight in g of fish *i*.

Expected weight (W_i') is calculated from

$$W_i' = aL^b$$

where L is fish length in cm. Parameters a and b of this relationship were calculated as required in each case: for the whole set, by separate sex and/or by areas.

A general linear model (GLM) was used to analyze differences among groups.

Greenland halibut feeding habits were studied using the same research surveys (Table 3). In each haul, a maximum of 10 stomachs from each 10 cm length group were analysed. Fish whose stomachs were everted or contained prey ingested in the fishing gear were discarded. Fish showing total or partial regurgitation were taken into account to estimate the emptiness indices. The method used has been the same since 1993 (Rodríguez-Marín *et al*., MS 1994).

Table 3. Characteristics of individuals of *R. hippoglossoides* sampled in the feeding study by area (NAFO Divs. 3LNO and 3M; ICES Div. IIb) and year (1993–2003). % FI = Feeding intensity; No. Reg. = Number of regurgitated stomachs.

Survey	Division	Year	No. Empty	No. Full	No. Reg.	Total	% FI	Size range (cm)	Depth range (m)	No. of hauls	No. Prey items
"Flemish Cap"	3M	1993	138	392	4	534	74.2	11–79	221–730	50	43
"Flemish Cap"	3M	1996	401	633	0	1 034	61.2	12–82	231–670	54	53
"Flemish Cap"	3M	1997	442	649	3	1 094	59.6	13–81	219–679	51	59
"Flemish Cap"	3M	1998	360	619	23	1 002	64.1	14–79	203–709	56	59
"Flemish Cap"	3M	1999	486	746	1	1 233	60.6	9–70	223–709	58	56
"Flemish Cap"	3M	2000	258	509	15	782	67.0	14–63	194–555	45	43
"Flemish Cap"	3M	2001	557	720	0	1 277	56.4	13–66	166–708	66	57
"Flemish Cap"	3M	2002	305	669	2	976	68.8	12–66	160–730	58	52
"Flemish Cap"	3M	2003	410	589	0	999	59.0	12–68	83–688	88	48
"Platuxa"	3NO	2002	488	367	0	855	42.9	9–89	68–1 377	72	30
"Platuxa"	3NO	2003	535	459	0	994	46.2	8–95	43–1 449	75	26
"3L - Fletan negro"	3L	2003	314	219	0	533	41.1	10–88	132–1 087	31	22
"Fletán Ártico"	II b	1997	1 644	531	0	2 175	24.4	25–102	543–1 312	99	32
"Fletán Ártico"	II b	2000	1 414	321	0	1 735	18.5	15–97	484–1 171	71	30
"Fletán Ártico"	II b	2001	1 686	294	0	1 980	14.8	21–101	563–1 123	26	25
"Fletán Ártico"	II b	2002	1 376	422	0	1 798	23.5	17–103	581–1 158	62	39
TOTAL	Div 3M	1993–2003	3 357	5 526	48	8 931	62.4	5–60	130–639	526	70
	Div. 3LNO	2002–2003	1 337	1 045	0	2 382	43.9	5–72	39–1 460	178	50
	Div. II b	1997–2002	6 120	1 568	0	7 688	20.4	15–103	484–1 312	258	57

Data taken for each predator were: total length (nearest cm below); volume of the stomach content in cm^3, measured by using a trophometer (Olaso, 1990); percentage of each prey in the total volume; and number of each prey. Prey were identified by species whenever the digestion stage allowed it, or to the lowest possible taxonomic level.

Feeding Intensity Index (*FI*) was calculated to analyse te percentage of individuals with stomach content, from

$$FI = 100n / N$$

where n is the number of individuals with stomach contents and N is the total number of individuals sampled.

The importance of each prey taxa (Vp) was evaluated using the percentage by volume, from

$$Vp = 100v / V$$

where v is volume of a determined prey, and V is the total volume of stomach contents. The volumetric method overvalues the importance of large organisms (Hyslop, 1980).

Results

Condition

In all areas. Relative condition factor showed significant differences with respect to area, year, season, size range and sex, but not all interactions between factors were significant (Table 4A). Condition decreased in the three areas, particularly in the NAFO area (Divisions 3LNO and 3M), throughout the considered period. In Flemish Cap (Division 3M), condition reached a minimum between 1998 and 2000; condition in summer and estimated biomass (Casas and González Troncoso, MS 2003) presented a significant negative correlation. On the other hand, in Div. 3LNO, condition recovered from 1998 to 2000, but the general trend was also descending. Condition and estimated biomass (González Troncoso *et al.*, MS 2004) were significant and positively correlated during the spring period. Individuals in Svalbard area (Division IIb) had better condition, so much in autumn as in the

TABLE 4. Tests of between-subjects effects of *R. hippoglossoides* sampled. df=degrees of freedom (*n*,error)

A.- Condition data of the individuals of the three areas

Source	*F*	df (n, 64 421)	Sig.
Area	3.6	2	p≤0.05
Year	7.4	11	p≤0.0001
Season	3.4	3	p≤0.05
Size range	14922	8	p≤0.0001
Sex	27.3	1	p≤0.0001
Area × Year × Season × Size range	2.0	16	p≤0.01
Area × Year × Season × Sex	2.5	4	p≤0.05

B.- Condition data of the females of the three areas

Source	*F*	df (n, 37 575)	Sig.
Area	9.8	2	p≤0.0001
Year	13.5	11	p≤0.0001
Season	4.8	3	p≤0.01
Size range	83.2	8	p≤0.0001
Area × Year × Season × Size range	3.4	16	p≤0.0001

C.- Condition data of the males of the three areas

Source	*F*	df (n, 13 710)	Sig.
Area	10.1	2	p≤0.0001
Year	12.8	11	p≤0.0001
Season	26.6	3	p≤0.0001
Size range	4.7	4	p≤0.001
Area × Season × Size range	4.9	4	p≤0.001
Year × Season × Size range	9.1	11	p≤0.0001

D.- Condition data of the individuals of Div. 3M

Source	*F*	df (n, 20 137)	Sig.
Sex	30.1	1	p≤0.0001
Season	11.3	3	p≤0.0001
Size range	54.4	7	p≤0.0001
Year	11.3	11	p≤0.0001
Sex × Size range × Year	2.5	53	p≤0.0001
Season × Size range × Year	2.5	17	p≤0.001

E.- Condition data of the individuals of Divs. 3LNO

Source	*F*	df (n, 26 292)	Sig.
Sex	10.4	1	p≤0.001
Season	4.6	3	p≤0.01
Size range	54.2	7	p≤0.0001
Year	14.2	8	p≤0.0001
Sex × Season × Year	3.2	4	p≤0.05
Season × Size range × Year	7.3	21	p≤0.0001

F.- Condition data of the individuals of Div. IIb

Source	*F*	df (n, 17 992)	Sig.
Sex	35.3	1	p≤0.0001
Season	0.3	2	p>0.05
Size range	26.0	7	p≤0.0001
Year	8.9	7	p≤0.0001
Sex × Size range × Year	2.3	28	p≤0.0001
Season × Size range × Year	3.0	6	p≤0.01

whole year, but the general trend showed slight decrease, especially for males. Condition and estimated biomass (Paz *et al*., MS 2004) were positively correlated. Males and females showed a similar trend in each area (Fig. 1).

Data on the condition of whole sampled female fish were significantly different in all variable interactions (Table 4B). However, the condition of male fish was significantly different with respect to area, year, season and size range, but not all interactions among factors were significant (Table 4C). Seasonal changes in condition presented remarkable geographical differences. Both sexes improved condition in winter-spring in Div. 3LNO; this improvement occurred in summer (and also in summer-autumn for males) in Flemish Cap; in Svalbard, females increased the condition from summer to winter, and the opposite happened for males (Fig. 2).

Flemish Cap (NAFO Div. 3M). Condition increased with the size in spring–summer, and was more noticeable in females. This index showed high interannual variability in individuals <20 cm, while it decreased from 1998–2000 and then recovered in individuals ≥20 cm (Fig. 3). There was a significant difference in condition with respect to sex, season, size range and year. Not all interactions among factors were significant (Table 4D).

Grand Bank and Flemish Pass (NAFO Div. 3LNO). Condition showed considerable interannual variability for individuals <20 cm and reached a maximum in 1999–2001 for individuals >20 cm. Condition stage diminished slightly for 40–59 cm fish size and increased considerably for individuals ≥70 cm (Fig. 4). Condition showed significant differences regarding sex, season, size range and year. Not all interactions among factors were significant (Table 4E).

Svalbard (ICES Div. IIb). Condition steady decreased along the period in individuals <30 cm, while it had a slight decrease in individuals ≥ 30 cm in 2000–2001. Female condition increased with size, and the opposite happened for males (Fig. 5). Condition

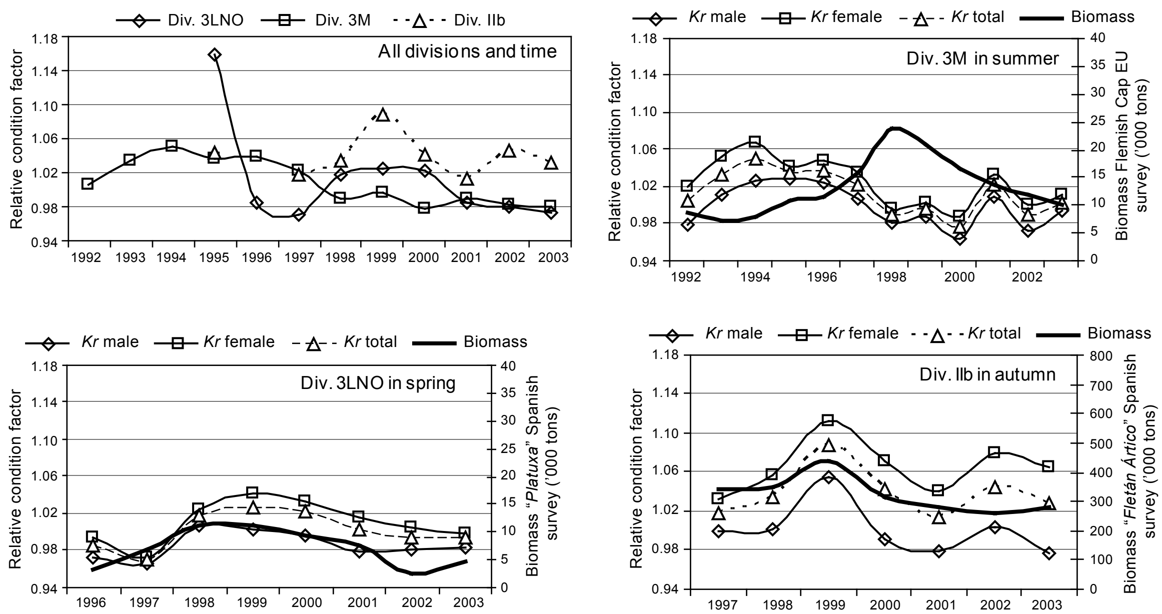

Fig. 1. Mean relative condition factor and biomass estimate of *R. hippoglossoides* by year.

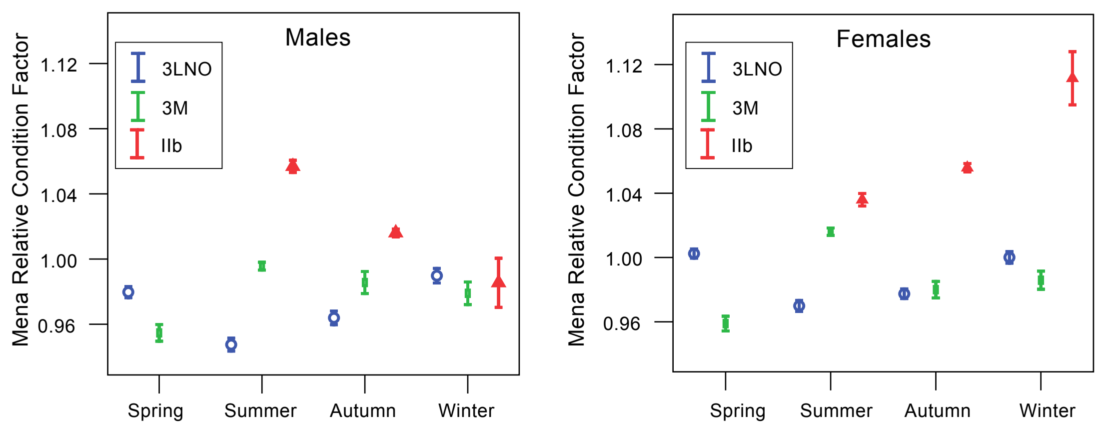

Fig. 2. Relative condition factor (mean and 95% confidence interval) of *R. hippoglossoides* by sex and season in each area. The sampled periods were: 1992–2003 in NAFO Divisions 3LNO and 3M, and 1995–2003 in ICES Division IIb.

showed significant differences with regard to sex, size range and year. Not all interactions among factors were significant (Table 4F).

Feeding intensity in adult females. Females within the size ≥60 cm, most of them mature (Junquera and Saborido-Rey, MS 1995), showed increasing feeding intensity when condition decreased. Feeding intensity increased from spring to winter in Flemish Cap and Div. 3LNO, and decreased from summer to winter in Svalbard (Fig. 6).

Feeding Habits

Data indicated a high feeding intensity in summer in Div. 3M (62.4%) and a low one in autumn in Div. IIb (20.4%) (Table 3). In Div. 3M, the composition of the main prey groups in the diet has virtually suffered no variation during the 1993–2003 period, however an increase of northern shrimp and decrease of fish in the last years has occurred. Pisces (66.4%) and crustacea (27.7%) were the main prey groups (Fig. 7), with *Sebastes* spp (14.1%) and northern shrimp (21.8%) the

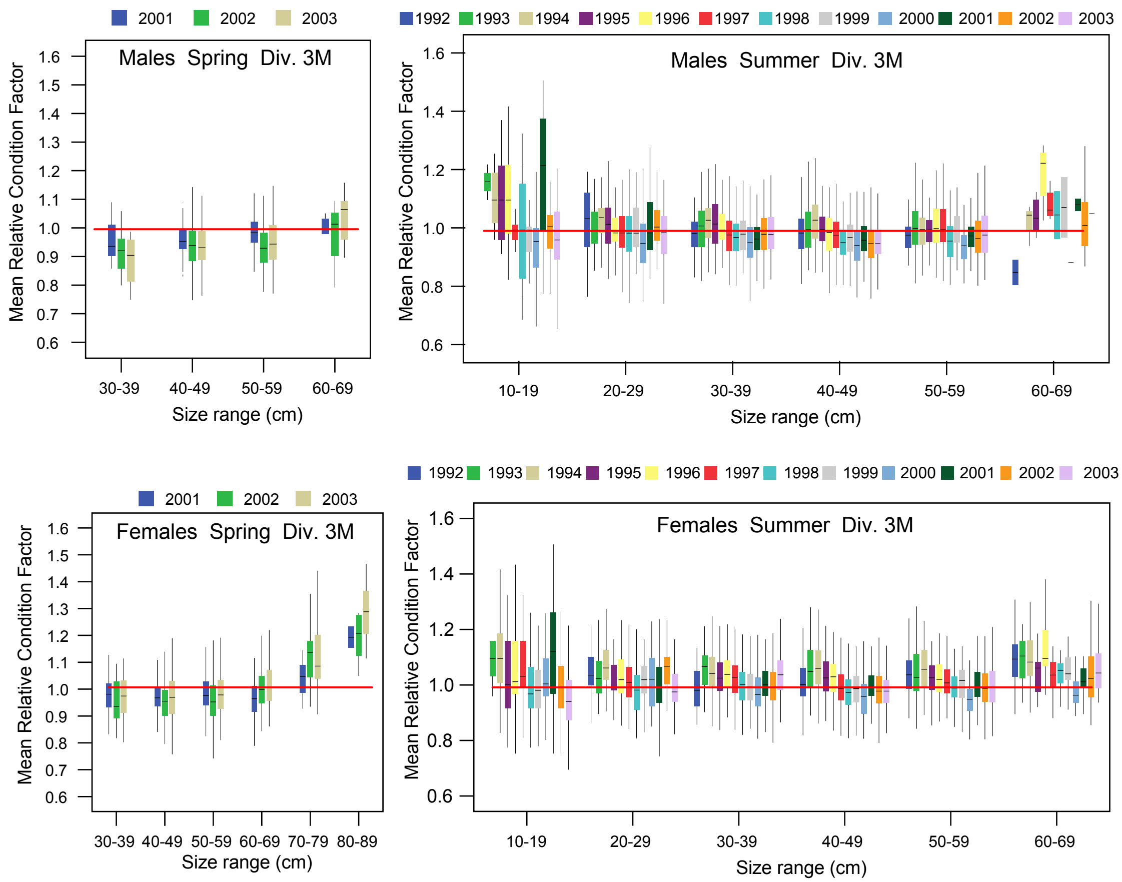

Fig. 3. Mean relative condition factor of *R. hippoglossoides* by year and size range in spring and summer in NAFO Division 3M from 1992 to 2003. Plots show the median (black horizontal line), interquartile (coloured box) and total (black vertical line) range.

species most abundant of these two groups, respectively. Crustacea, mostly hyperiids, predominated in the stomach contents of individuals <20 cm and pisces (mainly *Sebastes* spp and *Serrivomer beani*) were the principal prey in individuals ≥40 cm. Individuals of the size range 20–39 cm had an intermediate level between both diets, increasing the predation on northern shrimp and fish, and decreasing on the hyperiids (Table 5 and Fig. 8).

In Div. 3LNO, there was a higher volume of pisces (76.7%) in the diet composition than in the other areas, mainly *Mallotus villosus* (46.8%). Crustaceans were not so important in this area, but they were more important than fish in the individuals <20cm; and molluscs in intermediate sizes were remarkably important (Table 6, Fig. 8).

In Div. IIb, the diet composition followed a similar pattern. Pisces (66.2%) and crustacea (12.4%) were the main prey groups, with Greenland halibut (18.0%), *Micromesistius poutassou* (13.6%) and *Pasiphaea tarda* (9.6%) being the more abundant species in these two groups. Crustacea was the only prey group in individuals <20 cm, this prey was important until 50 cm size, and then fish became the main prey for bigger individuals. Molluscs were very abundant in the intermediate sizes (Table 7, Fig. 8).

Offal was a very important food component in Div. IIb (13.8%) and it was less important in Div. 3LNO (3.6%) where it was found in individuals of bigger size. Cannibalism was observed in Div. IIb (18%).

Females and males showed similar diet pattern in relation to size in Div. 3M. Females in Div. 3LNO presented more variety of prey than males in sizes >30 cm. In Div. IIb, differences in the diet composition between

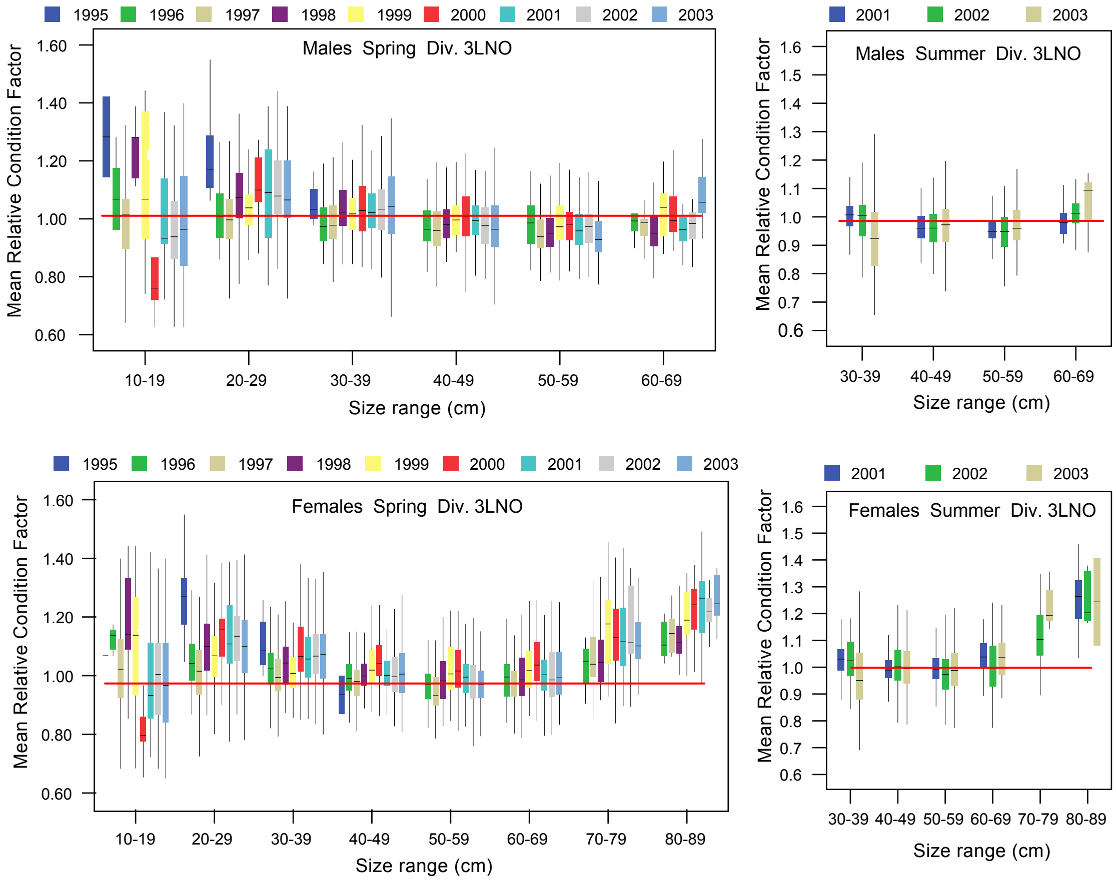

Fig. 4. Mean relative condition factor of *R. hippoglossoides* by year and size range in spring and summer in NAFO Div. 3LNO from 1995 to 2003. Plots show the median (black horizontal line), interquartile (coloured box) and total (black vertical line) range.

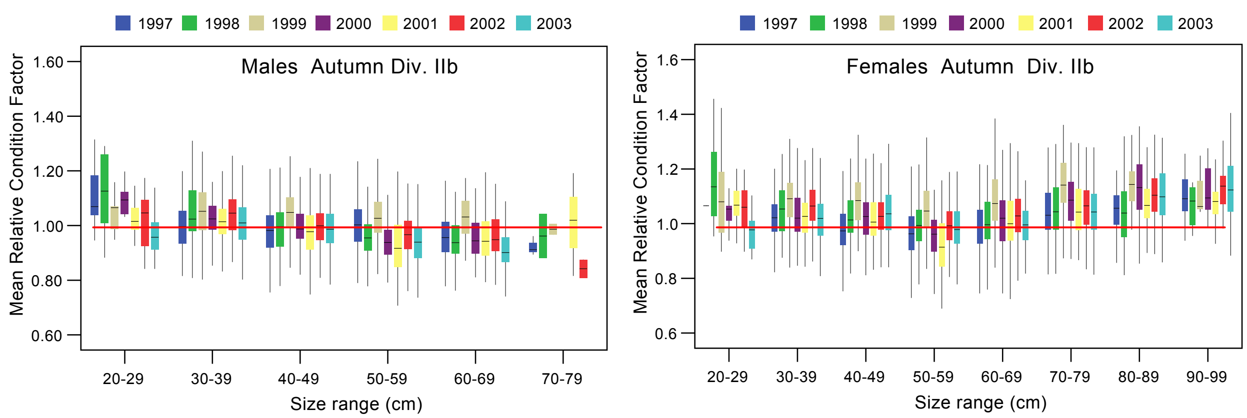

Fig. 5. Mean relative condition factor of *R. hippoglossoides* by year and length in autumn in ICES Division IIb from 1995, 1997–2003. Plots show the median (black horizontal line), interquartile (coloured box) and total (black vertical line) range.

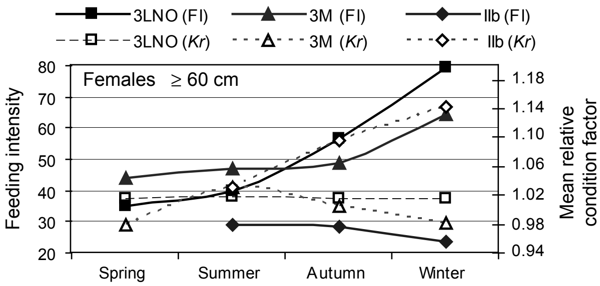

Fig. 6. Percent feeding intensity (FI) and mean relative condition factor (*Kr*) of adult females (≥60 cm) of *R. hippoglossoides* by area and season.

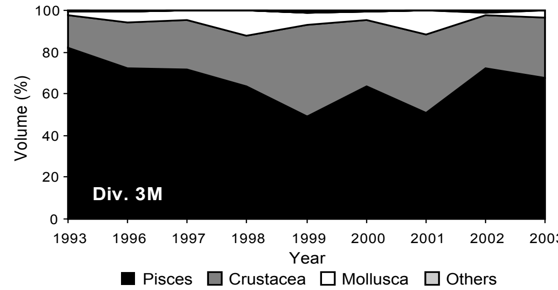

Fig. 7. Volume percent of the main prey groups for *R. hippoglossoides* by year in Flemish Cap (Div. 3M), 1993–2003.

TABLE 5. Volume percent of the main prey of *R. hippoglossoides* by size range in Flemish Cap (Div. 3M, 1993–2003).

	Size Range (cm)								
Prey	<20	20–29	30–39	40–49	50–59	60–69	70–79	80–89	Total
PISCES	2.0	8.6	41.6	65.3	84.5	92.6	91.1	100	66.4
Sebastes spp.		0.4	1.8	10.8	23.0	23.2	91.1	45.3	14.1
Serrivomer beani		1.6	5.4	12.2	14.0	30.3			11.6
Chauliodus sloani			3.1	2.6	1.4				2.0
Lycodes sp.			1.1	1.5	1.0				1.1
Nezumia bairdi		0.7	2.4	3.0	5.6	0.1			3.4
Anarhichas sp.		0.2	0.3	1.5	1.5	3.3		45.3	2.0
Anarhichas lupus		0.0	0.3	1.1	0.4	9.2			1.0
Lumpenus lumpretaeformis	1.1	0.8	3.1	1.0	0.3	0.2			1.1
Lampadena speculigera			2.8	6.1	10.3	2.4			6.2
Other Pisces	0.9	4.9	21.2	25.6	27.0	24.0		9.4	23.9
CRUSTACEA	86.3	85.6	48.9	28.4	11.5	7.0			27.7
Hyperiidea	62.3	38.9	8.2	1.3	0.2				3.8
Pandalus borealis	12.2	42.5	38.1	24.9	9.8	6.4			21.8
Other crustaceans	11.8	4.1	2.6	2.2	1.5	0.6			2.1
MOLLUSCA	11.1	3.8	8.6	5.9	3.7	0.2	8.9		5.4
Illex coindetii	1.3	0.6	2.6	1.2	0.0				1.0
Decapoda Cephalopoda	5.3	2.2	3.6	1.6	0.8				1.7
Other Mollusca	4.5	1.0	2.4	3.0	2.9	0.2	8.9		2.7
ECHINODERMATA		0.0	0.1	0.0	0.1				0.0
OTHER INVERTEBRATES	0.6	2.0	0.5	0.2	0.1	0.1			0.3
OTHER	0.1		0.3	0.2	0.2	0.1			0.2
No. indivs. with stomach contents	907	719	1 430	1 796	628	40	4	2	5 526

TABLE 6. Volume percent of the main prey of *R. hippoglossoides* by size range in NAFO (Div. 3LNO, 2002–03).

		Size range (cm)									
Prey		<20	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	Total
PISCES		31.5	97.8	93.9	68.7	51.2	80.1	100	71.7	100	76.7
	Ammodytes dubbius		1.9	1.0	2.9	0.4					1.3
	Antimora rostrata					6.8			11.7	100	4.2
	Gaidropsarus ensis								45.0		4.9
	Coryphaenoides rupestris				0.9	1.9	35.8				1.9
	Macrourus berglax				1.7	7.6	27.1				2.9
	Macrouridae			0.2		12.8					2.5
	Mallotus villosus	13.1	83.2	88.8	56.9	3.5					46.8
	Other Pisces	18.5	12.7	3.9	6.4	18.3	17.3	100	15.0		12.2
CRUSTACEA		68.2	1.0	3.3	5.0	2.7	2.5				3.3
	Pasiphaea tarda			1.6	1.8	2.3					1.3
	Other crustaceans	68.2	1.0	1.7	3.3	0.4	2.5				2.1
MOLLUSCA		0.0	1.1	2.8	26.2	35.2	1.9		20.0		16.4
	Oegopsida			1.5	18.8	10.0					7.0
	Cephalopoda	0.0	0.0	0.2	2.5	1.4			20.0		3.2
	Decapoda Cephalopoda		1.1	0.9	4.9	20.3	1.9				5.5
	Other Mollusca			0.0		3.5					0.7
ECHINODERMATA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OTHER INVERTEBRATES		0.1	0.0	0.0	0.0						0.0
OTHER		0.1	0.0	0.0	0.0	10.9	15.5		8.3		3.6
	Offal					6.8					1.3
	Greenland halibut offal						15.5		8.3		1.5
	Other	0.1	0.0	0.0	0.0	4.1					0.8
No. indivs. with stomach contents		260	321	237	147	60	12	3	4	1	1 045

sexes were more important; males preyed more on crustacea than females, and females fed more on molluscs (Fig. 9).

Discussion

It can be concluded that there were no remarkable differences among Greenland halibut populations regarding condition and feeding habits in the considered Northwest and Northeast Atlantic areas: NAFO Div. 3LMNO and ICES Div. IIb. Results from Bowering and Nedreaass (2001) on age validation and growth of the Northwest and Northeast Atlantic populations suggested that the growth patterns between the two regions might be converging to a similar pattern in recent years. Genetic studies carried out on individuals of different areas of the North Atlantic did not reveal any significant inter-area differences (Vis *et al.*, 1997; Igland and Nævdal, 2001). This could be related to their highly migratory behaviour over extreme distances, deduced from migratory experiments (Boje, 2001).

Several studies have analysed the condition stage and biological parameters relationship, and their implication in the stock status. Poor condition in Atlantic cod was related with an increase in the natural mortality and low reproductive potential (Dutil and Lambert, 2000; Lambert and Dutil, 2000) and skipped of spawning (Jørgensen *et al.*, 2006). Low condition is common during the spawning season (N´Da and Déneil, 1993). In American plaice (*H. platessoides*), condition factor and feeding activity decreased in the spawning season (Maddock and Burton, 1999); this fact can be caused by reserve mobilization of somatic energy to carry out the reproduction.

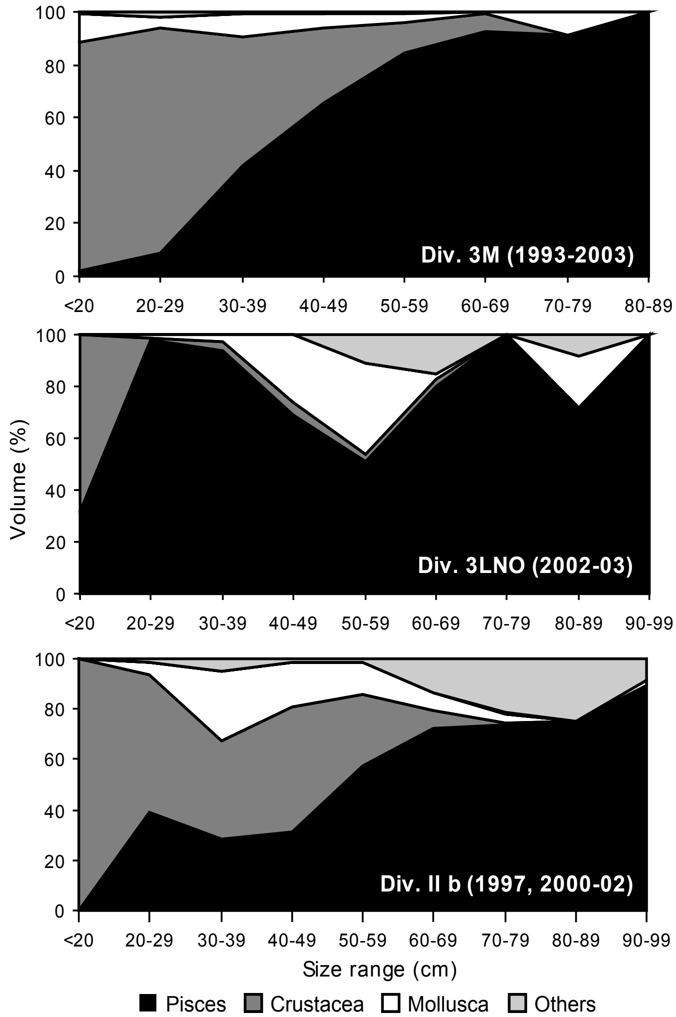

Fig. 8. Volume percent of the main prey groups by size range for *R. hippoglossoides* in NAFO (Divs. 3M, 1993–2003; and 3LNO, 2002–2003) and ICES (Div. IIb, 1997 and 2000–2002).

Junquera *et al*. (1999) analysed the Greenland halibut condition in the Northwest Atlantic, from 1991 to 1997, with regard age and year, and they did not found any differences. Nevertheless, significant differences in condition were observed in our study with regard factors such as the geographical area, year, season, size and sex; but the interactions among these variables were not always significant. Similar differences were observed in American plaice (Morgan, MS 2003; González *et al*. 2006).

Greenland halibut in the Northeast Atlantic (Svalbard) had better condition, mainly noted in females. Peak spawning of Greenland halibut is observed in November–January in the Northeast Arctic, Barents Sea and West Greenland (Gundersen *et al*., MS 2001; Simonsen and Gundersen, MS 2002). However, individuals distributed in the Northwest Atlantic (NAFO area) showed a steady decrease of condition throughout the studied period; it was more accused in Flemish Cap. Inter-annual variation of condition was reflected in the estimated biomass evolution, except in Flemish Cap. In this area, the strong 1995 annual class (Casas and González Troncoso, MS 2003) resulted in a high biomass level in 1998–2000. The high abundance could cause the poor condition observed in those years due to competition.

Changes in feeding habits also have influence on the condition stage. Greenland halibut is mainly a piscivo-

TABLE 7. Volume percent of the main prey of *R. hippoglossoides* by size range in Div. IIb (ICES, 1997 and 2000–02).

		Size Range (cm)									
Prey		<20	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	Total
PISCES			38.8	28.3	31.4	57.6	72.2	73.9	74.7	89.4	66.2
	Sebastes mentella					2.0	4.2	5.6	6.5		3.9
	Sebastes sp.							1.7	10.1		1.8
	Micromesistius poutassou			17.4	19.2	22.6	14.4	9.8	8.4		13.6
	Hippoglossoides platessoides							1.3	4.2		1.0
	Cottunculus microps						3.0		4.6		1.2
	Reinhardtius hippoglossoides				0.0	1.9	2.0	33.2	24.3	82.5	18.0
	Gaidropsarus argentatus					5.0	4.3				1.8
	Clupea harengus				0.5		1.6	1.7	2.8		1.3
	Lycodes sp.				0.8	6.0	8.1	7.2	1.4		5.4
	Other Pisces		38.8	10.9	10.9	20.0	34.6	13.3	12.4	6.9	18.3
CRUSTACEA		100	54.8	38.7	49.3	27.9	7.5	0.7	0.6		12.4
	Pasiphaea tarda		7.1	26.1	40.5	21.1	5.9	0.4	0.4		9.6
	Other crustaceans	100	47.7	12.6	8.8	6.8	1.6	0.3	0.2		2.8
MOLLUSCA			5.3	28.1	17.7	13.4	6.7	3.7	0.0	2.1	7.5
	Oegopsida			14.9	6.6	0.9	0.9	2.7			2.2
	Unidentified Cephalopoda			6.7	7.2	7.1	1.8	0.7	0.0		2.7
	Unidentified Octopoda			2.4	3.2	3.3	2.5	0.3			1.5
	Other mollusca		5.3	4.1	0.8	2.1	1.6	0.1		2.1	1.0
ECHINODERMATA						0.0	0.0				0.0
OTHER INVERTEBRATES						0.0	0.1	0.2			0.1
OTHER			1.1	4.9	1.6	1.1	13.5	21.5	24.7	8.5	13.8
	Greenland halibut offal					0.9	12.5	21.2	23.4	8.5	13.0
	Other		1.1	4.9	1.6	0.2	1.0	0.4	1.3		0.8
No. indivs. with stomach contents		1	9	147	432	465	301	160	45	8	1 568

rous predator (Fig. 7), redfish (*Sebastes* spp.) has been an important prey in Flemish Cap (Table 5) (Román *et al*., MS 2004). However, predation on fish decreased and predation on crustaceans increased (mainly on northern shrimp) from 1998 to 2001 (Fig. 7). This means an energy density loss (Lawson *et al*., 1998) that might influence in condition.

Seasonal differences in condition were found for both sexes. In Div. 3LNO, maximum occurred in winter–spring and minimum in summer, for both sexes. In Flemish Cap, maximum occurred later, in summer-autumn, and the minimum in spring, so the gradual decrease of condition is prolonged through a wider period, from summer to winter. Seasonal changes were more difficult to interpret in Svalbard. Females had the highest condition in winter, so the condition recovery would begin earlier in southern latitudes and it would be delayed in northern latitudes. Nevertheless, the process was not coincident for males. These differences would be related to the complex maturity behaviour of Greenland halibut (Bowering and Nedreaas, 2001; Morgan *et al*., 2003). No clear spawning seasonality was reported in Barents Sea (Federov, 1971a; Albert *et al*., MS 1998) and Northwest Atlantic (Junquera and Zamarro, 1994; Junquera and Saborido-Rey, MS 1995), besides high inter-annually variability was observed in the spawning peak (Morgan and Bowering, 1997). There is evidence that some mature females do not spawn annually and that the pause in reproduction could last for at least two years (Federov, 1971b). The prolonged

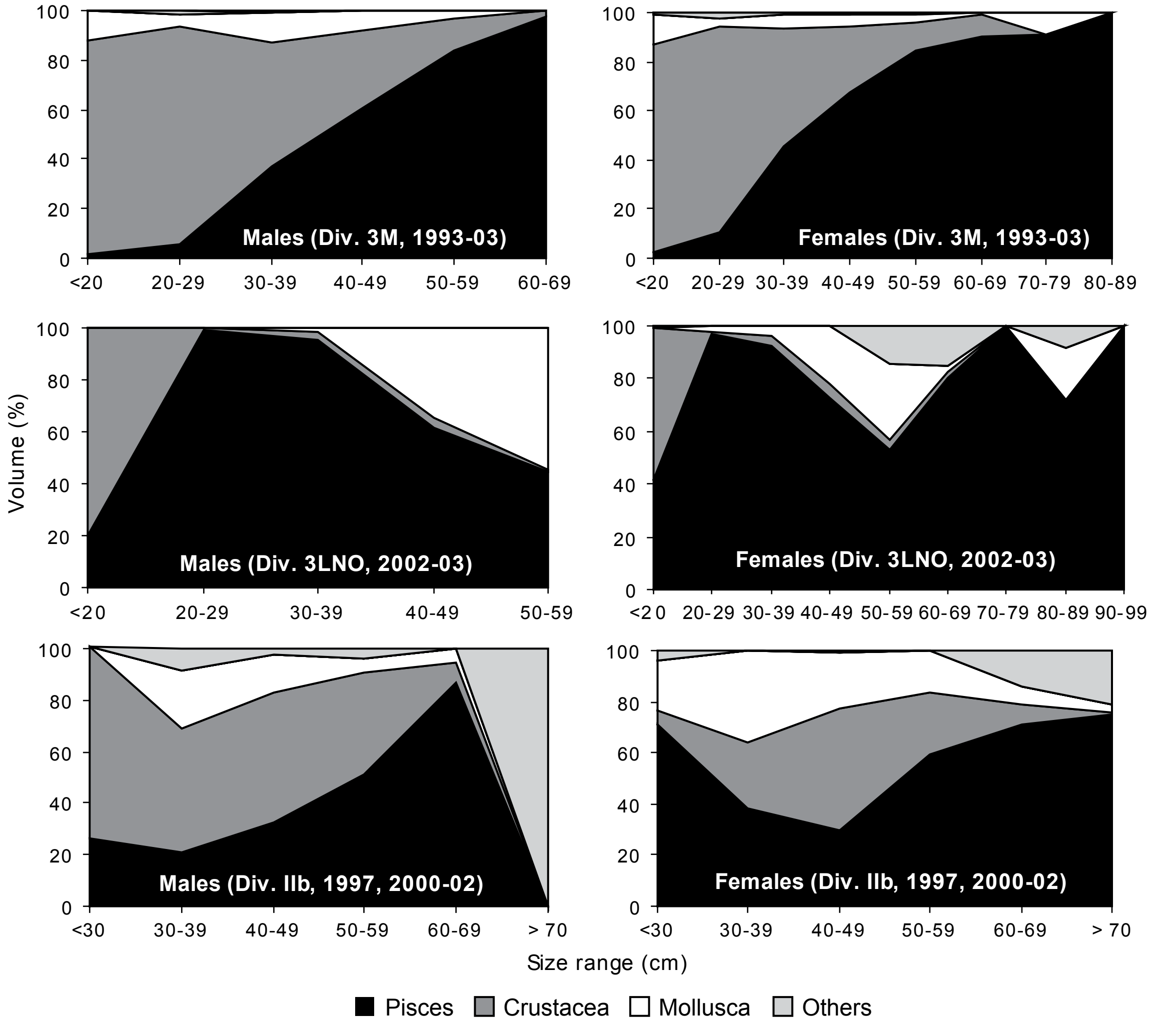

Fig. 9. Volume percent of the main prey groups by size range and sex for *R. hippoglossoides* in NAFO (Div. 3M, 1993–2003; and 3LNO, 2002–2003) and ICES (Div. IIb, 1997 and 2000–2002).

vitellogenesis process could explain the irregularity or lack of clear seasonality in the spawning season in the Northwest Atlantic (Junquera *et al*., MS 2001), while in the Northeast Atlantic, spawning is more synchronized, with peaks occurring in the last quarter of the year (Albert *et al*., MS 1998).

We cannot attribute the seasonal and geographical differences in condition (Fig. 2) to the maturation process exclusively, because mature and immature individuals were analysed jointly. Maturity of Greenland halibut is highly variable with regard to size and age (Morgan and Bowering, MS 2000), which would mask differences (geographical, seasonal, on size and sex) in condition.

Condition and feeding activity decrease in the spawning time (Maddock and Burton, 1999). Rodríguez-Marín *et al*. (MS 1997) founded decreased feeding intensity of Greenland halibut when females become reproductively active. We have used total weight data to calculate condition factor, and gonads and stomach content represent an important part of total weight. We founded a clear opposite trend between condition and feeding intensity in adult females. Seasonal feeding intensity would be dependent of the condition stage. A clear seasonal feeding being not observed, mainly in individuals <50 cm (juvenile individuals) in Flemish Pass (Junquera, 1995; Rodríguez-Marín, MS 1995) and West of Greenland (Pedersen and Riget, 1993) would be related with the lack of seasonality at spawning mentioned above.

Interannual in Div. IIb, influenced by the ecosystem characteristics and sampling season (spring–summer *vs*. winter). Higher feeding intensity in the Northwest

Atlantic than in Northeast has been already reported for other species (González *et al*., 2006). Piscivorous patterns were similar in the three areas, but the precise prey item changed depending on distribution and availability. Greenland halibut <20 cm fed almost exclusively on crustaceans, mainly hyperiids. Predation on crustaceans decreased and fish predation increased when predator size increased. Offal is an extra supply for food introduced by fishing activity (Rodríguez-Marín *et al*., MS 1997), mainly in larger fish diet in Svalbard. Occasional incidence of echinoderms and other bottom organisms is indicative of the bathypelagic habits of the Greenland halibut (Chumakov and Podrazhanskaya, 1986).

Greenland halibut condition showed some spatial, seasonal and temporal differences. The repercussions in the population stage seem clear, because condition, feeding intensity, food components and reproductive cycle should be closely linked, and even closer in adults. Nevertheless, life history of Greenland halibut is not very well-known, making it difficult to establish conclusive relationships between condition and biological parameters. However, other analyses with eviscered weight could be carried out to obtain more information on the seasonal condition of the individuals.

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