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Species Composition and Distribution of Fish Larvae in Yenliao Bay, Northeastern Taiwan

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Wann-Nian Tzeng, Yu-Tzu Wang and Yarng Tzung Chern (1997) Species composition and distribution of fish larvae in Yenliao Bay, northeastern Taiwan. *Zoological Studies* **36**(2): 146-158. Fish larvae were collected monthly in Yenliao Bay in northeastern Taiwan, using a Maruchi larval net at 11 stations from October 1992 to September 1993. A total of 9 969 larval fish representing 80 families and 138 species were collected. The larval fish assemblages included coral-reef, estuarine, and coastal pelagic species. Pomacentridae were the most abundant, making up 23% of the total catch, followed by Apogonidae (15%), *Ambassis* sp. (9%), *Auxis* sp. (9%), Gobiidae (6%), Carangidae (6%), Myctophidae (4%), Tripterygiidae (3%), *Engraulis japonicus* (3%), *Priacanthus macracanthus* (2%), and *Sebastiscus marmoratus* (2%). These 11 species groups constituted approximately 82% of the total collection. The abundance and number of species of fish larvae increased with temperature and reached a peak in May. Larvae were more abundant in the nearshore than the offshore stations. Pelagic fish (e.g., *E. japonicus*) spawned in offshore waters, and their larvae migrated to nearshore waters. The distribution of fish larvae in nearshore waters was independent of the distribution of plankton. The high species diversity reflects the complicated geomorphology and hydrography of the embayment environment. The mismatch in the distributions of peak abundance between fish larvae and zooplankton, and the relationship between the timing of occurrence and life history transition of fish larvae are discussed.

Key words: Fish larvae, Species composition, Seasonal occurrence, Spatial distribution.

Yenliao Bay is an open bay located on the northeastern coast of Taiwan. It is influenced by both the Kuroshio and China Coastal currents (Chu 1963, Chern and Wang 1990, Lin et al. 1992), as well as by runoff from the Shuangchi and Shihting rivers. The inner part of the bay has a mostly sandy bottom with the remainder being coral reefs (Yang and Dai 1982). The fish community in the bay is comprised of coral-reef and coastal pelagic fishes which support various fisheries in the coastal waters (Tzeng 1982, Liu et al. 1992a,b, Tzeng and Lee 1994). The bay is also an important nursery ground for anchovy and sardine, whose larvae and juveniles are the important target species in the coastal larval fishery.

Species composition and abundance of fish larvae and juveniles are important indicators for predicting coming fishing stocks (Stephens et al. 1986 1988). These factors have been studied in Yenliao Bay since 1980 when the government announced the plan to built a nuclear power plant near the bay (Su et al. 1981, Huang et al. 1985, Tzeng et al. 1985, Tzeng and Wang 1986). These studies have focused on species identification and inventories.

Species composition, diversity, life history, and recruitment of larval and juvenile fish communities differ among habitats (Austin 1971, Odum and Heald 1972, McErlean et al. 1973, Haedrich and Haedrich 1974, Blaber et al. 1985, Blaber and Milton 1990, Robertson and Duke 1990). In general, fish larvae and juveniles in estuaries and coastal areas are euryhaline and spend a relatively short time in these habitats, representing a phase

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of an inshore-offshore migration (Yàñez -Arancibia et al. 1980, Beckley 1984, Bell et al. 1984, Robertson and Duke 1987). Spatial and temporal variations in a larval fish community are influenced by physico-chemical environments and biological factors (Haines 1979).

This study was intended to determine the seasonal changes in the species composition, abundance, and distribution of fish larvae and juveniles in relation to environmental characteristics in Yenliao Bay.

MATERIALS AND METHODS

Fish larvae and juveniles were collected at 11 stations (Fig. 1) in Yenliao Bay from October 1992 to September 1993 in daytime using a Maruchi larval net. The net is 130 cm in diameter at the opening, 450 cm long, and has a mesh size of 0.5 mm (Nakai 1962). It was towed horizontally for approximately 10 min at a speed of 1.5 knots at the water surface of each station. A flowmeter was mounted in the net mouth to record the amount of water filtered. The collected fish were immediately fixed in a 5% formalin-seawater solution. They were identified to species (Wang 1987, Okiyama 1988); their developmental stages were determined (Kendall et al. 1984), and their total lengths were measured to the nearest 0.1 mm. The ecotype of the larvae was defined according to the habit of the adult fish (Tzeng 1982, Anon 1985, Liu et al. 1992b, Tzeng and Lee 1994). Eggs of *Engraulis japonicus* have an elliptical shape distinguishable from the round eggs of other species so their eggs could be identified. The biomass (volume) of zooplankton collected by the larval net was measured after overnight setting and compared to the distribution of fish larvae. The species composition of fish larvae and juveniles collected was compared with that collected by a commercial larval net, which has 2 wings, each 125 m long and is 15 m in height, and by a codend net of 15 m in diameter and 30 m long with a mesh size of 2 mm (Lee et al. 1995). Environmental data were collected during the sampling: sea surface temperature and salinity were measured with a salinometer (WTW microprocessor conductivity meter: LF 196); dissolved oxygen (DO) with a DO meter (WTW microprocessor oximeter: OXI 196); pH with a pH meter; and the depth of each sampling station with an echo sounder.

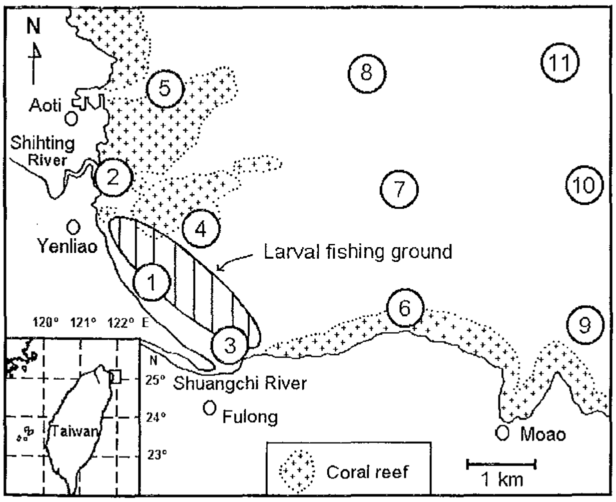

Fig. 1. Sampling stations (Sts. 1-11) of fish larvae collected by Maruchi larval net and the commercial larval fishing ground in Yenliao Bay, northeastern Taiwan.

The similarity in the species composition of fish larvae and juveniles among stations and seasons was determined by the Bray-Curtis dissimilarity index and clustered with UPGMA (unweighted pair-group using arithmetic averages) (Rohlf 1989). The species diversity was estimated using Shannon-Weaver's species diversity index (H') (Pielou 1966). Relationships between biotic and environmental variables were determined using canonical correlation and stepwise multiple regression analyses.

RESULTS

Environmental conditions

Sea surface temperatures (mean $\pm$ SD) were highest in August (29.3 $\pm$ 0.2 °C) and lowest in December (18.7 $\pm$ 0.2 °C). DO varied with season and ranged between a low of 5.2 $\pm$ 0.8 ml/l (May) to a high of 7.3 $\pm$ 0.7 ml/l (October). The pH values ranged between 7.7 and 9.0, and were lower at the river mouth stations. Salinities were lower and fluctuated more widely at the river mouth stations (St. 2, 31.7‰ $\pm$ 4.0‰; St. 3, 27.5‰ $\pm$ 7.7‰) than in the offshore stations (St. 10, 33.8‰ $\pm$ 0.3‰; St. 11, 33.8‰ $\pm$ 0.4‰). Depths increased from 5 to 19 m in the nearshore stations (Sts. 1-6) to 37 to 64 m in the offshore stations (Sts. 7-11).

Abundance of zooplankton and fish eggs and larvae

Fish larvae were more abundant in the nearshore stations (Sts. 1-6) than in the offshore stations (Sts. 7-11), but the situation was reversed for fish eggs (Fig. 2). The numbers of fish species were also higher in the nearshore stations than in the offshore stations. These results indicate that most pelagic eggs were spawned in offshore waters, and the community structure of fish larvae was more diverse in nearshore waters than in offshore waters.

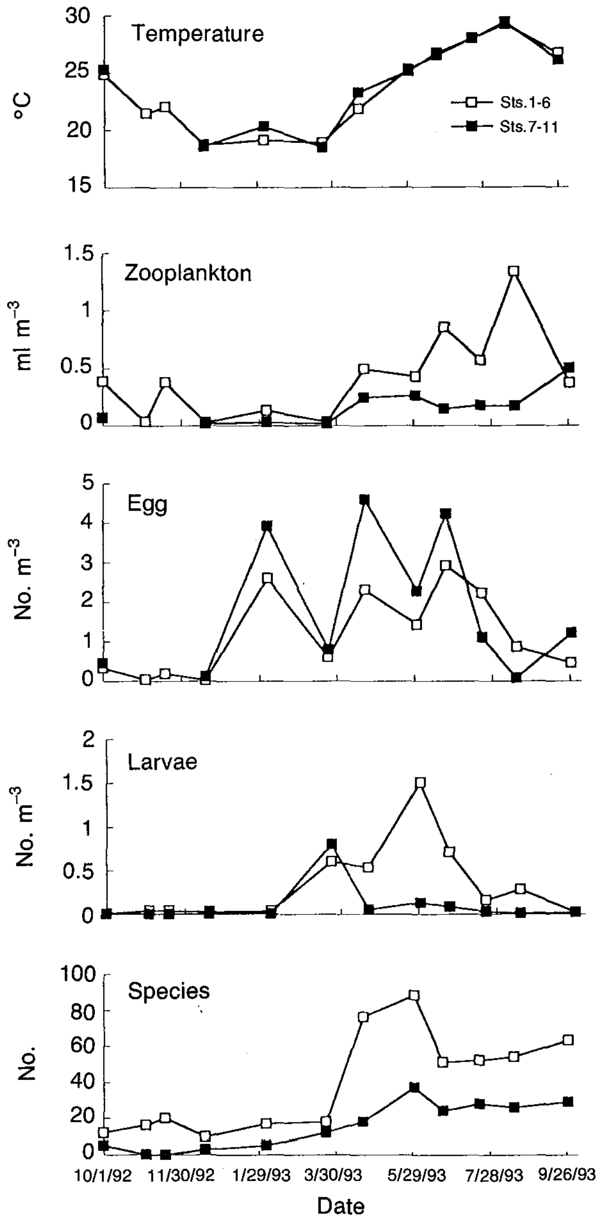

Fig. 2. Seasonal changes in mean water temperature, abundance of zooplankton, fish eggs and larvae, and the number of species of larvae at nearshore (Sts. 1-6) and offshore stations (Sts. 7-11) in Yenliao Bay, 1 October 1992 to 16 August 1993.

Zooplankton, fish larvae and eggs and the number of fish species varied with season. The abundance of zooplankton decreased in fall, reached the lowest in winter, then increased in spring. Fish eggs occurred abundantly from February to June and exhibited a great temporal fluctuation in abundance. Fish larvae reached a peak in abundance in May, and decreased thereafter. The seasonal change in the numbers of species of fish larvae corresponded with that of the abundance of fish larvae, indicating that most species of larvae were spawned in early spring (Fig. 2).

Spatio-temporal changes in species composition

A total of 9 969 larvae representing 80 families and 138 species was collected (Table 1). Pomacentridae were the most numerous, making up 23% of the total catch, followed by Apogonidae (15%), *Ambassis* sp. (9%), *Auxis* sp. (9%), Carangidae (6%), Gobiidae (6%), Myctophidae (4%), Tripterygiidae (3%), *Engraulis japonicus* (3%), *Priacanthus macracanthus* (2%), and *Sebastiscus marmoratus* (2%). These 11 species groups account for approximately 82% of the total collection, indicating that the larval fish assemblages in the bay are comprised mainly of resident coral-reef fishes, estuarine, and coastal pelagic fishes.

According to the index of Bray-Curtis dissimilarity among sampling months, the fish assemblages were divided into 2 seasonal groups: the fall-winter group (September-February) and the spring-summer group (March-August) (Fig. 3). There were 114 species collected in spring-summer, making up 82.6% of the number of fish species collected in the bay. Pomacentridae (24.5%), Apogonidae

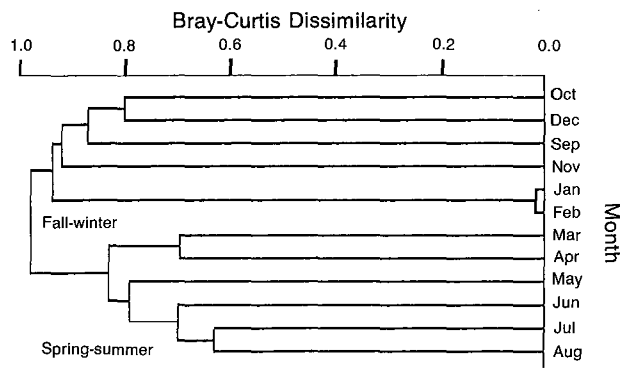

Fig. 3. Bray-Curtis dissimilarity among sampling months for species composition of fish larvae and juveniles collected by Maruchi net at 11 stations in Yenliao Bay, October 1992 to September 1993.

Table 1. Species composition of fish larvae and juveniles collected by Maruchi net in Yenliao Bay from October 1992 through September 1993

Family	Species	Stage[a]	No.	%	Occurrence		Ecotype[b]
					Month	Station	
Muraenidae	sp.	Le.	11	0.11	5,6	9	Rb
Muraenesocidae	*Gavialiceps* sp.	Le.	2	0.02	4	1,5,9	Sb
Nettastomatidae	sp.	Le.	1	0.01	9	4	Ds
Ophichthidae	spp.	Le	8	0.08	5,7,8,11	3,4,6,9	Sb
Clupeidae	*Spratelloides delicatulus*	Ju.	2	0.02	11	3,4	Ep
	Spratelloides gracilis	Ju.	2	0.02	10	4,8	Ep
	Ilisha sp.	Po., Ju.	4	0.04	11	1,3	Ep
Engraulidae	*Engraulis japonicus*	Ys., Pr., Fl., Ju.	275	2.76	3,4	1,2,3,4,5,6,8,9	Ep
	Encrasicholina punctifer	Pr., Fl., Ju.	38	0.38	5,10,11	1,3	Ep
	Thryssa sp.	Fl., Po.	2	0.02	5,11	1,7	Ep
Argentinidae	sp.	Pr.	2	0.02	4	3	Ds
Bathylagidae	sp.	Pr.	1	0.01	4	5	Mp
Stomiidae	sp.	Pr.	4	0.04	2,4,5	2,3	Mp
Gonostomatidae	*Vinciguerria nimbaria*	Fl., Po., Ju.	18	0.18	2,4,5	1,2,3,4,5	Mp
	Gonostoma gracile	Fl.	1	0.01	2	1	Mp
	Gonostoma sp.	Pr.	3	0.03	4	3,5	Mp
	Cyclothone pseudopallida	Po.	2	0.02	4	1	MP
	Cyclothone alba	Pr., Fl., Po., Ju.	29	0.29	4,5,6,7,9,11	1,2,3,4,5,10	Mp
	Cyclothone acclinidens	Fl.	1	0.01	8	4	Mp
	Cyclothone sp.	Po.	3	0.03	2,5	5,8	Mp
Synodontidae	*Trachinocephalus myops*	Pr., Fl., Po.	5	0.05	5,7,8,11	1,4,6,10	Sb
	sp.	Pr.	3	0.03	4,8	3,4	Sb
Scopelarchidae	sp.	Pr.	1	0.01	12	1,2,3,5,6,8	Mp
Paralepididae	sp.	Fl.	1	0.01	2	3	Mp
Myctophidae	*Benthosema pterotum*	Pr., Fl., Po., Ju.	47	0.47	4,5,8,9	1,3,4,6,7	Sb
	Benthosema fibulatum	Pr., Fl., Po.	10	0.10	5,11	3,11	Mp
	Benthosema suborbitale	Pr.	1	0.01	2	3	Mp
	Myctophum sp.	Pr.	1	0.01	4	5	Mp
	Lampadena sp.	Pr., Fl.	5	0.05	4,8,11	2	Mp
	Lampanyctus sp.	Fl.	1	0.01	11	3,4,6,8	Mp
	Diaphus sp.	Pr., Fl., Po., Ju.	49	0.49	2,4,5,8,10,11	1,2,3,4,6,8	Mp
	Notoscopelus sp.	Ju.	2	0.02	4	4	Mp
	Symbolophorus sp.	Pr.	9	0.09	4	2,4,5	Mp
	spp.	Pr., Fl., Po.	259	2.60	3,4,5,6,7,10,11	1,2,3,4,5,6,7,8,9,10	Mp
Bregmacerotidae	*Bregmaceros* sp.	Pr., Fl., Po., Ju.	26	0.26	5,6,7	1,3,4,6	Sb
Ophidiidae	sp.	Fl.	1	0.01	8	4	Ds
Lophiidae	*Lophiomus setigerus*	Pr.	1	0.01	7	1	Sb
Gobiesocidae	*Aspasmichthys ciconiae*	Ys., Pr., Fl.	170	1.71	2,3,4,5	1,2,3,4,5,6,9	Rb
	Discotrema crinophila	Pr.	10	0.10	4,5	2,3,4,9	Rb
	sp.	Pr.	3	0.03	4	6,7	Rb
Exocoetidae	*Cypselurus katoptron*	Po.	17	0.17	5,6	4,7,8,9	Ep
	Cypselurus poecilopterus	Ju.	2	0.02	5	8	Ep
	Hirundichthys oxycephalus	Ju.	2	0.02	5	8	Ep
	sp.	Po.	5	0.05	1,7	2,3,4,9,10,11	Ep
Belonidae	sp.	Po., Ju.	3	0.03	4,10	2,11	Ep
Hemiramphidae	spp.	Pr.	6	0.06	4	2,3	Ep
Atherinidae	sp.	Fl.	2	0.02	7	9	Ep
Holocentridae	sp.	Pr., Fl.	15	0.15	5,6,7,8,9	1,4,5,6,9,10,11	Rb
Zeidae	sp.	Pr.	2	0.02	6	2	Sb
Caproidae	*Antigonia rubescens*	Fl.	1	0.01	8	6	Sb
Fistulariidae	sp.	Pr.	4	0.04	4	2	Rb
Scorpaenidae	*Sebastiscus marmoratus*	Pr.	166	1.67	2,3,11,12	1,2,3,4,5,6,7	Rb
	spp.	Pr., Fl.	61	0.61	3,4,5,6,7,8,10	1,2,3,4,6,7,8,10,11	Rb
Synanceiidae	*Minous* sp.	Pr., Fl., Po., Ju.	17	0.17	4,5,7,8	1,4,6	Rb
Triglidae	sp.		1	0.01	5	3	Sb
Platycephalidae	spp.	Pr.	10	0.10	4,6	2,5	Sb
Centropomidae	*Ambassis gymnocephalus*	Pr., Po., Ju.	12	0.12	10,11	2,3,4,10	E

Table 1. (Cont.)

Family	Species	Stage[a]	No.	%	Occurrence		Ecotype[b]
					Month	Station	
Centropomidae	*Ambassis* sp.	Pr., Po., Ju.	936	9.39	4,5,6,7,8,9	1,2,3,4,5,6,7,8,9,10,11	E
Percichthyidae	*Acropoma* sp.	Fl.	1	0.01	10	4	Rb
	Synagrops philippinensis	Ju.	1	0.01	10	4	Rb
	Synagrops sp.	Fl., Po.	3	0.03	11	2,3	Rb
Serranidae	*Epinephelus* sp.	Pr., Ys.	59	0.59	4,5,6,7	1,2,3,4,5	Rb
	spp.	Pr., Fl.	33	0.33	2,3,4,5,6,7,8,11	1,2,3,4,5,6,7,10	Rb
Teraponidae	*Terapon jarbua*	Pr., Fl., Po., Ju.	58	0.58	5,6,7,8	1,2,3,4,5,6,7,8,9,10,11	E-Rb
Priacanthidae	*Priacanthus macracanthus*	Pr., Fl.	184	1.85	4,5,6,7,8	1,2,3,4,5,6,8,9	Sb
	Cookeolus boops	Pr., Po.	4	0.04	4	4	Sb
Apogonidae	spp.	Pr., Fl., Po., Ju.	1 465	14.70	2,3,4,5,6,7,8,9	1,2,3,4,5,6,7,8,9,11	Rb
Sillaginidae	*Sillago sihama*	Pr., Po., Ju.	7	0.07	4,5,8,11	1,3,4	Sb
	Sillago sp.	Pr., Fl.	8	0.08	4	3	Sb
	sp.	Pr.	1	0.01	12	6	Sb
Malacanthidae	sp.	Pr.	1	0.01	8	6	SB
Carangidae	*Trachurus japonicus*	Ys., Pr., Ju.	126	1.26	2,3,4,11	1,2,3,4,5,6,8,9	Ep
	Decapterus maruadsi	Pr., Fl., Ju.	75	0.75	5,6	1,3,5,6,8,9	Ep
	Decapterus macarellus	Pr., Fl., Po., Ju.	16	0.16	7,8	1,3,6,11	Ep
	Decapterus macrosoma	Pr., Fl., Po.	102	1.02	4,5,6,7	1,2,3,4,5,6,9,10	Ep
	Decapterus spp.	Pr., Fl., Po., Ju.	97	0.97	4,5,6,7	1,2,3,4,5,6,8,9,10,11	Ep
	Selar crumenophthalmus	Pr., Fl., Po.	9	0.09	7,8	2,3,4,6	Ep
	Scomberoides tol	Ju.	1	0.01	10	11	Ep
	Scomberoides sp.	Pr., Fl., Po., Ju.	134	1.34	4,5,6,7,8,11	1,2,3,4,5,7,8,9,11	Ep
	spp.	Pr., Fl., Po.	81	0.81	4,5,6,8,10,11	2,3,4,5,6,8,11	Ep
Formionidae	*Formio niger*	Pr., Fl., Po., Ju.	17	0.17	5,6,7,8	1,3,4,5,11	Ep
Coryphaenidae	*Coryphaena hippurus*	Pr., Fl., Ju.	54	0.54	4,5,6,8	1,3,4,5,6,8	Ep
Menidae	*Mene maculata*	Pr., Fl., Po., Ju.	23	0.23	4,5,6,7,8	1,3,4,5,6	Ep
Leiognathidae	sp.	Pr.	3	0.03	4,5	1,3	E
Bramidae	sp.	Pr., Fl.	7	0.07	4,5,8	3,6,10	Ep
Emmelichthyidae	*Erythocles schlegeli*	Ju.	3	0.03	7,8	4,5	Rb
Lutjanidae	sp.	Pr.	13	0.13	4,5,6,7,8	1,2,3,4,5,6,11	Rb
Gerreidae	sp.	Pr.	5	0.05	8	1	E
Sparidae	sp.	Pr.	14	0.14	4,5,6	1,3,11	E-Rb
Nemipteridae	sp.	Pr., Po.	2	0.02	5,6	3,10	Sb
Sciaenidae	spp.	Pr., Fl.	21	0.21	4,5,7,8,9	1,2,3,4,5,6	Sb
Mullidae	*Upeneus bensasi*	Pr., Fl., Po., Ju.	119	1.19	4,5,6,8,9	1,2,3,4,5,6,8,10,11	Sb
	sp.	Fl.	1	0.01	2	8	Sb
Pempheridae	*Pempheris* sp.	Ju.	1	0.01	12	4	Rb
	sp.	Fl.	4	0.04	4	2,3	Rb
Scatophagidae	*Scatophagus argus*	Ju.	2	0.02	7	10,11	E
Chaetodontidae	sp.	Pr.	4	0.04	6	4	Cr
Pomacentridae	spp.	Ys., Pr., Fl., Ju., Yo.	2 317	23.24	3,4,5,6,7,8,10,11	1,2,3,4,5,6,7,8,9,10,11	Rb
Cirrhitidae	sp.	Fl.	1	0.01	4	6	Rb
Cepolidae	sp.	Pr., Fl., Po.	16	0.16	4,5	5	Sb
Mugilidae	*Liza* spp.	Pr., Ju.	7	0.07	4,7	2,3,4,7,8,10,11	Sb
Sphyraenidae	*Sphyraena* sp.	Pr., Fl.	9	0.09	4,6	4,8,10	Ep
Labridae	spp.	Po.	20	0.20	5,8,10	1,2,3,4,6	Cr
Scaridae	spp.	Pr., Fl., Po.	6	0.06	4,5	2,3	Cr
Champsodontidae	*Champsodon* sp.	Fl.	2	0.02	11	4	Sb
Trichonotidae	*Trichonotus setigerus*	Ju.	1	0.01	9	1	Rb
Percophidae	sp.	Pr.	1	0.01	8	6	Sb
Mugiloididae	*Parapercis* sp.	Pr.	6	0.06	5,6	2	Rb
	sp.	Fl.	1	0.01	4	11	Rb
Tripterygiidae	spp.	Pr., Fl., Po., Ju.	338	3.39	3,4,5,6,7,8,9,10	1,2,3,4,5,6,9,10	Cr
Blenniidae	*Istiblennius* spp.	Pr., Fl.	66	0.66	5,7,8	1,2,3,4,5,6	Cr
	Omobranchus sp.	Pr.	36	0.36	4,5,7,8,9	3,4,6	Cr
	Petroscirtes breviceps	Yo.	1	0.01	10	3,6	Cr
	Petroscirtes sp.	Yo.	1	0.01	7	4	Cr
	spp.	Ys., Pr., Fl., Po., Ju.	111	1.11	2,3,4,5,6,7,11,12	1,2,3,4,5,6,7,9,10,11	Cr

Table 1. (Cont.)

Family	Species	Stage[a]	No.	%	Occurrence		Ecotype[b]
					Month	Station	
Callionymidae	spp.	Ys., Pr., Fl., Po., Ju.	49	0.49	3,4,5,6,7,8,9,11	1,2,3,4,5,6,9	Sb
Gobiidae	*Rhinogobius* sp.	Pr., Fl.	269	2.70	2,3,8	1,2,3,6,10	F
	spp.	Pr., Fl., Po., Ju.	326	3.27	3,4,5,6,7,8,9,10,11	1,2,3,4,5,6,7,8,9,10,11	E
Acanthuridae	sp.	Pr.	2	0.02	5,7	3,6	Rb
Gempylidae	*Diplospinus Multistriatus*	Fl.	2	0.02	4	3	Ep
	Gempylus serpens	Fl.	1	0.01	11	3	Ep
	sp.	Pr., Fl.	9	0.09	2,6	8	Ep
Trichiuridae	*Eupleurogrammus muticus*	Ys.	1	0.01	11	2	Sb
	Trichiurus lepturus	Ys.	112	1.12	3,4,6,7,10,11,12	1,2,3,4,5,6,8,9	Sb
	sp.	Ys.	2	0.02	4	1	Sb
Scombrolabracidae	*Scombrolabrax heterolepis*	Fl.	1	0.01	11	5	Ep
Scombridae	*Scomber australasicus*	Pr., Fl.	16	0.16	4	1,3,4,7,8	Ep
	Scomber japonicus	Pr., Fl.	26	0.26	2,4	3	Ep
	Auxis sp.	Ys., Pr., Fl., Po.	890	8.93	5,6,7,8	1,2,3,4,5,6,8,9,10,11	Ep
	Thunnus sp.	Pr.	2	0.02	4	3,5,6	Ep
	Sarda orientalis	Pr.	1	0.01	8	3	Ep
Paralichthyidae	sp.	Fl.	2	0.02	4	1	Sb
Bothidae	spp.	Pr., Fl., Po., Ju.	67	0.67	2,4,5,6,7,8,9,11	1,2,3,4,5,6,7,9	Sb
Pleuronectidae	spp.	Pr., Fl.	19	0.19	2,4,5,7,8	1,2,3,4,5,6,7,8	Sb
Cynoglossidae	sp.	Pr., Fl., Po., Ju.	80	0.80	5,6,7,8,9	1,2,3,4,6,8,9	Sb
Monacanthidae	*Stephanolepis cirrhifer*	Po.	1	0.01	8	2	Ep
Tetraodontidae	*Takifugu* sp.	Ys., Pr., Fl.	7	0.07	4,5,6	1,7,10,11	Ep
Diodontidae	*Diodon holocanthus*	Pr., Po.	6	0.06	5	3,4,10	Ep
Unidentified		Ys., Pr., Fl., Ju.	103	1.03			
Total			9 969				

[a]Ys, Yolk-sac larva; Le, Leptocephalus larva; Pr, Preflexion larva; Fl, Flexion larva; Po, Postflexion larva; Ju, Juvenile; Yo, Young.
[b]Cr, Coral-reef; Ds, Deep sea; E, Estuarine; Ep, Epipelagic; F, Freshwater; Mp, Mesopelagic; Rb, Rocky bottom; Sb, Sandy bottom.

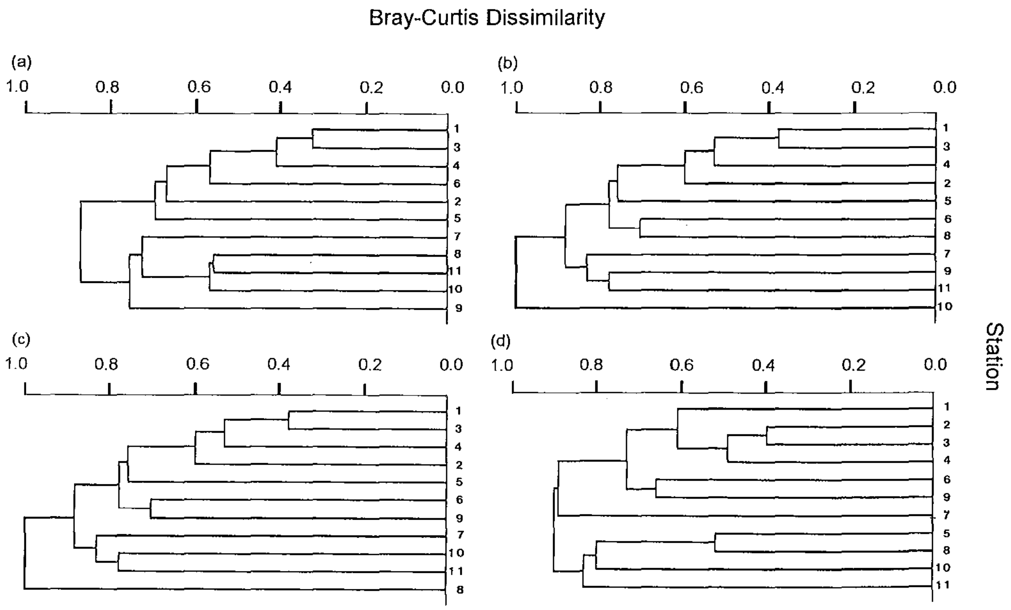

Fig. 4. Bray-Curtis dissimilarity among stations for species composition of fish larvae and juveniles collected by Maruchi net at 11 stations in Yenliao Bay, October 1992 to September 1993 (a, overall months; b, April; c, May; and d, July).

(15.1%), *Ambassis* sp. (9.6%), and *Auxis* sp. (8.9%) were dominant, making up approximately 1/2 of the collection, whereas, only 65 species were collected in fall-winter, and dominant species differed from those of the spring-summer group. The top 4 dominant species in fall-winter were *S. marmoratus* (28.6%), *Encrasicholina punctifer* (9.8%), *Trichiurus lepturus* (8.3%) and *Ambassis gymnocephalus* (7.1%). The results indicate that larval and juvenile fish assemblages in the bay change with season.

Similarities in fish assemblages among stations allowed clustering into nearshore and offshore groups (Fig. 4a). The clustering slightly changed between seasons, e.g., in April, May, and July, but in general, adjacent stations had a more similar species compositions (Fig. 4b-d). There were 129 species collected in nearshore waters, making up 93.5% of the number of fish species collected in the bay. Pomacentridae (23.3%), Apogonidae (15.6%), Tripterygiidae (10.4%), and *Ambassis* sp. (9.2%) were dominant. However, only 63 species were collected in offshore waters, the top 5 species were Tripterygiidae (10.3%), Pomacentridae (13.0%), *Ambassis* sp. (7.3%), *Terapon jarbua* (6.5%), and *T. lepturus* (6.0%).

In addition, the species compositions of fish larvae and juveniles differed greatly in the collections between the Maruchi larval net and the commercial larval net (Fig. 5). The former captured mainly of larval coral-reef fishes (Fig. 5a), while the latter contained mainly juveniles of the coastal pelagic species, *E. japonicus*, *Sardinella lemura*, *Etrumeus teres*, and *Leiognathus* spp. (Fig. 5b).

Spatial distribution pattern of larval fishes

Eggs of *E. japonicus* were more abundant at St. 4, but its larvae were more abundant at St. 2 (Fig. 6). This indicates that *E. japonicus* eggs were spawned in offshore waters and the larvae migrated to the bay.

On the other hand, the larvae of resident coral-reef fishes, e.g., Pomacentridae, Tripterygiidae, Apogonidae, and *Ambassis* sp., were concentrated at the nearshore stations with rocky substrata (Fig. 7a-d). *Rhinogobius* sp., a diadromous species, was more abundant in offshore waters than nearshore waters (Fig. 7e), while *Auxis* sp., a coastal pelagic species, was more abundant in nearshore waters than offshore waters (Fig. 7f). This indicates different spatial distribution patterns of larvae among species.

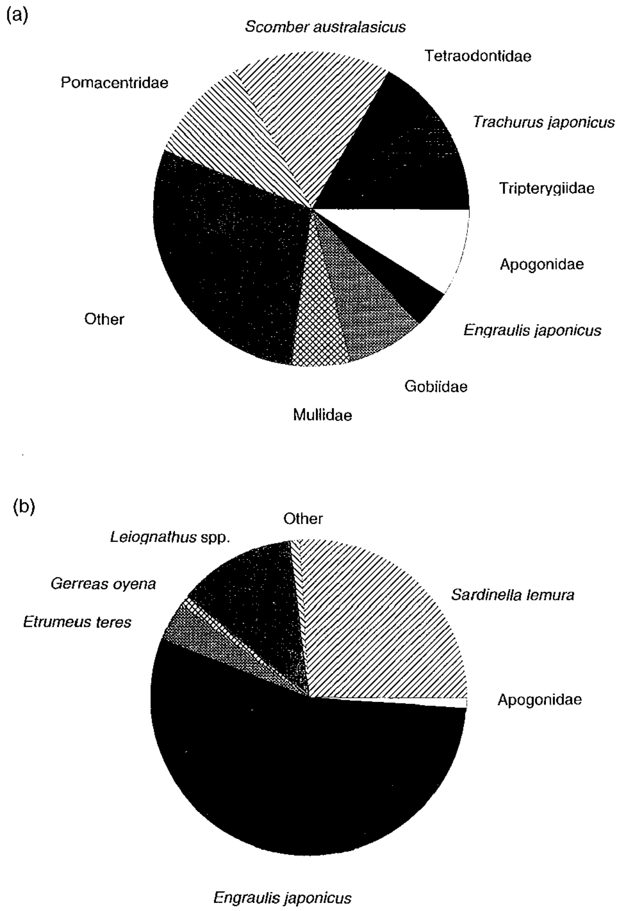

Fig. 5. A comparison of the species composition of fish larvae and juveniles between the Maruchi net (a) and the commercial net (b) in Yenliao Bay, 20 March to 30 May 1993.

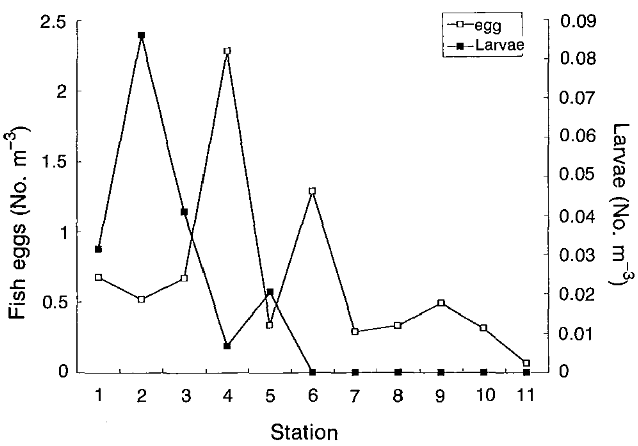

Fig. 6. Distribution of eggs and larvae of *Engraulis japonicus* in Yenliao Bay in April 1993.

Relationship of the relative abundance between zooplankton and fish larvae

In general, fish larvae and zooplankton were more abundant in nearshore waters (Sts. 1-6) than offshore waters (Sts. 7-11) (Fig. 2), indicating that fish larvae were concentrated in nearshore waters where prey organisms were abundant. However, in considering the data station by station, the peak abundance of zooplankton corresponded with that of fish larvae on 23 March at St. 6 (Fig. 8a), but not on 21 April (St. 2 vs. St. 4) or 31 May (St. 4 vs. St. 5) (Fig. 8b, c). This indicates that the distribution of fish larvae was at least in part independent of the abundance of plankton in nearshore waters.

Relationship between biotic and abiotic factors

The results of the canonical correlation analysis indicate that the 5 biotic variables, larvae, zooplankton, egg, species diversity (H'), and species, were highly correlated to the 5 abiotic variables, temperature, depth, salinity, pH, and DO. Correlation coefficients of the first 2 canonical axes were 0.78 and 0.71, respectively (p = 0.0003 and 0.0067). Larval fish abundance and the number of fish species were positively correlated with temperature, depth, and DO, and negatively correlated with pH in the 1st canonical axis, but the correlation was opposite for zooplankton, fish eggs, and species diversity. The contributions of the 5 abiotic variables in the 1st canonical axis were different,

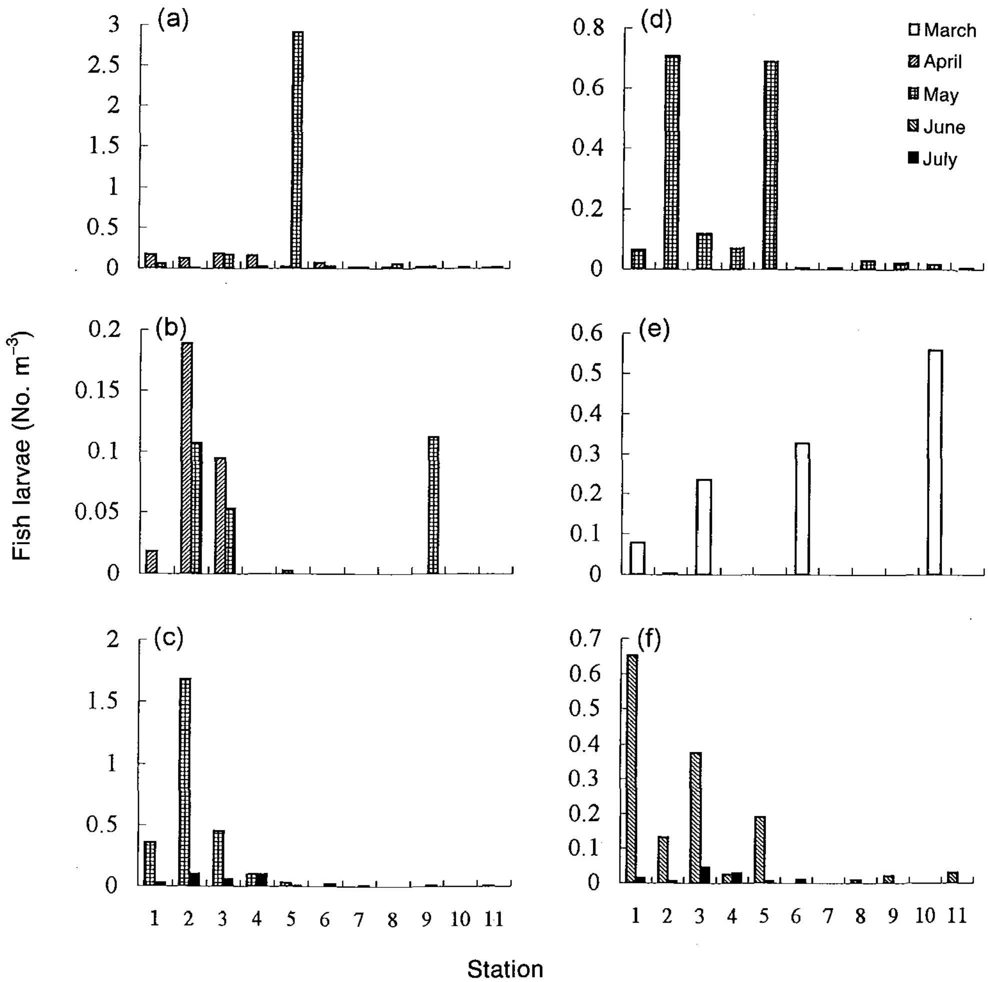

Fig. 7. Distribution of larvae of Pomacentridae (a), Tripterygiidae (b), Apogonidae (c), *Ambassis* sp. (d), *Rhinogobius* sp. (e), and *Auxis* sp. (f) in Yenliao Bay, March to July 1993.

with temperature being highest and salinity lowest (Table 2). The stepwise regression analysis indicated that fish abundance was only significantly correlated to the depth of stations in the 5 abiotic variables (r = −6.69, p < 0.01).

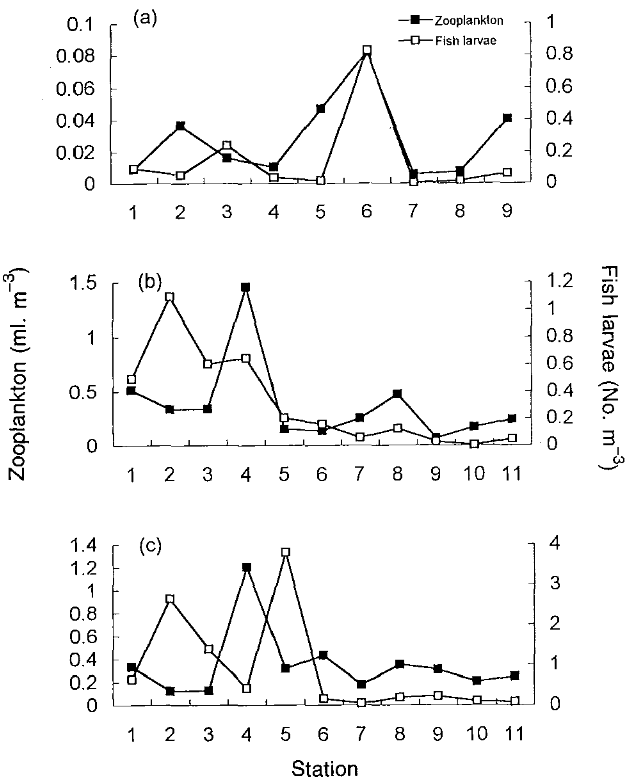

Fig. 8. Spatial coherence in the occurrence of zooplankton and fish larvae collected by the Maruchi larval net at 11 stations in Yenliao Bay, 23 March (a), 21 April (b), and 31 May (c) 1993.

DISCUSSION AND CONCLUSIONS

Yenliao Bay is covered mainly with rocks that provide a suitable environment for certain fish species, while the estuaries of the Shuangchi and Shihting rivers are suitable for estuarine fish. Fish of the families Pomacentridae, Apogonidae, and Tripterygiidae were dominant and more abundant at the rocky stations, and Gobiidae were abundant at the estuarine stations. In addition, the bay is well influenced by the Kuroshio Current and China Coastal Current which may transport the larvae of offshore fishes, such as *Engraulis japonicus*, *Auxis* sp., and Myctophidae, into the bay. Many studies have indicated that the occurrence, abundance, and species composition of fish larvae and juveniles in nearshore waters depend on the spawning seasons of the fish and the environmental physico-chemical conditions that prevail during the onshore movement (Blaber and Whitfield 1977a,b, Weinstein 1979, Bell 1980, Blaber and Blaber 1980, Quinn 1980, Yàñez-Arancibia et al. 1980, Bell et al. 1984, Norcross 1984, Loneragan et al. 1986, Mukai 1987, Powell et al. 1989, Blaber and Milton 1990, Robertson and Duke 1990, Sebatès 1990, Drake and Arias 1991a,b, Tzeng and Wang 1992 1993). The species composition of samples of fish larvae and juveniles from Yenliao Bay reflects the diverse habitats of the bay. Meanwhile, the abundance of fish larvae was highly significantly correlated with environmental factors. The geomorphology and hydrography of the embayment environment seem to be a key factors in determining the occurrence and diversity of fish larvae and juveniles in the bay.

Table 2. Canonical correlation between abiotic and biotic factors (H', species diversity index)

No. axis	Eigenvalue	Canonical correlation	χ^2	*d.f.*	Sign. level
1	.6141	.7836	56.662	25	.0003
2	.5087	.7132	33.336	16	.0067
3	.4409	.6640	15.924	9	.0685
4	.0657	.2563	1.681	4	.7942
5	.0007	.0258	.016	1	.8984

Coefficients of the variables of first 2 canonical axes

Biotic factors	Axis 1	Axis 2	Abiotic factors	Axis 1	Axis 2
Larvae	0.42470	−0.51573	Temperature	1.13464	0.73244
Zooplankton	−0.01341	0.57289	Depth	0.46546	−0.40817
Egg	−0.21668	−0.93386	Salinity	0.09850	−0.06082
H'	−1.50958	0.45656	pH	−0.14713	−0.94325
Species	0.35278	−0.10804	DO	0.43557	0.43409

The species compositions of fish collected in the nearshore waters with the Maruchi net and a commerciai net differed greatly. The former was dominated by larvae of coral-reef fishes, while the latter was dominated by juveniles of pelagic fishes such as *E. japonicus* (Fig. 5a, b). The reason is that most of coral-reef fishes spawn eggs which adhere to the rocky bottom. After hatching, the larvae move to the pelagic habitat around coral reef, and were collected in great amounts in the nearshore stations by the Maruchi larval net (Figs. 5a, 7a-d). As the larvae grow to juveniles, they seek suitable coral-reef habitats in which to live (Scheltema 1971, Hadfield 1978, Jackson and Strathmann 1981, Scheltema and Williams 1983, Domanski 1984, Pechenik et al. 1984, Richmond 1985, Christopher and Leggett 1987, Jenkins and May 1994). Probably because of this, juvenile coral-reef fishes were rarely collected by the commercial larval net (Fig. 5b). On the other hand, *E. japonicus* spawns offshore and its larvae move inshore after hatching (Fig. 6). This phenomenon was also found in the Japanese sardine (*Sardinops melanosticta*) in Sagami Bay (Nakata 1989). Accordingly, juveniles of Engraulidae and Clupeidae were collected in greater numbers at nearshore stations with the commercial larval net (Fig. 5b). In addition, *Rhinogobius* sp. is a diadromous species like the other freshwater gobies, *Stenogobius genivittatus* and *Awaous stamineus*, whose larvae spend a period of time in the sea, metamorphosis, and return to a freshwater stream as juveniles (Radtke et al. 1988). Probably for this reason, the larvae of *Rhinogobius* sp. were more abundant at offshore stations (Fig. 7e). Apparently, fish behavior and life history stage transition are other key factors affecting the perceived occurrence, abundance, and distribution of fish larvae and juveniles in nearshore waters.

High densities of fish larvae and zooplankton were found at nearshore Stations 2-6 (Figs. 2, 8). These stations seemed to be near the estuarine front as indicated by the low mean salinity with large standard deviations. The front functions as a barrier that causes an aggregation of fish larvae and zooplankton in the area (Nakata 1989). Fish larva and juvenile aggregation in the front is not only related to hydrological conditions, but also is related to the abundance of prey organisms and physiographic features (O'Boyle et al. 1984, Sinclair and Iles 1985). The peak abundances of fish larvae and zooplankton were mismatched at the nearshore stations (Fig. 8). The mismatch was also found in Bryant's Cove, Newfoundland during July and August 1979 (Frank and Leggett 1985), and it was considered to be due to the predation of zooplankton on fish larvae (Taggart et al. 1989), which depended on the size and species of zooplankton (Ogawa and Nakahara 1979, Frank and Leggett 1986, Frank 1988). The zooplankton collected by the Maruchi larval net included both micro- and macrozooplankton. Macrozooplankton prey on fish larvae, which in turn, prey on microzooplankton. Whether the mismatch was due to the predation of macrozooplankton or the independent distribution of microzooplankton and fish larvae, all have the potential to influence the survival of fish larvae and subsequently their density distribution (Cushing 1990). To understand small-scale fluctuations of fish larvae in the bay, the interactions between fish larvae and zooplankton must first be determined.

In conclusion, the community structure of fish larvae in Yenliao Bay consists of resident rocky environment fishes, coastal pelagic fishes, and estuarine species. Fish larvae were most abundant and diverse in May and tended to concentrate in nearshore shallow waters. The hydrography and geomorphology of the bay and life history patterns of the fishes are key factors that determine the species diversity of the larval fish community.

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鹽寮灣仔魚之種類組成及分布

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1992年10月起至1993年9月止，按月於臺灣東北部鹽寮灣的11個測站以Maruchi仔稚魚網進行採集，共計採獲仔魚9969尾，分屬於80科138種。仔稚魚群集包括岩礁性、河口性及沿岸表層性種類。雀鯛科仔魚的數量最多，佔總採集尾數的23%。其次是天竺鯛科(15%)、雙邊魚(3%)、圓花鰹(9%)、鰺科(6%)、鰕虎魚科(6%)、燈籠魚科(4%)、三鰭鳚科(3%)、日本鯷(3%)、大眼鯛(2%)及石狗公(2%)。這11種合計佔總採集尾數的82%。仔稚魚種類的多樣性與鹽寮灣的地質、水文環境的複雜性有關，而且隨季節及水深而改變。仔稚魚種類及數量5月達最高峰。近岸測站的仔魚比離岸測站多。表層性仔魚在外海孵化後，逐漸向近岸移動。沿岸淺水域生產力高，動物性浮游生物豐富，是仔稚魚漁場形成的主因。仔魚與動物性浮游生物數量的空間變化不一致現象，以及仔魚的出現與生活史變化之關係也在文中予以討論。

關鍵詞：仔魚, 種類組成, 季節性出現, 空間分布。

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