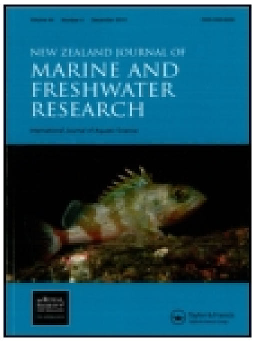

New Zealand Journal of Marine and Freshwater Research

ISSN: 0028-8330 (Print) 1175-8805 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzm20

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To cite this article: B. F. Webb (1972) Fish populations of the Avon-Heathcote estuary, New Zealand Journal of Marine and Freshwater Research, 6:4, 570-601, DOI: 10.1080/00288330.1972.9515447

To link to this article: http://dx.doi.org/10.1080/00288330.1972.9515447

FISH POPULATIONS OF THE AVON-HEATHCOTE ESTUARY

1. GENERAL ECOLOGY, DISTRIBUTION, AND LENGTH-FREQUENCY

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(*Received for publication 1 April 1968*)

ABSTRACT

Characteristic organisms are tabulated, and the substrate conditions briefly described for seven habitats in the Avon-Heathcote Estuary, Christchurch, New Zealand. Temperatures and water movements within the estuary are outlined. From April 1965 to April 1966, samples were collected by short otter-trawl shots, gill netting, beach seine hauls, and dip netting; the limitations of the gear are noted. The distributions and movements are recorded for nine fish species: sand flounder, *Rhombosolea plebeia* (Richardson); yellow-bellied flounder, *Rhombosolea leporina* (Hutton); common sole, *Peltorhamphus novaezeelandiae* (Gunther); yellow-eyed mullet *Aldrichetta forsteri* (Cuvier and Valenciennes); kahawai, *Arripis trutta* (Bloch and Schneider); spotty, *Pseudolabrus celidotus* (Bloch and Schneider); cockabully, *Tripterygion nigripenne* (Cuvier and Valenciennes); common bully, *Gobiomorphus basalis* (Gray); and globe fish, *Spheroides richei* (Freminville).

Length-frequency distributions showed that most of the nine species of fish used the estuary as a feeding area for adults and as a nursery area. Only two species did not migrate to and from the sea.

Length-weight relationships for eight species showed that weight was a function of length approximately cubed, and that the exponential equation could be used to predict weight from length.

Regressions of caudal fin length on standard length for four species gave a positive correlation ($r = +0.95$). Relative proportions of body length to caudal fin length were related to habitat; fish of benthic habits had proportionally shorter caudal fins than pelagic fish.

INTRODUCTION

This paper is the first of a series on fish populations in the Avon-Heathcote Estuary from April 1965 to April 1966. Movements, location, and biology of fish species in the estuary were studied. A brief survey of water surface temperatures, tidal currents, and the different types of habitats (as exemplified by invertebrates and substrata) was made. Observations on 19 less common species of fish, and aspects other than

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general ecology (breeding, maturation, feeding, parasites, and overall discussion) will be dealt with in later papers.

The complex, roughly triangular estuary of the Avon and Heathcote rivers adjoins Banks Peninsula in the South Island of New Zealand (Fig. 1). The area of the estuary is just under 7.77 km^2, and it is fed by two rivers and a number of shoreline streams. Sea water enters from Pegasus Bay and mixes with the fresh water to produce typical estuarine conditions. The main sources of pollution are: the trade wastes which empty directly into a 3.25 km reach of the Heathcote river, where only life forms adapted to polluted conditions persist; oxidation ponds which empty into a restricted area along the Avon channel, and always contain detergents (1–5 ppm); and decomposing estuarine animals and plants which pollute sheltered areas of the estuary. During high tide the estuary is completely covered by water to a depth of 0.3–5.5 m; at low tide a large central mudflat occupies about 75% of the estuary.

Studies of the Avon-Heathcote Estuary have been made by Thompson (unpublished 1929), Bruce (unpublished 1953), Williams (unpublished 1959), Rosenberg (unpublished 1962), Estcourt (unpublished 1962; 1967), and Webb (unpublished 1967).

METHODS

SAMPLING PROCEDURES

A small otter trawl was used which was 7.31 m across the head rope and 3.96 m from the mouth to the nearest part of the 1.21 m deep cod end. The gape of the net when fishing was 4.2 m wide and approximately 1.21 m deep. Stretched mesh size was 5.08 cm from knot to knot. The otter boards were 0.762 m square. The net was towed on two 25.9 m towing warps of treated, 6.35-cm-circumference hemp, by a 3.65 m boat, powered by a 3.5 h.p. outboard motor. Trawl shots lasted 30 minutes from the time that the net was fully out to the time that hauling in began. This time span was used in estimating the catch per unit area. Trawl shots were made twice each month at each trawl station (*see* Fig. 1).

A 6.35 cm (stretched) mesh herring net, was used either as a gill net for yellow-eyed mullet, *Aldrichetta forsteri* (Cuvier and Valenciennes), or as a beach seine. An extra 4.5 kg of lead added to the ground line made sampling more effective when beach seining. The net was 1.5 m deep and 20.1 m long, and had no purse. Spreader poles were 1.2 m long. Two haul ropes of hemp (6.35 cm in circumference and 54.8 m long) were used. This net was fished either to the full limit of the haul ropes from shore at high tide, or to the full width of the channels at low tide.

Dip nets were used from the shore as scoops and were sometimes baited to catch juvenile yellow-eyed mullet and sand flounder, *Rhombosolea plebeia* (Richardson), and adult common bullies, *Gobiomorphus basalis* (Gray), and adult cockabullies, *Tripterygion nigripenne* (Cuvier and Valenciennes).

The effectiveness of these techniques varied with the species and habitat. The mesh sizes (5.08 cm and 6.35 cm) of the otter trawl and beach seine caught only larger individuals e.g., yellow-eyed mullet 170–180 mm long or longer, sand flounder 90–100 mm long or longer, and yellow-bellied flounder, *Rhombosolea leporina* Hutton, of 110–120 mm long or longer. Kahawai, *Arripis trutta* (Bloch and Schneider), were too fast and scary to be caught in the nets, while spotties, *Pseudolabrus celidotus* (Bloch and Schneider), were caught in appreciable numbers away from the shore only, because obstacles hindered trawling close inshore. Globe fish, *Spheroides richei* (Freminville), were caught in larger numbers by the beach seine than by the otter trawl. The scoop net samples were not quantitative because they were used in shallow water on difficult substrates, resulting in chance sampling within a confined area. Nevertheless, sufficient numbers of bullies and cockabullies were caught to suggest a few trends.

The fish caught were placed in muslin bags and stored in a portable tank of 5% formalin; the gut was usually opened to stop digestion. The fish were dissected and measured within 24 hours of capture. The collecting points and sampling areas are shown in Fig. 1.

For 1 week in every 2 months, sand flounder and yellow-bellied flounder were tagged in Moncks Bay. During these periods I collected for gut samples all the untagged sand flounder and yellow-bellied flounder below 170 mm caught in 1 day of trawling, compiled a full list of all lengths from 1 day's catch, and kept a large sample of all the other fish species caught each day throughout the week.

ANALYTICAL METHODS

Statistical tests were applied to the various monthly samples, including an analysis of variance to test for similarity in size structure in different samples of the same species. When a difference was apparent between the samples, Duncan's multiple range test was used to verify differences between the means. Students *t*-test was used when two means only were compared for difference.

The means and their ranges of standard error at the 95% confidence level were graphed for those species showing a noticeable variation between the 2-monthly samples. Probability paper was also used for measurements of the populations of sand flounder, yellow-bellied flounder, yellow-eyed mullet, spotty, common bully, and globe fish, to separate size groups within samples.

Length-frequency analyses were made of fish lengths for fish of each species caught by the principal fishing methods: trawl and seine nets for sand flounder, yellow-bellied flounder, yellow-eyed mullet, kahawai, spotty, globe fish, and common sole (*Peltorhamphus novaezeelandiae* Gunther), dip nets for cockabully and common bully. Analysis of populations from such samples is significant only if all individuals within a species follow similar behavioural patterns.

In length-weight analyses, the measurements were transformed to $\log_{10}$ and plotted by the least squares regression. This regression was also used to investigate the caudal fin: standard length relationship.

HABITATS

Seven major habitats and four sub-habitats were recognized (*see* Fig. 1) and the invertebrates were recorded qualitatively within ten of these habitats (Table 1). Features not shown by the table are:

(1) The two *Euglena* species occupied a 27.5 m strip around most of the estuary margin, colouring the substratum yellowish-green. In polluted areas near the Heathcote River, *Euglena* disappeared.

(2) The mud snail *(Amphibola crenata)* occupied the shoreward zone of the estuary, and the mudflat top shell *(Zediloma corrosa)* and the speckled whelk *(Cominella lurida)* inhabited the central estuary, where they were covered for approximately 8 h in each 12 h tidal cycle.

(3) Microscopic organisms (protozoans, platyhelminthes, nematodes, and diatoms) were present in shoreline samples, but were not plotted.

(4) The algae *Ulva lactuca* and *Enteromorpha intestinalis* occurred predominantly in unattached clumps, although during winter from Charlestone drain to Linwood Avenue culvert and below Dyers Road bridge they were found attached in dense beds. The term 'clump' is used here for scattered patches of algae of about 50 g/m^2, and 'bed' for large areas of algae with concentrations of 3,000 g/m^2 (wet weights).

(5) Amphipods found belonged to the Calliopiidae, Gammaridae, and Oedicerotidae. Isopods found were *Metacirolana japanica* and *Zenobiana tubicola*.

Accounts of habitats have been given by Bruce (unpublished 1953), Williams (unpublished 1959), and Rosenberg (unpublished 1962); these are summarised here.

Shallow Channel (0.3–1.8 m): Because of tidal and river flow, the substrata of the channels varied from sand at the river junctions to predominantly mud near the Avon and Heathcote bridges. Extensive shell deposits provided shelter and protection for crustaceans, molluscs, and polychaetes. Fish permanently resident in this habitat include yellow-eyed mullet, yellow-bellied flounder, sand flounder, and kahawai (in lower reaches only). Globe fish, spotty, whitebait, *Galaxias maculatus attenuatus* (Jenyns), and brown trout, *Salmo trutta* Linnaeus, are seasonal residents.

Deep Channel (0.8–7.3 m): The substratum consisted of coarse to fine sand, with thick shell deposits. This area was continually being altered, either deepened by scouring, or filled by deposition, depending on the

TABLE 1—Occurrence of algae, invertebrates, and marine plants in relation to habitats in the Avon-Heathcote Estuary, 1965–66 (X = present, – = absent, ? = doubtful)

SPECIES	HABITATS									
	Shallow Channel	Deep Channel	Rocky Shore	Coarse Mudflats	Fine Mudflats	Very Shallow Channel	Sludge	Rushy Shore	Streams	Gravelly Pool
Chione stutchburyi (cockle)	X	X	–	X	–	X	–	X	–	–
Paphies australe (pipi)	X	X	–	X	–	–	–	–	–	–
Xenostrobus pulex (little blue mussel)	–	–	X	–	–	–	–	–	–	–
Mytilus edulis aoteanus (common mussel)	–	–	X	–	–	–	–	–	–	–
Macomona liliana (large wedge shell)	X	X	–	–	–	–	–	–	–	–
Cominella lurida (speckled whelk)	X	–	–	X	–	X	–	X	–	–
Zediloma corrosa (mudflat top shell)	X	X	–	X	–	X	–	X	X	X
Amphibola crenata (mud pulmonate)	–	–	–	X	X	–	–	X	X	–
Melagraphia aethiops (dark top shell)	–	–	X	–	–	–	–	–	–	–
Notoacmea parviconoidea (black-edged limpet)	X	X	–	–	–	–	–	–	–	–
Scutus breviculus (shield slug)	–	–	X	–	–	–	–	–	X	–
Amaurochiton glaucus (green chiton)	–	–	X	–	–	–	–	–	X	–
Sypharochiton pelliserpentis (snake-skin chiton)	–	–	X	–	–	–	–	–	X	–
Nicon aestuarensis (polychaete)	X	–	–	X	X	X	–	X	X	–
Pisione sp. (polychaete)	X	X	–	–	–	–	–	–	?	–
Eumenia sp. (polychaete)	X	X	–	–	–	–	–	–	?	–
Glycera americana (polychaete)	–	X	X	–	–	–	–	–	–	–
Pomatoceros cariniferus (serpulid worm)	–	–	X	–	–	–	–	–	X	–
Spirorbis sp. (spiral worm)	–	–	–	–	–	–	–	–	X	–
Lumbricid worms	–	–	–	–	–	X	–	–	–	X
Petrolithes elongatus (half crab)	–	X	X	–	–	–	–	–	–	–
Hemigrapsus crenulatus (hairy-handed crab)	X	X	–	–	–	X	–	–	X	–
Ovalipes bipustulatus (swimming crab)	–	X	–	–	–	–	–	–	–	–
Helice crassa (tunnelling mud crab)	X	–	–	X	X	X	–	X	X	X
Hombronia depressa (spider crab)	X	–	–	–	–	X	–	–	X	–
Amphipods	X	X	–	–	–	X	–	–	X	X
Isopods	–	X	–	–	–	–	–	–	–	X
Shrimps	X	X	X	–	–	–	–	–	X	–
Elminius modestus (common small barnacle)	–	–	X	–	–	–	–	–	X	–
Ulva lactuca (sea lettuce)	X	–	X	X	X	X	–	X	X	–
Enteromorpha intestinalis (alga)	X	–	–	X	–	–	–	X	X	–
Gracilaria sp. (alga)	–	–	–	–	–	–	–	–	X	–
Euglena limosa & *E. salina* (algae)	–	–	–	X	X	–	X	X	–	–
Zostera marina (eelgrass)	X	–	–	X	X	–	–	X	–	–
Spartina townsendi (saltwater grass)	–	–	–	–	X	–	–	X	–	–
Rushes and *Salicornia*	–	–	–	–	X	X	–	X	–	–

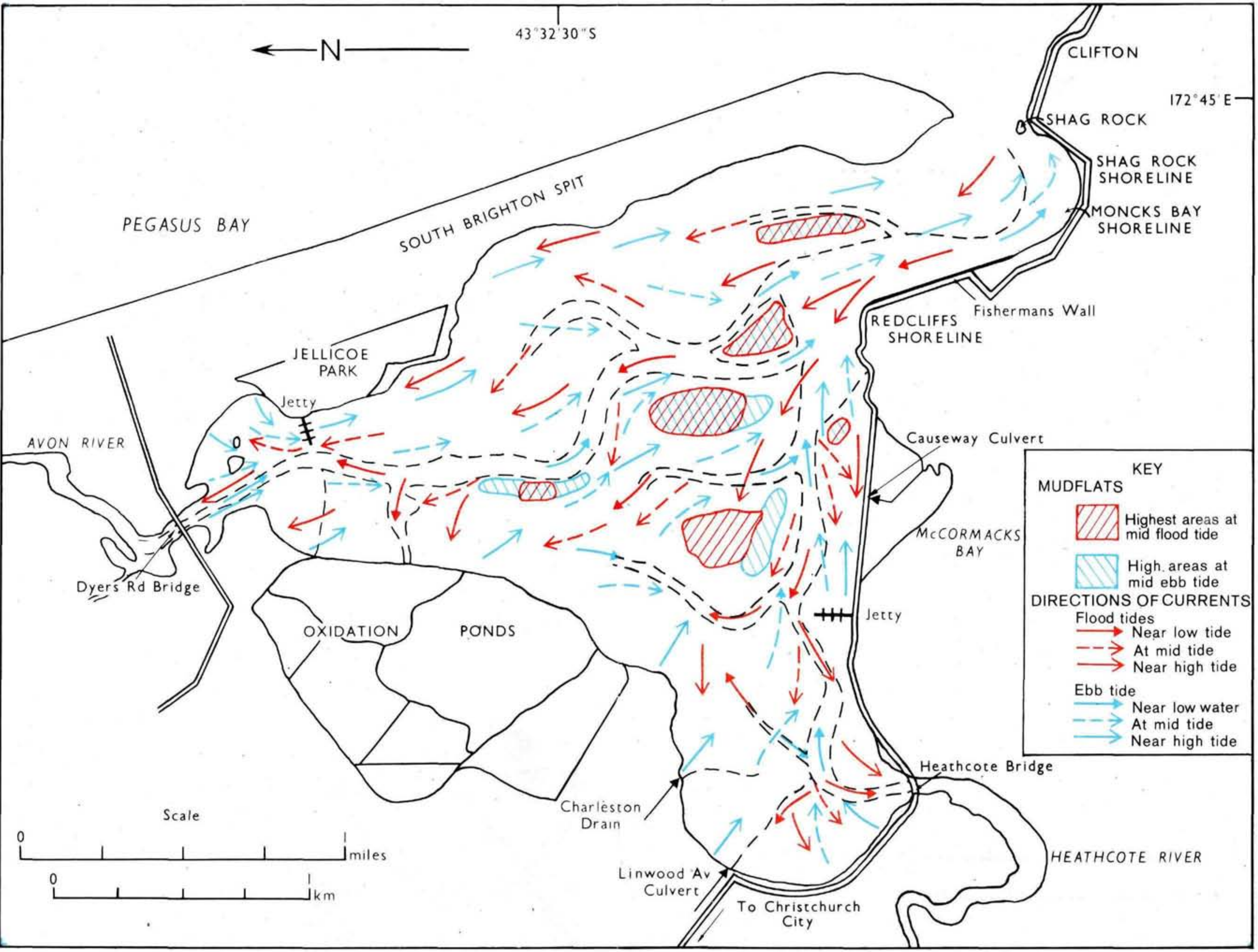

FIG. 2—Observed tidal currents and tidal differences in exposure of mudflats in Avon-Heathcote Estuary, 1965–66; flow rate in Moncks Bay was 6 knots (11.1 km.h^{-1}) at mid flood and 8 knots (14.8 km.h^{-1}) at mid ebb.

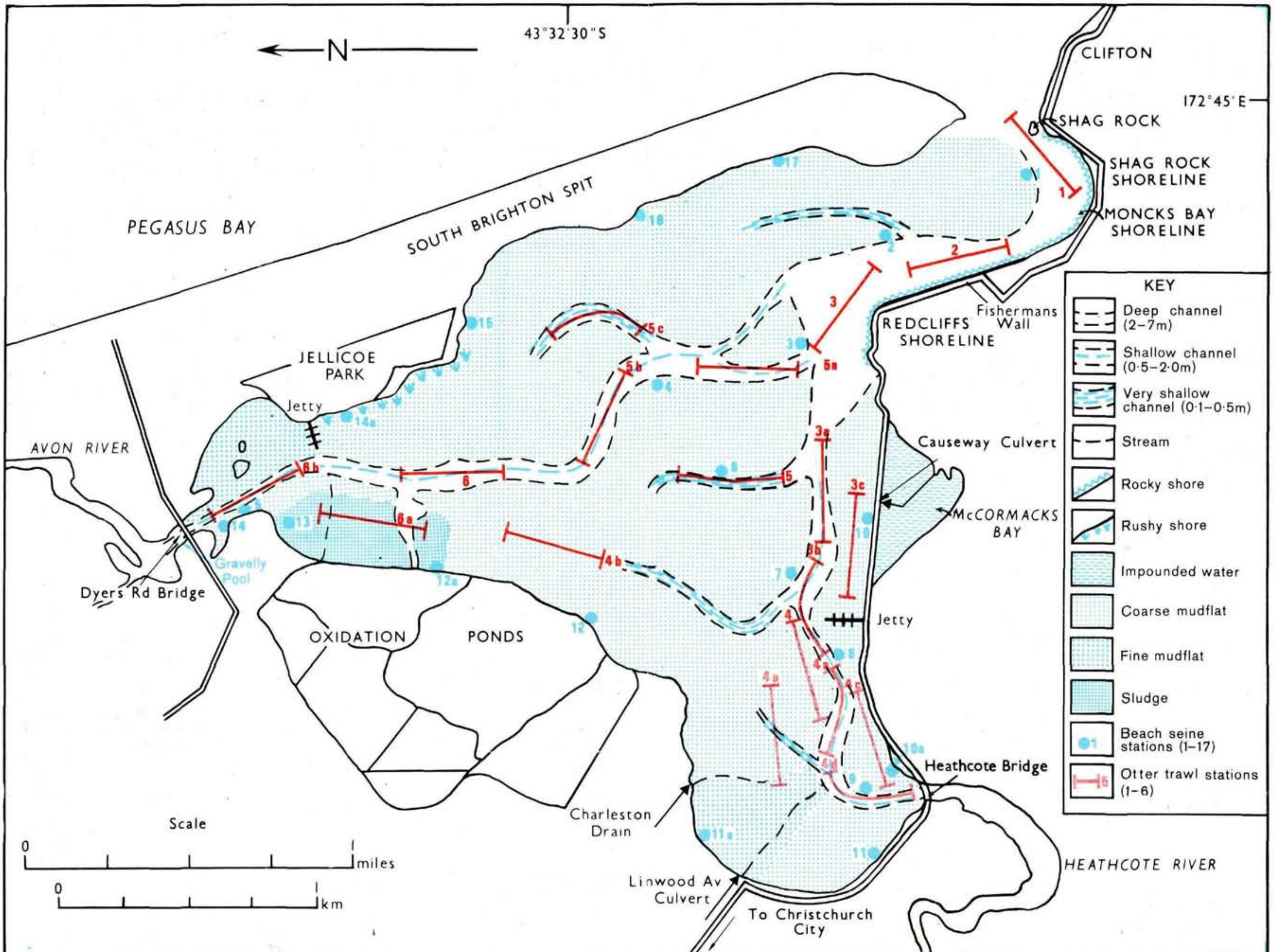

FIG. 1—Sampling stations and habitats in the Avon-Heathcote Estuary, 1965–66; dip nets were used to sample streams and gravelly pool.

season and precipitation. On 22 August 1965, for example, after 2 days of rain an aggraded shelf, 137 m long, 45 m wide, and 0.45 m from the surface, was formed in 24 h along the Redcliffs shoreline. Three days later the area had degraded to its normal depth of 3.0–3.65 m.

Tree trunks and branches embedded in the sand seriously hindered net fishing. On 12 August 1965, nine such obstacles were cleared from an area approximately 90 m long in front of the Fishermans Wall. These obstacles had been used by polychaetes and crabs for shelter and protection (52 *Glycera americana* were collected from depressions in one tree trunk), and by mollusca, e.g., *Notoacmea parviconoidea,* as a substratum.

It is through this region that fish such as globe fish, yellow-eyed mullet, sand flounder, yellow-bellied flounder, kahawai, brown trout, and whitebait enter from the sea and travel up the estuary.

Rocky Shoreline: This is a narrow region composed entirely of rocks, pebbles, and boulders, exposed between tides, and subjected to a great range of environmental fluctuations. The prevalence of the common mussel (*Mytilus edulis aoteanus*) decreased from the estuary mouth to the Redcliffs area. Young short-finned eels, *Anguilla australis* Richardson, breeding colonies of cockabullies, juvenile spotties, thornfish, *Bovichtus variegatus* (Richardson), and rockfish, *Acanthoclinus quadridactylus* (Bloch and Schneider), were present.

Mudflats: At low tide about 75% of the estuary consisted of exposed mudflats. Four sub-habitats were recognized:

(1) **Coarse Mudflats** occupy 66% of the mudflat area, and consist of firmly packed coarse to fine sand, with a dry solids content of 52–72% and a water content of 28–48% (Webb unpublished 1965). Eelgrass (*Zostera marina*) grew along the Avon Channel banks in front of the oxidation ponds, and in numerous patches below the Dyers Road bridge; Rosenberg (unpublished 1962) recorded three patches only near the Dyers Road bridge. Various fish species, including the short-finned eel, sand flounder, yellow-bellied flounder, and yellow-eyed mullet, moved into this area with the incoming tide to feed.

(2) **Fine Mudflats:** Two bays below the Dyers Road bridge which were sheltered from wind-driven waves had a substratum of very soft mud. Because of the distance from the estuary mouth this area was one of the last to be covered by high tide. Rushes, eelgrass *(Zostera marina),* and the grass *Spartina townsendi* provided feeding areas for juvenile yellow-eyed mullet and sand flounder.

(3) **Very Shallow Channels** (0.05–0.1 m), present in the lower areas of the mudflat, were permanently water filled and were thus not subject to the same environmental fluctuations as the other mudflat sub-habitats. The substratum was soft mud and fine silt with shell beds 0.6–0.9 m thick. The channels were unstable and changes in currents could aggrade or alter their courses. At low tide the only fish found were

juvenile sand flounders and yellow-bellied flounders (less than 20 mm long), but on flood tide adult yellow-eyed mullet and flounders moved into this area.

(4) **Sludge:** The depression in front of the oxidation ponds was surrounded by higher mud and sand banks; excess water trapped at low tide in this depression could escape only by seepage. This formed a soft, quaking bog devoid of invertebrates, although the surface had a covering of *Euglena limosa* and *E. salina.* Gut samples from yellow-eyed mullet, sand flounders, and short-finned eels, taken at high tide, were found to be packed with detritus and mud, but during summer the cladoceran *Moina* sp., originating from the oxidation ponds, was ingested by only adult yellow-eyed mullet.

Rushy Shoreline: This area was completely covered only at high spring tides (approximately 10 days per month). For the rest of the month, only the lower 75% was covered to depths of 5–60 cm. Southerly and westerly winds caused wave action at times. Shoals of juvenile yellow-eyed mullet were found feeding on *Spartina* and algae; whitebait were occasionally present.

Streams: Two streams drain McCormacks Bay, a partly enclosed area only half emptied between tides. The stream outlets are culverts 0.6–0.9 m above the low water level of the estuary. Water enters the bay on flood tide, at mean sea level, and drains out on the ebb tide, so that the direction of water flow changes only when the water levels in both the estuary and the bay are equal. In the larger stream, adult yellow-eyed mullet and juvenile kahawai and flounders are present. The smaller stream near Redcliffs shoreline contains rockfish, a breeding population of cockabullies, and a number of young spotted stargazers, *Geniagnus monopterygius* (Bloch and Schneider).

Freshwater drains subjected to tidal influence are located at Heathcote bridge (soft mud), Linwood Avenue culvert (soft mud), Charlestone drain (sand), and along the side of the oxidation ponds (sludge). These streams contributed to the estuary freshwater algae (*Ulothrix* sp., *Spirogyra* sp., *Scenedesmus* sp., Volvocales, and diatoms), ostracods, mysids, insect larvae, and detritus, which provided food at high tide for juvenile yellow-eyed mullet, short-finned eel, common bully, and sand flounder.

Gravelly Pool: This was a small pool, approximately 33.4 m² in area, with a mixture of gravel, sand, and mud on its bottom. It was covered at low tidt by 15–30 cm of freshwater and at high tide by 1.52 m of brackish water. The fish included a breeding colony of cockabully and a number of young eel and yellow-eyed mullet.

WATER MOVEMENTS

Observations on the direction of currents in the estuary were made with 25 cm-diameter plastic trawl floats (Fig. 2). The movement of floating seaweed and debris was also observed.

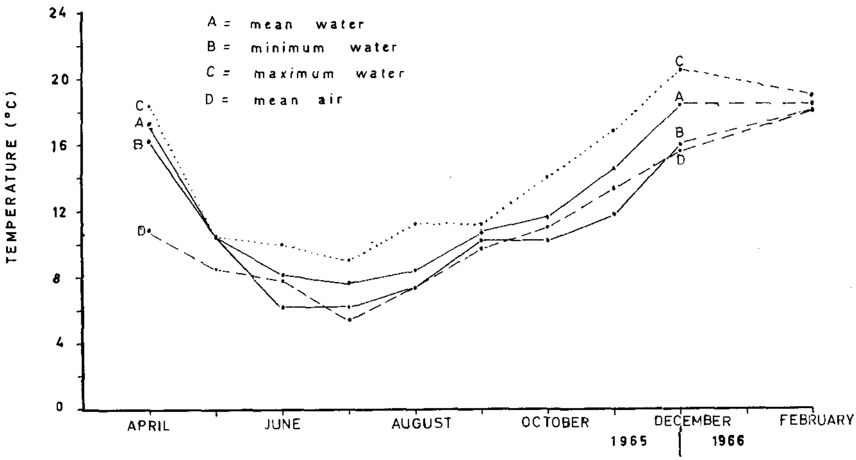

FIG. 3—Comparison of average monthly air and water temperatures (°C) in Avon-Heathcote Estuary, 1965-66. Air temperatures from daily (0900 h) readings at Christchurch Airport by N.Z. Meteorological Service; water temperatures from readings by author 1–3 times per week at 1100–1400 h at various of the fish sampling areas.

The sand bar at the estuary mouth and the volume and length of the estuary (*see*, e.g., Day *et al.* 1954) produced local variations in the tide times. Low tide was 40 min. later at the Heathcote bridge than at Lyttelton (local official standard), and 120 min. later at the Dyers Road bridge. Conversely, although the ebb tide at the estuary mouth began 10 min. after the predicted high tide at Lyttelton, it was 50 min. later at the Heathcote Bridge.

No investigations were made of pollution and chemical properties of the water, but reports by Linzey (1944), Bruce (unpublished 1953), Hogan and Wilkinson (1959), Webb (unpublished 1965), and Robb (unpublished 1966) give some indication of chemical contamination in the estuary.

TEMPERATURES

Water temperatures (Fig. 3) were taken 1–3 times a week at the 38 fish sampling areas. A 0–50°C full immersion mercury thermometer (accurate to 0.1°C) was used. Because all temperatures were measured either at extreme low or high water, the possible influence of the extreme mudflat temperatures was not considered significant; the mean water temperature for each month showed no bias towards either of these extremes. All mean monthly air temperatures were lower than the mean water temperatures for the same period. July was the coolest month for both air and water; this agreed with Moore's (1962) suggestion that the lowest temperatures occurred 4–5 weeks after the mid-winter period.

TABLE 2—Seasonal fluctuations in numbers of sand flounder (*Rhombosolea plebeia*) and yellow bellied flounder (*Rhombosolea leporina*) in selected areas of the Avon-Heathcote Estuary, 1965 (otter trawl stations = **3, 3a,** etc.; beach seine stations = 1, 2, etc.; – = none taken)

LOCALITY	STATIONS	MEAN NO. OF FISH PER SAMPLE May–July	MEAN NO. OF FISH PER SAMPLE September–November
Sand flounder			
Moncks Bay	1, 2	20.3	17.8
Heathcote River Channel	**3**, 3	3.6	10.8
	3a, 3b, 7	4.3	6.4
	4a	4.0	3.0
	4d	1.0	1.0
Avon River Channel	**5a**, 4	11.6	30.3
	6	17.1	14.0
	6b, 14	6.0	5.3
	5, 6	7.5	5.3
Yellow-bellied flounder			
Moncks Bay	1, 2	7.3	14.5
Heathcote River Channel	**3**, 3	–	1.0
	3a, 3b, 7	1.3	1.0
	4a	2.8	–
	4d	1.0	–
Avon River Channel	**5a**, 4	2.7	1.3
	6	5.2	1.2
	6b, 14	2.8	–
	5, 6	–	0.14

Surface differences in temperatures were also noted. On 8 November 1965 the low tide temperature at beach seine Sta. 2 was 13.5°C and at beach seine Sta. 10a, 16.3°C: on 15 December 1965 the high tide temperature at otter trawl Sta. **4e** was 18.3°C, and at beach seine Sta. 10a, 20.6°C. There were also vertical differences in water temperatures of about 1°C; on the 5 July 1965 at otter trawl Sta. **4b** (high tide) the temperature 15.2 cm below the surface was 6.6°C, while at 1.82 m it was 7.7°C. Similar differences were noted by Emery and Stevenson (1957).

DISTRIBUTION AND MOVEMENTS

During the 1 year period, 28 species of fish were recorded. Eight of the 9 main fish species within the estuary were permanent residents: sand flounder, yellow-bellied flounder, common sole, yellow-eyed mullet, kahawai, spotty, cockabully, and common bully; globe fish were seasonally present. These nine species comprised approximately 90% of the total numbers caught during the 1965–66 investigation.

Sand flounder *(Rhombosolea plebeia)*

Sand flounder inhabited the river channels, Moncks Bay, and the permanent mudflat streams. They were present throughout the estuary

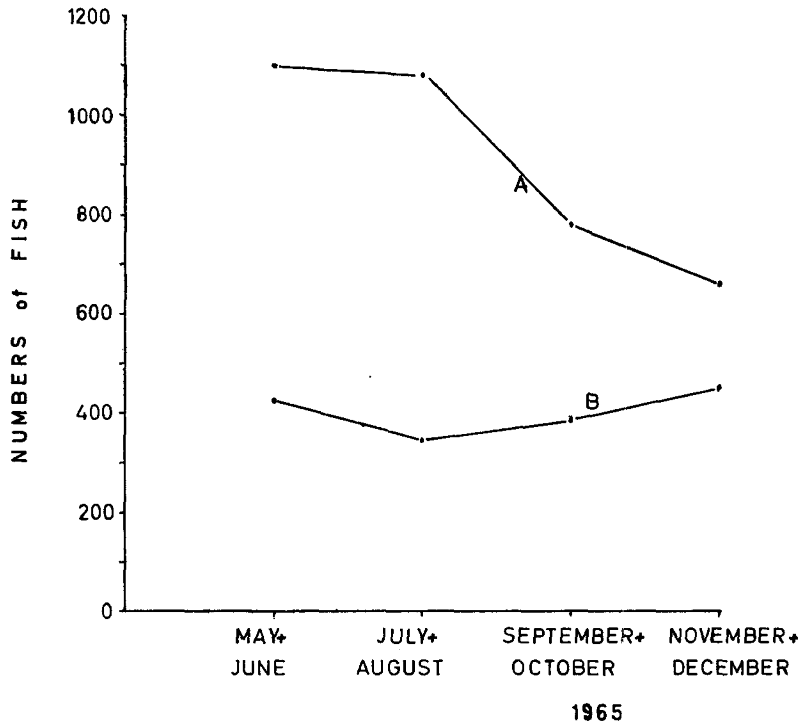

FIG. 4—Seasonal variations in numbers of sand flounder, *Rhombosolea plebeia*, caught in Avon-Heathcote Estuary, 1965–66. Samples are summed for 2-monthly periods; line A = all fish caught, including Marine Department samples from Moncks Bay; line B = fish caught by author.

all year, but numbers decreased in summer and increased in winter (Figs. 4 and 5).

Most of the population was found in Moncks Bay, numbers depending on the previous year's breeding success, the intensity of commercial fishing at sea, and the amount of amateur fishing and poaching in the estuary. A decrease in fish numbers showed that a movement from Moncks Bay to the river channels occurred from May to July and from September to November (Table 2).

At otter trawl Sta. 3 and beach seine Sta. 3 (*see* Fig. 1) fish numbers rose from a winter low figure of 3.6 to 10.8 fish per sample in the spring-summer period: this rise was probably due to breeding adults moving into the area (Webb, in press).

The Avon channel contained most of the sand flounder in the central estuary area. Sample areas half way up the Avon channel showed a rapid increase in numbers within the September-November period, due partly to an increase in mature adults, and partly to the high water pollution in the Heathcote River, which caused most sand flounders to move away from the western area of the estuary.

Small movements to feed occurred into waters over the mudflats at high tide. Juveniles (below 20 mm T.L.) were found in areas of calm waters and sluggish currents, such as streams, edges of river channels, and mudflat areas which were just covered at low tide. These juveniles were more abundant in the central estuary than in Moncks Bay.

Yellow-bellied flounder *(Rhombosolea leporina)*

There was a decrease in numbers of yellow-bellied flounder in the estuary during spring and summer (*see* Fig. 4, Table 2), except in Moncks Bay, where the population doubled.

A number of females with mature gonads were caught in Moncks Bay during October and November, indicating that this species breeds to a limited extent in the estuary. As with the sand flounder, most of the population was concentrated in Moncks Bay throughout the year, with a few spreading along the river channels in the central estuary. However, because yellow-bellied flounder are more sensitive to pollution than sand flounder, this spread is very limited. Nevertheless, both species occupied the same habitat.

Common sole *(Peltorhamphus novaezeelandiae)*

The common sole was the most stenohaline and the least tolerant of pollution of the pleuronectids found in the estuary. It was taken in Moncks Bay from Shag Rock to the end of the Fishermens Wall (*see* Fig. 4), in deeper waters; it rarely moved into the low tide shallows and never entered the mudflat stream emptying into Moncks Bay. On 22 November 1965, juveniles (172–180 mm) were netted at otter trawl Sta. **5a,** but despite numerous samples from this area, no further specimens were collected beyond Moncks Bay.

An increase in numbers caught was observed in summer:

		1965		1966
May-June	July-Aug.	Sept.-Oct.	Nov.-Dec.	Jan.-Feb.
19	13	53	58	56

This increase appeared to be a feeding response caused by the rise in temperatures rather than an influx of mature adults for spawning. A few juveniles (20–30 mm) were caught in the shallower waters (1.5 m).

Yellow-eyed mullet *(Aldrichetta forsteri)*

Because of the mobility of yellow-eyed mullet, the distribution of this species was complex, and showed tidal and seasonal differences (Fig. 6). During winter most adults retreated at low tide into Moncks Bay and the river junction. With the onset of flood tide, the adults moved rapidly up the river channels keeping pace with the tidal waters. By mid-flood, most adults had migrated up the river channels or moved over the mudflats. For example, at otter trawl sta. **3** on 26 June 1965, 34 adults were caught at low tide compared with only 2 adults 3.5 h after low tide on 28 June 1965. By high tide, most adults had moved beyond the Dyers Road and Heathcote bridges, with a few remaining on the flooded mudflats. On the ebb tide, the fish used the drainage streams and low mudflat areas as passageways to the rivers and Moncks Bay.

During summer there was an increase in the numbers of adults feeding on the large concentrations of *Moina* sp. near the oxidation ponds. On 21 June 1965, a half-hour otter trawl in front of the ponds did not catch any yellow-eyed mullet; on 19 September 1965 and 16 November 1965, similar tows caught 53 and 23 respectively, and the low tide distribution extended to the lower reaches of the river channels instead of concentrating in Moncks Bay.

Seasonal variations in numbers in the estuary were: May–June, 184 specimens; July–August, 281; September–October, 469; and November–December, 465.

Young, shoaling yellow-eyed mullet were not observed before 10 August 1965 (*see* Fig. 6). Like the adults, they retreated with the ebb tide and advanced on the flood, keeping very close to the water's edge, both along the channels and in Moncks Bay at low tide, and near the high water shoreline at full tide. It was not until the juveniles had reached a length of 130–140 mm or more that they ventured into deeper waters.

Kahawai *(Arripis trutta)*

For most of the year the kahawai kept to Moncks Bay (Fig. 7), where 207 fish of the total of 215 were caught. In summer, a few specimens moved into the lower reaches of the river channels, where seven were landed. Although large numbers of juveniles were caught in April 1966 in Moncks Bay, no specimens below 200 mm were found during 1965.

Spotty *(Pseudolabrus celidotus)*

During winter spotties kept very much to Moncks Bay, in rocky locations and deep areas close to the shoreline (*see* Fig. 7): this made sampling difficult, and gave very small winter numbers. The peak of numbers caught was in November-December:

		1965			1966
May-June	July-Aug.	Sept.-Oct.	Nov.-Dec.	Jan.-Feb.	Mar.-Apr.
3	0	29	60	8	14

Although there were few winter samples, specimens caught by anglers along the Shag Rock and Redcliffs shorelines indicated that spotties were present from June to August. In summer, spotties extended their habitat to the lower reaches of the river channels.

Juveniles were found throughout spring and summer beneath dense *Ulva*, below rocks, and amongst *Mytilus* beds. Their presence strongly suggested a breeding population along the Moncks Bay shore.

Cockabully *(Tripterygion nigripenne)*

Three colonies of cockabully were found in different habitats: a marine population along the shore of Moncks Bay and near Shag Rock, living amongst rocks, algae, and *Mytilus* beds (salinity 34‰); a second colony occurred in brackish water along the Redcliffs shore and in the small stream flowing from McCormacks Bay (salinity 18‰ to 34‰) under rocks and dense masses of *Ulva lactuca;* and a third colony, in restricted numbers, beneath rocks below the Dyers Rd bridge in salinity ranging from freshwater to 30‰. Mature specimens were found in each habitat (Webb, in press), and interchange of individuals could have occurred between these areas.

Common bully *(Gobiomorphus basalis)*

The common bully lives in tidal reaches when young and in freshwater streams and lakes as an adult (Woods 1963). In the estuary, this species was found below the Dyers Rd bridge (where most of the 142 specimens were caught), and in the vicinity of Linwood Avenue culvert and Charlestone drain. One specimen was caught by otter trawl in mid estuary, trapped amongst detritus and algae.

Globefish *(Spheroides richei)*

This was the main seasonal fish. After 29 May 1965 no further specimens were taken at otter trawl station **3b** until 11 October 1965. Temperature was a major factor in seasonal movement patterns, although other factors may have been involved. Average temperatures (°c) for May and October indicate that a minimum temperature of 11.0°c was a pre-requisite for globefish:

	Mean	Minimum	Maximum
May	11.0	11.0	11.0
October	11.8	10.2	14.0

Movement was not greatly related to tides; a small retreat occurred at low tide (Fig. 8). Average fish numbers per sample show a gradation in numbers from Moncks Bay to the river channels, further penetration being limited by brackish waters or pollution:

Moncks Bay 18.6 (**2** & 2)
Heathcote Channel 3.5 (**3**); 4.2 (**3a**); 1.5 (**3b**); 0.5 (**4a**)
Avon Channel 1.0 (**5a**); 1.0 (**5**).

LENGTH-FREQUENCY DISTRIBUTIONS

Sand flounder *(Rhombosolea plebeia)*

A gradual decrease in numbers occurred from winter to summer months, the fish totals declining from 1,100 in May-June to 665 in

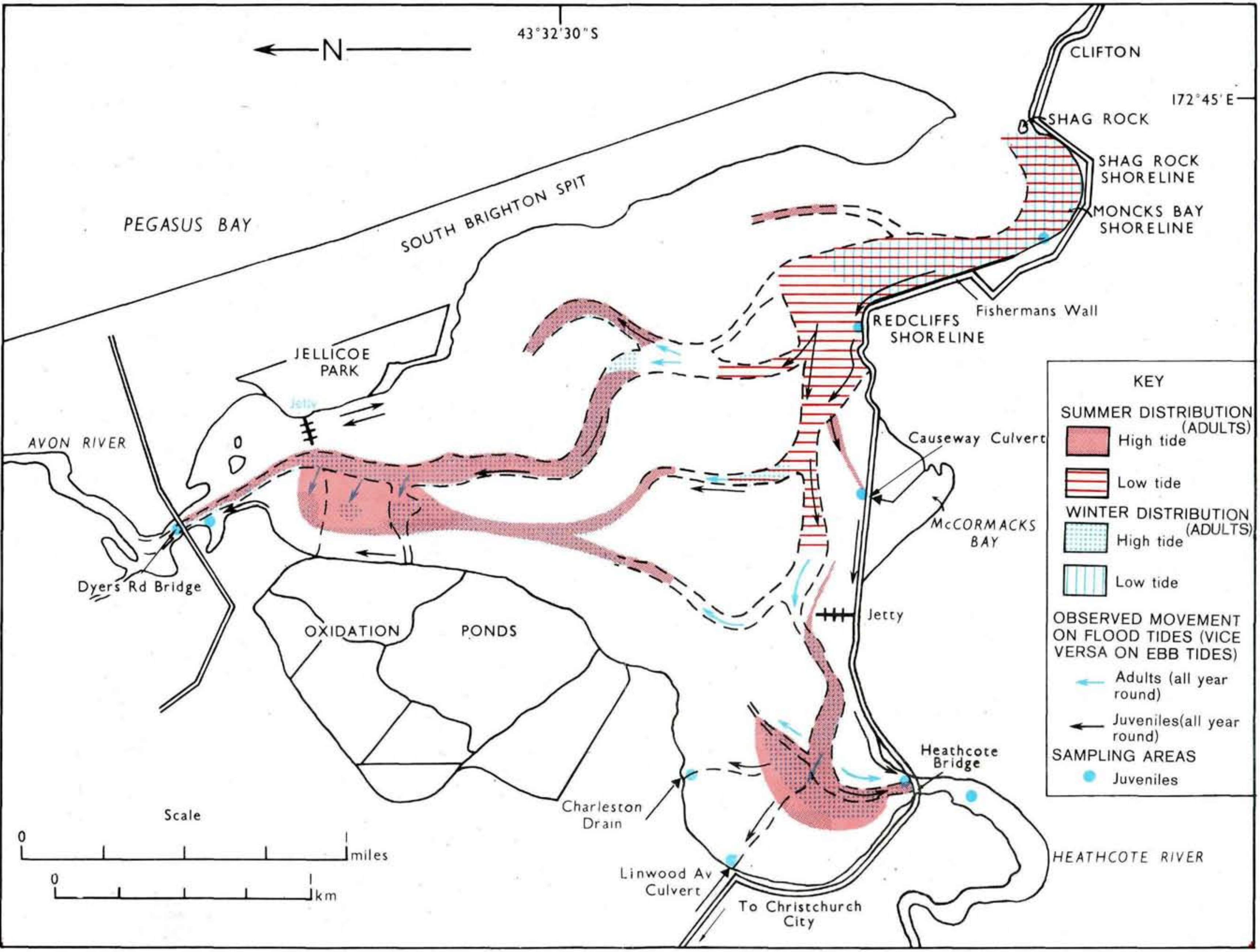

FIG. 6—Seasonal and tidal distributions for adult yellow-eyed mullet, *Aldrichetta forsteri*, movements of adults and juveniles, and sampling areas for juveniles, Avon-Heathcote Estuary, 1965–66.

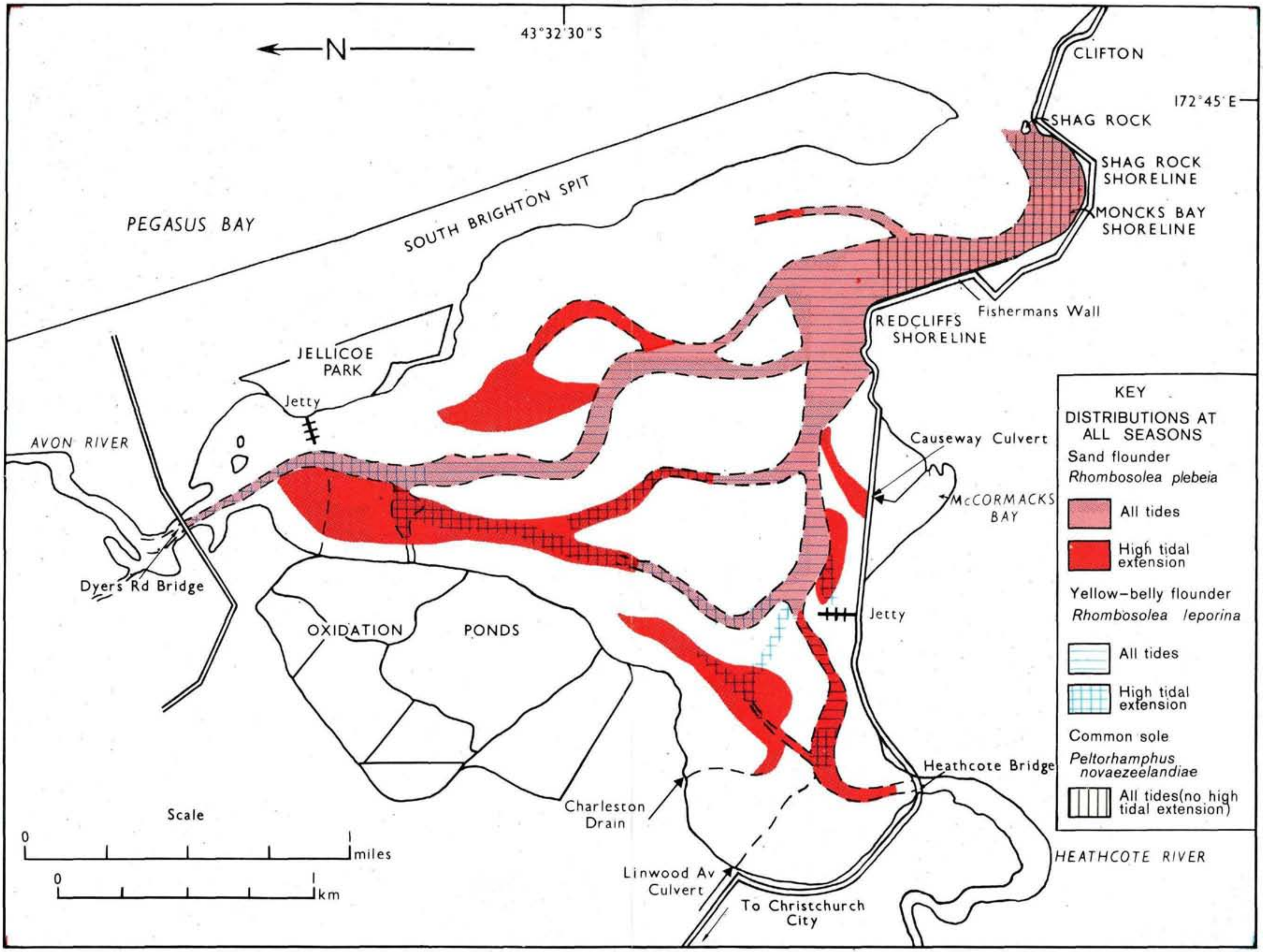

FIG. 5—Tidal distributions at all seasons of three species of flatfish (Pleuronectidae) in the Avon-Heathcote Estuary, 1965–66.

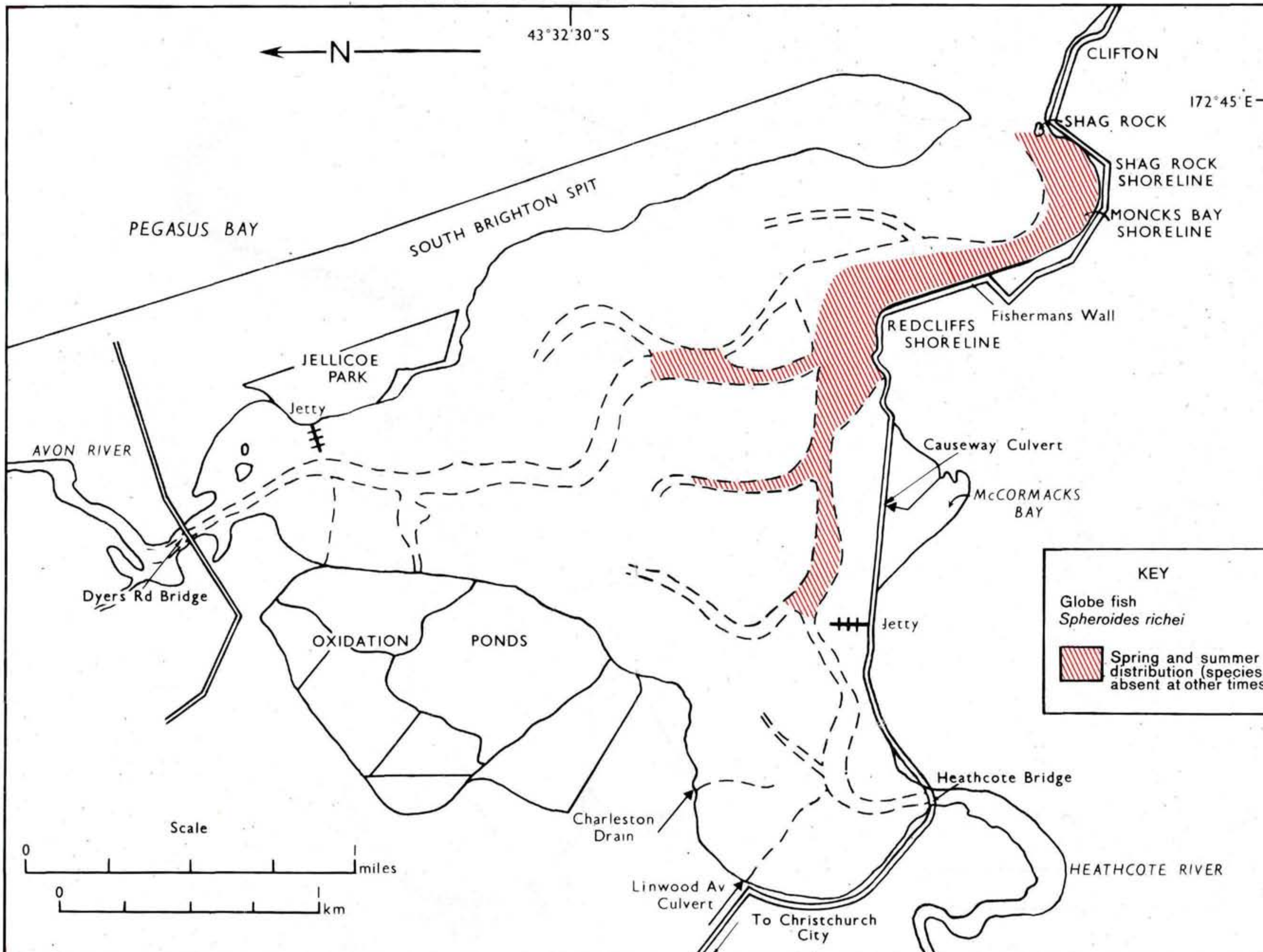

FIG. 8—Distribution of globe fish, *Spheroides richei*, in Avon-Heathcote Estuary, 1965–66.

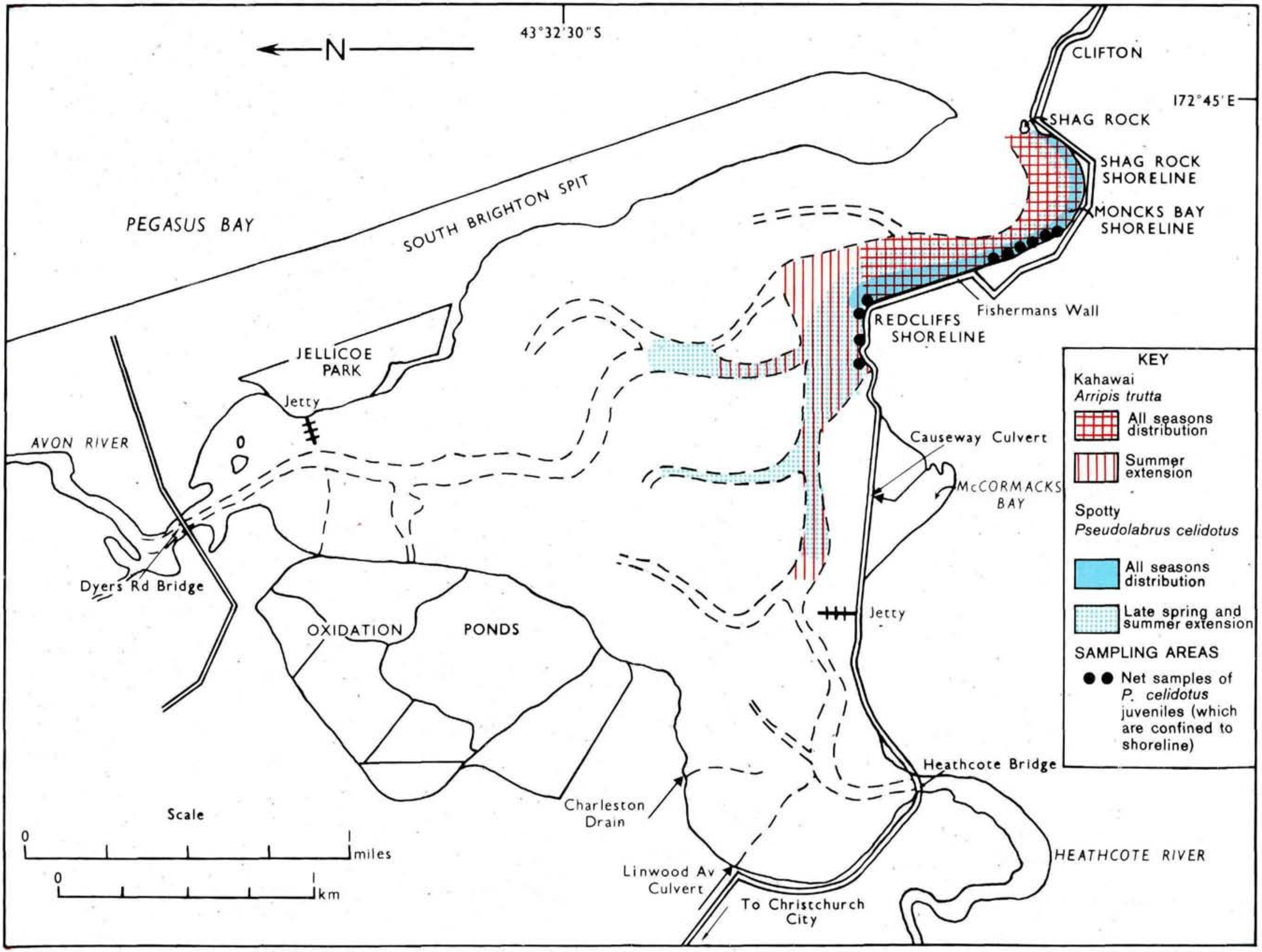

FIG. 7—Seasonal distributions for kahawai, *Arripis trutta*, and spotty, *Pseudolabrus celidotus*, in Avon-Heathcote Estuary, 1965–66; sampling areas for juvenile *P. celidotus* also shown.

November-December. Lower size groups (110–150 mm T.L.) decreased and there was a corresponding increase in the frequencies of young adult to adult size groups:

	Length Groups (mm)			
	110–150	160–200	210–250	260–300
May-June	43.7%	40.03%	7.43%	0.18%
July-August	39.5%	46.79%	8.64%	–
September-October	27.6%	60.1%	11.8%	0.2%
November-December	23.13%	57.89%	17.79%	0.38%

The juvenile decrease (110–150 mm T.L.) from winter to summer was about 50%. The adult increase (above 210 mm T.L.) in summer was probably caused by spawning adults remaining in the estuary (Webb, in press). A sudden shift to the 120–160 mm T.L. range during January-February (Fig. 9), indicated a spring migration of adults from the estuary, which increased the pressure of fishing on the remaining adults. One could predict that the March-April 1966 samples would have fallen somewhere between the positively skewed January-February 1966 samples and the apparently normal distribution of the May-June 1965 samples.

Because the sand flounder population was mainly immature fish, the estuary was chiefly a nursery area, but with a steady interchange of all sizes between estuary and sea.

Samples were analysed using probability paper (Harding 1949; Cassie 1950) for possible deviations within the Gaussian curves. In most cases the probability points plotted out as approximately straight lines, indicating normally distributed samples. The means and standard deviations were calculated, and the populations proved to be very close to the arithmetical calculations. However, November-December 1965 and January-February 1966 samples were found to have 2 main size groups:

	$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
November-December	125	92	20	2.0
	193	573	24	1.02
January-February	141	295	19	1.1
	200	102	28	2.7

$\bar{X}$ = mean, n = number, s = standard deviation, S.E.$_m$ = standard error of the mean.

The two size groups may represent year classes 1 and 2. To investigate similarity in size structure of the samples, summed for each period of

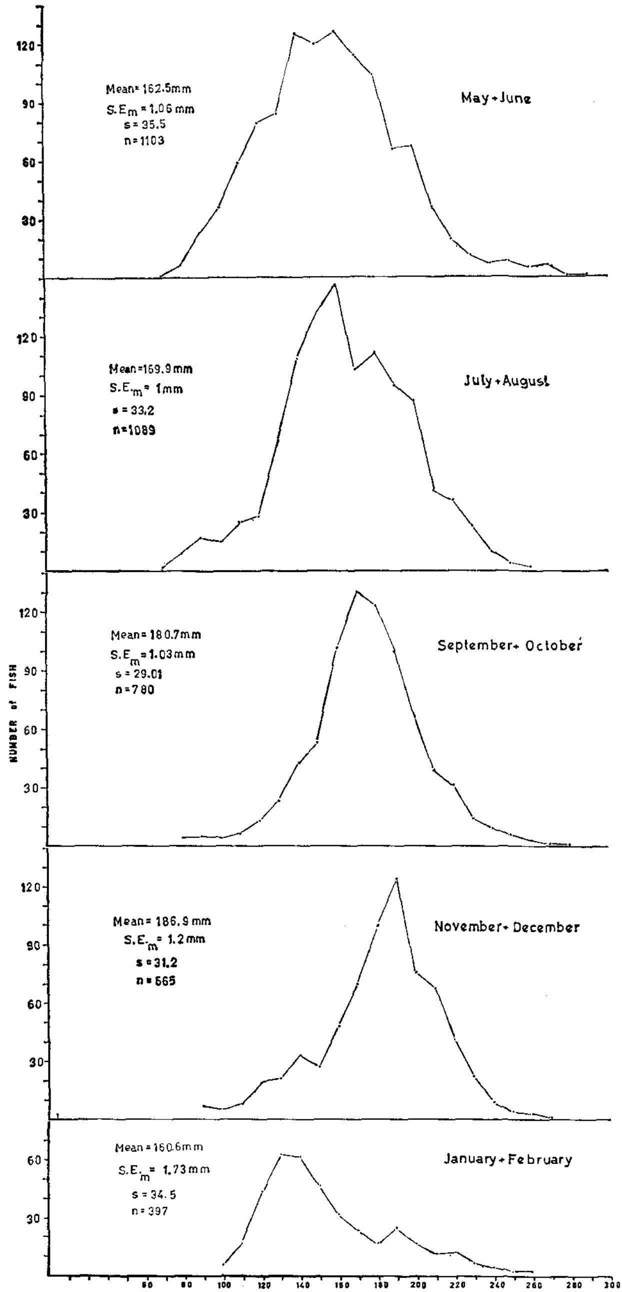

FIG. 9—Length-frequency of cumulated 2-monthly groups of samples of sand flounder, *Rhombosolea plebeia,* caught in Avon-Heathcote Estuary, May-June 1965 to January-February 1966; each 2-monthly group of samples includes 1 day's sample caught by Marine Department.

2 months, the analysis of variance test was used. The F value of 89.34 gave $P<0.001$, indicating real differences between the populations from which the samples were drawn. Since the samples were large, 95% confidence limits for the means were calculated as 1.96 estimated standard deviations either side of the mean (Fig. 10). Duncan's multiple range test underscored the means for January-February (1966) and May-June (1965), indicating similarity between the calculated means for these months, and a significant difference between the means for the rest of the samples. The increase from the winter to summer months substantiated the decline noted for juveniles as well as the increased catches of adults.

Yellow-bellied flounder *(Rhombosolea leporina)*

Further analysis of plotted length-frequencies (Fig. 11) on probability paper separated the length classes:

	$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
May-June	131	11	11	3.3
	176	38	14	2.2
	252	52	24	3.3
July-August	158	47	26	3.8
	235	49	22	3.1
	287	4	6	3.0
September-October	141	25	17	3.4
	212	29	41	7.6
	291	4	12	6.0
November-December	148	17	9	6.4
	197	53	18	7.8
	230	14	10	3.7
	274	14	10	3.7

There appeared to be three or four main size groups. Because most yellow-bellied flounder bred during spring and summer, the size groups for September-October and November-December may represent age groups, i.e., age 2=140–150 mm; age 3=190–210 mm; age 4=230–250 mm; and age 5=275–300 mm. Mr R. Mundy (pers. comm.) maintains that yellow-bellied flounder have a slower growth rate than sand flounder. A large proportion of the estuary population were juveniles or young adults, suggesting that yellow-bellied flounder used the estuary predominantly as a feeding ground for young fish.

An analysis of variance test was used on the samples summed over 2 month periods to look for similarity in size structure throughout the year. The F value of 4.44 gave $P<0.005$ of drawing more divergent samples from a common population, indicating a real difference between the populations from which they originated. However, by the more stringent Duncan's multiple range test all means were underscored, which is evidence for no significant difference between the samples.

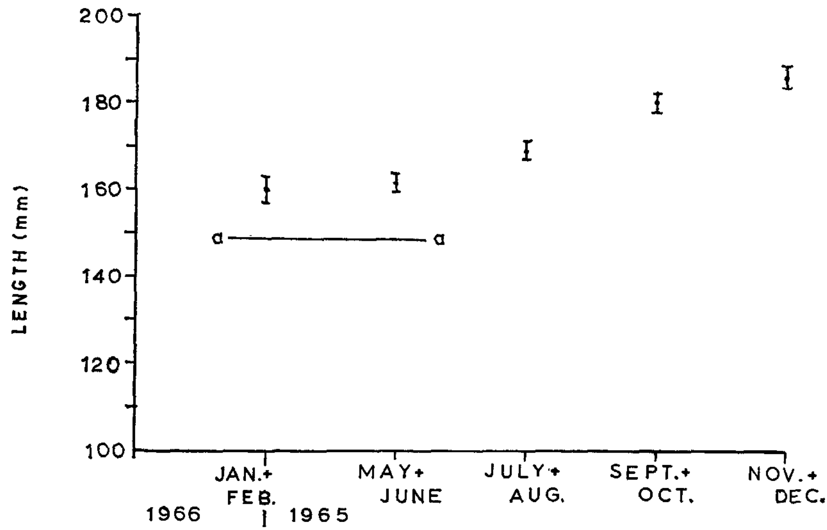

FIG. 10—Standard error ranges of the means of lengths of cumulated 2-monthly groups of samples of sand flounder, *Rhombosolea plebeia,* caught in Avon-Heathcote Estuary, 1965–66; similar means are underscored as a result of Duncan's multiple range test.

Despite this conflict, it is believed that a slight variation exists between the May-June sample and all other samples.

Common sole *(Peltorhamphus novaezeelandiae)*

Plotted length frequencies show that winter size groups were within the 150–160 mm T.L. range, although numbers and adults increased in summer, indicating that this species used the estuary throughout the year principally for feeding.

	$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
1965				
May-June	158.15	19	24.28	5.57
July-August	165.0	13	26.77	7.42
September-October	177.2	50	51.0	7.21
November-December	173.79	58	22.25	2.92
1966				
January-February	196.78	56	27.11	3.65
March-April	191.66	9	55.23	18.41

Analysis of variance between the samples gave an F value of 6.41 ($P<0.005$). There was therefore a difference between the populations from which the samples were drawn. Duncan's test, used to underscore the means (Fig. 12) into groups of similar lengths, showed variation in

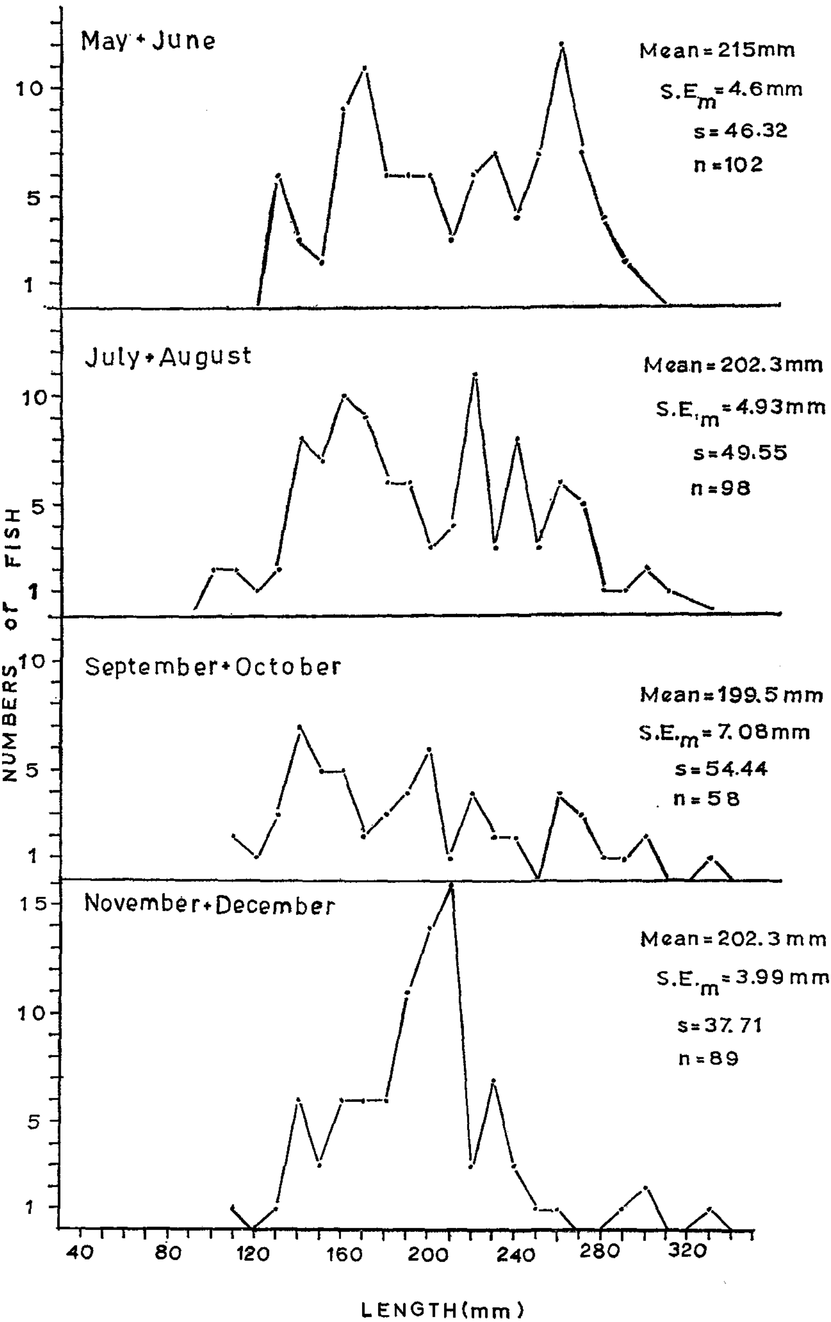

FIG. 11—Length-frequency of cumulated 2-monthly groups of samples of yellow-bellied flounder, *Rhombosolea leporina*, caught in Avon-Heathcote Estuary, 1965.

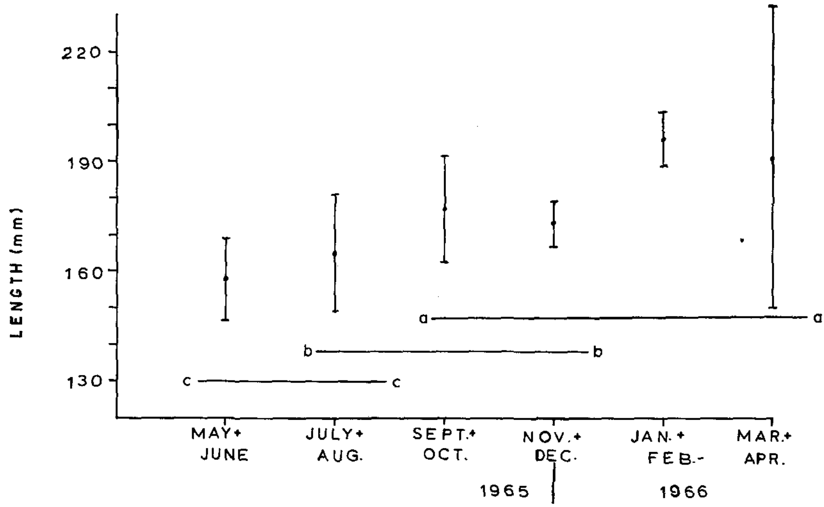

FIG. 12—Standard error ranges of the means of lengths of cumulated 2-monthly groups of samples of common sole, *Peltorhamphus novaezeelandiae,* caught in Avon-Heathcote Estuary, 1965-66; similar means are underscored as a result of Duncan's multiple range test.

size structure between the winter and summer. Because the common sole was restricted to the Moncks Bay area, this variation was thought to be due to the influx of adults with the rising water temperatures during the spring months. This would agree with suggestions by Hedgpeth (1957) that the invasion of estuaries is easier in warmer waters, and Pannikkar (1951) that the invasion of estuaries is correlated with increased osmoregulation in organisms because of higher water temperatures.

The standard error for the March-April 1966 mean was too large, and this sample should be disregarded. Year class estimations based on a small number of tag returns, (R. Mundy, pers. comm.) gave the following size ranges: year 1=120–130 mm; year 2=210–220 mm; year 3=300–310 mm.

Yellow-eyed mullet *(Aldrichetta forsteri)*

Length-frequencies of the yellow-eyed mullet samples were summed for each 2 months, and plotted with their sample statistics (Fig. 13). Plotted on probability paper, these produced straight line graphs, indicating normal distributions. An analysis of variance test gave an *F* value of 22 having $P<0.005$ of drawing more divergent samples from a common population. Because there was seasonal variation in the mean sizes of the samples, Duncan's test (Fig. 14) showed a significant size difference between the sample mean of September-October and the rest of the samples. This difference suggested a migration of adults out of the estuary for spawning at sea. It had been expected, however, that in

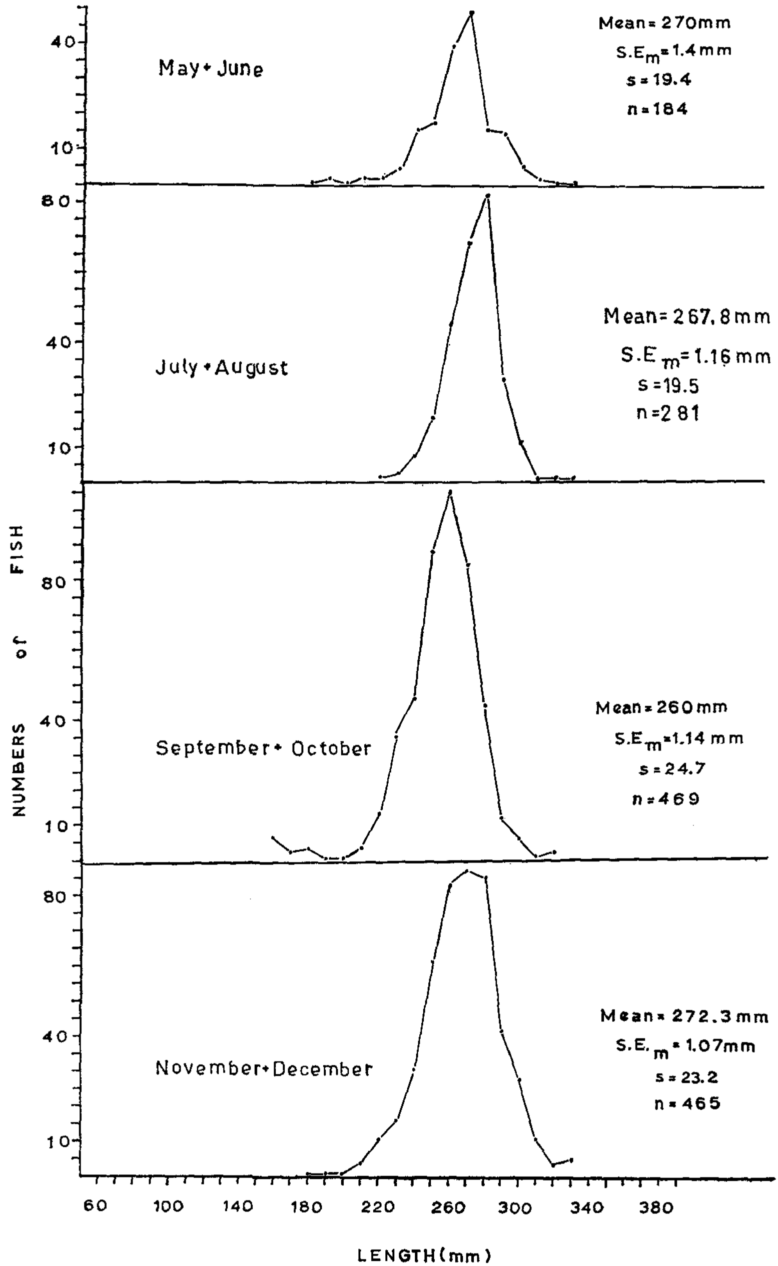

FIG. 13—Length-frequency of cumulated 2-monthly groups of samples of yellow-eyed mullet, *Aldrichetta forsteri*, caught in Avon-Heathcote Estuary, 1965.

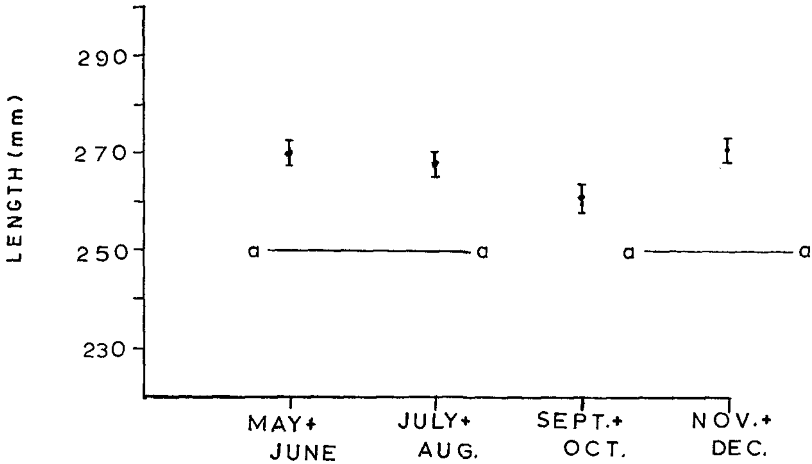

FIG. 14—Standard error ranges of the means of lengths of yellow-eyed mullet, *Aldrichetta forsteri*, caught in Avon-Heathcote Estuary, 1965; similar means are underscored as a result of Duncan's multiple range test.

summer lengths would be widely heterogeneous because of a build up from the winter population broadened by a seasonal influx of smaller animals. This did not occur, which suggested that a juvenile population (below 150 mm) in the estuary replaced the outward migrating adults, and was itself replenished by inward migrating juveniles and the resident estuary population. This is supported by the length-frequency calculations for the juvenile population:

	$\bar{X}$ (mm)	*n*	*s* (mm)	S.E.$_m$ (mm)
1965				
August	67.31	219	2.48	0.167
September	71.76	43	16.45	2.5
November	105.62	45	20.44	3.09
December	65.14	33	24.42	4.25
1966				
April	102.28	7	1.63	0.613

The monthly means show an increase in size from spring to summer, a decrease over mid-summer, and a rise again in autumn; with size composition variations of the samples, this suggests two concentrated spawning periods during the year, one in winter and the other in summer.

Kahawai *(Arripis trutta)*

Most of the population inhabiting the estuary throughout the year were young adults (300–400 mm); only 9 of the 214 specimens were maturing adults. Length parameters were:

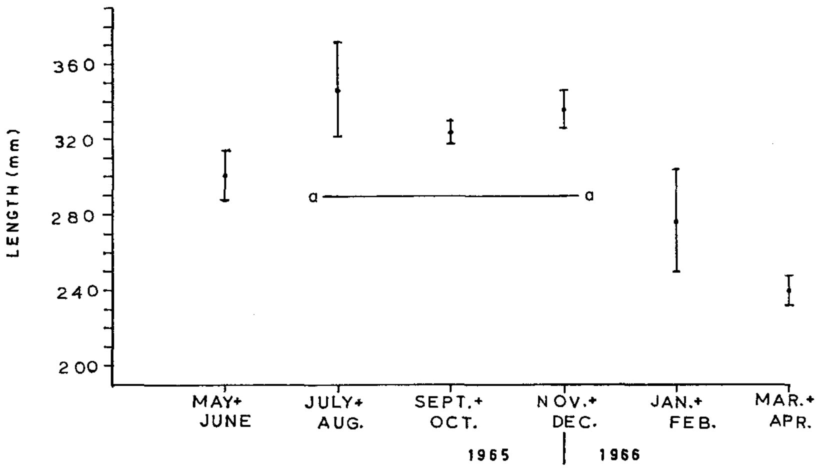

FIG. 15—Standard error ranges of the means of lengths of kahawai, *Arripis trutta,* caught in Avon-Heathcote Estuary, 1965–66; similar means are underscored as a result of Duncan's multiple range test.

	$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
1965				
May-June	301.8	22	30.61	6.52
July-August	347.5	28	64.21	12.13
September-October	324.5	57	20.71	2.74
November-December	336.7	29	25.36	4.7
1966				
January-February	277.8	26	67.68	13.27
March-April	240.4	53	29.51	4.05

The March-April 1966 decrease in the mean was caused by juveniles between 180–280 mm (T.L.) migrating into the estuary, and was probably accentuated by the larger size groups migrating out as shown by the percentage change:

	200–300 mm	>300 mm
September-October	3.7	94.5
March-April	78.9	21.0

The analysis of variance test, on the 2-month samples summed, gave an F value of 42.47 and $P<0.005$ of drawing more divergent samples from a common population. Duncan's test (Fig. 15) showed that size ranges increased from a low winter value to a higher summer value, and then dropped again in autumn.

Spotty *(Pseudolabrus celidotus)*

Although the samples were small, the size structure varied little throughout the year, and adults were abundant in all seasons. Length parameters of 2-monthly samples were:

	$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
1965				
May-June	180.0	3	4.18	2.41
September-October	201.4	29	14.91	2.77
November-December	203.2	70	22.99	2.75
1966				
January-February	219.9	8	28.66	10.16
March-April	210.7	14	20.88	5.58

Winter samples were smaller because spotties remained close to the rocky shore, making sampling difficult. An analysis of variance test between the 2-monthly samples gave an F value of 2.43 and P=0.05, signifying no real difference between the means. This suggested either a random movement of all size lengths between estuary and sea, or a sedentary population. There were more juveniles than adults. Plotting the lengths on probability paper gave the following results for November-December:

$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
168	19	5.0	2.39
200	37	5.5	1.84
232	14	8.25	4.7

Parrott (1957) suggested the following approximate age to length relationship: year 1$\simeq$65 mm; year 2$\simeq$105 mm and year 3$\simeq$140 mm. The above groups suggest year 4$\simeq$170 mm; year 5$\simeq$200 mm; and year 6$\simeq$230 mm. Only 10 juveniles were caught in the estuary over summer, all between 35 mm and 70 mm long.

Cockabully *(Tripterygion nigripenne)*

Three populations were recognised in waters of varying salinity; marine in Moncks Bay, brackish along the Redcliffs shore, and freshwater to brackish at the Dyers Rd bridge. It was not clear whether the 3 populations constituted either compatible colonies or separate races of the same species. As the Dyers Road sample was too small for analysis, the table of length parameters below is based on the combined totals of the Redcliffs and Moncks Bay areas:

	$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
1965				
August	61.5	16	18.27	4.56
September	78.88	9	12.72	4.26
November	61.66	12	13.86	4.0
December	68.25	4	10.9	5.45
1966				
April	50.0	5	2.82	1.99

The analysis of variance test on the combined population samples gave an F value of 19.77 and $P<0.005$ that the monthly size structures were similar; testing only the Moncks Bay colony gave $F=3.71$ and $P=0.05–0.025$ indicating no difference between months. Analysis by Student's t-test between the Redcliffs and Moncks Bay populations for August and November gave $t=0.3–0.2$ (13 d.f.) for August, and $t=0.01–0.001$ (8 d.f.) for November.

While there was no significant size difference between the two areas for August, there was one for November, suggesting a change in the size structure for both areas in September and October. These variations in size were probably caused by the establishment of territories with the onset of the breeding season, and, from mid-summer onwards, by a breakdown in territorial behaviour allowing a freer interchange of individuals. Where the adults wintered is uncertain, but most adults probably remained along the rocky shore. No specimens caught were smaller than 30 mm long.

Common bully *(Gobiomorphus basalis)*

From August 1965 to April 1966, 142 specimens of common bully were caught and dissected. Their 3-monthly length parameters from two areas were:

	$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
Dyers Rd Shoreline				
August-October	40.0	24	14.4	2.88
November-January	39.2	20	18.0	4.02
February-April	34.4	35	15.0	2.62
Linwood Av. culvert–Charlestone Drain				
August-October	26.6	3	5.74	3.31
November-January	36.3	18	13.15	3.09
February-April	34.4	42	17.2	2.6

The above standard errors and means showed that both populations were predominantly juvenile for most of the year. Analysis of variance tests for Dyers Road shore and Linwood Avenue-Charlestone Drain region

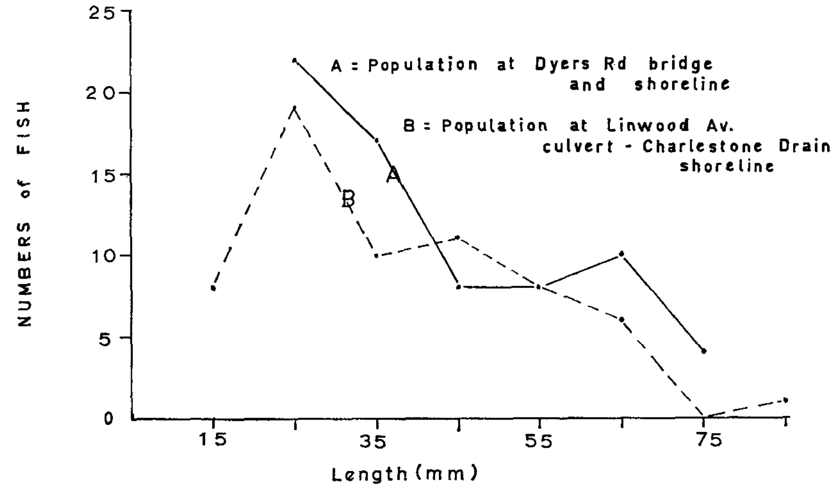

FIG. 16—Length-frequency of cumulated samples of common bully, *Gobiomorphus basalis,* caught in Avon-Heathcote Estuary, 1965–66.

gave *F* values of 0.48 and 1.083 respectively, both having P>0.1, indicating a similarity in size structure between the monthly groups for each area. Combined length-frequencies from each area were plotted to show population structure (Fig. 16). Both areas appeared to have permanent, self-maintaining populations, i.e., containing sufficient juveniles to overcome any mortality, migration, or predation. It was uncertain whether there was any interchange of individuals between areas. The apparent lack of juveniles below 20 mm implied possible freshwater migration; Woods (1963, and pers. comm.) stated that small fish (below 25 mm) usually moved into freshwater areas before re-entering areas similar to those sampled here.

Because analysis between the 2 areas by Student's *t*-test showed no significant differences in the lengths within the 3-monthly groups, the total populations from both areas were combined and analysed by probability paper:

$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
23.5	86	6.5	0.7
42.0	31	4.5	0.8
56.5	25	12.0	2.4

From the 3 groups which separated out, the following age-length relationships may be inferred: year 1=20–25 mm; year 2=40–45 mm; year 3=52–58 mm. McDowall (1965) found that the red-finned bully, *Gobiomorphus huttoni* (Ogilby), matured at year 2 at a standard length of 45 mm. The narrow limits of the standard errors of the 3 size groups indicated a reasonable estimation of the true population means.

Globefish *(Spheroides richei)*

Owing to the large numbers caught, many of all sizes were released as randomly as possible. The monthly length parameters of those retained were:

	$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
1965				
October	134.6	25	13.7	2.74
November	127.1	23	17.8	3.71
December	131.3	102	18.05	1.78
1966				
January–February	125.9	75	22.61	2.61
April	136.7	51	20.17	2.82

Analysis of variance test gave an F value of 2.14 ($P=0.1$–0.05), indicating no real difference between the monthly samples. The standard deviations gave a fairly accurate assessment of the monthly size structures in the estuary.

The total catches were plotted per size group on probability paper:

$\bar{X}$ (mm)	n	s (mm)	S.E.$_m$ (mm)
120	216	17.0	1.1
147	60	14.0	1.8

The two major size groups probably represent ages 3 and 4, ages 1 and 2 being absent because of the large mesh (50.8–63.0 mm) used.

LENGTH-WEIGHT ANALYSES

The regression results of $\log_{10}$ weight (g) plotted against $\log_{10}$ length (cm) for 8 fish species (Fig. 17; there was insufficient data for cockabullies) showed that the parameter b varied considerably between species. A fish having unchanging body form and unchanging specific gravity (isometric growth) had a theoretical value of $b=3$. Deviation from $b=3$ meant a deviation from the cubed form, indicating a change in body shape or in specific gravity with age. These changes may be caused by increased fat deposits, greater muscular density, increased deposition of calcium in cartilage, increase size of coelomic organs relative to coelomic space, or the presence or absence of an air bladder:

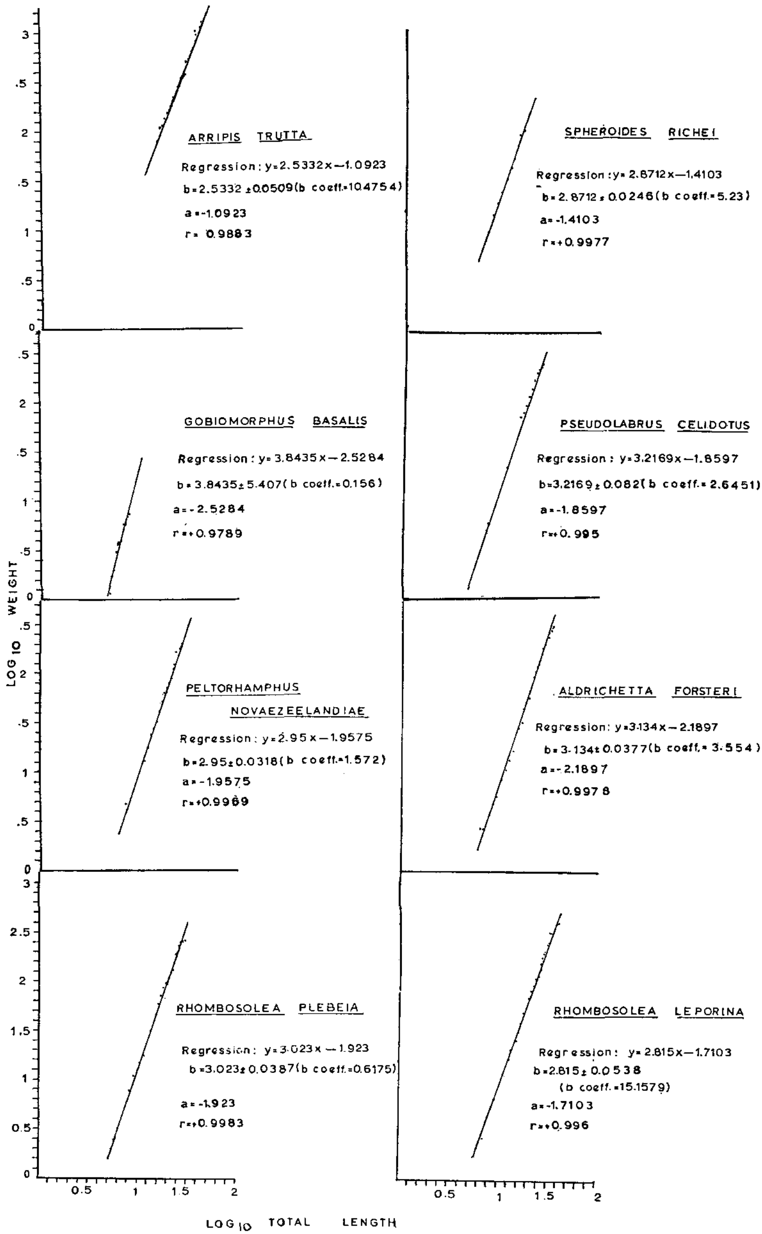

FIG. 17—Length: weight regressions for eight species of fish caught in Avon-Heathcote Estuary, 1965–66; lengths transformed to $\log_{10}$ from 10 mm size-groups, weights from means for each size group.

	Coefficient of b	Numbers ($n-2$)	P
Sand flounder	0.6175	22	0.6–0.5
Yellow-bellied flounder	15.1579	24	<0.001
Common sole	1.572	16	0.2–0.1
Yellow-eyed mullet	3.5545	27	0.01–0.001
Kahawai	10.4754	21	<0.001
Spotty	2.6451	12	0.05–0.02
Common bully	0.156	12	>0.9
Globefish	5.23	9	0.001

The b coefficient is a statistical measurement showing whether the calculated b varied from β, the hypothetical b, for the number of measurements under consideration, i.e.,

$$t=(b-\beta)\ (\text{S.E.}_{\cdot b})^{-1}$$

Where β=the hypothetical b value, and
S.E.$_{\cdot b}$=the standard error of b.

The equation gives the range both sides of the regression in which 68% of determinations of b would fall if these were from samples of this size drawn from the same infinite population. The standard errors of b, calculated at the 95% confidence level, showed that confidence could be placed on the respective b values for the species investigated.

Sand flounder, common bully, and common sole were the only species in which the calculated b value did not differ significantly from the hypothetical $b=3$. However, the results for common bully were considered suspect since the b value of 3.8435 (*see* Fig. 17) obviously differed from 3. This discrepancy reflected inaccurate weight measurements because of the use of whole gram weights for such small fish, and would make suspect any length to weight calculations based on them for this species. The other species showed significant b coefficients, indicating that growth was not isometric and that there was a change in specific gravity or in body form, or both, with increase in age.

The exponential forms of the length: weight regressions showed that this relationship could be used to predict weight from length as an alternative to the empirical regression provided by the log transformations of both variables.

CAUDAL FIN GROWTH

Regression analyses between caudal fin length (C.L.) and standard length (S.L.) were calculated for 4 species (sand flounder, yellow-eyed mullet, globe fish, and spotty) on the surmise that different modes of life would necessitate differences in the caudal fin, influencing its rate of growth. Millimetre lengths were converted to $\log_{10}$ and the linear regressions of log C.L. (y) on log S.L. (x) calculated as $y=a+bx$ (Fig. 18).

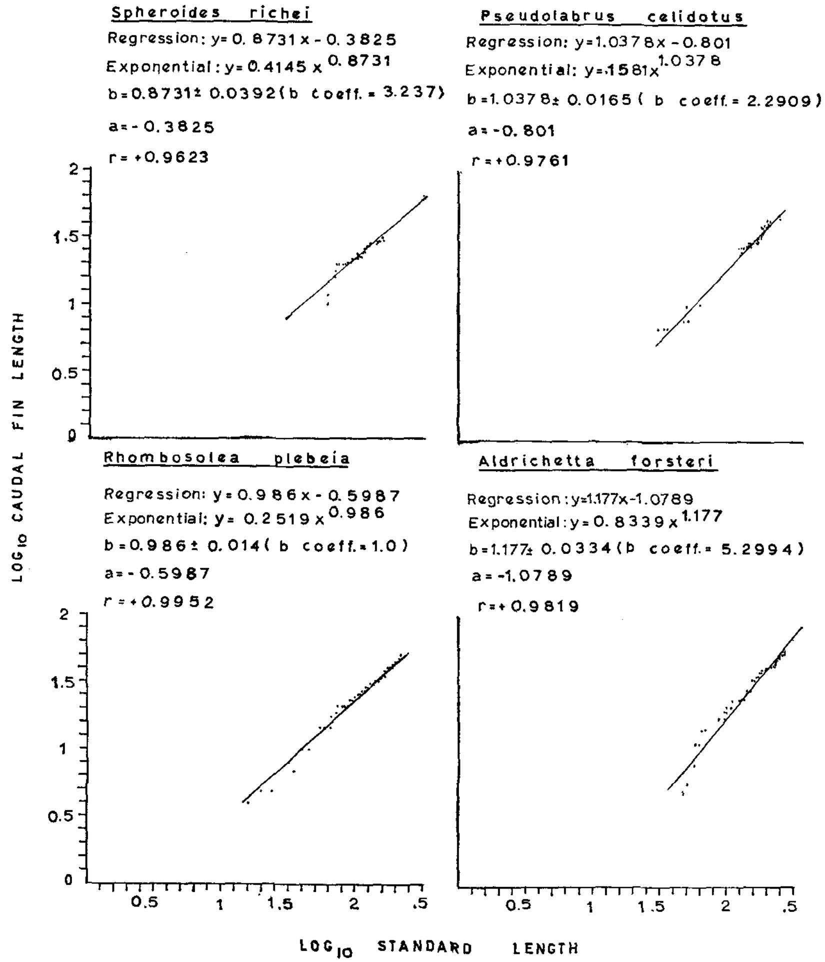

FIG. 18—Caudal fin length: standard length regressions for four species of fish caught in Avon-Heathcote Estuary, 1965–66; standard length = tip of snout to base of caudal fin; caudal fin length = base to outermost extremity, measured along body axis with fin folded.

The sand flounder was the only species for which the calculated b was not significantly different from 1. For yellow-eyed mullet the probability that these lengths equal 1 was less than 0.001; for spotty, 0.05–0.02; and for globefish, 0.01–0.001.

The caudal fin grew more rapidly than body length in yellow-eyed mullet and spotty and more slowly in globefish. This suggests that the species in the more exposed habitats had a faster caudal fin growth than those in sheltered habitats. Thus, parameter *a* could be used as an index for identifying the degree of mobility and the associated type of habitat.

DISCUSSION

Yellow-eyed mullet were the most spectacular migrants of all the species, moving 1.6–2.5 km into the estuary on each tide. Most species, however, confined their movements to encroachments onto the surrounding mudflats at high tide, or to small excursions along the river channels on the incoming tide. The effects of pollution were noticeable in the head reaches of the Heathcote River channel. Sand flounder, yellow-bellied flounder, and yellow-eyed mullet caught in the upper reaches of the Avon channel had a heavier coating of mucus than those caught in Moncks Bay. This was thought to be a response to irritation by detergent concentrations reaching 1-5 ppm in the treated sewage water.

Generally, the greater the numbers of a species, the more widespread it was throughout the estuary. In this light, the order of importance for the 9 species was sand flounder, yellow-eyed mullet, yellow-bellied flounder, kahawai and common sole, spotty, common bully, cockabully, and globefish. Although a few species (sand flounder, yellow-bellied flounder, yellow-eyed mullet) had a well mixed population structure (caused mainly by continual migration to and from the sea), only in the common bully did juveniles clearly predominate over adults (and juveniles below 15 mm T.L. probably moved into freshwater areas). A similar population structure for both the cockabully and the spotty was suspected although insufficient juveniles were caught to establish this. These three species were the only ones to depend on the estuary alone to maintain their populations; the other species relied heavily on replenishment from the sea. This prevalence of migration led to the conclusion that most species used the estuary as a nursery area and as a feeding area for migratory adults.

Because regression values are constant for a given population (Matsuda 1961; Jerison 1955, 1961), they may be used to compare populations for variation in size structure or length-weight relationships. Thus, the *b* values from this study could be used to distinguish between populations along the Canterbury coast.

ACKNOWLEDGMENTS

This paper was part of an M.Sc. degree from the Zoology Department, University of Canterbury, New Zealand. I wish to thank Professor G. Knox and Dr J. F. C. Morgans of the Zoology Department for helpful criticism; Dr B. Wisely of the Zoology Department and Mr M. Burnet of the Marine Department, Christchurch, for reading the manuscript; Mr P. Jansen for isopod identification; Mr G. Caughley for statistical advice; Messrs R. Mundy, E. Midgley, D. C. Macalister, J. Partington, and A. McKenzie, all of the Marine Department, Christchurch, for fishing assistance, advice, and loan of otter boards and towing ropes for trawls.

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