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Maturation in North-East-Arctic Haddock.

by

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Abstract

Maturation in north-east-arctic haddock was studied in relation to fish age, length, weight and condition factor using data from scientific surveys in 1989-1998. In order to investigate the reliability of the maturity determination undertaken routinely onboard, gonads from 165 female haddock sampled during the Barents Sea trawl survey in January-March 1998, were studied in binocular. The size of the oocytes were measured, fitted to a 6-point maturity scale, and compared with the 5-point maturity scale used. The results showed that the maturity determination of the routine sampling was reliable.

Additionally, maturity at length and age was investigated for males and females using data from the winter surveys in 1989-1998 by fitting logistic curves. Variations in maturity were compared with growth and condition. Males mature at a smaller size and younger age than females. Considerable year to year variations were found in length at 50% maturity in both sexes. Fluctuations in length and age at maturity followed similar trends, suggesting that length, as well as age, determine maturation.

Keywords: Haddock, maturity, growth, condition.

Introduction

North-east-arctic haddock (*Melanogrammus aeglefinus* L.) is the second most important commercial ground fish species inhabiting the Barents Sea (Korsbrekke 1998). The haddock population is distributed in the Norwegian, Greenland and Barents Seas (Sonina 1976), and main spawning sites are located along the continental shelf off Northern Norway (Solemdal *et al.* 1997). The most intensive spawning occurs in March-May with peak spawning in April (Sonina 1976). Haddock is a batch spawner, and spawns up to 24 batches within 5 weeks

(Hislop *et al.* 1978). Immature haddock stay in the Barents Sea, and migrate westwards when mature (Sonina 1969).

If a fish matures, depends on the amount of energy available. Roff (1983), suggested that a determined amount of energy may be used for either somatic or gonadal growth, and as was observed for repeat spawners of cod (*Gadus morhua* L.), individuals in poor condition missed spawning (Oganesyan 1993).

Fluctuations in length and age at maturity have been observed for several haddock stocks (Jones & Hislop 1978, Taylor & Stefansson 1998). The general warming of the Northern Atlantic from 1930 to 1950 increased growth rate of North-Sea haddock, reducing age at maturity (Tormosova 1983). A declining age and length at maturity has been observed for most of the Northwest Atlantic gadid stocks since the 1970's (Trippel *et al.* 1997). In the Icelandic haddock stock, maturation after 1988 is observed to occur earlier than in previous decades (Taylor & Stefansson 1998).

Low temperature will result in a shorter length at maturity as a result of low growth (Templeman & Bishop 1979a). Increased temperature affects food intake and metabolism (Døving & Reimers 1992), as was found in North-Sea haddock (Kovtsova 1993), and extend the feeding area and prolong the fattening season (Sonina 1964).

Jones (1983), found that intraspecific competition for food resulted in reduced growth of North-Sea haddock, and only fish of the same age or younger were affected. Strong year classes of North Sea haddock lowered recruitment of subsequent year classes up to the age of two (Cook & Armstrong 1984). Templeman *et al.* (1978), found that length and age at maturity decreased as a result of high density. Furthermore, increased maturation may be a response to increased fishing intensity, since the probability of dying increases with age (Pitcher & Hart 1982).

The north-east-arctic haddock population has shown large fluctuations in numbers of fish in each year class (Sonina 1969, Kovtsova 1987), and size- and age structure has varied considerably (Sonina 1969). The growth of the Barents Sea haddock increased from 1930 to 1970, and growth rate rather than length seemed to be important for maturation (Sonina 1981).

In the 1970's and 1980's, maturation in haddock accelerated while growth rate was the same (Kovtsova 1987). In 1990-1992, haddock growth and maturation was higher (Kovtsova 1993), caused by a reduction in the population abundance and a higher temperature in the southern Barents Sea.

Reliable determination of length and age at maturity are important for the estimation of the spawning population, and thus for growth and recruitment studies. High growth will lower the age at maturity, and younger fish will recruit to the spawning population (Kovtsova 1993, Marshall & Frank 1999). This will increase the probability that the fish lives long enough to spawn several times, but also result in a shortening of the life-cycle (Sonina 1981). If the spawning population consists mostly of young individuals, their lower fecundity can not compensate for a high exploitation pressure, and the stock biomass will decrease (Tormosova 1983). Older individuals have a higher fecundity and greater viability of eggs and larvae (Hislop 1988, Marteinsdottir & Thorarinsson 1998). Increased age diversity of the population will expand the spawning season due to the wide size range of the fish, and extend the spawning areas (Hutchings & Myers 1993, Marteinsdottir & Petursdottir 1995).

The paper is part of a master thesis. Relations between maturation and length, weight, age, condition and growth were established, in order to investigate how maturation was affected by these factors. A calibration procedure was undertaken to validate the data used in the analyses.

Materials and Methods

The calibration

Gonads from 165 female haddock were sampled during the Barents Sea trawl survey in January-March 1998. A small sector from the right ovary was cut and stored in buffered formaline. Lenght (cm), gonad weight, whole fish weight (g) and gutted weight (g) were recorded. With a binocular microscope (50x) equipped with a micrometer, the horizontal and vertical axis of 10 oocytes per fish were measured and the mean calculated. Original oocyte diameter was found using a micrometer, and calculated ± 5 µm. Measured oocyte size was fitted to a 6-point maturity scale (Kjesbu 1991), and compared with the 5-point maturity scale used (Borge *et al.* 1999).

Analyses of maturity

The data is from winter surveys, undertaken by the Institute of Marine Research in 1989-1998, and samples from the first quarter in the same period. Maturity at length and age was analysed by year and sex using a model

$$\text{logit}(p) \equiv \log [\, p/(1-p)] = \alpha + \beta x,$$

where p is estimated probability of the mature portion, x is length or age, and α and β are coefficients. A maturity of 50% is estimated as $(-\alpha/\beta)$. A curve was fitted to the observed values by using a logistic procedure with a logit link function, after the method for maximum likelihood estimation by using Fisher scoring algorithm (SAS Institute Inc. 1996 cited in Ajiad *et al.* 1998). Number of mature individuals represents the number of events, and the total number is the number of trials.

Growth in length and weight were calculated as

$$\Delta G_{L,y} = L_{a+1,y} - L_{a,y}$$

$$\Delta G_{W,y} = W_{a+1,y} - W_{a,y},$$

where ΔG is growth increment in length (L) or weight (W) at age (a) and year class (y). This is plotted against percent mature fish in the following year.

Condition is analysed by using Fulton's condition factor (K) (Cone 1989) shown in the following formula

$$K = (W/L^3) * 10^2,$$

where W is weight (g), L is whole body length (cm).

Results

The calibration

The calibration (Table 1) revealed four fishes classified as maturing (bold), but the diameter of the oocytes was 105-240 µm, and the same as for immature fish. Two fishes had oocytes with diameter 440 µm, and because of an overlap of the intervals 360-440 micrometer and 430-870 micrometer, it was not possible to decide whether this was early maturing (stage 3), or maturing (stage 4) fish. To be able to distinguish between stage 3 and 4, it is necessary to investigate the oocytes histologically, but this is not the purpose of this work.

Analyses of maturity

Estimated length and age at 50% maturity was less in males than in females in all years except 1989, and this difference between sexes seem to increase during the first half of the 1990's, but has declined in recent years (Tables 2 and 3, Figures 1 and 2).

In figures 3-6 is plotted the percentage mature for each age group against the increment in length and weight in the year prior to the maturity determination. Except for age 5 in both sexes-and perhaps also age 4 in males-there seem to be no trend in these plots. In females the fast growing year classes 1988 and 1989 matured at a considerably slower rate (age 3 and 4) than the year classes 1992-1994, which had less growth between age 2 and 4 years, while for males it seems to be no difference in maturation at age 4 between the fast growing (1987, 1988, 1989) and the more moderately growing (1992, 1993, 1994) year classes.

Both in females and males there appear to be a tendency that the percentage mature was positively related to the condition factor in the preceding year (Figures 7 and 8). This tendency was more clear at age 5 in both sexes.

In figures 9 and 10 are shown the percentage mature at age 3 as a function of year class strength (stock number at age 3) and total stock size (stock number aged 3+). Maturation seems to be negatively related to year class strength in both sexes, however with large variability for low abundant year classes (Figure 9). For males, there is a tendency towards reduced maturation with increasing total stock size, while for females there seems to be no relation between maturation at age 3 and total stock size.

Discussion

The calibration

Fish with an erroneous maturity stage, constituted 2.42 % of the total investigated, which is a rather small inaccuracy. The staff members taking part at the sampling, were informed about the purpose of this work, and might have spent time and effort to determine the correct maturity stage. The high speed, at which the sampling and classification usually is performed, could lead to more misclassifications than were found here.

Also, subjective evaluation and experience can have an important effect on the maturity determination (Albert *et al.* 1998). This was seen in Greenland halibut (*Reinhardtius hippoglossoides* Walbaum), where the distribution between maturing and spawning fish, was significantly different in fish classified by staff members working on different watches.

Analyses of maturity

The observation that males mature at a shorter length and younger age than females was also made for north-east-arctic cod (Aijad *et al.* 1998), north-east-arctic haddock (Sonina 1976), and several haddock stocks (Templeman *et al.* 1978, Templeman & Bishop 1979b, Beacham 1983, Tormosova 1983). The time series of differences between sexes in length and age at 50 percent maturity show a pattern with maximum differences occurring in the period 1993-1996 (Tables 2 and 3). Most probably this is due to the predominance in the stock by the abundant year classes 1989-1991 (particularly the 1990-year class) which matured in these years, causing the differences in 50 percent maturity between sexes for the stock to fluctuate along with the maturation of each of the sexes in these year classes.

If maturation is dependent upon length, then age at maturity should have declined with increased growth (Beacham 1983). The very similar fluctuations in length and age, may suggest that length, as well as age affects maturation. This is in contrast with the results found in Tormosova (1983), where maturation was found to be a function of length rather than age.

It was expected that fish with high growth would mature at a younger age than fish experiencing lower growth. The apparent poor relation between growth and maturation, as observed by us (Figures 3-6), may be caused if fish from different areas in the Barents Sea has undergone different growth. Depending on the fishing area, length at age will differ. Taylor and Stefansson (1998), found significant variation in length at age for Icelandic haddock at different trawl stations. The results obtained, can thus be affected by the geographical distribution of the various year classes.

It is doubtful whether condition factor increases as a result of maturation, or that maturation increases as a result of increased condition. For ages 5 to 7, it appeared that maturation increased with increasing condition the year before, and is in accordance with the observation made by Bohlin *et al.* (1994) for male wild Sea-run brown trout (*Salmo trutta* L.). Rowe and Thorpe (1990), found that the increase in condition factor in spring in male Atlantic salmon parr, probably was due to increased lipid content resulting from the effect of testosterone on growth in spring. This may occur in haddock as well. It should however be noted that the condition factor used by us (Fulton's K) may not be the most suitable for maturation studies.

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Tables and figures

Table 1: Calibration of the Kjesbu scale (Kjesbu 1991) and the usual maturity scale used (Borge *et al.* 1999). The number in brackets indicate the number of fish in maturity stage 4. For further description see text.

Kjesbu' s scale		HI' s scale				
		Maturity stage				
Maturity stage	Egg diameter (µm)	1 (immature)	2 (maturing)	3 (spawning)	4 (spent/resting)	5 (uncertain)
1 or 6 (immature/recovering spent)	105-240	54	4			6
2 (early maturing)	260-370					
3 (maturing)	360-440		2 (0)			
4 (late maturing)	430-870		(99) 97			
5 (spawning)	> 1100					

Two fishes with oocytes at 85 µm and 925 µm did not fit the division of the intervals, and are not shown in the table.

Table 2: Estimated length for females and males at 50% maturity in 1989-1998 and standard error (SE) for α and β.

Year	Sex	α (SE)	β (SE)	Length (cm) at 50% maturity	Length female - length male (cm)
1989	Female	-5.4823 (0.3657)	0.1399 (0.00888)	39.19	- 0.32
	Male	-3.5483 (0.2701)	0.0898 (0.00689)	39.51	
1990	Female	-5.8786 (0.3499)	0.1598 (0.00883)	36.79	3.31
	Male	-5.7352 (0.3085)	0.1713 (0.00884)	33.48	
1991	Female	-7.8449 (0.4723)	0.1787 (0.0108)	43.90	4.18
	Male	-4.8977 (0.2868)	0.1233 (0.00751)	39.72	
1992	Female	-6.7345 (0.4312)	0.1378 (0.00954)	48.87	4.25
	Male	-3.7306 (0.2602)	0.0836 (0.00675)	44.62	
1993	Female	-6.8710 (0.4394)	0.1378 (0.00965)	49.86	6.29
	Male	-4.0259 (0.2781)	0.0924 (0.00712)	43.57	
1994	Female	-5.1421 (0.3691)	0.0977 (0.00825)	52.63	5.25
	Male	-4.7195 (0.3277)	0.0996 (0.00811)	47.38	
1995	Female	-5.0111 (0.3590)	0.1061 (0.00828)	47.23	3.93
	Male	-5.2612 (0.3515)	0.1215 (0.00859)	43.30	
1996	Female	-5.5116 (0.4129)	0.1161 (0.00923)	47.47	5.40
	Male	-6.0881 (0.4047)	0.1447 (0.00982)	42.07	
1997	Female	-6.6324 (0.4634)	0.1784 (0.0120)	37.18	3.33
	Male	-5.4564 (0.3849)	0.1612 (0.0108)	33.85	
1998	Female	-8.4023 (0.5840)	0.2066 (0.0142)	40.67	2.06
	Male	-6.8072 (0.4612)	0.1763 (0.0118)	38.61	

Table 3: Estimated age for females and males at 50% maturity in 1989-1998 and standard error (SE) for α and β.

Year	Sex	α(SE)	β (SE)	Age at 50% maturity	Age female - age male
1989	Female	-3.6029 (0.2603)	0.7907 (0.0520)	4.56	- 0.30
	Male	-2.4938 (0.2012)	0.5130 (0.0412)	4.86	
1990	Female	-3.9876 (0.2370)	1.0257 (0.0553)	3.89	0.42
	Male	-3.6117 (0.1975)	1.0417 (0.0543)	3.47	
1991	Female	-5.6526 (0.3337)	1.2690 (0.0815)	4.45	0.44
	Male	-3.6114 (0.2069)	0.8997 (0.0584)	4.01	
1992	Female	-4.9224 (0.3220)	1.0149 (0.0811)	4.85	0.34
	Male	-2.8073 (0.1943)	0.6222 (0.0553)	4.51	
1993	Female	-4.9639 (0.3571)	0.9928 (0.0878)	5.00	0.63
	Male	-2.9372 (0.2357)	0.6714 (0.0661)	4.37	
1994	Female	-4.3041 (0.3342)	0.7635 (0.0754)	5.64	0.52
	Male	-3.8983 (0.3033)	0.7619 (0.0745)	5.12	
1995	Female	-3.3320 (0.2878)	0.5873 (0.0603)	5.67	0.50
	Male	-4.1303 (0.3122)	0.7983 (0.0655)	5.17	
1996	Female	-3.3609 (0.3055)	0.5548 (0.0578)	6.06	0.71
	Male	-3.9942 (0.3001)	0.7472 (0.0583)	5.35	
1997	Female	-3.8914 (0.2804)	0.9353 (0.0631)	4.16	0.34
	Male	-2.8030 (0.2196)	0.7347 (0.0510)	3.82	
1998	Female	-5.0076 (0.3499)	1.1170 (0.0798)	4.48	0.05
	Male	-4.1990 (0.2882)	0.9482 (0.0662)	4.43	

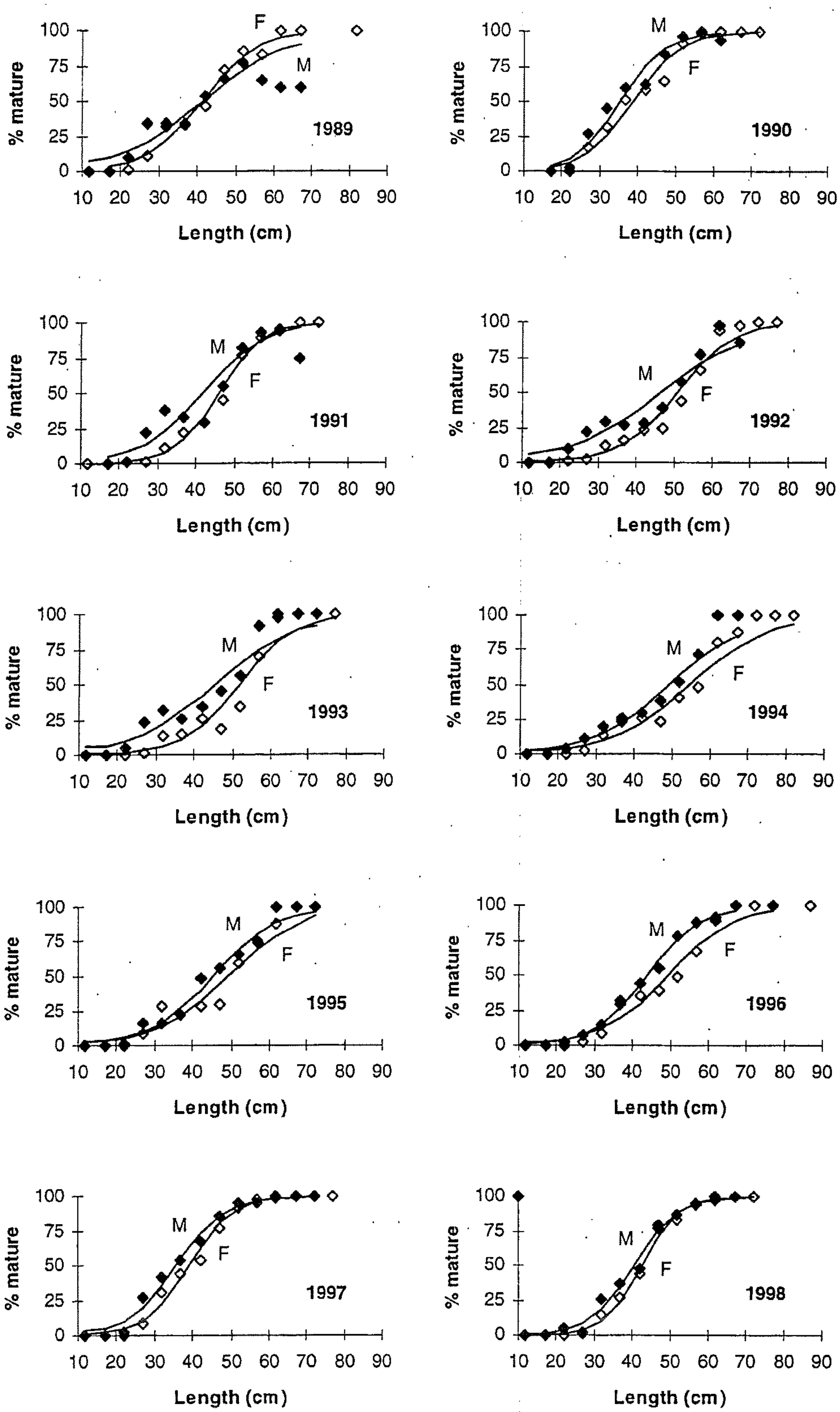

Figure 1: Maturity curves (solid line) for females (F) and males (M) in 1989-1998 fitted to percent mature at length for females (open diamonds) and males (filled diamonds).

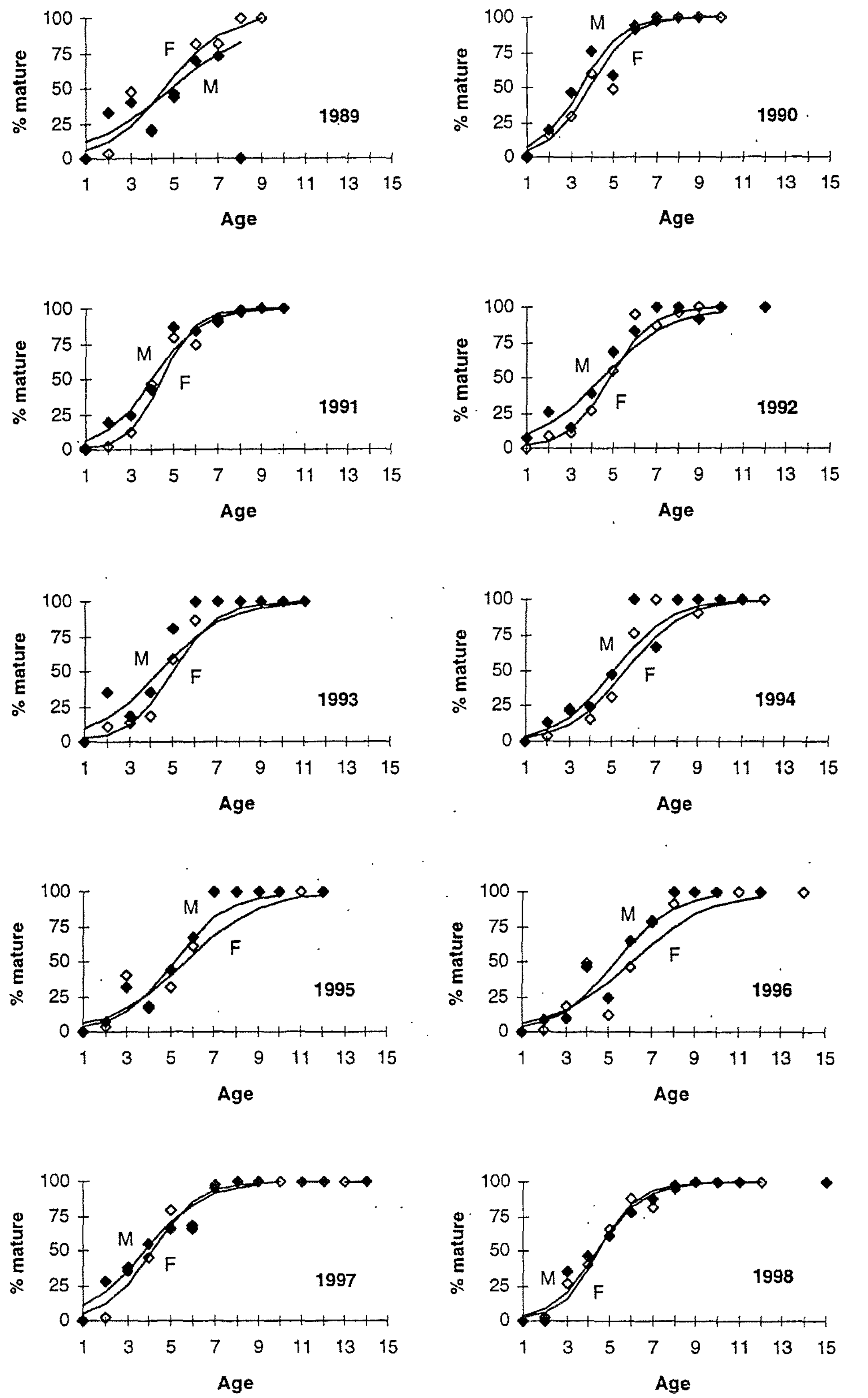

Figure 2: Maturity curves (solid line) for females (F) and males (M) in 1989-1998 fitted to percent mature at age for females (open diamonds) and males (filled diamonds).

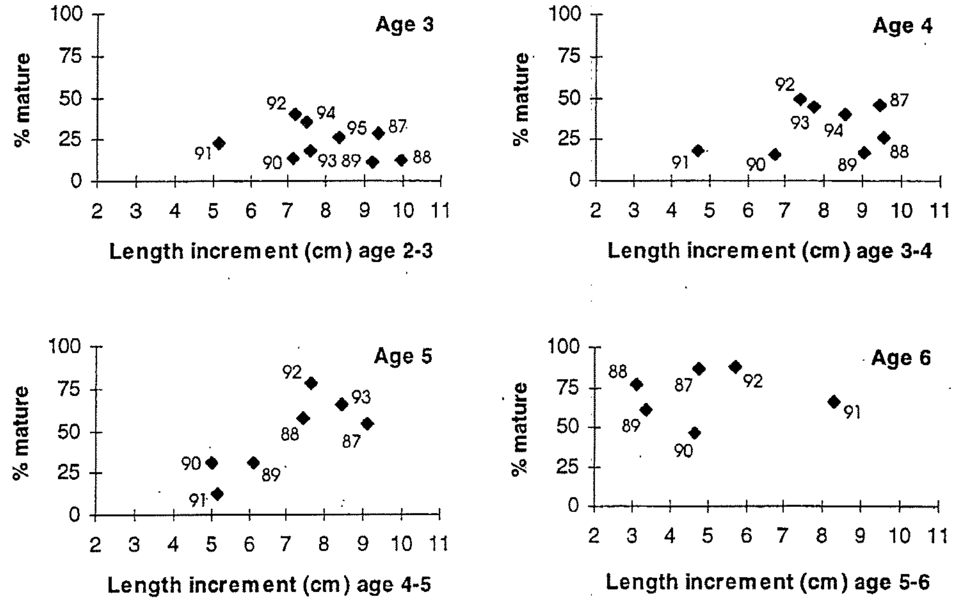

Figure 3: Increment in length and percentage of mature females in different year classes.

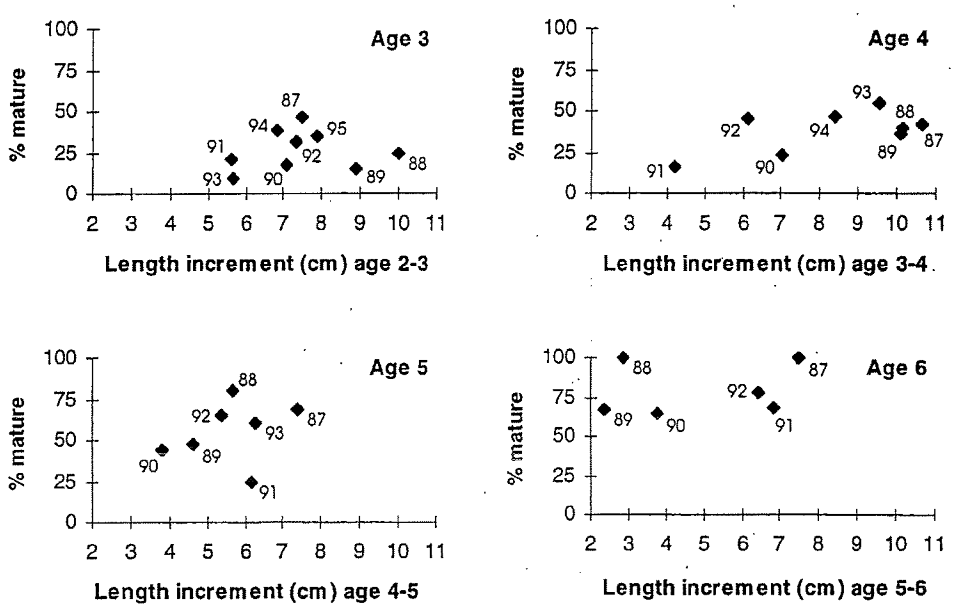

Figure 4: Increment in length and percentage of mature males in different year classes.

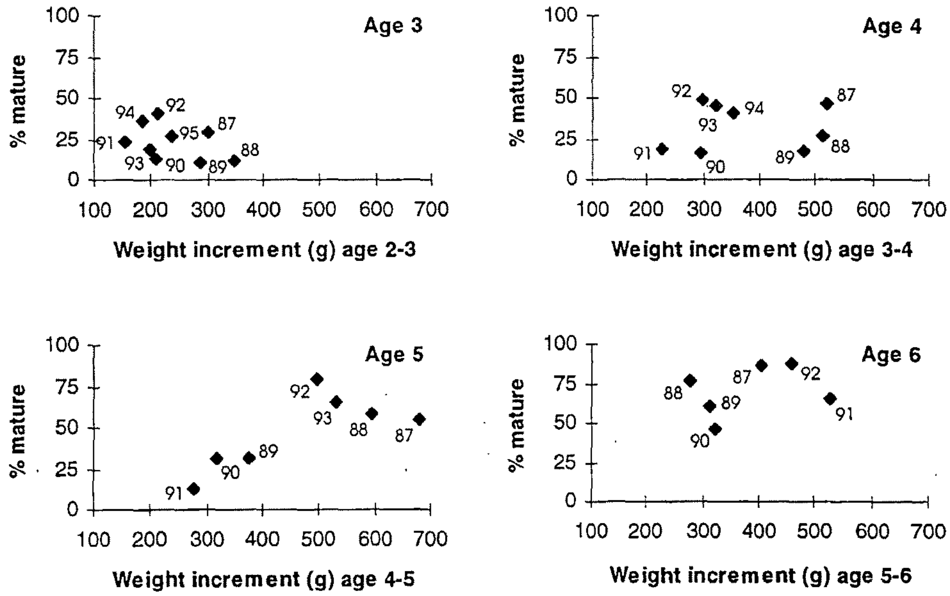

Figure 5: Increment in weight and percentage of mature females in different year classes.

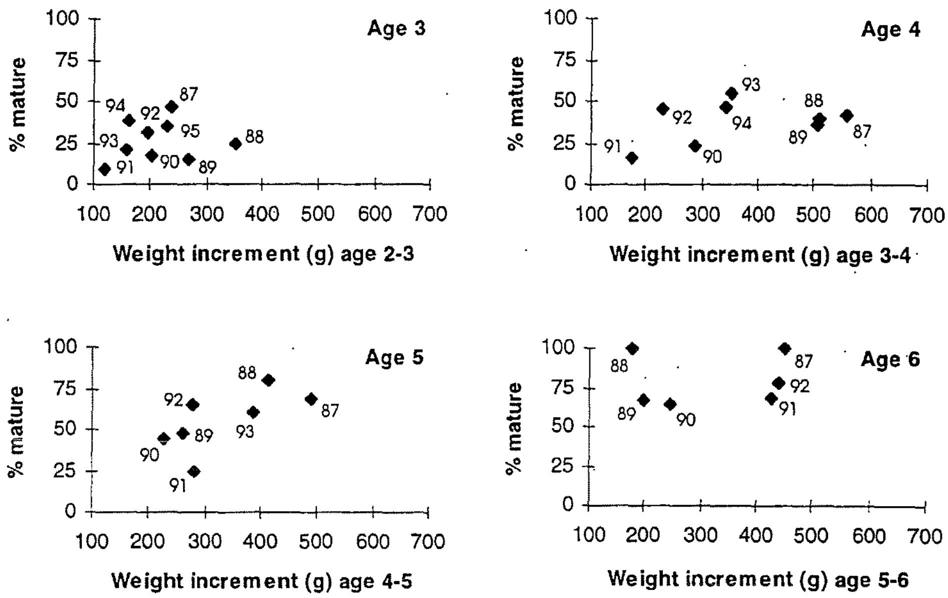

Figure 6: Increment in weight and percentage of mature males in different year classes.

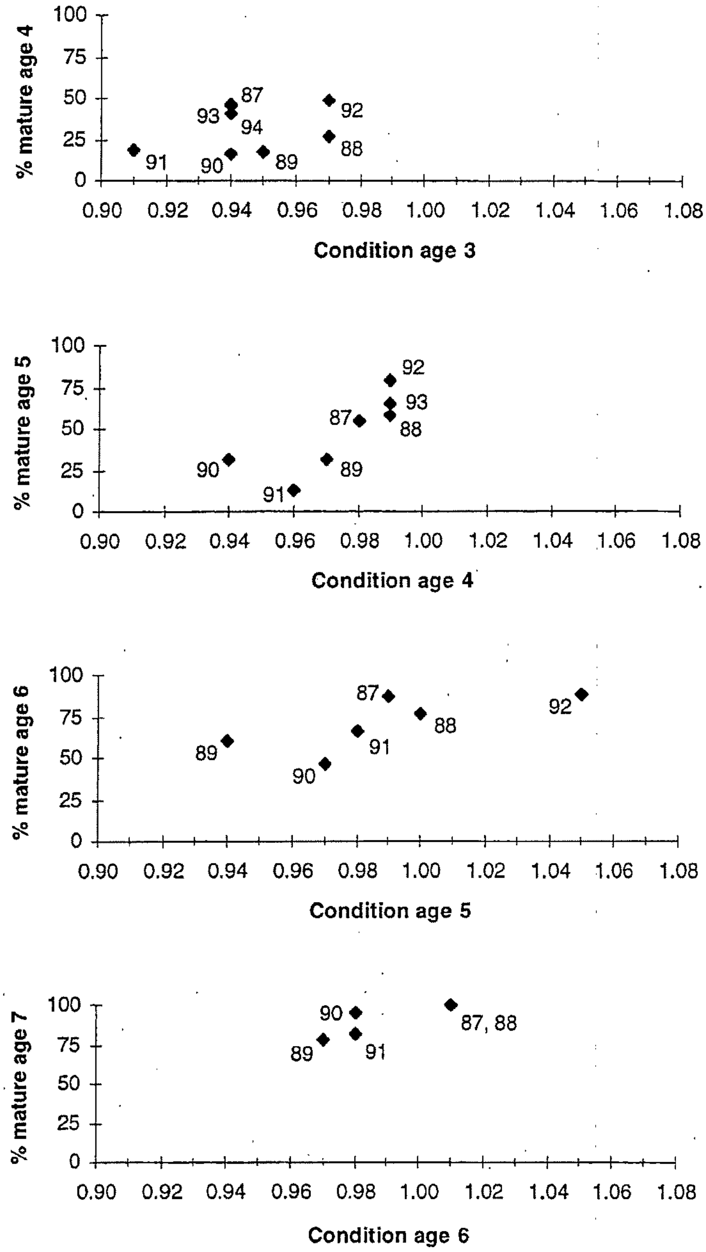

Figure 7: Condition factor and percentage of mature females in different year classes.

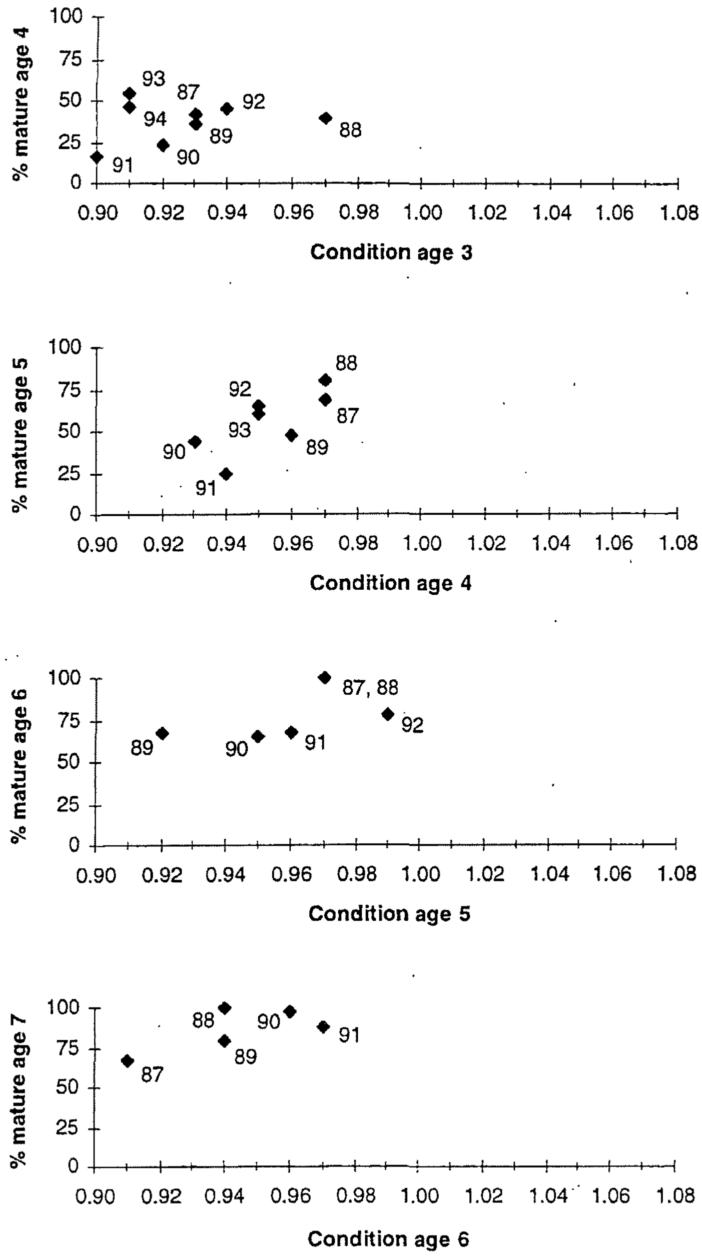

Figure 8: Condition factor and percentage of mature males in different year classes.

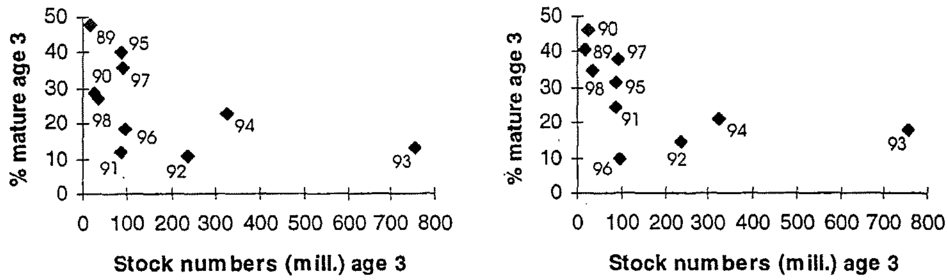

Figure 9: Stock numbers in millions at age 3 and percent mature 3-year old females (left) and males (right) in 1989-1998. Stock numbers are from ICES CM 1999/ ACFM: 3.

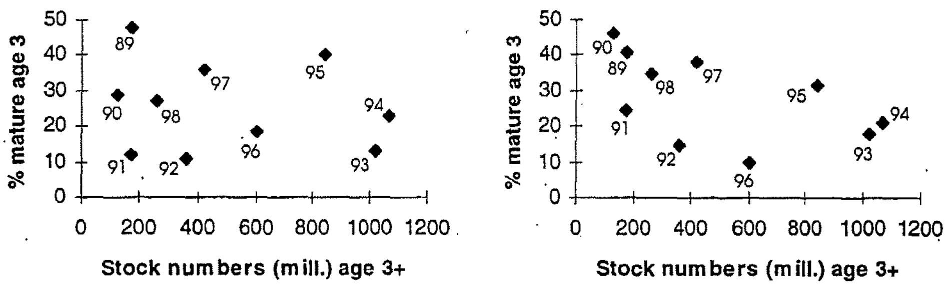

Figure 10: Stock numbers in millions at age 3 and older (3+) and percent mature 3-year old females (left) and males (right) in 1989-1998. Stock numbers are from ICES CM 1999/ ACFM: 3.