ICES C.M. 1995 (Theme Session P) Causes of Observed Variations in Fish Growth
"Not to be cited without prior reference to the author" CM 1995/P:9

FOOD CONSUMPTION AND GROWTH RATE VARIATIONS IN MALE AND FEMALE POLAR COD (*Boreogadus saida*)

by

Jørgen Schou Christiansen
Norwegian Institute of Fisheries and Aquaculture
N-9002 Tromsø, Norway

ABSTRACT

The polar cod (*Boreogadus saida*) is recognized as the piscine key species in Arctic marine food webs but, in spite of its ecological importance, there is little known about the feeding and growth of the species. Polar cod collected in the Pechora Sea, within the Eurasian region of the Arctic Ocean, have been held under laboratory conditions for a period in excess of two years. This communication reports the results of a long-term investigation carried out on polar cod of both sexes, in which the aim was to gather basic information about rates of feeding and growth. It is demonstrated that male and female fish display marked differences in growth which resulted in the female fish being almost double the body weight of the males. Consequently, it appears that it will be necessary to distinguish between male and female fish, as early as the juvenile stages, in order to provide realistic interpretations of polar cod growth.

Keywords: Arctic Ocean, *Boreogadus saida*, Sex, Appetite, Growth Rate

Introduction

The polar cod (*Boreogadus saida*) is a small-sized, short-lived gadoid fish which is abundant in the Arctic Ocean, where it often occurs in association with subzero temperatures and sea ice. The polar cod is of some commercial importance, being mainly exploited by Russian fisheries, and it is recognized as providing an important link between lower trophic levels and the bird and mammalian top predators in Arctic marine food webs (Hobson and Welch, 1992). Despite the ecological importance of polar cod there is surprisingly little known about the feeding and growth of the species (Gjøsæter and Ajiad, 1994).

Polar cod collected in the Pechora Sea, within the Eurasian region of the Arctic Ocean, have been held under laboratory conditions for a period in excess of two years. This communication reports the results of a long-term investigation carried out on polar cod of both sexes, in which the aim was to gather basic information about rates of feeding and growth.

Materials and methods

In January 1993, polar cod (age: 2-3 years; body size: ~ 146 mm and ~ 17 g) were collected by bottom trawl at a depth of approximately 60 m in the Pechora Sea south of Novaya Zemlya (70 N, 54 E), Russia. A representative subsample of fish (N = 20) was examined with respect to age, sex and reproductive status. These fish were all found to be sexually immature (i. e. juveniles) at the time of capture. The remaining fish were transported to the research facilities in Tromsø where they were acclimated to full strength sea water (water exchange rate: 3.5 L min^{-1}) at a constant temperature of approximately 0 °C. Light condition was kept constant at about 300 lux. The fish were weaned on to a formulated moist food based upon cod roe and krill meal (Christiansen and George, 1995) and all were seen to feed after approximately one month in captivity. Following weaning the fish were in good condition and no fish died during the experiment which lasted for 731 days from March 1993 to March 1995.

Experimental procedures

Two weeks prior to the start of the experiment, 45 fish were individually tagged with FTF-69 fingerling tags (Floy Tag™, Seattle, Washinton, U. S. A.) sewn just beneath the anterior cartilage of the first dorsal fin. This group of polar cod was then transferred to a 600 L aquarium and subjected to the conditions described above. Fish were hand fed the formulated moist food (gross energy content: 7.3 kJ g^{-1} w/w) to satiation at four to five days intervals. The fish were offered a total of 150 meals.

On nine occasions (1993: March, September; 1994: January, May, August, October; 1995: January, February, March), fish were anaesthetized with benzocaine (60 ppm) and body weight (bw to the nearest 0.5 g) and total body length (mm) were measured. At the same time, voluntary food intake was determined by X-radiography using food labelled with no. 8.5

Ballotini Glass Beads (Jencons™, Bedfordshire, U. K.), at a concentration of 0.45 % w/w (Jobling *et al.*, 1993; Christiansen and George, 1995).

Calculations and data analysis

A few fish lost their tags during the experiment and some X-ray plates were difficult to interpret, so complete data sets relating to food intake and growth were collected for 13 male and 27 female fish.

Food intake was calculated relative to fish body weight on each sampling date, and specific food intake was then converted to ingested energy (EC = kJ g bw^{-1} $meal^{-1}$) by multiplying the weight of food consumed by 7.3, the gross energy content of the food. Specific growth rates (= G; expressed as % bw day^{-1}) of individual fish were calculated for each period according to the formula [$G = (\ln bw_D - \ln bw_d)100/D-d$] where bw_D is body weight on day D and bw_d is body weight on day d an D-d is the time between weighings in days. Relative growth was calculated for each fish during each period according to the formula [$bw_D - bw_d/bw_d$] and results were expressed as g bw change g initial bw^{-1}. The energy consumption per average meal for the corresponding periods was calculated as [$(EC_d + EC_D)0.5$] where EC_D and EC_d is energy consumption on day D and d respectively.

Comparisons of arithmetic means between sexes were made using Student's *t*-test. The relationships between body weight and the specific growth rate were examined by regression analysis using the method of least squares, and regression lines for the two sexes were compared using ANCOVA. Differences present at the 5 % level were considered significant (Zar, 1984).

Results

All fish became sexually mature during January-March 1994 and 1995, and they released small quantities of eggs or sperm during handling. Data obtained during the spawning season were excluded from the detailed analyses of feeding and growth (Fig. 1). Retrospective analysis showed that the growth of males and females differed (Fig. 2), and the data for the two sexes were, therefore, analysed separately. Thus, in the following presentation the main focus is directed towards periods when the fish were either sexually immature (i. e. juveniles) or not immediately affected by spawning (Fig. 1).

Body weight and specific growth rate vs *time and season*

Figure 2 shows the changes in body weight of male and female polar cod during the time span of approximately two years. At the start of the experiment in March 1993, female fish were significantly heavier than the males (female bw ~ 21 g *vs* male bw ~ 17 g; $p < 0.05$) and the weight differences were maintained ($p < 0.001$) throughout the experiment. In January 1995, female fish weighed approximately 85 g. Male fish, on the other hand, had a much slower increase in body weight and they reached their final body weight of approximately 55 g in an asymtotic manner. Consequently, male and female fish differed in body weight several months before the onset of sexual maturation and spawning (denoted by asterisks in Fig. 2).

Specific growth rates of both male and female fish varied considerably with season (Fig. 1). The most marked fluctuations in growth rates occurred during spawning where the immediate effects of hydration, ovulation and the release of sexual products were conspicuous (hatched columns in Fig. 1). When the spawning periods were excluded, there was found to be a general decline in growth rate with time irrespective of sex. There were, however, some differences between male and female fish. Female fish grew significantly better ($p < 0.01$) than the males during the autumn, and male fish lost weight from August to October (Fig. 1).

Specific growth rate vs *body weight*

The influence of body weight (bw) on the specific growth rate (G) of individual fish is shown in Fig. 3. Both male and female fish displayed a linear and highly significant decrease in growth rate as body weight increased:

[1] Male fish: $G = - 0.009bw + 0.495$ ($n = 65$; $r^2 = 0.50$; $p < 0.001$)

[2] Female fish: $G = - 0.004bw + 0.423$ ($n = 135$; $r^2 = 0.37$; $p < 0.001$)

The slopes of the regression lines differed significantly between sexes ($F_{1, 196} = 5.68$; $p < 0.01$) with the slope of the regression being steeper for males than for female fish (Fig. 3). From the regressions it can be calculated that body weight is maintained constant (i. e. G_0 = neither bw gain nor bw loss) at a size of about 55 g and 106 g for male and female fish respectively. Female polar cod may, thus, attain a body weight almost double that of males (see also Fig. 2).

Energy consumption vs *body weight and body weight change*

The relationship between body weight and the specific energy consumption is shown in Figure 4. Fish were not fed on a daily basis and each meal is equivalent to the energy consumption during a four to five days period. Energy consumption decreased from about 1.8 to 0.4 kJ g bw^{-1} within an increase in body weight from 15 g to approximately 50 g. For fish larger than 50 g, energy consumption was maintained at the 0.4 kJ g bw^{-1} level. In other words, specific food intake (kJ g bw^{-1} $meal^{-1}$) decreased with increasing body weight amongst the smaller fish (i. e. all male and smaller female fish), whereas fish larger than 50 g (i. e. large female fish) consumed similar relative amounts (Fig. 4).

The relationship between energy consumption and relative growth is shown in Figure 5. It is interesting to note that the energy consumption required to maintain body weight (i. e. zero growth) corresponds to 0.3-0.4 kJ g bw^{-1} $meal^{-1}$. Consequently, it appears that polar cod would be required to consume slightly less than 0.4 kJ g bw^{-1} $meal^{-1}$ in order to support routine metabolism. This is the level of energy consumption that seems to be maintained by fish of 50 g and over (Fig. 4).

Discussion

There are no clear external morphological features that can be used to establish the sex of polar cod and sex had to be determined following *post mortem* dissection. The present study demonstrates that male and female fish display marked differences in growth which resulted in the adult female fish being almost double the body weight of the males (Fig. 2). This is in contrast to other gadoid fish such as the Atlantic cod (*Gadus morhua*) where there may be only slight differences in growth performance between sexes, except during the short period associated with reproduction (Pedersen and Jobling, 1989). Thus, polar cod seem to resemble many of the pleuronectid species in which there are also marked differences in growth between male and female fish. In several species, e. g. Atlantic halibut (*Hippoglossus hippoglossus*), the differences in growth between the sexes become apparent following sexual maturation (Haug, 1990), but in the polar cod females are larger than the males prior to the onset of sexual maturity (Fig. 2).

Apart from the spawning period, there were only small seasonal fluctuations in growth performance irrespective of sex (Fig. 1), and as expected (Jobling, 1983; 1988) growth rate declined with increasing body weight (Fig. 3). The data concerning the energy requirements are tentative. There was an initial decrease in the specific energy consumption as body weight increased (Fig. 4) and energy consumption fell to 0.4 kJ g bw^{-1} $meal^{-1}$ for all male and smaller female fish (< 50 g). A consumption of approximately 0.4 kJ g bw^{-1} $meal^{-1}$ was, however, maintained in female fish above approximately 50 g in body weight (Fig. 4). Since the fish were fed single meals at four to five days intervals, a value of 0.4 kJ g bw^{-1} $meal^{-1}$ is equivalent to about 90 J g bw^{-1} day^{-1}.

Energy consumption *vs* growth revealed a curvilinear relationship with the energy consumption required to maintain body weight (i. e. growth = 0) being close to 0.4 kJ g bw^{-1} $meal^{-1}$ (Fig. 5). Furthermore, it appeared that female fish grew better than the males for a given energy intake, i. e. the female fish may display better gross conversion efficiency than males (Fig. 5). Although, there has been a previous attempt to estimate growth and energy requirements of captive polar cod, there was no reference to the sex of the fish in that study (Jensen *et al.*, 1991), so there are no data comparable to those obtained in the present work.

Age is known to affect the growth of fish, and it has been shown that growth decreases with increasing age in captive Pacific halibut, *Hippoglossus stenolepis*, (Paul *et al.*, 1994) and in polar cod from the Barents Sea (Gjøsæter and Ajiad, 1994). Based upon the subsample of fish taken in the field, the Pechora Sea polar cod used in this study were aged 2-3 years, and it is therefore unlikely that age differences can explain the marked differences in growth found between male and female fish.

In conclusion, this study provides information about the growth *potential* of polar cod held under controlled environmental conditions in the laboratory. As such, the data do not nescessarily reflect growth of fish in the wild. It appears, however, that it will be necessary to distinguish between male and female fish, as early as the juvenile stages, in order to provide realistic interpretations of polar cod growth.

Acknowledgements

I wish to thank M. Jobling and R. Bergersen for for valuable criticism and comments and K. V. Nielsen for technical assistance. This study was supported by the Norwegian Research Council (grant no: 104765/110).

References

Christiansen, J. S. and George, S. G. 1995. Contamination of food by crude oil affects food selection and growth performance, but not appetite, in an Arctic fish, the polar cod (*Boreogadus saida*). Polar Biol., 15: 277-281.

Gjøsæter, H. and Ajiad, A. M. 1994. Growth of polar cod, *Boreogadus saida* (Lepechin), in the Barents Sea. ICES J. mar. Sci., 51: 115-120.

Haug, T. 1990. Biology of the Atlantic Halibut, *Hippoglossus hippoglossus* (L., 1758). Adv. Mar. Biol., 26: 1-70.

Hobson, K. A. and Welch, H. E. 1992. Determination of trophic relationships within a high Arctic marine food web using $\delta^{13}C$ an $\delta^{15}N$ analysis. Mar. Ecol. prog. Ser., 84: 9-18.

Jensen, T., Ugland, K. I., and Anstensrud, M. 1991. Aspects of growth in Arctic cod, *Boreogadus saida* (Lepechin 1773). Polar Res., 10: 547-552.

Jobling, M. 1983. Growth studies with fish - overcoming the problems of size variation. J. Fish Biol., 22: 153-157.

Jobling, M. 1988. A review of the physiological and nutritional energetics of cod, *Gadus morhua* L., with particular reference to growth under farmed conditions. Aquaculture, 70: 1-19.

Jobling, M., Christiansen, J. S., Jørgensen, E. H., and Arnesen, A. M. 1993. The Application of X-radiography in Feeding and Growth Studies with Fish: A Summary of Experiments Conducted on Arctic Charr. Rev. Fish. Sci., 1: 223-237.

Paul, A. J., Paul, J. M., and Smith, R. L. 1994. Energy and ration requirements of juvenile Pacific halibut (*Hippoglossus stenolepis*) based on energy consumption and growth rates. J. Fish Biol., 44: 1023-1031.

Pedersen, T. and Jobling, M. 1989. Growth rates of large, sexually mature cod, *Gadus morhua*, in relation to condition and temperature during an annual cycle. Aquaculture, 81: 161-168.

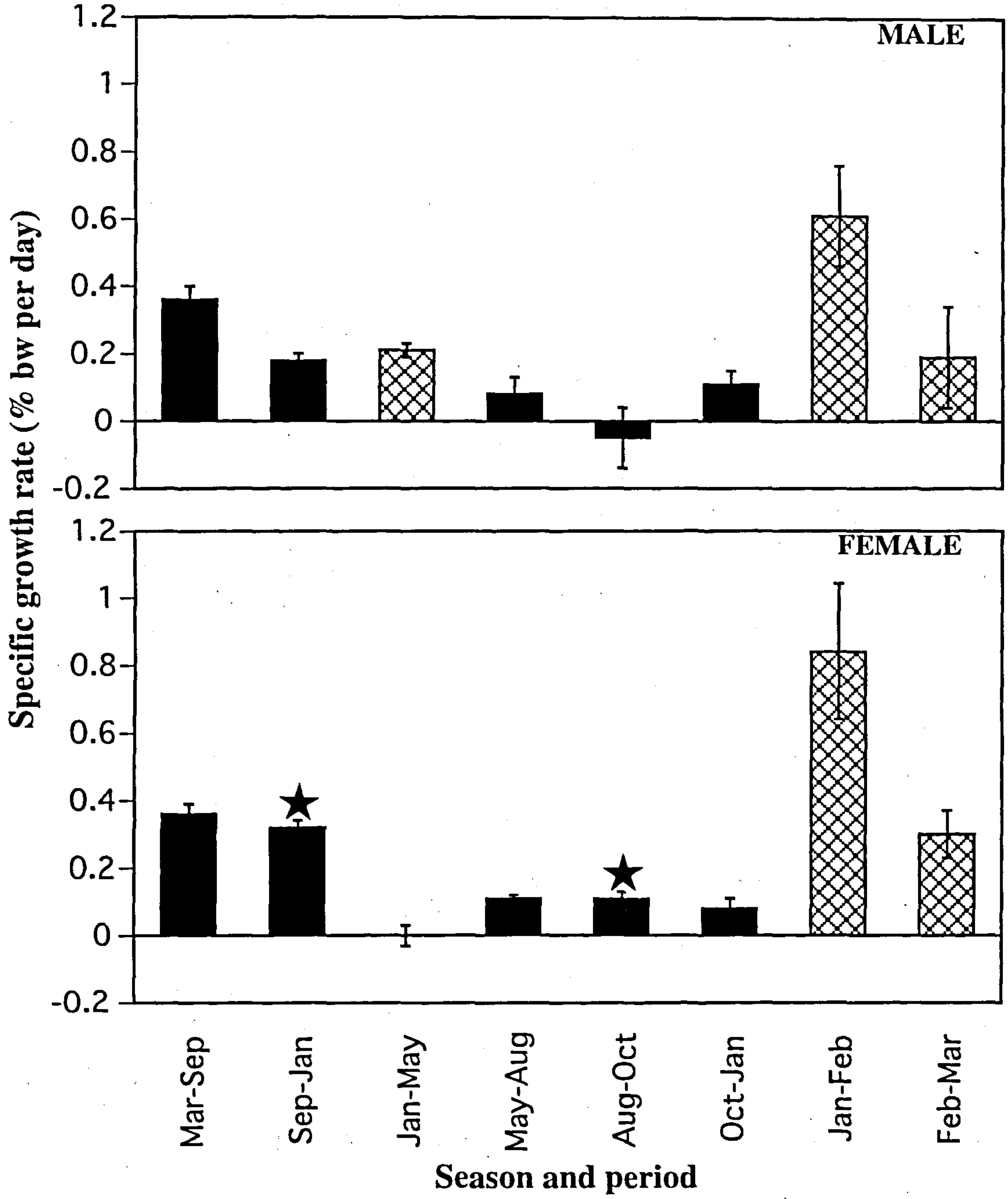

Figure 1. Seasonal variations in the specific growth rate of male (N = 13) and female (N = 27) polar cod. Spawning periods are denoted by hatched columns, and asterisks indicate significant differences in growth rate between sexes at the 1 % level. Bars indicate SEM.

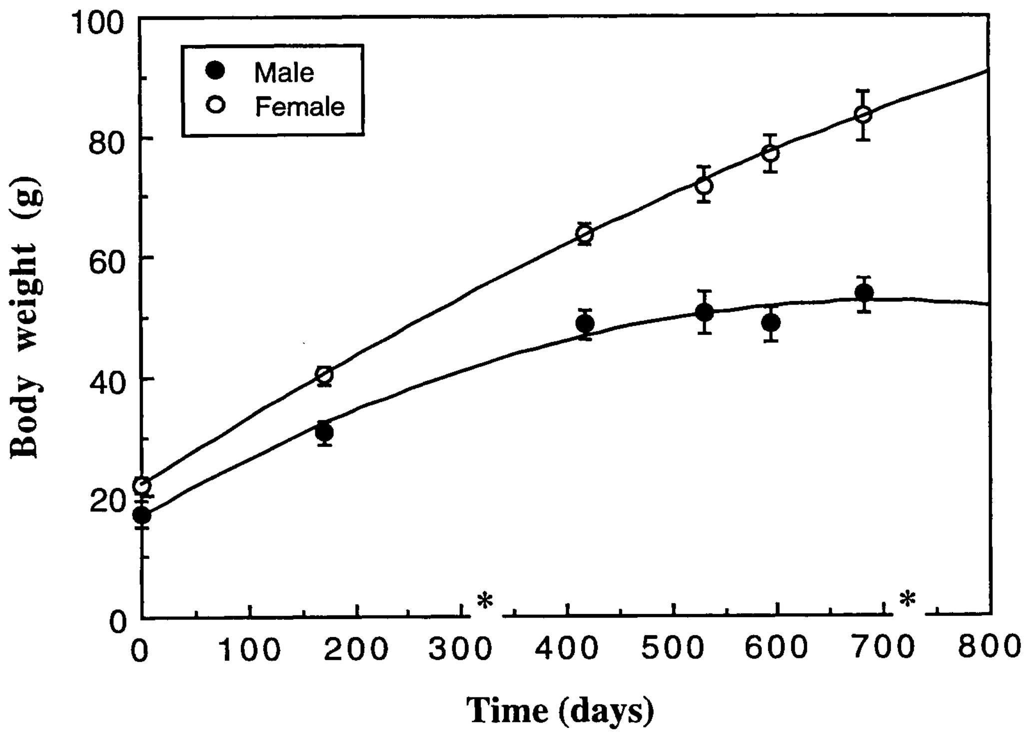

Figure 2. Temporal changes in body weight of male and female polar cod over a two year period. Spawning is denoted by asterisks. Female fish were significantly larger than the males ($p < 0.01$) on all sampling dates: day 0 = March 15, 1993; day 172 = September 2, 1993; day 418 = May 5, 1994; day 531 = August 26, 1994; day 593 = October 27, 1994; day 681 = January 23, 1995. Bars indicate SEM.

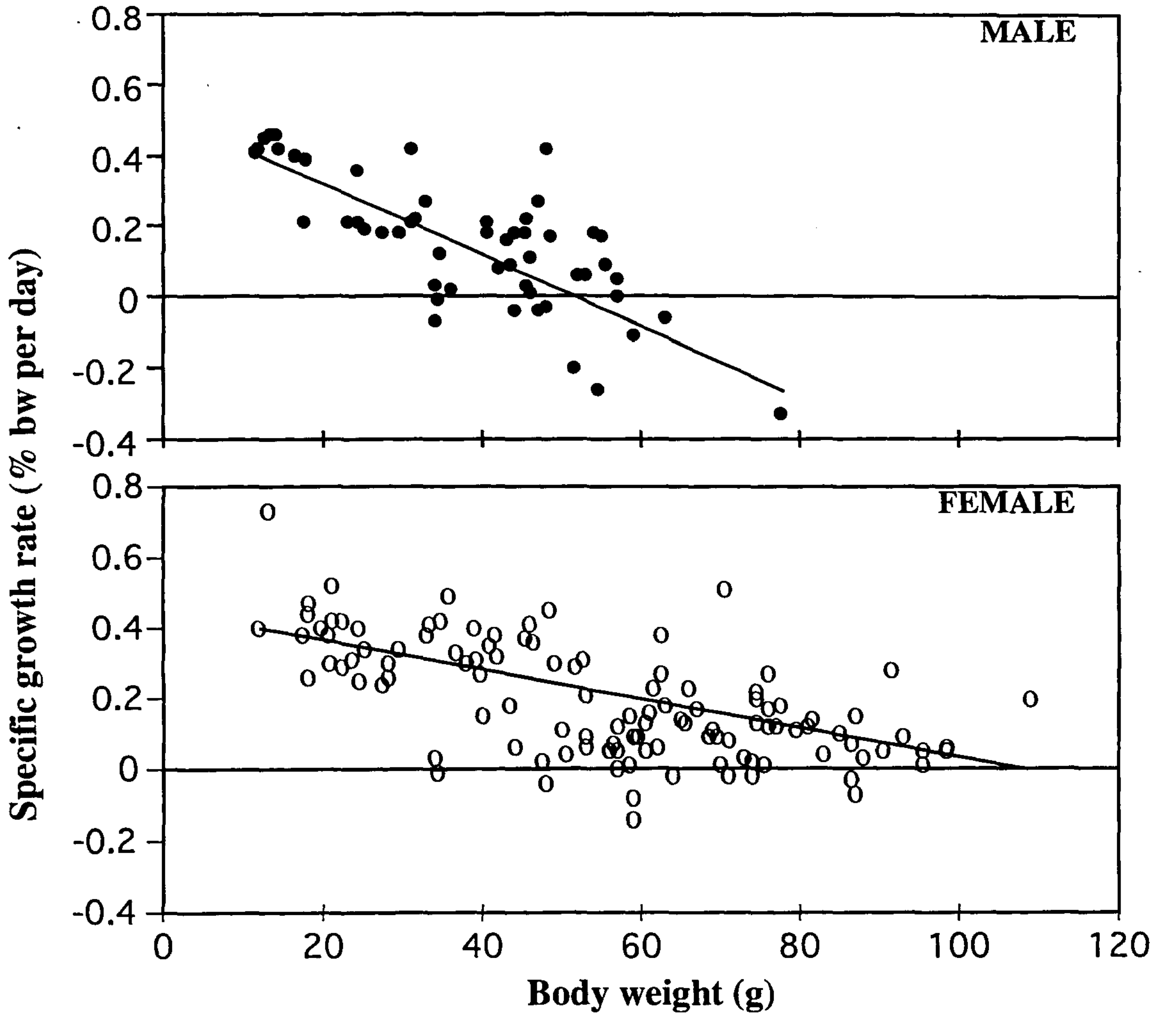

Figure 3. The influence of body weight on the specific growth rate of individual male and female polar cod. Data of individual fish are shown for all the periods combined (spawning periods excluded) resulting in 65 (5 x 13) and 135 (5 x 27) observations of male and female fish respectively. The slopes of the regression lines differ significantly between sexes ($p < 0.01$).

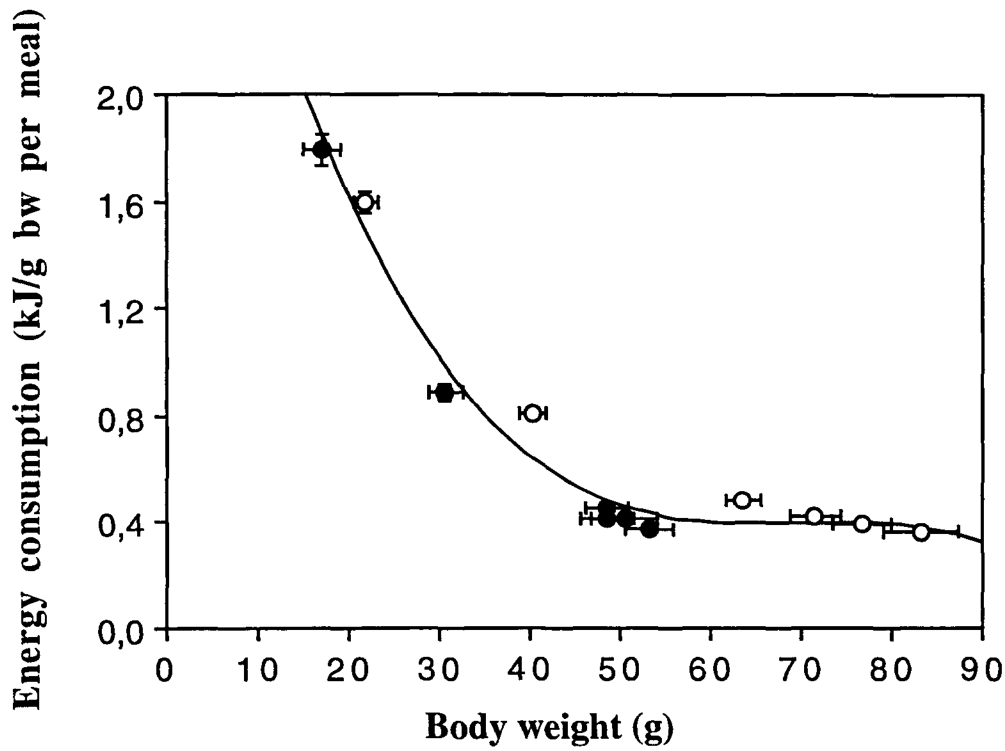

Figure 4. The relationship between body weight and specific energy consumption of polar cod. Male and female fish are denoted by filled and open circles respectively. Bars indicate SEM. The line is fitted by eye.

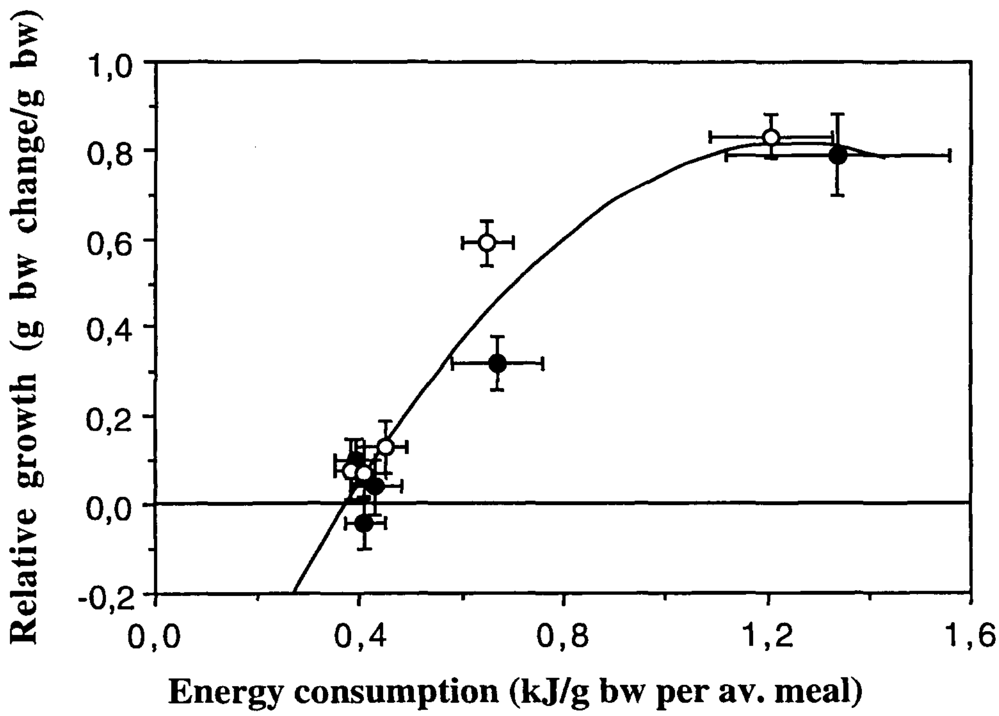

Figure 5. The relationship between specific energy consumption and relative growth of polar cod. Male and female fish are denoted by filled and open circles respectively. Bars indicate SEM. The line is fitted by eye.