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Correlation between fat content and features of generative growth of arabesque greenling *Pleurogrammus azonus*

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PEER REVIEW

Peer reviewer

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Comments

This is an actual research in which authors have demonstrated the real changes in fat of arabesque greenling during the process of its gametogenesis.
(Details on Page 683)

ABSTRACT

Objective: To determine the correlation between fat content and features of generative growth of arabesque greenling *Pleurogrammus azonus*.

Methods: The samples were collected by bottom trawl during trawl surveys of research vessel MRS-055 conducted by TINRO–Center in Peter the Great Bay (Sea of Japan). A total of 332 individuals of arabesque greenling were analyzed. Fat content was determined by the standard method of extraction by sulfuric ether from the dry rest.

Results: The most part of deposit fat of arabesque greenling is concentrated in muscles and hypodermis: 86.2%–97.0% (mean value 92.3%) of the total deposited fat mass. The liver fat was 1.1%–7.7% (mean value 4.8%) and the internal fat was 0.9%–5.2% (mean value 2.8%) of the total mass. Decreasing of the muscles fat was observed at sudden changes of qualitative and quantitative characteristics of sexual products, and for immature fish the relation between accumulation of fat in muscles and generative growth was not found.

Conclusions: Dynamics of fat in liver corresponds closely with the processes of generative growth, and increasing of gonads weight causes decreasing of liver fat content, both for mature and immature fish.

KEYWORDS

Arabesque greenling, *Pleurogrammus azonus*, Fat content, Generative growth**1. Introduction**

Lipids in fish are an important source of energy providing a variety of crucial moments of their life^[1]. Nevertheless, papers on the metabolism of lipids in fish are scarce in recent. Even in the Encyclopedia of Fish Physiology: from Genome to Environment it is a topic mentioned only in passing. The encyclopedia mentioned that excess energy is then available for storage or to support organismal growth and gonad maturation^[2,3]. In addition, during ovarian follicle growth the major lipid and protein nutrients–required for embryonic and larval development are stored within the

oocyte^[4].

Arabesque greenling *Pleurogrammus azonus* (*P. azonus*) is one of the dominating species of bottom fish communities in northern part of Japan Sea. Seasonal cyclicity of many physiological processes of *P. azonus* (Jordan et Metz, 1913) is caused by cyclicity of generative growth and gonad maturation^[5], so far as the main energy expenses of mature fishes are determined by the processes of reproduction^[6–8]. The purpose of this study was the investigation of the correlation between dynamics of deposit fat and development of gonads in fish under varying biological condition.

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2. Materials and methods

The arabesque greenling *P. azonus* begins an active generative growth in May and completes its spawning to the end of October[5,9]. Accordingly, the samples were collected by bottom trawl during trawl surveys of research vessel MRS-055 conducted by TINRO–Center in Peter the Great Bay (Sea of Japan) in the periods from May to October of 1989–1993. Individuals belonged to the most numerous age groups from 2+ to 5+ (immature, first mature and mature) were selected for the analysis. A total of 332 individuals of arabesque greenling were analyzed, with the total length from 21.2 cm to 36.8 cm. All examined fish were divided into three groups: immature fish, first maturing fish and mature fish.

Ontogenetic stages and stages of gonads maturity were characterized by the methods described by previous studies[5,10,11]. Lipid content was determined by the standard method of extraction by sulfuric ether from the dry rest[12]. The content of fat in muscles (including hypodermic fat) and in liver was measured individually. The content of internal fat was tested for sets of 5–12 specimens with similar biological condition; a total of 11 such tests were taken from 82 specimens.

Relative weight of deposit fat was used as the basic parameter:

$$Q_{\text{relative}} = \frac{Q_{\text{fat}}}{L^3} \times 10^4$$

Where Q_{relative} means relative weight of deposit fat; Q_{fat} means the mass of deposit fat at a part of fish; L means length (total length) by Smith[13]. This parameter was calculated for fat in liver, muscles, and internal fat (on bowels): $Q_{\text{relative.l}}$, $Q_{\text{relative.m}}$ and $Q_{\text{relative.i}}$, correspondingly. Relative weight of gonads and relative weight of liver were calculated similarly.

3. Results

The most part of deposit fat of arabesque greenling was concentrated in muscles and hypodermis: 86.2%–97.0% (mean value 92.3%) of the total deposited fat mass. The liver fat was 1.1%–7.7% (mean value 4.8%) and the internal fat was 0.9%–5.2% (mean value 2.8%) of the total lipid mass.

During the period of investigation, immature fish had a gradual increase of deposit fat content in muscles (Figure 1). Dynamics of this parameter was identical for males and females, although males had higher fat content, probably, because of smaller energy consumption for formation of testicles than for formation of ovaries.

Another dynamic was observed for fat content in liver of immature fish. The relative weight of fat in liver was almost stable and equal for males and females in the period from May to August (Figure 1). From September, decreasing of the fat content began, gradually for males and abruptly for females. The difference between males and females was caused by sexual dimorphism of generative growth: males had neither quick increase of gonads weight, nor abrupt decrease of deposit fat content, but females had both these changes (Figure 1).

Content of internal fat was permanently low for immature fish: $Q_{\text{relative.i}}$ varied from 0.020 to 0.040 for males and from 0.033 to 0.038 for females.

The first maturing fish had higher fatness mostly due to the fat deposited in muscles that was in 1.4–2.7 times higher (Figure 2). On the contrary, the content of fat in liver of these fish practically did not exceed that of immature fish (Figure 2). More essential difference between the first maturing and immature fish could be observed in dynamics of deposited fat: the immature fish had opposite changes of the fat contents in muscles and liver, but the first maturing fish didn't have this opposition

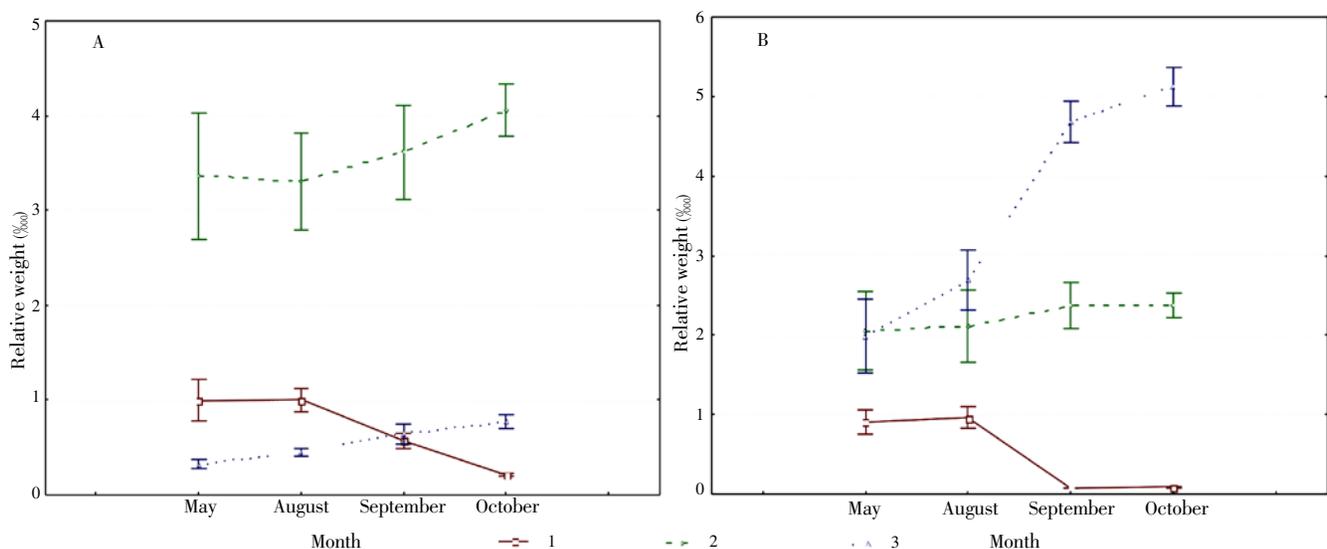


Figure 1. Dynamics of fat content and gonads weight of immature males (A) and females (B) of arabesque greenling.

1: Relative weight of fat in liver; 2: Relative weight of fat in muscles; 3: Relative weight of gonads. Vertical lines: Standard error bars.

so far as both parameters depended on maturing of sexual products.

Internal fat content of the first maturing fish was estimated for one sample only (five males on II stage of maturity) as $Q_{relative,i}=0.035$ that did not overstep the limits of $Q_{relative,i}$ fluctuation for immature males.

The first maturing males had the maximal content of fat in liver and muscles on II–III stage of gonad maturity, later it reduced gradually in correspondence with increasing of gonads mass, and reached the minimal value after spawning. The highest rate of generative growth was observed between II–III and III stages of maturity when the mass of sexual products of the first maturing males was increased in 6 times. Dynamics of fat content in liver and muscles for the first maturing females had similar features, but the fat content in liver was the highest on III stage of gonad maturity, and in muscles—on III–IV stage (Figure 2). Mass of females' sexual products increased in 3.7 times when they transit from II–III stage to III stage of maturity, in 2.8 times between III to III–IV stages, and in 1.9 times between III–IV and IV stages. However, energy expenses of females for sexual products formation didn't

depend directly on increasing of their gonads mass. The reason was a new qualitative phase of generative growth beginning at III stage of maturity—with oocytes of trophoplasmatic growth[11,14,15].

The part of first maturing females of arabesque greenling usually miss the spawning and their sexual products are exposed to total resorption[10,11]. However, the processes of generative growth and adipose metabolism of such fish corresponded basically to spawning individuals, but the fatness of females with resorpted sexual products was higher than for spawned females: $Q_{relative,l}=0.06$ and $Q_{relative,m}=3.97$. On the other hand, the content of abdominal fat of the first maturing females at II–III stage of maturity (one sample with $Q_{relative,i}=0.09$) was considerably higher than for immature females.

Mature fish had the most intensive adipose metabolism in the period of investigation, mostly due to muscle fat dynamics that was natural because of the most active generative growth of this group (Figure 3). Intensity and direction of lipid metabolism dynamics corresponded to population reproductive cycle, i.e. increasing of sexual products mass caused gradually increasing of deposited

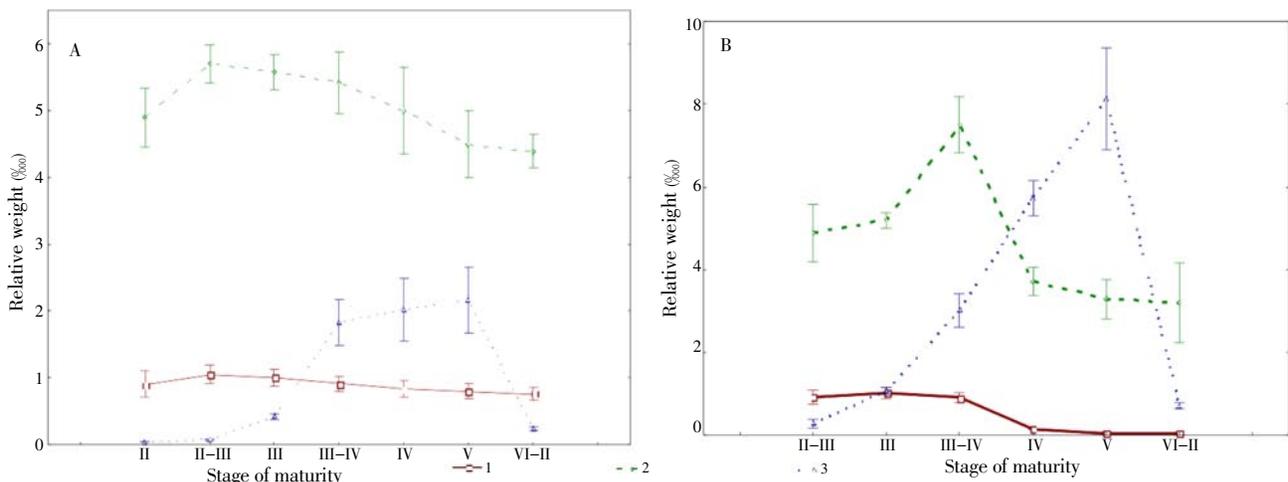


Figure 2. Dynamics of fat content and gonads weight of the first maturing males (A) and females (B) of arabesque greenling. 1: Relative weight of fat in liver; 2: Relative weight of fat in muscles; 3: Relative weight of gonads.

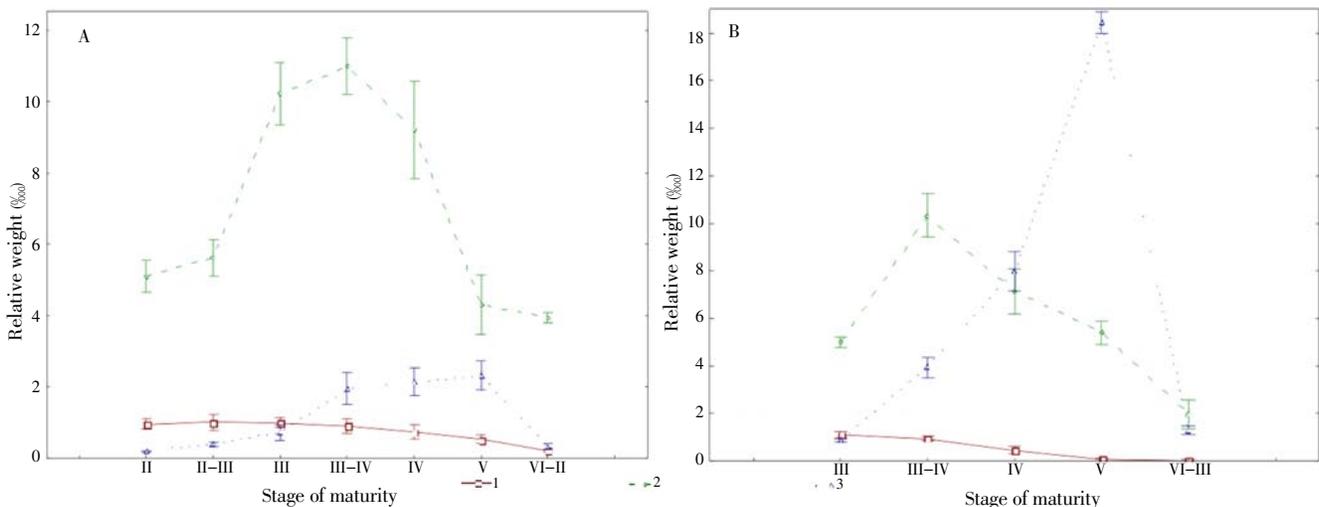


Figure 3. Dynamics of fat content and gonads weight of mature males (A) and females (B) of arabesque greenling. 1: Relative weight of fat in liver; 2: Relative weight of fat in muscles; 3: Relative weight of gonads.

Table 1Fat content parameter limits of different ontogenetic groups of *P. azonus* (%).

Fat content	Immature fish		First maturing fish		Mature fish	
	Male	Female	Male	Female	Male	Female
Liver	4.10–39.20	4.10–35.70	7.10–39.40	0.50–36.30	3.80–57.10	0.50–29.60
Muscles	2.10–4.10	2.10–3.90	3.90–14.40	2.10–15.10	2.50–16.30	1.50–17.40
Internal fat (on bowels)	1.10	0.70–2.10	2.60	4.60	10.60–14.30	5.60–6.30
Relative weight of liver	0.70–3.96	0.73–3.80	0.84–5.35	0.67–5.79	0.86–4.87	0.07–6.67

fat. The maximal value of $Q_{\text{relative,m}}$ of mature fish was 1.4–2.1 times higher than the first maturing fish and 2.9–3.7 times higher than immature fish. Mature fish had the highest weight of abdominal fat, too.

To compare the sexual difference of internal fat content of mature fish, five (two males and three females) samples were tested. Males had the relative weight of internal fat 0.76 at III stage of maturity and 0.55 at III–IV stage; females had $Q_{\text{relative,i}}=0.14$ at IV stage, 0.17 at IV–V stage, and 0.23 at V stage of maturity. These estimates are insufficient for discussion of any tendencies of the internal fat dynamics, and possibly are determined by individual variability.

Mature, first maturing and immature individuals of arabesque greenling had comparable fat contents in liver (Table 1). Moreover, the dynamics of this parameter was almost identical for mature and first maturing fish. The dynamics of muscle fat of the mature and first maturing females was also comparable. On the contrary, the mature males were more similar to mature females than to the first maturing males by dynamics of muscle fat, although the difference of gonads mass between mature and first maturing males is insignificant, in relative units. The suspected reason is a peculiarity of the spawning of arabesque greenling males. They spend a long time on spawning grounds, in opposite to the first maturing males, possibly because of several sperm portions laying, similar to several egg masses laying by mature females that was described previously^[10,11].

4. Discussion

In general, sexual dimorphism was apparent in the dynamics of the fat content parameters. Amplitudes of fluctuations of relative weight of fat in muscles and liver were very similar for males and females at every stage of ontogeny. Only immature males had higher weight of deposit fat in muscles than immature females. Percentage of fat in muscles of males and females was comparable as well, and was approximately identical for mature and the first maturing fish (males: 2.0%–16.3%, mean value 9.1%; females: 1.5%–17.4%, mean value 8.9%). The fat content in muscles of immature fish did not exceed 4.1%, both for males and females. Percentage of fat in liver was almost identical for immature males and females from 4.1% to 39.2%, but males had higher percent of fat on elder ontogenesis stages (3.8%–57.1% against 0.5%–36.3 % for males). The reason is the

different shares of fat in the liver: the weight of liver fat was 92.4% for males and only 45.2% for females, and females had the high correlation between mass of liver and mass of gonads. It means that the functions of liver are different for males and females of arabesque greenling. In general, a liver has two functions: fat storage and depot of blood^[16]. As far as the size of liver is proportional to fat content for males, the fat accumulation function is a priority for males. Female liver size is dependent on gonad mass, so probably they need higher intensity of blood supply for formation of their massive gonads, and larger reserves of blood, partly concentrated in liver.

Therefore, the hepato–somatic index could have limited use only as the indicator of fat content. This index is incorrect when the liver is not the basic depot of fat, as in the case of arabesque greenling. The tendencies in dynamics of liver mass of Asian smelt (*Osmerus mordax dentex*) and arabesque greenling are rather similar. Comparing the processes of fat deposit in the liver of these two species, the inaccuracy of the conclusion is obvious, because of the highest energy consumption for formation of sexual products at IV stage of maturity when the sharp decreasing of deposit fat reserve is observed^[17–19].

The main part of deposit fat of arabesque greenling (92.3% in average) is concentrated in hypodermic layer and between muscle myosepta; noticeable smaller part of fat accumulates in liver (4.8%) and the smallest part—as internal fat on bowels (2.8%).

Fat accumulation in muscles of immature fishes occurs simultaneously with generative growth. The abrupt reduction of muscle fat content takes place between III–IV and IV stages of maturity.

Dynamics of fat in liver is the closest linked with the processes of generative growth. Even immature fish have a decreasing of fat content in liver corresponded to abrupt increasing of sexual products mass.

Dynamics of liver mass of males reflects the process of fat accumulation only but does not reflect the degree of development of sexual products. On the contrary, the liver size of females correlates with the mass of sexual products better than with itself fat contents. Thus, the mass of liver can be used as a measure of fatness for males only.

Conflict of interest statement

We declare that we have no conflict of interest.

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Comments

Background

Publications on the marine fish lipids metabolism are really very rare in recent. But in Russia this problem constantly pays attention especially to marine fishes—the fishing objects. New information about the lipid metabolism of *P. azonus* (Hexagrammidae) is actual for its fishery management.

Research frontiers

The present manuscript has reported the research of *P. azonus* lipid metabolism during its reproductive cycle (immaturing fishes, first maturing, and mature ones) from May to October. Biochemically the present research investigated 332 pieces which seem to be representative samples.

Related reports

Investigations of *P. azonus* lipids metabolism between the liver, muscles and gonads in commercial fishes were conducted based on traditional Russian methods which have proven simple adequate results.

Innovations and breakthroughs

The present research work studied the new fish species (*P. azonus*) which is unexplored in the respect of lipids metabolism and authors used previous described method (biochemistry) to evaluate its biological condition necessary for sustainable fisheries.

Applications

The results allows to regulate the fishing of *P. azonus* for catching fish with the best commercial qualities while preserving sustainable state of arabesque greenling stocks.

Peer review

This is an actual research in which authors have demonstrated the real changes in fat of arabesque greenling during the process of its gametogenesis.

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