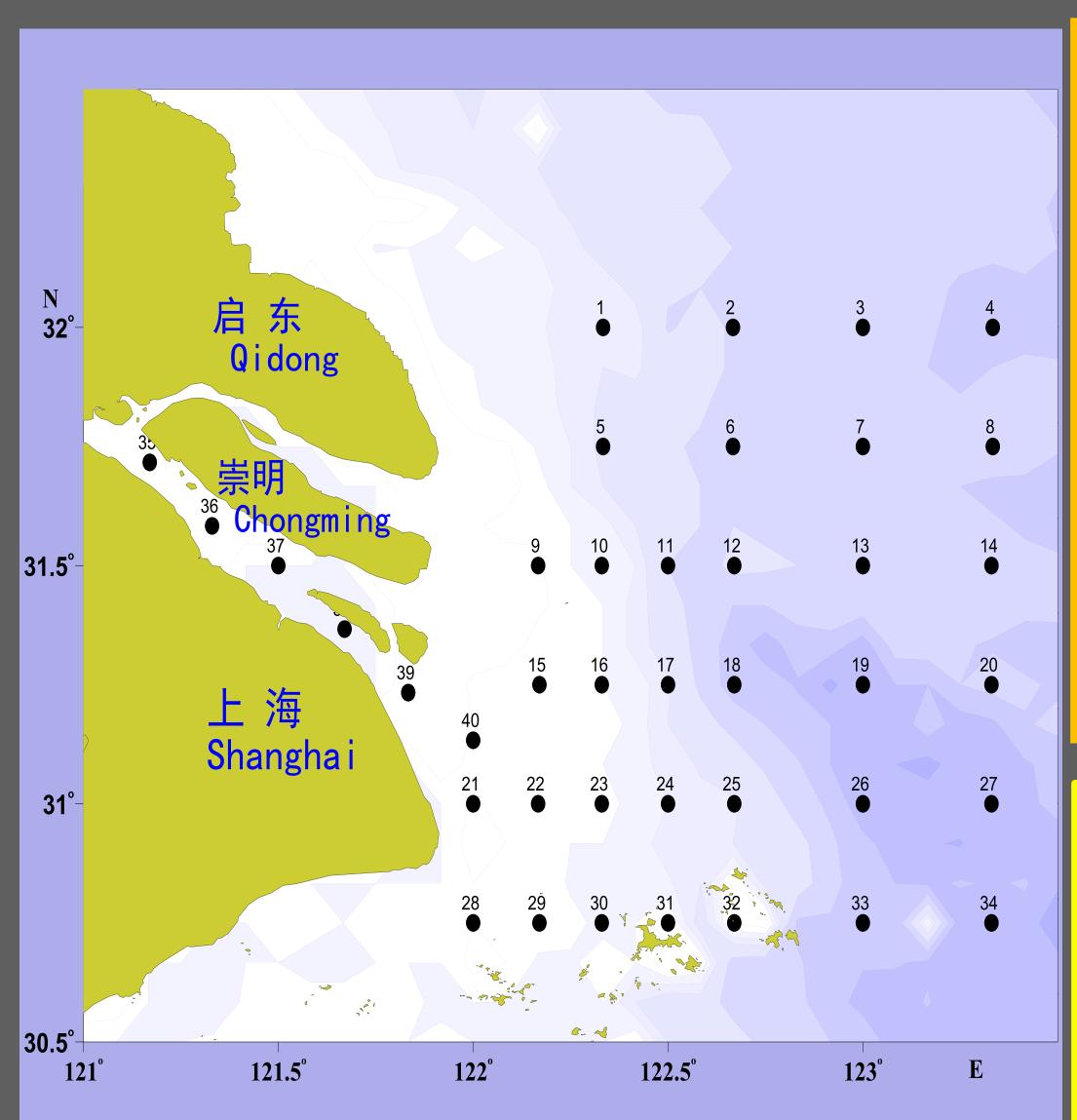
Ichthyoplankton assemblage structure of springs in the Yangtze Estuary revealed by biological and environmental visions

Hui Zhang*, Weiwei Xian* and Shude Liu Institute of Oceanology, Chinese Academy of Sciences, Qingdao, PR China. *E-mail: zhanghui@qdio.ac.cn; wwxian@qdio.ac.cn





Study area and sampling stations











Data analysis

Introduction

The Yangtze Estuary has been extensively modified and threatened during the last decades. The projects have considerably reduced rivers flowing to the Estuary, brought heavy contamination to estuarine aquaculture and habitation, and deteriorated water quality. This degradation has in turn led to a need for multi-year comprehensive surveys. The present study was based on surveys at four springs in 1999, 2001, 2004 and 2007. Our aims are to provide detailed characterizations of the ichthyoplankton assemblage in springs, examine the long-term dynamics of spring ichthyoplankton assemblages, and evaluate the influence of environmental factors on the spatial distribution and inter-annual variations of ichthyoplankton assemblages associated with the Yangtze Estuary.

Materials and Methods

Biological and oceanographic data were collected during four fishery evaluation cruises in four springs (05/1999, 05/2001, 05/2004, 05/2007) at 40 stations. This study encompasses 160 ichthyoplankton collections from four springs. Ichthyoplankton samples were collected by surface tows of a larva net (0.8m mouth diameter, 2.8 m long, 0.505mm mesh at the body, and 0.505mm mesh at the cod end) equipped with a flow meter. At each station, the net was towed at a depth of about 0.5m from the surface for 10 min against tidal flow. Towing speed was 2-3 knots. The samples were preserved in 5% buffered formaldehyde—seawater solution.

A conductivity, temperature, and depth device was used to measure environmental variables including depth (D), salinity (S), temperature (T), transparency (Trans), dissolved oxygen (DO), pH, total phosphorus (TP), total nitrogen (TN), suspended particulate matter (SPM), chemical oxygen demand (COD), chlorophyll a (Chla) and primary productivity (PP).

able 1 Johthers	nlankton enocies inf	ormation											
Table 1 Ichthyoplankton species Family Species			EG	Darcantaga	1	1999		2001	2004		2:	2007	
ашпу	Species	Б	EG	Percentage	F%	A%	- <u> </u>	A%	- 	A%	- 	A%	
ngraulidae	Engraulis japonicus	N	MED	20.15	34.38	51.10	32.35	10.60	16.67	11.66	26.32	6.70	
	Coilia mystus		AN	46.30	31.25	21.02	23.53	58.47	19.44	30.06	21.05	32.46	
	Thrissa kammalensis		MED MED	1.06 0.01			2.94 2.94	1.63 0.02			2.63	0.15	
	Setipinna taty Anchoviella commer		VIED ER	0.01			8.82	0.02	13.89	3.07	5.26	0.58	
	Anchoviella zollinger		ER	0.07			2.94	0.11	10.00	2.07	0.20	0.00	
Gobiidae	Chaeturichthys hexa	nema E	ER	2.86	12.50	10.98	5.88	0.28			2.63	0.15	
	Chaeturichthys stign		ER	2.88			14.71	4.48					
	Synechogobius hasta		ER ED	0.67			11.76	1.05			2.62	0.15	
ciaenidae	Gobiidae sp. Pseudosciaena polya		ER MED	0.28 0.18	6.25	0.28	5.88 20.59	0.43 0.12			2.63 5.26	0.15	
ciacinaac	Larimichthys crocea		MED	0.01	0.23	0.20	20.37	0.12	2.78	0.31	3.20	0.11	
	Collichthys lucidus	N	MED	0.28			2.94	0.43	2.78	0.31			
	Johnius belengeri	N	MED	0.02			0.00	0.04					
	Sciaenidae sp.		MED	0.01			2.94	0.02					
Cynoglossidae	Cynoglossus abbrevi		ER ED	0.05			2.94	0.07					
	Cynoglossus joyneri Cynoglossus spp.		ER ER	0.14 0.02			2.94 5.88	0.21 0.04					
Cyprinidae	Cynogiossus spp. Pseudolaubuca engra		EK ES	0.02			5.00	0.04	2.78	0.31			
/1	Pseudolaubuca sinen		FS	0.03			2.94	0.04	2.78	0.31			
alangidae	Hemisalanx prognat	hus A	AN	0.47	3.13	1.83			5.56	0.61			
	Salanx ariskensis		AN	0.02							5.26	0.29	
Atherinidae	Allanetta bleekeri		MED	8.61	40.63	7.93	41.18	3.92	25.00	30.37	26.32	39.01	
Cottidae	Trachidermis fasciat		CA	13.64	12.50	2.77	20.59	16.69	11.11	22.39	13.16	18.20	
tromateidae Ayctophidae	Pampus argenteus Benthosema pterotus		MED MS	0.13 0.85	3.13 15.63	0.23 3.24	2.94 2.94	0.07 0.09			5.26 2.63	0.29 0.15	
Apogonidae	Apogonichthys linear		MS	0.85	15.05	J.44	2.74	0.03			2.63	0.15	
Mugilidae	Liza carinatus		ER	0.06							2.63	0.73	
combridae	Pneumatophorus jaț	oonicus N	MS	0.08	6.25	0.09	14.71	0.09					
Carangidae	Trachurus japonicus		MS	0.01							2.63	0.15	
Platycephalidae	Platycepalus indicus		MS	0.19	3.13	0.05	8.82	0.28					
corpaenidae	Sebastiscus marmora		MS MS	0.20 0.01			8.82	0.32			2.63	0.15	
Hemiramphidae Zoarcidae	Hemirhamphus sajo Enedrias nebulosus		MS	0.01					2.78	0.31	2.03	0.15	
Taeniodididae	Odontamblyopus rui		ER	0.01			2.94	0.02	2.70	0.51			
istulariidae	Fistularia petimba		MS	0.01			2.94	0.02					
paridae	Sparidae sp.		MED	0.09	6.25	0.38							
etraodontidae	Taki fugu sp.	A	λN	0.00	3.13	0.09	2.94	0.05			5.26	0.29	
				0.08	3.13	0.02							
	Anguillidae sp.		CA	0.03	5.15		0.00	0.05	2.79	0.21			
i.id.1	Anguillidae sp.	(/			3.13				2.78	0.31			
a.id.1 a.id.2 a.id.3 otes. EG, Ecological g	uilds; F%, Frequency	/ / / / / / percentage; A	CA %, Abı	0.03 0.08 0.01 0.01	tage; MS,		0.00 2.94 2.94	0.05 0.11 0.02			lents; ER,	Estuarin	
n.id.1 n.id.2 n.id.3 otes. EG, Ecological g residents; FS, Fre	guilds; F%, Frequency eshwater species; CA, (ominant specie	/ / / percentage; A ^o Catadromous fis	%, Abushes; Al	0.03 0.08 0.01 0.01 undance percently, Anadromous	tage; MS,	Marine s	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02		ne-depend		Estuarin	
a.id.1 a.id.2 a.id.3 btes. EG, Ecological gresidents; FS, Fre	guilds; F%, Frequency eshwater species; CA, o ominant species	percentage; A ^o Catadromous fis	CA %, Abu shes; Al	0.03 0.08 0.01 0.01 undance percen N, Anadromous by the IRI.	tage; MS,	Marine s	0.00 2.94 2.94	0.05 0.11 0.02	ne-estuari	ne-depend	lents; ER,		
a.id.1 a.id.2 a.id.3 btes. EG, Ecological gresidents; FS, Fre	guilds; F%, Frequency eshwater species; CA, (ominant specie	/ / / percentage; A ^o Catadromous fis	%, Abushes; Al	0.03 0.08 0.01 0.01 undance percently, Anadromous	tage; MS,	Marine s	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02	ne-estuari	ne-depend		Estuarin	
a.id.1 a.id.2 a.id.3 btes. EG, Ecological g residents; FS, Fre	guilds; F%, Frequency eshwater species; CA, o ominant species 999	percentage; A ^o Catadromous fis	%, Abushes; Al	0.03 0.08 0.01 0.01 undance percen N, Anadromous by the IRI.	tage; MS, s fishes.	Marine s	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02	ne-estuari	ne-depend	2007		
n.id.1 n.id.2 n.id.3 otes. EG, Ecological g residents; FS, Fre	guilds; F%, Frequency eshwater species; CA, o ominant species 999	percentage; At Catadromous fise es determination Species	%, Abushes; Al	0.03 0.08 0.01 0.01 andance percen N, Anadromous by the IRI. I	tage; MS, s fishes. Spe	Marine s	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin	ne-estuari Spe	ne-depend	2 007	IRI	
n.id.1 n.id.2 n.id.3 otes. EG, Ecological gresidents; FS, Fre Table 2 Do 1 Species E. japonicus C. mystus	guilds; F%, Frequency shwater species; CA, of shwater species; CA, of species;	es determite Species C. mystus E. japonia	%, Abushes; Almed I 200	0.03 0.08 0.01 0.01 0.01 Indance percent N, Anadromous State IRI. I IRI 5,624 1,783	tage; MS, s fishes. Spe	Marine s bleekeri mystus	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 MED, Marin IRI 4,131 3,180	Spo A.	ne-depend 2 ecies bleekern mystus	2007 i	IRI 4,800 3,200	
a.id.1 a.id.2 a.id.3 btes. EG, Ecological gresidents; FS, Fre Table 2 Do 1 Species E. japonicus C. mystus A. bleekeri	guilds; F%, Frequency shwater species; CA, cominant species ominant species ominant species ominant species ominant species of the species of	es determination Species C. mystus E. japonic T. fasciati	%, Abushes; Almed I 200 Scus	0.03 0.08 0.01 0.01 0.01 ondance percent N, Anadromous State IRI. IRI 5,624 1,783 1,405	stage; MS, s fishes. Special A. l. C. 1. T. f.	Marine s Dleekeri Mystus Tasciatus	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 MED, Marin IRI 4,131 3,180 1,354	Spo A. C. T. f	ne-depend ecies bleekern mystus fasciatu	2007 i	IRI 4,800 3,200 1,100	
n.id.1 n.id.2 n.id.3 otes. EG, Ecological gresidents; FS, Fre Table 2 Do 1 Species E. japonicus C. mystus	guilds; F%, Frequency shwater species; CA, cominant species ominant species ominant species ominant species ominant species of the species of	es determite Species C. mystus E. japonia	%, Abushes; Almed I 200 Scus	0.03 0.08 0.01 0.01 0.01 Indance percent N, Anadromous State IRI. I IRI 5,624 1,783	stage; MS, s fishes. Special A. l. C. 1. T. f.	Marine s bleekeri mystus	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 MED, Marin IRI 4,131 3,180	Spo A. C. T. f	ne-depend 2 ecies bleekern mystus	2007 i	IRI 4,800 3,200	
Table 2 Do Table 2 Do Species E. japonicus C. mystus A. bleekeri C. hexanem Table 3 In	guilds; F%, Frequency shwater species; CA, cominant species ominant species ominant species ominant species ominant species of the species of	es determination Species C. mystus E. japonic T. fasciati A. bleeker	%, Abushes; Almed I 200 Scus	0.03 0.08 0.01 0.01 Indance percent N, Anadromous State IRI. I IRI 5,624 1,783 1,405 753 assemblage	stage; MS, s fishes. Special A. l. C. 1 T. f. E. j	Marine s deekeri mystus asciatus aponici	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin IRI 4,131 3,180 1,354 1,057	Spe A. C. T. J E. J	ne-depend ecies bleekern mystus fasciatu japonic	2007 i us us	IRI 4,800 3,200 1,100 800	
Table 2 Description of the control o	cuilds; F%, Frequency shwater species; CA, cominant species ominant species ominant species ominant species ominant species of the species of	es determination Species C. mystus E. japonic T. fasciati A. bleeker	%, Abushes; Almed I 200 Scus	0.03 0.08 0.01 0.01 Indance percent N, Anadromous State IRI. I IRI 5,624 1,783 1,405 753 assemblage	stage; MS, s fishes. Specific A. l. C. 1 T. f E. j	Marine s pleekeri mystus asciatus aponici	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin IRI 4,131 3,180 1,354 1,057	Spe A. C. T. J E. J	ecies bleekern mystus fasciatu japonic	2007 i us us	IRI 4,800 3,200 1,100 800 value	
i.id.1 i.id.2 i.id.3 ites. EG, Ecological gresidents; FS, Free Table 2 De 1 Species E. japonicus C. mystus A. bleekeri C. hexanem Table 3 In and signification.	cuilds; F%, Frequency shwater species; CA, cominant species ominant species ominant species ominant species ominant species of the species of	percentage; A ^o Catadromous fise es determinate Species C. mystus E. japonio T. fasciata A. bleeker nparison o	%, Abushes; All	0.03 0.08 0.01 0.01 Indance percent N, Anadromous Street IRI. I IRI 5,624 1,783 1,405 753 assemblage	stage; MS, s fishes. Special A. l. C. n. T. f. E. j. ge structure. ANOSI P	Marine s pleekeri mystus asciatus aponici	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin IRI 4,131 3,180 1,354 1,057	Spe A. C. T. J E. J	ecies bleekern mystus fasciatu japonic	2007 i us us	IRI 4,800 3,200 1,100 800 value	
i.id.1 i.id.2 i.id.3 ites. EG, Ecological gresidents; FS, Free Table 2 Do 1 Species E. japonicus C. mystus A. bleekeri C. hexanem Table 3 In and signification and signification and signification.	guilds; F%, Frequency shwater species; CA, of shwater species; CA, of species;	es determination of the control of t	%, Abushes; Almed I 200 Scus us ri	0.03 0.08 0.01 0.01 Indance percent N, Anadromous Street IRI. I IRI 5,624 1,783 1,405 753 assemblage	stage; MS, sishes. Special A. l. C. 1 T. f E. j Second ANOSI P 0.	Marine soleekeri mystus asciatus aponici cture ac	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin IRI 4,131 3,180 1,354 1,057	Spo A. C. T. J E. J	ecies bleekern mystus fasciatu japonic	2007 i us us	IRI 4,800 3,200 1,100 800 value	
i.id.1 i.id.2 i.id.3 ites. EG, Ecological gresidents; FS, Free Table 2 Do 1 Species E. japonicus C. mystus A. bleekeri C. hexanem Table 3 In and signification and signific	guilds; F%, Frequency shwater species; CA, one ominant species of the species of	es determination of the control of t	%, Abushes; All	0.03 0.08 0.01 0.01 Indance percent N, Anadromous Street IRI. I IRI 5,624 1,783 1,405 753 assemblage	stage; MS, s fishes. Special A. l. C. 1 T. f E. j Second A. NOSI P 0. 0. 0.	Marine s cies cleekeri nystus asciatus aponici ature ac M 443 235	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin IRI 4,131 3,180 1,354 1,057	Spene-way SIM Average 78.1	ecies bleekers mystus fasciatu japonic	2007 i us us	IRI 4,800 3,200 1,100 800 value	
i.id.1 i.id.2 i.id.3 ites. EG, Ecological gresidents; FS, Free Table 2 Do 1 Species E. japonicus C. mystus A. bleekeri C. hexanem Table 3 In and signification and signific	guilds; F%, Frequency shwater species; CA, one ominant species of the species of	es determination of the control of t	%, Abushes; Almed I 200 Scus us ri 24 4	0.03 0.08 0.01 0.01 Indance percent N, Anadromous Street IRI. I IRI 5,624 1,783 1,405 753 assemblage	stage; MS, s fishes. Special A. l. C. 1 T. f. E. j Se structure ANOSI P 0. 0. 0. 0.	Marine s cies cleekeri nystus asciatus aponici ture ac 443 235 325	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin IRI 4,131 3,180 1,354 1,057	Spo A. C. T. f E. f Ne-way 1 SIM Ave: 78.1 75.0	ecies bleekern mystus fasciatu japonic	2007 i us us	IRI 4,800 3,200 1,100 800 value	
i.id.1 i.id.2 i.id.3 ites. EG, Ecological gresidents; FS, Free Table 2 Do 1 Species E. japonicus C. mystus A. bleekeri C. hexanem Table 3 In and signification Years Global 1999 vs. 200 1999 vs. 200 1999 vs. 200 1999 vs. 200	guilds; F%, Frequency shwater species; CA, of cominant species of the species of	species C. mystus E. japonic T. fasciata A. bleeker mparison o R 0.002 0.014 0.007 0.023	%, Abushes; All	0.03 0.08 0.01 0.01 Indance percent N, Anadromous Street IRI. I IRI 5,624 1,783 1,405 753 assemblage	stage; MS, s fishes. Special A. l. C. n. T. f. E. j. T. f. E. j. T. f. C. n. O.	Marine s cies cleekeri mystus asciatus aponicu ture ac M 443 235 325 868	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin IRI 4,131 3,180 1,354 1,057	Spo A. C. T. J E. J Ne-way 18.1 75.0 75.1	ecies bleekern mystus fasciatu japonica ANOS	2007 i us us	IRI 4,800 3,200 1,100 800 value	
Table 3 In and signification of the series o	guilds; F%, Frequency shwater species; CA, of cominant species of the species of	es determination of the control of t	%, Abushes; All	0.03 0.08 0.01 0.01 Indance percent N, Anadromous Street IRI. I IRI 5,624 1,783 1,405 753 assemblage	stage; MS, s fishes. Special A. l. C. n. T. f. E. j. T. f. E. j. T. f. C. n. O.	Marine s cies cleekeri nystus asciatus aponici ture ac 443 235 325	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin IRI 4,131 3,180 1,354 1,057	Spo A. C. T. f E. f Ne-way 1 SIM Ave: 78.1 75.0	ecies bleekern mystus fasciatu japonica ANOS	2007 i us us	IRI 4,800 3,200 1,100 800 value	
n.id.1 n.id.2 n.id.3 otes. EG, Ecological gresidents; FS, Free Table 2 Do 1 Species E. japonicus C. mystus A. bleekeri C. hexanem Table 3 In and signification Years Global 1999 vs. 200 1999 vs. 200 1999 vs. 200 1999 vs. 200	guilds; F%, Frequency shwater species; CA, one ominant species of the species of	species C. mystus E. japonic T. fasciata A. bleeker mparison o R 0.002 0.014 0.007 0.023	%, Abushes; Almed I 200 Scus us ri 2 4 7 3 4	0.03 0.08 0.01 0.01 Indance percent N, Anadromous Street IRI. I IRI 5,624 1,783 1,405 753 assemblage	stage; MS, sishes. Special A. l. C. 1 T. f E. j Secure Structure ANOSI P 0. 0. 0. 0. 0. 0. 0.	Marine s cies cleekeri mystus asciatus aponicu ture ac M 443 235 325 868	0.00 2.94 2.94 pecies; M	0.05 0.11 0.02 IED, Marin IRI 4,131 3,180 1,354 1,057	Spo A. C. T. J E. J Ne-way 18.1 75.0 75.1	ecies bleekern mystus fasciatu japonic	2007 i us us	IRI 4,800 3,200 1,100 800 value	

able 4 Environmen	tal factors (means an	d range) in the	Yangtze Estuary.				
/ariables	1999	2	001		2004		2007
O (m)	19.52 (5.00–48.00)		0.48 (5.00–50.00)		19.57 (6.00–60.00)		21.45 (5.00–52.00)
(‰)	15.79 (2.86–27.56) ^A		7.93 (3.00–31.58) ^{A, J}		20.97 (3.00–30.19) ^F		21.46 (3.00–31.25) ^B
C (°C)	19.19 (14.98–20.86)		8.14 (16.37–21.17) ^B		20.79 (19.15–22.22)		18.77 (17.65–20.53) ^D
OO (mg/L)	9.11 (7.34–13.95) ^A		.99 (5.14–8.73) ^B ,C		6.27 (4.01–12.03) ^C		8.10 (3.90–10.20) ^D
oH	8.29 (7.82–8.85) ^A		$.17 (7.95 - 8.36)^{B}$		8.13 (7.94–8.47) ^C		8.39 (7.95–8.71) ^{C,D}
COD (mg/L) ΓΝ (μmol/L)	2.19 (0.77–3.47) 79.37 (35.80–151.30		.06 (0.64–4.32) 0.89 (13.70–77.70) ^B		1.92 (0.46–4.22) 62.90 (26.30–112.10		1.72 (0.73–4.24) 90.65 (35.71–176.18) ^C
ΓΡ (μmol/L)	1.64 (0.52–6.50)		.89 (0.30–7.00)		1.47 (0.61–3.50)	•	1.29 (0.17–4.28)
SPM (mg/L)	24.34 (1.30–95.20)		86.13 (1.30–1,685.0)		67.03 (2.30–298.70)		53.30 (1.20–541.40)
Chla (mg/m ³)	1.76 (0.21–5.85)		.83 (0.19–7.41)		2.73 (0.09–17.62)		0.82 (0.21–2.87)
Trans	1.82 (0.20–6.30)	1.	.57 (0.20–8.50)		1.99 (0.45-6.60)		1.93 (0.30–6.00)
$PP (mgC/(m^2*d))$	536.55 (9.86–2,801.	$(17)^{A,B}$ 38	89.91 (18.84–1,810.4	45) ^A	1048.22 (6.70–8,326	6.82) ^{A,B}	264.70 (11.84–1,232.01)
v tes. Values with different let	tters (^{A–D}) indicate signi	ificant difference	among years, and valu	ies with the	same letter indicate tha	at the difference v	was not significant.
Table 5 Resul	lts of CCA in th	e present s	tudy.				
					CCA axes		
			1	2	3	4	Total inertia
Eigenvalues			0.490	0.338	0.270	0.190	8.394
Species-enviro	nment correlati	ons	0.811	0.772	0.846	0.623	
•	rcentage variand						
*	C		5.8	9.9	13.1	15.3	
of species of		1. 4.					
-	environment ral		25.2	42.6	56.6	66.4	
Sum of all unc	onstrained eiger	nvalues					8.394
Table 6 Conc	onical eigenvalu ditional effect o onmental variab	f environn		-		ents and in	1.941 ntra-set correla-
Table 6 Conc	ditional effect o	f environn		s of CCA			
Table 6 Conc	ditional effect o onmental variab	of environn bles with th		s of CCA	1.		ntra-set correla- Correlation
Table 6 Conc	ditional effect o onmental variab	of environn bles with th	ne first two axi	s of CCA	A. fficient		ntra-set correla- Correlation I Axis 2
Table 6 Condition of environment of the Condition of environment of the Condition of the Co	ditional effect o onmental variab Lambda A	of environn ples with th	ne first two axi ————————————————————————————————————	s of CCA	A. fficient Axis 2	— — (Axis 1	Correlation Axis 2 0.43
Table 6 Condition of environment of the Condition of the Cond	ditional effect onmental variab Lambda A 0.31 0.41	of environmoles with the p 0.002 0.002	Axis 1 0.20 -0.52	s of CCA	A. fficient Axis 2 0.68 -0.91	Axis 1 -0.51 -0.69	Correlation Axis 2 0.43 0 -0.22
Table 6 Conc tion of environment of the concentration of environment of the concentration of the concentration of environment of the concentration of	ditional effect onmental variable Lambda A 0.31 0.41 0.06	of environmoles with the p 0.002 0.002 0.490	Axis 1 0.20 -0.52 0.15	s of CCA	A. fficient Axis 2 0.68 -0.91 -0.01	Axis 1 -0.51 -0.69 0.36	Correlation Axis 2 0.43 0 -0.22 0.01
Table 6 Condition of environment of the condition of environment of environment of the condition of environment of environment of the condition of environment of e	ditional effect onmental variable Lambda A 0.31 0.41 0.06 0.15	of environmoles with the p 0.002 0.002 0.490 0.052	Axis 1 0.20 -0.52 0.15 0.03	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09	Axis 1 -0.51 -0.69 0.36 -0.05	Correlation Axis 2 0.43 0.01 0.37
Table 6 Conc tion of environment of the concentration of environment of the concentration of the concentration of environment of the concentration of	ditional effect onmental variable Lambda A 0.31 0.41 0.06	of environmoles with the p 0.002 0.002 0.490	Axis 1 0.20 -0.52 0.15	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01	Axis 1 -0.51 -0.69 0.36	Correlation Axis 2 0.43 0.01 0.37
Table 6 Condition of environment of the condition of environment of environment of environment of the condition of environment of envir	ditional effect onmental variable Lambda A 0.31 0.41 0.06 0.15	of environmoles with the p 0.002 0.002 0.490 0.052	Axis 1 0.20 -0.52 0.15 0.03	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09	Axis 1 -0.51 -0.69 0.36 -0.05	Correlation Axis 2 0.43 0.01 0.37
Table 6 Condition of environment of the condition of environment of environ	ditional effect onmental variable Lambda A 0.31 0.41 0.06 0.15 0.10	of environmoles with the p 0.002 0.002 0.490 0.052 0.150	Axis 1 0.20 -0.52 0.15 0.03 -0.04	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22	Correlation Axis 2 0.43 0.01 0.37 0.39
Table 6 Condition of environment of the condition of environment of the condition of environment of the condition of environment of environme	ditional effect onmental variable Lambda A 0.31 0.41 0.06 0.15 0.10 0.10 0.10	of environmoles with the p 0.002 0.002 0.490 0.052 0.150 0.051 0.096	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03
Table 6 Condition of environment of the condition of environment of the condition of environment of the condition of environment of environme	0.31 0.41 0.06 0.15 0.10 0.10 0.15	of environmoles with the p 0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33
Table 6 Condition of environment of the condition of environment of the condition of environment of the condition of environment of environme	0.31 0.41 0.06 0.15 0.10 0.10 0.15 0.28	of environmoles with the p 0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080 0.008	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20 0.21	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11 -0.17	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52 0.39	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33 -0.29
Table 6 Condition of environment of the condition of environment of the condition of environment of the condition of environment of environme	0.31 0.41 0.06 0.15 0.10 0.10 0.15 0.28 0.13	of environmoles with the p 0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080 0.008 0.116	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20 0.21 -0.12	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11 -0.17 -0.27	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52 0.39 -0.20	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33 -0.29 0.19
Table 6 Condition of environment of the condition of environment of the condition of environment of the condition of environment of environme	0.31 0.41 0.06 0.15 0.10 0.10 0.15 0.28	of environmoles with the p 0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080 0.008	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20 0.21	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11 -0.17	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52 0.39	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33 -0.29 0.19
Table 6 Condition of environment of the condition of environment of the condition of environment of the condition of environment of environme	0.31 0.41 0.06 0.15 0.10 0.10 0.15 0.28 0.13	of environmoles with the p 0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080 0.008 0.116	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20 0.21 -0.12	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11 -0.17 -0.27	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52 0.39 -0.20	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33 -0.29 0.19 0.39
Table 6 Condition of environment of the tion of environment of environment of the tion of environment of environment of the tion of environment of environment of environment of the tion of environment	0.31 0.41 0.06 0.15 0.10 0.10 0.15 0.28 0.13 0.05	of environmoles with the p 0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080 0.008 0.116 0.644 0.264	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20 0.21 -0.12 -0.17 0.06	S of CCA	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11 -0.17 -0.27 0.04 0.39	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52 0.39 -0.20 -0.46 -0.27	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33 -0.29 0.19 0.39 0.44
Table 6 Condition of environment of the tion of environment of environment of the tion of environment of environment of the tion of environment of environment of environment of the tion of environment	0.31 0.41 0.06 0.15 0.10 0.10 0.15 0.28 0.13 0.05 0.08	of environmoles with the p 0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080 0.008 0.116 0.644 0.264	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20 0.21 -0.12 -0.17 0.06 nposition of the second control of the second c	coe coe	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11 -0.17 -0.27 0.04 0.39 for different y	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52 0.39 -0.20 -0.46 -0.27	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33 -0.29 0.19 0.39 0.44
Table 6 Condition of environment of the tion of the	0.31 0.41 0.06 0.15 0.10 0.10 0.15 0.28 0.13 0.05 0.08 tistic values of seconds	0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080 0.008 0.116 0.644 0.264	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20 0.21 -0.12 -0.17 0.06 nposition of the second control of the second c	coe coe	A. fficient Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11 -0.17 -0.27 0.04 0.39 for different y	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52 0.39 -0.20 -0.46 -0.27	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33 -0.29 0.19 0.39 0.44 NOSIM.
Table 6 Condition of environment of the tion of the ti	0.31 0.41 0.06 0.15 0.10 0.10 0.15 0.28 0.13 0.05 0.08 tistic values of serial of ser	0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080 0.080 0.008 0.116 0.644 0.264	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20 0.21 -0.12 -0.17 0.06 nposition of tl	coe coe	Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11 -0.17 -0.27 0.04 0.39 for different y	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52 0.39 -0.20 -0.46 -0.27 years by AN	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33 -0.29 0.19 0.39 0.44 NOSIM.
Table 6 Condition of environment of the tion	0.31 0.41 0.06 0.15 0.10 0.10 0.15 0.28 0.13 0.05 0.08 tistic values of standard of stand	of environmoles with the p 0.002 0.002 0.490 0.052 0.150 0.051 0.096 0.080 0.080 0.008 0.116 0.644 0.264 species consequences	Axis 1 0.20 -0.52 0.15 0.03 -0.04 -0.06 0.36 0.20 0.21 -0.12 -0.17 0.06 apposition of the control	coe he areas	Axis 2 0.68 -0.91 -0.01 -0.09 0.22 0.01 -0.06 -0.11 -0.17 -0.27 0.04 0.39 for different y	Axis 1 -0.51 -0.69 0.36 -0.05 -0.22 0.46 0.69 0.52 0.39 -0.20 -0.46 -0.27 years by AN 2004 0.471**	Correlation Axis 2 0.43 0.01 0.37 0.39 -0.06 -0.03 -0.33 -0.29 0.19 0.39 0.44 NOSIM. 2007 0.354*

	,		
Variable	Inner	Central	Outer
	Mean (range)	Mean (range)	Mean (range)
D (m)	8.37 (5.00–10.00) ^A	$12.20 (5.00-32.00)^{\mathrm{B}}$	34.17 (12.00–60.00) ^C
S (‰)	4.03 (2.86–18.03) ^A	$19.88 (3.30-28.61)^{\text{B}}$	24.50 (6.62–31.58) ^C
T (°C)	20.10 (18.68–22.22) ^A	18.91 (14.98–21.75) ^B	$18.84 (15.89-21.64)^{B}$
DO (mg/L)	7.64 (5.24–12.03)	6.88 (4.55–10.23)	7.77 (3.90–13.95)
pН	8.13 (7.90–8.36) ^A	8.19 (7.82–8.47) ^A	$8.35 (8.06-8.85)^{\text{B}}$
COD (mg/L)	$2.80 (1.04 - 3.52)^{A}$	$2.09 (0.77 - 4.32)^{B}$	1.50 (0.46–4.32) ^C
TN (μmol/L)	118.08 (45.90–176.18) ^A	$76.62 (34.80 - 146.87)^{B}$	49.85 (13.70–86.78) ^C
TP (μmol/L)	$2.83 (1.20-7.00)^{A}$	$1.88 (0.55 - 6.50)^{\mathrm{B}}$	$0.74 (0.17 - 1.50)^{\mathrm{C}}$
SPM (mg/L)	91.75 (28.10–398.00) ^A	163.44 (2.50–1,685.00) ^{A,B}	5.11 (1.20–30.40) ^C
Chla (mg/m ³)	$0.71 (0.10-2.20)^{A}$	$1.64 (0.10-11.70)^{A,B}$	$2.32 (0.20-17.6)^{B}$
Trans	$0.34 (0.20 - 0.60)^{A}$	$0.95 (0.20 - 4.50)^{\mathrm{B}}$	3.37 (0.40–8.50) ^C
$PP (mgC/(m^2*d))$	35.27 (6.70–102.13) ^A	265.04 (7.69–3.213.64) ^B	1,027.07 (64.39–8,326.82) ^C
XD2	D PP A7X PP A26 PP PH B26 D34 A33 B33 D3026 A425 B19 D20 B12 D20 C14 D32 C14 D32 C14 D32 B7 D6 B3 A66 C5	A2A19 27C3 A6 B10 B36 B38 C C36 C35 C A12 B0 C36 C35 C A12 B0 C40 A36	A37 335 D36 A39 OD35 35 D38 D39
S	C32 X A24 F B13 X D17 B5 C12 B30D10 A5 XB1 B15 B31 C25 B25 C107 C31 A9 D1 A31 D31 C	24 25 D 2016 B83 D22 B16 C23 B21 A28 C22 D C21 A16 A15 D2 D24 B28 C29 B28 C29 B28 C29 B29 C30A29 C28 SPIN	
0.7			□ — п × — ш
-1.0			1.0

Figure 3 Plot of scores on the first two axes from CCA for sampling stations in the Yangtze Estuary

(A, spring in 1999; B, spring in 2001; C, spring in 2004; D, spring in 2007; the numbers following A-D

indicate the station numbers)

Table 8 Environmental data (means and range) of the areas resultant of CCA.

Disscussion

- Forty-two ichthyoplankton species belonging to 23 families were collected. Engraulidae was the most abundant family, including six species and comprising 67.91% of the total catch. Only four species (Coilia mystus, Engraulis japonicus, Trachidermis fasciatus and Allanetta bleekeri) could be considered dominant, accounting for 88.70% of total abundance.
- The structure of the ichthyoplankton spring assemblage persisted on an annual basis, with the dominant species reappearing consistently even though their abundance fluctuated from year to year.
- >CCA indicated a spatial structure of the ichthyoplankton assemblage in three areas.
- The observed ichthyoplankton assemblage structure appears to be strongly influenced by depth, salinity and suspended particulate matter gradients.