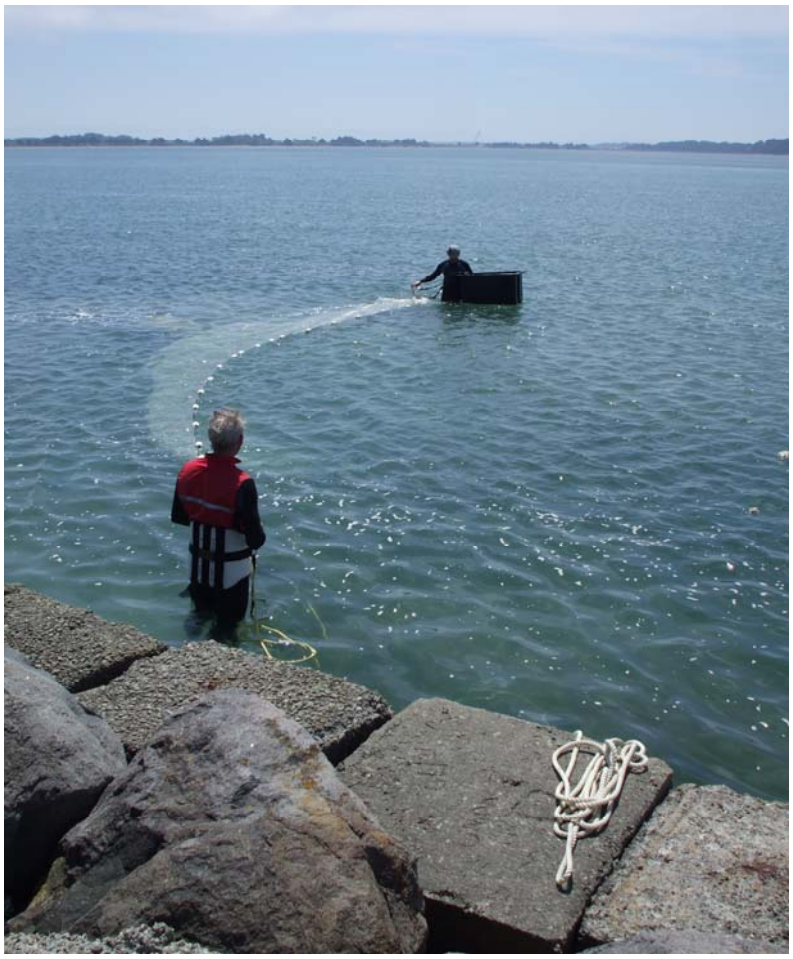
Assessment of fish populations in the Avon-Heathcote Estuary: 2007



Deploying the seine at high tide along the causeway.

NIWA Client Report: CHC2008-014
February 2008

NIWA Project: CCC08502

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Prepared for

Christchurch City Council

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Contents

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Summary

This describes the third of six planned annual surveys of the Avon-Heathcote estuary commissioned by the Christchurch City Council to monitor changes in fish species diversity and abundance following the removal of wastewater discharges. Three surveys have been undertaken before removal (2005-2007) and three will be undertaken at two yearly intervals following completion of the scheme.

Results from this survey, undertaken in November 2007, support previous indications that fish species diversity is presently somewhat less than during the 1960s. However, some species apparently now absent were present only occasionally in the estuary in the 1960s, and many have since been the target of commercial fishers with consequent declines in abundance. Current sampling protocols also reduce the opportunity of collecting some of the less common species.

Abundance of most fish species in 2007 was similar to that in 2005 and 2006, which suggests that sampling intensity is sufficient to reliably assess changes over time. Yellowbelly flounders abundance was high in 2005, low in 2006 and intermediate in 2007. This suggests that marked inter-annual variation in short-lived species like flatfish is not unusual and is the reason three pre- and three post-wastewater removal surveys were scheduled. The present survey has also confirmed the indication in the previous two surveys that relative abundance of the two important flatfish species in the estuary appears to have changed since the 1960s. Sand flounders, especially adults, are noticeably fewer, whereas adult yellowbelly flounders are now both larger and more abundant than in 1965. Moderate numbers of juvenile sand flounders were once again present, particularly along the muddy western shore. These changes in abundance may be related to increased commercial fishing pressure on sand flounders in Pegasus Bay, and/or increasing sea temperatures which could favour yellowbelly flounders, in addition to possible effects of wastewater discharges.

The sampling protocols developed for these surveys, one for adult fish (using trawling in the main channels at low tide) and the other for juvenile and small fish species (using beach seining around the margins at high tide) need to be repeated as closely as possible in future surveys. These will provide separate indices of fish abundance for juveniles (and smaller species) and adults, with possibly different trends for adults and juveniles of each species (as occurred for yellowbelly flounder in 2006). Changes in juvenile fish numbers could reflect recent events mostly within the estuary and may explain why numbers of larger fish have changed, whereas trawl surveys of larger fish will likely integrate changes over more than one year, and will better describe what recreational fishers in the estuary are experiencing.

Future surveys should be repeated in November each year. This month was chosen initially to coincide with the lesser quantities of net-clogging sea lettuce present at this time of the year but it is important now to maintain consistency in respect of possible seasonal variations within fish populations.

1. Background

NIWA was commissioned by the Christchurch City Council to undertake a series of six annual surveys in the Avon-Heathcote Estuary beginning November 2005, to assess changes in fish populations following the removal of wastewater discharges from the Estuary. The first three surveys were to establish baseline data on species composition, size and abundance of estuarine fish using consistent methodology that can be repeated in subsequent years, to identify any changes. This survey is the third of these surveys. Plans are to undertake three annual surveys prior to the removal of the discharges, followed by three once the scheme is completed, although the latter may not begin immediately or may be undertaken biannually if this seems appropriate for scientific reasons. This work was partly in response to claims that wastewater discharges from the Bromley ponds are relatively high in free ammonia, and that relatively few fish remain in the estuary. These surveys will indicate current population levels, and are expected to show improvements in fish abundance following removal of the wastewater from the Estuary.

The Avon-Heathcote Estuary is unique in the Canterbury area with its relatively large size (about 800 ha), historical use by a wide range of fish species, and its role as important habitat for many species of fish. It acts as a nursery area for many species, particularly the commercially important flounders, and provides an essential migration route for species such as freshwater eels, lamprey, common smelt, and brown trout, which spend different phases of their lifecycles in fresh water and the ocean.

In pre-European times, the Avon-Heathcote Estuary was among the most important and highly valued food-gathering sites for South Island Maori on the east coast. The estuary was rich with tuna (eels), karakara (lamprey), inanga (whitebait), and patiki (flounder) (Cromarty & Scott 1995).

Recreational fishers still catch some sand and yellowbelly flounders in the Estuary using drag nets, and whitebaiting is practiced in the lower reaches of the Avon and Heathcote Rivers, mostly above the extent of saltwater influence. While no reliable data are available on numbers of fishers or size of catch for any of these fisheries, anecdotal evidence suggests catches are much smaller than previously.

2. Historical information on changes in fish populations in the Estuary

The largest and most systematic survey of fish populations in the estuary was undertaken 40 years ago in 1965-66 (Webb 1967, 1972, 1973a, 1973b, 1973c, 1973d). Webb recorded 28 fish species compared with the 37 species recorded from all surveys (Table 1), and presented extensive biological information on the main species

Table 1 : Species and relative abundance of fish recorded during surveys of the Avon-Heathcote Estuary. Relative abundance between species is indicated by one of three categories: +++ = common, ++ = frequent, + = rare. For the recent surveys, ♦ = juveniles only. (N.B. relative abundance cannot be compared between reports as sampling effort in different habitats may be unequal).

Species	Webb 1972, Webb 1973d	Knox and Kilner 1973	Eldon and Kelly 1992	Nairn 1998	James 2005 James 2006 2007 survey
Barracouta (*Thyrsites atun*)	+	+			
Bully – Common (*Gobiomorphus cotidianus*)	+++	+	++	+++	+
Bully – Giant (*Gobiomorphus gobioides*)	+	+	+		+
Bully – Redfin (*Gobiomorphus huttoni*)	+	++			
Brown trout (*Salmo trutta*)	++	+	+	+	
Chinook salmon (*Oncorhynchus tshawytscha*)				+	+ ♦
Clingfish (*Trachelochismus pinnulatus*)	+	+			+
Eel – Shortfin (*Anguilla australis*)	++	+	++		+
Eel – Longfin (*Anguilla dieffenbachii*)	+	+	+		
Elephant fish (*Callorhinchus milii*)		+			
Flounder – Black (*Rhombosolea retiaria*)		+	+		
Flounder – Sand (*Rhombosolea plebeia*)	+++	+++	+	+++	++
Flounder – Yellowbelly (*Rhombosolea leporina*)	+++	+++	++	+++	++
Globefish (*Contusus richei*)	+++	++			+ ♦
Inanga or whitebait (*Galaxias maculatus*)	+++	+	+	+	+♦
Kahawai (*Arripis trutta*)	+++	++			+ ♦
Moki (*Latridopsis ciliaris*)	+	+			
Pipefish (*Leptonotus* sp.?)		+			
Piper or garfish (*Hyporhamphus ihi*)	+	+			
Red cod (*Pseudophycis bachus*)	++	++			
Red gurnard (*Chelidonichthys kumu*)	+	+			
Rig (*Mustelus lenticulatus*)	+	+			
Rockfish (*Acanthoclinus fuscus*)	+	+			
Seahorse (*Hippocampus abdominalis*)	+	+			+
Smelt – Common (*Retropinna retropinna*)			+		+++
Smelt – Stokell's (*Stokellia anisodon*)	+	+			
Sole – Common (*Peltorhamphus novaezeelandiae*)	+++	+		+	+
Sole – Speckled (*Peltorhamphus latus*)					+
Sprat – Slender (*Sprattus antipodum*)					+
Sprat – Stout (*Sprattus muelleri*)					+
Stargazer – Estuary (*Leptoscopus macropygus*)				+	+
Stargazer – Slender (*Crapatulus angusticeps*)	+	+			+
Stargazer – Spotted (*Genyagnus monopterygius*)	+	+			+
Spotty (*Pseudolabrus celidotus*)	+++	++		+	+
Thornfish (*Bovichtus variegatus*)	+	+			
Triplefins (Family Tripterygiidae)	++	+++	+	++	+
Yelloweye mullet (*Aldrichetta forsteri*)	+++	+++	++	++	+++

present. Webb used two methods to sample the fish resources: a small otter trawl and a beach seine (Table 2). We attempted to replicate the methodology as much as was practicable for this series of surveys so that major changes in fish abundance over the last 40 years could be better interpreted. The major difference between the surveys was the much smaller mesh of the beach seine used in the current surveys in order to sample small fish.

Table 2: Specifications of the fishing gear used in the present surveys compared with the 1965 survey (Webb 1972). *Assumed effective width for 20 m long seine net.

	Trawling		Seining	
	1965 survey	Present surveys	1965 survey	Present surveys
Headrope length (m)	7.31	7.3	-	-
Net length (m)	-	-	20.1	11
Codend length (m)	1.21	5.5	0	4
Net depth (m)	1.21	0.8	1.5	2.3
Effective fishing width (m)	4.2	6.0	15*	9
Mesh (stretched) (mm)	50.8	50	63.5	9
Otter board area (m^2)	0.76	0.56	-	-
Towing ropes (m)	26	20 & 30	55	20
Distance covered per tow/haul (m)		137-541	55	80-100
Area covered per haul ($m^{2)}$		822-3246	~ 825	720-900
Boat length (m)	3.65	5	-	-
Outboard motor horsepower	3.5	90	-	-

A 1996-97 attempt to repeat the 1965-66 survey using a beam trawl, was hampered by the large amount of sea-lettuce present at the time (Nairn 1998). Beach seining in the channels and dip-netting around the margins were substituted, but only qualitative comparisons could be made with Webb's earlier survey. In spite of recording only 11 fish species (39% of the total recorded in 1965-66), this survey concluded fish species diversity had not declined because sampling was more restricted (Nairn 1998).

3. Sampling methods and data analysis

3.1. Sampling gear and methodologies

Identical trawl and beach seine sampling gear was employed in November 2007 to that used in the previous surveys in November 2005 and 2006, so that changes in fish abundance between these and future surveys can be determined. As noted above, sampling gear used was also as similar as possible to that used in the 1965 survey (Table 2). Operation of the trawl net (a small research otter trawl, model "Florida Flyer") was described in the 2005 survey (James 2006). A backup net was purchased

in 2006 with both nets owned by the Christchurch City Council and stored at NIWA Christchurch.

3.1.1. Trawling

A total of 18 trawls were completed of which 5 were in the Avon channel, 4 in the Heathcote channel, and 9 in the main channel (Figure 1). Three tows in the main channel were discarded. Two, from Monks Bay to Shag Rock, were attempted at too high a flow, caught nothing, and were repeated next day at slack water with markedly better results. The third, from the cell phone tower to the Christchurch yacht club, veered off track into shallow water across a sandbar and caught many large paddle crabs (*Ovalipes* sp.*)* but little else. Up to this point (including previous years) we had caught mainly juvenile crabs. The trawl was repeated with better control. Optimum time in respect of site, tide level and tidal flow is critical to the success of our sampling protocols, especially that of trawling which relied on slack water at low tide. To help achieve this we were granted dispensation by the Harbourmaster to exceed 5 knots if necessary, and we sometimes did so when moving between sites to maximise the limited fishing time available around low tide.

3.1.2. Beach seining

The beach seine used was constructed in 2006 for the Christchurch City Council and identical to that used in 2005 (Table 2).

A total of 12 hauls were made at similar locations to the 2005 and 2006 surveys (Figure 2). Beach seining was undertaken over a period of about 2 hours either side of high tide when the shallow mud flats were mostly inundated and access from the shore was relatively easy. Sampling procedures were similar to those employed in previous years.

3.2. Fish processing

As previously, catches were processed as soon as possible after each tow/haul to ensure fish could be returned alive to the water where possible. Fish were quickly transferred to a large plastic bin containing seawater and thereafter identified, measured, given a visual check as to health (see Results and Discussion) and returned to the water. Small numbers of fish which were difficult to identify in the field were retained and examined later in the laboratory. In addition this year, a limited number of individuals of the most common species – yelloweyed mullet, yellowbelly flounder, and sand flounder were kept for genetics studies.

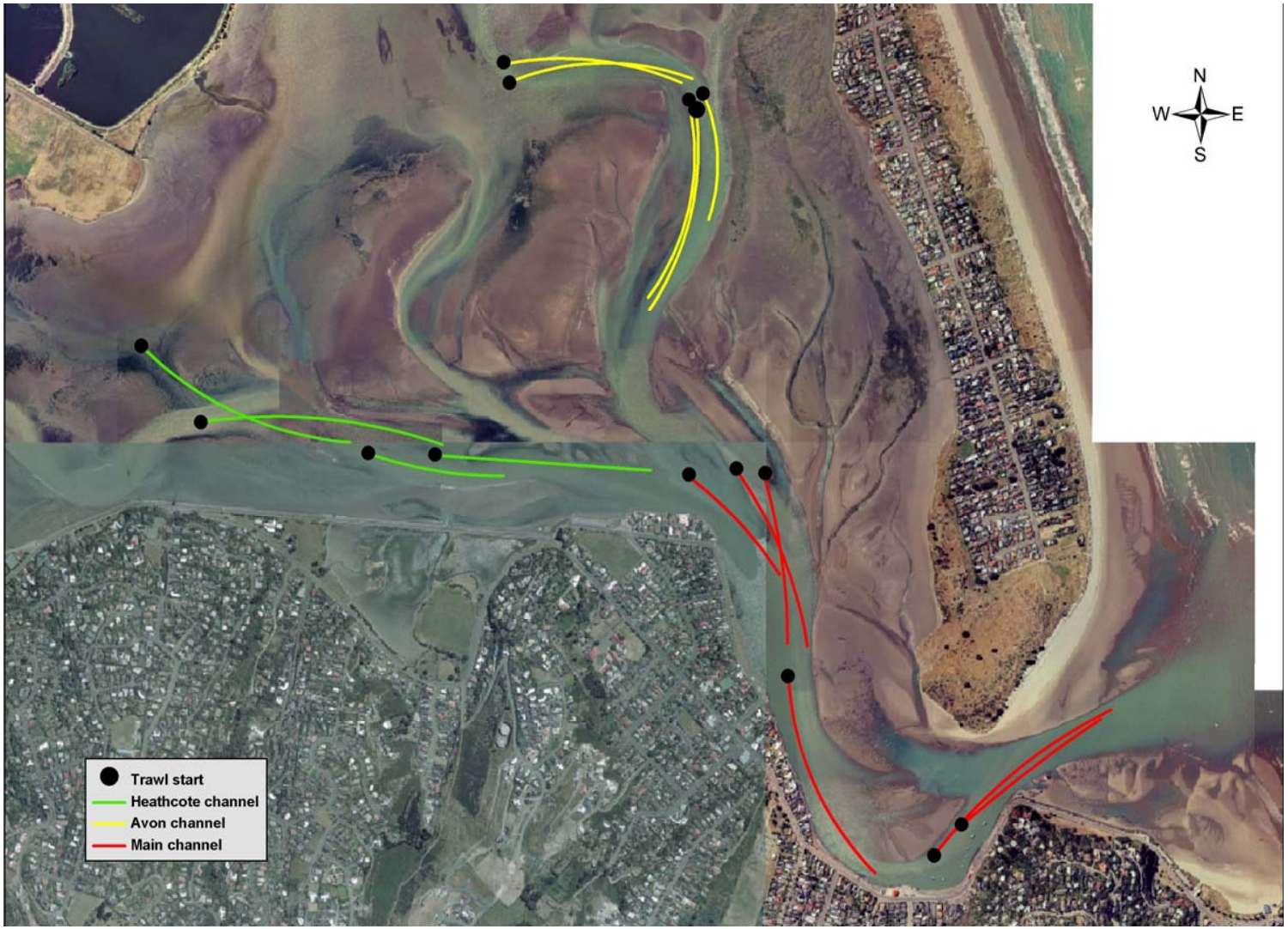

Figure 1: Trawl stations studied during the fish survey of the Avon-Heathcote estuary, November 2007.

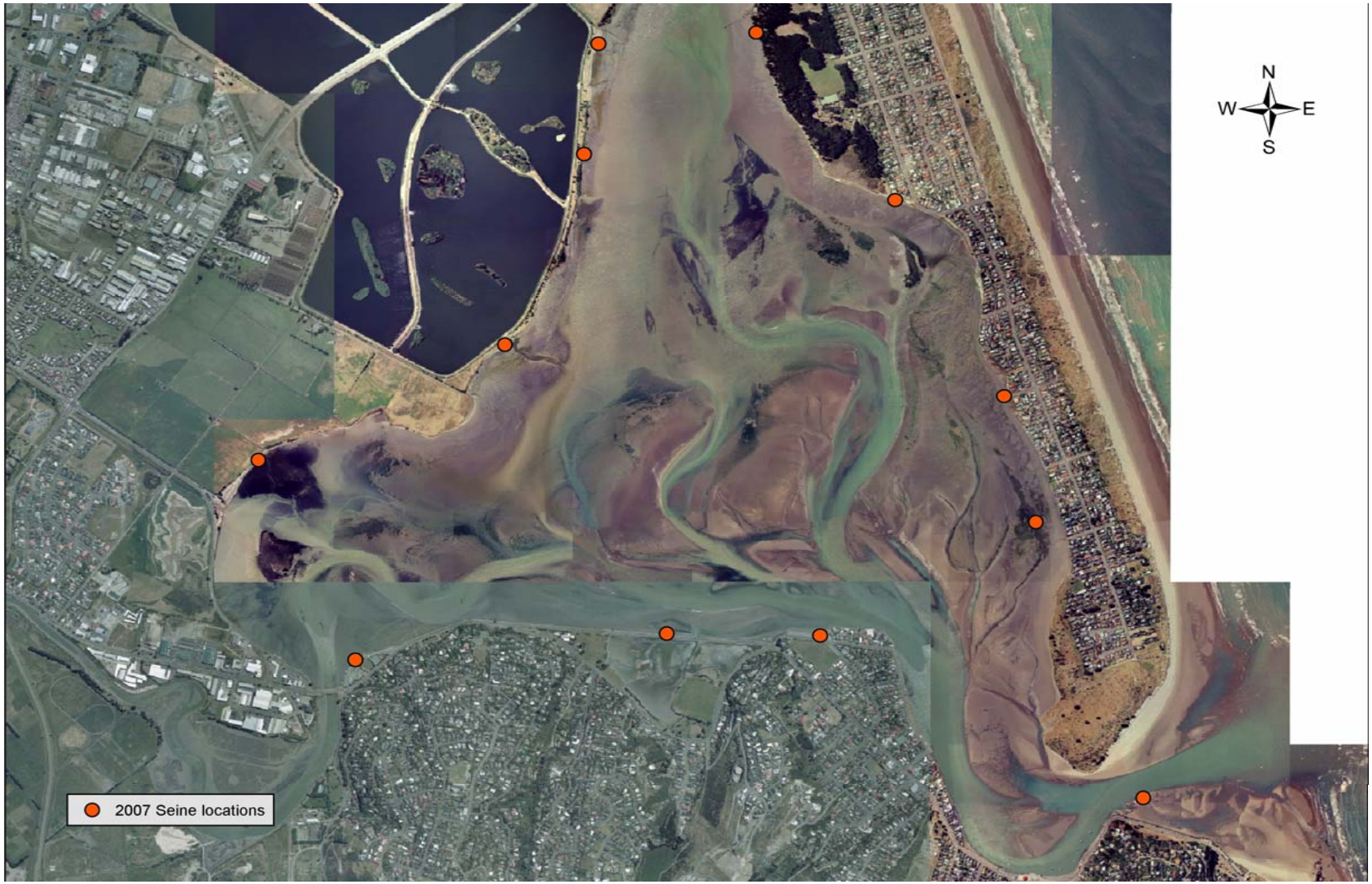

Figure 2: Seine stations studied during the fish survey of the Avon-Heathcote estuary, November 2007.

3.3. Data analysis

Data from the 2007 survey have been added to the MS-ACCESS database established for the 2005 and 2006 surveys. The database will be made available to the Christchurch City Council for archiving.

As for the other two surveys, fish abundance (number of each species captured per 1000 m^2) was estimated for both trawling and seining, and these data will provide the baseline to assess any future changes in abundance. As in 2005 and 2006, where seine hauls contained very large numbers of smelt and juvenile yelloweye mullet, subsamples were measured. Total numbers and abundance estimates of these species were then calculated by extrapolating from sub sampled numbers. Where relevant, the statistical significance of trends in size and abundance was assessed using t-tests or Anova as appropriate.

4. Results and discussion

4.1. Fish species diversity

Sixteen fish taxa were recorded during the 2007 survey, compared with sixteen in 2006, seventeen in 2005, and twenty for the three surveys combined (Table 3). This compares with 28 species recorded in the more intensive year-round survey in 1965 (Webb 1972), eleven species in the limited 1997 survey (Nairn 1998), and 37 taxa recorded in total over the last 40 years from all sources. Although the present surveys are single annual snapshots with no seasonal component and thus will miss some species which only occur seasonally, it appears that fish species diversity has diminished over the last forty years. Species recorded as present in the 1960s but not recorded during recent surveys are predominantly commercial marine species which are now harvested more heavily, and whose populations are likely to have declined as a result (barracouta, elephant fish, kahawai adults, moki, red cod, red gurnard, and rig). Whereas elephant fish and rig are currently making something of a comeback along our beaches since the heavy exploitation of the 1970s, they are not recovered to the extent that the northern beaches are once again littered with spent egg cases as suggested by anecdotal reports from the 1960s. Webb (1973d) caught only one rig among single examples of other species and drew no conclusions about their status in the Avon–Heathcote estuary, although prior to 1970, rig were seasonally pursued by recreational fishermen at night in the Monks Bay-Shag Rock area. Other absent taxa included rocky shore or riverine species whose habitats are not being sampled by the current fishing techniques (redfin bully, longfin eel, inanga, rockfish, and thornfish).

Of interest in 2007 was the capture of a number of sub-adult yellowbelly flounders by trawl in the main channel in lower Monks Bay. By contrast, no fish of this size were caught last year, although they were present in the 2005 catch when yellowbellies were relatively more abundant. Also of interest was the capture of both sub-adult and juvenile kahawai. Juvenile common sole were caught along the southern shore in the lower Heathcote channel although at this point there is a large Avon channel influence.

Table 3: Fish taxa recorded from the Avon-Heathcote estuary during the fish survey of 7-22 November 2007, compared with the November 2005 and 2006 surveys.

Common name	MFish code	2005	2006	2007
Chinook salmon	SAM		y	y
Clingfish	CLI	y		y
Common smelt	SME	y	y	y
Common sole	ESO	y	y	y
Estuary stargazer	ESZ	y	y	y
Giant bully	GBU	y		y
Globefish	GLB	y	y	
Inanga	INA			y
Kahawai	KAH	y	y	y
Sand flounder	SFL	y	y	y
Shortfin eel	SFE	y	y	y
Slender sprat	SPA	y		
Slender stargazer	SLZ	y	y	y
Speckled sole	SPS		y	
Spotted stargazer	SPZ	y	y	y
Spotty	STY	y	y	y
Stout sprat	SPM	y	y	
Triplefins	TRP	y	y	y
Yellowbelly flounder	YBF	y	y	y
Yelloweye mullet	YEM	y	y	y

In 2006 several shrimps, known properly as estuarine prawns *Palaemon affinis*, were recorded in the seine hauls on the eastern side of the estuary. This year large numbers appeared in the great volume of sea lettuce harvested by beach seine on the western shore in the vicinity of the windsurfing area. Numbers of juvenile pie-crust crab *Metacarcinus novaezelandiae* and paddle crab *Ovalipes catharus* were also caught in the lower Main channel – Monks Bay area, as were a larger number of adult paddle crabs. Two species of sea slug (*Scutus brevicus* and *Archidoris wellingtonensis*) featured as incidental captures.

4.2. Fish catch, size and abundance

Abundance and mean length for most species caught in 2007 were similar to those reported for 2005 and 2006 (Table 4). Yelloweye mullet and common smelt taken by seine were once again numerically the most abundant (totalling several thousand), most as small individuals averaging about 7 cm in length.

Table 4: Number and mean length (cm) for all fish species caught in the Avon-Heathcote estuary, 7-22 November 2007, by fishing method (boldface), compared to results for the 2006 and 2005 surveys.

	Trawl						Seine					
	N			L_{mean}			N			L_{mean}		
Species	**2007**	2006	2005	**2007**	2006	2005	**2007**	2006	2005	**2007**	2006	2005
Chinook salmon							**1**	3	0	**8.0**	7.3	
clingfish	**1**	0	2	**3.0**		2.5						
common sole	**4**	6	1	**19.3**	27.8	41.0	**12**	0	0	**4.7**		
estuary stargazer	**1**	1	6	**33.0**	16.0	17.5						
giant bully	**1**	0	2	**13.0**		12.5						
globefish							**0**	207	0		2.0	
inanga							**6**	0	0	**4.7**		
kahawai	**3**	0	0	**17.3**			**12**	12	2	**5.6**	6.1	6.0
sand flounder	**18**	16	23	**13.6**	11.0	10.4	**180**	137	130	**5.2**	3.9	4.3
short-fin eel	**4**	1	4	**88.0**	75.0	75.5	**6**	2	0	**59.5**	90.0	
slender sprat							**0**	0	2			5.0
slender stargazer	**1**	1	0	**27.0**	26.0		**0**	1	0		15.0	
smelt							**1 146**	573	1 611	**8.5**	6.9	6.9
speckled sole							**0**	1	0		3.0	
spotted stargazer	**13**	9	7	**25.4**	19.8	14.9	**0**	4	3		7.8	9.7
spotty	**20**	17	18	**16.6**	16.0	13.4	**1**	5	2	**13.0**	6.2	6.0
sprat							**0**	101	3		7.1	5.3
triplefin	**0**	0	1			7.0	**10**	27	28	**6.3**	5.2	5.2
yellow-belly flounder	**35**	34	41	**27.9**	34.1	31.2	**49**	29	79	**6.9**	11.8	8.4
yelloweye mullet	**39**	37	13	**19.3**	19.4	22.2	**3 400**	2 307	4 472	**6.9**	7.2	7.0

Of species likely to be of interest to recreational fishers, limited numbers of large yellowbelly flounder, sand flounder, yelloweye mullet, and common sole were caught along with a number of large shortfin eels, mostly taken by seine along the western shore. Catches of juvenile common sole were also higher than in previous years.

Notable for their absence once again were red cod, adult kahawai (although sub-adult kahawai were caught) and barracouta (Table 1).

As in 2005 and 2006, the average size of yellowbelly flounder, sand flounder, and yelloweye mullet taken by trawl was much larger than that taken by seine (Table 5). This is a reflection of sampling methods designed to sample different sections of fish populations, with trawling best suited to larger adult fish, and seining mostly to juveniles. Thus we are confident that the two indices of abundance which have been established will be important for monitoring changes in these two different segments of the populations in the future.

Table 5: Mean lengths (cm) of the three most important species measured (sand flounder, yellowbelly flounder, yelloweye mullet), by fishing method and location, November 2007.

		Sand flounder		Yellowbelly flounder		Yelloweye mullet	
Sampling method	**Area**	**N**	**L_{mean}**	**N**	**L_{mean}**	**N**	**L_{mean}**
Seine	East shore	81	5.4 ± 0.2	26	6.3 ± 0.8	389	5.9 ± 0.1
	South shore	32	5.4 ± 0.3	4	12.8 ± 2.1	254	8.7 ± 0.2
	West shore	67	4.8 ± 0.2	19	6.5 ± 1.0	355	7.1 ± 0.1
Total, all sites		**180**	**5.2 ± 0.1**	**49**	**6.9 ± 0.6**	**998**	**7.0 ± 0.1**
Trawl	Avon channel	6	10.5 ± 2.6	9	30.0 ± 2.7	6	21.2 ± 1.3
	Heathcote channel	5	24.4 ± 2.9	7	33.4 ± 3.1	1	21.0 ± 3.2
	Main channel	7	8.6 ± 2.4	19	24.9 ± 1.9	32	18.9 ± 0.6
Total, all sites		**18**	**13.6 ± 2.2**	**35**	**27.9 ± 1.5**	**39**	**19.3 ± 0.5**
Total, all methods		**198**	**6.0 ± 0.3**	**84**	**15.6 ± 1.3**	**1037**	**7.5 ± 0.1**

Juvenile sand flounder were larger and more abundant in seine catches than in 2005 and 2006, implying three consecutive years of successful spawning. Juvenile yellowbelly flounder were more abundant than in 2006 but less so than in 2005. Juveniles in the 10-30 cm class that were missing in 2006 have reappeared in the 2007 catch suggesting a better recruitment from the 2006 spawning (Figure 3. Trawl catches of adults of both species were similar to previous years, with yellowbellies more abundant than sand flounder. The relative lack of sand flounder adults caught by trawl (Figure 1) is consistent with results achieved by Webb (1972) who describes adult sandflounder abundance peaking through the winter months and decreasing during spring and summer, a trend characteristic of spawning migration.

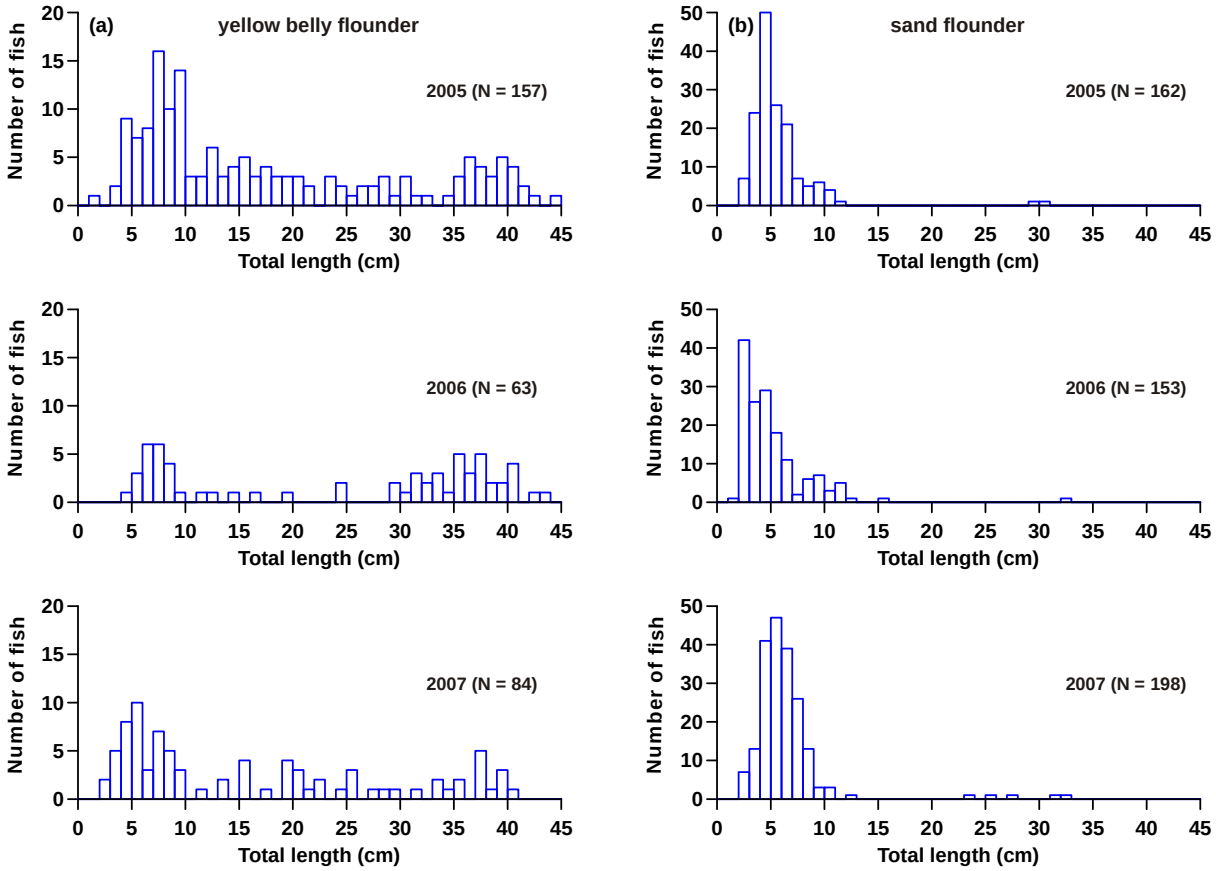

Figure 3: Annual length frequency distribution for yellow belly flounders (a) and sand flounders (b), 2005-2007, pooled across all sampling sites.

Mean size of all three important recreational species (yellowbelly flounder, sand flounder, yelloweye mullet) tended to vary among areas for both sampling methods (Table 5). Trawl caught (i.e., adult) sand flounder from the Heathcote channel were larger than those from the other two trawl stations ($p = 0.002$), as was the case when catches from all three 2005-07 surveys were analysed collectively ($p = 0.003$). During the 1965-66 survey sand flounder appeared to avoid this channel due to pollution effects from the Heathcote River (Webb 1972), and their presence in recent surveys may indicate some improvement in water quality over the intervening four decades. Seine caught (i.e., juvenile) yellowbelly flounder were largest on the southern shore ($p = 0.02$), although sample sizes were small ($N = 4$ for the south shore). When considered over the full three years of record, mean size for the south shore and west shore samples did not differ ($p \sim 1$), but juveniles from the east shore were consistently smaller than those from the other two sites ($p = 0.007$). The Heathcote Channel trawl samples also yielded the largest adult yellowbelly flounder, although inter-site size differences for this species in 2007 fell slightly short of statistical significance ($p = 0.06$). However, when analysed across all three surveys this trend was much more pronounced ($p < 0.001$), with adults from the Heathcote Channel

consistently larger than those from the Main Channel ($p << 0.001$). Sand flounder captured in the channels by trawl were smaller than yellowbelly flounder from the same areas ($p < 0.001$ both for the 2007 and pooled 2005-2007 data, Tables 5, 6).

As in 2006 both adult and juvenile yellowbelly flounder were less numerous than in 2005, although adults were larger and relatively more abundant than in 1965. This size trend appears to have been sustained over the last decade, as evidenced by the proportion of adults exceeding 320 mm (35% - 71%; Nairn (1998), James (2006, 2007), this report) compared to only 6% in 1965/55 (Webb 1972). The relatively low abundance of adults this season may reflect the absence of the 10-30 cm size class in the 2006 sample (Figure 3). Changes in abundance over the same period suggest that yellowbelly flounder are now more common than sand flounder. Trawl catches of adult (> 20 cm) sand flounder numbered five, one, and two in 2007, 2006, and 2005, respectively, compared with 22, 32, and 47 for adult yellowbelly flounder over the same period (Table 6). This is similar to results for the 1998 survey (one sand flounder vs. 80 yellowbelly flounder; Nairn 1998), but is in sharp contrast to 1965 when sand flounder were markedly more abundant than yellowbelly flounder (Webb 1972).

Numbers and mean size of yelloweye mullet in 2007 by sampling method and area (Table 5) were similar to that found in 2005 and 2006.

Estimates of fish abundance (number of each species captured per 1000 m^2) are in Table 7, together with a summary for all three years conducted to date in Table 8.

4.3. Changes in fish diversity and abundance

A similar number of fish taxa were recorded in each of the three surveys, totalling 20 for all surveys (Table 3). This is markedly less than the 28 species recorded in the more intensive year-round survey in 1965 (Webb 1972), and the 37 taxa recorded in total over the last 40 years from all sources.

However, these latest surveys are single annual snapshots with no seasonal component and thus will miss some species whose populations only occur seasonally. Some of the habitat studied in the past (rocky, deep areas close to the shoreline and the upper reaches of the Avon channel) which produced species such as the rockfish and giant bully, were not covered in this current survey.

Brown trout, a less common and transitory species, although caught in some numbers in the past, (Webb, 1973) were all caught by beach seine in the channels at low tide, a method and timing not used in this survey. Some of the species that were present in

Table 6: Length frequency distributions for all fish species caught in the Avon-Heathcote estuary, November 2007. Totals are the number of fish sub sampled for length measurements, rather than total catches as in Table 4. Seine and trawl samples are denoted s, t, respectively.

Length (cm)	Chinook salmon	clingfish	common sole (s)	common sole (t)	estuary stargazer	giant bully	inanga	kahawai (s)	kahawai (t)	sand flounder (s)	sand flounder (t)	short-finned eel (s)	short-finned eel (t)	slender stargazer	smelt	spotted stargazer	spotty (s)	spotty (t)	triplefin	yellow-belly flounder (s)	yellow-belly flounder (t)	yellow-eyed mullet (s)	yellow-eyed mullet (t)
1															1								
2										7										2			
3		1	6							13								1		5			
4			4				2			41										8		11	
5							4	6		47					7			1	2	10		267	
6								5		39		1			65				5	3		263	
7								1		21	5				118			1	2	7		242	
8	1									10	3				49					5		78	
9										1	2				52				1	3		19	
10											3				14							14	
11			2	1											3						1	19	
12										1						1						38	
13						1											1	2		2		10	
14				1												1		1				7	
15																		1		1	3	5	1
16				1														2				7	6
17									2			1				2		2		1		8	12
18									1									1				5	
19																		2			4	2	1
20																		1		1	2		5
21																		1			1		7
22																1		1			2	1	1
23											1					1						1	2
24																2				1			
25											1							1			3		
26																		2					3
27											1			1							1		1
28																					1		
29																					1	1	
30																							
31											1					2					1		
32											1					1							
33					1																2		
34																					1		
35																					2		
36				1												1							
37																					5		
38																					1		
39																					3		
40																					1		
…																							
47																1							
76												1											
80													1										
85													1										
92												2	1										
95												1	1										
Total	**1**	**1**	**12**	**4**	**1**	**1**	**6**	**12**	**3**	**180**	**18**	**6**	**4**	**1**	**309**	**13**	**1**	**20**	**10**	**49**	**35**	**998**	**39**

Table 7: Fish abundance (number per 1000 m^2 ± 1 standard error) by method and area for all species caught in the Avon-Heathcote estuary during the 2007 survey. Means for each species and method represent the mean of the three area means.

	Seine				Trawl			
Common name	**East**	**South**	**West**	**Mean**	**Avon**	**Heathcote**	**Main**	**Mean**
Chinook salmon	0	0.3 ± 0.3	0	0.1 ± 0.2	0	0	0	0
clingfish	0	0	0	0	0	0.1 ± 0.1	0	0.04 ± 0.10
common smelt	10.2 ± 6.5	14.6 ± 11.3	296.3 ± 272.1	107.0 ± 192.6	0	0	0	0
common sole	0.3 ± 0.3	2.6 ± 1.5	0	1.0 ± 1.1	0	0	0.3 ± 0.2	0.09 ± 0.16
estuary stargazer	0	0	0	0	0	0	0.1 ± 0.1	0.02 ± 0.05
giant bully	0	0	0	0	0.0 ± 0.1	0	0	0.02 ± 0.04
inanga	0	1.3 ± 1.5	0	0.4 ± 1.0	0	0	0	0
kahawai	1.2 ± 1.0	1.3 ± 1.2	0.3 ± 0.3	0.9 ± 1.1	0	0	0.2 ± 0.2	0.07 ± 0.15
sand flounder	22.5 ± 13.6	8.5 ± 7.1	20.6 ± 15	17.2 ± 15.2	0.3 ± 0.2	0.5 ± 0.3	0.5 ± 0.3	0.45 ± 0.32
short-finned eel	0	0	1.8 ± 0.7	0.6 ± 0.5	0	0.3 ± 0.3	0.1 ± 0.1	0.13 ± 0.22
slender stargazer	0	0	0	0	0	0.1 ± 0.1	0	0.03 ± 0.08
spotted stargazer	0	0	0	0	0.4 ± 0.2	0.7 ± 0.5	0	0.36 ± 0.37
spotty	0	0.2 ± 0.2	0	0.1 ± 0.2	0.1 ± 0.1	0.3 ± 0.2	1.0 ± 0.5	0.46 ± 0.39
triplefin	0.3 ± 0.3	2.3 ± 2.2	0.3 ± 0.4	1.0 ± 1.6	0	0	0	0
yellow-belly flounder	7.2 ± 4.2	1.2 ± 1.4	5.5 ± 2.6	4.6 ± 3.6	0.6 ± 0.2	0.8 ± 0.3	1.2 ± 0.5	0.89 ± 0.44
yellow-eyed mullet	318.1 ± 160.1	144.7 ± 66.1	397.4 ± 105.5	286.7 ± 143.4	0.6 ± 0.4	0.1 ± 0.1	1.8 ± 0.2	0.83 ± 0.34

Table 8: Fish abundance (number per 1000 m^2 ± 1 standard error) for species caught in the Avon-Heathcote estuary by method and area during the 2005, 2006 and 2007 surveys

Seine	East shore			South shore			West shore			Total		
Common name	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Chinook salmon	0	0	0	0	0.9 ± 1.1	0.3 ± 0.3	0	0	0	0	0.3 ± 0.8	0.1 ± 0.2
Common smelt	43 ± 17.1	21.8 ± 17.6	10.2 ± 6.5	8.0 ± 5.8	7.1 ± 4.3	14.6 ± 11.3	504 ± 378	108 ± 86	296 ± 272	185 ± 268	45.5 ± 62.2	107 ± 193
Common sole	0	0	0.3 ± 0.3	0	0	2.6 ± 1.5	0	0	0	0	0	1.0 ± 1.1
Globefish	0	0	0	0	63.9 ± 73.8	0	0	0	0	0	21.3 ± 52.2	0
Inanga	0	0	0	0	0	1.3 ± 1.5	0	0	0	0	0	0.4 ± 1
Kahawai	0	2.9 ± 3.2	1.2 ± 1.0	0.7 ± 0.8	0	1.3 ± 1.2	0	0	0.3 ± 0.3	0.2 ± 0.6	1.0 ± 2.2	0.9 ± 1.1
Sand flounder	9.3 ± 4.8	2.0 ± 1.6	22.5 ± 13.6	6.9 ± 5.7	3.8 ± 2.6	8.5 ± 7.1	27.8 ± 15.1	30.4 ± 20.8	20.6 ± 15	14.7 ± 11.9	12.1 ± 14.9	17.2 ± 15.2
Shortfin eel	0	0	0	0	0	0	0	0.5 ± 0.6	1.8 ± 0.7	0	0.2 ± 0.4	0.6 ± 0.5
Slender sprat	0	0	0	0.7 ± 0.8	0	0	0	0	0	0.2 ± 0.6	0	0
Slender stargazer	0	0	0	0	0.3 ± 0.4	0	0	0	0	0	0.1 ± 0.3	0
Speckled sole	0	0	0	0	0.3 ± 0.3	0	0	0	0	0	0.1 ± 0.2	0
Spotted stargazer	0	0	0	0	0	0	1.0 ± 1.2	0.7 ± 0.9	0	0.3 ± 0.9	0.2 ± 0.6	0
Spotty	0	0	0	0.6 ± 0.4	1.9 ± 1.7	0.2 ± 0.2	0	0	0	0.2 ± 0.3	0.6 ± 1.2	0.1 ± 0.2
Sprat	1.0 ± 0.8	0.9 ± 0.8	0	0	28.3 ± 28.7	0	0	1.4 ± 1.0	0	0.3 ± 0.5	10.2 ± 20.3	0
Triplefins	1.7 ± 2.0	1.0 ± 0.7	0.3 ± 0.3	7.3 ± 4.5	4.3 ± 2.9	2.3 ± 2.2	0	1.7 ± 0.9	0.3 ± 0.4	3.0 ± 3.5	2.3 ± 2.2	1.0 ± 1.6
Yellowbelly flounder	5.9 ± 6.8	1.5 ± 1.7	7.2 ± 4.2	2.4 ± 2.8	1.1 ± 0.9	1.2 ± 1.4	19.1 ± 11.9	4.8 ± 2.8	5.5 ± 2.6	9.1 ± 9.9	2.5 ± 2.4	4.6 ± 3.6
Yelloweye mullet	115 ± 67	246 ± 92	318 ± 160	460 ± 200	141 ± 112	145 ± 66	885 ± 733	170 ± 55	397 ± 106	487 ± 540	186 ± 110	287 ± 143

Table 8 continued

Trawl	Avon channel			Heathcote channel			Main channel			Total		
Common name	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Clingfish	0	0	0	0	0	0.1 ± 0.1	0.2 ± 0.1	0	0	0.1 ± 0.1	0	0.0 ± 0.1
Common sole	0	0	0	0	0.1 ± 0.1	0	0.1 ± 0.1	0.2 ± 0.1	0.3 ± 0.2	0.0 ± 0.1	0.1 ± 0.1	0.1 ± 0.2
Estuary stargazer	0.2 ± 0.3	0	0	0.6 ± 0.7	0	0	0.2 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.3 ± 0.5	0	0
Giant bully	0.2 ± 0.2	0	0.0 ± 0.1	0	0	0	0	0	0	0.1 ± 0.1	0	0
Kahawai	0	0	0	0	0	0	0	0	0.2 ± 0.2	0	0	0.1 ± 0.2
Sand flounder	2.3 ± 1.6	0.6 ± 0.4	0.3 ± 0.2	0.4 ± 0.5	0.4 ± 0.2	0.5 ± 0.3	0.2 ± 0.2	0.2 ± 0.1	0.5 ± 0.3	1.0 ± 1.2	0.4 ± 0.3	0.4 ± 0.3
Shortfin eel	0	0	0	0	0	0.3 ± 0.3	0.3 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.2	0	0.1 ± 0.2
Slender stargazer	0	0	0	0	0.1 ± 0.1	0.1 ± 0.1	0	0	0	0	0.0 ± 0.1	0.0 ± 0.1
Spotted stargazer	0.8 ± 0.5	0.5 ± 0.3	0.4 ± 0.2	0.2 ± 0.1	0.4 ± 0.2	0.7 ± 0.5	0	0	0	0.3 ± 0.4	0.3 ± 0.3	0.4 ± 0.4
Spotty	1.2 ± 0.7	0.2 ± 0.2	0.1 ± 0.1	0.2 ± 0.3	0.3 ± 0.1	0.3 ± 0.2	0.5 ± 0.3	0.6 ± 0.2	1.0 ± 0.5	0.7 ± 0.6	0.4 ± 0.2	0.5 ± 0.4
Triplefins	0.2 ± 0.2	0	0	0	0	0	0	0	0	0.1 ± 0.2	0	0
Yellowbelly flounder	1.4 ± 0.5	0.9 ± 0.4	0.6 ± 0.2	1.1 ± 0.8	0.8 ± 0.4	0.8 ± 0.3	1.2 ± 0.9	0.6 ± 0.3	1.2 ± 0.5	1.2 ± 0.9	0.8 ± 0.4	0.9 ± 0.4
Yelloweye mullet	0	1.3 ± 0.3	0.6 ± 0.4	0.1 ± 0.1	0.8 ± 0.6	0.1 ± 0.1	0.8 ± 0.4	0.7 ± 0.3	1.8 ± 0.2	0.3 ± 0.3	1.0 ± 0.5	0.8 ± 0.3

the 1960s but have not been captured during recent surveys, are commercial marine species which are now harvested more heavily and whose populations are likely to have declined as a result.

Fish abundance has changed little over all 3 years. Of the common species, sand flounders, yelloweye mullet and common smelt were all similarly abundant. Yellowbelly flounders were less abundant in 2006 than 2005 but were more abundant in 2007 than 2006. This seems to be related to spawning recruitment – something that is not uncommon amongst short-lived species like flatfish. Yelloweye mullet and common smelt appeared more abundant along the western shore than in previous years. Notable amongst the less common species was the increased abundance of sprat and globefish in 2006. These are all schooling species (e.g. juvenile globefish shoal) and the capture of a school can be hit or miss and thus apparent changes in abundance of these species may have little meaning.

Besides the effects of wastewater discharges, two other factors could be influencing the abundance of fish species in the estuary. First, fish populations sometimes experience natural climate-induced fluctuations in abundance of different age groups. This results from variable recruitment between years which is often linked to changes in climatic conditions such as the El Nino-Southern Oscillation Index. Second, changes in commercial fishing effort and catch can influence abundance although these are likely to be incremental over longer time periods.

Compared with the 1965 survey, the abundance of the two important flatfish species in the 2005 - 2007 surveys has changed; sand flounder, especially adults, are noticeably fewer than in 1965, although numbers are predicted to be higher during winter months; whereas yellowbelly flounder are now apparently both larger and more abundant than in 1965. These changes may be related to possible effects of wastewater discharges, increased commercial fishing pressure on sand flounders in Pegasus Bay or increasing sea temperatures which could favour yellowbelly flounder for example. Commercial catch data shows decreasing abundance of yellowbelly flounders towards the southern regions with a reverse trend for sandflounders (Paul 2000). Commercial fishing has almost certainly contributed to the reduced abundance of valuable species such as red cod, rig, elephant fish and kahawai.

5. Notes on Fish Health

Fish of all species were examined for gill and skin lesions or tumours and fin erosion or necrosis. All gill tissue appeared bright and healthy and there was no evidence of skin or fin damage. The one exception was a yellowbelly flounder which had predator damage to its tail. The flounder was otherwise healthy and the damage was healing well (Figure 4).

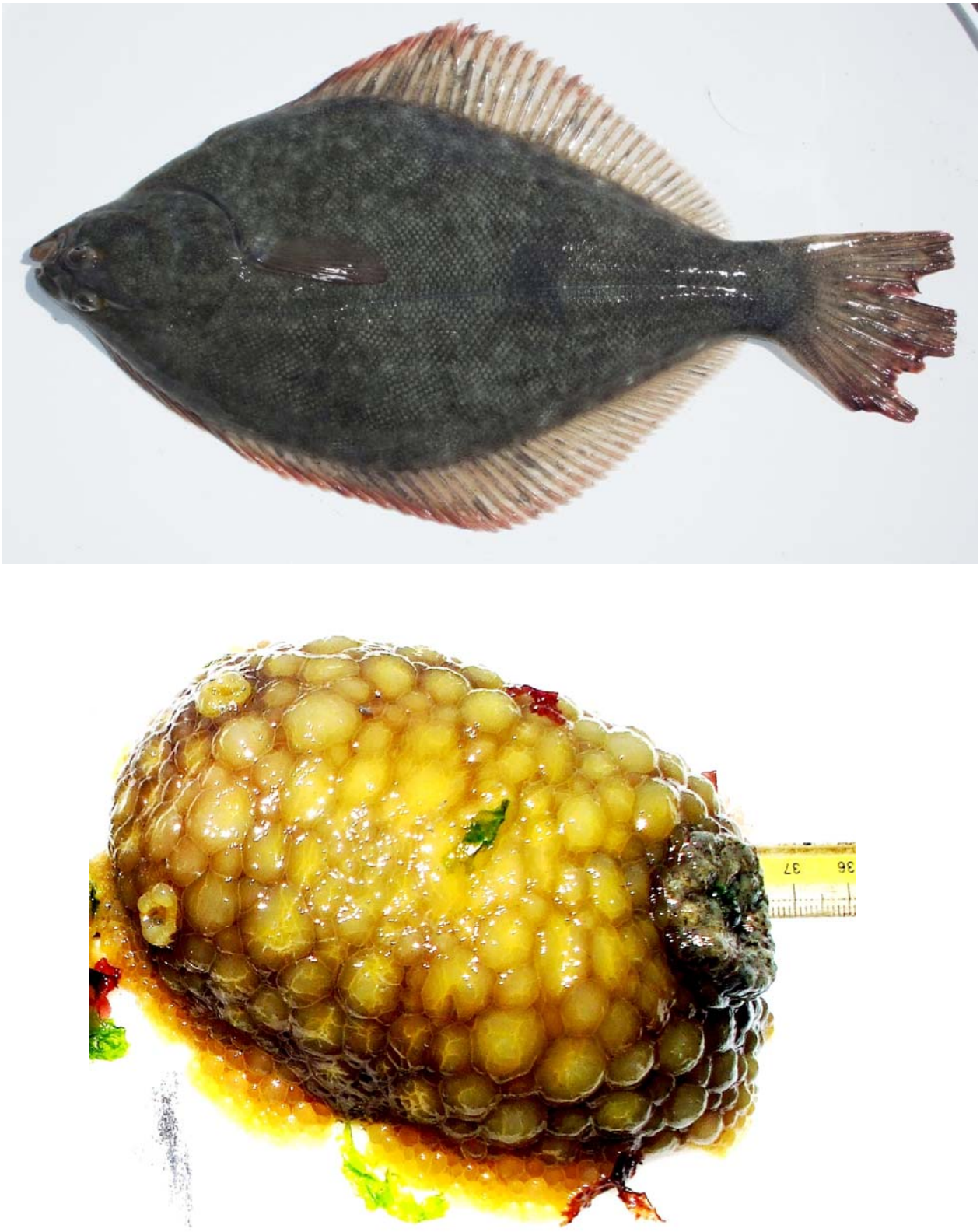

Figure 4: A Yellowbelly flounder (*Rhombosolea leporina*) showing signs of predator damage (above). Large Sea Slug (*Archidoris wellingtonensis*) retrieved from a sunken log when the trawl became snagged (below)

6. Future Surveys

The past three years of surveys, employing sampling methods designed to sample different elements of the fish communities have been remarkably consistent in their results and have provided an index of abundance against which the future fish populations in the estuary may be compared. The same sampling protocols both need to be adopted for future surveys as they may indicate different trends amongst adults and juveniles of different species. Changes in juvenile fish numbers will reflect recent events mostly within the estuary and may explain why numbers of larger fish have changed, whereas data from trawl surveys of larger fish will likely integrate changes over more than one year, and will better describe what recreational fishers in the estuary are experiencing.

7. Acknowledgements

The assistance of other NIWA staff is greatly acknowledged: Ned Norton and Julian Sykes assisted with the field work; Martin Unwin set up the database, undertook the analyses, and along with Don Jellyman, reviewed the report.

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