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Species Composition and Seasonal Occurrence of Mullets (Pisces, Mugilidae) in the Tanshui Estuary Northwest Taiwan

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ABSTRACT

Species composition and seasonal occurrence of mullets in the Tanshui estuary of northwest Taiwan were studied from September 1995 through September 1996. In total, juveniles and young from 6 species of mullet (*Chelon affinis, Chelon macrolepis, Chelon subviridis, Moolgarda cunnesius, Moolgarda formosae* and *Mugil cephalus*) were collected. Among them, *C. macrolepis* was the most abundant, while the presence of *C. subviridis, M. cunnesius* and *M. formosae* were first recorded in the estuary. Seasonal occurrence of juvenile mullets differed among species and represented a temporal succession dependent on the spawning period of adult mullets. Juveniles of *M. cephalus* occurred primarily in January, while those of *C. macrolepis* from January to March (young mullets year round), *C. affinis* in April (young mullets from September to November), *C. subviridis* from May to July, *M. formosae* and *M. cunnesius* from August to November. The occurrence of mullets in the Tanshui estuary was also associated with their salinity preference, which change with life history stages.

***Key words:** Mugilidae, Temporal succession, Salinity, Estuary.*

INTRODUCTION

Mullets (Pisces, Mugilidae) are dominant fish in coastal shallow waters and estuaries of the tropics and subtropics. Most species spawn in the sea and use estuaries as nursery grounds. Thus, they are estuarine-dependent marine fishes (Blaber, 1987; McDowall, 1988; Day *et al.*, 1989). Mullets are important food fishes that are either captured from the wild stock or restocked from juveniles collected in estuaries (Liao, 1981). Among the 66-80 species of mullets recorded in the world (Nelson, 1994), approximately 10 species have been commercially cultivated, with the circumtropically ubiquitous grey mullet *Mugil cephalus* remaining the most popular (Nash and Shehadeh, 1980). For effective management and exploitation of the Mugilid fishes, it is necessary to understand the species composition and seasonal occurrence of juvenile mullets in estuaries. This subject has been well investigated in southeastern Africa (Blaber, 1987), the northern Gulf of Mexico (Collins and Stender, 1989; Ditty and Shaw, 1996), Brazil (Vieira, 1991), and the Mediterranean and Aegean Seas (Koutrakis *et al.*, 1994; Gisbert *et al.*, 1996).

In Taiwan, 13 species of Mugilid fishes were recorded and found to be widely distributed in coastal waters and estuaries (Liu, 1991; Liu and Shen, 1991; Chang *et al.*, 1999). However, studies on species composition and seasonal occurrence of mullet juveniles are relatively limited. Distribution and occurrence of *Mugil cephalus* along the western coast (Tang, 1975; Tung, 1981; Lee and Kuo, 1990) and *Chelon*

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affinis and *C. macrolepis* in the northwestern coasts have been documented (Lee, 1992; Tzeng and Wang, 1992 and 1993; Tzeng, 1995; Tzeng *et al.*, 1995). In southern Taiwan, the seasonal occurrence of *C. macrolepis* (Chen *et al.* 1999) and an additional 3 species, *C. haematocheilus, C. subviridis* and *Ellochelon vaigiensis*, have been examined (Su, 1997). Except the 6 species of juvenile mullets mentioned above, the remaining species have yet to be studied. This study aims to examine the species composition and seasonal occurrence of juvenile mullets in the Tanshui estuary, along the northwestern coast of Taiwan.

MATERIALS AND METHODS

The Tanshui river is the largest river in northwestern Taiwan (Fig. 1). The estuarine region of the river is well-mixed with a tidal range from 1.5-3 m, neap and spring tides, respectively (Lee and Chu, 1965). The estuary and its adjacent waters are traditional mullet fishing grounds where adults are harvested for consumption and juveniles are collected for restocking. Sampling was conducted in the northern shore of the Tanshui estuary (Fig. 1), where the mullets were dominant (Lee, 1992; Tzeng and Wang, 1992; Wang and Huang, 1992). The fish were collected by a hand net (30 cm in diameter, 25 cm in depth and 1 mm in mesh size) twice a month from September 1995 to September 1996. Sampling duration for each collection was approximately 30 min during daytime flood-tide. Water temperature and salinity were monitored using a microprocessor conductivity meter (LF196, WTW).

Species identification was based on the lower jaw dentition and the body melanophore distribution pattern as described by Liu and Shen (1991) and Su (1997). Total length of fresh fish was measured to the nearest 0.1 mm with digital calipers. Development stage of the fish was determined according to their total lengths, i.e., juvenile is 20-50 mm and young 50-180 mm (Anderson, 1958; Thomson, 1963; Tung, 1981).

RESULTS

Water temperature fluctuated season-

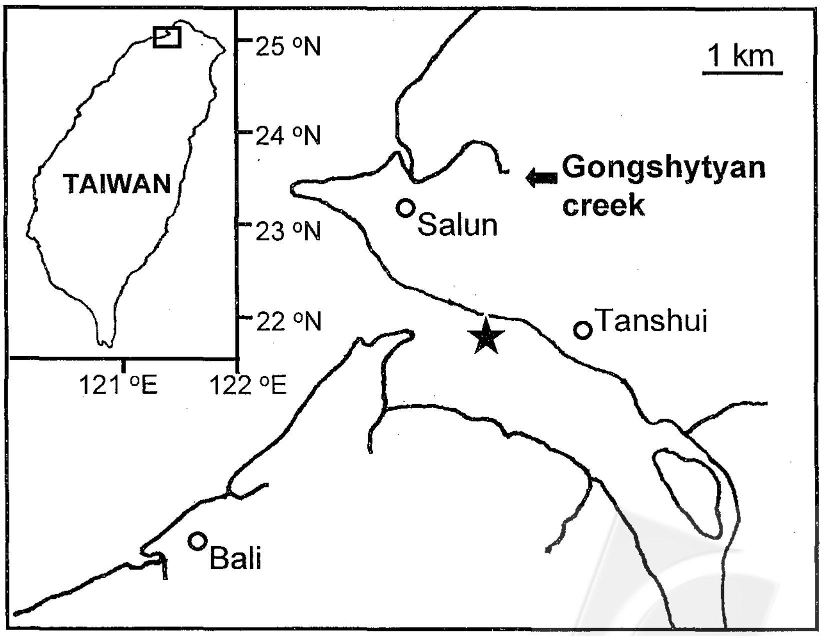

Fig. 1. Sampling site (★) of juvenile mullets in the Tanshui estuary of the northwestern Taiwan.

ally. It averaged 23.8 ± 4.7 ℃ with a low of 16.0 ℃ in February and a high of 30.5 ℃ in July. Surface salinity fluctuated dramatically. It averaged 13.4 ± 11.3 ‰ and ranged from 2 ‰ to 33.4 ‰ (Fig. 2). The low salinity in September 1995 through February 1996 and in late July 1996 was probably due to the precipitation resulting from northeastern monsoon and typhoon, respectively. These large ranges in temperature and salinity indicated that the physical condition of the Tanshui estuary was very severe.

A total of 2,487 individuals, representing 3 genera and 6 species of mullets, were collected (Table. 1). *Chelon macrolepis* was the most abundant, making up 61.8% of the total catch, followed by *C. subviridis* (15.0%), *Moolgarda formosae* (12.2%), *C. affinis* (4.7%), *Mugil cephalus* (3.5%) and *Moolgarda cunnesius* (2.9%). Among them, the first records of *C. subviridis, M. cunnesius* and *M. formosae* in the Tanshui estuary were obtained. Total length of the fish ranged from 12-125 mm, indicating that the mullets recruiting to the estuary were primarily juvenile and young stages, particularly those of *C. macrolepis* and *C. affinis*.

Seasonal variation in total length of mullets is shown in Fig. 3. *Chelon*

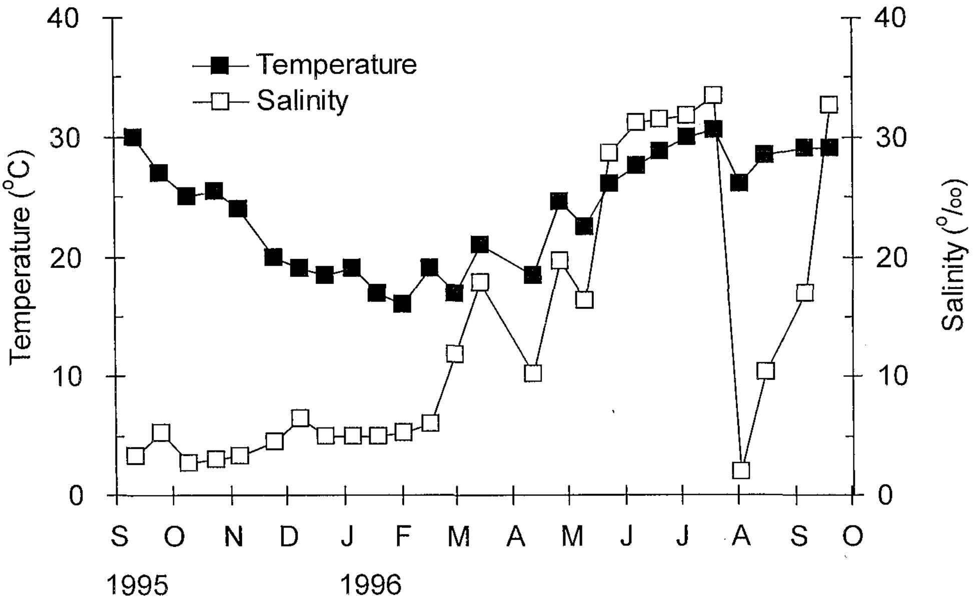

Fig. 2. Seasonal variations in water temperature and salinity in the Tanshui estuary.

Table 1. Species composition and total length of mullets collected in the Tanshui estuary

Species	n	%	Total length (mm)	
			range	mean ± SD
Chelon macrolepis	1536	61.8	12.0-125.0	46.5 ± 19.6
Chelon subviridis	372	15.0	12.0-51.0	25.0 ± 9.4
Moolgarda formosae	303	12.2	23.0-44.0	31.8 ± 3.8
Chelon affinis	117	4.7	15.0-95.5	25.4 ± 12.3
Mugil cephalus	87	3.5	21.0-30.5	25.7 ± 1.8
Moolgarda cunnesius	72	2.9	30.0-41.5	34.6 ± 2.9
Total	2487	100.0	12.0-125.0	39.4 ± 18.6

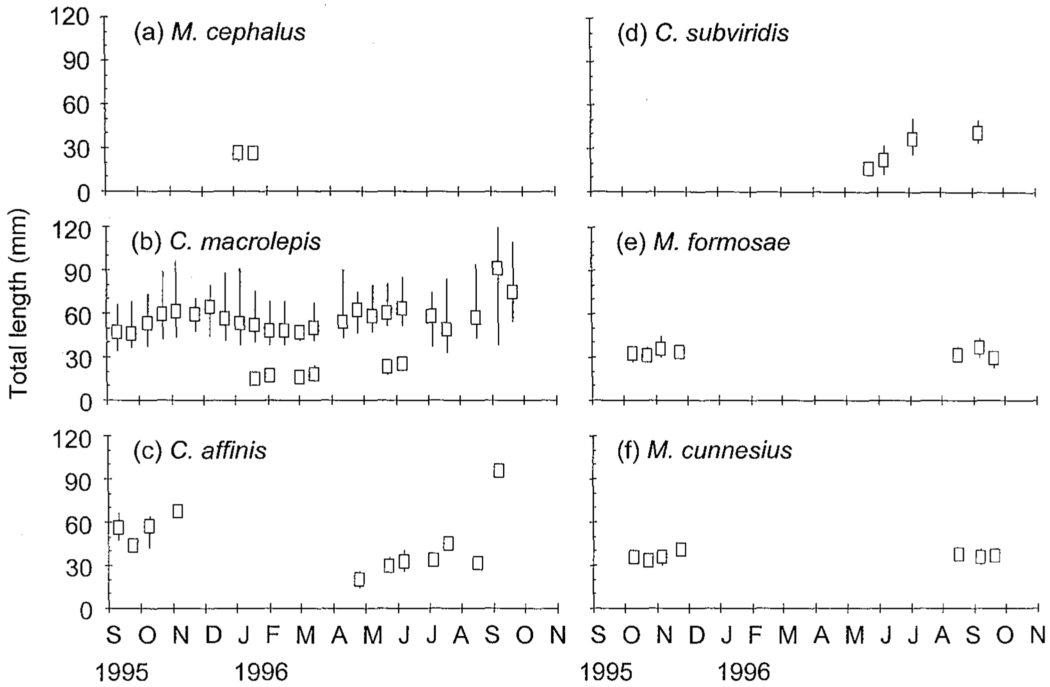

Fig. 3. Monthly changes in mean total length of *M. cephalus* (a), *C. macrolepis* (b), *C. affinis* (c), *C. subviridis* (d), *M. formosae* (e) and *M. cunnesius* (f) collected in the Tanshui estuary (Vertical line: range).

macrolepis constituted of a small-size group (juvenile mullets) at 10-20 mm and a large-size group (young mullets) at 40-120 mm. The former group occurred from mid winter through spring while the latter was present year round (Fig. 3b). *Chelon affinis* also constituted of two size groups with juveniles (ca. 30 mm) in the summer and young (ca. ≥ 60 mm) in autumn (Fig. 3c). The remaining 4 species averaged approximately 30 mm and briefly occurred in summer through autumn (*C. subviridis, M. formosae* and *M. cunnesius*) (Figs. 3d-f) and in winter (*M. cephalus*) (Fig. 3a).

Seasonal occurrence of mullets differed among species (Fig. 4). Regarding the juvenile stage of mullets, *M. cephalus* concentrated in January. *Chelon macrolepis* appeared from January to March, *C. affinis* in April, and *C. subviridis* from May to July. *Moolgarda formosae* and *M. cunnesius* were limited temporally from August to November. These results indicated that the occurrence of juvenile mullets in the estuary followed a pattern of species related temporal succession. In addition, the temporal occurrence of juvenile mullets showed greater similarity within than between genera, i.e., the 3 species of the genus *Chelon* and the 2 species of the genus *Moolgarda*. In young mullets, *C. macrolepis* was abundant and occurred year round, while the presence of *C. affinis* was fragmentary from September through November.

The size and seasonal occurrence of individuals suggested that *C. macrolepis* was resident species in the estuary, while *C. affinis* in doubt and the other 4 species might only take up estuarine residency during their juvenile stages.

The occurrence of mullets in relation to environmental factors in the estuary is shown in Fig. 5. For juvenile mullets, *M. cephalus* occurred during periods of low temperatures (17-19 ℃) and low salinity (5 ‰). A similar preference was exhibited by *Moolgarda* species, with both *M. formosae* and *M. cunnesius* occurring at relatively high temperatures (24-29 ℃) and across a

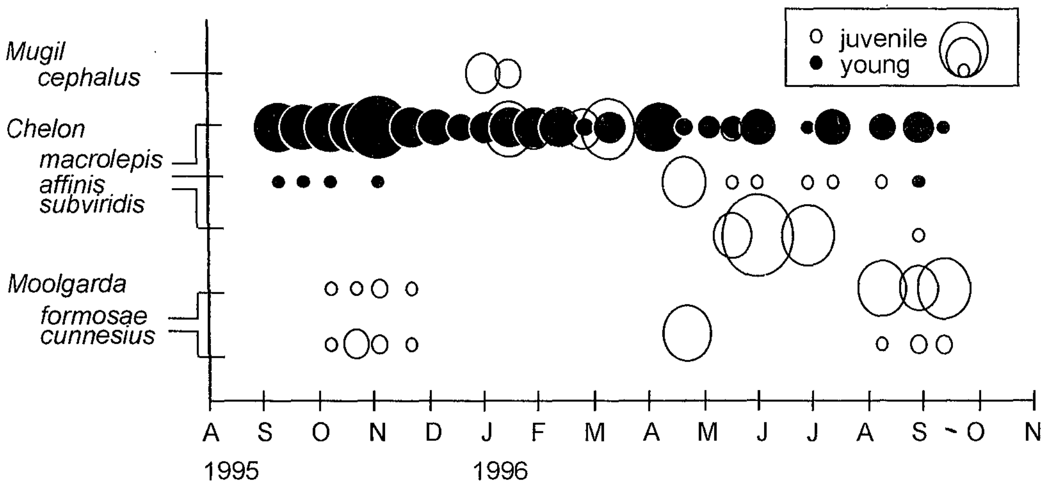

Fig. 4. Seasonal occurrence of juvenile and young mullets in the Tanshui estuary (Circular size: number of fish; circular scale: 100, 50 and ≤ 10 fish).

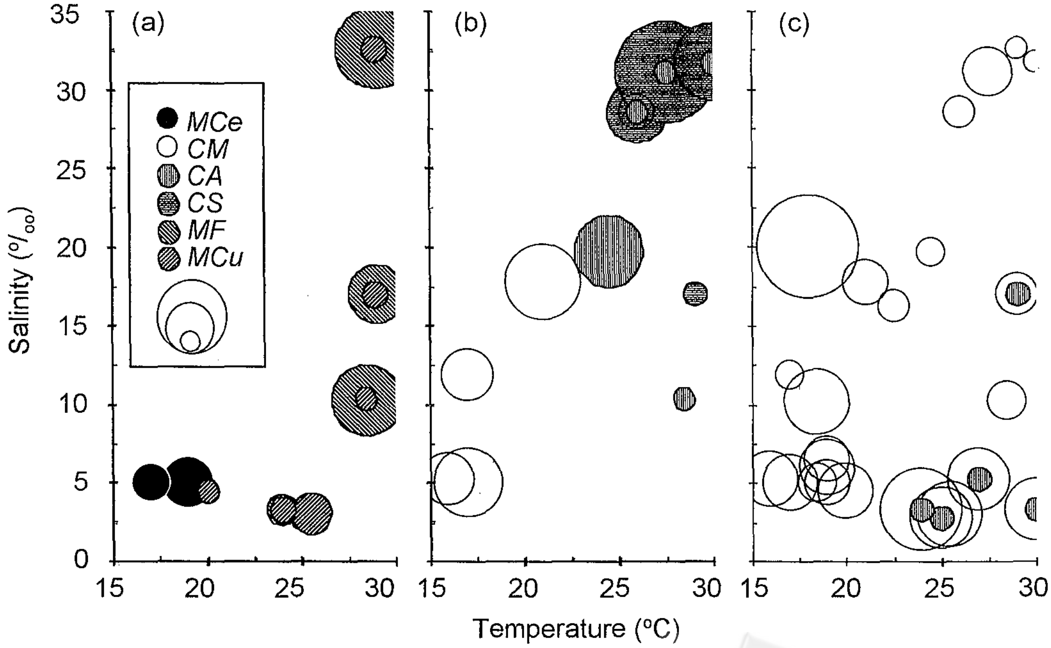

Fig. 5. Occurrence of juvenile (a, b) and young mullets (c) in relation to temperature and salinity in the Tanshui estuary (Circular size: number of fish; circular scale: 100, 50 and ≤ 10 fish; *MCe: M. cephalus; CM: C. macrolepis; CA: C. affinis; CS: C. subviridis; MF: M. formosae; MCu: M. cunnesius*).

range of salinities (2.5-32.5 ‰) (Fig. 5a). A gradual preference was shown by *Chelon* species. *Chelon macrolepis* was the most tolerant of temperature (16-26 ℃) and salinity (5-28 ‰) changes, followed by *C. affinis* 24-30 ℃ and 10-32 ‰ , and then finally with *C. subviridis*, the least tolerant, occurring from 26-30 ℃ and 17.5-32 ‰ , respectively. It seemed that *C. macrolepis* primarily occurred in relatively low temperature and low salinity, while *C. affinis* was present in moderate situations and *C. subviridis* in relatively high situations (Fig. 5b). In young mullets, *C. macrolepis* was both eurythermal and euryhaline, but dominated in relatively low salinity (less than 7.5 ‰). *Chelon affinis* occurred in relatively high temperatures (24-30 ℃) and low salinity (less than 5 ‰) (Fig. 5c). These indicated that preferences in temperature and salinity varied between both species and development stages.

DISCUSSION

The larval and juvenile fish community in the Tanshui river system has been investigated by many researchers, however, only 3 species of mullets, *C. affinis, C. macrolepis* and *M. cephalus* were recorded (Lee, 1992; Tzeng and Wang, 1992 and 1993; Tzeng, 1995; Tzeng *et al.*, 1995). In the present study, along with the abovementioned species of mullets, we collected an additional 3 species of juvenile mullets, *C. subviridis, M. cunnesius* and *M. formosae*, which have not been previously recorded in the Tanshui estuary (Table 1). The differences in the presence/absence of mullet species between this and previous studies were probably due to the following causes. First, juvenile mullets in the estuary are active schooling swimmers (Day *et al.*, 1989), and it is therefore difficult to catch with the larval or bag nets which were used by previous researchers. Secondly except *C. macrolepis*, species did not occur in the estuary year round and because of strict temporal concentration, low sampling frequency would not reveal their presence. Finally, the development of a new key established by Su (1997) and used in this study is more effective in identifying juveniles.

Resident species did not widely migrate, thus, almost all of their life history stages and size range could be found in a particular habitat. On the contrary, the migratory species changed their habitat with life stage and a single life stage with a limited size range of the species was found (McDowall, 1988). According to the size of the fish in the estuary through the season, *C. macrolepis* was regarded as resident species while the other species should be regarded as migratory species (Fig. 3, 4). In fact, Al Daham and Yousif (1990) and Hussain and Samad (1995) recorded permanent residents of *C. subviridis, M. cephalus* and *M. cunnesius* in an estuary of southern Iraq and along the coast of Pakistan, respectively. Liu and Shen (1991) considered that *M. formosae* was an endemic species in the southern Taiwan. Lee (1992) found *C. macrolepis, C. affinis* and *M. cephalus* at size ranges of 18-235 mm, 12-112 mm and 251-400 mm SL in the Tanshui estuary, respectively. Wen and Chen (1996) found *C. subviridis* at a size range of 100-230 mm FL in Kaohsiung harbor. Kuo and Shao (1998) considered *C. affinis, C. macrolepis* and *C. subviridis* as common species occurred in the mangrove swamps along the western coast of Taiwan. Chen *et al.* (1999) found *C. macrolepis* at a size range of 20-207 mm FL in the area of Kaohsiung harbor. Thus, these 5 species may also be resident species. However, our results could not support estuarine residency in these species because only early life stages were collected. This discrepancy may be a result of sampling gear bias. Since, in Mugilid fishes, an ontogenetic transition from pelagic to benthic feeding occurs (Blaber, 1987), larger benthos associated mullets may not of been easily collected with the hand net used in this study.

Most mullets use estuaries as nursery areas and, thereafter, recruitment of individuals to estuaries should correspond to adult spawning period and larval duration (Blaber, 1987; Collins and Stender, 1989; Koutrakis *et al.*, 1994; Ditty and Shaw, 1996). In Taiwan, previous studies indicate that *M. cephalus* spawns in the late November through late January (Chen and Su, 1986; Su and Kawasaki, 1995; Chang *et al.*, 2000) while *C. macrolepis* spawns from December through May (Chen *et al.*, 1999). The larval duration of Mugilid fishes was estimated to be approximately 1-2 month by laboratory rearing experiments (Nash and Koningsberger, 1981) and otolith based daily age (Chang *et al.*, 2000). Consequently, juvenile mullets of *M. cephalus* should occur in the estuaries from December through February and *C. macrolepis* from January through May that are both consistent with findings in the present study (Fig. 4). In contrast, the species of which spawning period remains unknown could be backcalculated from larval duration and the juvenile occurrence in the estuaries (Koutrakis *et al.*, 1994). Therefore, the spawning period of *C. affinis* was estimated to occur from February through March, *C. subviridis* from April through May and *M. formosae* and *M. cunnesius* from June through July. Accordingly, the difference in the spawning period of adult mullets could be regarded as the primary mechanism controlling temporal succession of juvenile mullet occurrence in the Tanshui estuary. Currently, we have no sufficient data to clarify why juvenile occurrence in the estuary was more similar within than between genera (Fig. 4). This may be due to the collection of a few species of mullet and their occurrence was coincidental.

Despite the biological factors mentioned above, researchers have postulated that the influence of environmental factors such as depth (Collins and Stender, 1989), salinity and temperature (Vieira, 1991; Koutrakis *et al.*, 1994) and turbidity (Blaber, 1987; Cyrus and Blaber, 1987a and 1987b) could alter the distribution of mullets in estuaries. In this study, Mugilid species also differed in preferences for temperature and salinity (Fig. 5). With juvenile mullets, the correlation between occurrence and temperature should be related to seasonal but spatial patterns as postulated in Cyrus and Blaber (1987a). Inversely, the correlation with salinity in this study may reveal the optimal preference of the fish. In juveniles of *M. cephalus*, the fewer numbers collected in low salinity in this study contrast the large numbers collected in high salinity by Lee (1992) and Chang *et al.* (2000), where the sampling site was located in the Gongshytyan creek estuary, a tributary of the Tanshui estuary (Fig. 1). Furthermore as in young mullets, the euryhaline preference of *C. macrolepis* could correspond to its estuarine-resident nature and hence the species was abundant in the estuary (Lee, 1992; Tzeng and Wang, 1993; Tzeng, 1995; Tzeng *et al.*, 1995). Accordingly, salinity could be regarded as a determinant environmental factor altering the distribution of juvenile and young mullets in the Tanshui estuary.

In conclusion, the seasonal occurrence of mullets in the estuary was primarily dependent upon the spawning period of the fish and their salinity preferences at the early life stages.

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台灣西北部淡水河口域鯔科魚類之種類組成及季節性出現

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(2000年9月4日收件；2000年10月6日接受)

本研究自1995年9月至1996年9月間，於臺灣西北部淡水河口域採集鯔科魚類，以瞭解其種類組成及季節性出現。結果共發現前鱗鮻 (*Chelon affinis*)、大鱗鮻 (*Chelon macrolepis*)、白鮻 (*Chelon subviridis*)、長鰭凡鯔 (*Moolgarda cunnesius*)、臺灣凡鯔 (*Moolgarda formosae*) 及烏魚 (*Mugil cephalus*) 等六種，發育階段分別爲稚魚及幼魚的鯔科魚類。其中以大鱗鮻爲最優勢種，白鮻、長鰭凡鯔及臺灣凡鯔則首次於該河口域發現。鯔科稚魚的出現季節因種而異，其時間演替與成魚的產卵期有關。烏魚主要出現期爲一月、大鱗鮻一月至三月 (幼魚全年出現)、前鱗鮻四月 (幼魚九月至十一月)、白鮻五月至七月、長鰭凡鯔及臺灣凡鯔八月至十一月。鯔科魚類在淡水河口域的出現與不同發育階段的鹽度喜好性有關。

關鍵詞：鯔科，時間演替，鹽度，河口。

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