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Changes in the Glycogen Content of Pacific Herring, *Clupea pallasi*, during Metamorphosis and the Subsequent Juvenile Stage

Masaaki FUKUDA

The glycogen content of the head, viscera and trunk of Pacific herring larvae and juveniles was measured during metamorphosis and the subsequent juvenile stage of development. The total glycogen content of both the viscera and trunk increased rapidly over the size range of from 25 to 30 mm standard length (SL) when metamorphosis occurred. Then the glycogen content of the viscera decreased gradually whereas that of the trunk continued to increase. The concentration of glycogen (i.e., the amount per unit weight) in the viscera reached a peak at about 30 mm SL and was three times higher than that of the trunk. However, past 30 mm SL the glycogen concentration of the viscera decreased rapidly with growth, finally reaching about the same value as that of the trunk. The total content of glycogen of the head increased slowly and the concentration of glycogen in the head remained nearly constant during the larval and juvenile stages. The glycogen in the viscera and trunk is considered to originate from the liver and muscle, respectively. The results suggest that the liver is the main organ for energy storage during metamorphosis. The role of glycogen storage then shifts from the liver to both the liver and muscle with the onset of muscle development upon entering the juvenile stage.

Key words: herring, glycogen, metamorphosis

It has previously been reported that the glycogen content of whole Pacific herring, *Clupea pallasi*, markedly increases during the transformation stage, that is, during the transition from larva to juvenile (FUKUDA et al. 1986). That report raised the question whether certain organs or tissues accumulate glycogen during the larval and juvenile stage. Glycogen is important for the survival of young fish because it serves as a major energy source during periods of starvation and for muscular motion. Glycogen accumulates mainly in the liver, muscle, heart and brain of adult fish (SHUL'MAN 1972). Liver glycogen becomes detectable after the post-larval stage in Ayu, *Plecoglossus altivelis* (TANAKA et al. 1972), but little information is available concerning the accumulation of glycogen in the various of organs and tissues of larval and juvenile fish. The organs and tissues of larval fish are very small and are difficult to dissect properly, accounting for the paucity of information about them. In this study, the glycogen content of the head, viscera and trunk of Pacific herring larvae and juveniles was measured to determine whether organs and tissues accumulate glycogen during metamorphosis and the subsequent juvenile stage.

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Materials and Methods

Mature fishes were caught at Fuuren Lake in eastern Hokkaido, Japan, on 24 April 1984. Their gametes were artificially fertilized and the larvae were reared using rotifers at first, then brine shrimp nauplii combined with artificial feed in a 20-kl concrete tank at 15°C at the Akkeshi Station of the Japan Sea Farming Association. Sampling began when larvae reached 25 mm standard length (SL), which is the minimum size for proper dissection of the viscera. After anesthetization in MS222 solution (1/20,000), the body weight and SL of the fish were measured. Then each fish was dissected into three parts; head, viscera and trunk. Consequently, the head samples contained brain, bone, skin and gills, the viscera samples contained liver, heart, stomach, intestines and other organs and tissues, and the trunk samples contained the remaining organs and tissues. Each sample for glycogen analysis contained dissected parts from 2 to 22 fish depending on their size. Each separated sample was weighed and kept in a freezer at −20°C until analysis. Glycogen was precipitated by the addition of ethanol to a NaOH digest of the samples, and the glycogen content was then determined by the anthrone method.

Because the amounts of material differed among body parts, then both the total values and relative values for glycogen needed to be considered. Thus the glycogen amounts in this study are expressed in two ways: as the total amount in each body part and as the concentration (i.e., the amount per unit weight).

Based on morphological criteria, the fish used in this study entered the period of metamorphosis at about 22 mm SL and transformed at about 30 mm SL from the larval into the juvenile stage.

Results and Discussion

The mean SL and the mean weight of each part are listed in Table 1. The mean weight of three body parts increased linearly with size development, with the exception that the weight of the viscera did not increase from 30 mm to 35 mm SL. The viscera weight as a percentage of body weight remained nearly stable at 26% up to 30 mm SL, then decreased to 14% and became stable again. The trunk weight relative to body weight was also stable at 45% up to about 30 mm SL, then increased

Table 1. Changes in mean weight and weight as a percentage of total body weight for head, viscera and trunk samples of Pacific herring during the larval and juvenile stages. The sum of the percentages of the body parts does not equal 100% because of water loss during dissection

Mean SL	Mean weight of dody part						N
	Head*		Viscera		Trunk*		
(mm)	(mg)	(%)	(mg)	(%)	(mg)	(%)	
25.41	19.1	21.5	22.9	25.7	40.2	45.2	51
28.93	45.6	21.5	55.5	26.2	97.1	45.8	35
34.40	95.2	22.2	60.5	14.2	244.8	57.3	22
41.78	167.0	22.5	102.4	13.8	434.8	58.6	16

* Bones and fins are included in the mean weight

rapidly to about 60% and became stable again. The head weight relative to body weight remained almost the same throughout the experimental period.

The total amount of glycogen accumulated in each part is depicted in Fig. 1. The total glycogen content of the viscera and trunk increased rapidly between 25 and 30 mm SL, but the viscera contained higher total levels of glycogen than the trunk during this period. This relationship reversed after the fish attained a body length of 32 mm, related to a slight decline in visceral glycogen. The amount of glycogen in the head increased very gradually as the fish developed.

The glycogen concentrations in each part are shown in Fig. 2. The concentration of glycogen in the viscera reached a maximum at about 30 mm SL, then decreased rapidly during further development. The glycogen concentration in the trunk showed a similar pattern to that in the viscera up to 33 mm SL, then increased slightly, finally attaining almost the same value as that of the viscera at about 42 mm SL. The concentration of glycogen in the head remained nearly constant throughout the developmental period.

These results indicate that the marked increase in glycogen in the whole body during the transformation from larva into juvenile (i.e., during the period of metamorphosis from 25 to 30 mm SL) is brought about mainly by the rapid accumulation of glycogen in both the viscera and trunk, but especially in the viscera. Since the liver is the main organ for glycogen accumulation in the viscera of other fish larvae and juveniles (TANAKA 1975), changes in the glycogen content of the viscera of herring

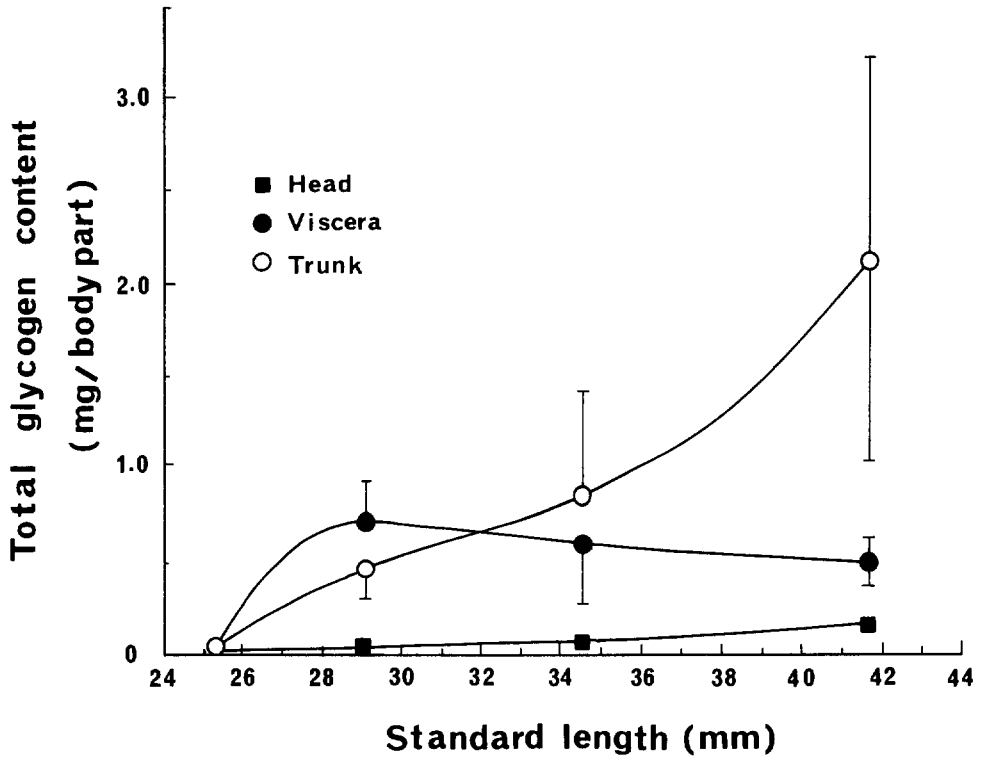

Fig. 1. Changes in the total glycogen content of parts of Pacific herring during the larval and juvenile stages: head (■), viscera (●) and trunk (○). The points and vertical bars represent the mean ± S.D. for three to six samples.

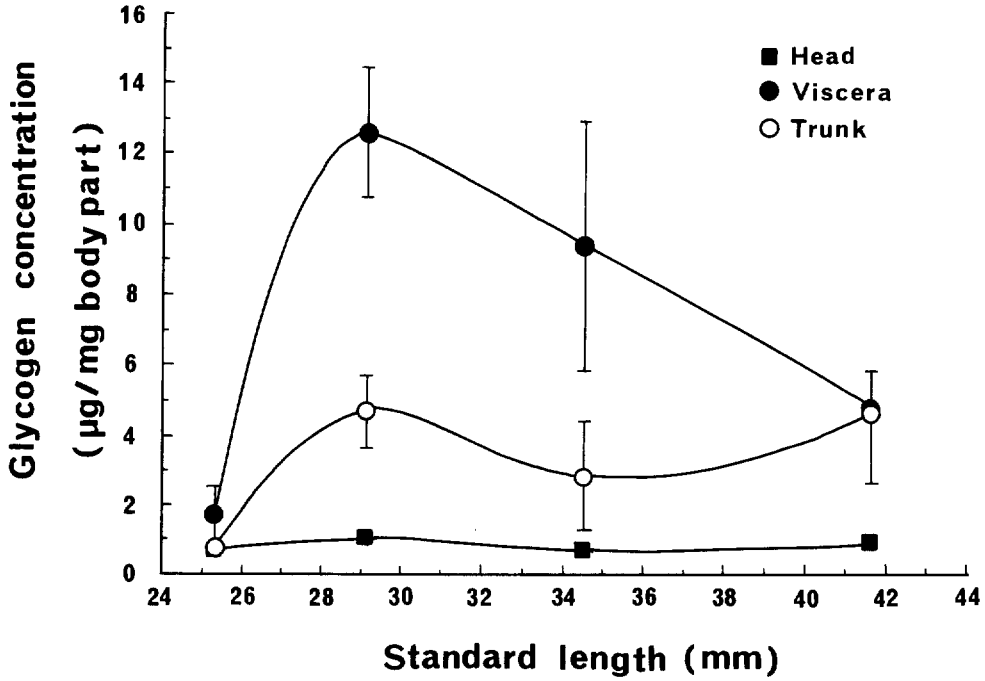

Fig. 2. Changes in the glycogen concentration in parts of Pacific herring during the larval and juvenile stages: head (■), viscera (●) and trunk (○). The points and vertical bars represent the mean ± S.D. for three to six samples.

larvae probably also involve the liver. The increase in visceral glycogen during metamorphosis implies energy storage in the liver to help avoid starvation. The trunk glycogen is very likely present mainly in the muscle because most of the tissue in the trunk samples consisted of muscle. Previous studies show that the total glycogen content of the trunk of Pacific herring increases along with muscle development during hypertrophy which begins in the early juvenile stage (FUKUDA et al. 1986, FUKUDA 1990). These results suggest that the liver is the main site of energy storage during metamorphosis, then the role shifts from the liver to both the liver and muscle as the muscles develop upon entering the juvenile stage.

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ニシンの変態期および稚魚期におけるグリコーゲン蓄積量の変化

福田　雅明

ニシンの変態期（仔魚期）およびその後に続く稚魚期にグリコーゲンがどのように蓄積されるか検討する目的で，体長 25 mm から 42 mm の仔稚魚を頭部，内臓および体幹部に分け，グリコーゲン量を測定した。変態開始から変態がほぼ完了する体長 25 mm から 30 mm までは内臓，体幹部ともにグリコーゲン量は急速に増加した。特に内臓では組織当りの蓄積量は多く，体幹部組織当りの約 3 倍含まれていた。しかし，体長 30 mm を越えると，内臓では組織当りの蓄積量が減少するものの，体幹部組織当りの蓄積量は逆に増加する傾向が認められ，両者はほぼ同じ値をとるようになった。一方，頭部のグリコーゲン量は緩やかに増加し，組織当りの蓄積量は常に一定の値で推移した。本研究で測定されたグリコーゲンは，内臓では主として肝臓に，体幹部では筋肉に蓄積されたものと推定され，変態期ではグリコーゲンは主に肝臓に蓄積され，稚魚期では魚体の発達とともに筋肉での蓄積量が増加するものと考えられた。