PICES-2011

Comparison between the biodiversity index, Exergy, and the AMBI index for the benthos during large-scale ocean engineering within the Yangshan Deep-water Harbor (Yangtze Estuary, China)

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Present work

- M. Luo, , et al., Community characteristics of macrobenthos in waters around the Nature Reserve of the Chinese sturgeon Acipenser sinensis and the adjacent waters in Yangtze River Estuary. **Journal of Applied Ichthyology**, 2011, 27 ,425–432.

- Luo, M.B., et al.,Salinity-induced oxidative stress and regulation of antioxidant defense system in the marine macroalga *Ulva* prolifera. J. Exp. Mar. Biol. Ecol. (2011), doi:10.1016/j.jembe.2011.08.023

Content

1、Background

2、Content

3、Method

4、Result

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1、Background

- As a living place of various fishes, shrimps, crabs and parrs and famous for the Zhoushan Fishing Ground, the Hangzhou Bay ecosystem has the typical flimsiness and complexities. In recent years, a series of ocean engineerings started at Hangzhou Bay and were put into use.






- Benthos has the direct or the indirect relationship with ecosystem, in the field of most physics and chemistry processes.

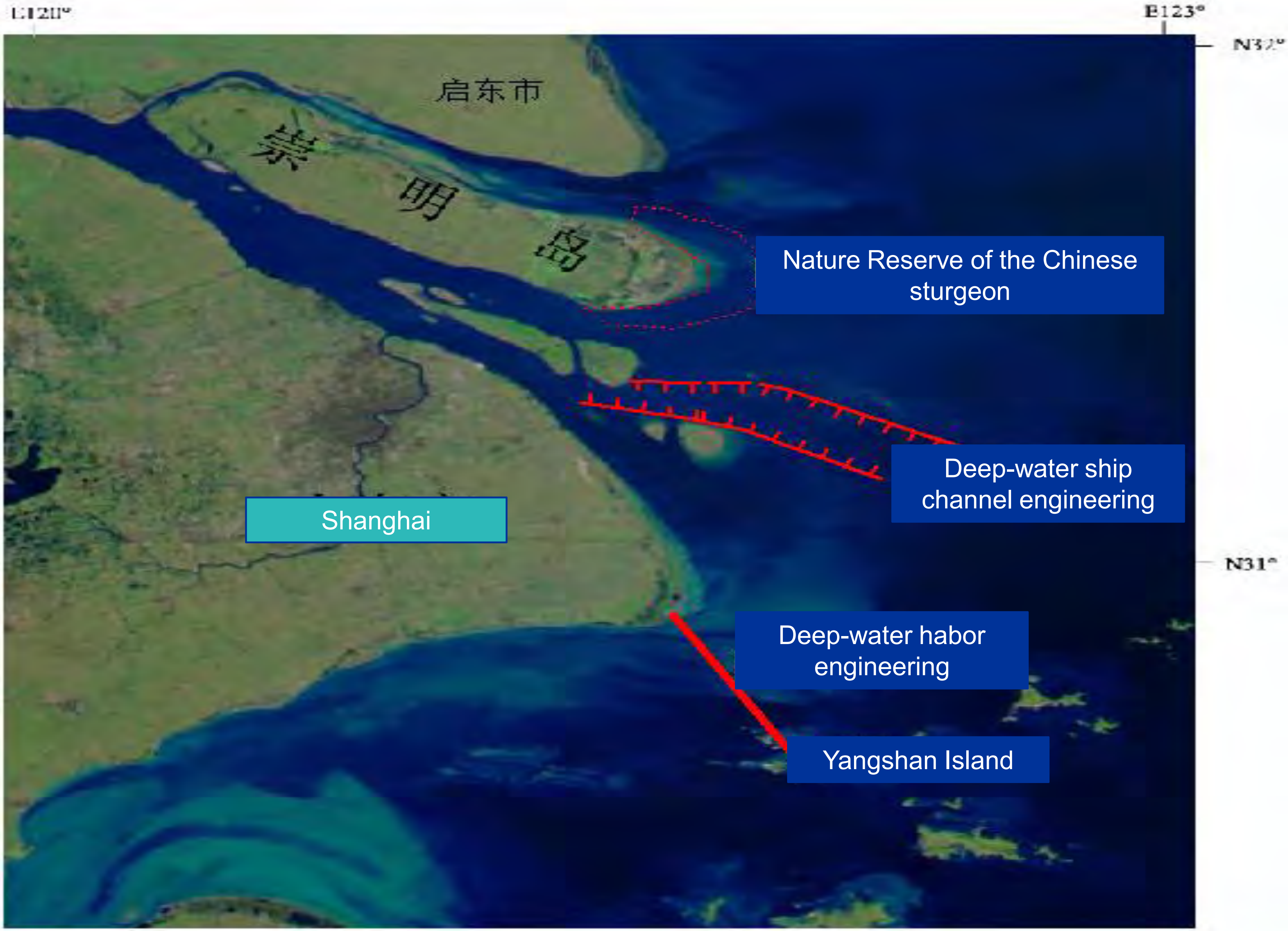


Fig. 1-1 Graphic figure of Yangtze Estuary

Impact forms of large-scale estuary engineering to the benthos community

- **1、Occupying the habitat,**
- **2、Reducing the bait resources of the foodweb(SS impacting),**
- **3、Destroying the biotope(**fragmentation**).**

2、Research parts

- **Biotic index change and PCA analysis**
- **Benthos community Exergy change under the huge ocean engineering**
- **AMBI index application on evaluation the benthos community change under the huge ocean engineering**

3、Method

From 2001 to 2005, an oceanographic comprehensive survey of 20 sampling sites was carried out in waters around the area of Yangshan Islands in Hangzhou Bay （30° 32′~30° 50′N、121° 53′~122° 17′E）during the months of February, May and August, representing winter, spring and autumn respectively.

The infauna and epifauna were the main survey contents.

Infauna samples were collected by 0.05 m^2 box corer and 4 successful grabs were regarded as one sample in a station

Epifauna samples were collected using an Agassiz trawl (AGT) (Piepenburg et al., 1996). The opening of the AGT was 1.5 m wide, 0.5 m high and 2.5 m long, and its mesh size in the cod-end was 5 mm. The along-bottom haul time was 10 min for the AGT, with trawling speeds of about one knot. Trawl catches were carried out at 20 stations, with one haul per station during a cruise.Hence the cover area of the waters by AGT was 463 m^2 inone haul of one station.

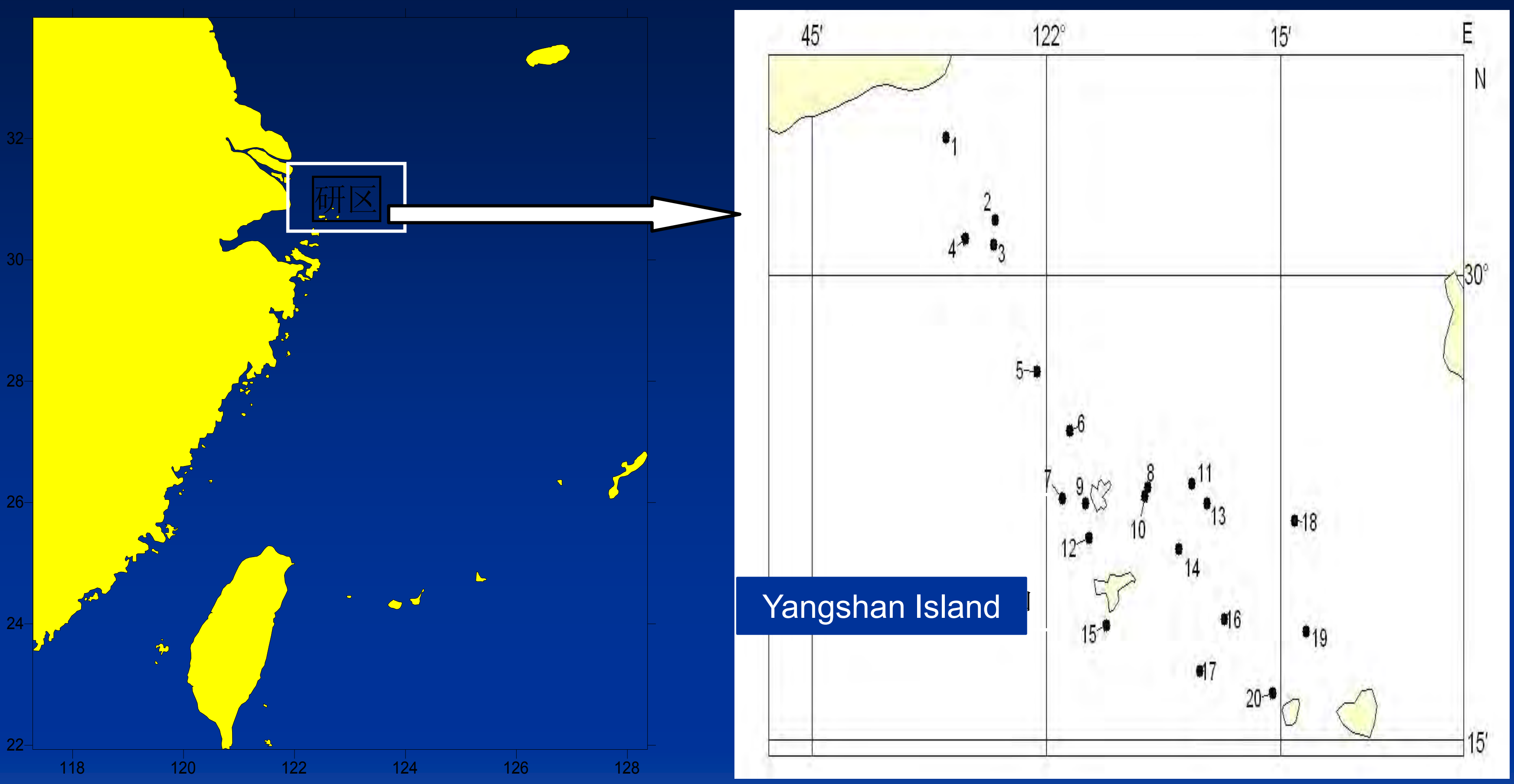
Samples were then fixied in 75% alcoho1. The biomass and density was determined by the alkohol fixed weight, alkohol fixed number and the 463 m2 cover water area in one haul. After preservation the macrobenthos of the sample was separated into major systematic groups, and species were identified to the nearest systematic categories by taxonomic experts.

Data analysis

$$\mathrm{Ex} = \sum_{i=1}^{n} W_i C_i$$

Ci is the contration of the component, unit : g/m^2； *Wi* is the weight factor; Ex is Exergy, unit:J/m^2

PCA analysis using the PRIMER 5.0 software.



Sampling site

4、Result

4.1 Community characteristics

- **Infauna：** From 2003 to 2005 ,**As the Yangshan Deep-water Habor engineering going, the biomass presented the downtrend(**ANOVA**, p** $<$ **0.05).**

Infauna biomass change （g/m^2）

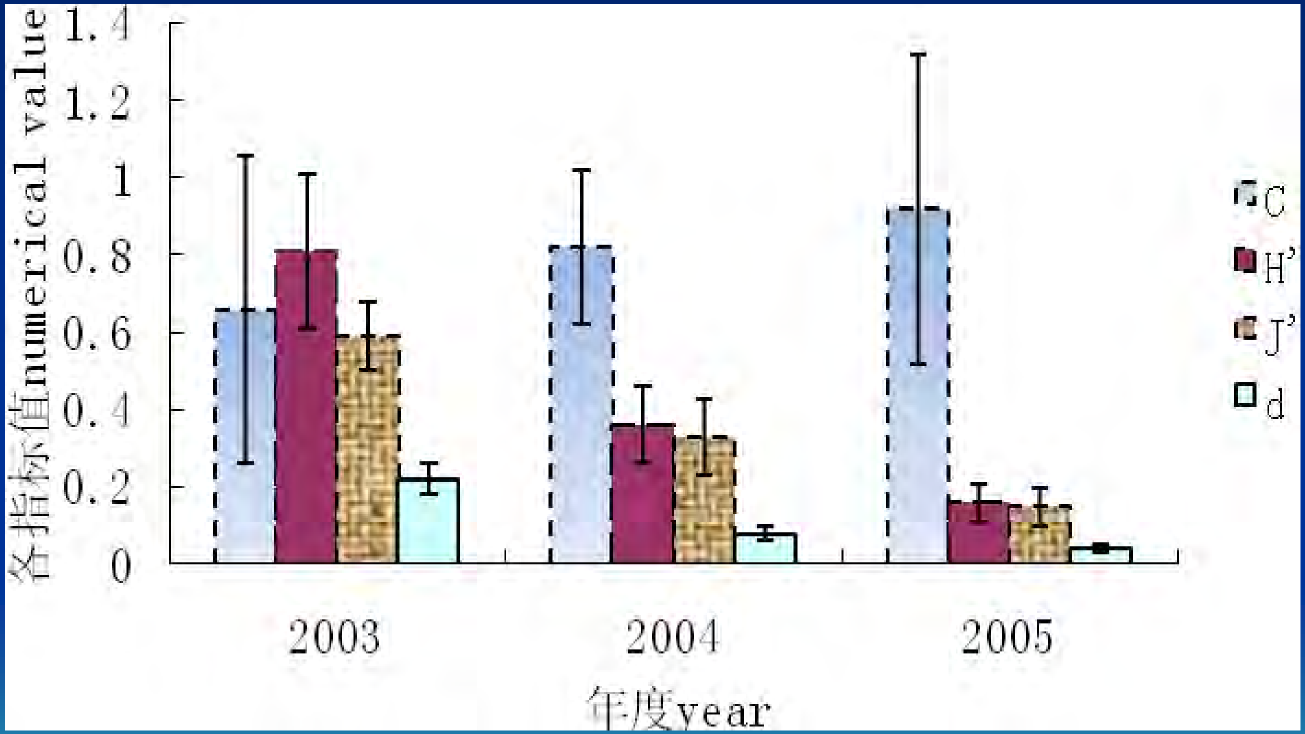
months	years	Bridge Zone	Habor Zone	Channel Zone	average
Feb.	2003	2.77	1.34	10.12	3.96
	2004	0.48	0.92	0.14	0.63
	2005	2.83	0.52	6.05	2.60
May	2003	3.01	3.66	0.64	2.67
	2004	0.04	0.92	0.88	0.86
	2005	0.63	2.24	6.66	2.86
Aug.	2003	1.50	5.83	12.34	6.16
	2004	0.24	0.15	0.93	0.37
	2005	2.28	0.40	0.88	1.08
average	2003	2.43	3.61	7.70	4.26
	2004	0.25	0.66	0.65	0.62
	2005	1.91	1.05	4.53	2.18

Dominant species： Mollusk *Sinonovacula constricata* got disappearance.

Dominance degree of dominant species of infauna((*Y*≥0.02，2003-2005)

Domient species	Dominance degree(*Y*)								
	2003			2004			2005		
	Feb.	May	Aug.	Feb..	May	Aug.	Feb.	May	Aug.
Sternaspis scutata	0.06	0.02			0.04				0.03
Capitella capitata	0.03			0.05					
Nemertini spp.								0.03	
Neanthes japonica				0.04					
Aglaophamus californiensis	0.02	0.03		0.08			0.02		
Praxillella pacifica		0.20			0.02	0.04			
Pista pacifica			0.32						
Amphicteis gunneri	0.02								
Nassarius(Varicinassa) variciferus							0.07	0.02	0.15
Nassarius succinctus				0.02					
Mactra venerformis						0.02			
Sinonovacula constricata	0.05	0.07	0.04						
Eriocheir leptognathus							0.03		
Amphiura vadicola					0.02			0.02	

Diversity： From 2003 to 2005, species diversity(Shannon-Wiener diversity), evenness(Pielou'S evennes), abundance(d)(Margalef'S index)got downtrend and the Simplicity got uptrend.



- **Epifauna:** In 2003, which was the beginning period of this engineering, the biomass distinctly increased. As the going of the engineering, the biomass got downtrend.and the biomass was lower than that in 2001.

Epifauna biomass change （g/m^2）

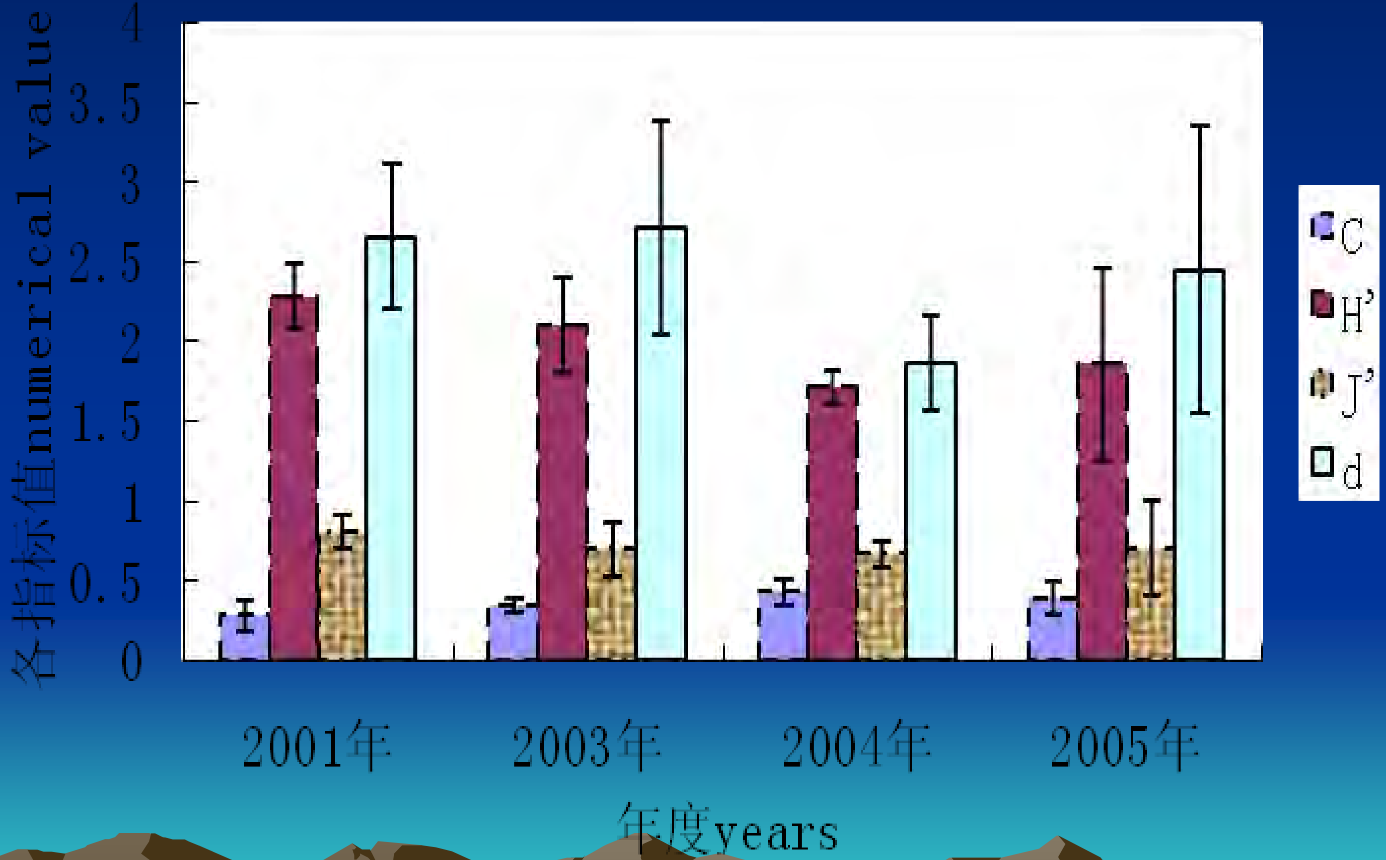
months	years	Bridge Zone	Habor Zone	Channel Zone	average
Feb.	2001	6.16	10.63	8.16	9.13
	2003	19.67	37.33	53.20	35.80
	2004	13.63	6.40	10.04	9.47
	2005	4.78	5.66	2.03	4.49
May	2001	10.04	13.59	6.08	10.65
	2003	18.00	43.56	22.20	30.48
	2004	12.28	25.67	9.75	17.67
	2005	12.37	6.65	7.71	8.63
Aug.	2001	9.56	17.66	12.48	13.93
	2003	27.00	30.44	13.80	25.20
	2004	12.85	13.91	26.45	16.73
	2005	12.16	6.83	13.88	10.19
average	2001	8.59	13.96	8.91	11.24
	2003	21.56	37.11	29.73	30.48
	2004	12.92	15.33	15.41	14.62
	2005	9.77	6.38	7.87	7.77

Dominant species: The impact to crustacea was very low. The dominant species of fish *Cynoglossus semilaevis* disappeared.

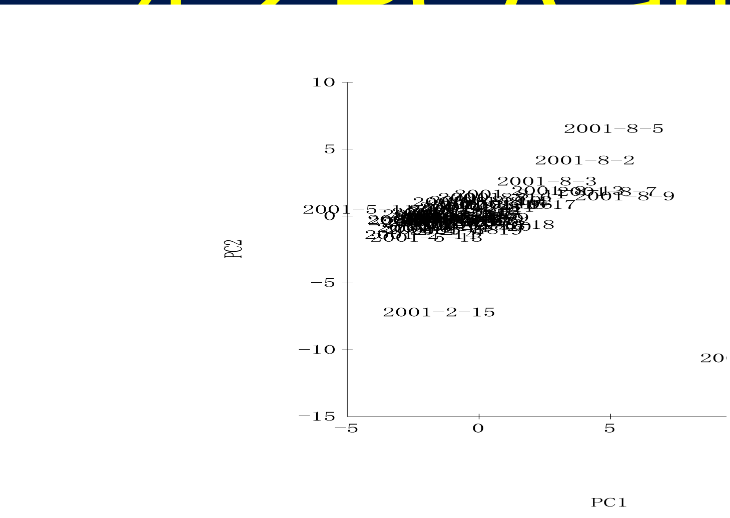
Dominance degree of dominant species of epifauna(($Y \geq 0.02$，2001,2003-2005)

dominant species	Dominance degree (*Y*)											
	2001			2003			2004			2005		
	Feb.	May	Aug.	Feb.	May	Aug.	Feb.	May	Aug.	Feb.	May	Aug.
Sternaspis scutata		0.03										
Solenocera crassicornis			0.07									0.09
Leptochela gracilis			0.03						0.06		0.04	0.07
Palaemon gravieri	0.22	0.11	0.31	0.28	0.13	0.26	0.52	0.11	0.13	0.35	0.26	0.20
Exopalaemon annandalei	0.04					0.06	0.08	0.07	0.03	0.12	0.11	0.10
Exopalaemon carinicauda	0.04		0.03	0.03		0.04	0.02		0.04			
Alpheus japonicus				0.03				0.02			0.06	
Charybdis japonica					0.03							
Squillidae oratoria			0.05									
Eriocheir leptognathus	0.04			0.08			0.02		0.08	0.09	0.09	0.04
Cynoglossus semilaevis	0.05	0.02	0.02									
Harpodon nehereus			0.04									
Collichthys lucidus			0.03									
Trypauchen vagina		0.02			0.09			0.02			0.03	

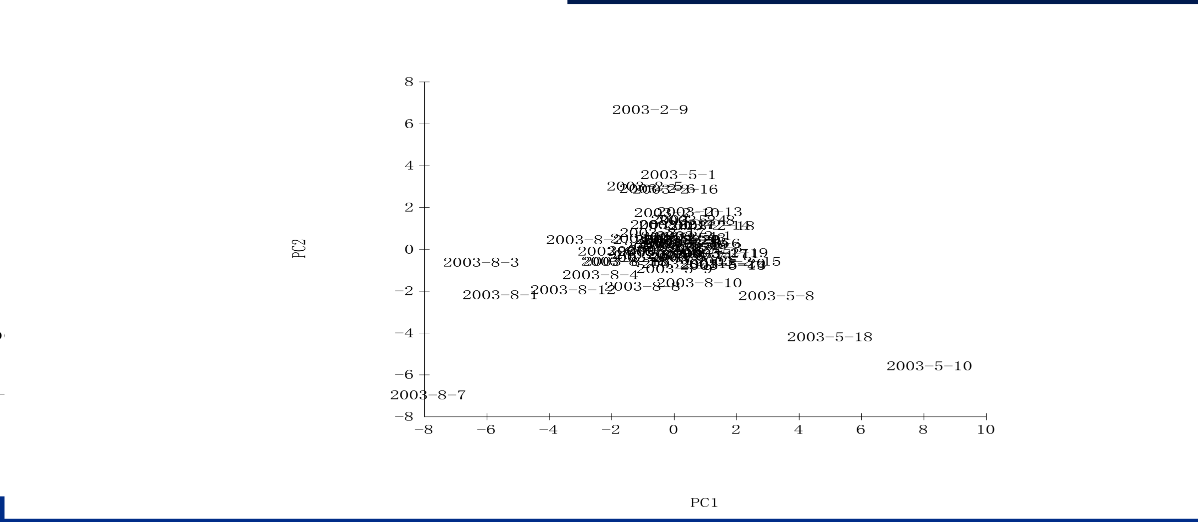
Diversity： species diversity(Shannon-Wiener diversity), evenness(Pielou'S evennes), abundance(d)(Margalef'S index)got downtrend and in the whole, the change is not significant.



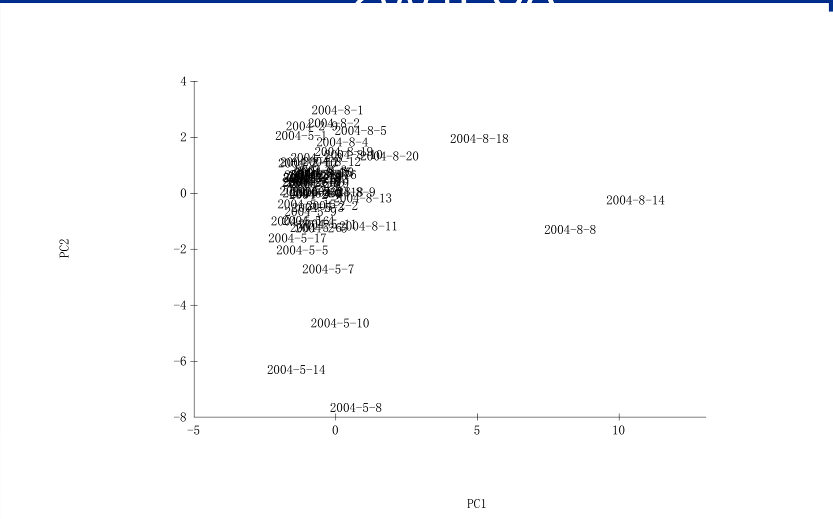
4.2 PCA analysis



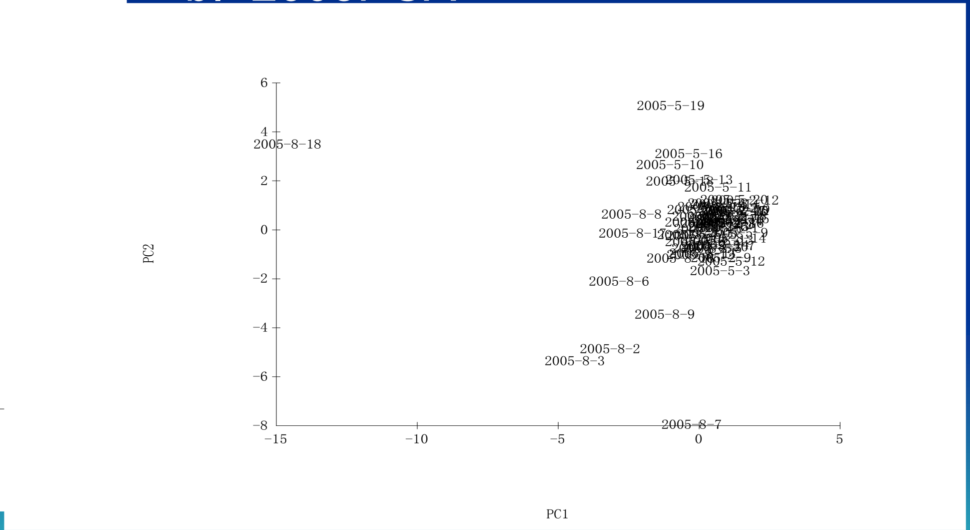
2001PCA



b. 2003PCA



2004PCA



b. 2005PCA

PCA analysis result

- In year 2001, PC1 value was -1 and this indicated that the epifauna community got no human being disturbance.
- In year 2003, PC1 value was zero and this indicated that the epifauna community got hard human being disturbance.
- In year 2003, PCA value was zero and this indicated that the epifauna community got hard human being disturbance.
- In year 2004, PC1 value dispersed a lot and this indicated that the epifauna community got even harder human being disturbance.
- In year 2005, PC1 value was more than 1 and this indicated that the epifauna community got heavily harder pollution or human being disturbance.(from （PILAR DRAKE, et al., 1999））

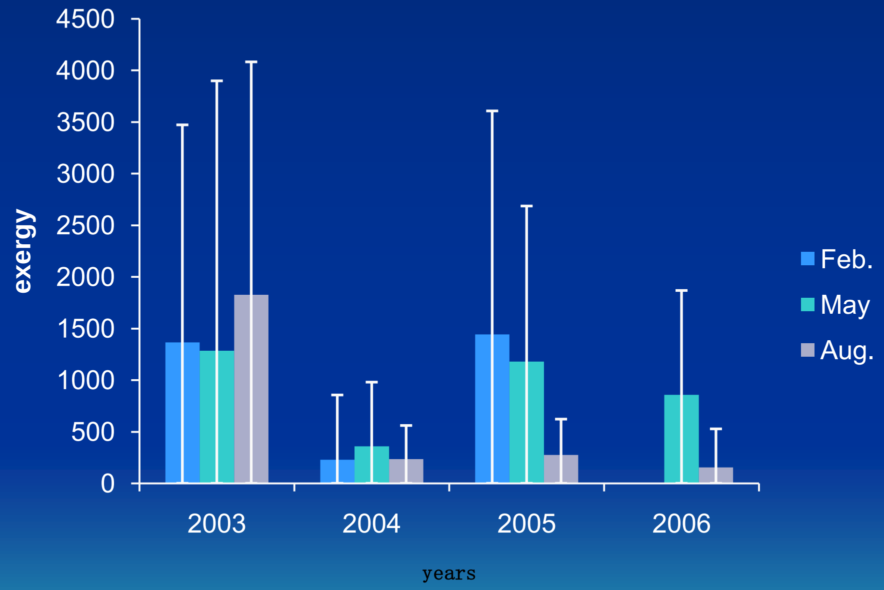
4.3 Exergy changing

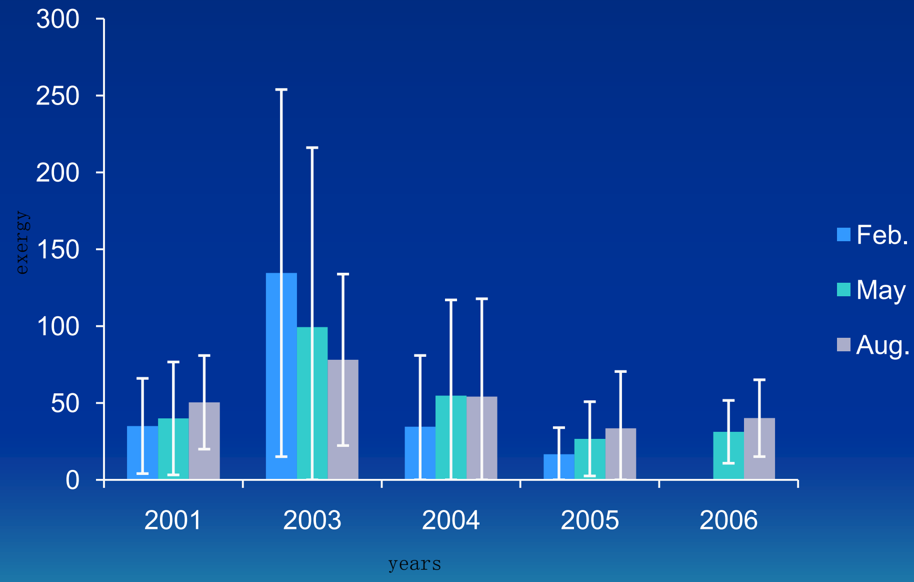
- Exergy is defined as the work capacity the system can perform when brought into
- thermodynamic equilibrium with the environment（Jørgensen，2009）。 Eco-exergy is defined as the work the ecosystem can perform relatively to the same ecosystem at the same
- temperature and pressure but at thermodynamic equilibrium, where there are no gradients and all components are inorganic at the highest possible oxidation state（Jørgensen，2009）.

- The more a ecosystem has the Eco-exergy, the more the ecosystem has the free energy. This indicates that the outer world will spend more energy to make the ecosystem recovery to the thermodynamic equilibrium. In this view, the more a ecosystem has the Eco-exergy,the higher that it has the ordering and the systematics. The stability of the ecosystem is higher.

Change of Exergy

From year 2003 to 2006, the Exergy of infauna declined(ANOVA, $P < 0.05$) and, from 2001 to 2006, the Exergy of epifauna got the tendency that went up in 2003 and then went down from year 2003 to 2006.





4.4 AMBI change of the macrobenthos community in Yangshan deep-water harbor

AMBI

- In Europe, the AZTI's Marine Biotic Index (AMBI) developed by Borja et al. (2000) is based upon the proportion of species assigned to one of five levels of sensitivity to increasing levels of disturbance, from very sensitive to opportunist species.
- This index has been tested under different stress sources (e.g.,Borja et al., 2003; Muxika et al., 2005) and has been applied not only in Europe, but also in Asia (Cai et al., 2003), northern Africa (Bazairi et al., 2005) and South America (Muniz et al.,2005).

- To apply AMBI, as most of the species in the current species-list
- (http://www.azti.es) are from the European biogeographical
- area (Borja et al., 2000) and some from South America (Muniz
- et al., 2005), it was necessary to assign the North American
- macrobenthic species to one of the five Ecological Groups (EG)
- defined by Borja et al. (2000) (i.e. EG I: species sensitive to
- disturbance; EG II: species indifferent to disturbance; EG III:
- species tolerant to disturbance; EG IV: second order opportunistic
- species; EG V: first order opportunistic species).

AMBI index value and the meaning（from Borja ,et al.,2000）

Biotic coefficient	Dominating ecological group	Benthic community health	Site disturbance classification	Ecological status
0.0< AMBI ≤0.2 0.2 < AMBI ≤1.2	I II	Normal Impoverished	Undisturbed	High status
1.2 < AMBI ≤3.3	III	Unbalanced	Slightly disturbed	Good status
3.3< AMBI ≤4.3 4.3 < AMBI ≤5.0	IV–V	Transitional to pollution Polluted	Moderately disturbed	Moderate status Poor status
5.0< AMBI ≤5.5 5.35< AMBI ≤6.0	V	Transitional to heavily pollution Heavily polluted	Heavily disturbed	Bad status
6.0 < AMBI ≤7.0	Azoic	Azoic	Extremely disturbed	

Tab. AMBI index of the benthos around Yangtze Estuary

Latin name	AMBI index group
Entoprocta	
Actiniidae	II
Nemertina	
Nemertini spp.	III
Polychaeta	
Acaudina molpadioides	II
Aglaophamus californiensis	II
Amphicteis gunneri (Sars)	III
Artacama occidentalis	I
Asychis gotoi (Izuka)	II
Capitella capitata (Fabicius)	V
Caprella scaura Templeton	II
Chaetopterus varieopedatus (Renier)	I
Chaetozone setosa Malmgren	IV
Cirriformia tentaculata (Montogu)	IV
Cossurella dimorpha Hartman	IV
Diopatra chiliensis Quatrefages	I
Euclymene lombricoides	I
Glycera chirori Izuka	II
Magelona cineta Ehlers	I
Neanthes japonica	III
Loimia medusa (Savigny)	III
Ophelia acuminata Oersted	III
Lumbrineris heteropoda (Marenzeller)	II
Mysta tchangsii	III
Pista cristata(Müller)	I
Pista pacifica Berkeley	I
Praxillella pacifica Berkeley	III
Pista sp.	I
Rhamphobrachium sp.	IV
Cirratulus filiformis Keferstein	IV
Sternaspis scutata (Renier)	III
Ceratonereis erythraeensis Fauvel	II
Mollusca	
Bullacta exarata ()	I
Cyclina sinensis(Gmelin)	I
Didontoglossa koyasensis(Yokoyama)	I
Littorinopsis intermedia()	II
Mactra venerformis Reeve	I
Nerita(Ritena) costata Gmelin	I

Neverita didyma(Röding)	I
Eocylichna cylindrella	II
Meretrix meretrix (Linnaeus)	I
Rapana bezoar	I
Nassarius succinctus	II
Nassarius(Varicinassa) variciferus(A.Adams)	II
Potamocorbucata ustulata	II
Scapharca subcrenata	I
Sinonovacula constricata	II
Crustacean	
Alpheus japonicus Miers	II
Charybdis japonica (A. Milne-Edwards)	II
Charybdis riversandersoni Alcock	II
Dorippe(Neodorippe) japonica von Siebold	II
Exopalaemon annandalei	I
Exopalaemon carinicauda Hotnuis	I
Geograpsus crinipes (Dana)	II
Helice sheni	II
Latreutes anoplonyx	I
Leptochela gracilis Stimpson	III
Ligia exotica	not list
Matuta lunaris (Forskal)	II
Matuta planipes Fabricius	II
Metapenaeus joyneri	I
Metopograpsus quadridentatus Stimpson	II
Ocypode stimpsoni	II
Oratosquilla oratoria (de Haan)	I
Palaemon gravieri (Yu)	I
Paphidopus ciliatus Stimpson	I
Parapenaeopsis cultrirostris (Alcock)	I
Parapenaeopsis hardwickii (Miers)	I
Philyra pisum	II
Portunus trituberculatus	I
Pseudograpsus albus Stimpson	II
Sesarma haematocheir (de Haan)	II
Solenocera crassicornis (H. Milne-Edwards)	I
Solenoceridae sp.	I
Squillidae oratoria	I
Squillidae sp.	I
Synidotea laevidorsalis Miers	II
Tullbergella cuspidate	I

	II
Macrobrachium nipponense(de Haan)	
	II
Macrobrachium nipponense(de Haan)	
	II
Parapenaeopsis tenella(Bate)	
	I
Parapenaeopsis hardwickii (Miers)	
	I
Acetes chinensis Hansen	
Echinodermata	
	II
Amphiura vadicola Matsumoto	
	I
Glossodorididae sp.	
	II
Protankyra bidentata	
Ophiophragmug japonicus	
	II
Ophiura kinhergi	
	II

Calculation of AMBI index value (Muxika, I., Borja, A., Bonne, W., 2005**)**

- AMBI=[(0 ×%EG I) + (1.5×%EG II) + (3×%EG III) + (4.5×%EG IV) + (6×%EG V)]/100。
- EG is ecological group.

Calculation interface of AMBI index

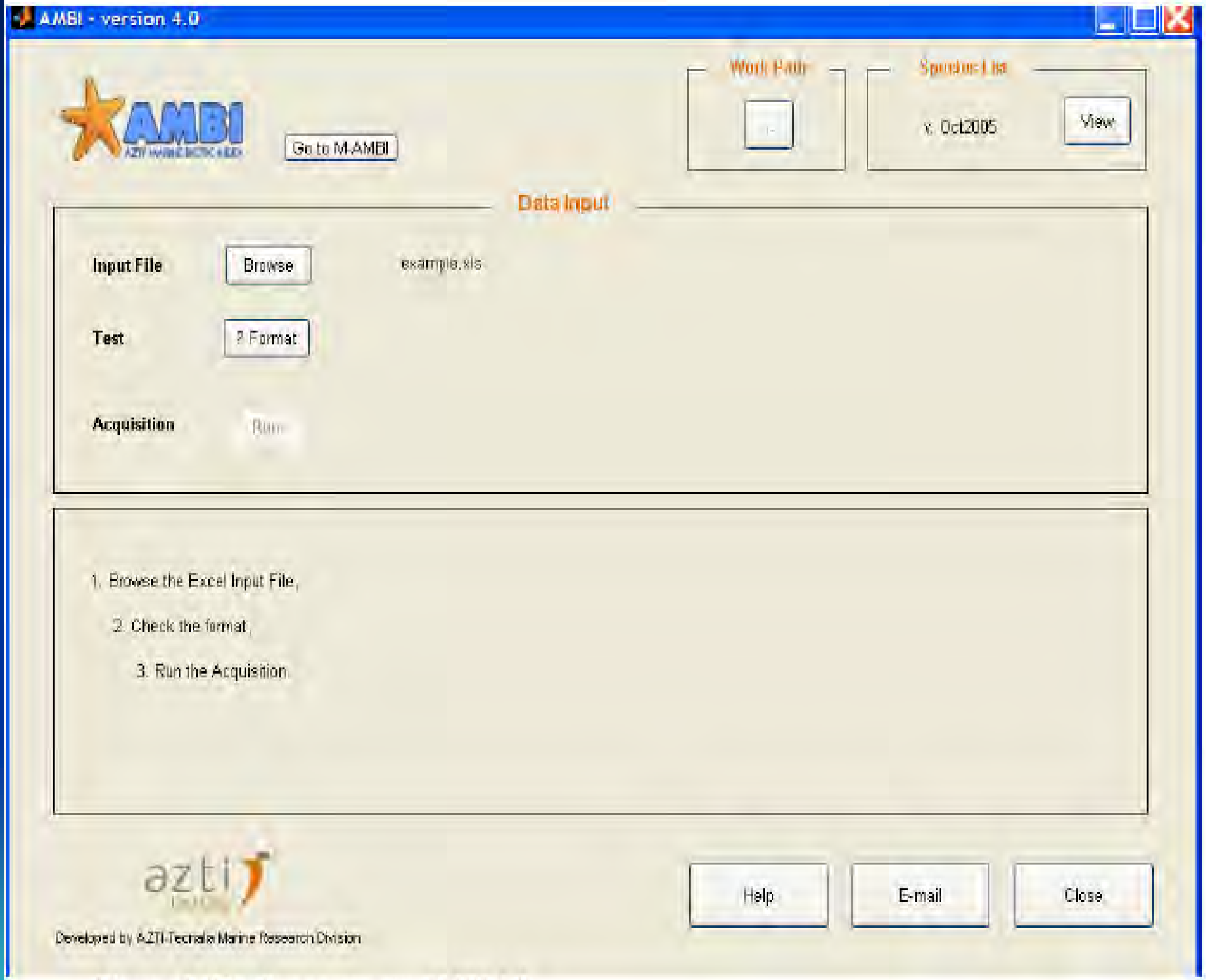


Figure 1. The first screen in *AMBI 4.0*.

AMBI index change

Infauna: In February and August from 2003 to2005, the AMBI index became uptrend(ANOVA, $P < 0.05$) ， and this indicated that ,in the condition of the engineering , the succession of the ecological groups has arisen.

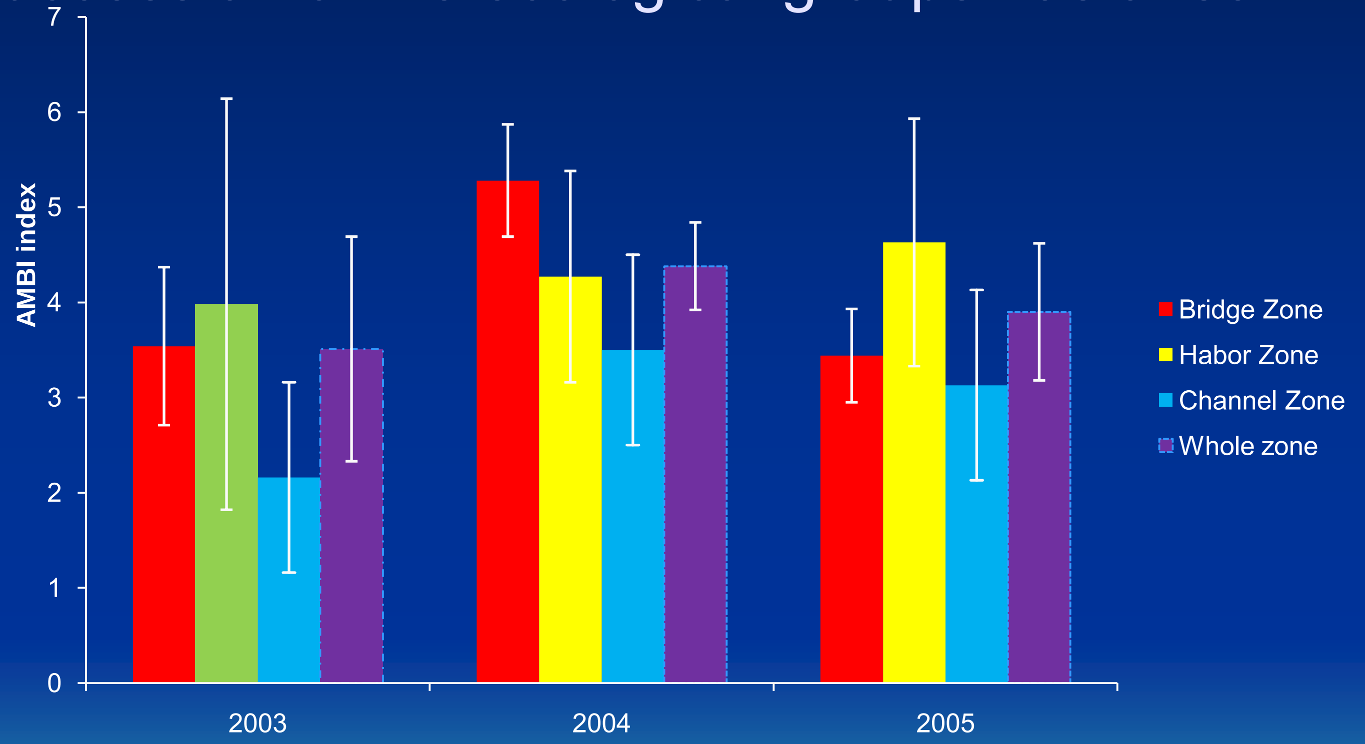
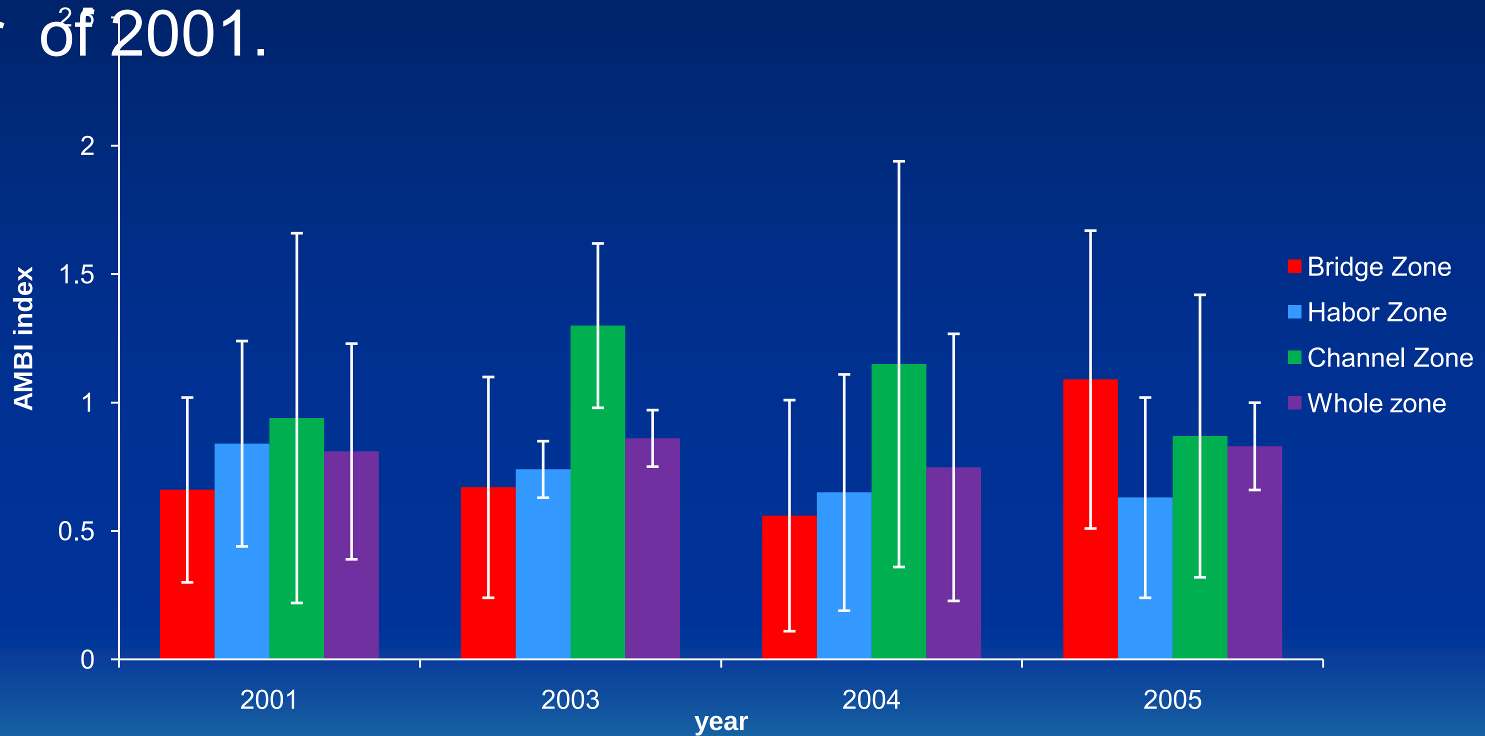


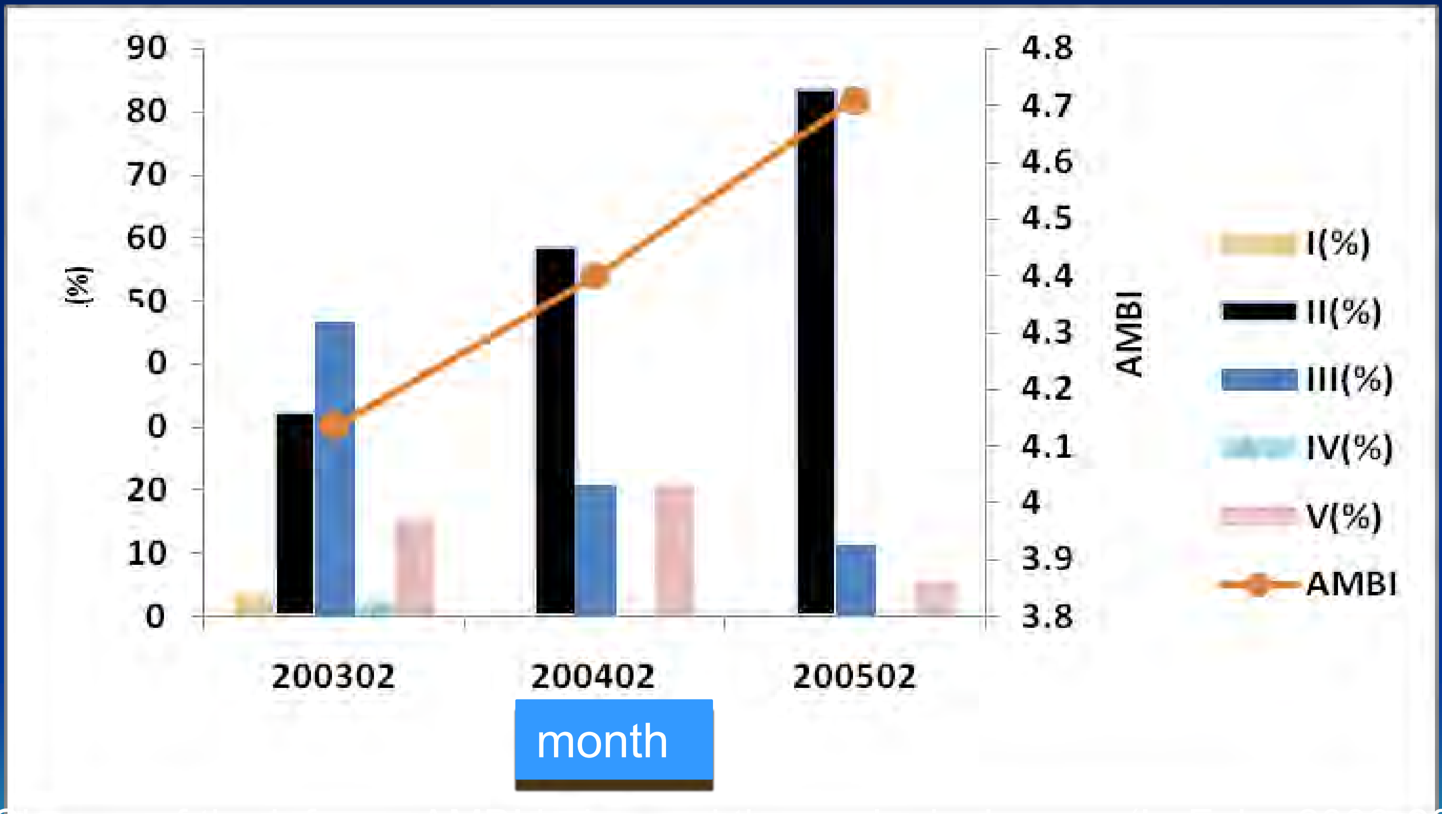
Fig.4-1 Change of infauna AMBI index

Epifauna：From the contrast year of 2001 to the construction year of 2005, average of the AMBI index was less than 1 and the change was innobable (ANOVA,P＞0.05). While in the Channel Zone, the AMBI index rose a lot and recovered to the contrast year of 2001.



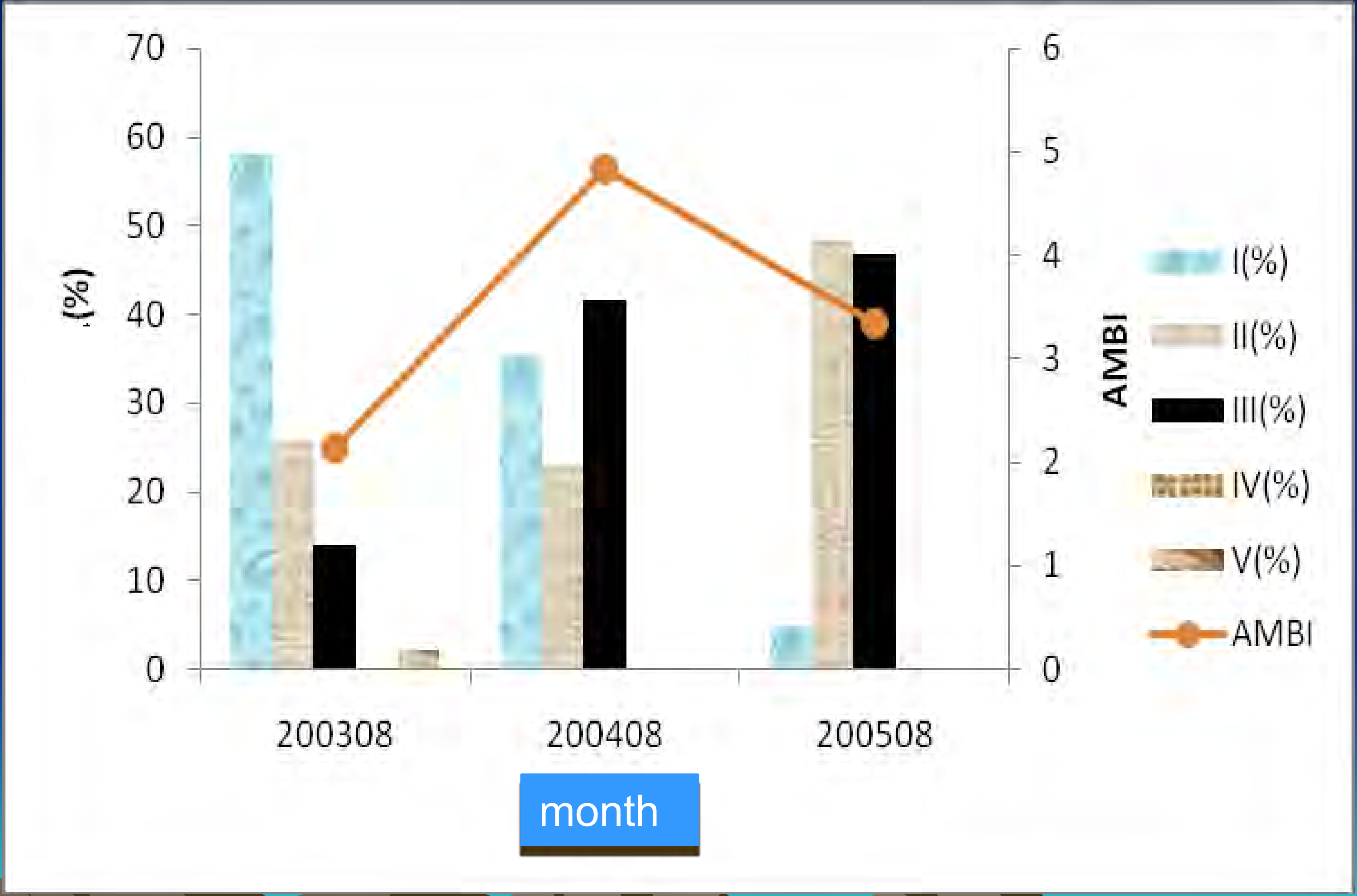
Change of epifauna AMBI index

In February from 2003 to 2005， the AMBI index got uptrend. The Eg Ⅰ disappeared and EGⅢ got downtrend.The Eg Ⅱ and EGⅤ got uptrend .



Change of the infauna AMBI index and the ecological group (in Feb., 2003-2005)

In August from 2003 to 2005, the AMBI index got uptrend. The Eg I got downtrend and Eg II and EGIII got uptrend.



- Change of the infauna AMBI index and the ecological group (In Aug., 2003-2005)

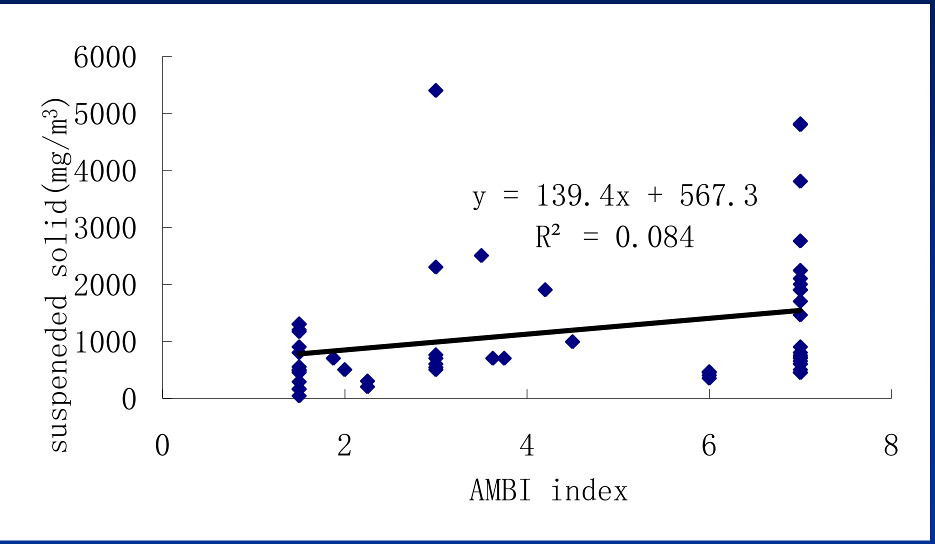
Correlation between AMBI and the environment factors(Feb.from 2003 to 2005)

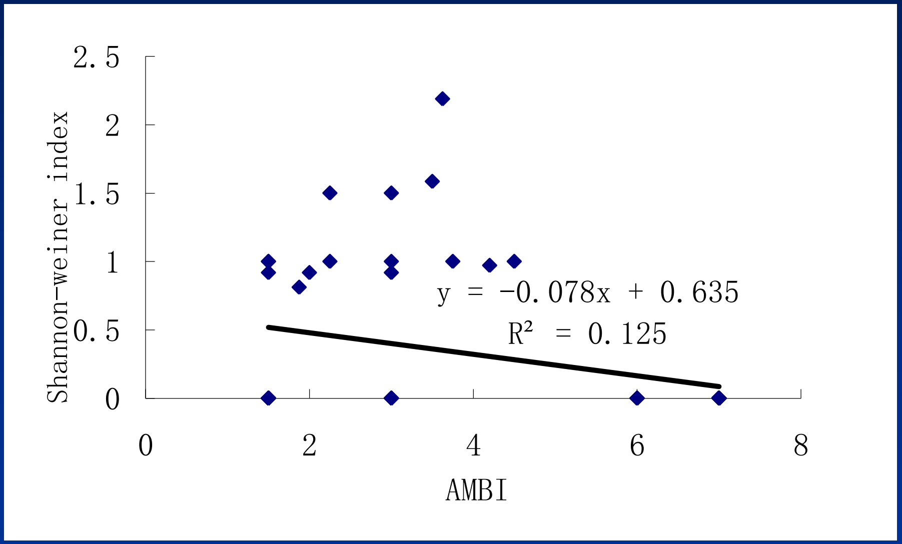
Content	Environment factors		
	SS	abundance	Shannon-weiner diversity
AMBI index	0.291**	-0.637**	-0.354**

Correlation between AMBI and the environment factors(Aug.from 2003 to 2005)

Content	Environment factors			
	biomass	density	Shannon-weiner diversity	abundance
AMBI index	-0.336**	-0.579**	-0.370**	-0.748**

AMBI index had high minus correlation between the biomass, density, Shannon-weiner diversity and the abundance.





Correlation between AMBI and the bottom SS

Correlation between AMBI and Shannon-weiner index

5、Conclusion

- Infauna： From 2003 to 2005 ,As the Yangshan Deep-water Habor engineering going, the biomass presented the downtrend(anova, $p < 0.05$).
- Dominant species： Mollusk *Sinonovacula constricata* got disappearance. Inter-annual variation of dominant species is very high.
- From 2003 to 2005, species diversity(Shannon-Wiener diversity), evenness(Pielou’S evennes), abundance(d)(Margalef’S index)got downtrend and the Simplicity got uptrend.

- Epifauna: In 2003, which was the beginning period of this engineering, the biomass distinctly increased. As the going of the engineering, the biomass got downtrend.and the biomass was lower than that in 2001.
- The dominant species of fish *Cynoglossus semilaevis* disappeared. Inter-annual variation of dominant species is very high.
- species diversity(Shannon-Wiener diversity), evenness(Pielou'S evennes), abundance(d)(Margalef'S index)got downtrend and in the whole, the change is not significant.

- PCA analysis: In year 2001, PC1 value was -1 and this indicated that the epifauna community got no human being disturbance.

- From 2003 to 2005, PC1 value was higher and highet and this indicated that the epifauna community got more and more harder pollution or human being disturbance.

- Exerg: From year 2003 to 2006, the Exergy of infauna declined(ANOVA, $P < 0.05$) and, from 2001 to 2006, the Exergy of epifauna got the tendency that went up in 2003 and then went down from year 2003 to 2006.

- AMBI index of infauna: In February and August from 2003 to2005, the AMBI index became uptrend(ANOVA, P＜0.05)， and this indicated that ,in the condition of the engineering , the succession of the ecological groups has arisen.
- In February from 2003 to 2005，the AMBI index got uptrend. The Eg Ⅰ disappeared and EGⅢ got downtrend.The Eg Ⅱ and EG Ⅴ got uptrend.
- In August from 2003 to 2005，the AMBI index got uptrend. The Eg Ⅰ got downtrend and Eg Ⅱ and EGⅢ got uptrend.

- AMBI index of epifauna: From the contrast year of 2001 to the construction year of 2005, average of the AMBI index was less than 1 and the change was innobable (ANOVA,$P > 0.05$). While in the Channel Zone, the AMBI index rose a lot and recovered to the contrast year of 2001.

- AMBI index would get higher and higher as the concentration of suspeneded solid got higher than 800 mg/m^3, and would reach the maxium when the concentration of suspeneded solid was 1460 mg/m^3.

- Biomass, density, PCA anslysis, Eco-exergy and AMBI index have different characteristics on explaining the benthos community response to the huge ocean engineering. Exergy and AMBI index could deeply explain the community state and species succession under outer disturbance.

THANK YOU FOR YOUR ATTENTION !