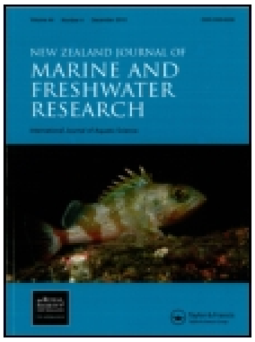

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Seasonal occurrence and distribution of flatfish (Pisces: Pleuronectiformes) in inlets and shallow water along the Otago coast

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The distribution and seasonal occurrence of planktonic larvae, juveniles, and adult flatfish were studied. Larvae of *Peltorhamphus latus, Rhombosolea plebeia,* and *R. tapirina,* were common in the Otago Harbour plankton from late winter to early summer, and settlement of larvae resulted in peak abundance of juveniles of all three species in Otago Harbour, Papanui Inlet, and Hoopers Inlet over summer. Densities of juveniles in the three inlets subsequently declined over winter, probably mainly because of predation and emigration. *Rhombosolea plebeia* and *R. tapirina* were the only adult flatfish found in the inlets. Eight flatfish species were caught off-shore; juvenile and adult *Pelotretis flavilatus, Peltorhamphus novaezeelandiae, P. tenuis,* and *P. latus* were relatively common, but only a few, mainly adult, *Colistium nudipinnis, C. guntheri, R. plebeia,* and *R. tapirina* were caught. For the common species there was a strong size-depth relationship in the off-shore waters; smaller individuals were found in the shallower, near-shore waters. All juvenile flatfish caught were concentrated in finite nursery areas, in inlets or shallow coastal water. Inlets and shallow coastal waters are of vital importance to populations of these flatfish and, if present stocks are to be maintained, their nurseries must be preserved.

Keywords: Blueskin Bay; Otago Peninsula; Pleuronectiformes; distributions; fish larvae; juveniles; inlets; fishery resources.

INTRODUCTION

Flatfish, which constitute a significant proportion of the Otago regional wetfish catch, are often found in coastal inlets and estuaries. New Zealand studies on flatfish in these areas have been limited to the Avon–Heathcote Estuary (Webb 1972, 1973a, b, Knox & Kilner 1973) and the Ahuriri Estuary (Kilner & Akroyd 1978). The main aim of this study was to assess the importance of the inlets and shallow waters along the Otago coastline as nurseries for juvenile flatfish. Planktonic larval stages, juveniles, and adults in inlets and off shore were sampled.

The inlets of Otago Harbour, Papanui Inlet, and Hoopers Inlet, and the off-shore waters of Blueskin Bay (Fig. 1) were sampled. Otago Harbour (4823 ha) is the largest of the inlets; Papanui and Hoopers Inlets are both about 400 ha. Portobello Marine Laboratory records show that the mean monthly salinities and water temperatures in Otago Harbour vary between 32.5 and 34.8‰, and 6.4 and 16.0 °C respectively. In Papanui and Hoopers Inlets, salinity and temperature ranges of 32.43–35.05‰, 6.1–19.0 °C and 29.79–34.50‰, 5.3–20.0 °C respectively were recorded between 1976 and 1978 (Roper 1979). All these inlets have a high flushing rate, and water exchange with the open sea is rapid. In all three inlets extensive areas of sandflats are exposed at low tide. Blueskin Bay is a large open bay with a sandy bottom sloping gently off shore. Robertson (1973) found little difference between surface and bottom salinities and temperatures; they varied between 33.80 and 34.91‰, and 9.0 and 16.6 °C respectively.

METHODS

PLANKTONIC LARVAE

The occurrence and abundance of planktonic larvae were studied in Otago Harbour. Papanui and Hoopers Inlets were not sampled, since, like the harbour, they are flushed with water from the open sea on each tide and it is unlikely that their plankton is very different from that of the harbour. All the planktonic flatfish larvae taken were identified to species level. Eggs of local flatfish, which are all very similar, can be identified reliably only to genus level (Colman 1973, Robertson 1975), and were not retained by the net used.

Plankton samples were collected off the Portobello Marine Laboratory wharf (Fig. 1) in the current of the flood tide. Up to 500 m^3 of water had to be filtered to obtain acceptable numbers of larvae,

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so a large mesh (1.0 mm aperture) was used to reduce catch size and facilitate sorting. This mesh size reliably retained larvae but not eggs. The net had a wooden frame with a mouth area of 0.25 m^2 (0.71 × 0.35 m); a flowmeter was placed in the mouth so that the volume filtered could be calculated. Samples were collected near the surface at night as preliminary work had shown that this yielded the largest catches (Roper 1979), but it was necessary to sample for about 3 h to obtain sufficient numbers of larvae. The net was placed in the water at low tide and removed at mid tide when tidal flow was at its peak, up to 0.4 $m.s^{-1}$. The contents of the net were washed out and preserved in 4% formaldehyde before sorting under a dissecting microscope. Regular samples were taken from August 1977 to August 1978; sampling was fortnightly while larvae were common in the plankton, but was at monthly intervals from January to June 1978.

JUVENILE AND ADULT FISH IN THE INLETS

Casual observers reported that juvenile flatfish were common at times around the edges of tidal sandflats in the inlets. This shallow water, therefore, was sampled regularly at about monthly intervals from June 1976 to June 1978 with a 1.5 m wide push-net (Riley 1971) having a stretched knot-to-knot mesh of 17 mm. The net was pushed in water less than 0.5 m deep at low tide at two locations in the harbour and at one location in each inlet (Fig. 1). Each station was 170 m long, so the collective area fished every month at the four stations was close to 1000 m^2.

Catches of juvenile fish were preserved in 10% formaldehyde before processing. Storage in formaldehyde for less than a week had no appreciable effect on length (Roper 1979). The samples were sorted into species and the total length of each fish was measured to the nearest millimetre within a week of capture.

Juveniles were fished for in the channels of Otago Harbour and Papanui Inlet at low tide in water 1.5–3.0 m deep with a 3 m wide beam trawl having a fine cod-end mesh of 17 mm, stretched knot-to-knot. However, samples taken during both winter and summer showed that juvenile fish occurred in this deeper water only occasionally (Roper 1979), and this sampling was therefore discontinued.

Adult fish were not sampled from Papanui and Hoopers Inlets and only those in Otago Harbour were studied. The fine-mesh beam trawl used to fish for juveniles in the harbour channels was not suitable for adult fish as it clogged with weed during long tows, so adult fish were sampled with a beach seine (or 'drag') net, 24 × 1.5 m, with a stretched knot-to-knot mesh of 105 mm. During 1 h either side of low tide, fishing was carried out at one of four stations in the channels along Otago Harbour (Fig. 1) on 10 days between June 1977 and February 1978. The choice of station on any one day depended upon the amount of algae present and the weather as it was best to be sheltered from the wind. Catches were quantified by relating them to the duration of each drag. Fish were identified and their total lengths measured to the nearest centimetre within a few hours of capture.

JUVENILE AND ADULT FISH IN OFF-SHORE WATER

Juvenile and adult fish in Blueskin Bay were sampled in three areas (Fig. 1) with a Vigneron-Dahl otter trawl from r.v. *Munida.* The trawl, described by James (1970), had a cod-end cover with a stretched knot-to-knot mesh of 19 mm. Every month, from June 1976 to May 1977, a trawl shot was made in each of the three areas. Trawling speed was about 2 knots and each shot lasted 30 min. Fish were identified and their total lengths measured to the nearest centimetre within a few hours of capture.

RESULTS

PLANKTONIC LARVAE

Planktonic larvae of six flatfish species were found in the harbour, but the only three species commonly taken were *Peltorhamphus latus, Rhombosolea plebeia,* and *R. tapirina.* Other species caught during August 1977 were *Pelotretis flavilatus* (3), *Peltorhamphus novaezeelandiae* (1), and *R. retiaria* (2). The three common species occurred from late winter 1977 through spring to early summer and reappeared in late winter 1978 (Fig. 2). *P. latus* was the most abundant, with a total of 298 larvae caught and a maximum density of 143 per 500 m^3. A total of 143 *R. tapirina* were caught, with a maximum density of 45 per 500 m^3, and *R. plebeia* was the least common of the three — only 33 were caught, maximum density 16 per 500 m^3. Although only large larvae were caught, eggs and small larvae were probably present in the plankton but were probably not retained by the coarse mesh.

All three common species were already present in the first sample in August 1977. This was probably near the start of their seasonal occurrence, however, as densities subsequently increased, and in 1978 they did not reappear until August. Although older larvae did not appear until late winter in both years, eggs and larvae would have been present earlier and spawning could have occurred in early winter.

JUVENILE AND ADULT FISH IN THE INLETS

Juveniles of only three species of flatfish were caught in the inlets, *Peltorhamphus latus, Rhombosolea plebeia,* and *R. tapirina.* Seasonal peaks of abundance occurred during the warmer months, November to March, but through winter, if present at all, they were caught only in small numbers.

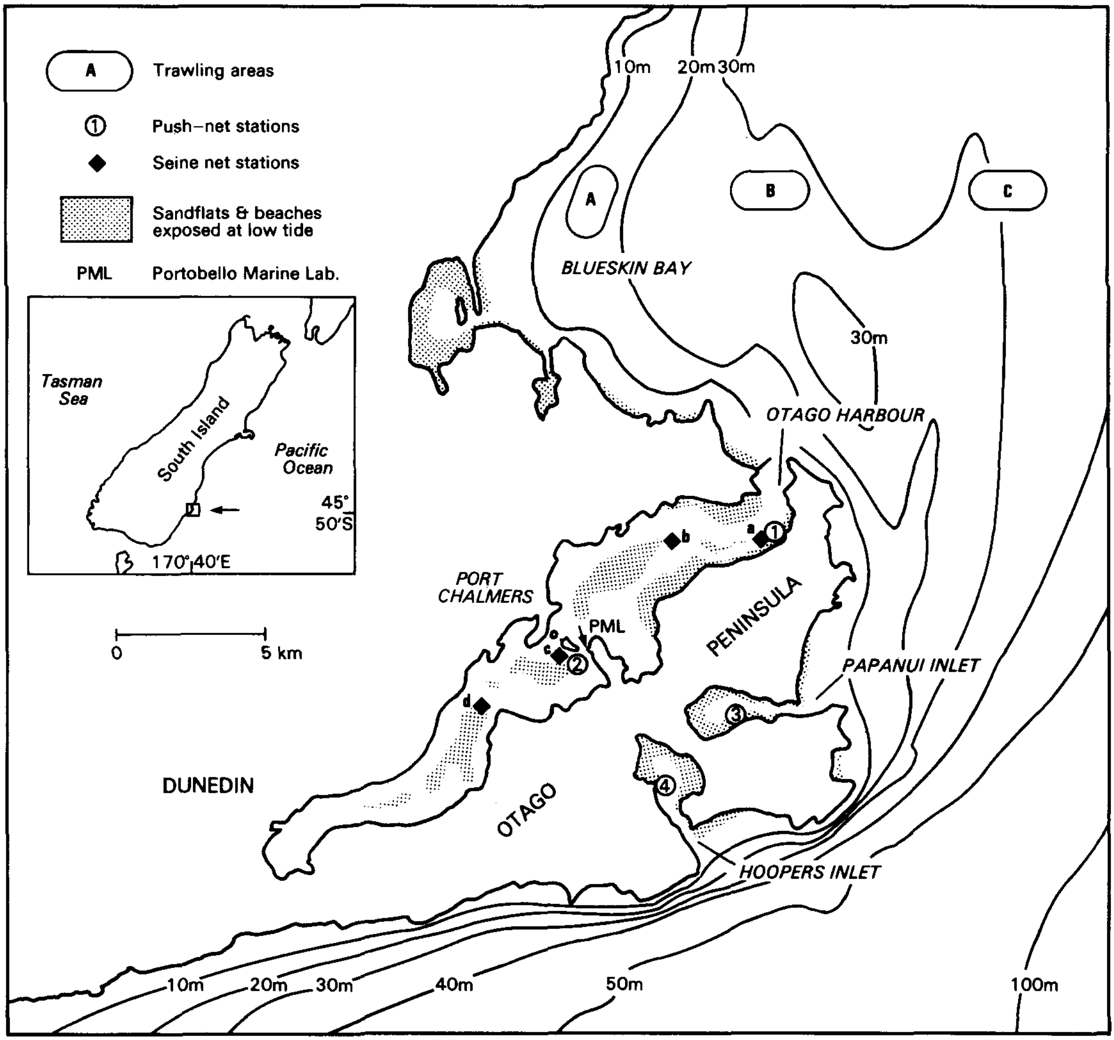


Fig. 1 Map of part of Otago coastline, showing sandflats and beaches, bathymetry, and positions of sampling stations and trawling areas (average depths; A, 15 m; B, 25 m; C, 30 m).

Densities also varied erratically between the four stations. During the 2 years, *P. latus* reached peak densities of 146 and 167 per 1000 m^2 at the four stations combined (Fig. 3a); this species was most abundant at Stns 1 and 2 and reached a maximum density of 296 per 1000 m^2 at Stn 2. In 1977 the peak density of *R. tapirina* was 124 per 1000 m^2 at the four stations combined, but in 1978 it was 207 per 1000 m^2 (Fig. 3b). At various times *R. tapirina* was present at every station in large numbers, but the maximum density of 432 per 1000 m^2 occurred at Stn 2. *Rhombosolea plebeia* was the least common of the three species and reached peak densities, at the four stations combined, of only 55 per 1000 m^2 and 38 per 1000 m^2 during the 2 years (Fig. 3c). During the first season *R. plebeia* occurred in similar numbers at each station, but during the second season was most abundant at Stn 4 where the maximum density found was 124 per 1000 m^2.

Length-frequency distributions for the three species are given in Figs 4–6. When sampling began, during winter 1976, only a few large individuals of these species were present. Although it was not possible to determine their ages accurately, most were almost certainly remnants of the 1975 year class. In spring 1976, large numbers of small fish appeared; after attaining peak densities over summer, their numbers dwindled. Remnants of this year class were

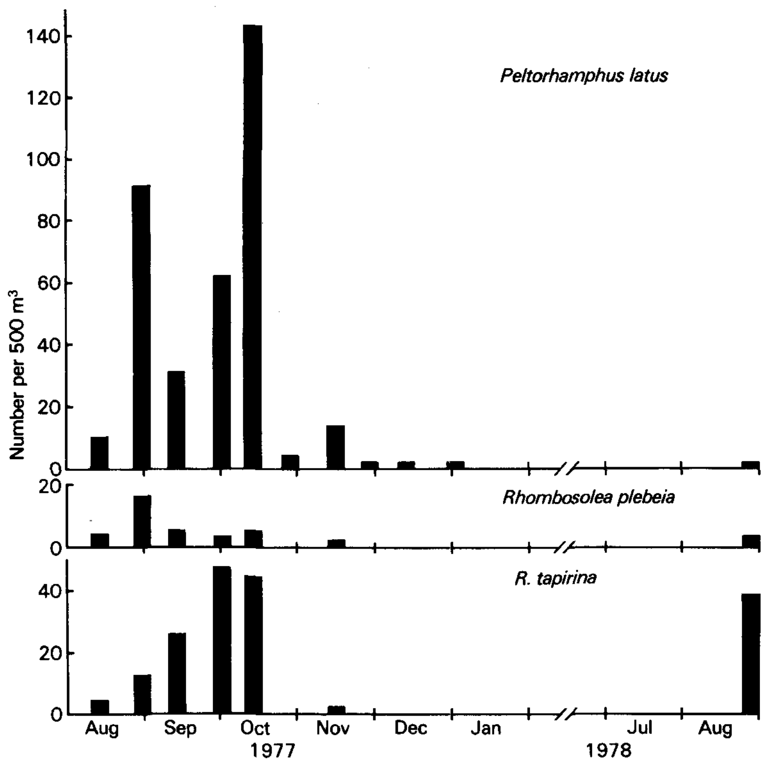


Fig. 2 Occurrence of larval flatfish in the Otago Harbour plankton, Aug 1977 - Aug 1978.

still present when the 1977 year class appeared in winter to spring of that year. When two age groups were present in the same monthly sample, they could generally be separated by length, but it is possible that a few fish were assigned to the wrong year class. Otoliths of some fish were examined, but this failed to clarify the situation. The 1977 year class again reached peak densities over summer before numbers dropped with the onset of winter. In the final sample, one small *R. plebeia,* probably an early arrival of the 1978 year class, was caught. After the summer peaks of abundance, numbers declined at average monthly rates for the three species of 30–48% (Table 1).

The average lengths of fish in each year class tended to increase between successive samples (Fig. 7), but the increases were often erratic and did not accurately reflect growth rates. There was no consistent difference in the lengths of fish from the four stations.

A total of 477 min was spent fishing for adult fish in Otago Harbour, but only 50 *Rhombosolea plebeia* (mean length 28.4 cm, range 18–36 cm) and 27 *R. tapirina* (mean length 27.8 cm, range 21–43 cm) were caught. The numbers of adults caught at the various stations are given in Table 2. Variation in the size of catches was probably affected most by the activity of recreational fishermen rather than by seasonal factors. Once a channel had been fished it probably took some time for numbers to recover. Although only Otago Harbour was fished for adults, local fishermen reported that the same species were caught in Papanui and Hoopers Inlets.

Juvenile and Adult Fish in Off-shore Water

Eight flatfish species were caught in Blueskin Bay. Juvenile and adult *Pelotretis flavilatus, Peltorhamphus novaezeelandiae, P. tenuis,* and *P. latus* were common, but only a few, mainly adult, *Colistium nudipinnis, C. guntheri, Rhombosolea plebeia,* and *R. tapirina* were caught (Table 3). Among the more common species there was a strong size-depth relationship; smaller fish occurred in the shallower, in-shore area A (Fig. 1). As these smaller fish were more numerous than adults, the densities were also greater in shore. Apart from the more uncommon species and *P. novaezeelandiae,* which occurred erratically throughout the year, the other species reached peak densities in summer (Table 4) because of the large number of juvenile fish which were caught then.

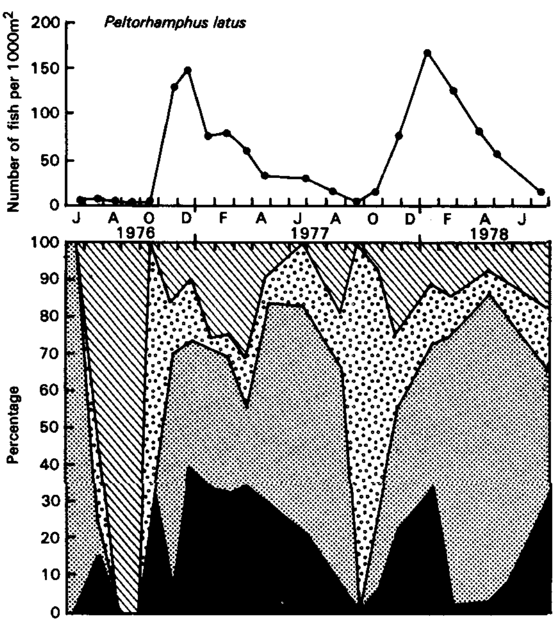
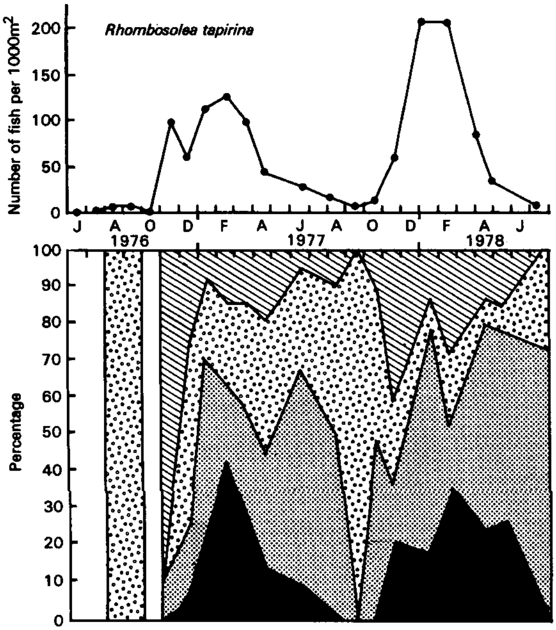


Table 1 Average percentage monthly decrease in numbers of juvenile flatfish after the summer peaks of abundance at the push-net stations in Otago Harbour, Papanui Inlet, and Hoopers Inlet.

	Period	Average monthly decrease (%)
Peltorhamphus latus	Dec 1976 - Sep 1977	30
	Jan 1978 - Jul 1978	32
Rhombosolea plebeia	Jan 1977 - Apr 1977	48
	Oct 1977 - May 1978	35
R. tapirina	Feb 1977 - Sep 1977	37
	Jan 1978 - Jul 1978	48

Table 2 Fishing time and number of adult flatfish (*Rhombosolea* spp.) caught at Stns a to d, Otago Harbour.

Date	Stn	Fishing time (min)	No. of fish caught *R. plebeia*	*R. tapirina*
18 Jun 1977	b	40	0	3
23 Jul	b	60	1	4
24 Jul	d	30	9	2
14 Aug	d	40	2	0
20 Aug	c	50	3	1
18 Sep	b	41	1	2
19 Sep	a	54	10	0
6 Feb 1978	b	23	7	11
8 Feb	d	60	13	2
22 Feb	a	79	4	2
Total		477	50	27



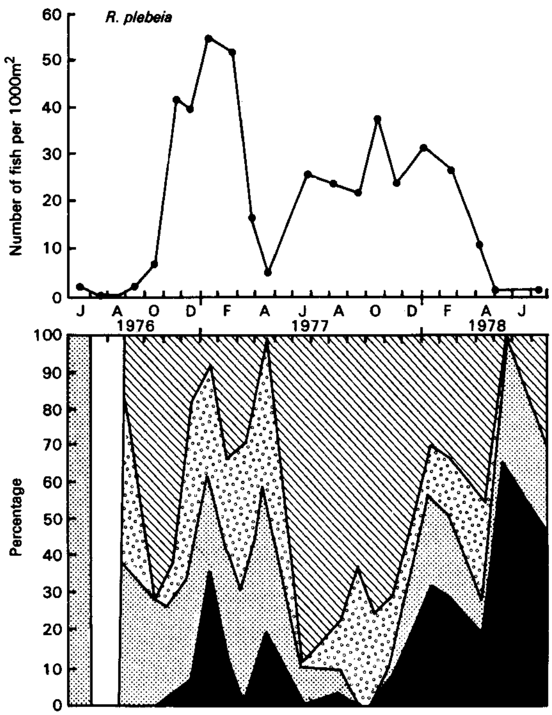


Fig. 3 *(left and above)* Total numbers of juvenile flatfish caught, and the percentage composition of the monthly catches, from the push-net stations in Otago Harbour, Papanui Inlet, and Hoopers Inlet, June 1976 - July 1978. (Stn 1, black; 2, stipple; 3, circles; 4, hatched).

DISCUSSION

Nine flatfish species were caught in the Otago area during this study, but only three species, *P. latus, R. plebeia,* and *R. tapirina,* were commonly found in the local inlets. In the Avon-Heathcote Estuary, Webb (1972) found *P. novaezeelandiae, R. plebeia,* and *R. leporina,* whereas in the Ahuriri Estuary Kilner & Akroyd (1978) caught *R. plebeia* and *R. leporina* commonly, *R. retiaria* frequently, and *P. novaezeelandiae* rarely. As *P. latus* and *P. tenuis* were not described until 1972 (James 1972) the true identity of the *Peltorhamphus* species found by Webb (1972) is uncertain. It is also possible that *P. novaezeelandiae* was not the only *Peltorhamphus* species in the Ahuriri Estuary, as young of these fish are difficult to separate. Apart from identification problems, differences in species composition between Otago and these other areas may have been due to differences in salinity as the Otago inlets are little affected by fresh water. It is also likely that the

Table 3 Length-frequency of flatfish caught in Blueskin Bay in the three trawling areas, A to C, June 1976 - May 1977.

Total length (mm)	*Pelotretis flavilatus*			*Colistium nudipinnis*			*C. guntheri*			*Peltorhamphus novaezeelandiae*			*P. tenuis*			*P. latus*			*Rhombosolea plebeia*			*R. tapirina*		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1																								
2																								
3																3								
4										2						14								
5	5									5			1			45								
6	75									7			6			84						1		
7	25	1								6			25			36								
8		2								4			8			10	1							
9	1									14			10			18	1							
10	3									37			6			3								
11										46			4	1			2							
12	1									13			3			5	4	1						
13				1						8	1		3			6						1		
14										8			1			6	1		1					
15										2						1								
16										8	2					4	1							
17	1		1							7	1					3							1	
18	1	1								5	1								1					
19										4	3								1		1			
20			1							8														
21			2							6	1								1				1	
22	1		1							5														
23		3	1							6	1	1							1					
24	1	2	1							15	3													
25	1	2	1							6	4	1							1			1		
26	1	3	1							8	5													
27		1	2							15	1								1					
28	2	3	4							14	6								1					
29		2	3							10	5								1					
30		1	3							3	2	1							1					
31			1							5	2													
32		1	5							4	1								1					
33		1					1			2	1													
34		2	2							2	1								1	1				
35			1				2	1		2	2													
36			3				3			3	3													
37							1			3	1									1				
38							1			5	2													
39										4	1									1				
40								2		2	2													
41										3	3													
42										3	2													
43				1					1	5	1													
44										1	1													
45								1		4	4	1												
46								1		2		1												
47											2													
48																								
49										1														
Total	**118**	**25**	**33**	**2**	**0**	**0**	**8**	**5**	**1**	**323**	**65**	**5**	**67**	**1**	**0**	**238**	**10**	**1**	**12**	**3**	**1**	**3**	**2**	**0**

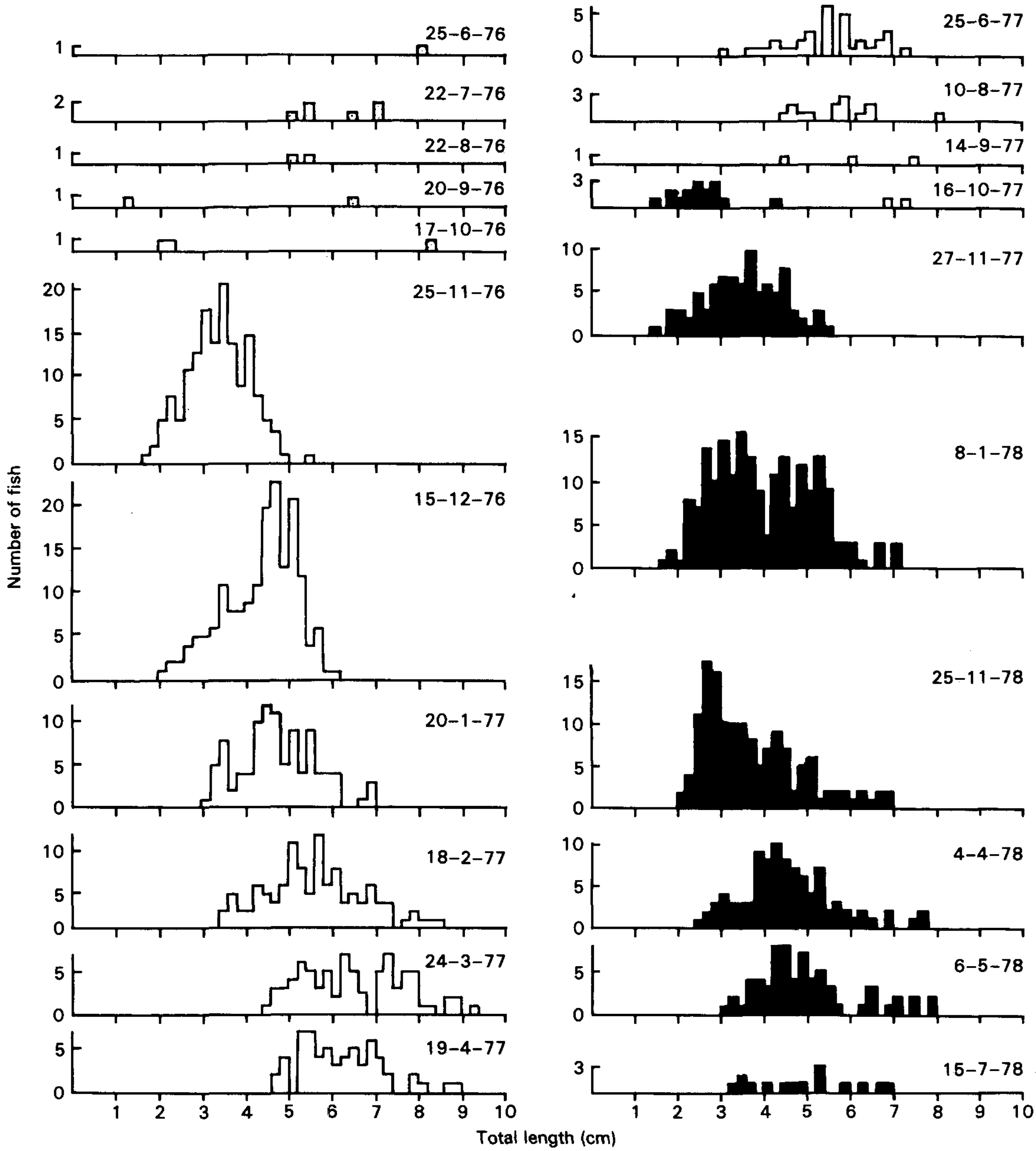


Fig. 4 Length-frequency distribution of juvenile *Peltorhamphus latus* caught at the push-net stations in Otago Harbour, Papanui Inlet, and Hoopers Inlet, June 1976 - July 1978. Three successive year classes — spawned in 1975 (stipple), 1976 (white), and 1977 (black) — present.

species composition reflects geographical differences; the Avon-Heathcote Estuary is 250 km north of Otago, on the east coast of the South Island, and the Ahuriri Estuary is 700 km north on the east coast of the North Island.

The abundance of *P. latus*, *R. plebeia*, and *R. tapirina* larvae in the harbour plankton from August to November indicates that spawning occurred in winter and spring. This is consistent with the results of Thomson & Anderton (1921) and Robertson (1973) who found that most flatfish in Otago waters spawn at this time. Some of the adult *R. plebeia* and *R. tapirina* caught in the harbour were in spawning condition, but because they were not very abundant, and because adult *P. latus* were not present at all, it is likely that most of the larvae originated from Blueskin Bay.

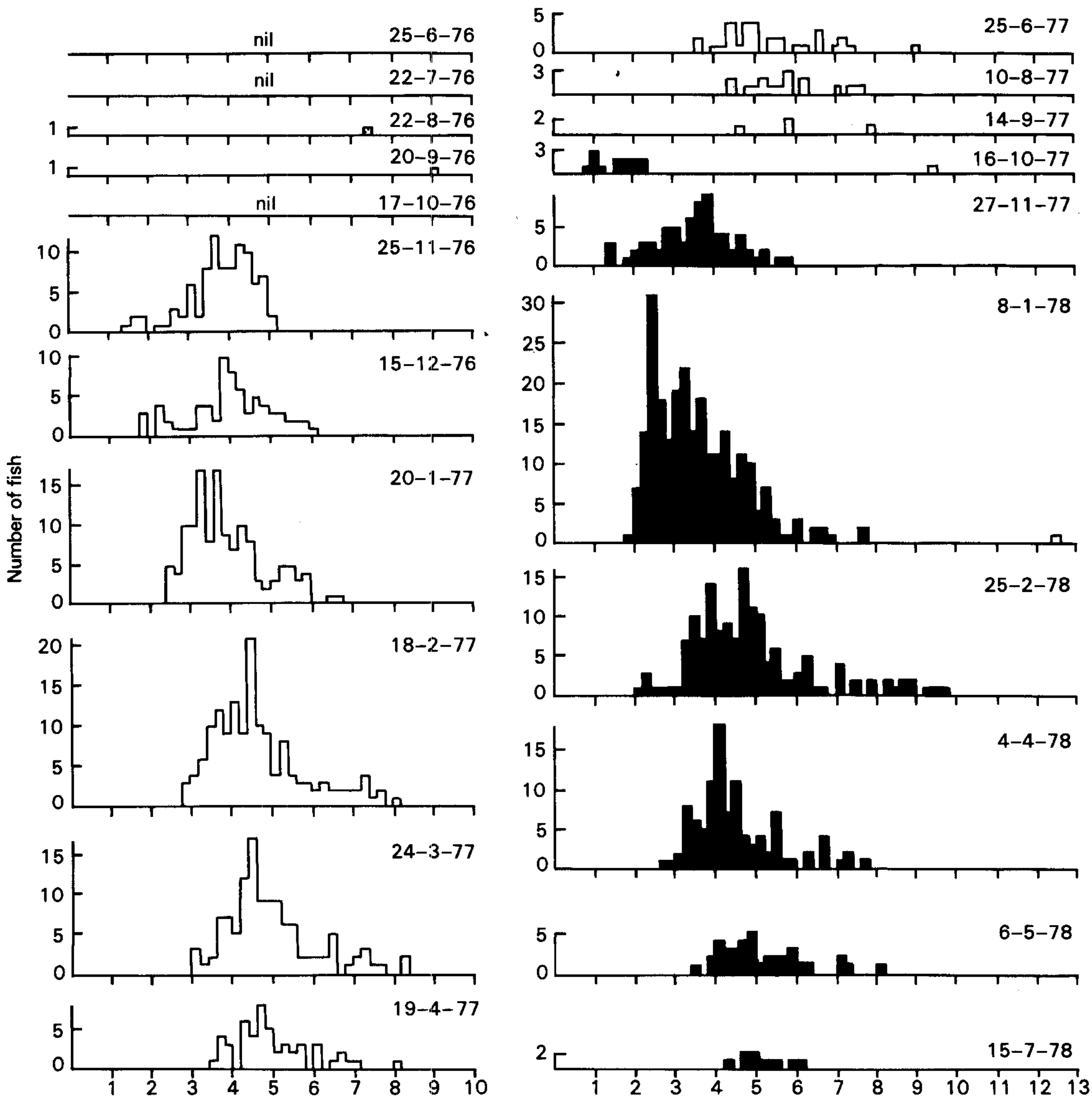


Fig. 5 Length-frequency distribution of juvenile *Rhombosolea tapirina* caught at the push-net stations in Otago Harbour, Papanui Inlet, and Hoopers Inlet, June 1976 - July 1978. Three successive year classes present (key as Fig. 4).

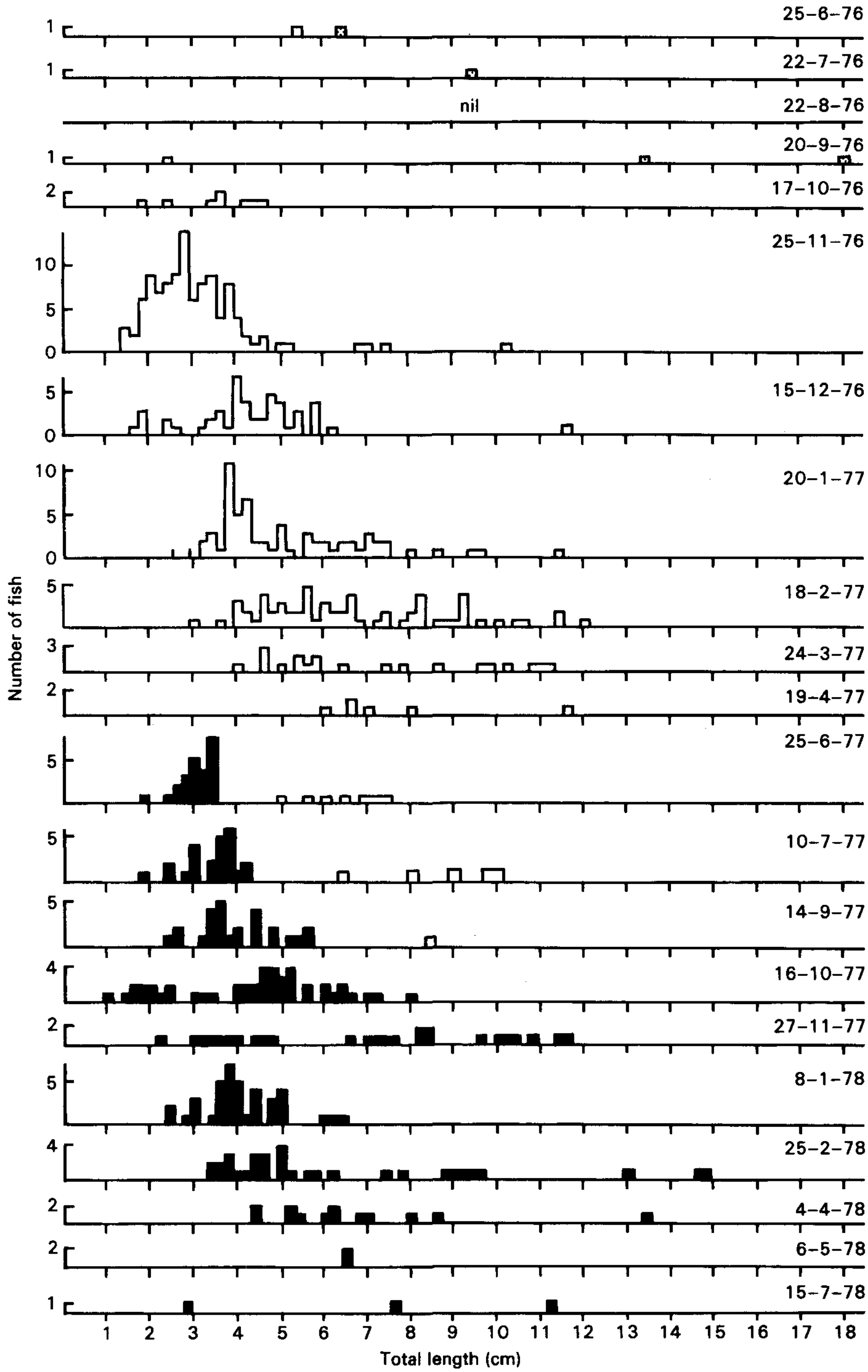


Fig. 6 Length-frequency distribution of juvenile *Rhombosolea plebeia* caught at the push-net stations in Otago Harbour, Papanui Inlet, and Hoopers Inlet, June 1976 - July 1978. Four successive year classes — spawned in 1975 (stipple), 1976 (white), 1977 (black), and 1978 (hatched) — are present.

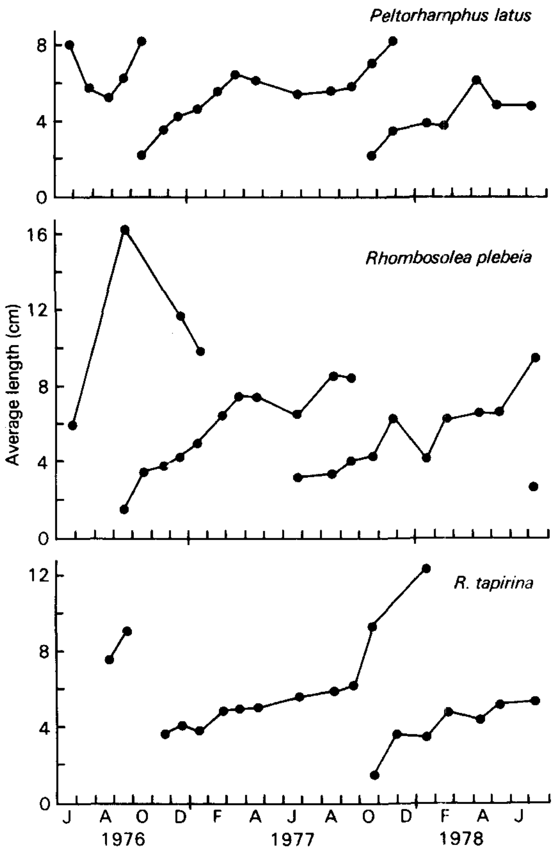


Fig. 7 Average lengths of juvenile *Peltorhamphus latus*, *Rhombosolea plebeia*, and *Rhombosolea tapirina* caught at the push-net stations in Otago Harbour, Papanui Inlet, and Hoopers Inlet, June 1976 - July 1978.

It is improbable that the larvae actively swim into the inlets, as this would require orientating to and swimming against strong tidal currents. Arnold (1969) found that larvae of the flatfish *Pleuronectes platessa* were weak swimmers and in an experimental chamber could orientate to a current only within 30 mm of the chamber walls. It is more likely, therefore, that they drift passively with the tide. On a flood tide, surface water travels from the harbour mouth to beyond the islands halfway up Otago Harbour (Quinn 1978), and larvae in the surface water of Blueskin Bay could, therefore, be swept into the harbour. Creutzberg *et al.* (1978) found that larval *P. platessa* rely upon tidal currents to carry them into coastal inlets; after entering with the flood tide they avoid being carried out on the ebb tide by rapidly settling to the bottom. They also found that swimming behaviour of the larvae was influenced by food, and suggested that settlement in coastal inlets was induced by the favourable feeding conditions. *P. latus, R. plebeia,* and *R. tapirina* may behave in a similar manner to *P. platessa.*

The other larvae taken in the harbour were *P. flavilatus, P. novaezeelandiae,* and *R. retiaria.* Adult *P. flavilatus* and *P. novaezeelandiae* were common in Blueskin Bay, and although no adult *R. retiaria* were caught there, local fishermen report that they are sometimes taken. Only a few of these larvae were found and no larvae of the other common Blueskin Bay species were present in the harbour. It appears that the larvae of some common, open-sea species can avoid being swept into enclosed waters, possibly by settling to the bottom off shore where the currents are weaker.

The settlement out of the plankton of *P. latus, R. plebeia,* and *R. tapirina* results in the spring appearance of numerous juveniles in the three inlets. Although *R. plebeia* spawns mainly during winter, juveniles appeared in June 1977 indicating that spawning must have begun that year in late summer; this is quite possible as Colman (1973) found this species spawning in March. Knox & Kilner (1973) found larvae of *R. plebeia* in the Avon-Heathcote Estuary between July and November.

This general pattern of settlement — the greatest densities of juveniles coinciding with the warmer part of the year — is very common among flatfish that have a nursery area. In Europe, juvenile *P. platessa* show a similar pattern with a peak in summer, following recruitment of newly metamorphosed larvae (Edwards & Steel 1968, Lockwood 1974). Juvenile *Limanda limanda* also reach a peak density in summer (Macer 1967, Edwards & Steel 1968) and juvenile *Scophthalmus maximus* reach a peak density in late summer (Jones 1973). Similarly, juvenile *Pseudopleuronectes americanus* and *Microstomus pacificus* are most abundant in America in summer (Pearcy 1962, Allen & Mearns 1976).

The density of larvae in the inlets will be affected by the number of adults spawning and their fecundity, survival of the eggs and larvae while in the plankton, and the numbers of eggs and larvae that are carried into the inlets. This in turn will determine the density of juveniles. The low densities of juvenile *R. plebeia* may have resulted from the lower numbers of this species in the plankton. Variation in density of the three species between stations was probably due to the different physical characteristics of the stations and to differences in the availability of food.

Observed abundance of juvenile fish in the inlets, as determined from push-net catches, is different from the true abundance. These catches were an underestimate because larger fish avoided the net and smaller ones escaped through the mesh; Jones (1973), who used a push-net with similar characteristics, quoted an efficiency of 30–60%. During this study

Table 4 Numbers of flatfish caught in Blueskin Bay, June 1976 - May 1977. Catches reflect changes in abundance as fishing effort was same each month.

	1976							1977				
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Pelotretis flavilatus	1	0	2	0	2	12	8	117	13	6	10	2
Colistium nudipinnis	1	0	0	0	0	0	0	1	0	0	0	0
C. guntheri	0	2	1	1	2	0	1	2	0	0	5	0
Peltorhamphus novaezeelandiae	107	25	18	25	45	12	30	38	0	0	67	26
P. tenuis	7	6	0	0	1	0	0	33	0	0	13	8
P. latus	21	6	0	0	2	2	0	153	12	0	10	43
Rhombosolea plebeia	1	0	5	0	2	1	2	2	0	0	3	0
R. tapirina	0	0	0	0	0	1	0	3	0	1	0	0

efficiency was estimated by fitting the net with a fine-mesh liner to catch the small fish which would otherwise escape, and by counting the larger fish seen outswimming the net. The greatest efficiency obtained was about 60%. When discussing densities of juveniles, it must be remembered that sampling was by push-net at low tide when the fish were concentrated in the channels; at high tide the young fish dispersed over the sandflats (Roper 1979).

After the summer peaks the rate at which numbers declined (an average monthly decrease of 30–48%) is consistent with rates found for other species overseas. The density of juvenile *P. platessa* declined at a monthly rate of between 30 and 50% (Riley & Corlett 1966, Macer 1967, Edwards & Steel 1968), and *L. limanda* may decline by 44% each month (Macer 1967). Jones (1973) calculated that in 1967 *Scophthalmus maximus* declined during the first month by 52%, but by 25% in the following months.

Predation may be a cause of the decrease. In the harbour, juvenile flatfish are the main prey item of Stewart Island shags (*Leucocarbo carunculatus chalconotus*) and little shags (*Phalacrocorax melanolencos*) also take them (C. Lalas, Portobello Marine Laboratory, pers. comm.). The white faced heron (*Ardea novaehollandiae*) may also feed on them as these birds are often seen wading in the shallow water around the sandflats at low tide. Graham (1939) listed seven species of harbour fish feeding on 'flounder', *Rhombosolea* spp., and 'sole', which were probably *Peltorhamphus latus*. Flounder were eaten by dogfish (*Squalus acanthias*), Maori chief (*Notothenia* sp.), ling (*Genypterus blacodes*), and toadfish (*Neophrynichthys latus*). Sole were eaten by red cod (*Pseudophycis bacchus*), flathead (*Kathetostoma giganteum*), ling, toadfish, and catfish (*Geniagnus monopterygius*).

It is unlikely that the decline in numbers is due only to mortality; the major cause is probably the emigration of larger juveniles into deeper water. Few adult or juvenile fish were found in the channels, which suggests that the movement into deeper water takes most of the fish out of the inlets. *Peltorhamphus latus* migrates out of the inlets because the largest individuals there were juveniles, and adults of this species were found only in Blueskin Bay. *Rhombosolea plebeia* and *R. tapirina* must also emigrate as adults were found off shore in Blueskin Bay, even though the juveniles were confined to the inlet nurseries. All *R. plebeia* caught by trawling in Blueskin Bay were more than 13 cm long, and only one specimen of *R. tapirina* was shorter than this. Also, James (1970), while trawling in Blueskin Bay with a similar net, found only one specimen of *R. plebeia* shorter than 14 cm. It appears that near the end of their first year all *P. latus* and most *R. plebeia* and *R. tapirina* emigrate from the inlets into Blueskin Bay. The adult *R. plebeia* and *R. tapirina* in the inlets possibly re-entered when older, or may have been a residual population that never emigrated.

Emigration of juvenile flatfish out of their nursery areas has been observed in *P. platessa* and *L. limanda* (Macer 1967, Edwards & Steel 1968, Gibson 1973, Lockwood 1974). Gibson (1973) suggested that the function of emigration might be to avoid the low temperatures and increased turbulence that occur in shallow water during winter, or a move to different feeding grounds. Lockwood (1974) also thought that the movement might be an overwintering response, reflecting a general behavioural change possibly initiated by shortening day length or lack of suitable food.

Five of the eight species of flatfish in Blueskin Bay were never found in the inlets and, although *P. latus* juveniles occurred in both areas, juvenile *R. plebeia* and *R. tapirina* were found only in the inlets. Gibson (1973) studied several flatfish species and suggested that their distributions might be the result of depth preferences. The distribution of flatfish in Otago may also result from specific depth preferences, which may vary between juvenile and adult as well as between species. *Pelotretis flavilatus, P. novaezeelandiae, P. tenuis, C. nudipinnis,* and *C. guntheri* were found only in Blueskin Bay; these species may avoid the shallow water of the inlets. Among the common species restricted to Blueskin

Bay, however, it was evident that the juveniles preferred shallower water as they were most common at the in-shore trawling area. Juvenile *P. latus* appeared to have a wide depth range and occurred both in the inlets and in Blueskin Bay. Adults of this species, however, occurred only in Blueskin Bay, suggesting a difference in the depth preference between juvenile and adult. Adult *R. plebeia* and *R. tapirina* were caught in the inlets and Blueskin Bay, but juveniles of these species were restricted almost solely to the inlets. These juveniles were usually associated with tidal sandflats, and a preference for shallow water, and tidal sandflats in particular, may explain why these fish were not common in Blueskin Bay.

If depth preferences are important in determining the distribution of local flatfish, emigration out of the inlets may result from changes in these preferences with age.

It is unclear why fish associated with the deeper water of Blueskin Bay are not found in the inlet channels. Although they are certainly within a comparable depth range, up to 20 m deep in Otago Harbour, fish possibly avoid them because of their strong tidal currents, or because they lack suitable food.

The catches of adult *R. plebeia* and *R. tapirina* were small, despite the abundance of juveniles in the inlets. Normally these fish are common and are fished commercially in Blueskin Bay; the small catches may have been due to a poor season such as local fishermen sometimes experience. James (1970) fished from the same vessel and recorded catches well in excess of those made during the present study.

The growth rate can usually be estimated from length–frequency data obtained from successive samples, but this could not be done because catches in Blueskin Bay were too small and because the inlet populations turned over as larval fish settled over several months and larger individuals emigrated. The length–frequency data for juvenile fish in the inlets did show that initially the mean lengths increased, although this slowed as more fish were continually recruited. Later, when emigration exceeded recruitment, the length increase diminished; sometimes the mean length decreased.

The coastal inlets of Otago are frequented by three flatfish species. Although adult *R. plebeia* and *R. tapirina* were caught there, the areas appear to be more important for the juveniles of these species, which were almost exclusively restricted to the inlets and probably require shallow nursery areas with extensive tidal sandflats. *Peltorhamphus latus* juveniles were common in the inlets, but were also found in large numbers in the shallow waters of Blueskin Bay together with the juveniles of *P. novaezeelandiae, P. tenuis,* and *Pelotretis flavilatus.*

The juveniles of all these species are therefore concentrated in finite nursery areas; inlets for *R. plebeia* and *R. tapirina* and shallow coastal water for the other four species. It is not clear whether each nursery serves an adjacent off-shore area or if the respective adult populations are displaced some distance along the coast. Colman (1978) found that adult *R. plebeia* off the Canterbury coast of the South Island undergo a pre-spawning migration, which suggests that, for this species at least, the spawning grounds for some adult stocks may be some distance away from the nurseries. It is likely that the position of the nursery relative to the spawning ground depends upon the local prevailing currents which carry the planktonic eggs and larvae.

Zijlstra (1972) discussed the importance of nurseries to the European flatfishes *Solea solea* and *Pleuronectes platessa*, and concluded that if the size of a nursery were reduced juvenile fish would not compensate by increasing their densities in the remaining area, but rather the total stock would be reduced by the number of fish which previously used the lost area as a nursery. It is not known if this applies to the New Zealand species of flatfish, but if it does it is essential that the areas serving as nurseries be preserved if the present stocks of these fish are to be maintained.

Although this study was restricted to the area adjacent to Otago Peninsula, it is probable that inlets and shallow coastal waters are of vital importance to populations of these species throughout their distributional ranges.

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