Fish Fauna of the Avon-Heathcote Estuary, Christchurch

a thesis presented in
partial fulfilment of the degree of
Master of Science in Environmental Science
Department of Zoology
University of Canterbury

By

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1998

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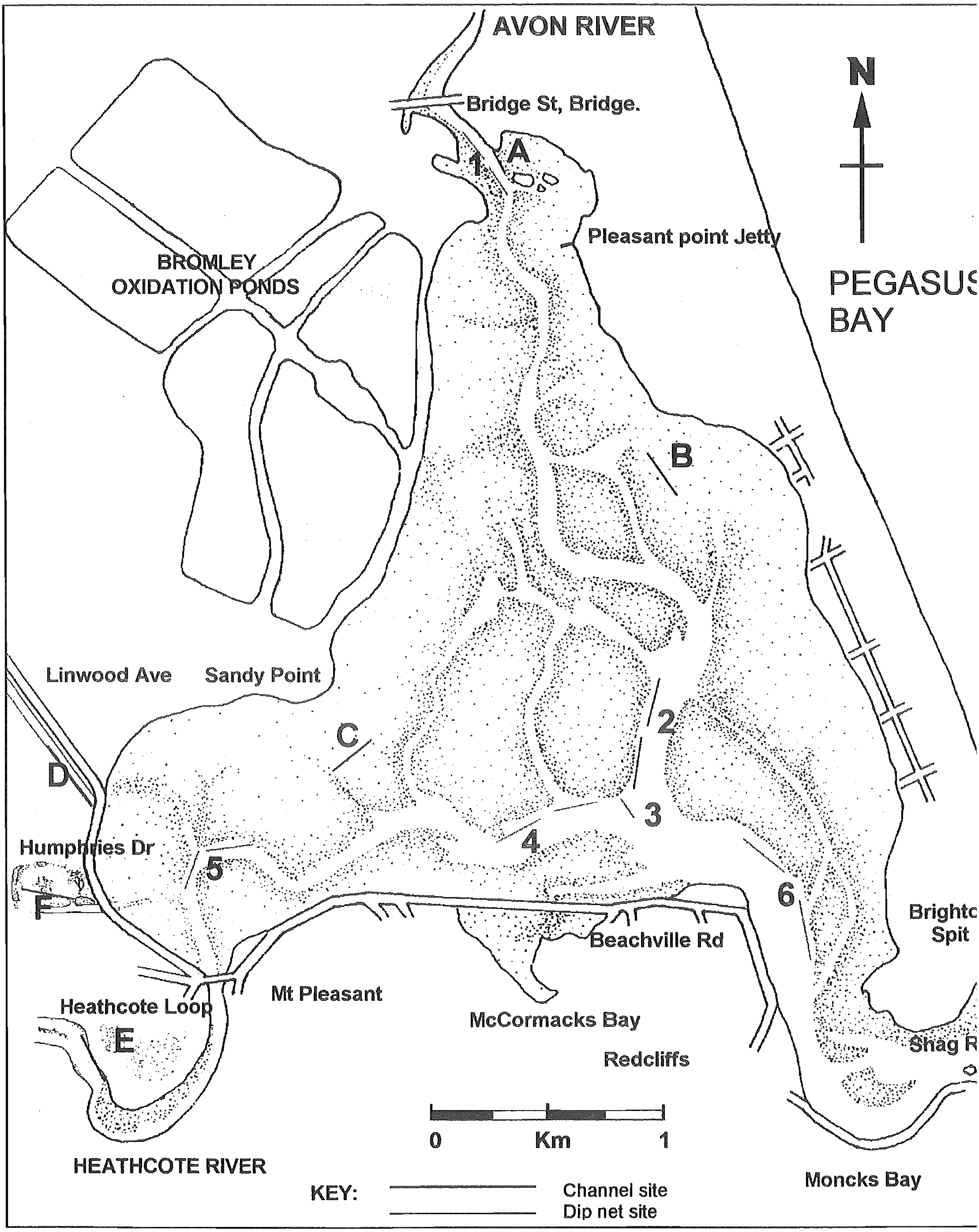
Figure 2.1, Map of sample sites in the Avon-Heathcote Estuary.



Section 1.0

Abstract

Aspects of the biology of common fish species in the Avon-Heathcote Estuary were investigated from two distinct types of sample site, during two sample periods between July 1996 and April 1997. The sites consisted of sites 1-6 (channel sites), which were sampled using a seine net, and estuarine fringe sites A-F, which were dip-net sampled. Although a relatively low diversity of fish species were captured, this was believed to be partly due to sampling methods and conditions. The species that were captured however did appear to be healthy, and were feeding in the estuary. Gonad analyses indicated that most of the adult *Rhombosolea leporina* in the estuary were nearly ripe females, that may have been in the estuary to feed prior to spawning elsewhere. The estuarine fringe sites had an abundance of juvenile flatfish of both common species *Rhombosolea lrporina,* and *R. plebeia*, which were using these areas as "nurseries" as they possessed food and cover from predators.

Introduction

The Avon Heathcote Estuary is roughly triangular with an area of approximately 7 km^2, consisting of tidal mudflats and channels at the junction of the Avon and Heathcote rivers. Although there have been many studies on the invertebrates of the estuary e.g. Knox (1992), relatively little research has been conducted on the fish of the Estuary since Webb (1966). Kilner conducted a study on the biology of the sand flounder in 1977, with the most recent relevant study being Eldon & Kelly's survey of the Avon River in 1991 – 92.

Since 1966, conditions in the estuary have changed markedly. "A 1973 report concluded that up to the late 1960s a large percentage of the incoming nutrients were retained within the estuarine system, particularly within the Heathcote Basin and along the western margin". "Since the "big cleanup" in the 1960s, and with the oxidation ponds only on the outgoing tide, comparatively little of the incoming nutrients are now retained within the estuary system" (The Estuary, Where Our Rivers Meet the Sea1992). Thus it was thought timely to re-survey the fish fauna.

For many fish species, estuaries are extremely important, particularly as sheltered food-rich nurseries for their young. Roper (1986) found that large numbers of juvenile or larval flatfish are taken into the estuary by the tide, and ensure their retention by rapidly settling out. Roper *et al* (1983) found that there was a relatively rich and constant supply of zooplankton in the estuary, which is the main food of larval flatfish (Minami & Tanaka 1992). As well as investigating the adult population in the main estuary channels. I also sampled to see what juvenile fish species inhabited some "fringe" sites around the Estuaries periphery. As there have been no previous studies of the areas close to the upper level salt marshes.

Channel sites were sampled using a seine net, which was the chosen capture method for larger fish partly by default as the beam trawl proved to be unusable due to the excessive amount of sea-lettuce *Ulva lactuca*. There were six sample sites with one (site 3) being sampled with a herring-meshed gillnet as a control for the seine nets inability to capture swift swimming species. Seine net sampling was conducted during the "slack-water period" which exists between the flood and ebb tides. The sample periods were July – September 1996, and November 1996 – April 1997.

The nursery areas or shallow fringe sites were sampled using a dip-net for 30 minutes at low tide during each sample period. The sample periods were similar to the seine net samples, August – September 1996, and April 1997. The fish that were captured by both methods were measured, weighed, and released. A small random sub-sample was euthanased and dissected in the laboratory for gut, and gonad analyses where appropriate.

The aims of this study were:

1) To evaluate the size distributions of fish species captured in the Avon-Heathcote estuary and river mouths during the sampling periods.

2) Compare fish taxa captured in particular habitats, deep and shallow channels, rocky/mud shoreline, and tidal marshes.

3) Relate fish fauna to environmental variables, sediment, temperature, salinity, food availability (from previous studies), water clarity, and vegetation.

4) Seasonal variation in the diets of the most common species of fish.

5) Evaluate the marsh areas and remnants as recruitment areas for fish.

Section 2.0

Materials and Methods

Site descriptions

The sample sites marked on the map (Figure 2.1) consist of two major types, shallow fringe, and deep channel. There were six sample areas within each grouping, however one channel site (site 3) was sampled using a gill net, as the seine net was unusable in that area. The channel sites are numbered one to six, whereas the shallow fringe sites are identified alphabetically (A-F). The channel sites were chosen because they allowed comparisons between different areas at the head of the estuary, the central estuary and its' lower reaches. The channel sites exact location was however dependent on where the snags were. The shallow fringe sites were chosen because of their proximity to remnant marsh areas, to provide insight into their possible role as fish "nursery" areas.

Channel sites:

1: This site was located in the Avon channel opposite the Pleasant Point Yacht Club. The depth in the central channel at this sample was approximately 2 meters at low tide, although two thirds of the channel were less than 1.5 meters deep. Salinity varied between 4ppt, and 1ppt $NaCl_2$ at low tide. Water turbidity was highly variable, with algae causing it to have a slight greenish tinge. The substrate was a well-sorted mixture of clay mud and sands. The average water temperature was at the time of the summer sample was16°C with a variation of one-degree Celsius between mid channel and the edges. This was probably because the shallower edge water flowed more slowly and received warmer water retreating from the tidal fringes. Sampling was hindered somewhat by the lack of a usable low-tide boat ramp, and shallowly submerged sandbars. The solution to this was to swim across with a rope, pull the net across, lay the net out on a clear region of the bank, and then swim back with the other end of the rope.

2: This site was located in the central region of the estuary opposite Redcliffs, most of the water flow from the Avon river flowed through this channel but was well mixed with seawater by the time it reached this site. The maximum depth was approximately 2.2 meters but it was only this deep for 25 % of the channel. Salinity was ranged between 28, and 33 ppt NaCl2 at low tide. The substrate was a mixture of poorly sorted sand and shell fragments. The surface water temperature during the summer sampling period was found to be 15°C, one degree cooler than the average water temperature from site 1on the same day. There was no detectable variation in temperature within the channel indicating that the water was well mixed. Unfortunately there were often branches and other snags at this site.

3 : This site was located closer to the Redcliffs shoreline where the Avon and Heathcote channels converged. The depth was approximately 1.8 meters where the net was set at low tide. Salinity was recorded at 32 ppt $NaCl_2$ at low tide.The water temperature during the summer sampling effort was a constant 15°C. The substrate was a patchy mixture of sand and smooth stones, and had large numbers of shellfish, mainly beds of *Mytilus edulis* and *Austrovenus stutchburyi*. The shellfish beds would have contributed to the high instance of snags in this area, as there were often live mussels in entangled in the net which prevented the effective use of the seine here.

4: This area was opposite the causeway between Mount Pleasant and Redlcliffs. The water was very turbid owing to the suspended sediment from the Heathcote River, which mixed with a large proportion of the very green oxidation pond outflow. The depth was approximately 1.9 meters at low tide, for 60 % of the channel. The salinity was recorded at a surprisingly low 3 ppt $NaCl_2$ at low tide. The water temperature was 15°C throughout the channel The substrate was a well sorted mixture of sand, mud, and small broken *A. stutchburyi* shell fragments. The current was usually quite strong here permitting sampling only during the short period of “slack water”. As with the lower Avon channel, submerged branches snagged the net, the water was also significantly more turbid due to the algae rich sewage outflow, most of which made its way into this channel.

5: This area was in front of the Mount Pleasant Yacht Club. The maximum depth was approximately 1.6 meters at low tide, in a small pool-like area of the sample site. Approximately 70 % of the channel was less than 1 meter deep at low tide. Low tide salinity was recorded at 3 ppt $NaCl_2$. The substrate was soft composed of fine sand and mud it was also noticeably blacker than sediment from the other sites. The water temperature was recorded at 15 °C, and was the same throughout the channel. The water was very turbid to the point where it looked muddy. Due to the width of the channel the current did not seem to be as strong here as at site (4). There were surprisingly few snags perhaps due to the amount of recreational fishing that occurs there.

6: This was the nearest site to the mouth of the estuary, it was located at the mouth of the Estuary in the channel between the end of the Brighton Spit, and Beachville Road. The maximum depth was approximately 3.5 meters for most of the channel at low tide. Salinity was 35 ppt $NaCl_2$, from all measurements. The substrate consisted of poorly sorted sand particles, and shell fragments. Water temperature was 15°C throughout the channel. This area was more influenced by the ocean, than the input from the rivers. It was constantly changing and thus the sand was very soft which sometimes caused the bottom of the net to dig down into the sediment making retrieval difficult. There were reasonable numbers of pipis on the New Brighton side, and beds of *Mytilus edulis* along the Redcliffs shoreline. Large numbers of the small paddle crabs of the species *Ovalipes catharus*, were often caught in the net, and could give a painful bite when being removed.

Shallow fringe sites:

A: This site was on the opposite side of the channel to site 1. The depth sampled ranged from 2-70 cm along the edge of the channel at low tide, and for a short distance up a small stream. At low tide three salinity recordings were made, they were 4 ppt $NaCl_2$ against the shore, 1ppt $NaCl_2$ in the channel, and 14 ppt $NaCl_2$ in the small stream. Water temperature varied between 12.5°C into the channel and 13°C at the edge. The small stream crossing the mud flat however was 19°C, 6 degrees warmer than the air temperature (recorded in the shade). The substrate consisted of sand, shell fragments, and large lumps of clay that had eroded out of the clay bank immediately upstream from the sample site. There were large areas of marsh remnants surrounding this area, which were well above the water level at low tide.

B: This site was off the New Brighton spit near the start of the estuary walk. The depth sampled at varied from 2cm to 30 cm of. Salinity was recorded to be 33ppt $NaCl_2$ at low tide. The substrate consisted of well-sorted layers of sand, and broken shells, interspersed with beds of sea lettuce *Ulva lactuca* and sea grass *Zostera novazelandica*. The temperature of the water was 16°C, which was the same as the air temperature. The site was made up of small shallow channels and pools weaving through the beds of algae. Thus there was a lot of cover for the small fish.

C: This site was directly in front of Sandy Point, which is near the most southern of the oxidation ponds. The depth of the area sampled ranged from 2 to 10 cm. The salinity was 25ppt $NaCl_2$ at low tide. The substrate was a very soft and muddy mixture of fine sediment and clay, with large areas of unidentified weed, and extremely large amounts of decomposing *Ulva lactuca*. The temperature of the water was 17°C in the small tidal streams and pools that were sampled. There were very large numbers of burrowing mud crab (*Helice crassa*) tunnels, which along with the algae provided a refuge for the small animals that inhabited the streams. There was a small amount of marshy vegetation fringing Sandy point, which grew on an area of clay. Most notable was the amount of rotting sea lettuce, and black mud, which produced a vile hydrogen sulphide odour.

D: This area was along one side of a man made drainage ditch which runs beside Linwood Ave opposite the Windsurfers car parking area. The depth was relatively constant at approximately 70 cm's. Water temperature was 9°C when sampled in July 96, and was 17°C when recorded in April 97 The substrate consisted of fine mud, a clay bank with marsh vegetation to the waterline. The salinity of the water was less than 1ppt $NaCl_2$ at low tide. There were tidal gates on the large culvert connecting the drain to the Estuary, which inhibited tidal flow. Any current that was present was only evident at the culvert, so it was not surprising that the water was very green with algae.

E: This area was immediately up-stream and opposite Ferrymead Historic Park. The water depth of the site at low tide ranged from 2-70 cm. Salinity was recorded as 1ppt $NaCl_2$ at low tide, and was uniform throughout the channel. Water temperature was also relatively similar averaging 17°C during the summer sampling effort. The substrate was muddy sand interspersed with layers of clay, this allowed channel depth to vary rapidly where the current had cut into the bank. The water was extremely turbid, making depth difficult to judge while negotiating the channel edge. There were extensive areas of marginal vegetation surrounding this site, which were similar to parts of site (A) in the Avon. This vegetation also was well above the water during sampling.

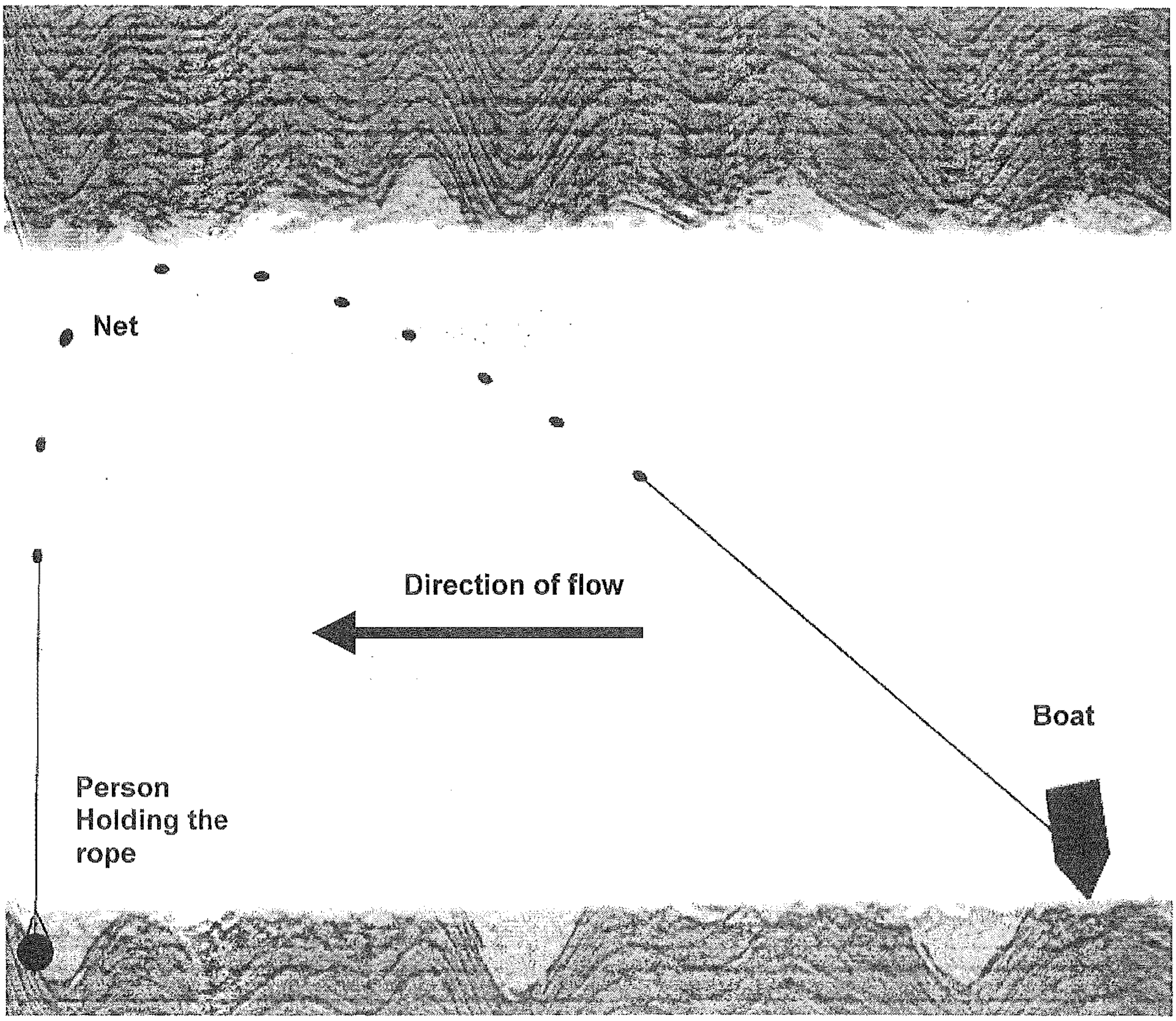
F: This site consisted of a small, recently created experimental wetland area located between Ferry Road and Linwood Avenue. It consisted of four small-interconnected ponds with two links to a tidal drain. The sample area was shallow, with a maximum depth of 60cm. The water temperature was recorded at 16°C, and was the same in all of the pools. Salinity was recorded as 25ppt $NaCl_2$ at low tide, and was the same throughout the pond system. The substrate consisted of soft black mud, covering a dense hard clay layer. There were no visible macrophytes growing in the pools, however salt-marsh plants surrounded the pools.

Sampling methods:

Channel sites

The channel sites (1-6) were sampled using a 20-meter beach seine net with a stretched mesh size of 50mm.A 20-meter heavy rope was attached to each end of the net, and acted to funnel fish into the net. The net was placed into the water at the full extent of each rope, and then hauled in by hand. This required three people, one to hold an end of the rope on the shore one to "lay" the net into the water from the boat, and one to drive the boat (Fig 2.2). The people holding the -ropes pulled at the same speed, and moved gradually toward each other as the net came in to form a tight semi-circle in the net as it reached the shore. Each site was sampled at least twice during each sampling effort and, care was taken to ensure that the net didn't pass over the same area of substrate twice. The captured fish were either immediately identified, measured, weighed, and released, or killed by stunning. Dead fish were immediately placed into labeled bags, and kept in a coolbox. The fish that were killed were the first ten captured from each site plus those too damaged to survive, they were used in the laboratory for gut and gonad analyses.

Figure 2.2 Setting the seine net.



A 15-meter gill-net with a stretched mesh size of 50mm net was used to supplement these samples, and was placed at site (3) to catch swift swimming species such as kahawai. Although this often became clogged with sea lettuce, there did not appear to be a relationship between captures and sea lettuce in the net. This net could not be left for more than two hours as the estuary crab *Hemigrapsus crenulatus* rapidly consumed the dead specimens if left in the net.

Estuarine fringe sites (dip-net)

The estuarine fringe sites (A-F) were sampled at low tide, with a small dip-net for thirty minutes. The dip-net consisted of a steel equilateral triangle connected to a 1.5-meter wooden handle, with a nylon bag of 5mm-mesh size. The thirty-minute sampling period included the time taken to remove the fish from the net. The fish were placed immediately into an anesthetic MS222 solution to euthanase them. Due to the size of most of the fish they were identified under a dissection microscope in the laboratory. Juvenile *Rhombosolea* sp were identified using the method described by Eldon and Smith (1986), weighed, and measured to the nearest 0.5mm.Dead specimens were preserved in a 10% formaldehyde / sea water solution for later gut sample analyses.

Adult fish had their gut removed in the laboratory, and preserved in 10 % formaldehyde and seawater solution. Preserved gut samples from mature specimens were separated into thirds, the contents identified, and the wet weight of each portion recorded. The overall fullness the gut as a whole, and of each third was estimated.

Each third was separately sorted under a dissecting microscope; food items were identified to species if possible, counted, and measured. Measurements taken from food items were those most appropriate for the type of organism measured. Carapace width was recorded from crabs, the longest shell dimension for mollusca, and the width of the head segment from annelids. Owing to the rapid decomposition of soft-bodied polychaetes additional measurements were recorded such as the jaw length of some of the nereid species.

Gonads were removed from mature fish and an individual gonad was measured, and weighed. A sample of gonad tissue was than placed under the dissection microscope, if eggs were visible their diameter was measured using an eyepiece scale. Ovaries can be classified from previous descriptions of egg diameter; testes could be characterized by their size and color (Table 2.1).

Table 2.1 Gonad analysis table (from Webb 1973).

STAGE	DESCRIPTION after Bowers (1954)	*Rhombosolea plebeia*	*Rhombosolea leporina*	Aldrichetta forsteri
MALES				
1 IMMATURE	Testes small, no sperm, but sperm bodies discernible under microscope.	Testes translucent	Testes usually black or blue – black.	Testes translucent.
2 MATURE UNRIPE	Testes enlarged slightly, tending to lose translucent colour and becoming whitish. Density of sperm bodies increases. A little sperm extruded on cutting.	Testes about 5-10mm long, 1-2mm wide.	Testes about 5-10mm long, 1-2mm wide.	Not recorded
3 RIPE	Testes enlarged and with lobate internal structure, very white. Sperm extruded on cutting.	Testes 35-45 mm long, 10-15mm wide.	Testes 35-45 mm long, 10-15mm wide.	Testes 65-75mm long 5mm wide.
4 RIPE RUNNING	Testes reach maximum size. Sperm extruded by pressure when alive.	Testes triangular, 60mm long, 20mm wide.	Testes triangular, 60mm long, 20mm wide.	Testes 65-75mm long, 5mm wide.
5 SPENT	Testes shrunken and crinkled, a little sperm left. Testes slowly revert to stage 2.	As description (not recorded further).	As description (not recorded further).	As description (not recorded further).

Table 2.1 continued.

STAGE	DESCRIPTION after Bowers (1954)	*Rhombosolea plebeia*	*Rhombosolea leporina*	*Aldrichetta forsteri*
FEMALES				
1 IMMATURE	Ovaries very small, translucent, may be slightly bloodshot. Eggs microscopic but discernible, under 500x magnification by binocular microscope as a few very small, rounded discrete bodies.	Ovaries 1-2mm long, 1mm wide.	Ovaries 1-2mm long, 1mm wide.	Ovaries 45-50 mm long, 1mm wide.
2 MATURE UNRIPE	Ovaries small to moderate size, often translucent, may be bloodshot. Eggs clearly discernible under 500x magnification, but still very small; a few small granules appear in eggs.	Ovaries 15-20mm long, 4-5mm wide.	Ovaries 15-20mm long, 4-5mm wide.	Ovaries 50-60 mm long 2 mm wide. In fish 290 mm long, egg diameter range is 0.025 – 0.175 mm, with majority 0.075 mm.
3 MATURE RIPENING	Ovaries enlarged and translucent may or may not be bloodshot. Eggs opaque, increase in size (visible by eye); granules begin to concentrate in the centre.	Ovaries 40-50mm long, 15mm wide. In fish 245mm long, egg diameter range is 0.025 0.075mm.	Ovaries 40-50mm long, 15mm wide. In fish 250mm long, egg diameter range is 0.025 0.225mm with majority 0.05 0.15mm.	Ovary length increases to 70-80mm, width about 4mm. In fish 285mm long, egg diameter range is 0.025 0.225mm, with the majority 0.175mm.
4 NEARLY RIPE	Ovaries enlarged and distended. A few ovaries start developing a orange or yellow coloration. Eggs, clearly visible by eye, opaque, begin to differentiate into a cortical zone, surrounding a large, dark, granulated central region. Differentiating eggs about 10% of total egg mass, rest a mixture of stages 2 and 3.	Ovary length increases to 80-90mm, width to 20-25mm.	Ovary length increases to 80-90mm, width to 20-25mm.	Length usually the same as 3, but may increase to 90-100mm, width 8-10mm.

Table 2.1 continued

STAGE	DESCRIPTION After Bowers (1954)	*Rhombosolea* plebeia	*Rhombosolea leporina*	*Aldrichetta forsteri*
5 RIPE	Eggs with a dark central mass and a semi-transparent cortical zone make up 50-605 of the total egg mass, rest of eggs a mixture of stages 3 and 4. Ovaries turning orange or orange yellow, enlarged and distended. Differentiating eggs have a narrow cortical zone and a large granulated central area. Tunica easily burst at this stage.	Length of ovaries as in stage 4, width extends to 30-40 mm.	Length of ovaries as in stage 4, width extends to 30-40mm. In fish 300 and 400mm long, egg diameter range is 0.125-0.65mm, with majority0.325mm.	Length of ovaries as in stage 4, width extends to 15mm. In fish 270mm long, egg diameter range is 0.3-0.75mm, with majority0.55mm.
6 RIPE RUNNING	Ovaries remain same length as in stage 5, but width increases with swelling eggs. About 95-100% of the eggs are mature and differentiated (i.e., transparent), eggs extruded by slight pressure on flank of live fish. Ovaries a distinct orange, red, or orange-yellow, with a very spongy consistency.	Length of ovaries as in stage 4, but width may increase to 45mm. In fish 265mm long, egg diameter range is 0.075-0.35mm, with majority 0.35mm.	Length of ovaries as in stage 4, but width may increase to 45mm. In fish 305mm long, egg diameter range is 0.175-0.675mm, with majority 0.625mm.	Length of ovaries as in stage 4, but width may reach 20mm. In fish 295mm long, egg diameter range is 0.25-0.70mm, with majority 0.70mm. Pressure of eggs against each other distorts egg shape.
7 SPENT	Ovaries have collapsed, flaccid, or shrivelled appearance. Few residual eggs present. Ovaries quickly revert to stage 2.	As description (not recorded further).	As description (not recorded further).	As description (not recorded further).

Section 3.0

Invertebrate Surveys:

Sediment samples were taken from four areas, (Humphries Dr, Sandy Point, Heathcote Loop, and Pleasant Pt) to investigate food availability to fish during summer and winter. Cores measuring 100mm by 100mm by 100mm were taken from 4 randomly selected areas within each site. The top and bottom 50-mm segments were separated and placed into labeled plastic bags. Once in the laboratory samples were carefully washed, and sorted on a 500-micron Endecott sieve. All invertebrates were placed into labeled plastic containers containing 10 % formaldehyde. Sorting was conducted with the naked eye, and under a low-power dissecting microscope. Invertebrates were identified according to Jones (1983), and McLay (1998). Measurements of the smaller invertebrates were taken from the microscopes 0.1 mm-graduated eyepiece. As most of the polychaetes had broken into a number of pieces, only the head regions were counted. As it was not known how relevant the vertical locations of the invertebrates in the substratum at low tide would be (as the fish fed at high tide), it was decided best to combine the top and bottom samples.

Results

A list of all invertebrate species identified from the sediment samples is given in Table 2. Twenty-one species were identified, but the five dominant species made up 80% of the total number sampled. These were *Scolecolepidaes benhami* 31%, *Nicon aesturiansis* 27%, *Haploscoloplos cylindrifer* 11%, *Helice crassa* 7%, and *Paracorophium excavatum* 5%. The highest densities were recorded at the Avon and Sandy Point sample sites, which made up 73% of the invertebrates sampled. Overall density at the sites was significantly different, as is shown in the ANOVA output ($F_{3, 28}$=3.4 P>0.3), despite the large amount of variation between samples from the same site. The size frequency distribution of the polychaete worms was determined (figure 3.2), as there might be a relationship between prey item size and the size of the predatory fish.

Table 3.1

Polychaeta	Crustacea	Mollusca
Scolecolepidaes benhami	*Helice crassa*	*Austovenus stutchburyi*
Nicon aesturiensis	*Paracorophium excavatum*	*Paphies australis*
Haploscoloplos cylindrifer	*Macropthalmus hirtipes*	*Mactra ovata*
Orbinia papillosa		*Potamopyrgus estuarinus*
Perinereis nuntia		*Marinula filholi*
Glycera americana		*Amphibola crenata*
Capitella capitella		*Cellana radians*
Hemipodus simplex		*Diloma nigerrima*
Terebellidae sp.		*Tellina liliana*

The invertebrate data were combined into summer and winter components only and analysed using a one-way ANOVA, no significant difference was detected between the total numbers of all invertebrates ($F_{1, 30}$=0.90, P<. 05). The mean abundance of the invertebrate groupings Crustacea, Polychaeta, and Mollusca from both seasons is given in figure 3.1, polychaetes represented an average proportion of 79% from all the samples, followed by molluscs at 11% and crustaceans at 10%.

Figure 3.1 Average invertebrate counts by type from all sites Summer and Winter combined.

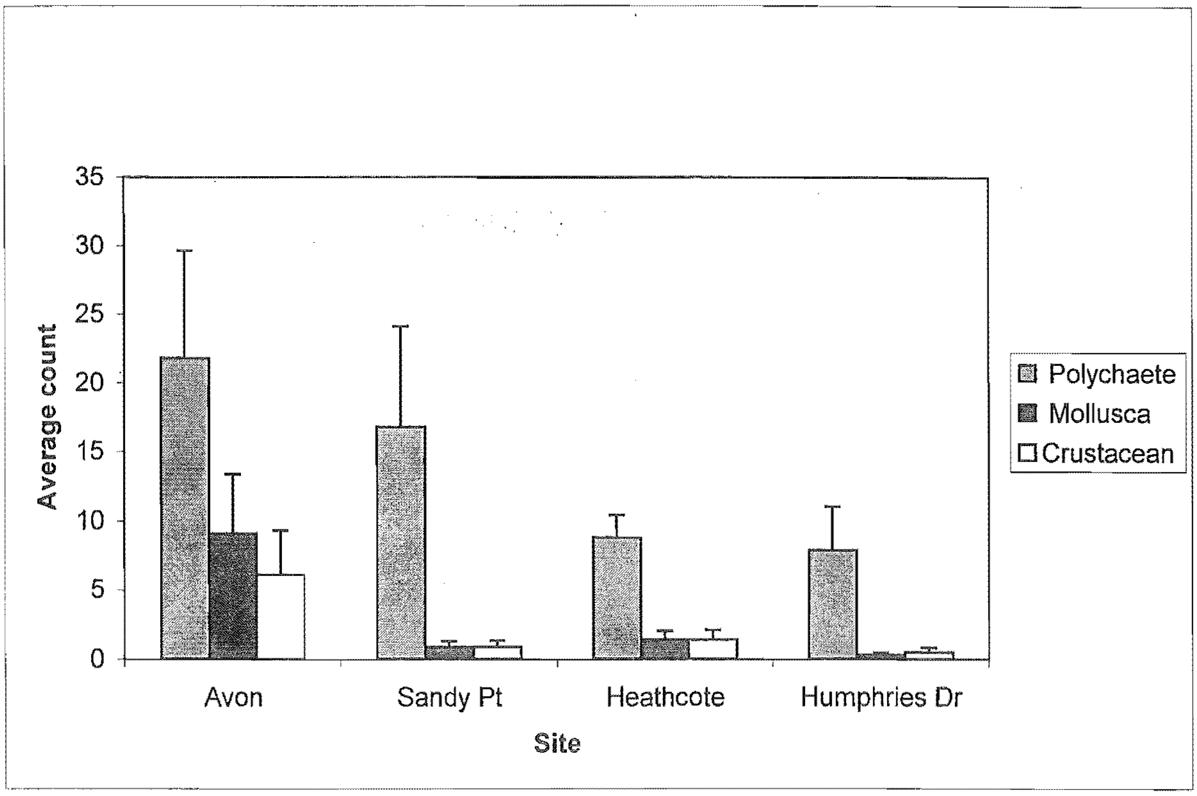
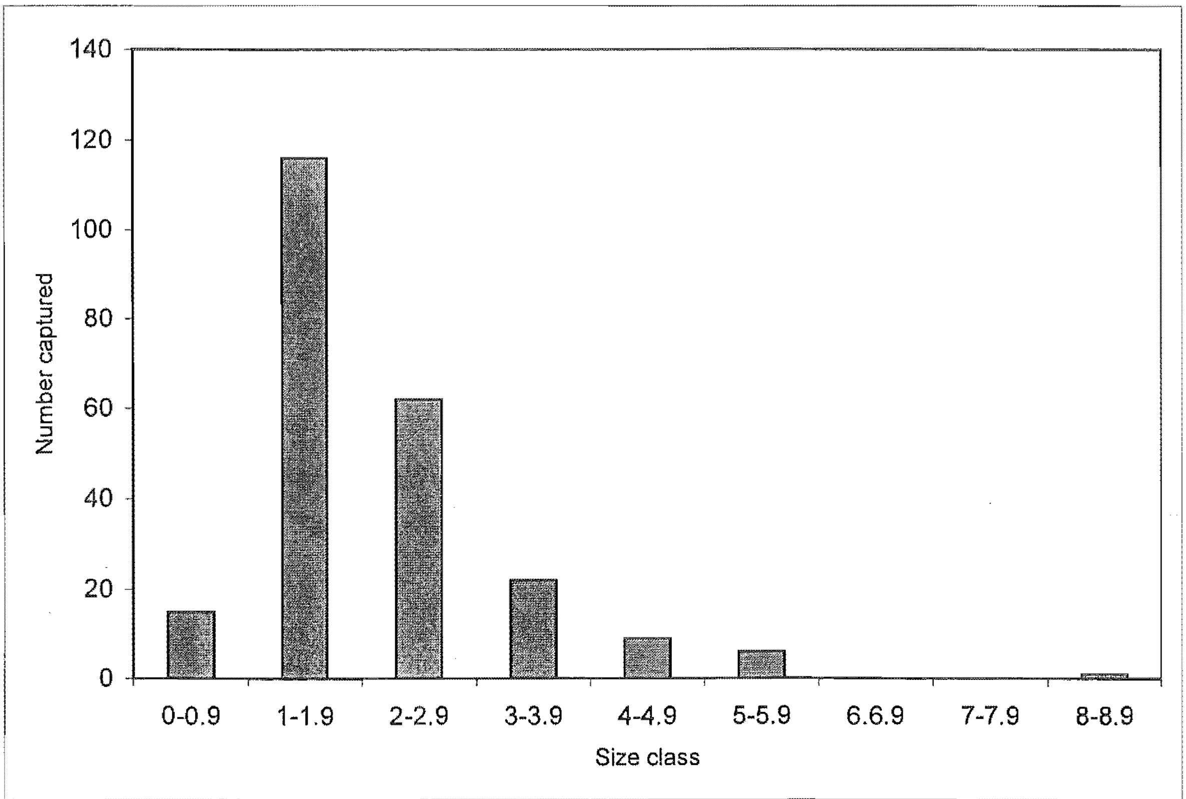


Figure 3.2 Size frequency distribution of polychaete worms from all samples (n=231).



Total winter invertebrate density was 49 % more than summer, however this difference was not found to be significant.

Discussion:

It was surprising that there were such differences in the abundance of invertebrates from the Avon and Heathcote sites, as the two sites were physically quite similar. The water quality might have been a major factor as he Avon water is clearer, with more suspended sediment in the Heathcote. Crustaceans were less abundant over all than was expected possibly due to their distributions being somewhat patchy, e.g. *Helice crassa* seemed to prefer clay substrate where more permanent tunnels could be constructed. Even so it would be difficult to not bias the survey toward a high abundance of crustaceans given that they don't break down rapidly like soft-bodied organisms, and are easy to sort due to their constant movement.

The data obtained from the survey is intended to reflect the abundance's of the most common invertebrates, and their habitats. It may not directly relate to gut content data obtained from flatfish in the Estuary. One reason for this being that the abundance's of various invertebrates from sediment cores would not necessarily relate to their availability to feeding fish at low tide.

Section 4.0

Seine net captures

Rhombosolea leporina

Eighty *R. leporina* specimens were captured using a seine net during the period from July 1996 to April 1997. Fifty were captured during the July - September sample period, and thirty were captured during November – April.

Table 4.1 Length (mm) of *R. leporina* from each sample period.

July – September 1996		November 1996 – April 1997	
Mean length (mm) :	309.1	Mean length (mm) :	338.1
Sample size:	50	Sample size:	30
SEM:	11.1	SEM:	8.3
CV:	25.3	CV:	13.4
Median:	310.0	Median:	332.5
Minimum :	145.0	Minimum :	250.0
Maximum :	480.0	Maximum :	420.0

The summary of length data from the two sample periods (table 4.1) shows that the mean lengths from the two sample periods were similar. As the coefficient of variation from the July –September 1996 sample period was large enough to cancel out the difference between the means, the difference is unlikely to be significant.

A Mann – Whitney Test was performed on these data, (U – statistic = 579.0, U' = 921.0) the calculated value equated to a two – tailed P value of 0.0902, which shows no significant difference between the mean lengths from of the two sample periods.

Data from both time periods were combined for each sample site and compared using a one – way ANOVA. The result (F = 6.965, df = 79, P < 0.0001) indicated that the lengths of individuals were significantly different between some of the sample sites.

Table 4.2 Summary of site data

Site	**1**	**2**	**4**	**5**	**6**
Mean	288.1	357.1	342.9	276.2	353.6
Sample size	8	11	18	26	17
SEM	15.4	16.2	11.9	13.4	16.1
CV	15.2	15.0	14.8	24.8	18.8
Median	303	380	345	280	380
Minimum	190	250	273	145	180
Maximum	320	420	450	390	480

Table 4.2 shows a summary of the data collected from each site, and the range of the lengths of the fish captured from those sites. These data do seem to indicate that there may be a tendency for larger fish to occur nearer the estuary mouth at sites such as 4, and 5. Smaller fish were more likely to be captured from the sites further towards the head of the estuary, such as site 1, and site 5. However due to the sample size the significance of this is likely to be relatively low, although the difference may be important.

A Tukey – Kramer multiple comparisons test was then performed to indicate which sites were different (Table 4.3).

Table 4.3 Tukey – Kramer Multiple Comparisons Test.

Comparison	Mean Difference	P	Value
4 vs. 6	-10.7	ns	P>0.05
4 vs. 2	-14.1	ns	P>0.05
4 vs. 1	54.8	ns	P>0.05
4 vs. 5	66.7	**	P<0.01
6 vs. 2	-3.4	ns	P>0.05
6 vs. 1	65.5	ns	P>0.05
6 vs. 5	77.4	**	P<0.01
2 vs. 1	69.0	ns	P>0.05
2 vs. 5	80.9	**	P<0.01
1 vs. 5	11.9	ns	P>0.05

All significant differences that occurred among the means of the site data were between site 5, which was in the Heathcote channel opposite the Mt Pleasant Yacht Club, and sites nearer the estuary mouth. The major contributing factor to this was the relatively large sample size from site 5. Site 1, in fact had a smaller size range and probably also had significantly smaller fish. As only eight fish were captured from that site the significance of that difference was not high.

The length data collected from each sample period, and site were analyzed using a one – way ANOVA (F = 3.411, P = 0.0016, df = 79), which found significant differences between the samples.

Table 4.4 Summary of site data, a= July – September 1996, b= November 1996 – April 1997, site 3 is absent as it was only sampled using a gillnet.

Site	1a	2a	4a	5a	6a	1b	2b	4b	5b	6b
Mean	275.0	366.7	356.0	271.8	361.2	310.0	253.5	332.5	330.0	342.9
Sample size	5	3	8	24	10	3	8	10	2	7
SEM	22.9	23.3	22.9	14.2	24.2	10.0	21.2	11.4	5.0	20.1
CV	18.6	11.0	18.1	25.6	21.2	5.6	23.6	10.9	2.2	15.5
Median	300	390	350	275	380	320	375	335	330	345
Minimum	190	320	273	145	180	290	250	280	325	250
Maximum	315	390	450	390	480	320	420	380	335	400

A Tukey – Kramer multiple comparisons test was then performed to indicate which samples were different (Table 4.5).

Table 4.5 Tukey – Kramer Multiple Comparisons Test, comparing sites (1-6), and Samples (a= July-September 1996, b= November 1996-April 1997).

Comparison			Mean Difference	P	Value
4a	vs.	6a	-5.2	ns	P>0.05
4a	vs.	2a	-10.7	ns	P>0.05
4a	vs.	1a	81.0	ns	P>0.05
4a	vs.	5a	84.3	*	P<0.05
4a	vs.	1b	46.0	ns	P>0.05
4a	vs.	2a	2.5	ns	P>0.05
4a	vs.	6b	13.1	ns	P>0.05
4a	vs.	5b	26.0	ns	P>0.05
6a	vs.	4b	23.5	ns	P>0.05
6a	vs.	2a	-5.5	ns	P>0.05
6a	vs.	1a	86.2	ns	P>0.05
6a	vs.	5a	89.5	**	P<0.01
6a	vs.	1b	51.2	ns	P>0.05
6a	vs.	2a	7.7	ns	P>0.05
6a	vs.	6b	18.3	ns	P>0.05
6a	vs.	5b	31.2	ns	P>0.05
2a	vs.	4b	28.7	ns	P>0.05
2a	vs.	1a	91.7	ns	P>0.05
2a	vs.	5a	94.9	ns	P>0.05
2a	vs.	1b	56.7	ns	P>0.05
2a	vs.	2a	13.2	ns	P>0.05
2a	vs.	6b	23.8	ns	P>0.05
2a	vs.	5b	36.7	ns	P>0.05
2a	vs.	4b	34.2	ns	P>0.05
1a	vs.	5a	3.3	ns	P>0.05
1a	vs.	1b	-35.0	ns	P>0.05
1a	vs.	2a	-78.5	ns	P>0.05
1a	vs.	6b	-67.9	ns	P>0.05
1a	vs.	5b	-55.0	ns	P>0.05
1a	vs.	4b	-57.5	ns	P>0.05
5a	vs.	1b	-38.3	ns	P>0.05
5a	vs.	2a	-81.8	*	P<0.05
5a	vs.	6b	-71.1	ns	P>0.05
5a	vs.	5a	-58.3	ns	P>0.05
5a	vs.	4b	-60.8	ns	P>0.05
1b	vs.	2a	-43.5	ns	P>0.05
1b	vs.	6b	-32.9	ns	P>0.05
1b	vs.	5b	-20.0	ns	P>0.05
1b	vs.	4b	-22.5	ns	P>0.05
2a	vs.	6b	10.6	ns	P>0.05
2a	vs.	5b	23.5	ns	P>0.05
2a	vs.	4b	21.0	ns	P>0.05
6b	vs.	5b	12.9	ns	P>0.05
6b	vs.	4b	10.4	ns	P>0.05
5b	vs.	4b	-2.5	ns	P>0.05

Significant differences among the samples were only encountered when sample 5a was compared with samples 4a, 6a, and 2a, which were nearer the estuary mouth

The size frequency distributions for *R. leporina* from the two sample periods are shown in figure 4.1 and the mean length of individuals captured at each site shown in figure 4.2. Both size-frequency plots for *R. leporina* are relatively similar between sample periods. The average numbers of fish captured in each seine haul has been tabulated in table 4.6. It should be noted that capture success was highly variable, for instance at site 5 one haul captured twenty specimens, whereas the previous haul nearby captured only four. In all cases the rate was calculated from at least three effective hauls.

Table 4.6 Average success per seine-net haul.

Site	1	2	4	5	6
Jul – Sept 1996	1.7	1	2	8	1.4
Nov 1996 – Apr 1997.	1	3	2.3	0.7	2.3
Combined samples.	1.3	2	2.1	4.3	1.7

Figure 4.1 Size frequency distributions of *R. leporina* captured during two sample periods July – September 1996, and November 1996 – April 1997.

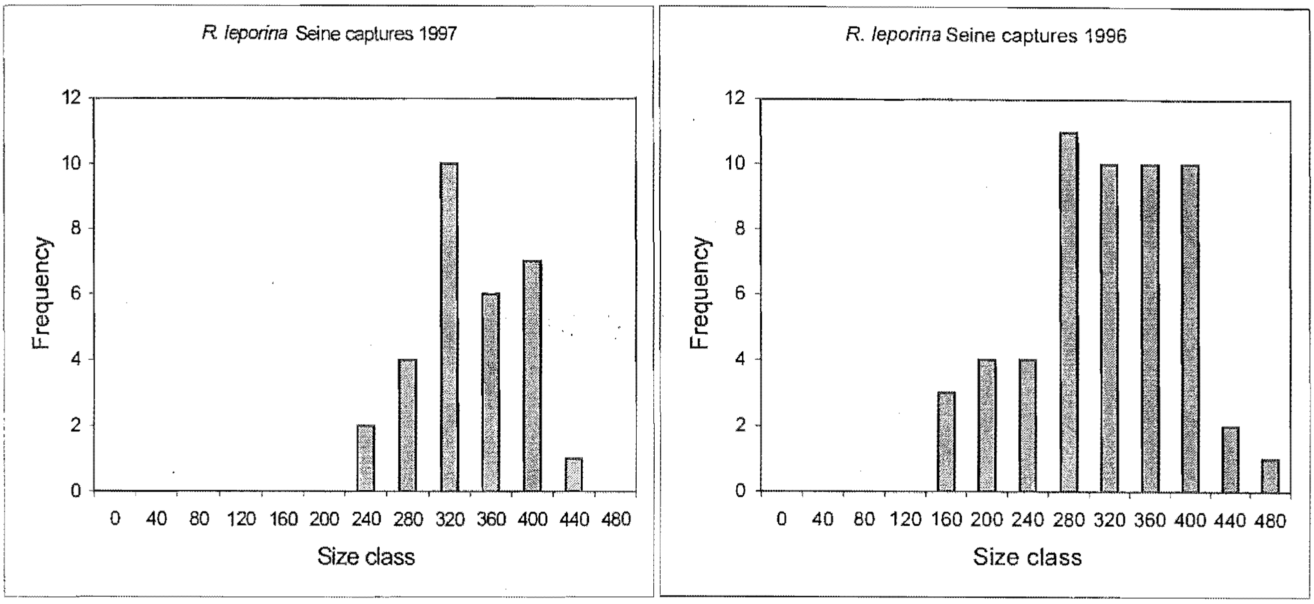
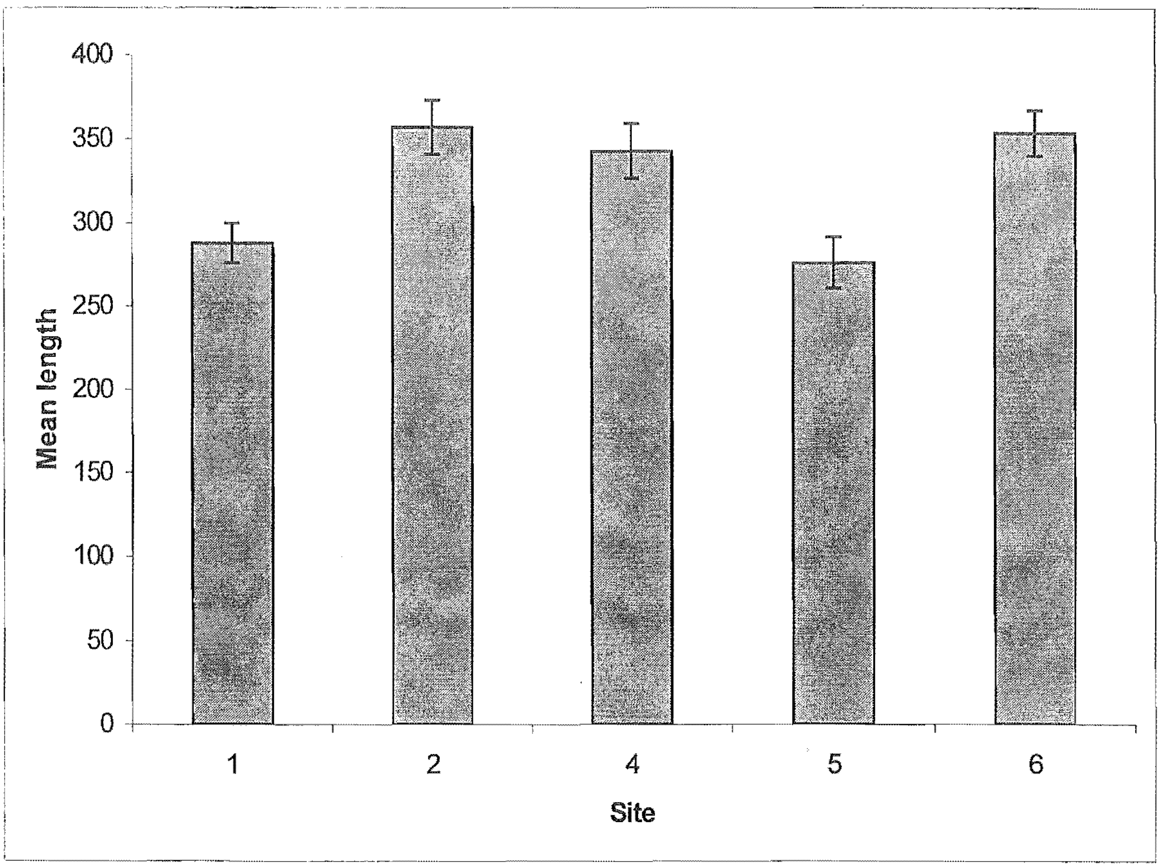


Figure 4.2 Combined sample period data, mean length ± SE.



***Rhombosolea Plebeia*:**

One *R. plebeia* was captured on Thursday April the 24th 1997, using a seine net at site 2 in the lower Avon channel. It measured 200 mm long, and weighed 185 grams.

***Aldrichetta forsteri*:**

Five *A. forsteri* were captured in the seine net, all from site 6 in Monck's Bay. The inability of the seine net to capture swift swimming fish was controlled for by the use of a gillnet, which captured 38 throughout the course of the study.

Table 4.7 Length (mm) of *A. forsteri* from each sample period, (gillnet and seine combined).

July – September 1996		November 1996 – April 1997	
Mean length (mm) :	318.53	Mean length (mm) :	280
Sample size:	17	Sample size:	27
SEM:	9.19	SEM:	5.00
Median:	310.0	Median:	280
Minimum :	280	Minimum :	210
Maximum :	400	Maximum :	325

The two sample periods were compared using a Mann – Whitney Test, which calculated a two - tailed P value of 0.0010, which is considered very significant. Therefore the mean length of *A. forsteri* from the November – April sample is significantly larger than the mean length of those from the November 1996 – April 1997 samples.

Brown Trout, *Salmo trutta*:

One brown trout was captured in the gillnet on the 21st of November, it was 650 mm long and had presumably just come into the Estuary from the ocean (as it's gut contained only marine species).

Quinnat salmon, *Oncorhynchus tshawytscha*:

One quinnat salmon was captured in the gillnet on the 21st of November, it was 310 mm long. It's gut contents was investigated and found to contain 6 Rhombosolea, which could all be identified as *Rhombosolea retaria* or juvenile black flounders. Since very few juvenile black flounders were captured in the Estuary in the dip-net samples this might suggest that it had been feeding outside the Estuary mouth.

Discussion:

Overall the data obtained did not show a significant difference in the sizes of *R. leporina* specimens from the two sample periods, if significant differences had occurred they would probably have been due to migration. The reason for this being that given the sample size taken, growth would not have been enough to detect.

As discussed earlier there did seem to be a quite real trend for there to be smaller individuals towards the head of the estuary, and larger individuals towards the mouth. This is further supported by the fact that a number of smaller individuals were seen to escape the net, both from site 5 and 1. Although obviously such escapes would have occurred elsewhere they were not observed to such an extent. The July – September sample from site 5 was found to have significantly smaller individuals than sites 6, 2 and 4 during the same sample period, which illustrates the importance of a large enough sample size to achieve "significant" differences between data.

The mean lengths of the *R. leporina* specimens sampled at each sample site were compared with the mean lengths of those captured by Webb (Webb 1972[1]), and it was found that in all instances the mean lengths were larger from this study. Webb's mean lengths ranged from 199.5 mm to 215 mm with a grand mean of 204.8, whereas the range for this study was 288.1 mm to 357.1 with a grand mean of 323.6. Quite obviously there were great differences between the samples whether they were due to sampling methodology or a real indication of the population is a matter of conjecture. The huge difference in the sizes of the individuals captured in this study are best summed up by the fact that Webb caught only 2 *R. leporina* longer than 320 mm whereas 44 were captured longer than 320 mm during the course of this study. The flip side to this is that Webb caught 343 *R. leporina* under 320 mm, with 36 < 320 mm being captured for this study.

The captures of *A. forsteri* cannot really be compared with anything in particular, as they were sampled from one site only. The gillnet did however show that there was still a large number of *A. forsteri* using the Estuary and that they did appear to move out of the lower reaches to feed with the tide as described in Webb (1972[1]).

The chance captures of the Quinnat salmon, and the brown trout did not really provide much information on their roles in the Estuary as they appeared to be passing through on the tide. They could well have been feeding in the more saline lower reaches though.

It was surprising that no *Arripis trutta* or Kahawai were captured as they should have occurred at least in the lower reaches. More surprising still was the capture of just one *Rhombosolea plebeia* or sand flounder as they were the most frequently captured flounder during Webb's study. Webb captured 4034 sand flounders which although most were relatively small. Webb noted however that "The minimum size caught for *Rhombosolea leporina* was 100 – 110 mm, as distinct from 80 mm for *Rhombosolea plebeia*. This difference was most certainly due to the ovoid shape of *Rhombosolea leporina* allowing smaller sizes to escape through the 2 – 2 ½ " mesh netting". This seems to suggest that there was a real lack of *R. plebeia* in the Estuary during this study.

Section 5.0

Dip net Captures

Dip-net sampling was conducted as described previously in the methods section, there were two main sampling periods which were as near as practicable to the seine net sampling periods. These were August-September 1996, and April 1997. During these time spans samples were taken which would indicate the juvenile fish fauna at the sample sites during winter/spring and summer periods. Juvenile flounders were identified using the methods described by Eldon and Smith (1986), and thus they could only be identified to species at sizes greater than 12mm.

Rhombosolea Sp (all flounders captured under 12mm total length).

One hundred and twelve individuals were captured, eighty three during August/September 1996 from site C (50), site B (24), and site F (9). Twenty-nine were captured during April 1997, from site B (5), and site E (24).

Table 5.1

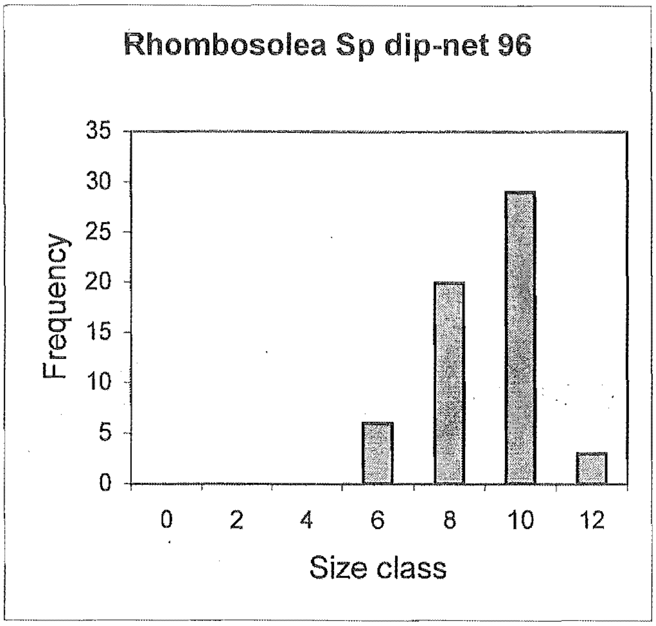
August – September 1996		**April 1997**	
Mean length (mm) :	8.67	Mean length (mm) :	9.91
Sample size:	83	Sample size:	29
SEM:	0.14	SEM:	0.02
CV:	0.15	CV:	0.10
Median:	9.00	Median:	10.00
Minimum :	6.30	Minimum :	7.00
Maximum :	11.50	Maximum :	11.00

The size-frequency distributions were plotted, and did not indicate any major differences in the overall population structure, between the 1996 and 1997 samples. Size differences between the sample periods were very unlikely given that the grouping was determined by size constraint (>12mm), and that the size that the pleuronectids recruited into the estuary was ≥ 6.0mm (Kilner 1974).

The site data were combined up into two groupings (1996 data, and 1997 data). An unpaired t test was performed to investigate whether the mean of the 1996 sample lengths was equal to the mean of the 1997 sample lengths, resulting in a t value of 4.696 (df=110) and a P value of <0.0001. Therefore the average length of the Rhombosolea specimens under 12mm was significantly different between sample periods. Data from all samples were analyzed using a Kruskal-Wallis Nonparametric ANOVA Test yielding a Kruskal-Wallis Statistic KW = 23.075, which is equivalent to a P value of 0.0001. Therefore the variation among sample means was significantly greater than expected by chance. The site data were further investigated using Dunn's Multiple Comparisons Test (table 5.2), to gain insight into where the differences occurred. Significant differences were only detected between the samples from the different seasons.

Table 5.2 Dunn's Multiple Comparisons Test. Comparing the lengths of *R. leporna* from all dip-net samples.

Comparison	Mean Difference	P	Value
F 96 vs. C 96	-20.5	ns	P>0.05
F 96 vs. E 97	-45.9	**	P>0.01
F 96 vs. B 96	-11.8	ns	P>0.05
F 96 vs. B 97	-48.9	ns	P>0.05
C 96 vs. E 97	-25.4	*	P>0.05
C 96 vs. B 96	8.7	ns	P>0.05
C 96 vs. B 97	-28.4	ns	P>0.05
E 96 vs. B 96	34.1	**	P>0.01
E 96 vs. B 97	-3.0	ns	P>0.05
B 96 vs. B 97	-37.1	ns	P>0.05



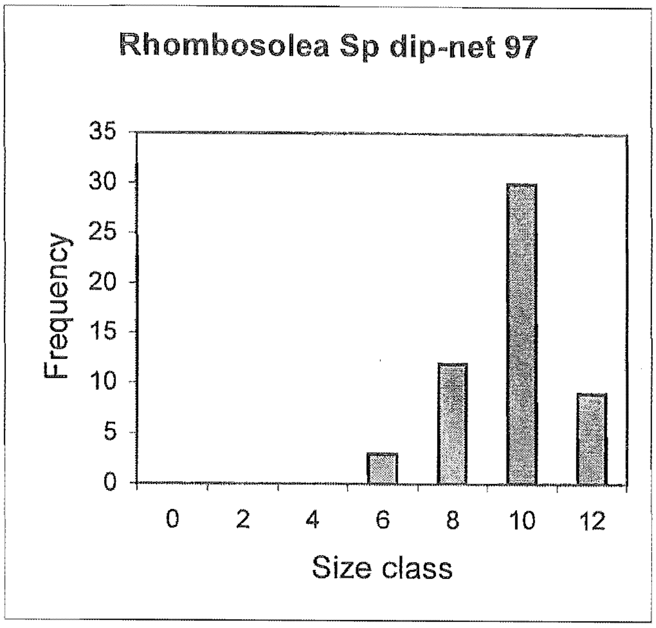


Figure 5.1, Size frequency distributions of Rhombosolea Sp From dip-net captures 1996/97.

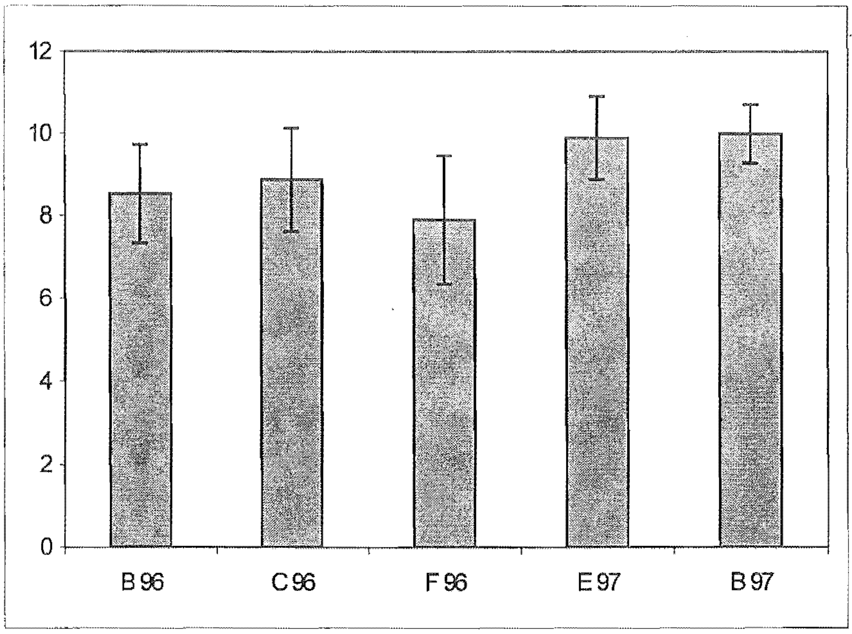


Figure 5.2, Mean lengths of Rhombosolea Sp From dip-net captures 1996 and 1997±SD.

Rhombosolea leporina Yellowbelly flounder.

One hundred and sixty eight individuals of this species were captured, seventy-seven during August/September 1996, and ninety-one during April 1997. They were only captured from the more central sample sites B (New Brighton), C (Sandy Point), and the river sites A (Pleasant Pt), and E (Heathcote loop).

Table 5.3

August – September 1996		April 1997	
Mean length (mm) :	22.33	Mean length (mm) :	23.63
Sample size:	77	Sample size:	91
SEM:	0.85	SEM:	0.90
CV:	0.33	CV:	0.36
Median:	22.00	Median:	22.00
Minimum :	12.00	Minimum :	12.00
Maximum :	45.00	Maximum :	57.00

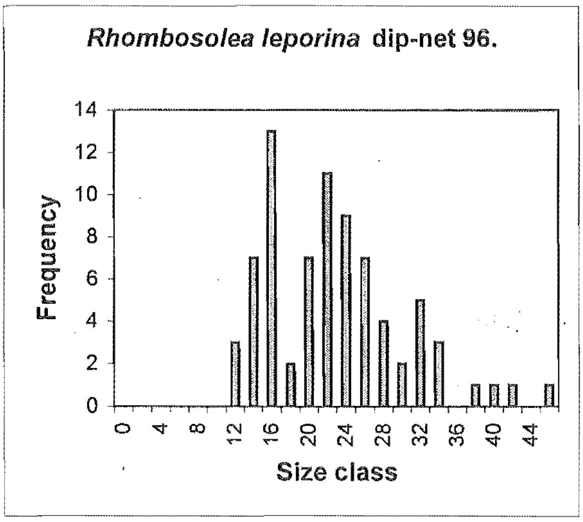
An unpaired t-test was performed comparing the combined 1996 site data with the combined 1997 site data, t was 1.039 (df =166). The two-tailed P value of 0.3004 was not significant. There was not a significant overall difference in the size of the individuals of *R. leporina* captured during the different sample periods. Sample data from the different sites and sample periods were compared using the Kruskal-Wallis Nonparametric ANOVA Test. The Kruskal-Wallis Statistic KW = 72.106 was highly significant as it equated to a P value of < 0.0001.

Table 5.4, Dun's Multiple Comparisons Test. Comparing the lengths of *R. leporina* captured in dip-net samples.

Comparison	Mean Difference	P	Value
A 96 vs. E 96	-2.4	ns	P>0.05
A 96 vs. B 96	63.1	***	P<0.001
A 96 vs. A 97	-20.3	ns	P>0.05
A 96 vs. E 97	13.0	ns	P>0.05
A 96 vs. C 97	61.1	**	P<0.01
A 96 vs. B 97	45.0	ns	P>0.05
E 96 vs. B 96	65.5	***	P<0.001
E 96 vs. A 97	-17.8	ns	P>0.05
E 96 vs. E 97	15.4	ns	P>0.05
E 96 vs. C 97	63.5	***	P<0.001
E 96 vs. B 97	47.5	ns	P>0.05
B 96 vs. A 97	-83.4	***	P<0.001
B 96 vs. E 97	-50.1	***	P<0.001
B 96 vs. C 97	-2.1	ns	P>0.05
B 96 vs. B 97	-18.1	ns	P>0.05
A 97 vs. E 97	33.2	ns	P>0.05
A 97 vs. C 97	81.3	***	P<0.001
A 97 vs. B 97	65.3	**	P<0.01
E 97 vs. C 97	48.1	**	P<0.01
E 97 vs. B 97	32.1	ns	P>0.05
C 97 vs. B 97	-16.0	ns	P>0.05

Therefore variation among sample means was significantly greater than expected by chance. Dunn's Multiple comparisons test was used to establish where the significant differences occurred between samples (table 5.4) Significant size differences were only found to occur between the more riverine sites (A and E), and the central sites (B and C). The source of these differences becomes evident from figure 5.4, in which sites A and E have a larger mean length recorded for the *R. leporina* captured from both years than from sites B and C.

Figure 5.3, Size frequency distributions of *Rhombosolea leporina* from dip-net captures 1996 and 1997.



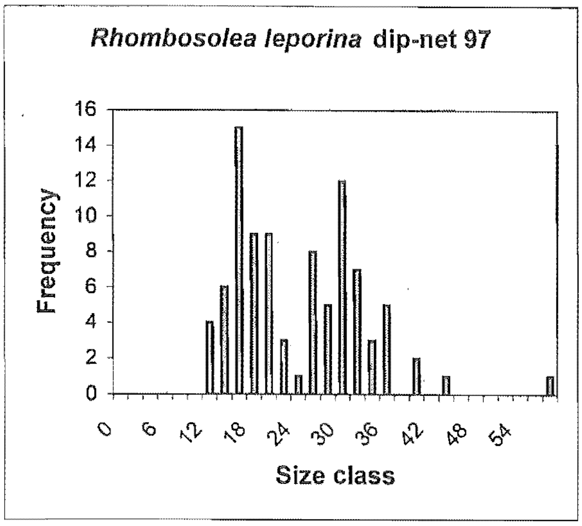
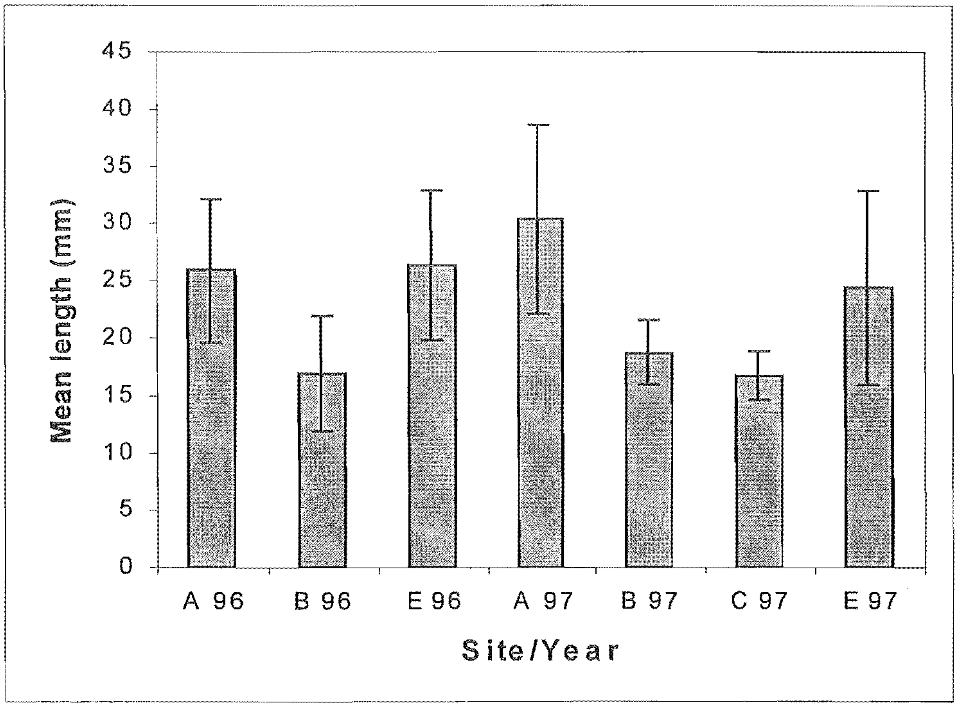


Figure 5.4, Mean lengths of *R. leporina* from dip-net captures 1996 and 1997 ± SD.



Rhombosolea plebeia Sand flounder.

One hundred and eighty juvenile sand flounders were captured, thirty during August/September 1996, and one hundred and fifty during April 1997. Of those captured during August/September 17 were from site E and 11 were from site A, with only two being caught at two other sites (B and C). The occurrence of this species was also rather patchy during April 1997 with catches ranging from 4 at site A, to 99 from site B.

Table 5.5

August – September 1996		**April 1997**	
Mean length (mm) :	28.25	Mean length (mm) :	20.01
Sample size:	30	Sample size:	150
SEM:	1.836	SEM:	0.51
CV:	0.343965	CV:	0.313896
Median:	25.50	Median:	19.00
Minimum :	18.00	Minimum :	21.022
Maximum :	65.00	Maximum :	51.00

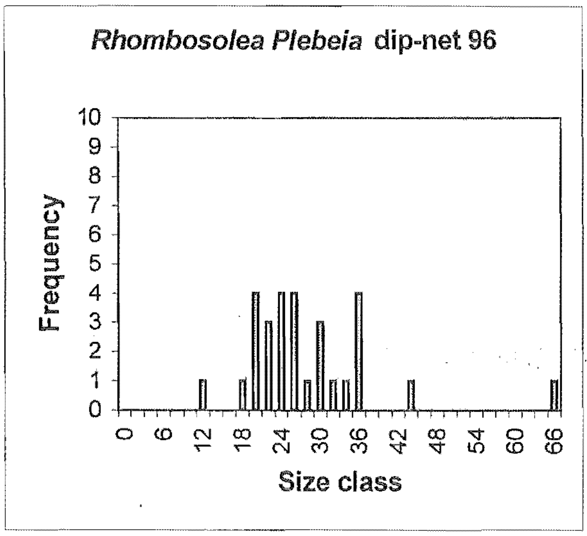
An unpaired t test was performed to compare the combined 1996 data with the combined 1997 data (t=5.78, df=175), and equated to a two-tailed P value of <0.0001. Therefore the means of the combined 1996 and the combined 1997 *R. plebeia* data were significantly different. A Kruskal-Wallis Nonparametric ANOVA test was performed on all the *R. plebeia* site data (KW = 43.48, P < 0.0001), which showed that the variation among the samples was significantly greater than expected by chance. Dunn's Multiple Comparisons Test was then used to further compare the samples and find where significant differences occurred (table 5.6).

Table 5.6 Dunn's Multiple Comparisons Test, for *R. plebeia* dip-net.

Comparison	Mean Difference	P	Value
E 96 vs. A 96	-9.0	ns	P>0.05
E 96 vs. A 97	-32.9	ns	P>0.05
E 96 vs. E 97	65.7	**	P>0.01
E 96 vs. C 97	53.1	*	P>0.05
E 96 vs. B 97	56.0	***	P>0.001
A 96 vs. A 97	-23.9	ns	P>0.05
A 96 vs. E 97	74.6	**	P>0.01
A 96 vs. C 97	62.1	*	P>0.05
A 96 vs. B 97	64.9	***	P>0.001
A 97 vs. E 97	98.6	**	P>0.01
A 97 vs. C 97	86.0	*	P>0.05
A 97 vs. B 97	88.9	**	P>0.001
E 97 vs. B 97	-12.6	ns	P>0.05
E 97 vs. B 97	-9.7	ns	P>0.05
C 97 vs. B 97	2.9	ns	P>0.05

There seemed to be quite an array of significant differences between the mean lengths of the sampled *R. plebeia*, however there doesn't appear to be any clear pattern. Generally speaking however the trend is for larger specimens to be captured from sites A, and E.

Figure 5.5 Size frequency distributions of *R. plebeia* from dip-net samples 1996/97.



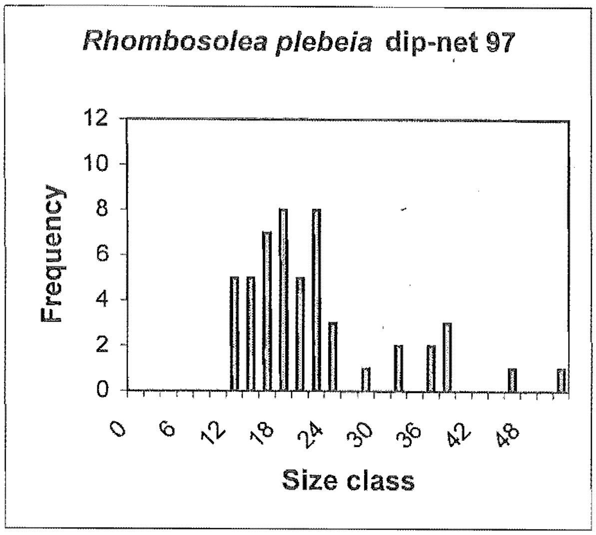
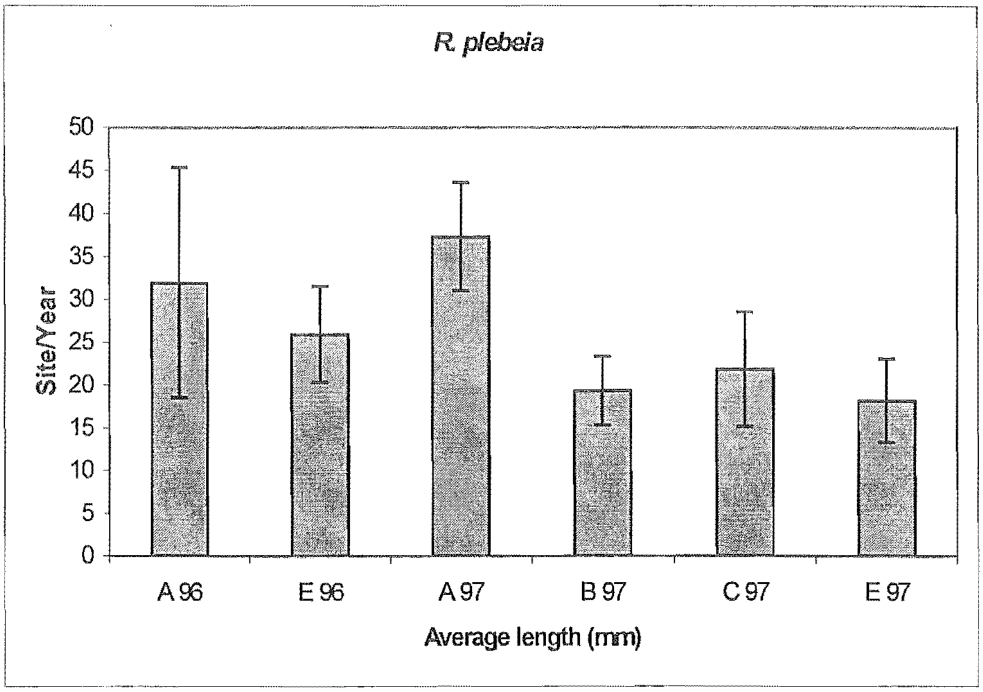


Figure 5.6 Mean lengths of *R plebeia* from dip-net samples ± SD.



The size-frequency distributions of *R. plebeia* were not significantly different from the size frequency distributions of *R. leporina*. The mean length was slightly larger for *R. leporina* suggesting that they had recruited into the Estuary earlier.

Peltorhamphus novaezelandiae (common sole)

All nine specimens of this species were captured during September 1996, from three sites (B, C, and F). The mean size of the specimens captured was 11.3mm, with a range of 7.6 to 15.5mm.

Gobiomorphus cotidianus (common bully)

One hundred and twenty-eight specimens were captured, forty-two during August/September 1997 from sites A(7), and D(35). During the April 1997 sample period eighty-six specimens were captured from sites A(8), D(71), E(2), and F(5).

Table 5.7

August – September 1996		**April 1997**	
Mean length (mm) :	34.31	Mean length (mm) :	20.01
Sample size:	42	Sample size:	86
SEM:	1.01	SEM:	0.95
CV:	0.190469	CV:	0.291143
Median:	35.00	Median:	27.50
Minimum :	23.00	Minimum :	18.00
Maximum :	44.00	Maximum :	65.00

A Mann-Whitney Test was performed on the combined site data from each season (Mann-Whitney U – Statistic = 1185.0, U' = 2427.0), and equated to a two tailed P value of 0.0016. Therefore the mean length of *G. cotidianus* specimens captured during 1996 was significantly different than the mean length of *G. cotidianus* specimens captured during 1997. This equates to the mean length of specimens captured in 1996 being 4mm longer. All samples where *G. cotidianus* were captured were then compared using a Kruskal-Wallis Nonparametric ANOVA Test (KW = 38.776), and equated to an extremely significant P value of 0.0001.Which showed variation among column means was significantly greater than expected by chance. Dunn's PostTest was used to further compare site data (table 5.8), and found significant differences only when comparing sites with site D.

Table 5.8 Dunn's multiple comparisons test, *G. cotidianus*.

Comparison	Mean Difference	P	Value
D 96 vs. D 97	20.9	ns	P>0.05
D 96 vs. F 97	56.2	*	P<0.05
D 96 vs. A 97	75.1	***	P<0.001
D 96 vs. E 97	70.9	ns	P>0.05
D 96 vs. A 97	42.7	ns	P>0.05
D 97 vs. F 97	35.3	ns	P>0.05
D 97 vs. A 97	54.2	**	P<0.01
D 97 vs. E 97	50.0	ns	P>0.05
D 97 vs. A 96	21.9	ns	P>0.05
F 96 vs. A 97	18.9	ns	P>0.05
F 96 vs. E 97	14.7	ns	P>0.05
F 96 vs. A 96	-13.4	ns	P>0.05
A 96 vs. E 97	-4.2	ns	P>0.05
A 96 vs. A 96	-32.3	ns	P>0.05
E 96 vs. A 96	-28.1	ns	P>0.05

Figure 5.7 Size frequency of *Gobiomorphus cotidianus* from dip-net samples.

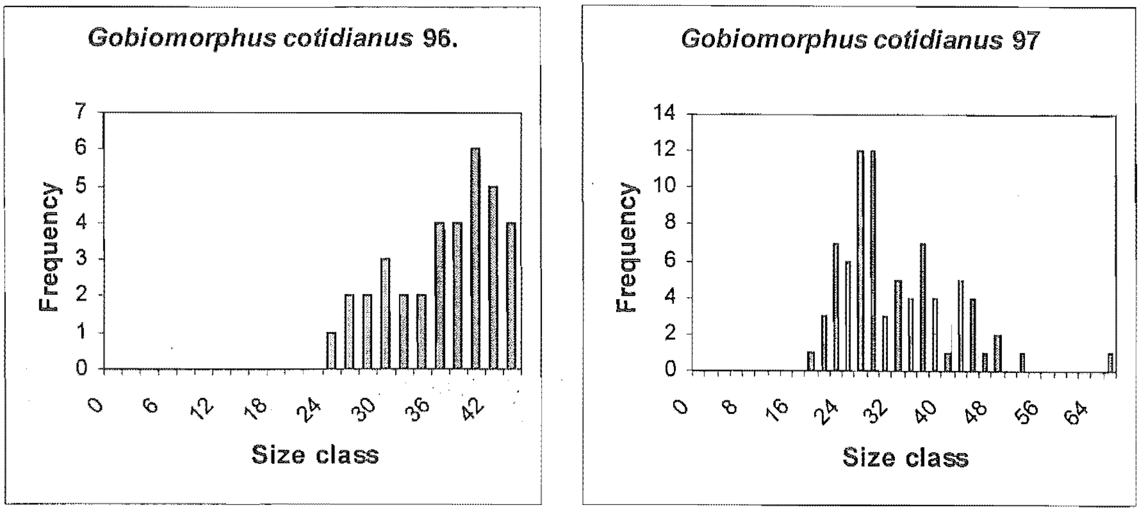
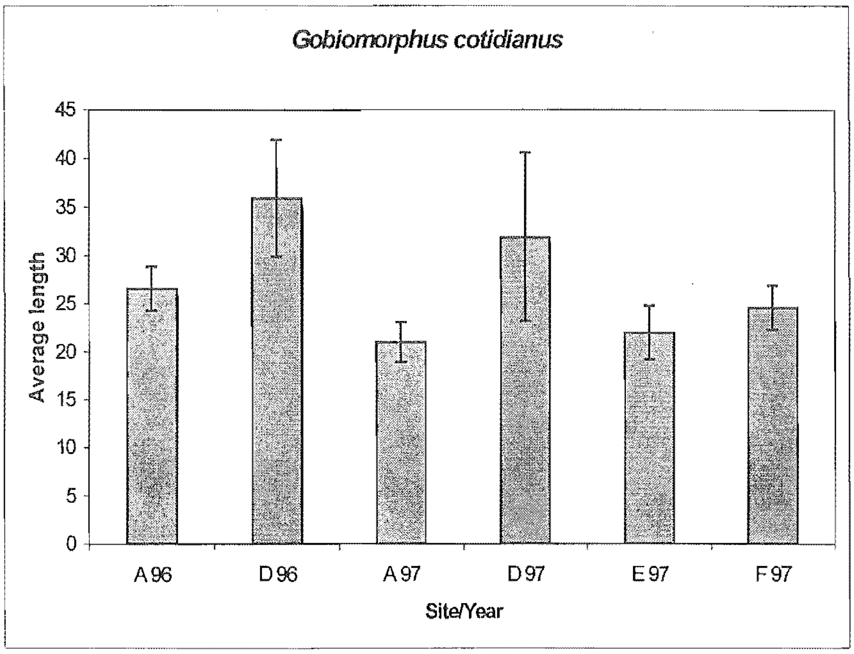


Figure 5.8, Mean lengths of *G. cotidianus* by site and year ± SD.



There was a trend for the individuals from site D (Linwood Ave drain), to be much larger than those captured from the other sites. This was most probably due to the stable population of all life stages of the common bully being present here during the sample period. The other sample sites did not appear to have many adults perhaps due to their unsuitability as breeding sites, or their water chemistry.

Fosterigion Sp.

Ninety-seven members of this family were captured in total, fifteen during August/September 1996, A(8), C(2),E(5), and eighty-two during April 1997 A(57), C(7), E(19) .

Table 5.9

August – September 1996		**April 1997**	
Mean length (mm) :	27.024	Mean length (mm) :	32.60
Sample size:	82	Sample size:	15
SEM:	0.4099	SEM:	1.170
CV:	0.137359	CV:	0.139018
Median:	26.00	Median:	34.00
Minimum :	20.00	Minimum :	23.00
Maximum :	38.00	Maximum :	40.00

An unpaired t test was performed on the comparing the lengths of the specimens from the combined August-September samples, with the lengths of specimens sampled during April 1997. The t value was calculated as 5.165 with 95 degrees of freedom, which equated to an extremely significant P value of <0.0001. Therefore the mean difference of 5.58 (Mean of 1996 minus mean of 1997) was significant. All samples were then compared using a Kruskal-Wallis Nonparametric ANOVA Test, calculating a Kruskal-Wallis Statistic (KW = 28.39), which equated to a P value of <0.0001. This meant that the variation amongst sample means was significantly greater than expected by chance.

The site data were further compared using Dunn's PostTest to indicate where significant differences occurred (table 5.10). Significant differences were only detected between sample periods, from the river sites probably due to the low numbers sampled from the other sites.

Table 5.10

Comparison	Mean Difference	P	Value
E 97 vs. A 97	24.15	*	P<0.05
E 97 vs. C 97	-0.63	ns	P>0.05
E 97 vs. A 96	-15.35	ns	P>0.05
E 97 vs. E 96	-9.22	ns	P>0.05
E 97 vs. C 96	-15.67	ns	P>0.05
A 97 vs. C 97	-24.78	ns	P>0.05
A 97 vs. A 96	-39.51	**	P<0.01
A 97 vs. E 96	-33.37	ns	P>0.05
A 97 vs. C 96	-39.82	ns	P>0.05
C 97 vs. A 96	-14.72	ns	P>0.05
C 97 vs. E 96	-8.59	ns	P>0.05
C 97 vs. C 96	-15.04	ns	P>0.05
A 97 vs. E 96	6.14	ns	P>0.05
A 96 vs. C 96	-0.31	ns	P>0.05
E 96 vs. C 96	-6.45	ns	P>0.05

Figure 5.9, Fosterigion sp. Dip-net size frequency distributions, August/September 1996, April 1997.

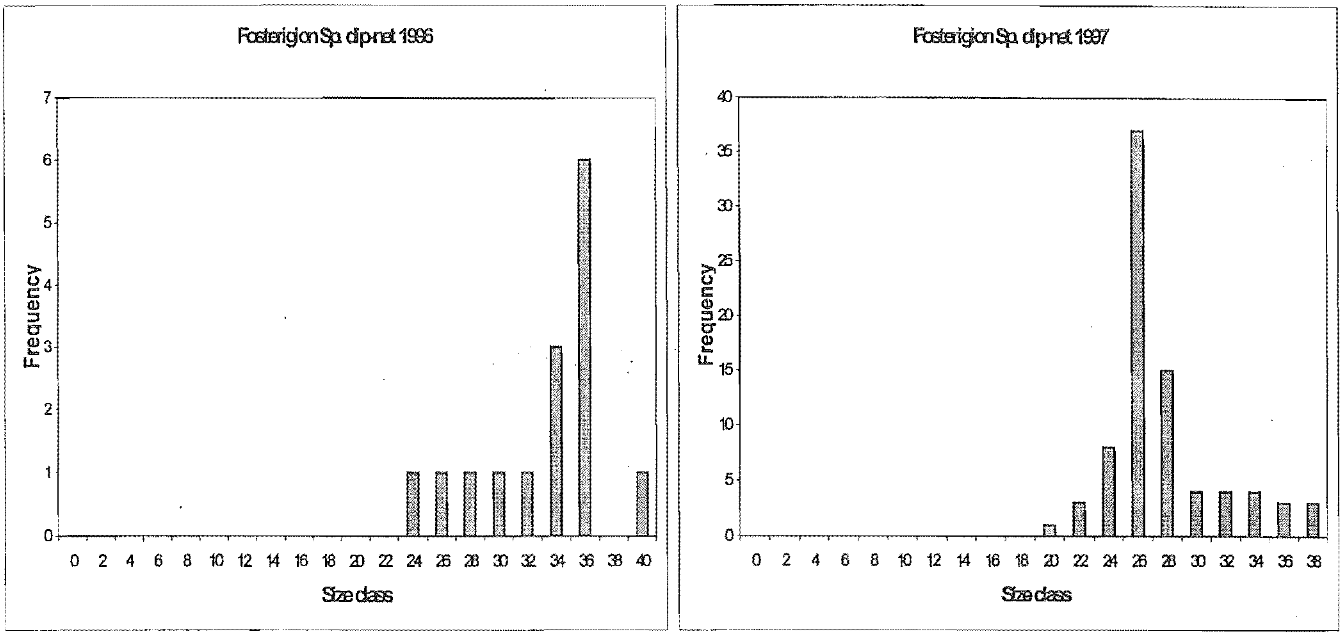
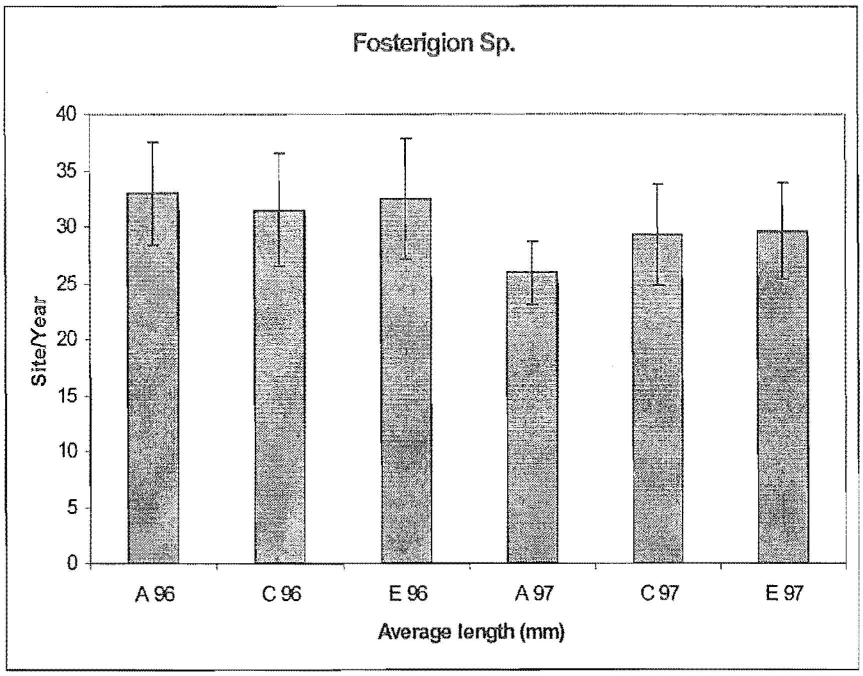


Figure 5.10, The mean lengths of Fosterigion sp. From each sample ±SD.



There was an overall trend for the individuals sampled during the August/September sample period to be slightly larger. However there was a large amount of variability in the lengths of the individuals captured.

Aldrichetta forsteri (yellow-eyed mullet)

Only one individual was captured in the as the fish could easily evade the sluggish net. It was captured at site E during April 1997, and was 46 mm long.

Notolabrus celidotus (spotties)

One specimen was captured amongst *Ulva lactuca* at site C during April 1997, its length was 24mm.

Galaxias maculatus (whitebait or juvenile inanga)

As with *A. forsteri* this species could probably evade the net. One individual was captured at site E during August 1996, and was 49mm long.

Leptoscopus macropygous (Estuary stargazer)

One individual large enough to be easily identified was captured from site C during April 1997, it was 55mm long and was partially buried in the substrate in a shallow pool. Two smaller individuals, were captured during the August - September sample period, one from site A measuring 21mm, and one from site E measuring 26mm.

Discussion:

The dip-net data showed that the Estuary contains large numbers of juvenile fish, especially flatfish which use it as a nursery area. It was surprising to find that juvenile *R. plebeia* were plentiful despite a lack of adults from the seine net captures. As with the seine net captures it is difficult to compare findings with Kilner (1974) as the average length of the sand flounders captured during his study was approximately 60mm. Although the sampling was conducted at low tide when any use of vegetation as a refuge from predators was impossible due to the absence of water, young flatfish were frequently observed to use crab or polychaete burrows to escape capture.

Section 6.0

Gut contents of *Rhombosolea leporina* (adult):

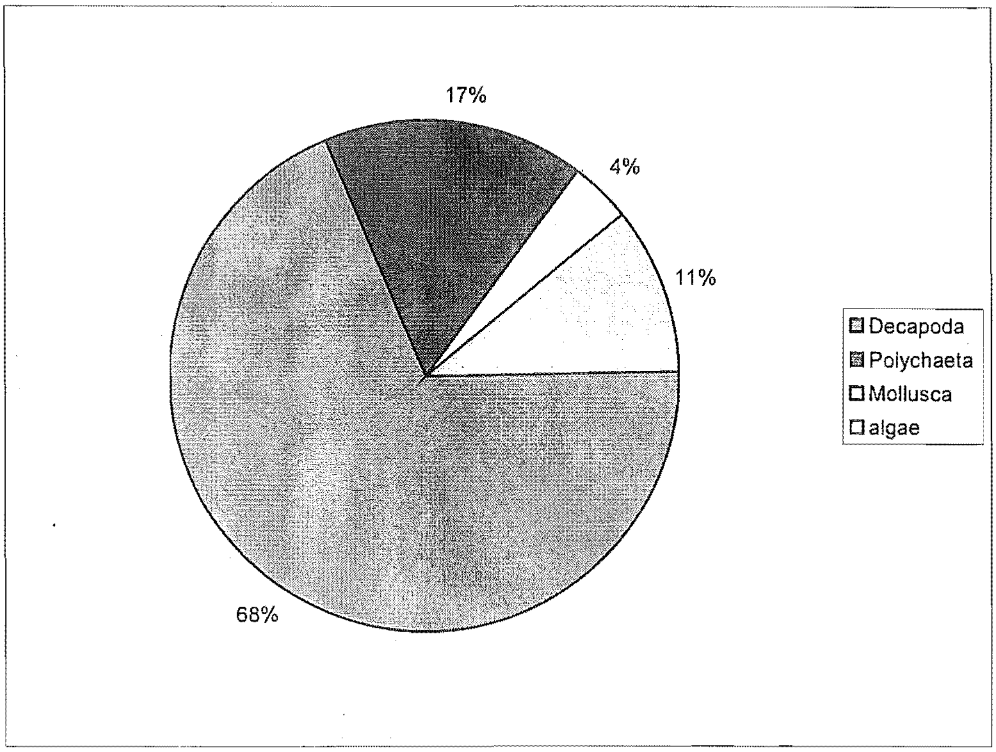
Gut samples were taken from a randomly selected sub-sample of adult (or those large enough to be captured in the seine net), *R. leporina*. Gut samples were examined as described in the materials and methods section, consisting of two sub samples of ten individuals from each sample period. The sample periods were the same as for the sample periods for adult captures being July – September 1996, and November 1996 – April 1997. The gut contents were identified as close as was practicable to the species level and the size of prey items measured using a graduated eyepiece.

Table a Length (mm) of *R. leporina* sub-sample.

July – September 1996		November 1996 – April 1997	
Mean length (mm) :	305.8	Mean length (mm) :	346.5
Sample size:	10	Sample size:	10
SEM:	27.7	SEM:	12.1
Median:	379.0	Median:	335
Minimum :	185	Minimum :	295
Maximum :	480	Maximum :	400

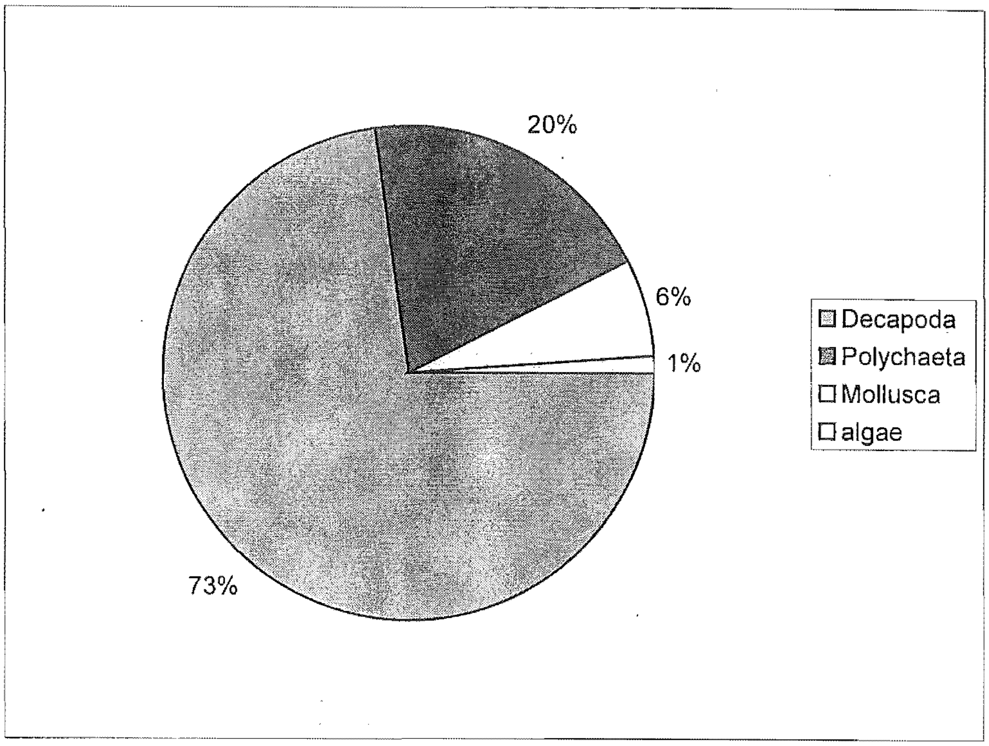
The mean lengths of individuals from the sub samples were not found to differ markedly from the means of the population samples, indicating a representative sub-sample.

Figure 1 Percentage breakdown of food items by occurrence for *R. leporina* both samples combined (n=20)



The pie graph above of the combined gut sample data serves to illustrate the predominance of decapods overall in the gut samples, followed by polychaetes with molluscs and algae being relatively rare.

Figure 2 Percentage breakdown of food items by occurrence for *R. leporina* July – September 1996 (n=10)



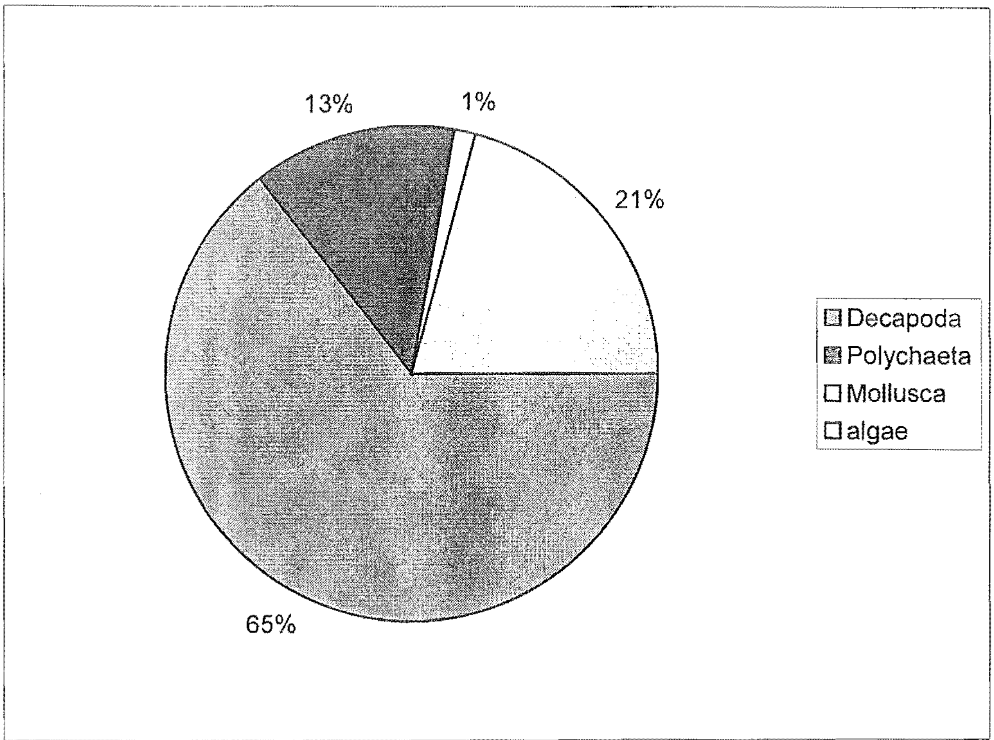


Figure 3 Percentage breakdown of food items by occurrence for *R. leporina* November 1996 – April 1997 (n=10)

The two preceding figures illustrate that there was no significant change in prey importance between the sample periods, excluding algae. There was a noticeable increase in the percentage of algae in the November 1996 – April 1997 samples.

Table ??Decapod counts from the *R. leporina* sub-samples.

July – September 1996		November 1996 – April 1997	
Mean count :	12.4	Mean count :	10.2
Sample size:	10	Sample size:	10
SEM:	2.5	SEM:	4.1
Median:	11.0	Median:	5.5
Minimum :	0	Minimum :	0
Maximum :	30	Maximum :	40

Table a. Carapace width measurement summary of measurable Decapoda from all adult *R. leporina* gut samples (n=95).

July – September 1996 and November 1996 – April 1997.	
Mean carapace width in millimeters :	8.6
Sample size:	95
SEM:	0.48
Median:	6.5
Minimum :	2.0
Maximum :	30.0

The preceding two tables show that crabs were a relatively consistent occurrence in the gut samples of *R. leporina* with a mean count of around ten per individual from both seasons.

Figure 4 Average carapace widths of crabs relative to total length of the predator.

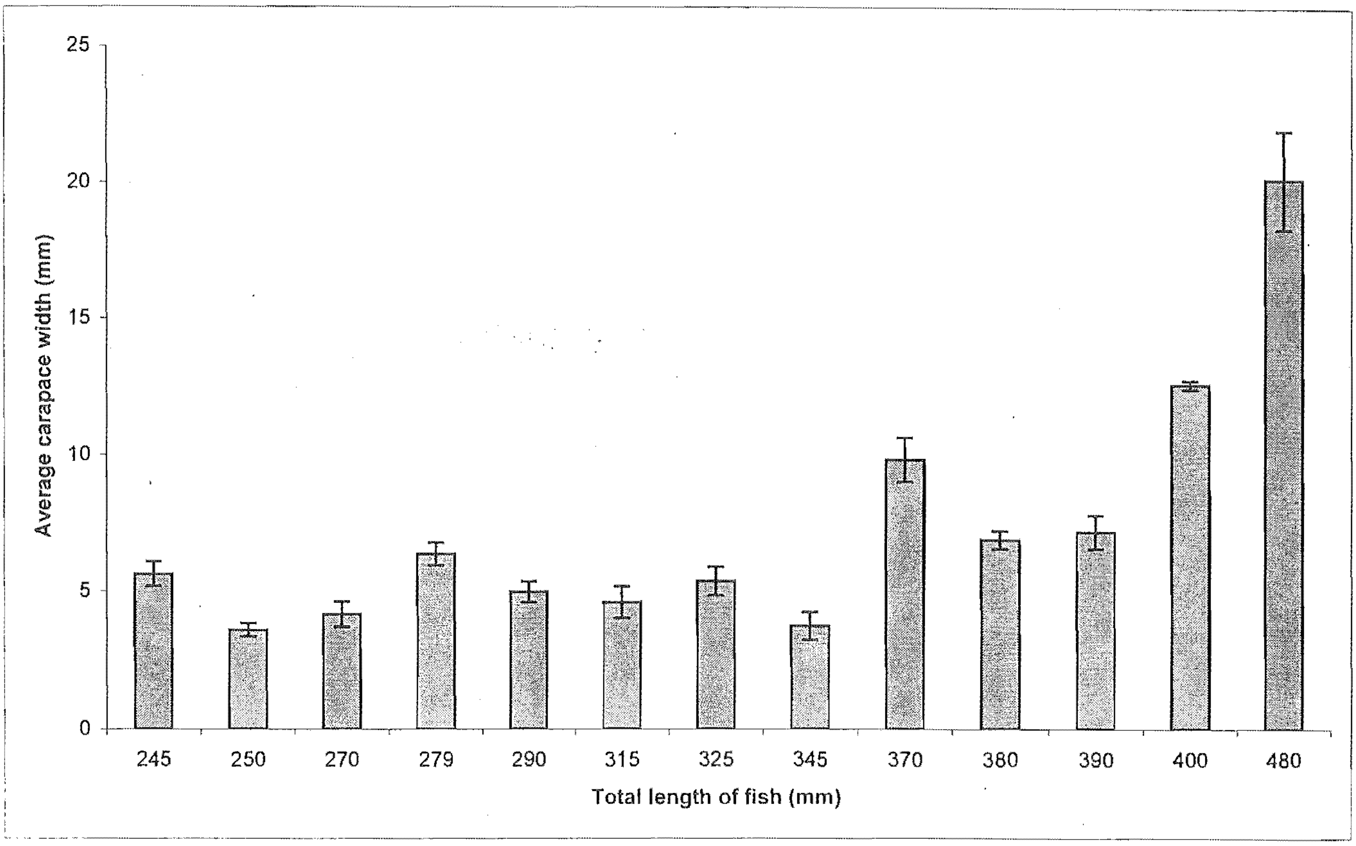


Table a. Counts of polychaetes from *R. leporina* gut samples (n=20).

July – September 1996		November 1996 – April 1997	
Mean count :	3.4	Mean count :	2.1
Sample size:	10	Sample size:	10
SEM:	1.9	SEM:	0.8
Median:	1.0	Median:	1.5
Minimum :	0	Minimum :	0
Maximum :	20	Maximum :	6

Polychaetes played a relatively minor role in the diet of adult *R. leporina* making up only 17 percent of the total food intake.

Discussion

It was interesting that the average carapace width of crabsfrom the gut samples was so small, as Webb (1966) states " The young *Rhombosolea leporina* tended to select smaller sized crabs, while the adults, above 220-230 mm utilized the larger crabs." This is somewhat apparent in the graph of average carapace width Vs length of predator. However this relationship only becomes apparent in the individuals over 350 mm in this study, possibly due to the small sample size.

The increased incidence of algae in the November 1996 – April 1997 samples was probably due to chance ingestion as the algal density may have changes seasonally. Also there was a greater abundance of algae especially *Ulva lactuca* during that sample period. Polychaetes were surprisingly under represented given their abundance (in the invertebrate surveys), and their importance in the diets of the specimens examined by Webb (1972[3]). Webb thought it probable that the pre-adult flatfish foraged more on polychaetes than larger individuals. Whereas the larger specimens captured in this study would have been less limited as to their prey selection due to their larger gape. My gut analysis methodology may have caused considerable bias towards more indigestible food items such as the carapaces of crabs than polychaetes. This was evident when often all that remained of the polychaetes in the digestive tract was a pale piece of skin, with jaws attached. Thus those species of polychaete without jaws were difficult to detect, although setae made it obvious when polychaetes were present. Although the present study investigated a randomly selected cross-section of the population, and assumed that the highly mobile adults would forage over a wide area this was probably not the case, as there did appear to be regional differences in prey selection throughout the Estuary.

Gut contents of dip-net captured *Rhombosolea leporina*, *Rhombosolea plebeia*, and *Gobiomorphus cotidianus*.

Gut samples were taken from a randomly selected sub-sample of dip-net captured *R. leporina, R. plebeia, and G.cotidianus*. Gut samples were examined as described in the materials and methods section, consisting of two sub samples of ten individuals from each sample period. The sample periods being August-September 1996, and April 1997. The gut contents were identified as close as was practicable to the species level, and counted.

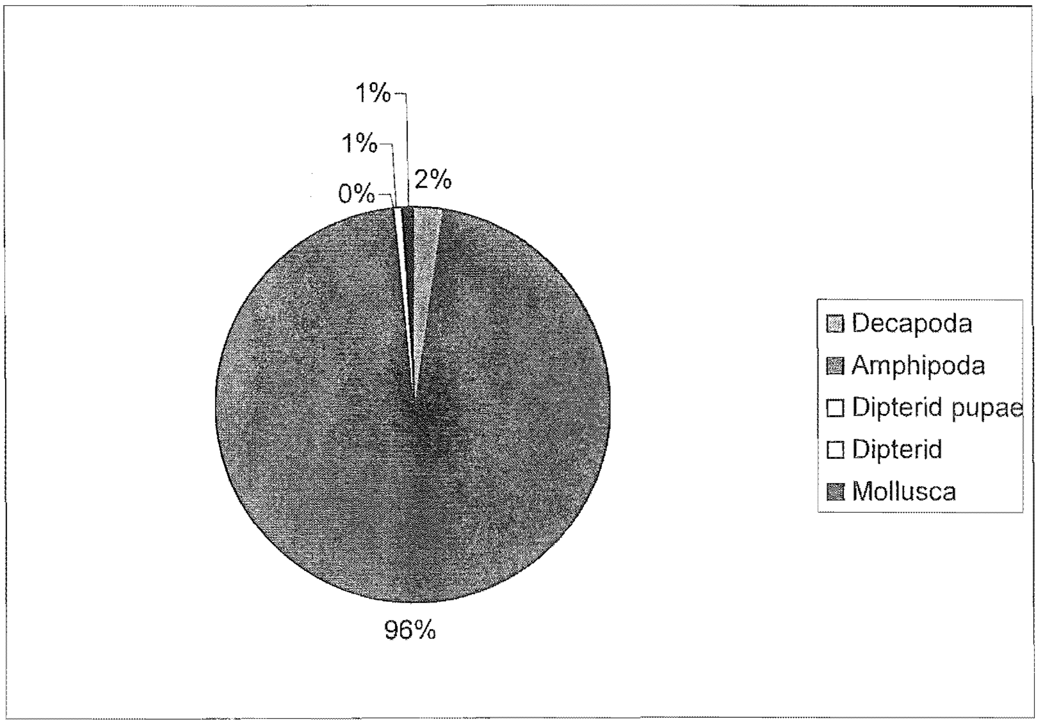
Table 6.5 Descriptive statistics of dip-net captured, gut content sub samples. Both samples combined (n=20 for each species).

	R. leporina	*R. plebeia*	*G. cotidianus*
Mean length of sample:	33mm	28.3 mm	41 mm
Minimum length:	25 mm	12 mm	19 mm
Maximum length:	65 mm	65 mm	66 mm
Number with empty digestive tracts:	11	10	7

Gut contents:

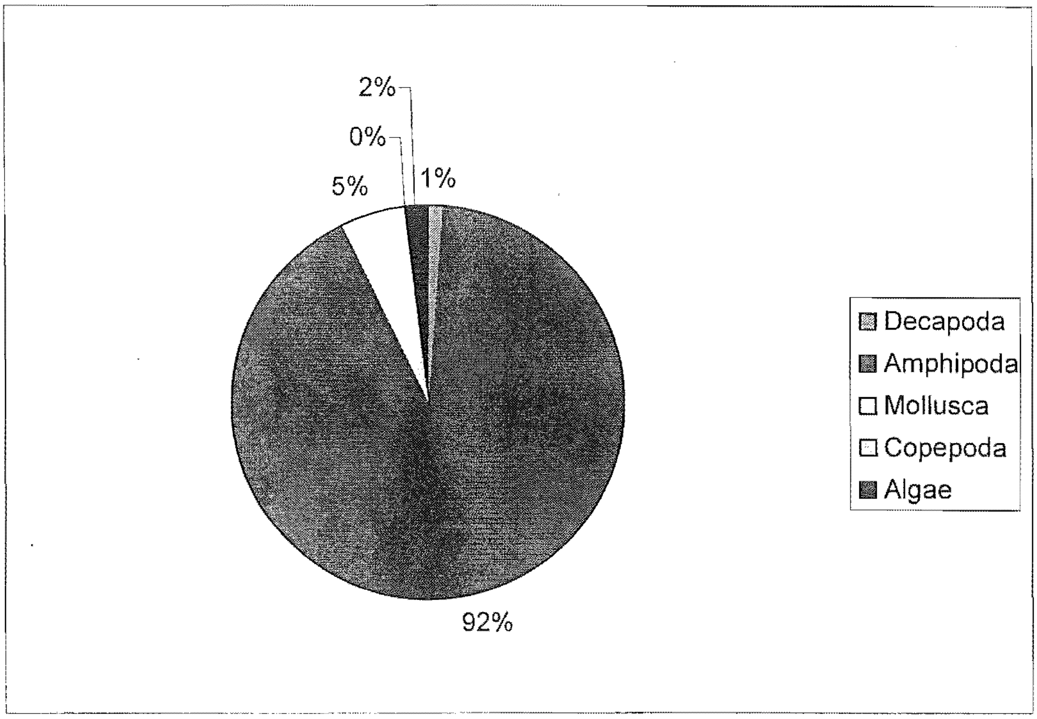
The gut samples were compared between the two sample periods, with no significant differences being apparent between the samples. The two samples have therefore been grouped together to give an overall indication of the food preferences of the juvenile flatfish, and Bullys.

Figure 6.5, Gut contents of *R. leporina*, percentage occurrence (n=20).



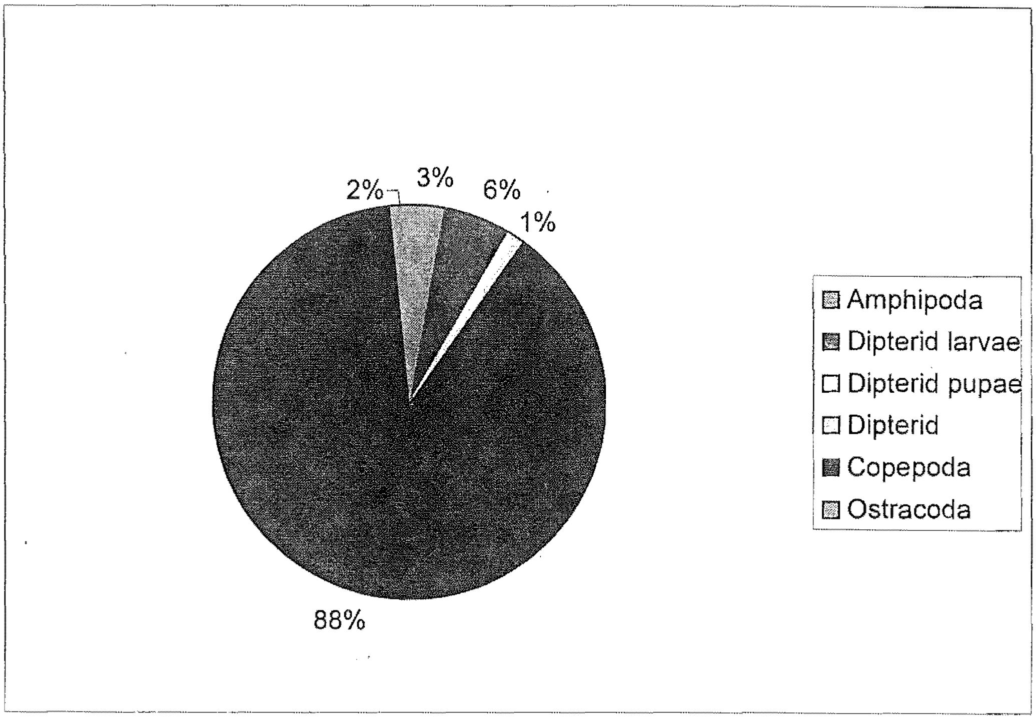
There was a strong preference for amphipods, however the few decapods, and molluscs that did occur were relatively larger than the more common amphipods.

Figure 6.6, Gut contents of *R. plebeia*, percentage occurrence (n=20).



As with R. leporina the main prey item was amphipods, however molluscs were relatively important with respect to their mass.

Figure 6.7, Gut contents of *G. cotidianus* percentage occurrence (n=20).



Copepods were the dominant food item from the guts of the *G. cotidianus* specimens examined, however the various dipterid stages had considerably more mass than the small copepods.

Discussion:

Gee *et al* (1984) found that small estuarine fish generally had their fullest gut 3-4 hours after high tide, which makes it likely that the guts were less "full" than they could have been. However Ansell and Gibson (1990) found that it depended on the species as to whether the juvenile flatfish would feed significantly more at high tide. It was interesting that there was quite a high degree of parasitism in the juvenile flatfish of both species, some in fact seemed to have their gut almost full of nematodes. Although it was beyond the scope of this investigation, it would be interesting to attempt to correlate parasitism levels with environmental stresses (possibly pollution). As numerous studies have shown that stress in the environment exacerbates parasite problems. There was heavy parasitism however in fish taken from both the Avon and Heathcote Rivers, which have been shown to have quite different levels of pollution (Eldon et al 1989, Eldon and Kelly 1992, Cameron 1970). There was very little difference between the two flounder species (*R. leporina* and *R. plebeia*), and it seems probable that they were limited to prey types that were small enough to pass through the mouth. Given that the amphipods were very common at the sample sites (large numbers were present in the dip-net samples but were not counted), and highly mobile. Thus the flounders would encounter large numbers of amphipods and probably drawn to them by their movement. Lincoln & Smith and Jones (1995) found that amphipods were associated with decaying plant matter which also served as a refuge for juvenile fish. Kilner (1974), found that the R. plebia gut samples of the 0^+ fish contained 20 % Polychaeta, 5% Decapoda, and only 10 % Amphipoda. This could quite likely be due to the much larger sizes of the individuals sampled by Kilner as their average total length was 61 mm, compared with 30 mm (both flatfish species combined), from the present study. So it is likely that the flounders move on from various food types as length increases, with the dominant prey types changing from Amphipoda to Polychaeta and finally to Decapoda with the likely key factor being the size of the mouth. A similar situation has been described by Poxton et al (1983), studying flatfish in the Northern Hemisphere where "As they grow"the fish "take progressively larger siphons, fragments of siphonids and some crustaceans".

The common bully *G. cotidianus* fed predominantly on copepods, and dipterid larvae. Tank observations of feeding bullys indicated that they were highly visual predators, and strongly attracted to moving prey items such as highly motile copepods or struggling dipterids. They were never observed to eat slow moving *Potamopyrgus* sp. This was similar to observations made by Eldon (1979) when viewing the feeding of the Canterbury mudfish.

Section 7.0

Gonad samples:

Gonad samples were obtained from a random selection of "common species" as discussed in the materials and methods section. Their state was then interpreted as in table (2.1) of materials and methods. Due to the small sub-sample examined, statistical analyses were not performed.

Figure 7.1 Gonad stage from *R.leporina* Stage and fish length from July – September 1996 (n=10).

Stage	Number taken at that stage	Average length of individual (s) taken
1 Immature	1	255
2 mature unripe	1 female, 1 male	330, 270
3 Mature ripening		
4 Nearly ripe	7 females	373
5 Ripe		
6 Ripe running		
7 Spent		

There was an obvious lack of males from this sample, but as the sample is so small this may be entirely due to chance. It is also notable that seven out of ten individuals were nearly ripe.

Figure 7.2 Gonad stage from *R.leporina* Stage and fish length from November 1996 – April 1997 (n=10).

Stage	Number taken at that stage	Average length of individual (s) taken
1 Immature	2	290
2 mature unripe	2 females	310
3 Mature ripening	1 female, I male	310
4 Nearly ripe	2 females	349
5 Ripe	3 females	365
6 Ripe running		
7 Spent		

As with the July – September sample there was a predominance of females, with five ripe or near ripe females from the sample.

Discussion:

Webb (1972[2]) examined the gonads of 323 *R. leporina* specimens. Although the sample size is far too small to draw many conclusions there seems to be a trend for relatively large females, approaching ripeness to be present in the Estuary during both sample periods. The absence of ripe running females suggests that the females use the estuary as a rich-feeding area to increase condition prior to the spawning. This seems even more likely given that both Coleman (1973), and Minami & Tanaka (1992) state that flatfish generally spawn in deeper water than occurs in the estuary. The absence of ripe males supports this hypothesis in that the males put relatively little energetically into the spawning process producing relatively inexpensive sperm, so there is little need to move into the estuary. A parallel could be drawn with the freshwater long-finned eel *Anguilla dieffenbachii*, which only the females tend to grow particularly large. As they need to be large to produce large numbers of eggs females migrate at an average age of 34 years, at an average size of 1150 mm. The males on the other hand usually spawn soon after they reach maturity at between 480 and 7040 millimeters long, at an average age of 23 years old (McDowall 1990).

Section 8.0

Conclusion

Aspects of the biology of various fish species in the Avon-Heathcote Estuary have been investigated to compare with the studies of Webb (1966), and Kilner (1977). I found high abundance's of juvenile flatfish, suggesting this area acts as a nursery area for these species. The estuary also supports a good population of large adult yellow-bellied flounders, which probably use it as a feeding ground before going to sea to breed. It was surprising that adult sand flounders were not captured during this study this may be due to a number of factors, such as their smaller size, different biology. This may be due to increased commercial fishing around the coast, and Banks Peninsula. As was discussed earlier the results of this study are not directly comparable to Webb's (1966), due to the sea lettuce restricting the sampling methodology. It is unclear what impact the sea lettuce would have had on the ability of the seine net to capture fish, but it would undoubtedly would have had some negative effect. The most unfortunate impact of the sea lettuce on this study was that it turned sampling into a logistical nightmare. One possible result of the unsuitability of the beam trawl as a capture method was the low number of species captured in the channels, as the initial trials captured star-gazers and sole in relatively large numbers, but none were captured in the seine net. This is why I don't believe that there has necessarily been any decrease in the diversity of fish species. There has been no simple explanation given as to why there was such a huge increase in the amount of sea lettuce present, and it is probably the culmination of a number of factors. But an important factor is likely to be the huge amount of nutrient-rich water discharged from the

Bromley Treatment Plant each high tide, of which there is no recent data on how much is retained within the estuarine system (Owen 1992). I hope that the council decides to give a higher priority to the fishery of the Avon-Heathcote Estuary, and conduct on-going monitoring. To ensure that its activities are beneficial to the communities of organisms that thrive in the estuary.

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