Journal of Fish Biology (1993) **43,** 643–645

BRIEF COMMUNICATIONS

Allometric growth in juvenile cod (*Gadus morhua*) and possible effects on cannibalism

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(*Received 21 October 1992, Accepted 4 February 1993*)

Cod juveniles of about 20 mm had the lowest potential predator : prey length ratio based on mouth gape of the predator and the body height of the prey. This implies that the cannibalistic potential is maximized in this size range.

Key words: *Gadus morhua*; juveniles; cannibalism; mouth gape.

Cannibalism is a major problem in the juvenile phase in farming of many fish species, including cod *Gadus morhua* L. (Folkvord, 1991). Relative size differences within a population are important for cannibalistic behaviour, as maximum prey size generally is believed to be a function of mouth size (e.g. Smith & Reay, 1991). To evaluate the possibility that allometric changes in body proportions could influence predation on conspecifics, morphometric measurements were made on cod during the juvenile period.

All measurements were made on newly killed, unstarved fish. Maximum body height (without fins or finfold) and height of mouth opening were measured on about 100 cod larvae and juveniles with standard lengths (S.L.) ranging from 6 to 140 mm. Although other measures, such as mouth and body width may influence the prey catching abilities of cod juveniles, body height and mouth height could be more accurately measured. The smallest fish were collected from a production pond (Blom *et al.*, 1991) where they preyed upon plankton, while the larger fish were taken from tanks where they were fed dry food. The measurements were made with a dissecting microscope or micrometer depending on fish size. The mouth was stretched with two dissecting needles, to where it was judged to be fully open before mouth height was measured. Maximum height and mouth height were regressed against standard lengths. The regressions were performed on ln-transformed values to stabilize the variances.

Body proportions changed with the length of the fish. Fish smaller than about 20 mm had their maximum height at the head, while larger fish had maximum height at their belly. This corresponds to the development of a functional stomach with food storing capacity at this size (Pedersen & Falk-Petersen, 1992). Visible teeth were observed on the jaw from a size of about 20 mm.

Maximum body height increased linearly with length [Fig. 1(a); equation (1)]. The mouth height *v.* length relationship was significantly improved by also including a quadratic term [$P<0{\cdot}001$, stepwise regression; Fig. 1(a); equation (2)].

$$\ln(\text{max height}) = -1{\cdot}815 + 1{\cdot}059 \times \ln(\text{S.L.});\ N=103;\ R^2=0{\cdot}995 \quad (1)$$

$$\ln(\text{mouth height}) = -3{\cdot}270 + 1{\cdot}818 \times \ln(\text{S.L.}) - 0{\cdot}1219 \times (\ln(\text{S.L.}))^2;\ N=102;\ R^2=0{\cdot}990 \quad (2)$$

On the basis of equations (1) and (2) a predator : prey length ratio curve was constructed [(Fig. 1(b); equation (3)]. The curve gives a theoretical relationship between the length of

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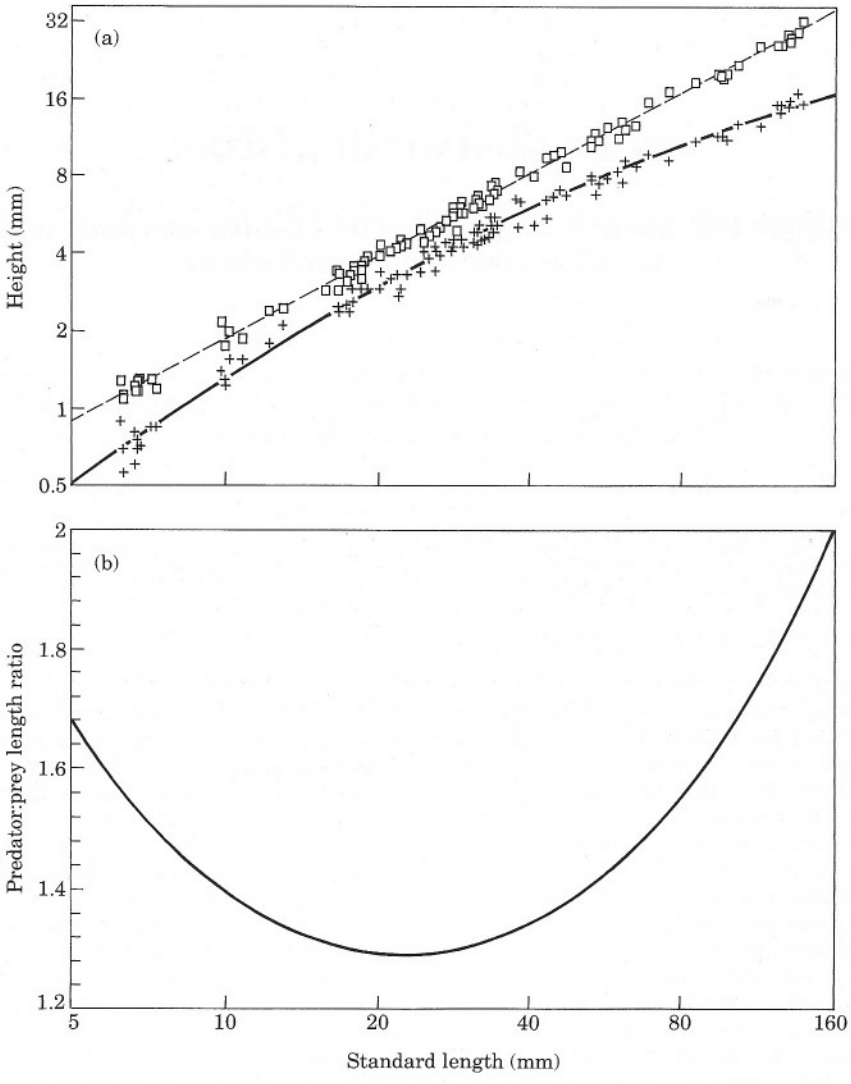

FIG. 1. (a) Maximum body height (– – –□– – –) and mouth height (——+——) with fitted equations [equations (1) and (2)] *v.* S.L. (b) Predator : prey length ratios *v.* S.L. [equation (3)].

a predator and the maximum length of a prey when assuming that a predator can catch fish with body height less or equal to its mouth gape.

$$\text{S.L.}_{\text{pred}} : \text{S.L.}_{\text{prey}} = 3{\cdot}951 * \text{S.L.}^{(-0{\cdot}717 + 0{\cdot}115 \times \ln(\text{S.L.}))} \quad (3)$$

The minimum predator : prey length ratio is defined directly by the parameters in equation (3). We performed a Monte Carlo simulation ($n=1000$) based on the error terms of the regression parameters [equations (1) and (2)] to obtain an error estimate of the standard length yielding the minimum value. The ratio has a minimum of 1·3 at a fish size of 22·5 mm S.L. (11–52 mm, 95% confidence interval). If a predator can only catch fish with body height less than for example 90, 80 or 70% of its mouth gape, the ratios will be proportionally higher.

In a laboratory experiment cannibalism among 0·6 g (40 mm) cod was observed when the ratio of the largest *v* smallest fish length was above 1·5 : 1, and cannibalism was the

main mortality factor when this ratio was above 2 : 1 (Folkvord & Otterå, in press). On the other hand, cannibalism was not observed among 10 g (100 mm) fish with similar max : min length ratios. Similarly van Damme *et al.* (1989) found cannibalism among koi carp (*Cyprinus carpio* L.) juveniles to start at predator : prey length ratios of about 1·8 : 1, and decreased with size although predator : prey length ratios were similar or higher.

Although the high cannibalistic rates during the early juvenile period can be partly explained by limited access to food during the transition from live to formulated food, allometric changes in body proportions make cod particularly vulnerable to cannibalism in this period. This is in accordance with Kawai & Isibasi (1982) who found that mouth gape relative to length was highest at the post larval stage where cannibalism was presumed to be the main mortality factor.

The authors thank Dr K. Pittman for reviewing the manuscript.

References

Blom, G., Otterå, H., Svåsand, T., Kristiansen, T. S. & Serigstad, B. (1991). The relationship between feeding conditions and production of cod fry (*Gadus morhua* L.) in a semi-enclosed marine ecosystem in western Norway, illustrated by use of a consumption model. *ICES Marine Science Symposia* **192,** 176–189.

Folkvord, A. (1991). Growth survival and cannibalism of cod juveniles (*Gadus morhua*): effects of feed type, starvation and fish size. *Aquaculture* **97,** 41–59.

Folkvord, A. & Otterå, H. (in press). Effects of initial size distribution, day length, and feeding frequency on growth, survival and cannibalism in juvenile Atlantic cod (*Gadus morhua* L.). *Aquaculture*.

Kawai, T. & Isibasi, K. (1982). A study of comparative biology on Japanese Pisces to population analysis—III. A quantitative analysis on the larval mortality by cannibalism. *Canadian Translation Fisheries and Aquatic Sciences* **4859**.

Pedersen, T. & Falk-Petersen, I. B. (1992). Morphological changes during metamorphosis in cod (*Gadus morhua* L.), with particular reference to the development of the stomach and pyloric caeca. *Journal of Fish Biology* **41,** 449–461.

Smith, C. & Reay, P. (1991). Cannibalism in teleost fish. *Reviews in Fish Biology and Fisheries* **1,** 41–64.

van Damme, P., Appelbaum, S. A. & Hecht, T. (1989). Sibling cannibalism in Koi carp, *Cyprinus carpio* L., larvae and juveniles reared under controlled conditions. *Journal of Fish Biology* **34,** 855–863.