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The changes of the catch and age structure of lake anchovy and the relationship with environmental variation in Lake Taihu

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Abstract: Lake anchovy, *Coilia ectenes taihuensis*, a kind of small-sized and zooplanktivorous fish was the dominant fish in Lake Taihu. The changes of the fish catch and the relationship with environmental variation were studied, based on historical data from 1952 to 2004 and the studies from 2003 to 2005. The results were as follow: (1) The catches of the fish increased from 640.5 t in 1952 to 21 221 t in 2004. Especially since 1994 the increase had speeded up; (2) The age structure of the fish population was that 0^+ individuals occupied only 33% in 1979 and 34% in 1980, but the figure increased to 99.04% ± 2.21% in 2003 and 99.08% ± 0.80% in 2004; (3)0^+ lake anchovy mainly fed on zooplankton. Cladocera, Copepoda and Rotifera respectively accounted for 89.77% ± 13.69%, 7.84% ± 11.53% and 2.39% ± 4.95% of its diet. The conclusion was that, human activities such as the obstructed buildings between river and the lake, over fishing, environmental pollution and the ecological characteristics of the fishes in Lake Taihu were responsible to the changes of catches and age structures of the fish. With the fish catches increasing, there was the trend of zooplankton standing mass declining during October in the lake. So the increase of the fish catches might enhance phytoplankton development in the lake.

Key words: lake anchovy (*Coilia ectenes taihuensis*); fish catch; age structure; diet composition; Lake Taihu
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Lake Taihu, located in the delta of the Yangtze River, is the third largest freshwater lake in China. The lake is a shallow lake, with the surface water area of 2338.1 km^2 and an average water depth less than 2 m[1]. It has been a famous fishery base in China. There were 107 species of fishes recorded in the lake[2]. But in recent years, fish fauna has greatly changed. With fish species decreasing to only 48 species collected in the survey from 2002 to 2003[3] and the total fish catches increasing to 33 242 t in 2004, the changes of fish fauna showed the trend that only lake anchovy, *Coilia ectencs taihuensis*, had increased in its catches, while most other species had declined[4]. Lake anchovy, *Coilia ectencs taihuensis*, a kind of small-sized and zooplanktivorous fish is the dominate species in the lake and its catch was 21 221 t and occupied 63.8% of the total fish catches in 2004. So the causes of the fish increasing and the effects of its increasing on environment have to be studied.

There have already been lots of reports on fishes in Lake Taihu, which reports mainly focused on fish biology[5-8]. But there are few reports on the mutual relationship between fish fauna and environmental factors[9-10]. The paper is to analyze the causes and the effects of the increasing on environmental factors

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in the lake, based on the historical records of fish catches from 1952 to 2004, past studies and the study on age structure and diet composition from 2003 to 2005.

1 Materials and methods

1.1 Data of fish catches

The data of fish catches in Lake Taihu from 1952 to 2004 was offered by Lake Taihu Fisheries Management Committee of Jiangsu Province. The fish catches were divided into seven groups such as ①. lake anchovy, *Coilia ectenes taihuensis*; ②. ice fish, *Neosalanx taihuensis*; ③. topmouth culter, *Erythroculter ilishaeformis*, and *Mongolian redfin*, *E. mongolicus*; ④. common carp, *Cyprinus carpio*, and crucian carp, *Carassius auratus*; ⑤. silver carp, *Hypophthalmichthys molitrix*, and bighead carp, *Aristichthys nobilis*; ⑥. black carp, *Mylopharyngodson piceus*, and grass carp, *Ctenopharyngodson idella*; ⑦. other fishes. The groups were approximately classified by the standards of the sameness in ecological characteristics and resemblance in food type, while other fishes mainly included various small-sized fishes. So the fish catches could show the changes of fishes with different food types.

1.2 Sampling sites of age structure and diet composition

The samples of age structure of lake anchovy were collected in No.1 site and No.2 site during the period from September 1 to October 15 in 2003 and 2004(Fig.1). The samples of diet composition were collected in all of the 5 sites during the period from September 1 to October 15 in 2004 and on April 30 in 2005.

1.3 Sampling methods of age structure and diet composition

The samples of age structure and diet composition of lake anchovy were performed by purse net, a kind of nets specially catching the fish, with meshes size 5 mm, about 2550 m in length and 3 m in height and about 52 hm^2 in area for each operation.

The age was identified according to annuli in the fish scales[7]. 161 of 0^+ individuals, 67 of 1^+ individuals, 43 of 2^+ individuals was identified and then the average length and weight of the fish in each age were respectively calculated. After samples of 3 – 5 kg were taken from each operation, the age composition was calculated according to the average length and the average weight. 35 482 of lake anchovy individuals were analyzed during the period from September 1 to October 15 in 2003 and 2004 which was the only time allowed catching the fish every year in the lake.

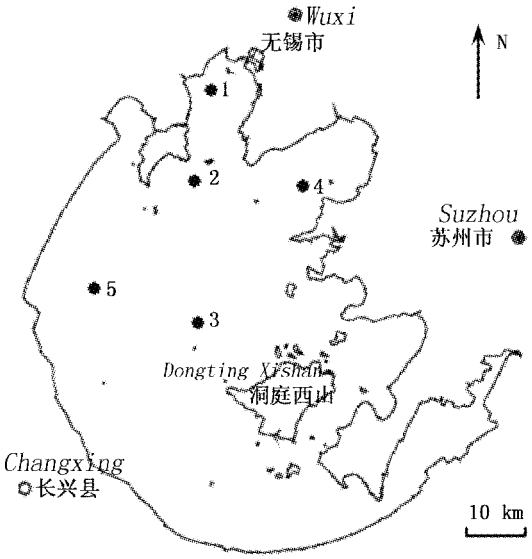

Fig.1 Sampling sites distribution in Taihu Lake

The diet composition of the fish was performed twice. The first time was from September 1 to October 15 in 2004. The second time was on April 30 in 2005. About 22 – 30 individuals were chosen in each sampling site. The diet species were identified with microscope and the percentage of individual's composition and apparent rates and the average numbers in each intestine were calculated.

2 Results

2.1 The change of catches of lake anchovy from 1952 to 2004

The catches of lake anchovy increase to 21 221.0 t in 2004 from 640.5 t in 1952. Its percentage in total fish catches was from 15.8% in 1952 to 63.8% in 2004. Based on the annual increase

rate of the fish catches, the slow increase period, the stable period and the quick increase period could be divided. The slow increase period was from 640.5 t, accounting for 15.8% of the total fish catches in 1952 to 6 584.9 t, 62.2% in 1964, and the fish catch increased annually at the rate of 457 t. The stable period was from 1964 to 1994, and the annual average catches fluctuated in (6175 ± 1051) t. The percentage of the fish in total fish catches fluctuated in 49.71% ± 10.63%. The quick period was from 6 706.6 t, 49.71% in 1994 to 21 221 t, 63.8% in 2004, and the fish catches annually increased at the rate of 1451 t[11].

2.2 The change of age structure of lake anchovy

0^+ lake anchovy occupied 99.04% of the individuals composition of its catch in 2003 and 99.08% in 2004 compared with only 33% in 1979 and 34% in 1980(Fig.2).

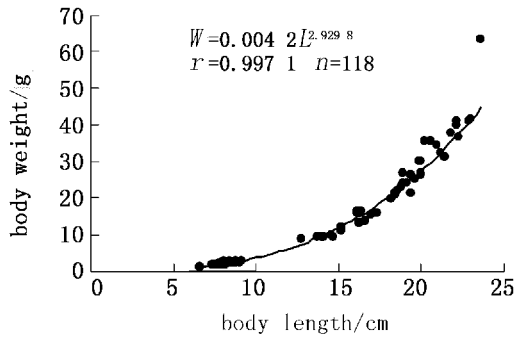

Fig.2 The percentage of 0^+ individuals in the catches of lake anchovy

The average weight and the average length of 0^+ lake anchovy were respectively (1.94 ± 0.53) g and (80.4 ± 7.1) mm; These of 1^+ individual were (14.53 ± 10.04) g and (161.6 ± 38.6) mm; These of 2^+ individual were (35.48 ± 20.17) g and (211.6 ± 27.4) mm. The relationship between body weight and body length of the fish was $W = 0.0042L^{2.9298}$, $r = 0.9971$, $n = 118$(Fig.3). 3^+ lake anchovy could not be collected. The average weight of 0^+ individuals respectively accounted for 92.2% of the fish catch in 2003 and 92.9% in 2004 compared with only 4.53% in 1979 and 5.64% in 1980 while that of 1^+ and 2^+ lake anchovy accounted for only 7.1% in 2003 and 7.8% in 2004. It was very clear that the population showed the more miniaturization in size than that in past (Fig.2).

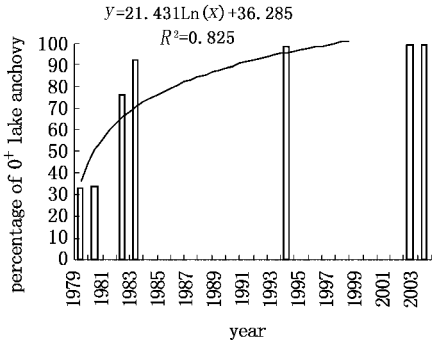

Fig.3 The relationship between body weight and body length

2.3 The diet composition of 0^+ lake anchovy

The studies were conducted twice. In the first study from September 1 to October 15 in 2004, only the diet composition of 0^+ individuals was carried out because 0^+ individuals occupied 99.08% in the fish catch. The diet compositions of 1^+ and 2^+ individual were not done for there were few. The results showed that 0^+ lake anchovy mainly fed on zooplankton and the individual percentage of Cladocera, Copepoda and Rotifera were respectively 89.77% ± 13.69%, 7.84% ± 11.53% and 2.39% ± 4.95% in its diet (Tab.1).

Tab.1 The diet composition of individuals in 43 alimentary canals of 0^+ lake anchovy (body length from 58 mm to 89 mm; samples $n = 43$)

	total average(%)
Calanoida	3.61 ± 5.80
Cyclopidae	1.18 ± 2.47
Nauplius	3.05 ± 5.12
shrimp	0
Bosmina	85.66 ± 15.4
Daphnia	80.83 ± 1.44
Moina	2.11 ± 3.63
Diaphanosoma	1.17 ± 2.76
Rotifera	2.39 ± 4.95

Additionally, lots of blue-green algae were found and averagely accounted for 15% – 35% of the volume of the diet. It remained unclear whether blue-

green algae could be assimilated by lake anchovy.

The second time was on 30th April in 2005. Only the diet composition of 1^+ individuals was conducted in 2005, for 1^+ lake anchovy in 2005 were born in the same time as 0^+ lake anchovy in 2004. The diet composition of other age individuals was not done for there were few. The results showed that 1^+ lake anchovy also mainly fed on zooplankton among which, the individual percentage of Cladocera, Copepoda and shrimp were respectively 79.35% ± 11.42%, 19.97% ± 10.78% and 0.20% ± 0.44% (Tab.2). Rotifera was almost not found. lots of blue-green algae were also found in alimentary canals of the fish and averagely accounted for 35% – 55% of the volume of the fish food.

Tab.2 The diet composition of individuals in 110 alimentary canals of 1^+ lake anchovy(body length from 111 mm to 144 mm; samples $n = 110$)

	No.1	No.2	No.3	No.4	No.5	total average(%)
Calanoida	3.62	8.09	10.68	19.77	10.04	10.44 ± 5.90
Cyclopidae	1.76	6.37	8.00	12.82	5.53	6.89 ± 4.02
Nauplius	0.20	3.84	2.21	3.30	3.66	2.64 ± 1.51
shrimp	0	0	0	0.98	0	0.20 ± 0.44
Bosmina	45.11	62.42	54.42	12.33	37.28	42.31 ± 19.26
Daphnia	0.78	0.33	1.43	12.86	9.11	4.90 ± 5.72
Moina	25.86	11.19	15.75	26.57	26.38	21.15 ± 7.20
Diaphanosoma	2.79	3.02	2.53	1.46	1.62	2.28 ± 0.70
Simocephalus	16.96	2.45	3.22	4.11	5.11	6.37 ± 6.00
Leptodorkindtii	0.39	0	0.55	2.64	0	0.72 ± 1.10
longispina	0.68	0.49	0	0.57	0.26	0.40 ± 0.27
Chydorus	1.86	0	0.83	0.16	0	0.57 ± 0.80
D. magna	0	0.41	0.14	1.22	0	0.35 ± 0.51
Bosminopsis	0	0.33	0	0.36	0.77	0.29 ± 0.32
Rotifera	0	1.06	0.28	0.85	0.26	0.49 ± 0.45

3 Discussions

3.1 The causes of lake anchovy increasing

After the changes of fish fauna were analyzed based on the changes of environmental factors, there were several reasons which maybe resulted in the increase of lake anchovy in the lake.

The construction of numerous embankments and dams was the main reason that caused the disappearance of migratory and semi-migratory fishes. There were 137 embankments and dams built during 1958 – 1986 in the low catchment's area of Yangtze River. On the waterways between the Yangtze River and the lake, there were more than 12 dams[2]. These embankments and dams obstructed the pathways of migratory and semi-migratory fishes. For example, there were 12 species of migratory fishes and 15 species of semi-migratory fishes which disappeared or at least were difficult to be collected in the survey from 2002 to 2003[3]. Among the 18 species of migratory fishes, there are only 6 species of fishes left which have become lake dwellers from migratory fishes after adapting well to the ecological environment in the lake. These semi-migratory fishes such as *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Mylopharyngodson piceus*, *Ctenopharyngodson idella* have been kept by restocking[2]. There are no doubts that the disappearance of these fishes which eat the same food as lake anchovy or prey on the fish benefit for its development.

Over fishing caused the declines of the piscivores fishes such as *Erythroculter ilishaeformis* and *E. mongolicus* which mainly fed on lake anchovy. Historical records showed that the intensity of fishing had been increased since 1980. Taking the horse power of machine boats in the lake as an example, the figure was only 364 hp in 1975 and 4824 hp in 1980, but the figure increased to 129 967 hp in 1997[2].

The relationships among main fishes were also the very important reasons that led to the increase of lake anchovy. On the basis of the analysis of the catches recorded and surveys, the catches of *Erythroculter ilishaeformis* and *E. mongolicus* mainly feeding on lake anchovy showed the decrease trend compared with the increase trend of lake anchovy. The relationship between the two categories of fishes showed the negative correlation at highly significant level of $P < 0.01$[12]. There was a report that apparent rate of lake anchovy in the food of *Erythroculter ilishaeformis* was 48.6 %[13], while *E. mongolicus* nearly eat the same food as *Erythroculter ilishaeformis*. In the survey in 2004, appearance rate of lake anchovy in the food of *Erythroculter ilishaeformis* was 100%[12]. However the catches of *Erythroculter ilishaeformis* and *E. mongolicus* have been decreased because of the over fishing and especially the fishes captured as a kind of enemy fish traditionally in Chinese lake fishery. So the decrease benefited the increase of lake anchovy.

Additionally, correlation analysis showed that the catches of lake anchovy had the negative correlation at the very significant level with catches of silver and bighead carp which also feed on zooplankton. The catches of silver and bighead carp totally showed the decrease trend since 1985. So lake anchovy had nearly no diet competition from these fishes[14].

Eutrophication of Lake Taihu resulted in the quickly increase of lake anchovy diet, which enhanced the growth of the fish. With the economical development of the industry and the agriculture, more and more nutrients and waster flowed into the lake since 1980s'. Especially since 1990s', the amount of nutrients and waster increased quickly. The eutrophication index such as COD was 1.90 $mg \cdot L^{-1}$ in 1960, but the figure respectively increased to 2.83 $mg \cdot L^{-1}$ in 1981 and 5.28 $mg \cdot L^{-1}$ in 2000(Fig.4). The direct results caused by the eutrophication was that the biomass of algae and zooplankton increased. The average biomass of algae and zooplankton were respectively 22 162 $ind \cdot L^{-1}$ and 2 $mg \cdot L^{-1}$ in 1960, but the figure respectively increased to 102.8×10^4 $ind \cdot L^{-1}$ and 4.77 $mg \cdot L^{-1}$ during 1980 – 1981, and 15.12 $mg \cdot L^{-1}$ and 5.42 $mg \cdot L^{-1}$ in 1992[2]. The analysis of the relationship between the catches of lake anchovy and COD showed positive correlation at significant level of $P < 0.05$[4].

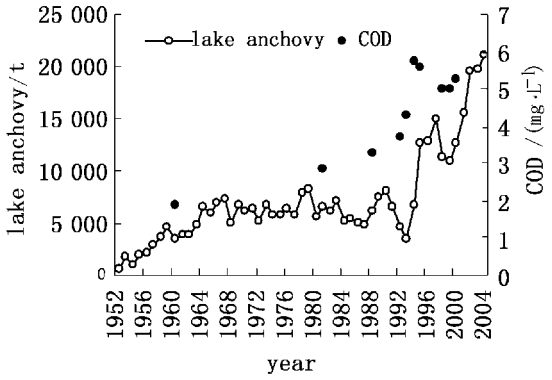

Fig.4　Relationship between the catches of lake anchovy and COD

3.2　The effects of lake anchovy catches increasing on environment

Lake anchovy has become the dominant fish in Lake Taihu, while 0^+ lake anchovy mainly feeding on zooplankton occuped 99.08% of the catches. There is no doubt that the great lots of 0^+ lake anchovy are assuming enormous zooplankton in the lake. According to the data of zooplankton standing mass from 1991 to 2000[1] in the lake, with the catches of lake anchovy increasing, there was the trend of zooplankton standing mass declining during October which were the time of lake anchovy growing quickly and in the largest amount in every year. However there was no the trend during February which was the time of lake anchovy in fewer amount and 0^+ fishes were not born[4].

4　Conclusions

Human activities such as the obstructed between river and the lake, over fishing, environmental pollution and the ecological characteristics of the fishes in Lake Taihu were responsible to the changes in lake anchovy catches and age structures. With the catches of lake anchovy increasing, there was the

trend of zooplankton standing mass declining in the lake. So the changes in fish catches of Lake Taihu might enhance the development of phytoplankton in the lake.

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太湖湖鲚渔获量及年龄结构变化与环境间的相互关系

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摘要：在太湖，随着鱼类总渔获量的不断增加和鱼类种类的不断减少，湖鲚（*Coilia ectenes taihuensis* Yen et Lin），一种小型浮游动物食性鱼类已成为绝对优势种。根据 1952－2004 年的统计数据和 2003－2005 年对湖鲚年龄结构和食物组成的调查，研究了湖鲚快速增加的原因以及与环境间的相互关系。结果如下：(1)在 1952 到 2004 年期间，湖鲚渔获量从 1952 年的 640.5 t、占总渔获量的 15.8% 上升到 2004 年的 21 221 t、占 63.8%。尤其是 1994 年后湖鲚渔获量以每年 1280.5 t 的速度增加；(2)湖鲚种群年龄结构低龄个体呈现不断增加趋势。1979 和 1980 年 0^+ 个体仅占 33% 和 34%，而 2003 和 2004 年 0^+ 个体分别上升到 99.04% 和 99.08%；(3)0^+ 湖鲚主要摄食浮游动物。按照个数组成比例计算，枝角类平均占 89.77% ± 13.69%、桡足类占 7.84% ± 11.53%、轮虫仅占 2.39% ± 4.95%。分析认为：江湖阻隔、过度捕捞、富营养化不断加重等人类活动以及太湖特有的鱼类生态学特点是导致湖鲚渔获量不断增加、年龄结构发生变化的根本原因。随着湖鲚数量的快速增加，在湖鲚生长期间太湖浮游动物现存量呈现相应下降趋势，这可能使太湖浮游植物更易暴发。

关键词：湖鲚；渔获量；年龄结构；食物组成；太湖
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