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摄食水平和饵料种类对3种海洋鱼类生长和生长效率的影响

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摘 要:采用室内流水模拟法测定了摄食水平与饵料生物种类对真鲷、黑鲷、黑鲪特定生长率和生长效率的影响。3种实验鱼类的特定生长率均随摄食水平增大呈减速增长趋势,二者间的定量关系可用对数曲线描述;而其生长效率则均随摄食水平增大呈倒"U"形变化趋势,二者间的定量关系可用二次曲线描述。曲线相关检验结果表明,其特定生长率和生长效率与摄食水平之间均呈显著相关关系。依据上述定量关系,分别求得3种鱼的维持摄食量和最佳摄食量,其中黑鲪的维持摄食量最低。以玉筋鱼为饵料时,3种鱼类的特定生长率和生长效率湿重均显著高于摄食鹰爪糙对虾,但用能值计算的生长效率则没有这种差异。

关键词:真鲷;黑鲷;黑鲪;特定生长率;生长效率;摄食水平;饵料种类
中图分类号:S963 **文献标识码**:A

我国海洋鱼类生态学研究多集中于自然种群结构及其数量变动上[1~3]。鉴于这种现场调查本身的局限性,要深入了解和定量鱼类在海洋生态系统中的功能与过程,则需配合现场或室内实验模拟手段,以期进行更深一步的探讨。生态转换效率是指处于食物网某一环节的生物生长量与食物摄入量的比值,而鱼类生长效率则是定量水生生态系统高营养层次食物网能量和物质传递的重要环节[4~6]。因此,进行海洋鱼类生长效率的研究,对海洋食物网营养动力学过程的定量十分重要。但迄今为止,国内有关方面的研究尚较少涉及[7,8]。显然,上述研究状况,难以满足我国业已起动的"海洋生态系统动力学及生物资源持续发展"研究的需要。真鲷(*Pagrosomus major*),黑鲷(*Sparus macrocephalus*)和黑鲪(*Sebastodes fuscescens*)均是渤黄海近岸海域的重要经济鱼类和增养殖种类,属底层肉食性鱼类,在该海域有着较为广泛的代表性;本研究目的在于通过上述3种鱼类的特定生长率和生长效率研究,揭示浅海底层肉食性鱼类的生态能量学特征,为我国海水鱼类增养殖潜力和效果分析提供基础资料。

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1 材料与方法

1.1 材料来源与驯养

真鲷和黑鲷均系人工培育苗种经在浅海网箱或土塘中暂养,而黑鲪则系捕自青岛沿岸海域。真鲷、黑鲷和黑鲪初始体重分别为(37.7±6.1)g、(63.4±13.4)g和(141.9±29.6)g;实验鱼经质量浓度为2~4 mg/L氯霉素溶液处理后,置于室内小型水泥池中进行预备性驯养,待摄食趋于正常后,再将其置于0.15 m^3玻璃钢试验水槽中,在实验所要求的条件下(如摄食水平、饵料种类等)进行正式驯养,待摄食再次趋于正常后,开始生长和转换效率模拟测定实验。一般预备性驯养时间为15~30 d,正式驯养时间为7~10 d。

1.2 实验装置和方法

实验采用室内流水模拟测定法,其装置见图1。

各实验水槽内流水速率的调节，以各水槽内水体中DO、NH_4-N、pH和盐度等化学指标与自然海水无显著差别为准，一般流速>6 m^3/d。实验海水经沉淀和高压沙滤处理。实验在遮光条件下进行，采用自然光照周期，最大光强250 lx，水温(14.7±0.45)℃。

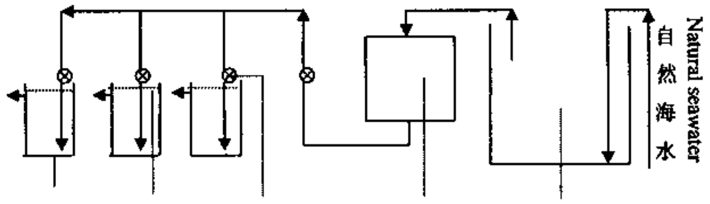

图1 室内流水模拟测定装置

Fig.1 Structure of continuous-flow simulating determination

实验前后需将鱼饥饿1~2 d后，称重。实验周期为15 d。每个实验测定条件下设5个平行组，每组中实验鱼1~4尾。摄食水平(*FL*)实验的饵料种类为玉筋鱼(*Ammcdytes personatus*)；饵料种类实验在最大摄食水平下进行。实验中各摄食水平的确定，是按实验前5 d预实验结果计算并投喂后，经实际实验结果校正得到的；摄食水平为日摄食量/鱼平均体重(%)；不同种类的摄食水平设置分别为：真鲷(2.0±0.3)%、(3.4±0.5)%、(5.7±0.7)%、(7.3±1.0)%，黑鲷(1.4±0.1)%、(2.0±0.3)%，(2.9±0.5)%、(3.3±0.4)%，黑鲪(1.0±0.3)%、(3.0±0.6)%，(4.8±0.8)%、(6.2±1.0)%。饵料生物玉筋鱼采用去头和内脏的鱼段，鹰爪糙对虾(*Trachypenaeus curvirostris*)则采用去头、皮的虾段或整虾，其大小以实验鱼易于吞食为准。每天7:00、12:00和17:00投饵，每次投喂后，至下次投喂前收集残饵；由于残饵被海水浸泡后有较大幅度的增重，故本文中残饵湿重是其干重经鲜饵含水量校正后的结果。实验结束后，收集各实验组的鱼及饵料生物进行生化组成分析；其中，能值采用能量计直接测定，总氮与总碳采用元素分析仪测定，其它则按《食品卫生理化检验方法》[9]进行测定。

鱼类的生长效率(Eg)和特定生长率(SGR)计算公式为：

$$E_g=(G_d/C_d)\times 100\% \quad (1)$$

$$SGR=[(\ln W_t-\ln W_0)/t]\times 100\% \quad (2)$$

式中，G_d－鱼日增长量；C_d－鱼日摄食量，该值经实测饵料流失率校正后得到；W_t－鱼实验后的重量，W_0－鱼实验前的重量，t－实验时间。

2 结果

2.1 实验鱼类及饵料生物的生化组成

见表1。作为饵料生物，玉筋鱼的生化组成比鹰爪糙对虾更接近于实验鱼类。

2.2 摄食水平对3种鱼生长及生态转换效率的影响

在实验条件下，真鲷、黑鲷和黑鲪的最大摄食量分别为其体重的(7.3±1.0)%、(3.3±0.6)%和(6.2±1.0)%。3种鱼的生长效率均随摄食水平增大呈倒"U"形变化趋势(图2)，二者间的定量关系均可用二次曲线描述，即：

真鲷 $Eg=-1.10\ FL^2+10.16\ FL+5.54(R^2=0.999\ 5)$；

黑鲷：$Eg=-5.96\ FL^2+35.57\ FL+26.69(R^2=0.999\ 2)$；

黑鲪：$Eg=-1.61\ FL^2+13.25\ FL+5.77(R^2=0.937\ 7)$。而特定生长率均随摄食水平升高呈减速增长趋势，二者间的定量关系均可用对数曲线加以定量描述，即：

真鲷：$SGR=0.97\ \ln FL-0.25(R^2=0.998\ 4)$；

黑鲷：$SGR=0.46\ \ln FL-0.017(R^2=0.992\ 7)$；

黑鲪：$SGR=0.72\ \ln FL-0.17(R^2=0.987\ 3)$。

经曲线相关检验结果表明，3种鱼的特定生长率和生长效率与摄食水平之间均呈显著相关关系。

表 1　实验鱼类及饵料生物的生化组成

Table 1　Biochemical composition of experimental fishes and feed organisms

种类 Species	水分/% Water	总氮/% (DW) Total nitrogen	总碳/% Total carbon	蛋白质/% Protein	脂肪/% Lipid	灰分/% Ash	能值/(kJ·g^{-1}) Energy value
真鲷 *P. major*	68.1±1.2	8.2±0.3	48.9±2.1	51.3±1.9	29.4±2.8	15.6±1.4	24.1±1.4
黑鲷 *S. macrocephalus*	67.7±1.0	8.3±0.2	49.4±2.5	51.9±1.3	25.7±2.2	13.9±0.9	24.6±1.0
黑鲪 *S. fuscescens*	68.1±1.8	9.7±0.6	50.2±2.4	60.4±3.7	23.2±4.2	13.4±2.1	24.3±1.4
玉筋鱼 *A. personatus*	69.8	9.2	47.7	57.3	16.8	12.5	22.2
鹰爪糙对虾 1 *T. curvirostris*	79.7	9.6	38.3	59.9	1.4	23.8	19.0
鹰爪糙对虾 2 *T. curvirostris*	81.2	11.2	41.3	69.8	3.1	16.2	20.4

注:实验鱼为全鱼,玉筋鱼去头去内脏,鹰爪糙对虾 1 去头,鹰爪糙对虾 2 去头和壳。Experimental fish with total body, except *A. personatus* without head and viscera, *T. curvirostris* 1 without head and *T. curvirostris* 2 without head and shell;实验鱼测定结果为不同实验组的平均值;除水份,其它以干重计。On the basis of dry weight except water content.

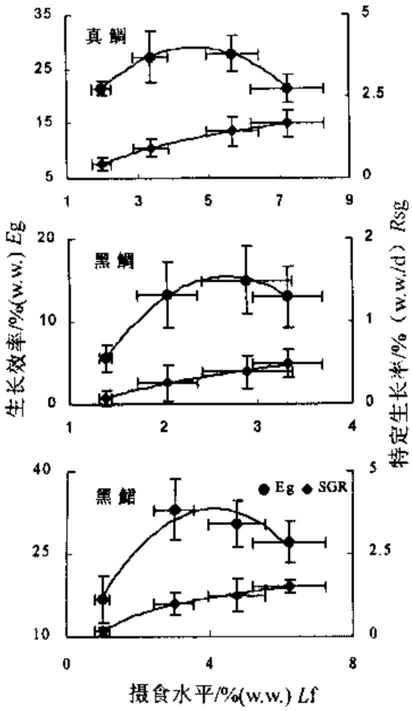

图 2　3 种鱼的 SGR 及 *Eg* 与 *FL* 的关系

Fig.2　Relation of the fishes' SGR or *Eg* with ration

2.3　维持摄食量与最佳摄食量的估算

所谓维持摄食量是使鱼体重维持不变的摄食水平,而最佳摄食量则是使生长率/摄食率为最大的摄食水平。依据本文 2.2 中所得 3 种鱼的特定生长率和摄食水平之间的关系公式,令式中 SGR=0,可求得维持摄食量分别为其体重的 1.29%、1.17% 和 0.79%;而依据生长效率与摄食水平之间的关系公式,则可求得 *Eg* 值为最大时的 *FL* 值,即实验条件下真鲷、黑鲷和黑鲪的最佳摄食量,分别为其体重的 4.60%,2.62% 和 4.10%,约为其最大摄食量的 63%、79% 和 66%。

2.4　饵料种类对 3 种鱼生长及生长效率的影响

对分别以玉筋鱼和鹰爪糙对虾为饵料生物的 2 组实验进行 *t* 检验。结果表明,当以玉筋鱼为饵料时,3 种鱼类的特定生长率均显著较以鹰爪糙对虾为饵料时大;以湿重为单位计算得到的 2 组生长效率同样有显著性差异,但考虑到上述 2 种饵料生物体内含水量等生化指标的显著不同,难免给生长效率的计算结果带来偏差。因此,又以能值为单位计算 3 种鱼的生长效率。由表 2 可见,用能值为单位所求得的 3 种鱼的生长效率均无显著性差异。

3　讨论

(1)在相同温度下,3 种鱼的特定生长率与摄食水平之间的关系均为一减速增长曲线,而生长效率与摄食水平之间的关系呈倒“U”型,该结论也为许多其它研究结果所证实[10-13]。因而上述关系代表了包括海洋鱼类在内的鱼类生长率或生长效率与摄食水平的普遍关系;本研究中 3 种鱼的特定生长率与摄食水平之间的关系均可用减速增长趋势的对数曲线 $SGR = m \cdot \ln FL - n$ 加以定量描述;而其生长效率与摄食水平之间的关系,均可用二次曲线 $Eg = -a \cdot FL^2 + b \cdot FL + c$ 定量描述,与其它研究结果相同,在较高摄食水平下,增加摄食量并未引起 3 种鱼特定生长率的显著增大。

(2)通常,鱼类的最大摄食量占其体重的 1.8%~36.0%[14],其中温带鱼类平均约为 5.9%,热带鱼类平均约为 16.7%。作为温带海洋鱼类,在本研究的适温条件下,真鲷、黑鲷和黑鲪的最大摄食量分别为 7.26%、3.30% 和 6.21%,均接近于温带鱼类平均水平。真鲷、黑鲷和黑鲪虽然同属浅海底层肉食性鱼类,但其生态习性有显著不同;其中,真鲷和黑

鲷生态习性相近，摄食游动量和游动速度均显著大于黑鲪，而大游动量必将提高其日代谢水平，从而解释了实验中的两个现象：即真鲷和黑鲷的维持摄食量大于黑鲪，而它们的生长效率相对低于黑鲪。

表2 摄食不同饵料生物对3种鱼SGR和*Eg*的影响

Table 2 Effect of different feed organisms on SGR and *Eg* of expermental fishes

项目 Item	实验鱼 Species	SGR/%		*Eg*/%	
		玉筋鱼 *A. personatus*	鹰爪糙对虾 *T. curvirostris*	玉筋鱼 *A. personatus*	鹰爪糙对虾 *T. curvirostris*
湿重 Wet weight	真鲷 *P. major*	16.7±0.32	1.17±0.28	21.23±2.65	14.51±3.21
		d.f.=8,	$0.01<P<0.05$	d.f.=8,	$P<0.01$
	黑鲷 *S. macrocephalus*	0.49±0.17	0.29±0.13	13.26±3.72	6.37±1.61
		d.f.=8,	$0.01<P<0.05$	d.f.=8,	$0.05>P>0.01$
	黑鲪 *S. fuscescens*	1.56±0.37	0.98±0.29	26.12±2.82	18.31±3.42
		d.f.=10,	$0.01<P<0.05$	d.f.=10,	$0.05>P>0.01$
能值 Energy value	真鲷 *P. major*	16.7±0.32	1.17±0.28	26.30±2.93	28.92±6.56
		d.f.=8,	$0.01<P<0.05$	d.f.=8,	$P>0.05$
	黑鲷 *S. macrocephalus*	0.49±0.17	0.98±0.29	14.42±4.05	12.78±3.24
		d.f.=8,	$0.01<P<0.05$	d.f.=8,	$P>0.05$
	黑鲪 *S. fuscescens*	1.56±0.37	0.98±0.29	34.05±4.53	38.86±7.28
		d.f.=10,	$0.01<P<0.05$	d.f.=10,	$P>0.05$

(3)本研究结果表明，当3种鱼摄食玉筋鱼时，特定生长率均显著高于摄食鹰爪糙对虾，其原因显然与玉筋鱼的生化组成比鹰爪糙对虾更接近于实验鱼类有关。杨纪明和李军[7,8]也研究了不同饵料生物对5种海洋鱼类摄食、生长和生长效率的影响，认为作为饵料生物，玉筋鱼较巢沙蚕、火枪乌贼等更有利于实验鱼类提高其生长率和生长效率；其欠缺之处在于仅采用可比性较差的湿重为单位，计算和比较了不同饵料生物对鱼类生长效率的影响。本研究结果表明，尽管以湿重为计算单位时，也得到摄食不同饵料生物使得3种鱼生长效率显著不同的结果，但用能值计算和比较上述3种鱼类生长效率，却无显著性差异。

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Effect of ration and feed species on growth and ecological conversion efficiency of 3 species of sea fishes

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Abstract: Using flowing - water simulating experiment in laboratory, the experiment was conducted with 3 species of fishes which were *Pagrosomus major*, *Sparus macrocephalus* and *Sebastodes fuscescens*. The results show that their specific growth rates (SGR) increase with the rise of temperature or ration (*FL*), and the quantitive relationship between them can be described as SGR = m·ln*FL* - n; the ecological conversion efficiency (*E*g) decreases gradually after increasing to a peak value with the rise of temperature or ration, and their quantitive relationship can be described as $E_g = -a \cdot FL^2 + b \cdot FL + c$. According to the formula above, the maintenance rations and optimum ration can be calculated that the maintenance ration of *S. fuscescens* was the lowest among the 3 fishes. Different feed can affect their growth that when using *Ammodytes personatus* as feed the SGR of the 3 fishes are higher than using *Trachypenaeus curvirostris*. But the *E*g has no significant difference between the 3 when using energy value ($kJ \cdot g^{-1}$) as calculated basis.

Key words: *Pagrosomus major*; *Sparus macrocephalus*; *Sebastodes fuscescens*; specific growth rate; growth efficiency; ration; food species

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The geographical characteristics and fish species diversity in the Laizhou Bay and Yellow River estuary

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Abstract: This paper analyzed the history, topography and sedimentary characteristics of the Laizhou Bay and Yellow River estuary, and their relationships with fish species diversity. This region has a relatively short geological history of about 10 000 years, which determines a low level of fish species diversity. There are 96 fish species belonging to 46 families, of which the temporal and spatial distributions are closely related to the topography and sedimentary in this region. The sharp decrease of fresh water discharge from the Yellow River recent years threatens the fishery resources, fish species diversity and ecosystem in the Yellow and Bohai Sea.

Key words: Laizhou Bay; Yellow River estuary; geography; fish species diversity
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There have been publications on geographical formation, marine sediments, hydrological characteristics etc and fishery resources in the Bohai Sea[1-4]. But there was little study on the geographical characteristics of the Laizhou Bay and Yellow River estuary, particularly their relationships with fish species diversity. The purpose of this investigation is to explore the relationships and provide some basic data for the sustainable development and the fishery resources.

1 History

The laizhou Bay lies at the south of the Bohai Sea, which is between the Yellow River estuary and Jimu Island (Fig. 1). The width from east to west is 96 km, and the length of shoreline is 319 km, and its area is 6 966 km^2. Its location is about 118°50′~120°20′E, 37°08′~38°05′N.

The laizhou Bay is one of the three big bays in the Bohai Sea. The modern Bohai Sea was immersed about 8 000 years ago -- Holocene Epoch[5]. By the time when the water level raised, the seawater broke through the east barrier and filled in the Bohai Sea delta. Then the present Bohai Sea came into being. The Laizhou Bay was also formed at the same time. Its area and shape were slightly changed due to the effects of transgression, sedimentation and hydrodynamic power of seawater. The present Laizhou Bay is becoming smaller and shallower because of the sedimentation from the Yellow River and the other rivers along the coast.

The formation of the modern Yellow River delta took place very recently. In 1855 the Yellow River changed its route to the Laizhou Bay, and therefore, the Yellow River delta formed with an area of about 5 400 km^2, which is one of the least stable deltas in the world.

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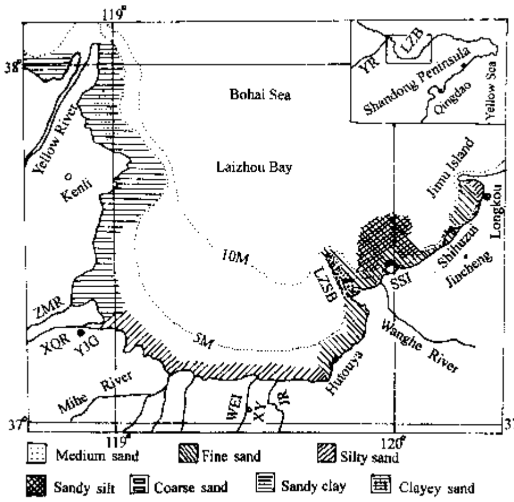
2 Geological characteristics

2.1 Characteristics of geology and physiography



JR – Jiaohe River; LZB – Laizhou Bay; LZSM – Laizhou Shallow Bank; SSI – Sanshan Island; WEI – Weihe River; XQR – Xiaoqing River; XY – Xiaying; YJG – Yangjiaogou; YR – Yellow River; ZMR – Zimai River; DLZ – Diaolongzui. The same in Fig. 2.

Fig. 1 Geographical location, topography and sedimentary of the Laizhou Bay and Yellow River estuary

The geological structure of the Laizhou Bay is complex. The famous Yanlu Rupture runs through the Bay's middle. The coastal geology and physiography is divided into eastern and western parts with the boundary at Hutouya. The eastern part is ascending area and the beach is composed of sand and gravel overlying on rocky bed. The sea cliffs are well developed in Shihuzui, Sanshan Island, and Hutouya. The inter-tidal zone is narrow, mainly with fine sand. The 5 m and 10 m isobaths are close to the coast, except that the 5 m contour near Diaolongzui extends northwest and forms the Laizhou Shallow Bank, which is made up of silt and sand that came from the rivers flowing into the Laizhou Bay. Laizhou Shallow Bank plays an important role in forming the Sanshan Island fishing ground. The western part belongs to sink area, and the shore is made up of silty sand and silt. The inter-tidal zone is getting broader slowly; the water channel system is getting more complex. When extending westward further, its coastal sediment changes from sandy silt to silt gradually due to the Yellow River discharge. There comes a large amount of silt and sand of about 1 billion tons per year from the Yellow River. This influences the development of the physiography and the underwater delta, i. e. the silty coast and underwater shelf.

2.2 Sediment characteristics and distribution

From east to west, the sediment changes gradually (Fig. 1). In the eastern Laizhou Bay, the sediment mainly consists of less-coarse sand and fine sand. In the southern Laizhou Bay, the sediment is mainly sandy silt and silty sand. In north of Zimai River, the recently formed Yellow River delta has gradually more clayey sand. At both sides of the Yellow River estuary, there is a semi-suspended sandy clay area, which is a special port of refuge for the fishing vessels working in the area. From south to north, the sediment becomes thinner gradually, and the sediments deposit well. All these determine the distribution of fish species in the Laizhou Bay.

3 Hydrology

Laizhou Bay lies within the temperate-zone, and belongs to monsoon climate. The combined effects of land climate, diluted water of the Yellow River and cold-water mass of the Yellow Sea dominate the intrinsic hydrological characteristics in this region.

3.1 Temperature and salinity

Temperature and salinity play the key role in fish metabolism and fish distribution. An example of monthly variations of water temperature and salinity in the Laizhou Bay is shown in Table 1, showing that temperature and salinity vary distinctively between seasons. For example, in the eastern Laizhou Bay (Jincheng), the maximum difference of annual water temperature was as high as 28.9℃. Similarly, salinity changes seasonally due to evaporations and precipitation. This is especially distinctive in the Yellow River estuary. Because of the fresh water discharge from the Yellow River, in summer and autumn the salinity declines sharply (in September 24.56 and October 18.62); in winter and spring it is relatively high. In some estuaries, such as the Zimai River estuary, the salinity is only 3.

Table 1 Monthly variations of temperature and salinity in the Laizhou Bay (Jincheng)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature/℃	−0.5	−0.9	3.0	11.2	17.5	22.8	27.6	28.0	23.2	16.8	10.7	2.5
Salinity	31.35	31.59	30.90	30.24	30.31	30.94	30.76	29.65	30.48	31.36	31.75	31.82

From early January to the end of February, sea ice appears widely in the mid-west of the Laizhou Bay and the shallow waters of the Yellow River estuary. Its boundary can extend 5～20 km into the sea, with narrow ice band in the east and wide band in the west. Its thickness is less than 20 cm in the east, and 30 cm in the Yellow River estuary. The drift ice range is so wide that it covers the whole area (Fig.2)[6].

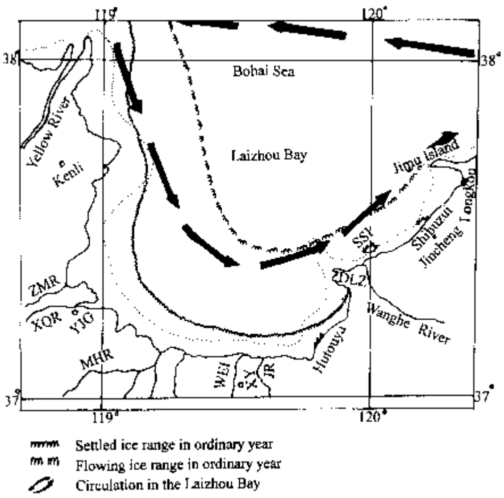


Fig.2 Sea ice and circulation in the Laizhou Bay and Yellow River estuary

The above means that only cold temperate, temperate and eurythermal species can live in the area all year round. The warm-temperate and warm water species appear here only seasonally[3].

3.2 Water current and water mass

3.2.1 Water current The Bohai Sea branch of the Yellow Sea warm current turns southward into the Laizhou Bay and mixed with the low salinity silty water in the Yellow River estuary. The water current then flows out of the eastern Laizhou Bay. This forms the stable anti-clockwise circulation (Fig.2). There are 2 types of tidal current in the Laizhou Bay. In west of Diaolongzui, the tide is regular semidiurnal, and in the east the tide is irregular semidiurnal. The direction of the tide is mainly southward or northward and is bi-directional current. Residual current, especially the tide residual current, relates to marine sedimentation, substance transportation, as well as larvae and prey organism abundance. The total tidal residual current in this area is dominated by M_2 tide residual current[7]. There is a strong offshore tide outside the old Yellow River estuary. The direction of its residual tide in the Laizhou Bay is basically southward or northward, but there is also a tendency to form an anti-clockwise circulation. This may be one of the important reasons why the juvenile fish born in the Laizhou Bay can stay there for a long period.

3.2.2 Water mass Water mass in the Laizhou Bay generally belongs to those in the Yellow and Bohai Sea, which can be divided into Bohai Sea water mass and Bohai Sea coastal water mass. The former is a denaturalized section of Yellow Sea water mass, which extends into the central part of the Bohai Sea. It is the habitat of cold-temperate fishes in summer and wintering ground of endemic fishes in the Bohai Sea. The latter dominates the Yellow River estuary and almost the whole Laizhou Bay. The area dominated by this water mass is the spawning and feeding grounds of the commercially important fishes in the Yellow and Bohai Sea.

4 Characteristics of fish species diversity

The fishes in this area almost represent the fish species in the Bohai Sea, with the total number of 96 species. In comparison with the total number of 326 species in the Yellow and Bohai Sea[8], it confirms that the Bohai Sea is poor in fish species diversity[1].

Table 2 shows the investigation results since 1980s that there are 46 families, 96 fish species in this area.

Table 2 Fish species and distribution in the Laizhou Bay and Yellow River estuary

No.	Species	Temperature adaptation			Distribution type			Distribution area		
		WWS	WTS	CTS	MS	EnS	EsS	ELB	MLB	YRE
1	*Mustelus manazo*		√		√			+		
2	*Triakis scyllium*		√		√			+	+	
3	*Raja porosa*			√		√		+	+ +	+
4	*Dasyatis laevigatus*		√		√			+		
5	*Ilisha elongata*	√			√			+	+	+
6	*Clupea pallasi*			√	√			⊙		
7	*Harengula zunasi*		√		√			+	+ +	+ +
8	*Sardinops melanosticta*		√		√			⊙		
9	*Clupanodon punctatus*	√			√			+ +	+ + +	+ +
10	*Engraulis japonicus*		√		√			+ +	+	
11	*Scutengraulis Kammalensis*	√	√		√			+ +	+ +	+ +
12	*S. mystux*	√	√		√			+	+	+ +
13	*Setipinna gilberti*	√	√		√			+ +	+ +	+ + +
14	*Coilia mystus*		√				√		+	+ +
15	*C. ectenes*		√				√			+
16	*Neosalanx anderssoni*	√					√		+ +	+ + +
17	*Protosalanx hyalocranius*	√					√			+ +
18	*Salanx acuticeps*	√					√	+	+	+
19	*Salanx ariakensis*	√					√		+	+
20	*Saurida elongata*		√		√			+	+	
21	*Anguilla japonica*		√				√		+	+
22	*Muraenesox cinereus*	√			√			+		
23	*Astroconger myriaster*		√		√			+	+	
24	*Tylosurus anastomella*		√		√			+	+	+ +
25	*Hyporamphus sajori*		√		√			+ +	+	+
26	*H. intermedius*		√		√			+	+	+
27	*Syngnathus acus*		√			√		+ +	+	+
28	*Hippocampus japonicus*		√			√		+	+	
29	*Sphyraena pinguis*	√			√			+		
30	*Liza haematochelia*		√			√		+ +	+ +	+ + +
31	*Mugil cephalus*	√			√			+		
32	*Lateolabrax japonicus*		√			√		+ +	+ +	+ +
33	*Apogon lineatus*	√			√			+ +	+	
34	*Sillago sihama*		√			√		+	+	
35	*Atropus atropus*	√			√			+		
36	*Seriola aureovittata*		√		√			+		
37	*Nemipterus virgatus*		√		√				⊙	
38	*Hapalogenys mucronatus*		√		√			+		
39	*Collichthys niveatus*		√			√		+	+	+
40	*C. fragilis*		√			√		+	+ +	+ +
41	*Pseudosciaena polyactis*		√		√			+	+ +	+ +
42	*Miichthy miiuy*	√			√			+		
43	*Argyrosomus argentatus*		√		√			+	+ +	
44	*Nibea albiflora*		√		√			+ +	+ +	+
45	*Johnius belengerii*		√		√			+	+ +	+ +
46	*Sparus macrocephalus*		√			√		+ +	+	
47	*Pagrosomus major*	√			√			+ +		
48	*Ditrema temmincki*		√		√			+		
49	*Enedrias nebulosus*			√		√		+ +	+	
50	*Zoarces elongatus*			√		√		+ +	+	+
51	*Ammodytes personatus*			√		√		+ +	+	

(Be continued)

(Continuing table 2))

52	*Callionymus kitaharae*		√			√	+	+	+
53	*Trichiurus haumela*	√			√		+ +	+ +	+
54	*T. muticus*		√		√		+	+	+ +
55	*Pneumatophorus japonicus*	√			√		+		
56	*Scomberomorus niphonia*	√			√		+ +	+	+
57	*Stromateoides argenteus*	√			√		+	+	+
58	*Tridentiger obscurus*		√			√	+		+
59	*T. trigonocephalus*		√			√	+ +		+
60	*Triaenopogon barbatus*		√			√	+		+
61	*Luciogobius guttatus*		√			√	+		
62	*Chaenogobius annularis*		√			√	+	+	
63	*Cryptocentrus filifer*	√				√		+	
64	*Ctenogobius pflaumi*		√			√	+ +		
65	*Aboma lactipes*		√			√	+	+	
66	*Synechogobius hasta*		√			√	+	+ +	
67	*S. ommaturus*		√			√	+	+ +	+ + +
68	*Chaeturichthys stigmatias*		√			√		+ +	+ +
69	*C. hexanema*		√			√	+	+ +	+ + +
70	*Apocryptodon madurensis*	√				√	+		
71	*Odontamblyopus rubicundus*		√			√		+	+ +
72	*Ctenotrypauchen microcephalus*		√			√		+	+ +
73	*Periophthalmus Cantonensis*		√			√	+	+ +	+
74	*Sebastodes fuscescens*		√			√	+		
75	*Chelidonichthys kumu*	√			√		+		
76	*Hexagrammos otakii*			√		√	+	+	
77	*Platycephalus indicus*	√			√		+ +	+	+
78	*Liparis tanakae*			√		√	+	+	
79	*Paralichthys olivaceus*		√		√		+	+	
80	*Cleisthenes herzensteini*			√	√		+		
81	*Pleuronichthys cornutus*		√		√		+	+ +	+
82	*Pseudopleuronectes yokohamae*			√	√		+ +	+	
83	*Platichthys bicoloratus*			√	√		+		
84	*Zebrias zebra*	√			√		+	+	+
85	*Cynoglossus semilaevis*		√			√	+	+	+ +
86	*C. lighti*		√			√		+	+ +
87	*C. abbreviatus*		√			√	+ +	+	+
88	*Triacanthus brevirostris*	√			√		+	+	
89	*Cantherines modestus*	√			√		+		
90	*Fugu xanthopterus*		√		√		+	+	
91	*F. vermicularis*	√			√		+	+	+
92	*F. niphobles*		√		√		+	+	
93	*F. flavidus*		√		√			+	+
94	*F. ocellatus*		√		√			+	+
95	*F. pseudommus*		√		√		+	+	+
96	*Lophius litulon*		√		√		+	+	

Note: "⊙" showing the rare species appearing occasionally in this area WWS: warm water species; WTS: warm temperate species; CTS: cold temperature species; MT: migrating species; EnS: endemic species; EsS: estuary species; ELB: eastern Laizhou Bay; MLB: mid Laizhou Bay; YRE: Yellow River estuary

4.1 Systematic classification

The fishes in Table 2 almost covers the main families, genus and common fishes in the Yellow and Bohai Sea. There is no endemic fish species in this area.

4.2 Temperature adaptation types

Among the 96 fishes are 25 warm water species (26.04%), 61 warm temperate species (63.54%), 10 cold temperate water species (10.42%). There is no real cold water species. The warm temperate species, usually belonging to their Yellow and Bohai Sea population, almost dominate the populations in this region. This area is the northern boundary of their distribution. Because the Laizhou Bay and Yellow River estuary are located at south of 38°N within the warm temperate zone, there is usually no cold temperate fish species. The distribution of cold temperate species, such as fat greenling (*Hexagrammos otakii*), elongate eel pout (*Zoarces elongatus*), pointhead plaice (*Cleisthends herzensteini*), is related to the distribution of the Yellow Sea cold water mass in this area.

4.3 Migration types

There are 54 migratory species, making up 56.25% of the total species, including the main commercial fish species. There are 35 endemic species, making up 36.46%. Most of the endemic fishes are of little commercial value and with small sizes excluding a few species. There are only 7 species (7.29%) confined only in the estuary or estuary-and-river. These fishes are closely related with the Yellow River waters, locally famous but with small biomass.

4.4 Distribution

There are 32 species (33.33%) distributing in the whole bay and 82 species (85.41%) distributing in the eastern Laizhou Bay, 49 species(51.04%) in the Yellow River estuary. All those in the whole bay are mainly endemic species. In the eastern Laizhou Bay, apart from the endemic species, the increased number of species is migratory species. In the Yellow River estuary, most of the fishes are eurythermal, euryhalinous and estuary fish species. Therefore, the species diversity is low in the Yellow River estuary, only 60% of which in the eastern Laizhou Bay.

5 Discussions and conclusions

5.1 History and species diversity

The history of modern Laizhou Bay and Yellow River estuary is not more than 10 000 years. In such a short developing period, it is impossible to form highly abundant fish species. The fish species came here following the open sea water. Part of those eurythermal and euryhalinous species settled down gradually, most of which still keep their intrinsic behavior. The migratory species only appear seasonally and form fishing seasons once a year. This is why the Laizhou Bay and Yellow River estuary do not have their own endemic species.

5.2 Hydrological characteristics biodiversity

It has been stated that the temperature and salinity in this region vary sharply between seasons. For example the monthly average temperature in summer can be up to 28℃, but in some shallow water area of the Yellow River estuary it can exceed 30℃. In winter, the Laizhou Bay has a wide coverage of ice in shore, and drift ices almost spread all over the area. Similarly, the salinity in the Yellow River estuary also changes sharply between flood season and low water season. This makes it difficult for the cold temperate and cold water species to summer, and warm water and warm temperate species to winter, which restricts the development of fish species diversity.

5.3 Geological conditions and fish species diversity

The topography of the Laizhou Bay and Yellow River estuary is complex. In the eastern part, there are rocky/gravely shores, and with sea cliffs in many places such as Shihu Rib, Sanshan Island. The western part is characterized by silty sand, and transits into silt when extending to the Yellow River estuary. Different fishes inhabit in this topography and sediment accordingly. For example, the reef fishes of schlegel's blackrockfish (*Sebastodes fuscescens*) and fat greenling can only be found in the eastern and middle Laizhou Bay. Sandy beaches are ideal for common asohos (*Sillago sihama*), and sandlance (*Ammodytes personatus*), which do not appear in the Yellow River estuary because of their hiding-in-sand characteristics. The species like red eel goby (*Odontamblyopus rubicurdus*) and smallhead goby (*Ctenotrypauchen microcephalus*), which usually inhabit in clayey silt caves, do not appear in the eastern part. The sediment becomes finer from shore in the south to the deep water in the north Laizhou Bay. This helps demersal fish species to select their suitable sediments to live.

5.4 Effect of reduction of Yellow River fresh water discharge

Fishery productivity in the Laizhou Bay and Yellow River estuary depends on the nutrition and organic matters from the Yellow River. Therefore the reduction of fresh water discharge will decrease the primary productivity and endanger the fishery resources. According to the statistics in early 1990s, there were about 38 billion m^3 of water flowing into the Laizhou Bay[9]. In recent years the excessive irrigation projects in the upstream region resulted in the sharp decrease of fresh water discharge from the Yellow River. In 1997, the low stream of the Yellow River dried for 226 d. This will directly affect the productivity and fishery resources in the Laizhou Bay, especially for the estuary fish species. For example in 1950s, estuary tapertail anchovy (*Coilia ectenes*) could go to Dongping Lake[10], but now it is even difficult to find a specimen because the low stream of yellow River dries when estuarine tapertail anchovy (*Coilia ectenes*) spawns. Before 1980s, the crossing-river species, such as large icefish (*Protosalanx hyalocranius*), sharphead icefish (*Salanx acuticeps*), which belong to Salangidae, dominated, but now the dominant species are Andrsson's icefish (*Neosalanx anderssoni*), a kind of estuary species. Therefore, the reduction of the Yellow River fresh water discharge will negatively affect the fish species diversity and fishery resources in the Laizhou Bay, and endanger the fishery ecological system in the Yellow and Bohai Sea.

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莱州湾及黄河口水域地理学特征与鱼类多样性

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摘　要: 以历史和调查资料为基础, 介绍了莱州湾及黄河三角洲的地理位置及其发育史, 指出莱州湾是一个年轻的海湾, 而黄河三角洲则是一个不稳定的河口三角洲。莱州湾地质构造复杂, 东部为上升区, 西部属沉陷区; 黄河三角洲则属于淤泥岸坡, 沉积物呈从东向西, 由南向北逐渐细化为特征。其水文特征因地处暖温带北缘, 属季风气候区。在陆上气候、黄河冲淡水和黄海冷水团交互影响下, 本水域形成温、盐季节变化显著, 逆时针环流、往复流性质的潮流及以 M_2 潮汐余流占主要地位的余流特征。出现的鱼类共有 46 科, 96 种, 几乎覆盖黄渤海软骨和真骨鱼类的主要科、属及其习见种类, 但无地方特有种。与黄渤海 326 种鱼类相比, 仍属黄渤海生物区系的贫乏化表现。在适温类型上, 仍以暖温种占优势, 占 63.54%, 暖水、冷温种分别占 20.04% 和 10.42%, 无冷水种。其生态分布型, 洄游性鱼类占优势, 为 56.25%, 定居型占 36.46%, 河口性鱼类仅占 7.29%。认为现代莱州湾与黄河口水域的短暂发育史难以产生高丰度的物种多样性, 同时, 该水域的水文特征也不利于生物多样性的发展; 还探讨了地质条件与鱼类生物多样性分布关系和黄河径流锐减将危及鱼类生物多样性与渔业资源问题。

关键词: 莱州湾; 黄河口; 地理学; 鱼类多样性