Scientific reports on the recovery of the Richmond and Macleay Rivers following fish kills in February and March 2001

Edited by

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April 2002

NSW Fisheries Final Report Series
Report No. 39

ISSN 1440-3544

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OVERALL EXECUTIVE SUMMARY

Major floods in the upper reaches of the Richmond and Macleay river systems in February and March 2001 led to deoxygenation of the water in the lower reaches of these rivers. Evidence strongly suggested that most fish and crustaceans in these rivers were flushed, migrated actively from the river system or were killed by the anoxic water.

The rivers and adjacent inshore ocean waters were closed to all fishing following this fish kill for approximately four and a half months to provide the systems with time to recover. These fishing closures were lifted to allow limited recreational fishing on 1 July 2001 and fully lifted on 28 September 2001, by which time normal commercial and recreational fishing practices were allowed.

A series of scientific programs were initiated at the time of the kills to monitor the recovery of fish, crustaceans and water quality in the rivers. The enclosed reports detail each of these studies. Scientific surveys were done every month for 12 months in each river using a variety of commercial fishing methods and scientific sampling techniques (see Sections 1 & 2). In addition, intensive creel surveys of recreational fishing activities were done in each river for 3 months after the rivers were re-opened to recreational fishing (see Sections 3 & 4). A small study was also done of the catches and by-catches occurring in the closed waters immediately outside the Richmond River using a chartered prawn trawler (see Section 5).

The data from the scientific sampling work showed that, by the time fishing restrictions were lifted, the populations of fish and crustaceans in the Richmond and Macleay rivers had recovered to levels that were sufficient to sustain normal commercial and recreational fishing practices. Some species appeared to recover relatively quickly in the main river channel to levels that have been more or less maintained since, while some other species took longer to recover.

The creel surveys revealed that the recreational fisheries in the Richmond and Macleay rivers were productive and providing quality recreational fishing opportunities after their re-opening, despite the adverse impacts of the February and March 2001 fish-kill events.

The small study done in the oceanic closure off the Richmond River showed that this closure was protecting significant quantities of prawns and small fish, especially juvenile mulloway.

The overall conclusion from this work is that closing these systems to fishing for the months after the fish kills allowed the systems to recover naturally to the point where normal commercial and recreational fishing could safely occur.

SECTION 1

Macbeth, W.G, Pollard, D.A., Steffe, A.S., Morris, S. and Miller, M. (2002). Relative abundances of fish and crustaceans and water quality following the fish kill of early February 2001 in the Richmond River, northern New South Wales. Pages 1 - 60 in: Kennelly, S.J. and McVea, T.A. (Eds) (2002). '*Scientific reports on the recovery of the Richmond and Macleay Rivers following fish kills in February and March 2001*'. NSW Fisheries Final Report Series. No. 39. ISSN 1440-3544.

Relative abundances of fish and crustaceans and water quality following the fish kill of early February 2001 in the Richmond River, northern New South Wales

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April 2002

ACKNOWLEDGEMENTS

The following NSW Fisheries staff are thanked for their contributions to this study:

Dr Steve Kennelly for his editorial comments on this report, Marcus Miller for co-ordinating and conducting the data collection, and Shaun Morris, Brett Rankin, Darren Reynolds, Karina Worrell and Cairo Forrest for assisting with the fieldwork during the monitoring programme. The staff at the Ballina Fisheries Office are also thanked for providing help with the logistics of the sampling when help was needed.

Tom O’Grady and Warren Beddoes (commercial fishermen, Richmond River) are thanked for their guidance and assistance with the sampling operations.

EXECUTIVE SUMMARY

Following major flooding in the upper reaches of the Richmond River system at the beginning of February 2001, a major fish kill occurred in the lower reaches of the river approximately one week later, peaking on or about 9 February 2001. Available information indicated that the flood led to deoxygenation of the water in the river and that this was the direct cause of the fish kill. Evidence gathered by NSW Fisheries staff strongly suggests that most fish and crustaceans were either flushed or actively migrated from the river system, or were killed by the anoxic water during the period of the fish kill.

Very low levels of dissolved oxygen were recorded throughout the lower Richmond River in the fortnight following the fish kill, although pH levels (a measure of acidity) in most of the areas studied were generally close to what is considered normal for this system (Westlake & Copeland, 2002). Towards the end of February, dissolved oxygen levels in the main channel generally improved, turbidity became reduced and salinity slightly increased, especially towards the mouth of the river. Acidity, however, increased in some mid-river areas following the subsidence of the flooding (especially in the case of waters flowing out of the Tuckean Swamp sub-catchment recorded at approximately pH 4 on 19 February).

The main fish species of commercial and/or recreational fisheries importance recorded as having died in the fish kill in the lower Richmond River from 7-9 February 2001 were yellowfin bream, dusky flathead, Australian bass, sea mullet, sand whiting and long-finned eel, together with smaller numbers of luderick, many-banded sole and forktail catfish (Westlake & Copeland, 2002). Very large numbers of school prawns and numerous mud crabs were also killed. Amongst the non-commercial fish species killed in some numbers were southern herring, estuarine catfish and bullrout (Westlake & Copeland, 2002).

The river and adjacent inshore ocean waters were closed to all fishing following this fish kill for an initial period of three weeks from 9 February 2001. Two initial post-fish kill sampling surveys, involving the collection of biological information (i.e. the distribution and relative abundance of fish and crustaceans) and water quality information, were done during the latter half of February 2001, approximately 2-3 weeks after the kill. Following the late-February survey, the fishing closure was extended for a further three months pending the results of subsequent four-weekly surveys. The sampling surveys were continued throughout this three-month period.

The fishing closure in the Richmond River was lifted to some types of fishing on 1 July 2001. From this date, limited recreational line fishing was allowed downstream of the Burns Point Ferry (only from 6am to 7pm; bag limit of 10 fish in total; no more than 5 bream and no more than 1 mulloway). In addition, commercial and recreational crab trapping was allowed in the area normally open to crab trapping (upstream of Burns Point Ferry). This partial fishing closure was then lifted fully on the 28 September 2001, from which date normal commercial and recreational fishing practices were allowed. The regular four-weekly sampling surveys of the fish and crustacean populations in the river were then continued throughout the partial closure and then when the river was fully opened to fishing, up until March 2002.

In summary, there were three main objectives of the four-weekly sampling surveys of the fish and crustacean populations in the river done as part of the post-fish kill monitoring programme:

1. to provide the necessary biological and water quality information required to make fisheries management decisions as to if, when and how the fishing closures in the river should be lifted;
2. to monitor for any possible deleterious effects relating to the resumption of fishing activities once these closures were lifted; and

3. to contribute useful information regarding the "normal" state of stocks in the river for the purpose of comparisons with data collected during the initial surveys conducted immediately after the fish kill.

A regular, structured sampling regime was designed and implemented with the help of local commercial fishers and interest groups in order to monitor the recovery of the fish and crustacean populations in the river immediately following the fish kill. These four-weekly sampling surveys incorporated the use of three commercial fishing methods to regularly sample the biota in the river – prawn hauling, mesh netting and crab trapping. Regular scientific seining involving the use of small-mesh seine nets was also done, as was the collection of water quality information.

The question of whether the stocks of fish and crustaceans have now recovered to pre-fish kill levels cannot be answered directly because we do not have detailed information describing the precise status of these fish and crustacean stocks in the Richmond River immediately before the fish-kill event, and nor do we have comparable detailed information about fish and crustacean communities in other non-impacted estuaries in the region that could be used as controls or reference sites. Therefore, we are primarily restricted to making inferences about the recovery of the fish and crustacean populations by interpreting spatial and temporal trends in the distribution and abundance of fish and crustaceans which are apparent in the data collected as part of this monitoring programme.

In general, by the time the fishing restrictions were lifted, the populations of fish and crustaceans in the Richmond River had recovered to levels that could sustain normal commercial and recreational fishing practices, comparable to the levels during the months immediately prior to the fish kill. Some species appeared to recover relatively quickly in the main river channel to levels that have been more or less maintained since (e.g. school prawn, mud crab, sea mullet, yellowfin bream and juvenile mulloway), while some other species took much longer to recover (e.g. sand whiting and silver biddy). In contrast, some species recovered in the lower part of the estuary (i.e. downstream of Burns Point Ferry) quite quickly, but were quite slow to recolonise the main river channel (e.g. luderick).

Increased recreational fishing activities (which have been allowed in some parts of the river since 1 July 2001) and normal commercial fishing activities (which have been allowed since 1 October 2001) may have been minor influencing factors in fluctuations detected in the relative abundances of some species subsequent to the lifting of fishing restrictions. However, natural seasonal variations in the abundances of these fish, and/or in their catchability, are the most likely influences on the results observed in this monitoring programme after the re-opening of the river.

This post-fish kill monitoring programme provided valuable information to fisheries scientists and managers with respect to the status of recovering populations of fish and crustaceans in the lower Richmond River following the fish-kill event of February 2001. A similar sampling programme should be implemented if a fish kill (or an equivalent ecological emergency) was to occur again in this or another NSW coastal river or estuary in the future.

Fishery-independent sampling surveys should also be done on a regular basis in NSW rivers and estuaries to provide data regarding the status of fish and crustacean populations at times of relative health of these rivers and estuaries. This would provide valuable baseline information that could be used for the purpose of comparison should a fish kill (or an equivalent ecological emergency) occur in any NSW river or estuary in the future.

Further work should be undertaken to develop a standard sampling design protocol for use in similar monitoring programmes. This would require detailed review of the techniques used and analyses of the data collected during this present monitoring programme. The development of robust and reliable sampling regimes would result in more accurate overall assessments of the status of populations of fish and crustaceans in any given river or estuary.

1. INTRODUCTION

Following major flooding in the upper reaches of the Richmond River system at the beginning of February 2001, a major fish kill occurred in the lower reaches of the river approximately one week later, peaking on or about 9 February 2001. Available information indicated that the flood led to deoxygenation of the water in the river and that this was the direct cause of the fish kill. The evidence strongly suggested that most fish and crustaceans were either flushed or migrated actively from the river system, or were killed by the anoxic water during the period of the fish kill.

NSW Fisheries staff collected records of the dead fish involved and took measurements of water quality parameters in this system between 7-9 February 2001 (Westlake & Copeland, 2002). Water quality monitoring was maintained on a regular basis through the cooperation of local agencies in the Ballina area for approximately 4 months after the fish kill (Westlake & Copeland, 2002). Very low levels of dissolved oxygen were recorded throughout the lower Richmond River in the fortnight following the fish kill, although pH levels (a measure of acidity) in most of the areas studied were generally close to what is considered normal for this system (Westlake & Copeland, 2002). Towards the end of February, dissolved oxygen levels in the main channel generally improved, turbidity became reduced and salinity slightly increased, especially towards the mouth of the river. Acidity, however, increased in some mid-river areas following the subsidence of the flooding (especially in the case of waters flowing out of the Tuckean Swamp sub-catchment – recorded at approximately pH 4 on 19 February).

The main fish species of commercial and/or recreational fisheries importance recorded as having died in the fish kill in the lower Richmond River from 7-9 February were yellowfin bream, dusky flathead, Australian bass, sea mullet, sand whiting and long-finned eel, together with smaller numbers of luderick, many-banded sole and forktail catfish (Westlake & Copeland, 2002). Very large numbers of school prawns and numerous mud crabs were also killed. Amongst the non-commercial fish species killed in some numbers were southern herring, estuarine catfish and bullrout (Westlake & Copeland, 2002).

The river and adjacent inshore ocean waters were closed to all fishing following this fish kill for an initial period of three weeks from 9 February 2001. Two initial post-fish kill sampling surveys were done during the latter half of February 2001, approximately 2-3 weeks after the kill. Following the late-February survey, the fishing closure was extended for a further three months pending the results of subsequent four-weekly surveys. The initial objective of these surveys was to provide the necessary biological information (i.e. the distribution and relative abundance of fish and crustaceans) and water quality information required in order to make fisheries management decisions as to if, when and how the fishing closure in the Richmond River should be lifted.

The fishing closure in the Richmond River was lifted to some types of fishing on 1 July 2001. From this date, limited recreational line fishing was allowed downstream of the Burns Point Ferry (only from 6am to 7pm; bag limit of 10 fish in total; no more than 5 bream and no more than 1 mulloway). In addition, commercial and recreational crab trapping was allowed in the area normally open to crab trapping (upstream of Burns Point Ferry). A four-month recreational fishing survey was begun on 1 July 2001, the results of which are reported in detail elsewhere (see Steffe & Macbeth 2002).

The partial fishing closure in force from 1 July 2001 was lifted fully on 28 September 2001, following large recreational catches being recorded during the recreational fishing survey, as well as a relatively favourable assessment of stocks in the river during the August 2001 sampling survey. Normal commercial and recreational fishing practices were allowed from 28 September

2001 onwards. It was decided that the regular four-weekly sampling surveys of the fish and crustacean populations in the river should be continued until March 2002 in order to monitor for any possible deleterious effects relating to the resumption of normal fishing activities. In addition, it was concluded that the continued collection of data after the fish and crustacean populations were thought to have recovered to levels which can sustain normal commercial and recreational fishing activities would provide useful information regarding the "normal" state of stocks in the river.

In summary, there were three main objectives of the four-weekly sampling surveys of the fish and crustacean populations in the river done as part of the post-fish kill monitoring programme:

1. to provide the necessary biological and water quality information required to make fisheries management decisions as to if, when and how the fishing closure in the river should be lifted;
2. to monitor for any possible deleterious effects relating to the resumption of fishing activities once these closures were lifted; and
3. to contribute useful information regarding the "normal" state of stocks in the river for the purpose of comparisons with data collected during the initial surveys conducted immediately after the fish kill.

The assessment of environmental disturbance or impacts is difficult because it is often uncertain whether a causal relationship exists between the detrimental environmental event that has occurred (e.g. a flood followed by a fish-kill) and any changes that are measured at a later time. The changes in the distributions of fish and crustaceans detected after the fish-kill event include a component attributable to the detrimental flood event and a component due to natural fluctuations of fish populations that occur at various spatial and temporal scales. An appropriate experimental design is needed to discriminate between changes in the distribution and abundance of fish and crustaceans due to the fish-kill event and changes caused by natural fluctuations in abundance and catchability. Ideally, an experiment designed to test for the impacts of the fish-kill event would have included spatial replication at the level of rivers (i.e. other riverine fisheries would be used as controls or reference sites), and these multiple riverine fisheries would have been surveyed both before and after the fish-kill event. This type of experimental design is referred to as a Before-After-Control-Impact (BACI) design in the scientific literature. Underwood (1991) provides a detailed description of this type of design.

The present post-fish kill monitoring programme, however, did not meet the rigorous requirements for such a BACI experimental design. There were no comparable data describing the status of the stocks of fish and crustaceans immediately before the unexpected fish-kill event, and nor were there comparable data describing the status of other riverine fisheries in the region that could be used as control sites. Thus, the data collected during this monitoring programme could only be used to describe the status of the stocks of fish and crustaceans in the lower Richmond River after the fish kill event. We are therefore primarily restricted to making inferences about the recovery of the fish stocks in the lower Richmond River through interpreting spatial and temporal trends in the distribution and abundance of fish and crustaceans which were apparent in the data collected as part of this monitoring programme.

2. MATERIALS & METHODS

2.1 Site description

The Richmond River (28°53'S, 153°35'E) is a large river discharging to the north coast of New South Wales (NSW), on the east coast of Australia, with a water area of approximately 19 km^2 and a total catchment area of approximately 6850 km^2 (Roy *et al.* 2001)(Figure 1). The river is open permanently to the ocean, with twin training breakwaters at its entrance. Being a wave-dominated barrier estuary, the Richmond River is more strongly influenced by river discharge than by tide, with tidal ranges near its mouth being approximately 5-10% less than in the ocean (Roy *et al.* 2001). The main river arm is approximately 170 km in length. For the purpose of monitoring the recovery of fish and crustacean stocks throughout the lower river stretch (i.e. from Coraki downstream), the extent of the regularly sampled survey area in the lower Richmond River was, for the most part, restricted to waters in the main river channel between Coraki and the Burns Point Ferry (Figure 1). Nevertheless, some regular sampling (i.e. scientific seining) and some extra sampling (i.e. night mesh net sets) were done in waters downstream of the Burns Point Ferry (Figure 1). See below for further descriptions of sampling methods and sites.

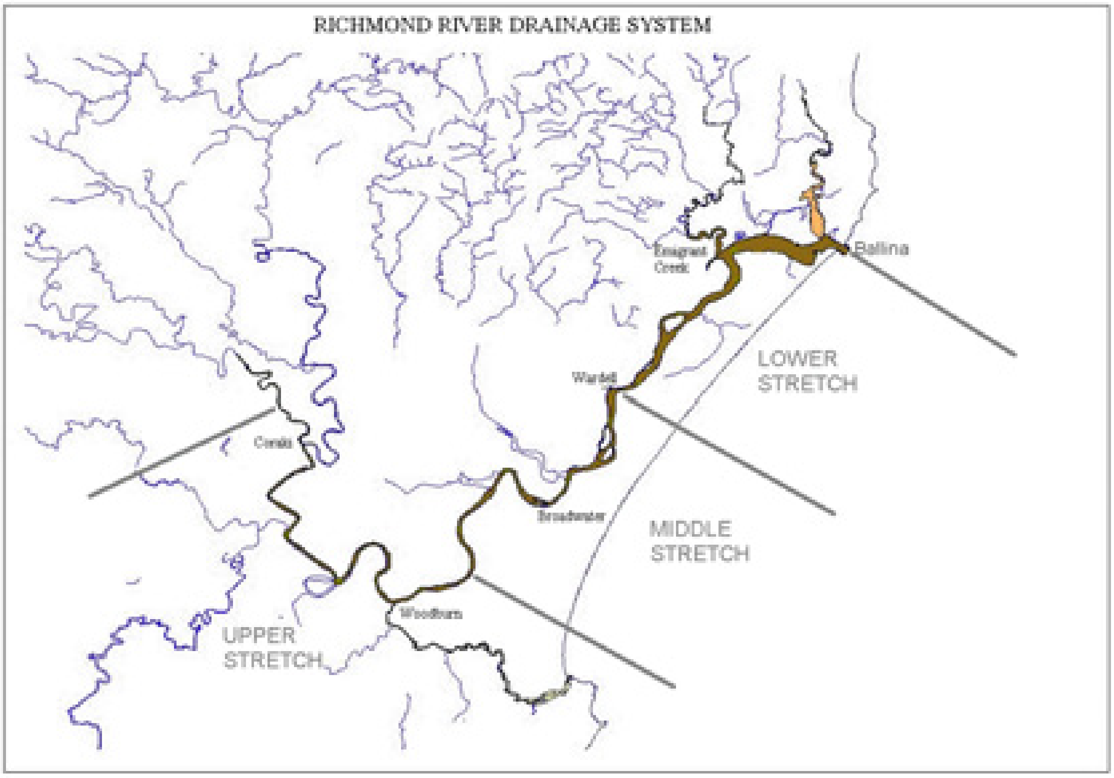

Figure 1. Map showing the categorisation of the lower Richmond River for the purpose of spatial and temporal comparisons during the post-fish kill monitoring programme. Boundaries of the "upper stretch", "middle stretch" and "lower stretch" are shown.

2.2. Spatial and temporal scales

For the purposes of spatial and temporal comparisons of results, the portion of the lower Richmond River system in which monitoring took place was divided into three sections: the upper, middle and lower stretches (Figure 1). The upper stretch extends from upstream of Coraki to just downstream of Woodburn; the middle stretch from downstream of Woodburn to just upstream of the Wardell Bridge; and the lower stretch from just upstream of the Wardell Bridge to the river mouth. Data from each of the 15 four-monthly sampling surveys completed during the monitoring programme (February 2001 to March 2002) were classified into the above spatial divisions, allowing valid temporal comparisons between them. The dates of each sampling survey are shown in Table 1.

The sampling sites chosen for each of the fishing methods were those that were, under normal circumstances at the time of year of the fish kill, fished regularly by local commercial fishermen. The distribution of sampling units with respect to the spatial divisions applied in the surveys for each of the sampling methods (mesh nets, haul nets, crab traps, etc.) is shown in Table 2. These tallies include any extra sampling that was done aside from the regular sampling regime (e.g. night mesh netting).

An important point to make with respect to the temporal categories used in this report is that the four-monthly surveys from March 2001 onwards (i.e. March 2001 to March 2002 in Table 1) involved the collection of congruous sets of data. For some sampling methods there were, however, two sets of data collected one week apart in February 2001 subsequent to the fish kill, and data from these two data sets are represented separately in the results of this report (i.e. Mid-February and Late-February 2001 in Table 1).

Table 1. Dates of each sampling survey during the post-fish kill monitoring programme in the lower Richmond River.

SAMPLING SURVEY	DATES OF SAMPLING
MID-FEBRUARY 2001	20th February - 24th February , 2001
LATE-FEBRUARY 2001	26th February - 28th February , 2001
MARCH 2001	26th March - 30th March , 2001
APRIL 2001	23rd April - 27th April , 2001 *
MAY 2001	28th May - 2nd June , 2001 #
JUNE 2001	25th June - 29th June , 2001
JULY 2001	23rd July - 28th July , 2001
AUGUST 2001	20th August - 25th August , 2001
SEPTEMBER 2001	17th September - 21st September , 2001
OCTOBER 2001	15th October - 19th October , 2001
NOVEMBER 2001	12th November - 16th November , 2001
DECEMBER 2001	10th December - 14th December , 2001
JANUARY 2002	14th January - 18th January , 2001
FEBRUARY 2002	4th February - 8th February , 2001
MARCH 2002	4th March - 8th March , 2001

* Additional night meshing was actually done on the 4th & 5th of May.
\# Two of the six scientific seine sites were sampled on the 5th of June.

Table 2. Number of sampling units (replicates taken) in the upper (U), middle (M) and lower (L) stretches of the lower Richmond River, for each sampling method during each sampling survey in the post-fish kill monitoring programme.

SAMPLING SURVEY	SAMPLING METHOD														
	WATER QUALITY			PRAWN HAULING			MESH NETTING						CRAB TRAPPING	SCIENTIFIC SEINING	
							DAY			NIGHT				LARGE MESH	SMALL MESH
	U	M	L	U	M	L	U	M	L	U	M	L	Lower only	Lower	Lower
MID-FEBRUARY 2001	4	1	7	12	4	14	4	-	4	-	-	-	9	3	-
LATE-FEBRUARY 2001	5	-	-	10	8	6	5	4	3	-	-	-	31	-	-
MARCH 2001	5	4	3	10	8	6	5	4	3	-	-	-	27	4	-
APRIL 2001	5	4	4	10	8	6	5	4	4	-	-	4	27	4	-
MAY 2001	5	4	3	10	8	6	5	3	3	-	-	4	23	6	12
JUNE 2001	5	3	3	10	8	6	5	3	4	5	-	3	30	6	12
JULY 2001	5	4	3	10	8	6	5	3	4	2	-	-	30	6	12
AUGUST 2001	5	4	3	10	8	6	5	3	4	-	-	-	30	6	12
SEPTEMBER 2001	5	4	3	10	8	6	6	3	4	-	-	-	30	6	12
OCTOBER 2001	5	4	3	10	8	6	5	3	4	-	-	-	30	6	12
NOVEMBER 2001	5	4	3	10	8	6	6	3	4	-	-	-	35	6	12
DECEMBER 2001	5	4	3	10	8	6	5	3	4	-	-	-	25	6	12
JANUARY 2002	5	4	3	10	8	6	5	3	4	-	-	-	30	6	12
FEBRUARY 2002	5	4	3	10	8	6	5	3	4	-	-	-	26	6	12
MARCH 2002	5	4	3	10	8	6	5	3	4	-	-	-	33	6	12
TOTALS		173			366			178			18		416	77	132

2.3. Water quality

During each sampling survey, water quality parameters were measured at approximately 2 metres depth at each prawn hauling site in the river: 5 in the upper stretch, 4 in the middle stretch and 3 in the lower stretch (Table 2, Figure 2), using a Horiba U10 Water Quality Meter. The three exceptions to this were the first two sampling surveys (Mid-February and Late-February 2001), and the June 2001 sampling survey, during which the water quality samples were taken at the mesh netting sites (Table 2). Water quality parameters measured were dissolved oxygen (mg/L), pH (a measure of acidity/alkalinity), salinity (%), conductivity (mS/cm), turbidity (NTU) and water temperature (degrees C).

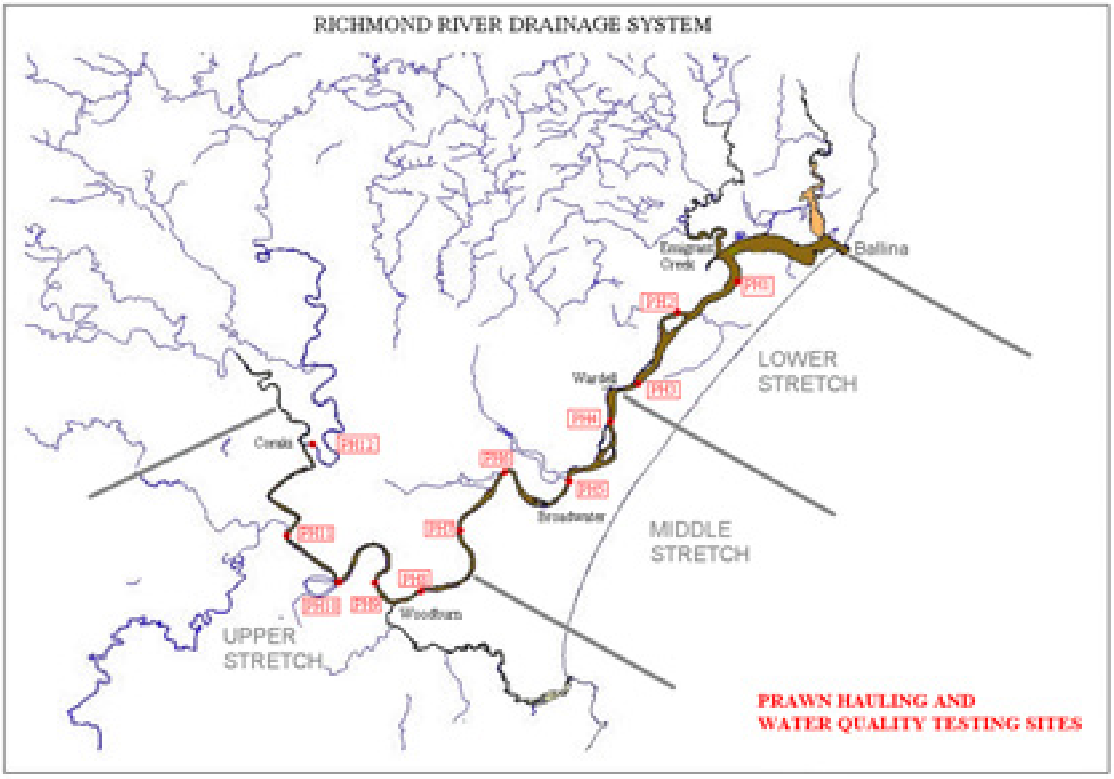

Figure 2. Map showing the prawn hauling and water quality testing sites (PH1 - PH12) in the lower Richmond River sampled during the post-fish kill monitoring programme.

2.4. Prawn hauling

Prawn haul sampling operations were done using the equipment and expertise of local commercial fishers at 12 sites: 5 in the upper stretch, 4 in the middle stretch and 3 in the lower stretch (Table 2 and Figure 2). It is, however, noteworthy that the number and distribution of sampling sites among the three river sections, or stretches, was slightly different during the first sampling survey (Mid-February 2001)(Table 2). Two replicate shots were done at each site.

The commercial prawn hauling gear consisted of a 40 metre length of 30mm mesh net with an approximately 10 metre long bunt. The wings of the haul net were approximately 2.5 metres deep when laid out, although the net fished to a maximum of 0.5 metres above the substrate. The winch-ropes attached to the net were approximately 130 metres long and the working spread of the net was approximately 12 metres. The net was shot from a punt and immediately winched back onto the punt. Each shot took around 10 to 15 minutes to complete.

The catches were sorted, counted and weighed by species. Only the smallest and largest individuals were measured for each species due to time constraints relating to releasing the animals back into the river alive. A sub-sample of 0.25kg of school prawns was taken from any catch that exceeded approximately 0.3kg. The number of prawns in this sub-sample was used to estimate the total number of prawns caught in the shot.

In 1998-99, commercial prawn hauling data were collected by NSW Fisheries as part of an Fisheries Research & Development Corporation (FRDC)-funded study investigating the by-catch associated with prawn hauling activities in this system (data courtesy of Dr Charles Gray, NSW Fisheries). These data were added to the graphs presented in this report showing the data from all of the post-fish kill prawn haul surveys to provide a comparison between pre- and post-fish kill catches from prawn hauling. There are important points to consider, however, when making these comparisons that will be discussed in more detail later.

2.5. Mesh netting

In all but the first (Mid-February 2001) survey, daytime mesh netting was done together with a local commercial mesh netting crew at 12 sites: 5 in the upper stretch, 3 in the middle stretch and 4 in the lower stretch (Table 2 and Figure 3). One mesh net set was done at each site. Data collected at the 4th site in the lower stretch (Burns Point Ferry), which was sampled during most surveys, were not included in the graphs, because this site was sampled in addition to the standard mesh netting sampling design, which comprised 11 sites (i.e. only 3 in the lower stretch). Similarly, 2 extra sets were done inside Swan Bay in the upper stretch, one during the September 2001 survey and the other during the November 2001 survey. As in the case of the extra sets at Burns Point Ferry, these 2 extra sets were not included in the graphs. In the Mid-February 2001 survey, the number and distribution of sampling sites among the three river sections, or stretches, was notably different (Table 2). No meshing was done in the middle stretch during that survey.

This meshing was done during daylight hours using a length of 82mm mesh-size commercial floating mesh net consisting of a total of 10 panels of net during most surveys (see explanation below); each was approximately 30 metres in length, with an approximately 2.5 metre drop. The net was set for approximately 10 minutes, during which time the meshing vessel was used to frighten the fish into swimming into the net.

All catches were counted and weighed by species. The smallest and largest individuals for each species were measured except in the case of commercially and/or recreationally important species, for which all individuals were measured.

It is important to note that in the May 2001, June 2001 and July 2001 surveys, only 6 panels of 82mm mesh net were used instead of the usual 10 to accommodate four extra panels of 104mm (x2) and 72mm (x2) mesh as requested by the Richmond River Working Group. Consequently, the units used for temporal comparisons of catches are the numbers of fish caught per panel.

As mentioned above, 2 additional panels of larger mesh (104mm) and 2 of smaller mesh (72mm) were added to the 6 panels of standard 82mm mesh for use during the May 2001 survey in an attempt to target a wider range of species and sizes of individuals. It was thought that the single mesh-size (82mm) used in the previous surveys might have selected for only a limited range of species and/or size range of individuals. However, the 2 panels of 72mm mesh were discarded after the May 2001 survey due to their ineffectiveness, but the 6 panels of 104mm mesh continued to be used during the two subsequent surveys in June 2001 and July 2001. The composite net was abandoned in favour of the original 10 x 82mm panel mesh net for the daytime meshing during the August 2001 survey and all subsequent surveys after relatively poor catch rates were recorded for the panels of 104 mm mesh.

Over and above the regular four-weekly downstream to upstream sequence of daytime mesh net sets in the main river channel, additional mesh netting was carried out at night in the lower stretch of the estuary during the April 2001, May 2001 and June 2001 surveys, using a variety of panel configurations that involved the use of 72mm, 82mm, 104mm, 152mm and 178mm mesh panels (see Tables 4, 5 and 6). It was suggested that greater numbers of larger fish (e.g. mulloway) might be caught within a few kilometres of the mouth of the river (near Ballina), at night. Unlike the regular daytime meshing in the lower stretch, the mesh net sets done at night in the lower stretch included sets in North Creek (Figure 1) and near the entrance to Mobbs Bay. Information gathered from these night sets thus complimented the information that was gleaned from the regular four-weekly daytime mesh netting operations.

Additional meshing was also done at night in the upper stretch of the river near Coraki during the June 2001 and July 2001 surveys. Although there was a distinct lack of catch from the two daytime mesh net sites near Coraki in the previous post-fish kill surveys, it was suggested that primarily demersal (bottom-dwelling) species such as bream and luderick may actually be present at these sites and that our method of sampling may not have been ideal in detecting their presence. Consequently, “diver” nets (with a lead-line which sinks to the bottom) with a mesh-size of 82mm were used at night around Coraki in the upper stretch. These nets were set for between 10 minutes and 4 hours. The configurations of the mesh nets used at night are given in Tables 7 and 8.

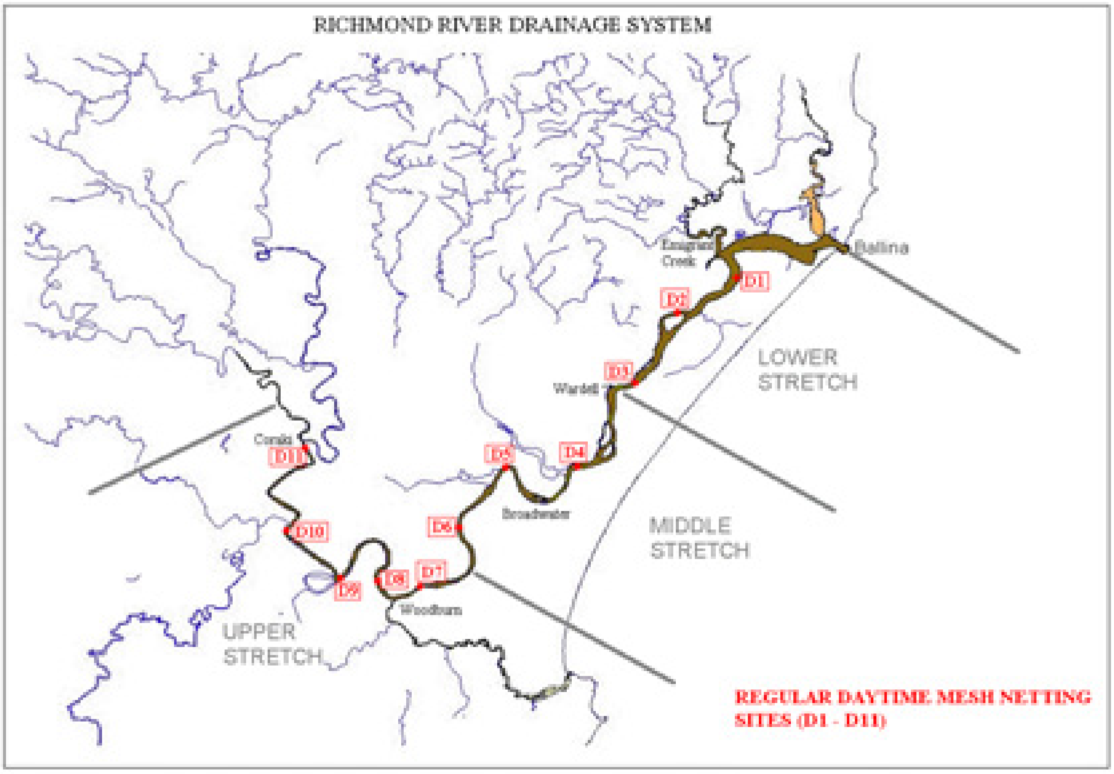

Figure 3. Map showing the regular daytime mesh netting sites (D1 - D11) in the lower Richmond River sampled during the post-fish kill monitoring period.

2.6. Crab trapping

For all surveys except the first (Mid-February 2001) survey, a total of approximately 30 (± 7) crab traps were set, left overnight and retrieved the following morning as per normal commercial crab trapping operational practice (Table 2). Only 9 crab traps were set and retrieved during the Mid-February 2001 survey. All crab trapping was done in the lower stretch of the river between Burns Point Ferry and Wardell (Figure 4).

The crab traps used during the surveys were approximately 1 metre x 1 metre x 60cm deep, with approximately 60mm wire mesh. There were two entry funnels in each trap.

The catches of mud crabs and associated fish and crustacean by-catches were counted and weighed by species. The mud crabs were also sexed. All individuals for all of the species caught (including the by-catch) were measured.

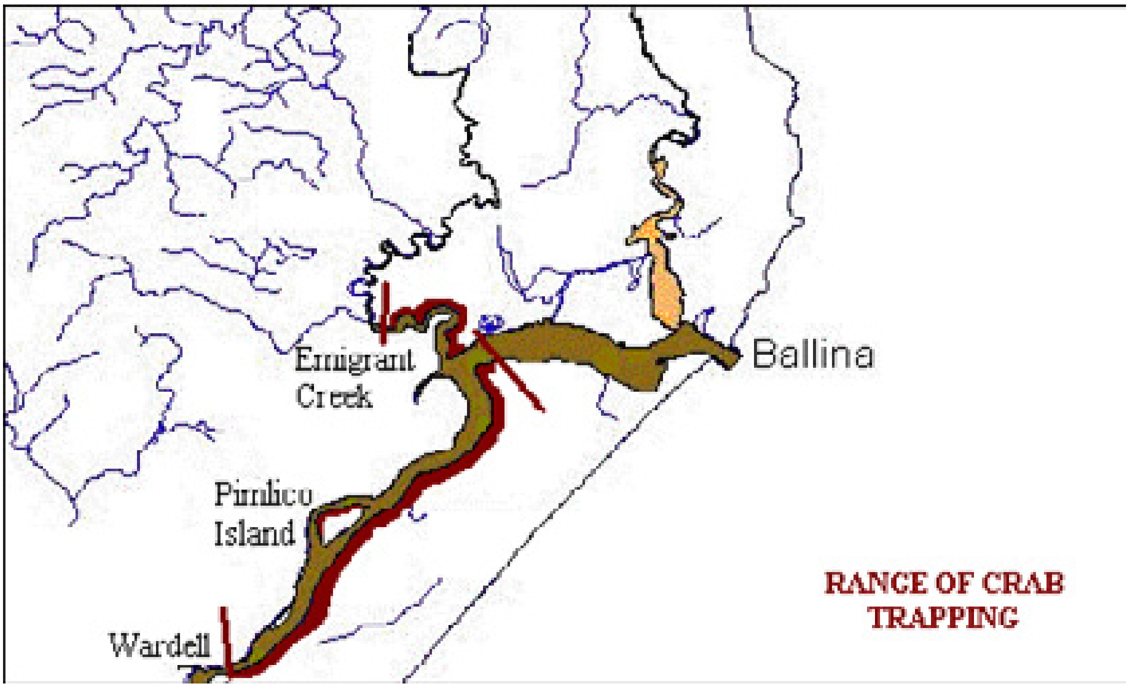

Figure 4. Map showing the area in which crab traps were set in the lower stretch of the lower Richmond River during the post-fish kill monitoring programme.

2.7. Scientific seining

A 44m scientific seine net (19m wings and a 6m bunt) with a drop of 1.8m and stretched mesh-sizes of 12.5mm in the wings and 25mm in the bunt was used at three sites in the lower stretch of the river near Ballina and in North Creek (S1 – S3 in Figure 5). All three sites were characterised by sandy substrates (i.e. no aquatic vegetation). Two replicate shots were done at each site. The regular sampling regime of two replicate shots at each of the three sites was maintained from the May 2001 survey onwards (Table 2). Prior to this May survey, shots with the 25mm seine net were done when possible at the three sites (i.e. without a regular protocol).

An 11m scientific seine net with a 2.3m drop and a stretched mesh-size of 7mm was included in the regular sampling regime from the May 2001 survey onwards, at the three seining sites mentioned above (S1 – S3) as well as three additional sites in the lower stretch (S4 – S6 in Figure 5). Site S4 is in Mobbs Bay and is characterised by a seagrass-covered substrate, while sites S5 and S6 are characterised by sandy substrates. Two replicate shots were done at each site. It was thought that this smaller mesh net should catch any very small fish that the larger mesh seine net might miss, and may also provide evidence of recently settled juvenile fish in the sand and/or seagrass habitats.

All catches were identified and counted by species where possible. The smallest and largest individuals for each species were measured.

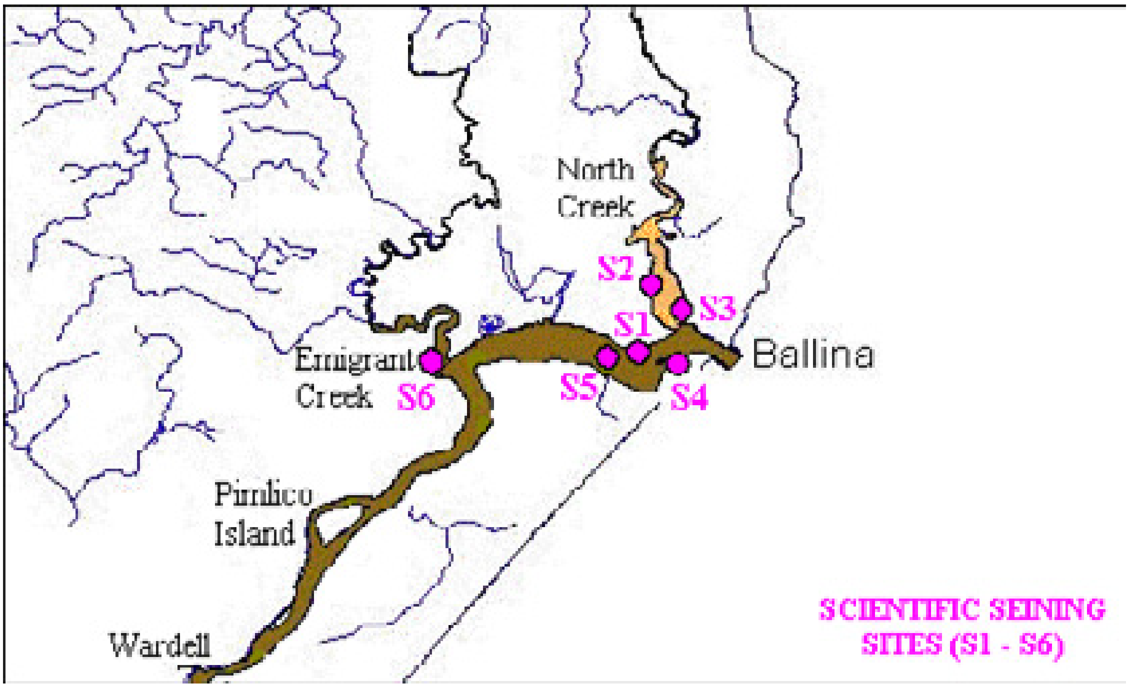

Figure 5. Map showing the scientific seining sites (S1 - S6) in the lower stretch of the lower Richmond River sampled during the post-fish kill monitoring programme.

3. RESULTS

3.1. Water quality

Dissolved oxygen (DO) levels were very low (~2 – 5 mg/L) in the middle and lower stretches of the lower Richmond River during the first (Mid-February 2001) survey, while DO levels in the upper stretch had returned to levels considered relatively normal by that first survey (Figure 6a). The DO levels had, however, returned to levels accepted as healthy throughout the sampling area by the April 2001 survey (Figure 6a). In general, these improved levels were sustained during each of the remaining surveys of the monitoring programme (Figure 6a). In contrast, pH levels remained more or less within the range considered healthy (between 7 and 8) throughout the entire monitoring programme (Figure 6b).

There were very low levels of salinity and conductivity recorded throughout the main river channel (upstream of Burns Point Ferry to Coraki) during the two surveys completed during February 2001 (Figure 6c and d). Salinity and conductivity levels had increased considerably at sites in the lower stretch by the March 2001 survey, while levels remained low at sites in the middle stretch until the July 2001 survey (Figure 6c and d). The levels of salinity and conductivity then remained relatively constant in each of the lower, middle and upper stretches through time from this July survey to the final (March 2002) survey, although there were minor fluctuations during this period (e.g. in December, due to rainfall – see Figure 6c and d).

Turbidity levels were very high in the middle and lower stretches during the Mid-February 2001 survey, though turbidity levels were quite low in the upper stretch at this time (Figure 6e). Turbidity levels fluctuated between around 5 and 20 NTU during the remaining surveys (where measurements were taken) (Figure 6e). This was almost certainly due to variable rainfall in the catchment.

The trends in water temperature recorded throughout the monitoring period showed that, as expected, the water throughout the river was generally warmer in the summer months and colder in the winter months (Figure 6f).

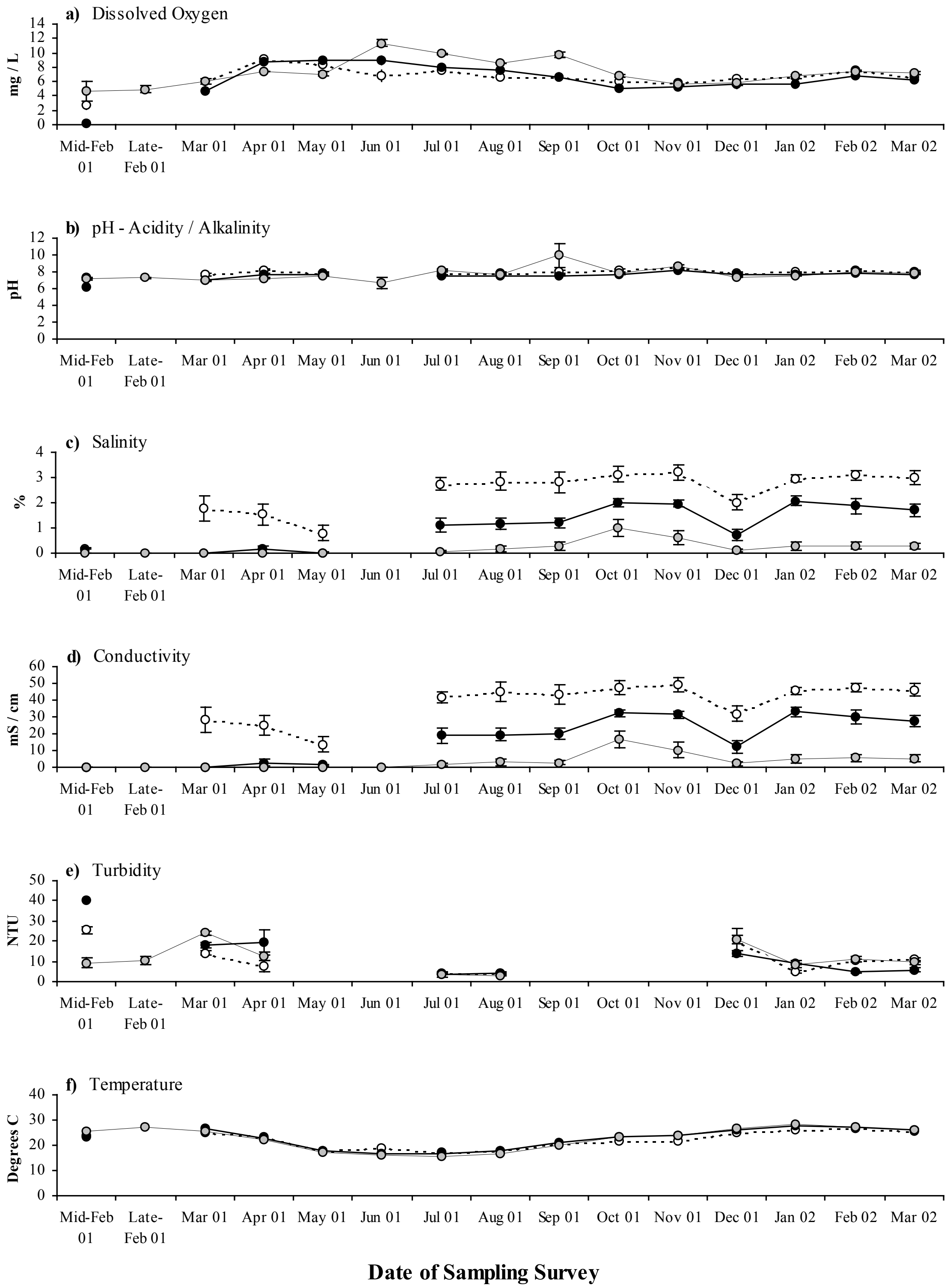

Figure 6. Results of water quality measurements (mean ± SE) taken in the main river channel of the lower Richmond River during the post-fish kill monitoring programme. Data are for the upper stretch (grey-filled data points), middle stretch (black-filled data points) and lower stretch (white-filled data points).

3.2. Prawn hauling

A total of approximately 1.08 tonnes of school prawns (~ 335,000 individuals) was caught in prawn haul shots made as part of the post-fish kill monitoring programme. Average catches per shot ranged between 0.006 kg and 10.9 kg (in Mid-February 2001 and September 2001, respectively) in the upper stretch, 0 and 13.6 kg (in Mid-February 2001 and April 2001, respectively) in the middle stretch, and 0.0003 kg and 9.9 kg (in November 2001 and February 2002, respectively) in the lower stretch of the river.

Very few school prawns were caught during the two February 2001 surveys undertaken soon after the fish-kill (Figure 7). Modest catches of prawns were recorded in the lower stretch during the March 2001 survey, although very few were caught at sites further upstream (Figure 7). During the April 2001 survey, relatively good catches of prawns came from shots done in the middle stretch and some prawns were also caught in the upper stretch (Figure 7). Overall, an average of approximately 5 kg per shot was caught during the April 2001 survey. Although similar quantities of prawns were caught overall during each of the May, June, July and August 2001 surveys, the stretch of river that yielded the most prawns per shot varied among these four sampling surveys (Figure 7). During May the lower stretch yielded the best catches, while the best catches during the June survey came from the middle stretch (Figure 7). In contrast, the best catches during the July and August surveys came from the upper stretch (Figure 7). Very good catches came from shots in the upper stretch during the September 2001 survey, although catches of prawns decreased steadily overall from the September 2001 survey through to the January 2002 survey (Figure 7). Nevertheless, the best catches continued to come from the upper and middle stretches during these latter surveys (Figure 7). Interestingly, the highest catches recorded from the lower stretch throughout the whole monitoring programme occurred during the two most recent surveys (February 2002 and March 2002), while catch rates in the upper stretch again increased slightly (Figure 7).

The data suggest that the overall numbers of school prawns recorded during each the surveys completed as part of this post-fish kill monitoring programme were generally lower than those levels recorded in spring-summer 1998-99 (Figure 7). Such interpretations must, however, be treated with extreme caution due to differences in the times of year and/or the fact that normal commercial prawn hauling operations involve targeting sites where the prawns are known to be present (as opposed to the strict sampling protocol adhered to throughout this monitoring programme). This will be discussed in further detail in the Discussion section of this report.

The numbers of by-catch individuals (i.e. all animals excluding school prawns) recorded from the prawn haul shots were relatively high during the Late-February 2001 survey, although this by-catch steadily decreased through subsequent surveys to the relatively low levels recorded during the September and October surveys (Figure 8). Interestingly, the relatively high numbers of by-catch individuals recorded in shots done in the lower stretch during the early surveys (Late-February 2001 and March 2001 in particular) can be largely attributed to the quite high numbers of juvenile mulloway caught in these shots (Figure 9). Similarly, the peaks in by-catch individuals evident in the upper stretch throughout the monitoring programme (Figure 8) can be largely attributed to high numbers of forktail catfish caught in that part of the river (Figure 10). The overall levels of by-catch increased to a general peak during the January 2002 and February 2002 surveys (Figure 8).

The total numbers of species (including school prawns) recorded from prawn haul shots during each sampling survey shows a distinct pattern of increasing biodiversity in the catches from the early surveys (February and March 2001) to the August 2001 survey. Diversity then fell in September 2001 and gradually rose again to reach a second peak in February 2002 (Figure 11).

There was, however, a relatively wide range of species caught in the lower stretch during the first (Mid-February 2001) survey, conducted soon after the fish kill.

Many commercially and/or recreationally important species were caught as by-catch in the prawn haul shots during the post-fish kill monitoring programme. These species included juvenile mulloway, rock prawn, juvenile yellowfin bream, silver biddy, king prawn, juvenile large-toothed flounder, Australian bass, sand whiting and dusky flathead. Catches of sand whiting in prawn haul shots during the monitoring period showed a clear increase from the earlier surveys (February/March/April 2001) to the later surveys (November 2001 to March 2002), although there may be a seasonal influence to this pattern (Figure 12). A similar pattern is evident for silver biddy, although none were caught in prawn haul shots before June 2001 (Figure 13). In contrast, catches of small yellowfin bream in prawn haul shots were relatively consistent throughout the monitoring period, with the only clear pattern being a distinct increase in the numbers of bream being caught in the upper stretch from the November 2001 survey to the March 2002 survey (Figure 14). There was no clear pattern evident in the catches of dusky flathead in the prawn haul shots throughout the monitoring period (Figure 15).

Non-commercially/recreationally important species caught in the prawn haul shots in notable quantities during the post-fish kill monitoring programme included bullrout, many-banded sole, southern herring, bottle squid, glass perch and glass shrimp. For a full list of the species caught as by-catch in prawn hauling during the monitoring programme, refer to Table 3.

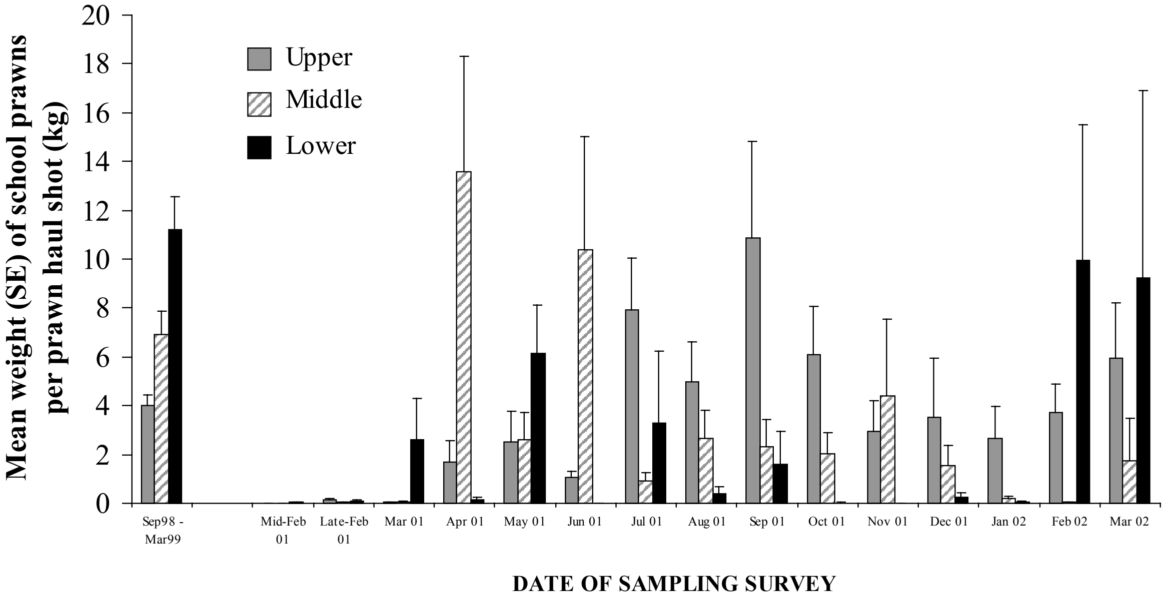

Figure 7. Mean weight of school prawns (+SE) per prawn haul shot in the upper, middle and lower stretches of the lower Richmond River. Data are from an observer survey undertaken in 1998/1999 ("Sep 98 to Mar 99") and each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

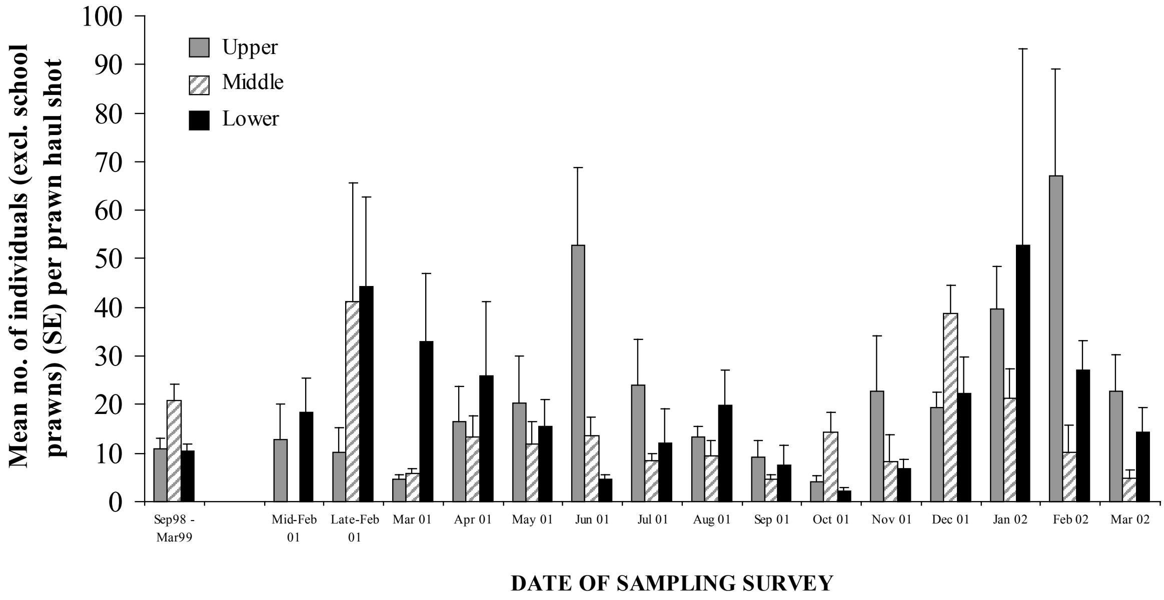

Figure 8. Mean number of individuals (excluding school prawns) (+SE) in the by-catch per prawn haul shot in the upper, middle and lower stretches of the lower Richmond River. Data are from an observer survey undertaken in 1998/1999 ("Sep 98 to Mar 99") and each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

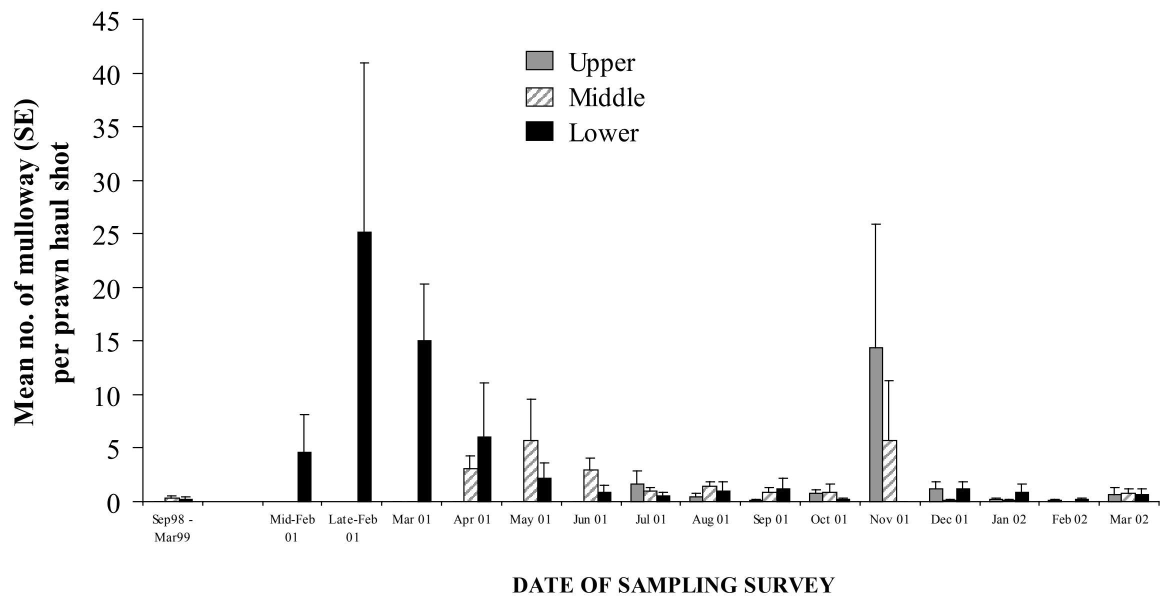

Figure 9. Mean number of mulloway (+SE) in the by-catch per prawn haul shot in the upper, middle and lower stretches of the lower Richmond River. Data are from an observer survey undertaken in 1998/1999 ("Sep 98 to Mar 99") and each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

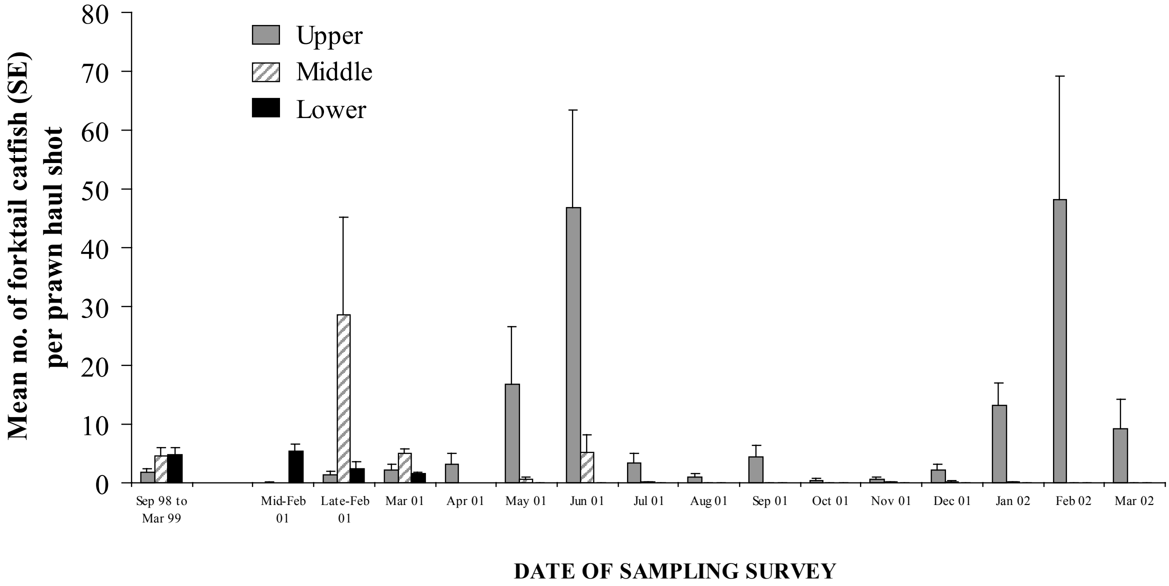

Figure 10. Mean number of forktail catfish (+SE) in the by-catch per prawn haul shot in the upper, middle and lower stretches of the lower Richmond River. Data are from an observer survey undertaken in 1998/1999 ("Sep 98 to Mar 99") and each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

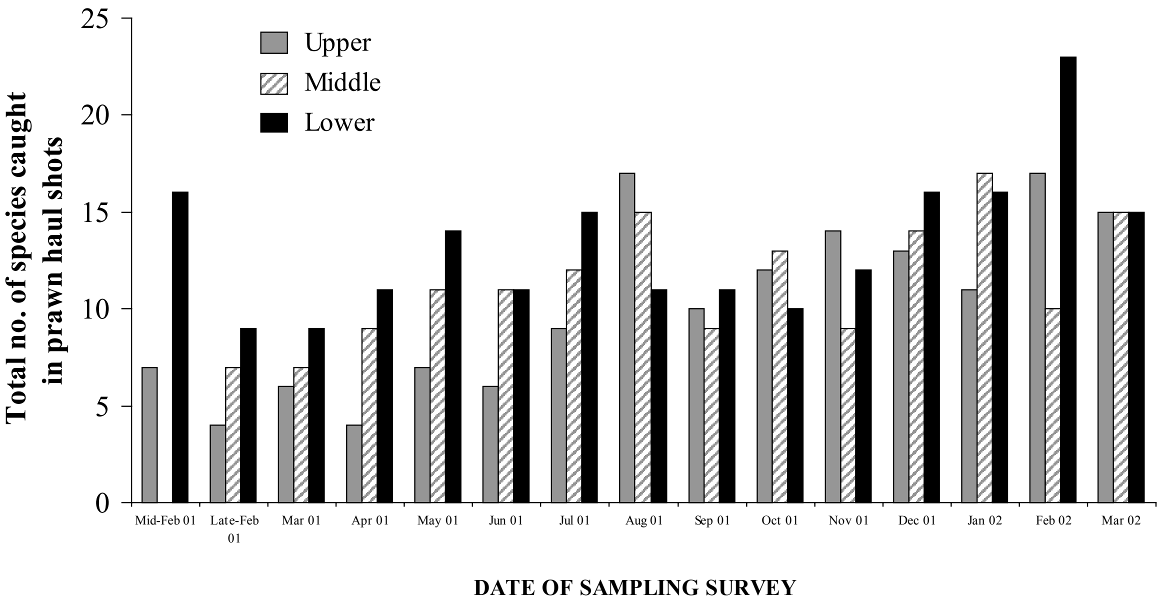

Figure 11. Total number of species caught per prawn haul shot in the upper, middle and lower stretches of the lower Richmond River. Data are from an observer survey undertaken in 1998/1999 ("Sep 98 to Mar 99") and each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

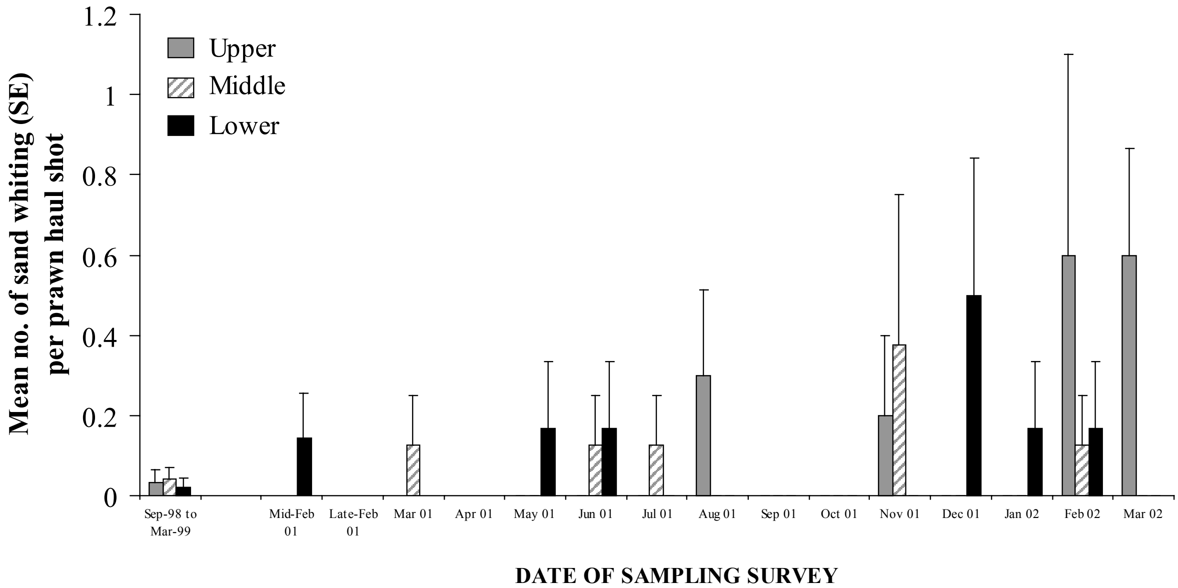

Figure 12. Mean number of sand whiting (+SE) in the by-catch per prawn haul shot in the upper, middle and lower stretches of the lower Richmond River. Data are from an observer survey undertaken in 1998/1999 ("Sep 98 to Mar 99") and each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

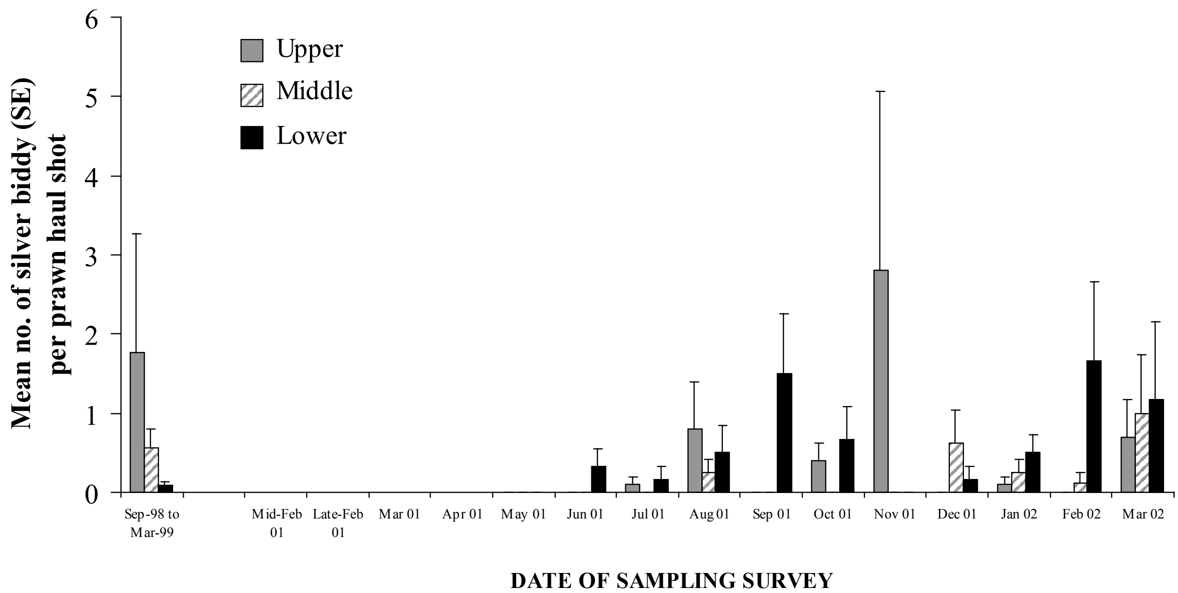

Figure 13. Mean number of silver biddies (+SE) in the by-catch per prawn haul shot in the upper, middle and lower stretches of the lower Richmond River. Data are from an observer survey undertaken in 1998/1999 ("Sep 98 to Mar 99") and each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

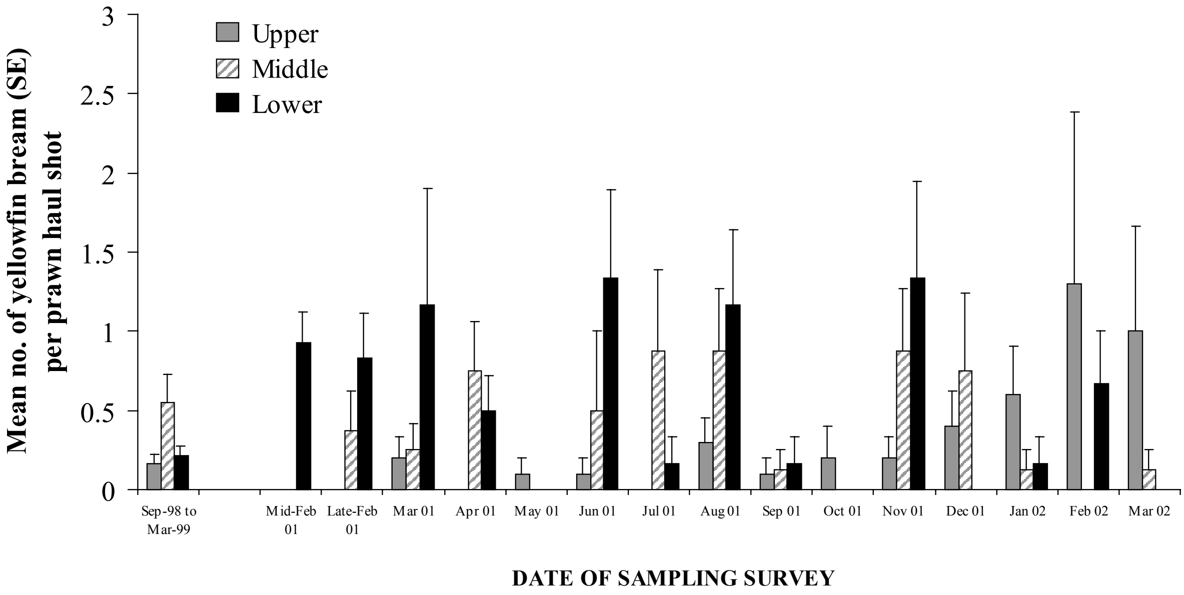

Figure 14. Mean number of yellowfin bream (+SE) in the by-catch per prawn haul shot in the upper, middle and lower stretches of the lower Richmond River. Data are from an observer survey undertaken in 1998/1999 ("Sep 98 to Mar 99") and each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

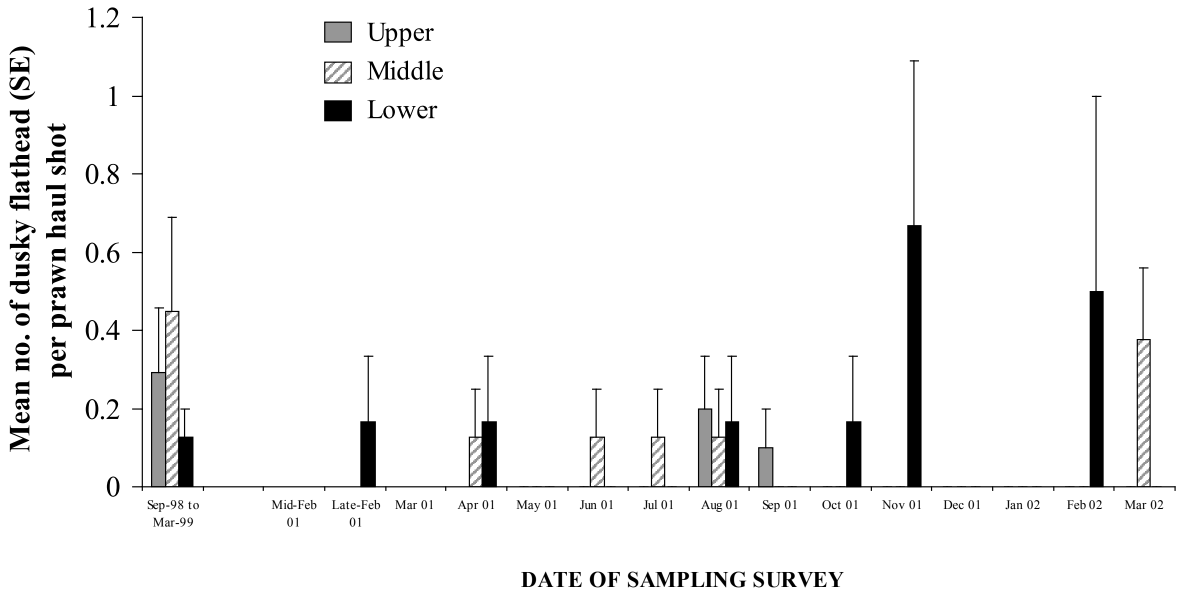

Figure 15. Mean number of dusky flathead (+SE) in the by-catch per prawn haul shot in the upper, middle and lower stretches of the lower Richmond River. Data are from an observer survey undertaken in 1998/1999 ("Sep 98 to Mar 99") and each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

Table 3. The total number and length range (mm) of individuals caught during prawn hauling operations for all taxa across all sampling surveys as part of the post-fish kill monitoring programme in the lower Richmond River. Note that the length range refers to total length in the case of the fish and carapace length in the case of the crustaceans.

Common name	Scientific name	Total no. caught	Length range (mm)
School prawn	*Metapenaeus macleayi*	335,195	3 - 23
Forktail catfish	*Arius graeffei*	1,960	40 - 485
Bullrout	*Notesthes robusta*	912	16 - 280
Mulloway	*Argyrosomus japonicus*	770	30 - 538
Many-banded sole	*Zebrias scalaris*	625	40 - 150
Rock prawn	*Macrobrachium sp.*	553	3 - 59
Southern herring	*Herklotsichthys castelnaui*	416	14 - 240
Bottle squid	*Loliolus sp.*	308	70 - 80
Glass shrimp	*Acetes sp.*	291	3 - 19
Glass perch	*Ambassis marianus*	165	24 - 106
Estuary catfish	*Cnidoglanis macrocephalus*	163	76 - 420
Yellowfin bream	*Acanthopagrus australis*	148	49 - 300
Silver biddy	*Gerres subfasciatus*	107	60 - 218
Eastern king prawn	*Penaeus plebejus*	91	4 - 17
Fortescue	*Centropogon australis*	50	28 - 87
Large-toothed flounder	*Pseudorhombus arsius*	48	38 - 180
Australian bass	*Macquaria novemaculeata*	39	136 - 320
Peppered sole	*Aseraggodes sp.*	37	46 - 91
Sand whiting	*Sillago ciliata*	33	85 - 331
Tarwhine	*Rhabdosargus sarba*	26	38 - 153
Dusky flathead	*Platycephalus fuscus*	21	194 - 533
Silver batfish	*Monodactylus argenteus*	23	46 - 145
Blue swimmer crab	*Portunus pelagicus*	13	13 - 68
Unidentified goby A	Gobiidae *sp.*	13	10 - 55
Unidentified goby B	Gobiidae *sp.*	12	45 - 115
Unidentified gudgeon	Eleotrididae *sp.*	12	20 - 42
Long-finned eel	*Anguilla reinhardtii*	9	311 - 610
Mud crab	*Scylla serrata*	8	49 - 121
Triple tail cod	*Lobotes surinamensis*	7	76 - 226
Sand goby	*Favonigobius tamarensis*	6	30 - 55
Tiger prawn	*Penaeus esculentus*	6	35 - 42
Javelin fish	*Pomadasys kaakan*	5	132 - 166
Stripey	*Microcanthus strigatus*	5	60 - 77
Tailor	*Pomatomus saltatrix*	5	20 - 90
Flathead gudgeon	*Philypnodon grandiceps*	4	53 - 76
Sandy sprat	*Hyperlophus vittatus*	6	50 - 70
Common toadfish	*Tetractenos hamiltoni*	3	86 - 120
Yellowtail scad	*Trachurus novaezelandiae*	3	31 - 36
Black sole	*Aesopia microcephalus*	2	60 - 61

Table 3 (continued)

Common name	**Scientific name**	**Total no. caught**	**Length range (mm)**
Flutemouth	*Fistularia commersonii*	2	200 - 263
Freshwater herring	*Potamalosa richmondia*	2	108 - 136
Greasyback prawn	*Metapenaeus bennettae*	2	22 - 27
Sea mullet	*Mugil cephalus*	2	280 - 360
Short-finned eel	*Anguilla australis*	2	340 - 350
Smooth toadfish	*Tetractenos glaber*	2	90 - 130
Stinkfish	*Foetorepus calauropomus*	2	52 - 90
Bull shark	*Carcharhinus leucas*	1	784
Coral crab	*Charybdis cruciata*	1	26
Spotted sand-dragnet	*Repomucenus calcaratus*	1	90
Dwarf gudgeon	*Philypnodon sp.*	1	59
Hairtail	*Chelidonichthys kumu*	1	617
Giant tiger prawn	*Penaeus monodon*	1	25
Oxeye herring	*Megalops cyprinoides*	1	170
Pinkeye mullet	*Myxus petardi*	1	250
Spotted scat	*Scatophagus argus*	1	255
Whiptail ray	*Dasyatis sp.*	1	180
Striped catfish	*Plotosus lineatus*	1	230
Unidentified toadfish	Tetraodontidae *sp.*	1	44

3.3. Mesh netting

An overall total of approximately 3,160 fish and crustaceans was caught in the 82mm mesh net panels during the regular daytime mesh netting (i.e. at the sites included in the standard mesh netting sampling design) over the entire post-fish kill monitoring programme. A wide range of species was caught during this regular daytime mesh netting, with sea mullet comprising the majority of the overall catch (Table 9).

Some of the commercially and/or recreationally important species that were caught reasonably regularly in the 82mm mesh net panels during the regular daytime mesh netting included sea mullet, forktail catfish, yellowfin bream, flattail mullet and luderick (Table 9). Other commercially and/or recreationally important species that were recorded included silver trevally, tailor, dusky flathead, sand whiting and blue swimmer crab. Non-commercially/recreationally important species caught regularly in the 82mm mesh net panels during the regular daytime mesh netting included pinkeye mullet, whiptail ray and spotted scat (Table 9). For a full list of the species caught in the 82mm mesh panels as part of the regular daytime mesh netting, refer to Table 9.

The average number of individuals (fish and crustaceans) caught per 82mm mesh net panel set throughout the monitoring programme showed no clear pattern with respect to the upper, middle and lower stretches, although the highest catch rates were generally recorded during the June, July and August 2001 surveys (Figure 16). Relatively few fish (~6 individuals per panel) were caught in the 82mm panels in the lower stretch during the Mid-February 2001 survey, which was undertaken soon after the fish-kill. Interestingly, the number of species caught in these lower stretch sets was quite high (Figure 17). Mesh netting with the 82mm panels in the middle stretch during the following survey (Late-February 2001) yielded approximately 6 individuals per panel, suggesting that the fish had already begun to recolonise the main river channel. In general, catches of fish during the regular daytime mesh netting (i.e. at the sites included in the standard mesh netting sampling design) were disappointing, especially in the case of surveys completed after the August 2001 survey (Figure 16).

The average catches of sea mullet per 82mm mesh net panel, recorded as part of the regular daytime mesh netting, were very low during the first (Mid-February 2001) survey (Figure 18). In general, the catches then increased through time to the June 2001 survey, especially in the cases of the middle and upper stretches, although catches were relatively small and sporadic during the surveys following the June survey (Figure 18).

Only a few luderick were caught in the 82mm mesh net panels during the first few sampling surveys following the fish kill (February and March 2001) (Figure 19). Subsequently, however, there was a steady increase in the catch rates of luderick in the lower stretch from the March 2001 survey through to the July 2001 survey. After this time, catches were greatly reduced throughout the remainder of the monitoring programme (Figure 19).

The extra daytime mesh net sets done at Burns Point Ferry in the lower stretch yielded relatively good catches of fish as early as the April 2001 survey (Table 10). In general, the catches from the Burns Point Ferry site were, more often than not, considerably better (i.e. more diverse and/or contained more fish) than catches recorded at other meshing sites sampled as part of the regular daytime mesh netting at any given time. Quite good catches of luderick came from the Burns Point Ferry meshing site during the June, July, August and September 2001 surveys (Table 10). Yellowfin bream, sand whiting and sea mullet were also regularly caught, albeit in smaller quantities (Table 10).

The extra daytime mesh net sets done inside Swan Bay (i.e. away from the main river channel) in the upper stretch during the September and November 2001 surveys yielded large catches of sea mullet and pinkeye mullet (Table 11). In contrast, relatively few fish were being caught in mesh net sets in the main river channel (as part of the regular daytime mesh netting).

The extra mesh net sets done at night in the lower stretch of the river during the surveys done in April, May and June 2001 yielded good catches of fish. A total of 36 large mulloway, with a total (gutted) weight of around 400 kg, was caught in the net with 152mm and 178mm mesh that was set near the mouth of the river during the April 2001 survey (Table 4). Sets of the same net during subsequent surveys did not repeat this catch, but nevertheless several large mulloway were again caught during the surveys in May 2001 and June 2001 (Tables 5 and 6). A few bull sharks were also caught in these larger-mesh net sets (Tables 4 and 6).

The night mesh netting using the composite net (see Table 5) near the mouth of the river during the May 2001 survey yielded a total of 238 fish, which were caught from just three sets (Table 5). These catches comprised mostly yellowfin bream, luderick and tailor, many of which were of legal size. Further sets of this composite net at night during the June 2001 survey at the same sites yielded similar results, with 92 fish, mostly luderick, being caught from two sets (Table 6).

Night meshing using a diver net in the upper stretch of the river near Coraki during the June and July 2001 surveys yielded a greater range of fish species than was caught at the same sites during the daylight mesh netting during both of these sampling surveys (Tables 7 and 8). During the June 2001 survey, only 1 sea mullet and a few pinkeye mullet were caught during the daylight mesh netting, whereas more of these two species plus some yellowfin bream, Australian bass and forktail catfish were caught during the night mesh netting, confirming the presence of these latter species in the upper stretch of the river at that time (Table 7). During the July 2001 survey, only 2 pinkeye mullet were caught during the regular daytime mesh netting at the two sites near Coraki, whereas very large quantities of sea mullet (~ 800 fish) and Australian bass (~ 350 fish) plus some yellowfin bream, eeltail catfish, forktail catfish and freshwater herring were caught during the night mesh netting (Table 8).

Table 4. Catches of fish resulting from night mesh netting in the lower stretch of the Richmond River during the April 2001 survey as part of the post-fish kill monitoring programme.

Sampling method	Sampling site	Species	No. caught	Length range (mm)
Night mesh netting	Burns Point Ferry	Forktail catfish	25	230 - 400
Approx. 200m		Mulloway	1	180
104mm mesh		Mud crab	1	70 (CL)
Approx. 30 min set				
Night mesh netting	Upper Pimlico	Forktail catfish	~100	190 - 350
Approx. 100m		Sand whiting	4	310 - 330
72mm mesh		Bullrout	5	100
Approx. 30 min set		Tailor	2	320
		Mud crab	3	70 (CL)
Night mesh netting	Near Mobbs Bay	Mulloway	3	200 - 1400
Approx. 200m diver net	(set 1)			
152 & 178mm mesh				
2 hour sets	Near Mobbs Bay	Mulloway	33	1040 - 1300
	(set 2)	Bull shark	3	1200 - 1430

Table 5. Catches of fish resulting from night mesh netting in the lower stretch of the Richmond River during the May 2001 survey as part of the post-fish kill monitoring programme.

Sampling method	Sampling site	Species	No. caught	Length range (mm)
Night mesh netting	Mobbs Bay	Tailor	19	170 - 380
Approx. 420m		Yellowfin bream	5	170 - 220
Composite net		Flattail mullet	11	290 - 350
(72, 82 & 104mm mesh)		Eagle ray	1	630
Approx. 30 min sets				
	North Creek	Yellowfin bream	72	190 - 300
		Luderick	57	210 - 350
		Tailor	39	250 - 430
		Dusky flathead	2	290 - 310
		Mud crab	2	112 - 127 (CL)
		Bullrout	2	240 - 255
		Queenfish	1	200
		Sand whiting	1	340
		Southern herring	1	140
	North Creek 2	Luderick	11	300 - 370
		Flattail mullet	3	310 - 340
		Forktail catfish	7	280 - 350
		Mulloway	1	230
		Tailor	2	380 - 420
		Yellowfin bream	1	150
Night mesh netting	Near Mobbs Bay	Mulloway	2	1120 - 1480
Approx. 200m diver net		Mud crab	1	115 (CL)
152 & 178mm mesh				
2 hour set				

Table 6. Catches of fish resulting from night mesh netting in the lower stretch of the Richmond River during the June 2001 survey as part of the post-fish kill monitoring programme.

Sampling method	Sampling site	Species	No. caught	Length range (mm)
Night mesh netting Approx. 420m Composite net (72, 82 & 104mm mesh) Approx. 30 min sets	Mobbs Bay	Luderick	53	260 - 360
		Flattail mullet	16	200 - 310
		Tailor	13	180 - 380
		Yellowfin bream	3	220 - 270
		Sand whiting	3	340
		Sea mullet	1	430
		Silver batfish	1	-
		Mud crab	1	-
	North Creek	Sand whiting	1	330
Night mesh netting Approx. 200m diver net 152 & 178mm mesh 2 hour set	Near Mobbs Bay	Mulloway	4	1270 - 1390
		Bull shark	1	840

Table 7. Comparison of catches of fish resulting from daytime and night mesh netting in the upper stretch of the Richmond River during the June 2001 survey as part of the post-fish kill monitoring programme.

Sampling method	**Sampling site** (see Figure 3)	**Species**	**No. caught**	**Length range (mm)**
Daytime mesh netting Approx. 400m floating net 82 & 104mm mesh 10 minute set	Coraki (D11)	Sea mullet	1	400
		Pinkeye mullet	2	370
	Bungawalbyn (D10)	Pinkeye mullet	1	390
Night mesh netting Approx. 200m diver net 82mm mesh 4 hour set	Coraki (D11)	Yellowfin bream	2	210 - 220
		Australian bass	7	250 - 420
		Sea mullet	14	260 - 380
		Pinkeye mullet	1	350
		Forktail catfish	23	230 - 360
	Bungawalbyn (D10)	Yellowfin bream	2	210 - 330
		Australian bass	1	270
		Sea mullet	14	310 - 410
		Pinkeye mullet	2	330 - 340
		Forktail catfish	13	260 - 310
Night mesh netting Approx. 400m diver net 82mm mesh 10 minute set	Coraki (D11)	Australian bass	1	260
		Sea mullet	2	320 - 350
		Pinkeye mullet	1	350
		Forktail catfish	1	250
	West Arm (near D11)	Sea mullet	20	260 - 390
		Pinkeye mullet	2	430 - 440
		Forktail catfish	1	350
	North Arm (near D11)	Sea mullet	6	310 - 360
		Pinkeye mullet	8	310 - 470
		Forktail catfish	6	290 - 360

Table 8. Comparison of catches of fish resulting from daytime and night mesh netting in the upper stretch of the Richmond River during the July 2001 survey as part of the post-fish kill monitoring programme.

Sampling method	Sampling site (see Figure 3)	Species	No. caught	Length range (mm)
Daytime mesh netting Approx. 400m floating net 82 & 104mm mesh 10 minute set	Coraki (D11)	-	0	
	Bungawalbyn (D10)	Pinkeye mullet	1	330 - 360
Night mesh netting Approx. 200m diver net 82mm mesh ~ 4 hour set	Coraki (D11)	Sea mullet	~ 350	-
		Australian bass	~ 150	-
		Forktail catfish	3	-
		Eeltail catfish	1	-
		Freshwater herring	2	-
	Bungawalbyn (D10)	Sea mullet	~ 450	-
		Australian bass	~ 200	-
		Yellowfin bream	1	-
		Forktail catfish	5	-
		Eeltail catfish	1	-

Table 9. The total number and length range (mm) of individuals caught during the regular daytime mesh netting operations (i.e. at the sites included in the standard mesh netting sampling design), for all taxa across all sampling surveys as part of the post-fish kill monitoring programme in the lower Richmond River. Note that the length range refers to total length in the case of the fish and carapace length in the case of the crustaceans.

Common name	Scientific name	Total no. caught	Length range (mm)
Sea mullet	*Mugil cephalus*	1,846	270 - 480
Pinkeye mullet	*Myxus petardi*	518	300 - 485
Forktail catfish	*Arius graeffei*	194	280 - 420
Flattail mullet	*Liza argentea*	164	200 - 350
Yellowfin bream	*Acanthopagrus australis*	156	150 - 320
Luderick	*Girella tricuspidata*	138	260 - 380
Silver trevally	*Pseudocaranx dentex*	28	300 - 420
Blue swimmer crab	*Portunus pelagicus*	22	50 - 68
Whiptail ray	*Dasyatis sp.*	16	150 - 650
Tailor	*Pomatomus saltatrix*	15	121 - 460
Spotted scat	*Scatophagus argus*	11	175 - 235
Dusky flathead	*Platycephalus fuscus*	9	170 - 640
Sand whiting	*Sillago ciliata*	9	172 - 345
Fantail mullet	*Valamugil georgii*	7	180 - 250
Bullrout	*Notesthes robusta*	4	- -
Mud crab	*Scylla serrata*	4	69 - 100
Southern herring	*Herklotsichthys castelnaui*	4	120 - 170
Bull shark	*Carcharhinus leucas*	3	610 - 880
Silver batfish	*Monodactylus argenteus*	3	130 - 140
Silver biddy	*Gerres subfasciatus*	3	110 - 170
Australian bass	*Macquaria novemaculeata*	2	340 - 340
Narrowlined puffer	*Arothron manillensis*	2	- -
Freshwater catfish	*Tandanus tandanus*	1	- -
Mulloway	*Argyrosomus japonicus*	1	190 190
Oxeye herring	*Megalops cyprinoides*	1	460 - 460
Silver perch	*Bidyanus bidyanus*	1	- -
Striped toadfish	Tetraodontidae *sp.*	1	205 205

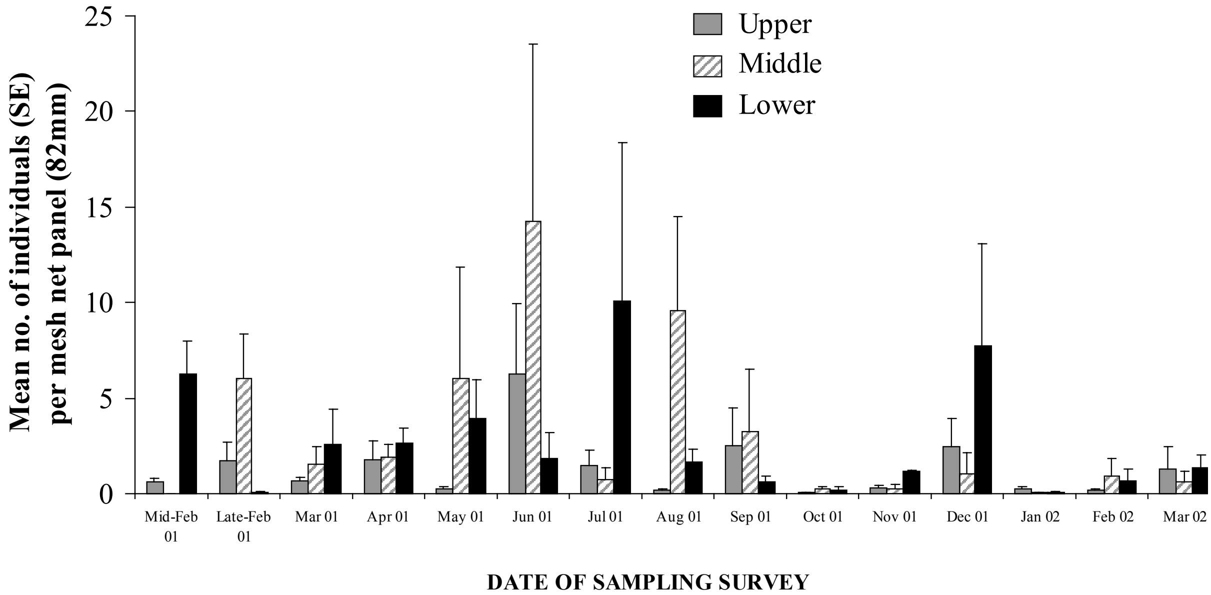

Figure 16. Mean number of individuals (+SE) caught per 82mm mesh net panel (30-metre length of net) in daytime mesh net sets in the upper, middle and lower stretches of the lower Richmond River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey). Note that no meshing was done in the middle stretch during the "Mid-Feb 01" survey.

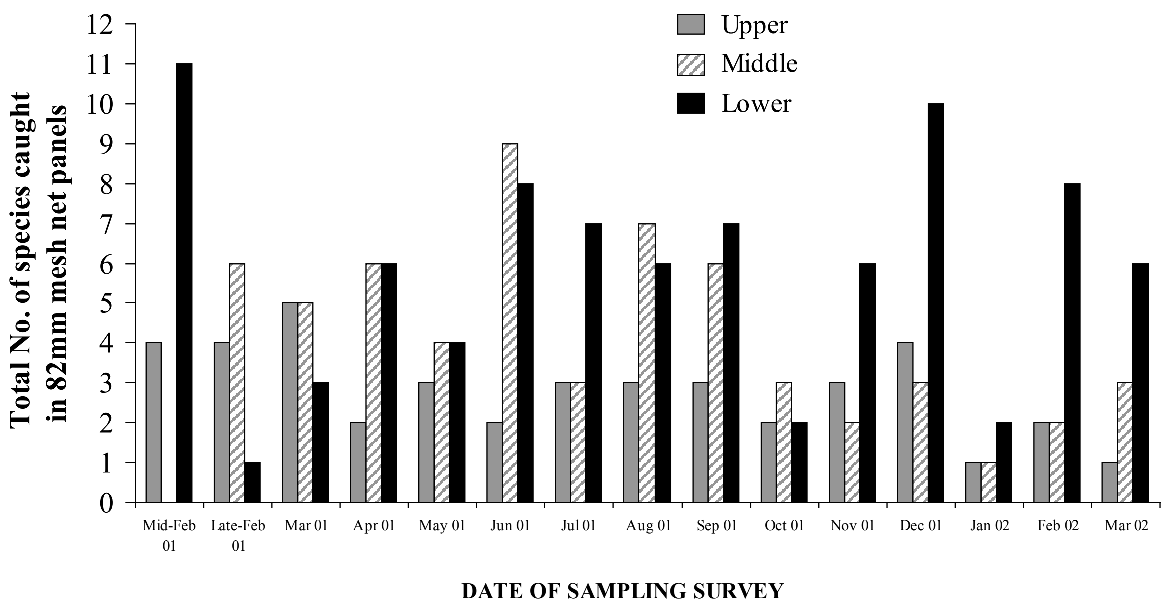

Figure 17. Number of species recorded from daytime 82mm mesh net sets in the upper, middle and lower stretches of the lower Richmond River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey). Note that no meshing was done in the middle stretch during the "Mid-Feb 01" survey.

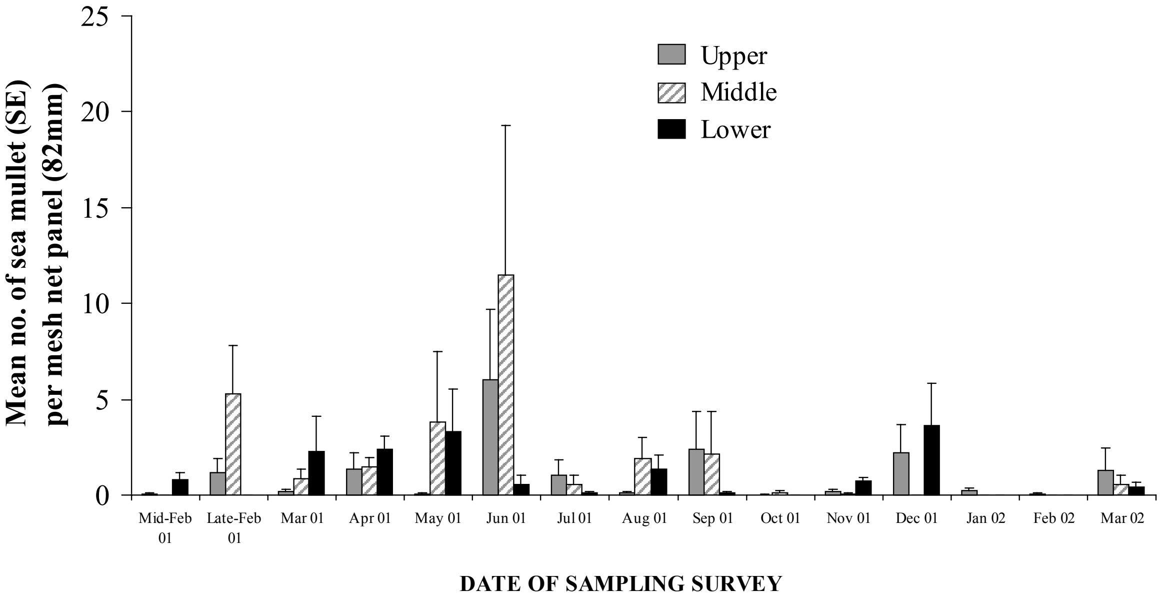

Figure 18. Mean number of sea mullet (+SE) caught per 82mm mesh net panel in daytime mesh net sets in the upper, middle and lower stretches of the lower Richmond River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey). Note that no meshing was done in the middle stretch during the "Mid-Feb 01" survey.

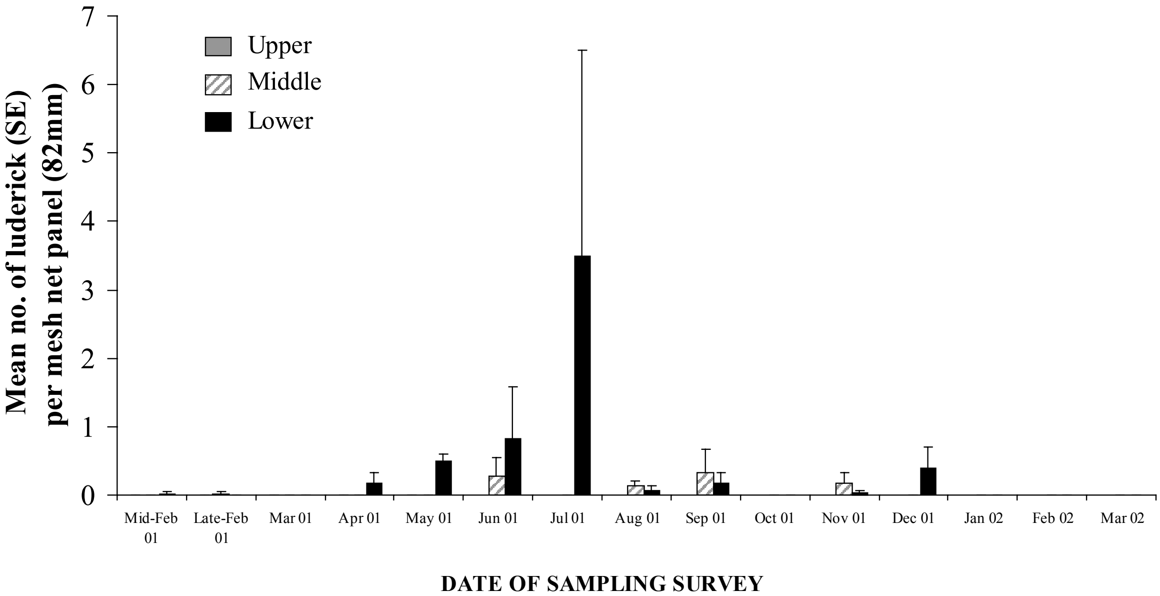

Figure 19. Mean number of luderick (+SE) caught per 82mm mesh net panel in daytime mesh net sets in the upper, middle and lower stretches of the lower Richmond River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey). Note that no meshing was done in the middle stretch during the "Mid-Feb 01" survey.

Table 10. Catches of fish resulting from the extra daytime mesh net sets done at Burns Point Ferry in the lower stretch of the Richmond River throughout the post-fish kill monitoring programme. Note that the mesh net used in each of the sets is the same as that used for the regular daytime meshing during that particular survey. Catch is for all mesh sizes combined where applicable.

Sampling Survey	Species	No. caught	Length range (mm)
APRIL 2001	Luderick	9	-
	Sand whiting	1	-
	Sea mullet	37	-
	Yellowfin bream	2	-
JUNE 2001	Silver biddy	2	145 - 156
	Sea mullet	19	310 - 410
	Luderick	102	230 - 420
	Yellowfin bream	5	200 - 290
	Sand whiting	2	260 - 350
JULY 2001	Luderick	33	260 - 370
	Sand whiting	1	345
	Sea mullet	5	310 - 415
AUGUST 2001	Bullrout	1	235
	Luderick	25	260 - 370
	Sea mullet	7	310 - 385
SEPTEMBER 2001	Luderick	24	280 - 370
	Sand whiting	3	300 - 350
OCTOBER 2001	Sand whiting	1	385
	Yellowfin bream	1	220
	Luderick	3	255 - 320
NOVEMBER 2001	Yellowfin bream	1	205
	Sand whiting	1	305
DECEMBER 2001	Luderick	14	280 - 410
	Blue swimmer crab	2	55 - 65
	Fantail mullet	3	180 - 210
	Sea mullet	4	375 - 390
	Sand whiting	1	320
	Dusky flathead	1	445
	Yellowfin bream	1	230
JANUARY 2002	Luderick	12	300 - 370
	Fantail mullet	2	170 - 190
FEBRUARY 2002	Sea mullet	6	330 - 380
	Blue swimmer crab	4	45 - 65
MARCH 2002	Luderick	1	350
	Sea mullet	4	325 - 390
	Mud crab	1	86
	Blue swimmer crab	14	45 - 70
	Coral crab	1	55

Table 11. Catches of fish resulting from the extra daytime mesh net sets done inside Swan Bay in the upper stretch of the Richmond River during the post-fish kill monitoring programme. Note that the mesh net used in each of the sets is the same as that used for the regular daytime meshing during that particular survey.

Sampling Survey	Species	No. caught	Length range (mm)
SEPTEMBER 2001	Sea mullet	90	300 - 430
	Pinkeye mullet	59	360 - 480
	Forktail catfish	4	380 - 480
	Australian bass	3	280 - 350
	Long-necked turtle	1	88
NOVEMBER 2001	Sea mullet	17	335 - 445
	Pinkeye mullet	67	330 - 495
	Forktail catfish	1	375
	Whiptail ray	1	-

3.4. Crab trapping

A total of 577 mud crabs (348 male and 229 female) weighing approximately 412 kg was caught in the 416 crab traps (an average of ~1 per trap set) successfully set and retrieved as part of the post-fish kill monitoring programme. These crabs ranged in size between 65mm and 140mm carapace length. In general, the mean number of mud crabs caught per trap set showed a gradual increase from the first (Mid-February 2001) survey through to the May and June 2001 surveys (Figure 20). Catch rates subsequently decreased considerably to lower levels in the July, August, September and October 2001 surveys (Figure 20). Average catches of mud crabs then increased again through the period from November 2001 to February 2002 (Figure 20).

The major by-catch species recorded during the crab trapping operations throughout the monitoring programme was yellowfin bream (Table 12). Many of the bream caught in the crab traps were relatively large fish (i.e. >30cm length). No bream were caught in crab traps during the initial (Mid-February 2001) survey. In general, average bream catches then increased to a peak during the July 2001 survey, after which the average catches decreased to extremely low levels during the October 2001, November 2001, December 2001, January 2002 and February 2002 surveys (Figure 21). Bream catches then increased during the final (March 2002) survey (Figure 21).

Other species recorded as by-catch in crab traps included blue swimmer crab, coral crab, whiptail ray and forktail catfish (Table 12).

Table 12. The total number and length range (mm) of individuals caught during all crab trapping operations for all taxa across all sampling surveys as part of the post-fish kill monitoring programme in the lower Richmond River. Note that the length range refers to total length in the case of the fish and carapace length in the case of the crustaceans.

Common name	Scientific name	Total no. caught	Length range (mm)
Mud crab	*Scylla serrata*	577	65 - 140
Yellowfin bream	*Acanthopagrus australis*	206	200 - 370
Blue swimmer crab	*Portunus pelagicus*	7	51 - 83
Coral crab	*Charybdis cruciata*	2	70 - 85
Whiptail ray	*Dasyatis sp.*	1	320
Forktail catfish	*Arius graeffei*	1	430

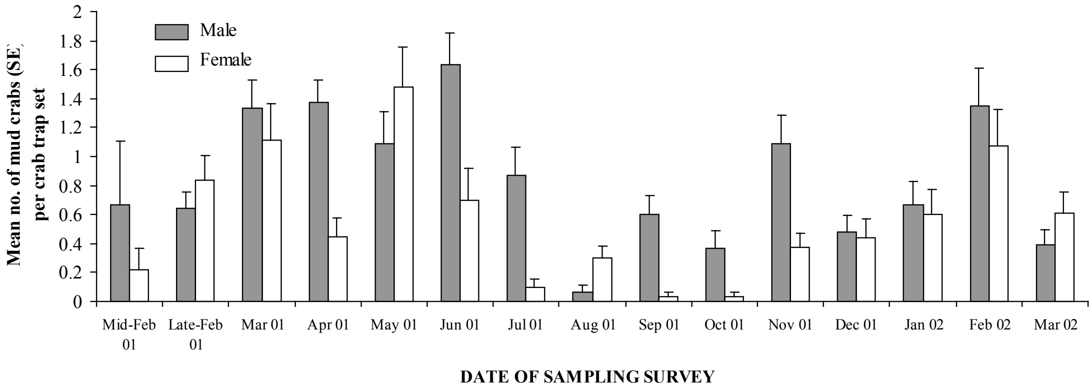

Figure 20. Mean number of male and female mud crabs (+SE) caught per crab trap set in the lower stretch of the lower Richmond River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

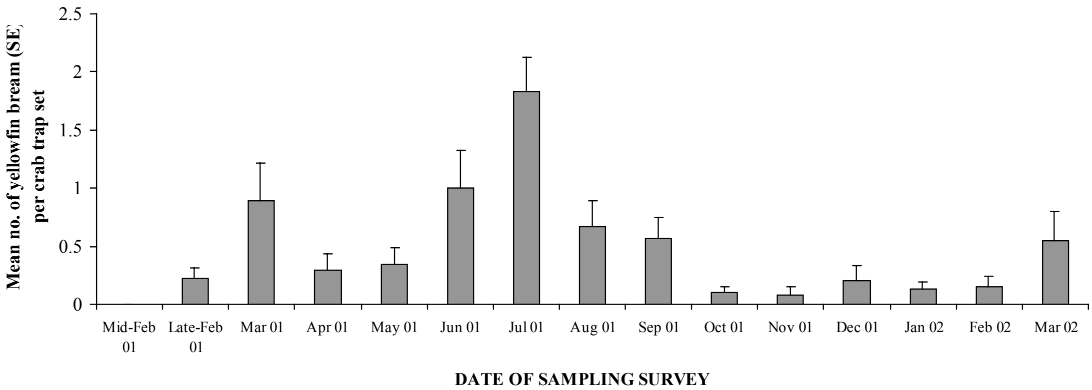

Figure 21. Mean number of yellowfin bream (+SE) caught per crab trap set in the lower stretch of the lower Richmond River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

3.5. Scientific seining – 25mm mesh net

A total of over 5,100 fish and crustaceans from 31 species was caught in the scientific seine shots using the 25mm mesh seine net at the three sites (S1, S2 and S3 in Figure 5) in the lower stretch of the lower Richmond River. Interestingly, the numbers of individual fish and crustaceans caught per shot using this 25mm seine net were quite high during the earlier surveys that were undertaken in February 2001, soon after the fish kill (Figure 22). With the exception of the May 2001 and August 2001 surveys, the mean numbers of individuals caught per shot were quite consistent between the April and November 2001 surveys (Figure 22). There was an increase in the mean number of individuals caught per shot in the December 2001 survey and in the subsequent January and March 2002 surveys (Figure 22). The peaks in the mean numbers of individuals evident in Figure 22 can be largely attributed to sporadic large catches of glass perch (Figure 23) and juvenile sand whiting (Figure 24). These two species account for approximately 75% of all the individuals caught in the 25 mm mesh net throughout the monitoring programme (Table 13).

There does not seem to be a clear pattern in the mean number of species caught in the scientific seine shots using the 25mm mesh seine net (Figure 25). There does, however, appear to be a slight trough in the mean number of species recorded during the surveys between June and September 2001 (Figure 25).

Other species caught in notable quantities in the seine shots using the 25mm mesh seine net included sand mullet, flattail mullet, silver biddy, sandy sprat, common toadfish, weeping toadfish, yellowfin bream, sea garfish, dusky flathead and sea mullet (Table 13). For a full list of the species caught in the scientific seine shots using the 25mm mesh seine net during the monitoring programme, refer to Table 13.

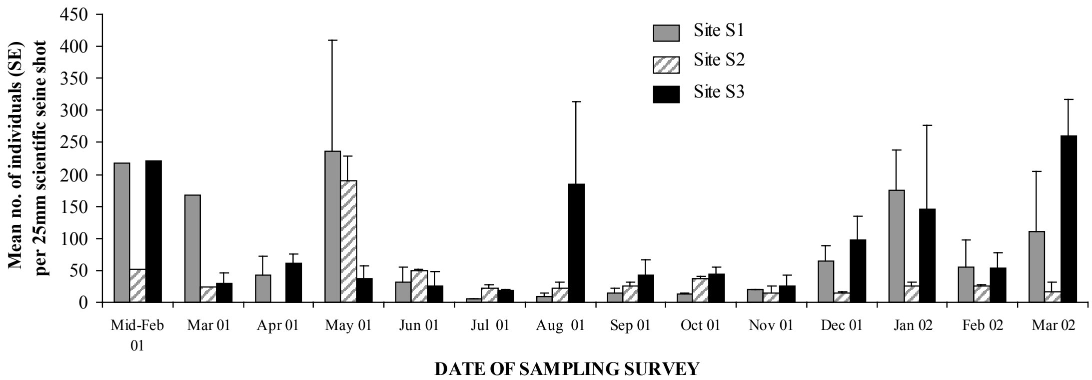

Figure 22. Mean numbers of individual fish and crustaceans (+SE) caught per shot of the 25mm mesh scientific seine net at sites S1, S2 and S3. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

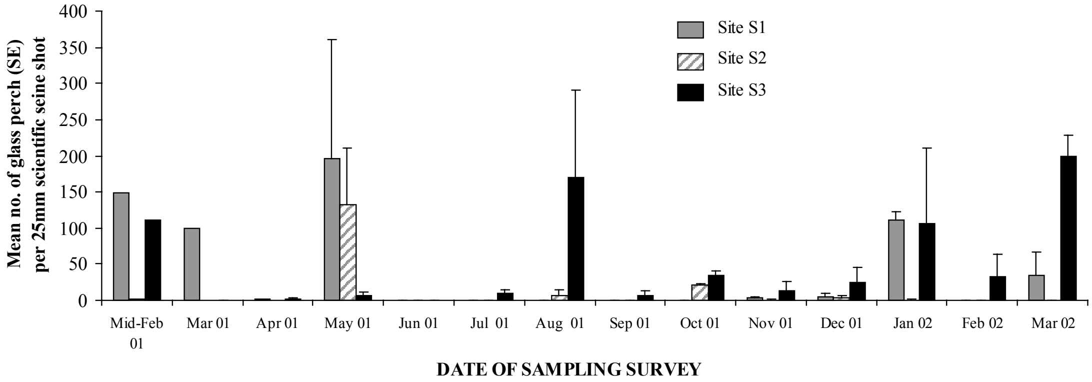

Figure 23. Mean numbers of glass perch (+SE) caught per shot of the 25mm mesh scientific seine net at sites S1, S2 and S3. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

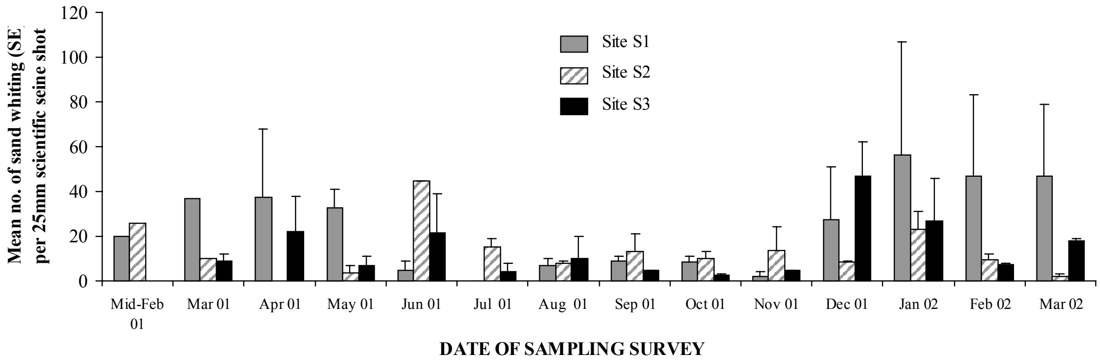

Figure 24. Mean numbers of sand whiting (+SE) caught per shot of the 25mm mesh scientific seine net at sites S1, S2 and S3. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

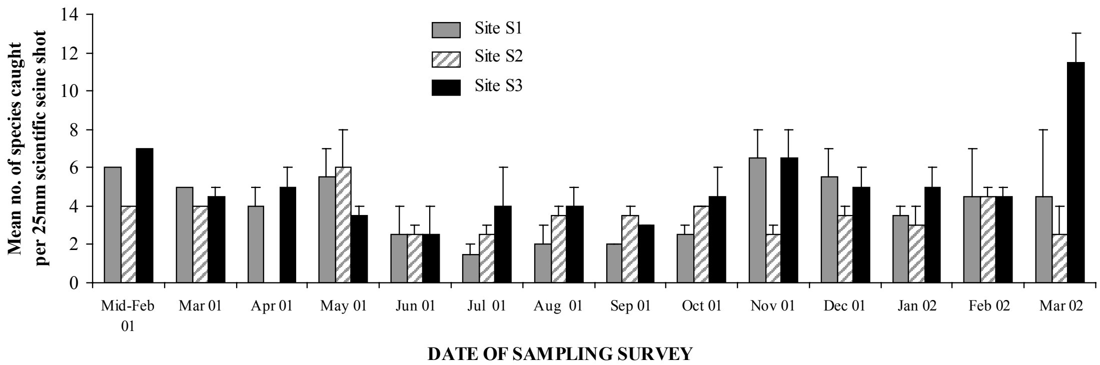

Figure 25. Mean numbers of species (+SE) caught per shot of the 25mm mesh scientific seine net at sites S1, S2 and S3. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

Table 13. The total number and length range (mm) of individuals caught during scientific seining using the 25mm mesh seine net at sites S1 - S3. Data are for all taxa across all sampling surveys as part of the post-fish kill monitoring programme in the lower Richmond River. Note that the length range refers to total length in the case of the fish and carapace length in the case of the crustaceans.

Common name	Scientific name	Total no. caught	Length range (mm)
Glass perch	*Ambassis marianus*	2,596	24 - 73
Sand whiting	*Sillago ciliata*	1,324	23 - 337
Sand mullet	*Myxus elongatus*	414	51 - 340
Flattail mullet	*Liza argentea*	255	50 - 330
Silver biddy	*Gerres subfasciatus*	137	116 - 181
Sandy sprat	*Hyperlophus vittatus*	98	36 - 84
Common toadfish	*Tetractenos hamiltoni*	96	55 - 197
Weeping toadfish	*Torquigener pleurogramma*	62	33 - 125
Yellowfin bream	*Acanthopagrus australis*	58	47 - 277
Sea garfish	*Hyporhamphus australis*	34	110 - 130
Dusky flathead	*Platycephalus fuscus*	27	85 - 366
Sea mullet	*Mugil cephalus*	21	113 - 375
Snub-nosed garfish	*Arrhamphus sclerolepis*	9	- -
Tailor	*Pomatomus saltatrix*	9	131 - 131
Large-toothed flounder	*Pseudorhombus arsius*	6	29 - 131
Luderick	*Girella tricuspidata*	4	310 - 380
Northern sand flathead	*Platycephalus arenarius*	4	111 - 129
Unidentified toadfish	Tetraodontidae *sp.*	4	55 - 91
Pebble crab	*Ixa inermis*	3	17 - 32
Tarwhine	*Rhabdosargus sarba*	3	76 - 110
Hardyhead	*Atherinomorus ogilbyi*	2	76 - 81
Queenfish	*Scomberoides lysan*	2	60 - 60
Trevally	Carangidae *sp.*	2	-
Australian anchovy	*Engraulis australis*	1	38
Dart	*Trachinotus coppingeri*	1	130
Lemon tongue sole	*Paraplagusia unicolor*	1	65
Pinkeye mullet	*Myxus petardi*	1	355
School prawn	*Metapenaeus macleayi*	1	6
Southern herring	*Herklotsichthys castelnaui*	1	131
Crescent Perch	*Terapon jarbua*	1	70
Trumpeter	*Pelates quadrilineatus*	1	38

3.6. Scientific seining – 7mm mesh net

A total of over 19,400 fish and crustaceans from 38 species was caught in the scientific seine shots using the 7mm mesh seine net at the sites characterised by a sandy substrate (S1, S2, S3, S5 and S6 in Figure 5), in the lower stretch of the lower Richmond River as part of the post-fish kill monitoring programme. In comparison, a total of over 17,400 fish and crustaceans from 39 species was caught in the 7mm mesh scientific seine shots at the one and only site characterised by a seagrass substrate – Mobbs Bay (S4 in Figure 5).

The highest mean number of individual fish and crustaceans (excluding glass shrimps) recorded per shot of the 7mm seine net occurred in the surveys undertaken during the spring and/or summer months at all of the six sites sampled (S1 – S6, Figure 26a – f). It is important to note that glass shrimps were excluded from the calculations of average numbers of individuals per shot in Figure 26 primarily due to the extreme variability in their abundances recorded during the surveys (some shots caught many thousands while other shots caught none), which tended to mask the overall trends discernible in the graphs. A large proportion of the fish caught at the sites with sandy substrates (S1, S2, S3, S5 and S6) was juvenile sand whiting (Table 14, Figure 27a, b, c, e and f). Likewise, large numbers of glass perch were also caught at these sites and at Mobbs Bay (S4) (Tables 14 and 15 respectively).

There did not appear to be any clear trends evident with respect to the mean number of species recorded per shot of the 7mm seine net throughout the extent of the sampling with that net (the May 2001 survey to the March 2002 survey) at sites S1, S2, S3 and S5 (Figure 28a, b, c and e). A slight trend is, however, apparent in the cases of sites S4 and S6 (Figure 28d and f). The mean numbers of species recorded per shot at these two sites were highest during the spring and summer months (September 2001 – January 2002) (Figure 28d and f). It is also notable that the mean number of species recorded per shot of the 7mm seine net at Mobbs Bay seagrass site (S4) was, in general, considerably higher than that recorded at the other five sites (Figure 28d).

Small juvenile yellowfin bream, luderick and tarwhine were first caught in the 7mm seine net during the July 2001 and August 2001 surveys. For a full list of the species caught in the scientific seine shots using the 7mm mesh seine net at sites with sandy (S1, S2, S3, S5 and S6) and seagrass (S4) substrates during the monitoring programme, refer to Tables 14 and 15 respectively.

Table 14. The total number and length range (mm) of individuals caught during scientific seining using the 7mm mesh seine net at "sand" sites S1 - S3, S5 and S6. Data are for all taxa across all sampling surveys as part of the post-fish kill monitoring programme in the lower Richmond River. Note that the length range refers to total length in the case of the fish and carapace length in the case of the crustaceans.

Common name	Scientific name	Total no. caught	Length range (mm)
Glass shrimp	*Acetes sp.*	6,555	1 - 13
Glass perch	*Ambassis marianus*	4,827	9 - 62
Sand whiting	*Sillago ciliata*	4,776	10 - 166
Flattail mullet	*Liza argentea*	930	13 - 170
Rock prawn	*Macrobrachium sp.*	812	2 - 11
Sand goby	*Favonigobius tamarensis*	602	18 - 62
School prawn	*Metapenaeus macleayi*	433	2 - 13
Sandy sprat	*Hyperlophus vittatus*	202	26 - 70
Unidentified goby	Gobiidae *sp.*	74	20 - 57
Yellowfin bream	*Acanthopagrus australis*	55	21 - 134
Sea mullet	*Mugil cephalus*	42	14 - 36
Tarwhine	*Rhabdosargus sarba*	37	12 - 63
Common toadfish	*Tetractenos hamiltoni*	33	19 - 137
Dusky flathead	*Platycephalus fuscus*	20	38 - 176
Weeping toadfish	*Torquigener pleurogramma*	12	8 - 53
Large-toothed flounder	*Pseudorhombus arsius*	10	25 - 117
Silver biddy	*Gerres subfasciatus*	9	14 - 165
Pacific blue-eye	*Pseudomugil signifer*	8	18 - 22
Trumpeter	*Pelates quadrilineatus*	8	19 - 23
Flagtail flathead	*Platycephalus endrachtensis*	7	65 - 100
Northern sand flathead	*Platycephalus arenarius*	6	26 - 134
Bottle squid	*Loliolus sp.*	3	- -
Sea garfish	*Hyporhamphus australis*	3	93 - 120
Soldier crab	*Mictyris longicarpus*	3	- -
Sand mullet	*Myxus elongatus*	2	17 - 41
Stinkfish	*Foetorepus calauropomus*	2	60 - 60
Angler fish	Antennariidae *sp.*	1	38
Bridled goby	*Arenigobius bifrenatus*	1	63
Coral crab	*Charybdis cruciata*	1	17
Longtom	*Tylosurus gavialoides*	1	106
Mud flathead	*Suggrundus jugosus*	1	23
Pipefish	Syngnathidae *sp.*	1	71
River garfish	*Hyporhamphus regularis*	1	80
Smooth flutemouth	*Fistularia commersonii*	1	930
Stargazer	*Ichthyscopus lebeck*	1	53
Tailor	*Pomatomus saltatrix*	1	37
Triple-tail cod	*Lobotes surinamensis*	1	56
Unidentified toadfish	Tetraodontidae *sp.*	1	9

Table 15. The total number and length range (mm) of individuals caught during scientific seining using the 7mm mesh seine net at the "seagrass" site (S4). Data are for all taxa across all sampling surveys as part of the post-fish kill monitoring programme in the lower Richmond River. Note that the length range refers to total length in the case of the fish and carapace length in the case of the crustaceans.

Common name	Scientific name	Total no. caught	Length range (mm)
Glass shrimp	*Acetes sp.*	11,018	3 - 7
Glass perch	*Ambassis marianus*	4,272	6 - 90
Rock prawn	*Macrobrachium sp.*	617	2 - 9
Flattail mullet	*Liza argentea*	245	22 - 58
Unidentified goby A	Gobiidae *sp.*	243	18 - 46
Sand goby	*Favonigobius tamarensis*	223	18 - 58
School prawn	*Metapenaeus macleayi*	215	3 - 18
Yellowfin bream	*Acanthopagrus australis*	200	15 - 124
Bridled goby	*Arenigobius bifrenatus*	101	28 - 90
Trumpeter	*Pelates quadrilineatus*	72	9 - 87
Bottle squid	*Loliolus sp.*	54	- -
Unidentified goby B	Gobiidae *sp.*	51	15 - 40
Tarwhine	*Rhabdosargus sarba*	45	18 - 96
Luderick	*Girella tricuspidata*	21	19 - 55
Unidentified blenny	Blenniidae *sp.*	21	22 - 56
Unidentified leatherjacket A	Monacanthidae *sp.*	18	7 - 78
Sea mullet	*Mugil cephalus*	17	28 - 80
Eastern king prawn	*Penaeus plebejus*	5	11 - 25
Tiger prawn	*Penaeus esculentus*	5	9 - 21
Dusky flathead	*Platycephalus fuscus*	4	96 - 203
Sand whiting	*Sillago ciliata*	4	48 - 80
Black sole	*Aesopia microcephalus*	3	63 - 116
Carid prawn	Caridea *sp.*	3	3 - 6
Silver biddy	*Gerres subfasciatus*	3	38 - 58
Southern herring	*Herklotsichthys castelnaui*	3	108 - 126
Unidentified gudgeon	Eleotrididae *sp.*	3	47 - 96
Bullrout	*Notesthes robusta*	2	21 - 25
Mud crab	*Scylla serrata*	2	21 - 48
Longfin pike	*Dinolestes lewini*	2	38 - 38
Angler fish	Brachionichthyidae *sp.*	1	105
Blue swimmer crab	*Portunus pelagicus*	1	38
Common toadfish	*Tetractenos hamiltoni*	1	80
Fortescue	*Centropogon australis*	1	40
Giant trevally	*Caranx ignobilis*	1	83
Half-bridled goby	*Arenigobius frenatus*	1	71
Pipefish	Syngnathidae *sp.*	1	61
Sandy sprat	*Hyperlophus vittatus*	1	63
Snapping shrimp	*Alpheus sp.*	1	3
Unidentified leatherjacket B	Monacanthidae *sp.*	1	35

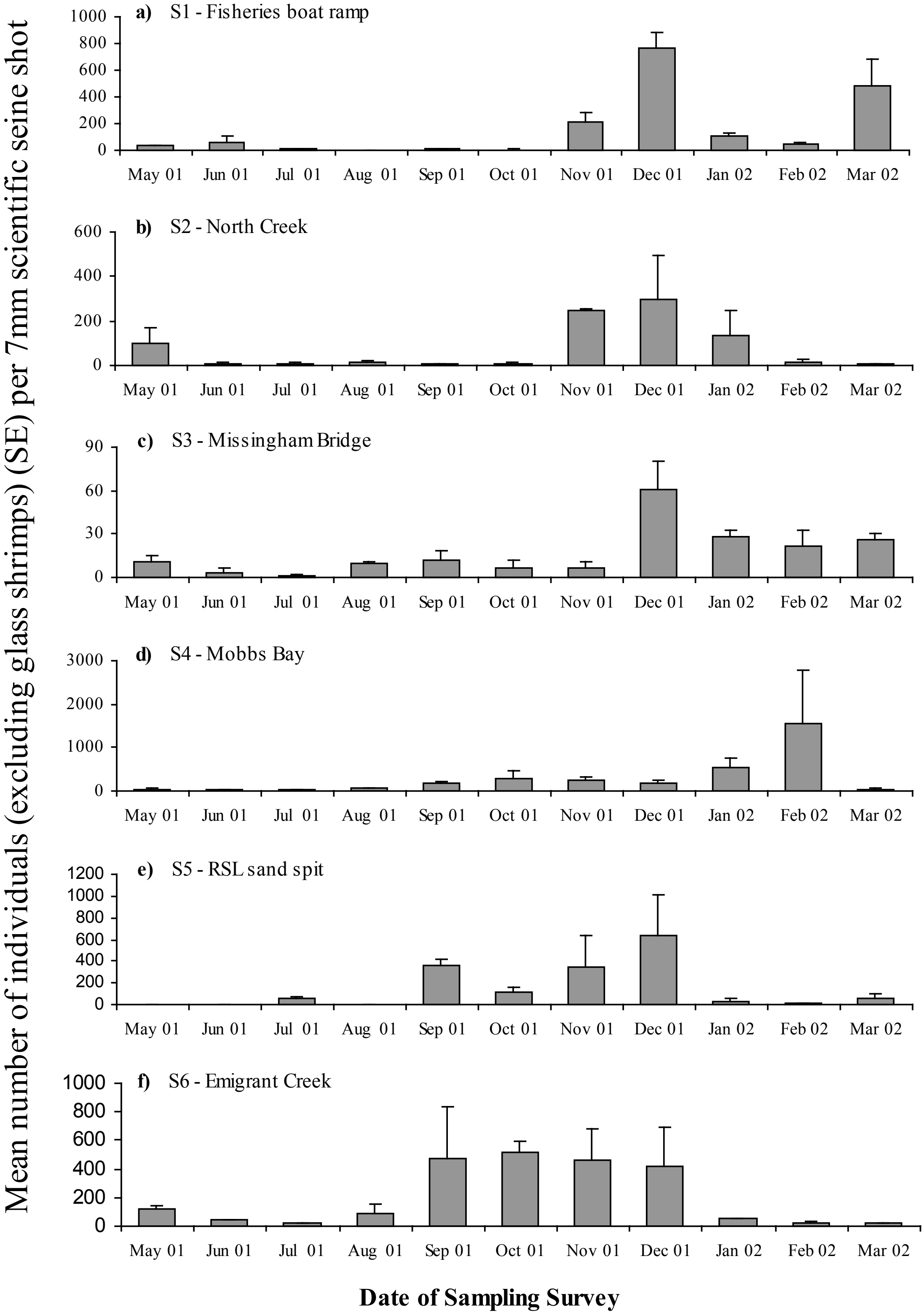

Figure 26. Mean number of individuals (excluding glass shrimps) (+SE) caught per 7mm mesh scientific seine shot. Data are for sites S1 to S6, during each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

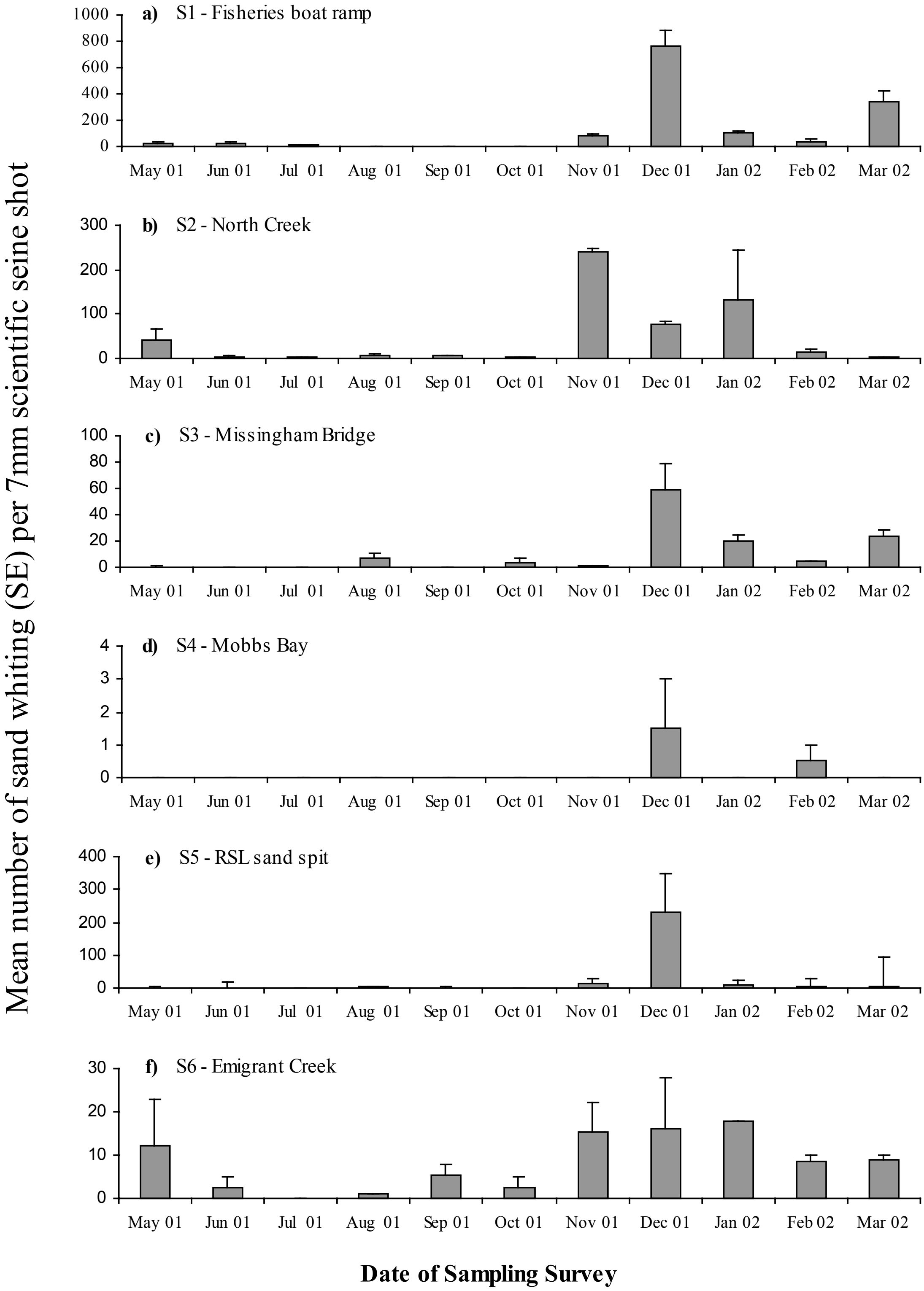

Figure 27. Mean number of sand whiting (+SE) caught per 7mm mesh scientific seine shot. Data are for sites S1 to S6, during each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

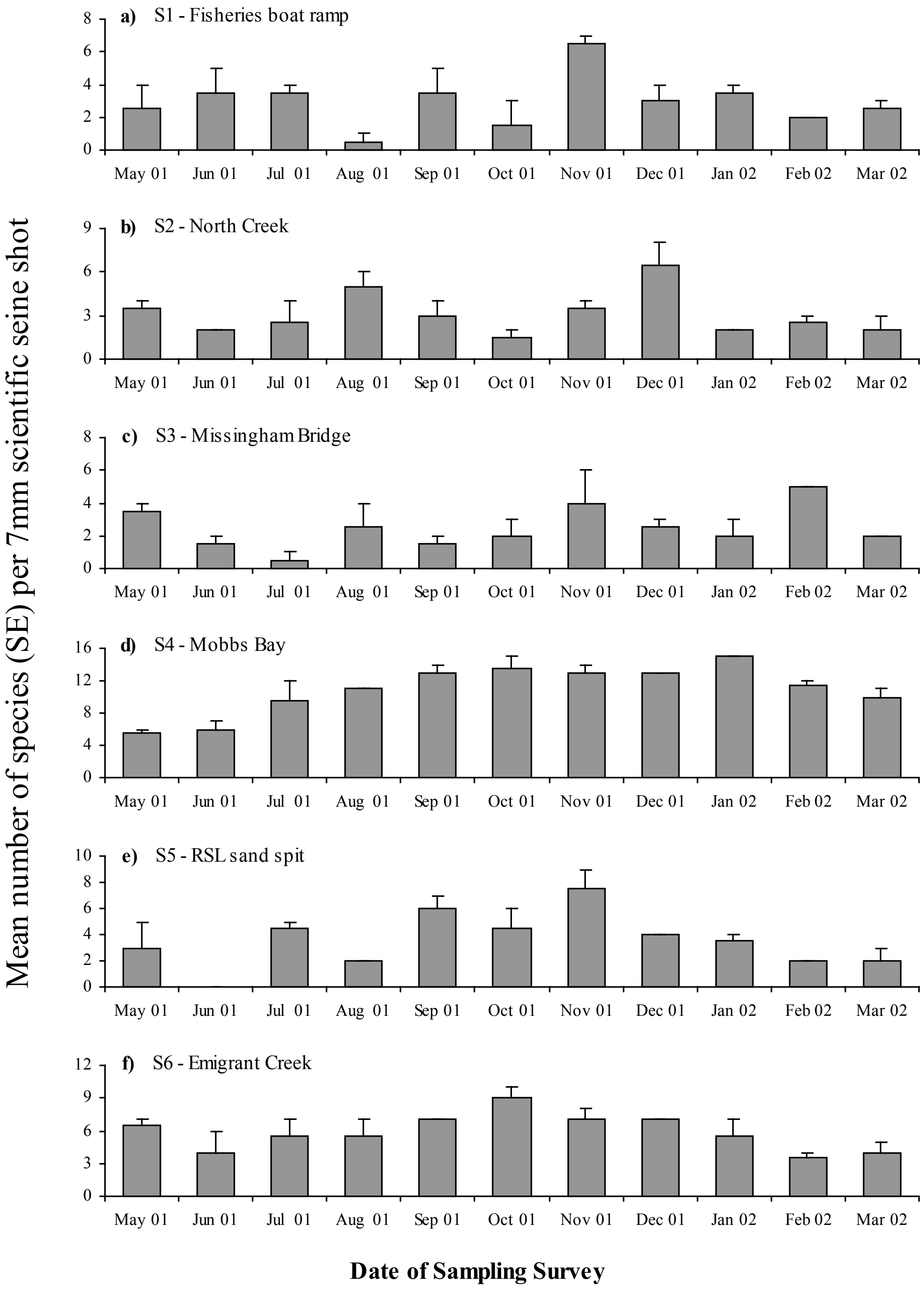

Figure 28. Mean number of species (+SE) caught per 7mm mesh scientific seine shot. Data are for sites S1 to S6, during each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mid-Feb 01" survey - "Mar 02" survey).

4. DISCUSSION

4.1. General overview

Considering the urgent response to the Richmond River fish kill that was required by NSW Fisheries and other government agencies and local government groups, in general the methods of sampling chosen and the sampling designs implemented sufficiently addressed the main aim of the monitoring programme, which was to provide the necessary biological information (i.e. the distribution and relative abundance of fish and crustaceans) and water quality information required to make fisheries management decisions as to if, when and how the fishing closure placed on the Richmond River should be lifted. The outstanding cooperation between local fishers and other interest groups and NSW Fisheries staff with respect to organising the monitoring programme was paramount to the successful implementation of the sampling surveys.

The continuation of monitoring well past the time of the re-opening of the river to fishing (i.e. 1 October 2001), provided valuable information regarding the response of the recovering populations of fish and crustaceans to the resumption of recreational and commercial fishing in the river. In addition, a better understanding of the rates of recovery of populations of fish and crustaceans in the river after a fish kill event was facilitated by acquiring better information regarding the natural state of these populations in the river. Certainly the results from this monitoring programme, along with those reported by Westlake and Copeland (2002) regarding the causes and immediate effects of the fish kill, and Steffe and Macbeth (2002) regarding the extent of the recreational catch upon the re-opening of the river, provide a better understanding of the response of the biological communities in and around estuaries to major fish kill events such as this one. This in turn will allow for better planning of management responses to such events in the future.

One issue that raised concern was the low catches in the regular daytime mesh netting, especially from the July 2001 survey onwards. It is most likely that the main contributing factor to these low catch rates was the necessarily rigid sampling regime, which was initially designed with the conditions in the river immediately following the fish kill, as well as the time of year of the earlier surveys, in mind. No plans for a long-term monitoring programme had been considered at that time. During this ongoing monitoring programme, however, the extra daytime and the nightime meshing that was done addressed the issue to some degree by confirming the presence of large numbers of fish in the river in spite of the poor catches achieved during the regular daytime meshing. Refining the rigid sampling design to provide more flexibility with respect to the exact locations of mesh net sets might be a step in the right direction in formulating a response to similar situations in the future.

The responses of the populations of fish and crustaceans to the situation in the river after the fish kill varied by species. Following is a discussion of the temporal improvement in water quality in the river, as well as a detailed discussion of the responses to this improvement exhibited by the various species encountered during the monitoring programme.

4.2. Water quality

The water quality parameters measured during the monitoring programme indicated that the improvement in water quality detected during the first couple of months since February 2001 throughout the river was maintained (Figure 6) and that the water quality from March 2001 onwards was generally quite good. These results are consistent with those documented by Westlake and Copeland (2002).

At the time of the first survey (Mid-February 2001), the water in the river downstream of Woodburn (i.e. the middle and lower stretches) was essentially fresh, very low in dissolved oxygen and very turbid (Figure 6). It took over a month from this time for the waters in this section of the river to return to a relatively healthy condition. Thus approximately 6 weeks were required from the time of the flood and subsequent fish kill for the water quality in the main river to improve to levels close to normal. Interestingly, it took several months for the return of higher salinity levels the middle and upper stretches (Figure 6c). This could possibly have been a factor in the slow recovery of some of the more marine species (e.g. luderick and sand whiting) in the main river channel upstream of Burns Point Ferry.

The trough in the salinity and conductivity levels evident at the time of the December 2001 survey (Figure 6c and d) can be explained by a short period of heavy rainfall in the river catchment immediately prior to that survey. It is interesting to note that it took less than a month for the salinity and conductivity levels to return to normal levels at that time of year. This is in contrast to the aforementioned longer-lasting effects of the much more severe February flood on the salinity and conductivity of the water in the river.

4.3. School prawn

Catches of school prawns in the lower Richmond River increased during the period of the four-weekly surveys from virtually zero in February to an average of ~ 5 kg per prawn haul shot in the late April survey. Similar catch rates were achieved during subsequent surveys, suggesting that the stock of adult prawns in the river had stabilised by the April 2001 survey. After the September 2001 survey the catch rates declined steadily (Figure 7), possibly due to the effects of the resumption of commercial prawn hauling or, alternatively, some seasonal influence. More likely this decline was due to a combination of both of these factors. In any case, prawn catches during the last two surveys (February and March 2001) were again particularly good.

The distribution of prawns with respect to the upper, middle and lower stretches of the river fluctuated throughout the monitoring programme (Figure 7). One possible explanation for these fluctuations is the varying state of the tide at particular locations during our sampling there. It is known, for example, that increased catches of prawns tend to occur when shots are done during slack water (i.e. during the peak of high tide and the trough of low tide), with reduced catches occurring when the tide is running faster. The distribution of prawns in the river may also be influenced by the input of fresh water from the river catchment. This explanation is supported by data from the May and July 2001 surveys. In May, a large freshwater input was experienced from the catchment prior to the May survey, and the prawn hauling results showed the prawns to be in greatest abundance in the lower stretch. In contrast, there was a lack of rainfall in the weeks leading up to the July survey which continued to the August survey, and the prawn hauling results here indicated that prawns were in greatest abundance in the upper stretch at the times of those surveys. Interestingly, there was, however, a large input of freshwater prior to the December 2001 survey, but prawns remained in the upper stretch in relatively large quantities (Figure 7).

Although catch rates of school prawns in the commercial prawn hauling gear from April 2001 onwards generally approached the catch rates recorded in the spring – summer 1998-99 prawn haul observer programme, interpretations of this comparison must be made with caution and a number of points need to be considered. First, an assumption in any such comparison is that the prawn hauling gears and operations used were very similar to those that were used by the prawn haul fishers in the Richmond River during the 1998-99 observer programme. Second, the original observer programme occurred between the months of September and March, confounding any direct comparison with results from the surveys between February 2001 and August 2001. Third, the 1998-99 observer sampling was of a moderately fished school prawn population as opposed to the current sampling which was of a recovering population that had not recently been fished commercially. Fourth, these two datasets were collected more than 2 years apart, confounding any impacts of the fish kill with temporal fluctuations among years. Finally, and probably most importantly, normal commercial prawn hauling operations generally involve active "chasing" of the prawns. That is, the fishers do trial shots at a site and if quantities of prawns are present more shots are done, while if the prawns are few or absent, another site is trialled. This is, of course, more conducive to greater catch rates than a spatially and temporally rigid sampling design such as that employed during this monitoring programme.

4.4. Sea mullet

Catches of sea mullet in the regular daytime mesh net sets in the lower Richmond River during the first (Mid-February 2001) survey were very low, although the catches improved steadily from that survey to the relatively large catches recorded during the June 2001 survey (Figure 18). Although relatively low numbers of sea mullet were caught in the regular daytime mesh net sets completed since the June 2001 survey (Figure 18), the very large numbers caught during the night diver net sets in the upper stretch of the river during the July 2001 survey (Table 8) suggest that considerable recolonisation of the upper reaches of the system by this species had occurred by that time.

The small catches of sea mullet using the floating (surface set) mesh nets during the late-winter and early-spring months (July to October) may be attributed to a decrease in water temperature, particularly closer to the surface, which would be expected at that time of year. The detection of only slightly saline water near the surface in the upper stretch during the late-winter and early-spring months (Figure 6) indicates that the water nearer the riverbed could have possibly been more saline (known as "sweet" water by the fishers). This bottom water may also have been slightly warmer than the surface water during the winter. Consequently, the sea mullet may be attracted to this slightly warmer and more saline water nearer the river bed during the winter months. However, the fact that the small catches of sea mullet continued through into the summer months (Figure 18) suggests that other factors are involved. A substantial catch of sea mullet in the extra mesh net set done inside Swan Bay – a tributary to the main river channel in the upper stretch – during the September 2001 survey (Table 11) suggests that most of the mullet in the river may have been present in these tributaries, which were not sampled as part of the regular daytime mesh netting. The fact that the water quality in other tributaries similar to Swan Bay took much longer to improve than that in the main river (Westlake and Copeland, 2002) may explain why better catches came from the regular daytime mesh netting during the earlier surveys (March to June 2001), than those daytime surveys carried out after June 2001.

Quite a few juvenile sea mullet were caught in the scientific seine nets during the monitoring programme (Tables 13, 14 and 15), indicating that substantial larval and/or juvenile recruitment of this species had occurred since the fish kill.

4.5. Yellowfin bream

Results from this post-fish kill monitoring programme indicated that the yellowfin bream population in the lower Richmond River has, in general, recovered since the February fish kill. Small numbers of yellowfin bream were caught in prawn haul shots in every sampling survey (Figure 14), suggesting that this species was fairly quick to begin recolonising the river. Results from the crab trapping (Figure 21) and the extra mesh net sets at Burns Point Ferry (Table 10) support this conclusion.

Although catches of yellowfin bream from crab traps declined after the July 2001 survey and remained at relatively low levels for the remainder of the monitoring programme (Figure 21), the relatively high catches of bream in crab traps during the earlier surveys indicated that yellowfin bream were consistently present in the lower stretch of the main river at that time.

The extra night mesh net sets done in the river near Ballina during the May 2001 survey indicated that bream were present in that part of the river in quite large numbers at that time (Table 5). The results reported from the recreational fishing survey, which was begun at the start of July, confirmed that the bream population in the lower stretch of the river downstream of Burns Point Ferry had recovered to levels considered sustainable to normal commercial and recreational fishing activities in the river by July (Steffe and Macbeth, 2002).

The aforementioned reduction in the numbers of bream caught in crab traps in the lower stretch of the river after the July 2001 survey may be due to a variety of factors. The resumption of recreational fishing downstream of the Burns Point Ferry during July may have had an impact on the bream stocks throughout the lower stretch of the main river, especially considering the numbers of bream estimated to have been caught by recreational fishers after the opening of the river (Steffe and Macbeth, 2002). Alternatively, seasonal variation in the abundances of these fish, and/or in the catchability of the fish (i.e. in relation to spawning aggregations), may account for the observed temporal variation in the abundance of bream in the river. A combination of these factors is a likely cause of the reduced catches observed.

Confirmation of the presence of bream in the upper stretch near Coraki from the results of the additional night meshing done during the June and July 2001 surveys (Tables 7 and 8), indicated that at least some bream had recolonised the upper reaches of the river by that time. In addition, the numbers of juvenile bream caught in the prawn haul shots in the upper stretch increased steadily from the November 2001 survey to the relatively high numbers caught during the two most recent surveys (February and March 2002) (Figure 14), suggesting that yellowfin bream may be moving upstream in greater numbers.

Quite a few very small juvenile yellowfin bream were caught in the scientific seine shots done at the Mobbs Bay site during the August 2001 survey and in subsequent surveys, confirming larval and/or juvenile recruitment of this species to the lower Richmond River since the fish kill.

4.6. Luderick

Results from the regular daytime meshing (Figure 19), extra meshing done at Burns Point Ferry (Table 10) and the night meshing done near the mouth of the river (Tables 4 and 5) during this post-fish kill monitoring programme indicated that the luderick population in the lower Richmond River was certainly recovering during the earlier surveys between April and July 2001. The subsequent reduction in luderick catches in the regular daytime mesh netting during the August 2001 survey, which then persisted throughout all of the remaining surveys, could be due to a number of factors. As with bream, it is possible that the resumption of recreational fishing downstream of Burns Point Ferry during July may have had an impact on the stocks of luderick throughout the lower stretch of the main river, especially considering the very large numbers of luderick estimated to have been caught by recreational fishers after the opening of the river (Steffe and Macbeth, 2002). Alternatively, seasonal variation in the abundances, and/or the dispersion of spawning (or recently spawned) aggregations of luderick may account for the observed temporal variation in abundance of luderick in the river. A combination of all of these factors is most likely.

Although very few luderick were caught in daytime mesh net sets during surveys completed after the July survey, very high estimates of luderick catches calculated from the recreational fishing survey (which started in July 2001) confirmed that a large population of luderick existed in the lower stretch of the river downstream of the Burns Point Ferry at that time (Steffe and Macbeth, 2002).

Very small juvenile luderick were caught in the scientific seine shots done at the Mobbs Bay seagrass site from the August 2001 survey onwards, confirming some larval and/or juvenile recruitment of this species to the lower Richmond River.

4.7. Sand whiting

Sand whiting catches in the main river upstream of Burns Point Ferry remained very low throughout most of the monitoring programme, with a total of only 9 whiting being caught during all of the regular daytime mesh netting (Table 9). In general, there was an increase in the catches of whiting in prawn haul shots from the November 2001 survey onwards, with most of the whiting caught during the February and March 2002 surveys coming from the upper stretch (Figure 12). This is a clear indication that, although it took many months for the catches of whiting in the main river channel to discernibly increase, recolonisation of the upper stretch of the river by this species had occurred by March 2002. It is also possible that there is some sort of seasonal influence on the distribution and abundance of the sand whiting throughout the main river.

The estimates of sand whiting catches during the recreational fishing survey (July to October 2001, inclusive) certainly suggested that sand whiting were present in reasonably healthy numbers in the lower part of the river downstream of Burns Point Ferry at that time (Steffe and Macbeth, 2002). Interestingly, only a few whiting were caught during the night mesh net sets in that part of the river during the May and June 2001 surveys (Tables 4 and 5).

Reasonably consistent catches of small juvenile sand whiting throughout the post-fish kill monitoring programme indicated a quite healthy larval recruitment of this species to the estuary. Juvenile sand whiting were caught in reasonable quantities in 25mm mesh scientific seine shots in the lower stretch of the river near the mouth during the first (Mid-February 2001) survey (Figure 24), indicating that sand whiting may have been very quick to begin to recolonise the lower stretch of the river downstream of the Burns Point Ferry via post-larval recruitment. Although catches of whiting using this net decreased over the late-winter and spring months (Figure 24), the increase in the numbers caught during the summer months illustrates a seasonal pattern of post-larval recruitment. This pattern is more or less evident with respect to the trends in catches of sand whiting using the 7mm mesh seine net also (Figure 27).

4.8. Dusky flathead

Catches of dusky flathead in the main part of the river upstream of Burns Point Ferry during the monitoring programme were restricted to 9 individuals caught during the regular daytime mesh netting (Table 9), and 21 caught in the prawn haul shots (Table 3). Some of these fish were, however, quite large individuals. In any case, there did not seem to be any clear temporal patterns associated with dusky flathead catches in the main river throughout the monitoring programme (Figure 15).

The estimates of dusky flathead catches during the recreational fishing survey (July to October 2001, inclusive) indicated that dusky flathead were present in numbers considered sustainable to normal commercial and recreational fishing activities in the lower part of the river downstream of Burns Point Ferry at that time (Steffe and Macbeth, 2002). In addition, some good sized dusky flathead (> 40 cm length) were recorded in prawn haul shots in the upper stretch for the first time during the August 2001 survey, indicating that recolonisation of the upper stretch of the river by this species had occurred by that time.

Although never caught in large numbers, juvenile dusky flathead were caught regularly in the scientific seine shots in the lower stretch near the mouth of the river throughout the monitoring period, indicating successful larval and/or juvenile recruitment of this species to the lower Richmond River since the fish kill.

4.9. Mulloway

As with yellowfin bream, mulloway was a species fairly quick to begin recolonising the main river upstream of Burns Point Ferry. Relatively large numbers of juvenile mulloway (<25 cm) were caught in prawn haul shots in the lower stretch of the river during the first few surveys (Figure 9). Although these large catches decreased during subsequent surveys, the distribution of mulloway appeared to have steadily spread into the middle and upper stretches by the July 2001 survey (Figure 9).

The presence of large mulloway in the lower river was confirmed during the April 2001 survey, with a good catch of large mulloway (36 fish ~ 500 kg total) being taken in night mesh sets near the mouth of the river (Table 4). A couple of large fish were also caught in night mesh sets at the same spot during the May 2001 survey (Table 5). The presence of these large predators suggests that there may have been large numbers of smaller fish in the lower part of the river near the mouth at that time.

4.10. Australian bass

The large quantities of Australian bass caught in the night mesh net sets in the upper stretch during the July 2001 survey (Table 8) suggests that a sizeable population of bass still exists in the Richmond River system. It is more than likely that, although many bass were killed during the fish kill, the majority of the population may have been far enough upstream to have avoided the lethal water in the lower reaches of this system at the time of the fish kill.

4.11. Mud crabs

Catches of mud crabs from the crab traps set in the lower stretch of the river were reasonable during the first (Mid-February) survey (Figure 20), suggesting that mud crabs may have recolonised the lower stretch of the river quite quickly or, alternatively, many crabs may have survived the fish kill, as there were many reports of mud crabs crawling up the banks of the river and out of the water at the time of the fish kill. More likely it is a combination of both of these possibilities.

Mud crab catches increased, then remained reasonably steady between the March 2001 survey and the June 2001 survey (Figure 20), suggesting that the population of mud crabs had possibly recovered and stabilised during those earlier months. However, catches during the spring months were substantially less than those catches during the earlier surveys (Figure 20). One possible explanation for this would be a reduction in the catchability of crabs in traps (as would be expected at this time of year) due to seasonal influences. Alternatively, increased fishing activities since the opening of the river to mud crab trapping may have reduced the mud crab population. In any case, catches during the February 2002 survey had returned to levels recorded during the surveys done in the first half of 2001 (Figure 20), suggesting that populations of mud crabs had indeed recovered relatively quickly after the fish kill and that the fluctuations in catch rates observed during the monitoring programme are most likely due to seasonal influences.

4.12. Other species of commercial and recreational importance

Comparatively smaller numbers of a variety of other commercially and/or recreationally important species were caught in the Lower Richmond River during the monitoring programme. These species included tailor, tarwhine, black sole, large-toothed flounder, long-finned eel, blue swimmer crab, forktail catfish, estuary catfish, flattail mullet, sand mullet and silver biddy. Forktail catfish were very quick to recolonise the main river channel after the fish kill (Figure 10), while interestingly, no silver biddies were caught in the river at all until the June 2001 survey (Figure 13). It is possible that the fish kill killed the entire population of silver biddies in the river system and that the natural seasonal pattern of migration and/or larval recruitment may have delayed the recolonisation of the river by this species until mid-year.

4.13. Species of non-commercial/recreational importance

The non-commercially or recreationally important species caught in significant quantities during the monitoring programme were bullrout, pinkeye mullet, southern herring, bottle squid and many-banded sole in the main river, while many glass perch and glass shrimps, along with a variety of species of gobies and toadfish, were caught in the scientific seine nets nearer the mouth of the river. Certainly, the variety of species caught in the scientific seine nets near the mouth of the river throughout the monitoring programme confirmed that the communities of fish and crustaceans associated with sandy substrates and/or the seagrass habitat exhibited considerable diversity with respect to the species present.

4.14. General conclusions

The question of whether the stocks of commercially and recreationally important fish and crustaceans have recovered to pre-fish kill levels cannot be answered directly because we do not have any detailed information describing the status of these fish and crustacean stocks in the Richmond River immediately before the fish-kill event, and nor do we have comparable information about fish and crustacean communities in other non-impacted estuaries in the region that could be used as controls or reference sites. Therefore, we are primarily restricted to making inferences about the recovery of the fish and crustacean populations from interpreting spatial and temporal trends in the distribution and abundance of fish and crustaceans apparent in the data collected as part of this monitoring programme.

In general, relative to the months immediately following the fish kill by the time the fishing restrictions were lifted, populations of fish and crustaceans in the Richmond River had recovered to levels which could sustain normal commercial and recreational fishing practices. Some species appeared to recover relatively quickly in the main river channel to levels that have been more or less maintained since (e.g. school prawn, mud crab, sea mullet, yellowfin bream and juvenile mulloway), while some other species took much longer to recover (e.g. sand whiting and silver biddy). In contrast, some species recovered in the lower part of the estuary (i.e. downstream of the Burns Point Ferry) quite quickly, but were quite slow to recolonise the main river channel (e.g. luderick).

Normal recreational fishing activities, which have been allowed in some parts of the river since 1 July 2001, and normal commercial fishing activities, which have been allowed since 1 October 2001, may have been minor influencing factors in the fluctuations detected in the relative abundances of some species subsequent to the lifting of the fishing restrictions. However, natural seasonal variations in the abundances of these fish, and/or in their catchability, are the most likely influences on the results observed in this monitoring programme after the re-opening of the river.

5. RECOMMENDATIONS

On the basis of the above findings, the following recommendations are made:

1. This post-fish kill monitoring programme provided invaluable information to fisheries scientists and managers with respect to the status of recovering populations of fish and crustaceans in the lower Richmond River following the fish-kill event of February 2001. A similar sampling programme should be implemented if a fish kill (or an equivalent ecological emergency) were to occur again in this or another NSW river or estuary in the future.

2. Fishery-independent sampling surveys should also be done on a regular basis in NSW rivers and estuaries to provide data regarding the status of fish and crustacean populations at times of relative health of these rivers and estuaries. These would provide valuable baseline information that could be used for the purpose of comparison should a fish kill (or an equivalent ecological emergency) occur in any NSW river or estuary in the future.

3. Further work should be undertaken to develop a standard sampling design protocol for use in similar monitoring programmes that will probably be necessary in the future. This would require detailed review of the techniques used and analyses of the data collected during this present monitoring programme. The development of robust and reliable sampling regimes would result in more accurate overall assessments of the status of populations of fish and crustaceans in any given river or estuary.

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SECTION 2

Macbeth, W.G, Pollard, D.A., Steffe, A.S., Morris, S. and Miller, M. (2002). Relative abundances of fish and crustaceans and water quality following the fish kill of March 2001 in the Macleay River, northern New South Wales. Pages 61 – 100 in: Kennelly, S.J. and McVea, T.A. (Eds) (2002). *'Scientific reports on the recovery of the Richmond and Macleay Rivers following fish kills in February and March 2001'*. NSW Fisheries Final Report Series. No. 39. ISSN 1440-3544.

Relative abundances of fish and crustaceans and water quality following the fish kill of March 2001 in the Macleay River, northern New South Wales

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April 2002

ACKNOWLEDGEMENTS

The following NSW Fisheries staff are thanked for their contributions to this study:

Dr Steve Kennelly for his editorial comments on this report, as well as Brett Rankin, Darren Reynolds and Cairo Forrest for assisting with the fieldwork during the monitoring programme.

Ted Byrnes, Dennis Cook and Darren Cook (commercial fishers, Macleay River) are wholeheartedly thanked for their guidance and assistance with the sampling operations.

EXECUTIVE SUMMARY

Following major flooding and minor fish kills upstream in the Macleay River system just before the middle of March 2001, a major fish kill occurred in the lower part of the system around 15 - 19 March 2001. Available information indicates that the flood led to deoxygenation of the water in the main river and that this was the direct cause of the fish kill. The evidence strongly suggests that most fish and crustaceans were either flushed or actively migrated from the river system, or were killed by the anoxic water during the period of the fish kill.

Water quality monitoring was maintained on a regular basis by the Kempsey Shire Council for approximately 1 month after the fish kill (Westlake & Copeland, 2002). On 19 March 2001, dissolved oxygen levels measured near the river mouth at the entrance to the North Arm were below 0.4 mg/L (normal healthy estuarine conditions are above 5.0 mg/L). Dissolved oxygen levels at this time in some of the inflowing tributaries and flood drains further upstream were as low as ~ 0.2 mg/L, although pH measurements (a measure of acidity) were all around or above 6 (7 being neutral). In general, water quality in the river gradually improved during the first month following the fish kill (Westlake & Copeland, 2002), and had certainly returned to acceptable levels by early-July 2001.

The fish kill was most severe downstream of Jerseyville towards the river mouth, with large quantities of dead fish being washed up on the shore in this area (Westlake & Copeland, 2002). Species involved in the kill included yellowfin bream, sand whiting, dusky flathead, sea and pinkeye mullet, luderick, silver biddy, long-finned eel, estuary cod, Australian bass, mud crab and school prawn, together with a number of smaller non-commercial species such as gudgeons, gobies, mosquitofish and toadfish.

The river and adjacent inshore ocean waters were closed to all fishing for an initial period of approximately three and a half months immediately following this fish kill. The first of 13 post-fish kill sampling surveys was done during the latter half of March 2001, approximately one week after the fish kill. The sampling surveys were continued throughout this three and a half month period.

The fishing closure in the Macleay River was lifted to some types of fishing on 1 July 2001. From this date, limited recreational line fishing was allowed downstream of Kinchela (only from 6am to 7pm; bag limit of 10 fish in total; no more than 5 bream and no more than 1 mulloway). In addition, commercial and recreational crab trapping and eel trapping was allowed throughout the river, along with commercial mesh netting downstream of Kinchela. This partial fishing closure was then lifted fully on 28 September 2001, from which date normal commercial and recreational fishing practices were allowed. The regular four-weekly sampling surveys of the fish and crustacean populations in the river were then continued throughout the partial closure and then when the river was fully opened to fishing, up until March 2002.

In summary, there were three main objectives of the four-weekly sampling surveys of the fish and crustacean populations in the river done as part of the post-fish kill monitoring programme:

1. to provide the necessary biological and water quality information required to make fisheries management decisions as to if, when and how the fishing closures in the river should be lifted;
2. to monitor for any possible deleterious effects relating to the resumption of fishing activities once these closures were lifted; and
3. to contribute useful information regarding the "normal" state of stocks in the river for the purpose of comparisons with data collected during the initial surveys conducted immediately after the fish kill.

A regular, structured sampling regime was designed and implemented with the help of local commercial fishers and other stakeholder groups in order to monitor the recovery of the fish and crustacean populations in the river immediately following the fish kill. These four-weekly sampling surveys incorporated the use of three commercial fishing methods to regularly sample the biota in the river – mesh netting, crab trapping and eel trapping. Regular scientific seining involving the use of small-mesh seine nets was also done, as was the collection of water quality information.

The question of whether the stocks of fish and crustaceans have now recovered to pre-fish kill levels could not be answered directly because we did not have detailed information describing the precise status of these fish and crustacean stocks in the Macleay River immediately before the fish-kill event, and nor did we have comparable detailed information about fish and crustacean communities in other non-impacted estuaries in the region that could be used as controls or reference sites. Therefore, we were thus primarily restricted to making inferences about the recovery of the fish and crustacean populations by interpreting spatial and temporal trends in the distribution and abundance of fish and crustaceans which were apparent in the data collected as part of this monitoring programme.

In general, by the time the fishing restrictions were lifted, the populations of fish and crustaceans in the Macleay River had recovered to levels that could sustain normal commercial and recreational fishing practices, comparable to the levels during the months immediately prior to the fish kill. Some species appeared to recover relatively quickly in the main river channel to levels that have been more or less maintained since (e.g. mud crab, sea mullet, yellowfin bream, long-finned eel and pinkeye mullet), while some other species took longer to recover (e.g. luderick and sand whiting).

Increased commercial and recreational fishing activities (which have been allowed in some parts of the river since 1 July 2001) and normal recreational and commercial fishing activities (which have been allowed since 1 October 2001) may have been minor influencing factors in fluctuations detected in the relative abundances of some species subsequent to the lifting of fishing restrictions. However, it is important to consider that natural seasonal variations in the abundances of these fish, and/or in their catchability, are the most likely major influences on the results observed in this monitoring programme.

This post-fish kill monitoring programme provided invaluable information to fisheries scientists and managers with respect to the status of recovering populations of fish and crustaceans in the lower Macleay River following the fish-kill event of March 2001. A similar sampling programme should be implemented if a fish kill (or an equivalent ecological emergency) was to occur again in this or another NSW coastal river or estuary in the future.

Fishery-independent sampling surveys should also be done on a regular basis in NSW rivers and estuaries to provide data regarding the status of fish and crustacean populations at times of relative health of these rivers and estuaries. This would provide valuable baseline information that could be used for the purpose of comparison should a fish kill (or an equivalent ecological emergency) occur in any NSW river or estuary in the future.

Further work should be undertaken to develop a standard sampling design protocol for use in similar monitoring programmes that will probably be necessary in the future. This would require detailed review of the techniques used and analyses of the data collected during this present monitoring programme. The development of robust and reliable sampling regimes would result in more accurate overall assessments of the status of populations of fish and crustaceans in any given river or estuary.

1. INTRODUCTION

Following a significant flooding event and minor fish kills upstream in the Macleay River system just before the middle of March 2001, a major fish kill in the lower part of the system occurred around 15 - 19 March. Available information indicated that the flood led to deoxygenation of the water in the main river and that this was the direct cause of the fish kill. The evidence strongly suggested that most fish and crustaceans were flushed or migrated actively from the main river, or were killed by the anoxic water during the period of the fish kill.

This fish kill was most severe downstream of Jerseyville towards the river mouth, with large quantities of dead fish being washed up on the shore in this area (Westlake & Copeland, 2002). Species involved in the kill included yellowfin bream, sand whiting, dusky flathead, sea and pinkeye mullet, luderick, silver biddy, long-finned eel, estuary cod, Australian bass, mud crab and school prawn, together with a number of smaller non-commercial species such as gudgeons, gobies, mosquitofish and toadfish.

Water quality monitoring was maintained on a regular basis by the Kempsey Shire Council for approximately 1 month after the fish kill (Westlake & Copeland, 2002). On 19 March 2001, dissolved oxygen levels measured near the river mouth at the entrance to the North Arm were below 0.4 mg/L (normal healthy estuarine conditions are above 5.0 mg/L). Dissolved oxygen levels at this time in some of the inflowing tributaries and flood drains further upstream were as low as ~ 0.2 mg/L, although pH measurements (a measure of acidity) were all around or above 6 (7 being neutral).

The river and adjacent inshore ocean waters were closed to all fishing for an initial period of approximately three and a half months immediately following this fish kill. The first of 13 post-fish kill sampling surveys was done during the latter half of March 2001, approximately one week after the fish kill. The initial objective of these surveys was to provide the necessary biological information (i.e. the distribution and relative abundance of fish and crustaceans) and water quality information required in order to make fisheries management decisions as to if, when and how the fishing closure in the Macleay River should be lifted.

The fishing closure in the Macleay River was lifted to some types of fishing on 1 July 2001. From this date, limited recreational line fishing was allowed downstream of Kinchela (only from 6am – 7pm; bag limit of 10 fish in total; no more than 5 bream and/or 1 mulloway). In addition, commercial and recreational crab trapping and eel trapping was allowed throughout the river, along with commercial mesh netting downstream of Kinchela. A four-month recreational fishing survey was begun on 1 July 2001, the results of which are reported in detail elsewhere (see Steffe & Macbeth, 2002).

The partial fishing closure in force from 1 July was fully lifted on 28 September, following large recreational catches being recorded during the recreational fishing survey, as well as a relatively favourable overall assessment of stocks in the river in the August 2001 sampling survey report. Normal commercial and recreational fishing practices were allowed from 28 September onward. It was decided that the regular four-weekly sampling surveys of the fish and crustacean populations in the river would continue until March 2002 to monitor for any possible deleterious effects relating to the resumption of normal fishing activities. In addition, it was concluded that the continued collection of data after the populations were thought to have recovered to levels which could sustain normal commercial and recreational fishing activities would provide useful information regarding the "normal" state of stocks in the river.

In summary, there were three main objectives of the four-weekly sampling surveys of the fish and crustacean populations in the river done as part of the post-fish kill monitoring programme:

1. to provide the necessary biological and water quality information required to make fisheries management decisions as to if, when and how the fishing closure in the river should be lifted,
2. to monitor for any possible deleterious effects relating to the resumption of fishing activities once these closures were lifted, and
3. to contribute useful information regarding the "normal" state of stocks in the river for the purpose of comparisons with data collected during the initial surveys that were conducted immediately after the fish kill.

The assessment of environmental disturbance or impacts is difficult because it is often uncertain whether a causal relationship exists between the detrimental environmental event that has occurred (e.g. a flood followed by a fish-kill) and any changes that are measured at a later time. The changes in the distributions of fish and crustaceans detected after the fish-kill event include a component attributable to the detrimental flood event and a component due to natural fluctuations of fish populations that occur at various spatial and temporal scales. An appropriate experimental design is needed to discriminate between changes in the distribution and abundance of fish and crustaceans due to the fish-kill event and changes caused by natural fluctuations in abundance and catchability. Ideally, an experiment designed to test for the impacts of the fish-kill event would have included spatial replication at the level of rivers (i.e. other riverine fisheries would be used as controls or reference sites) and these multiple riverine fisheries would have been surveyed before and after the fish-kill event. This type of experimental design is referred to as a Before-After-Control-Impact (BACI) design in the scientific literature. Underwood (1991) provides a detailed description of this type of experimental design.

This post-fish kill monitoring programme undertaken did not, however, meet the rigorous requirements of such a BACI experimental design. There were no comparable data describing the status of the stocks of fish and crustaceans immediately before the unexpected fish-kill event nor were there comparable data describing the status of other riverine fisheries in the region that could be used as control sites. Thus, the data collected during this monitoring programme could only be used to describe the status of the stocks of fish and crustaceans in the lower Macleay River after the fish kill event. We were thus restricted to making inferences about the recovery of the fish stocks in the lower Macleay River from interpreting spatial and temporal trends in the distribution and abundance of fish and crustaceans apparent in the data collected as part of this monitoring programme.

2. MATERIALS & METHODS

2.1. Site description

The Macleay River ($30^{0}52$'S $153^{0}01$'E) is a large river on the mid-north coast of New South Wales (NSW) on the east coast of Australia, with a water area of approximately 18.2 km^2 and a total catchment area of approximately 11,385 km^2 (Roy *et al*. 2001) (Figure 1). The river is open permanently to the ocean and has twin training breakwaters at its entrance. Being a wave-dominated barrier estuary, the Macleay River is more strongly influenced by river discharge than by tide, with tidal ranges being approximately 5-10% less than in the ocean (Roy *et al*. 2001). The main river arm is approximately 150 km in length. For the purpose of monitoring the recovery of fish and crustacean stocks throughout the lower river stretch (i.e. downstream of Kempsey), the extent of the regularly sampled survey area in the lower Macleay River was, for the most part, restricted to waters in the main river between Kempsey and Kemps Corner (near South West Rocks)(Figure 1). Nevertheless, some regular sampling (i.e. crab trapping) was also done in waters in the North Arm (Figure 1). See below for further descriptions of sampling methods and sites.

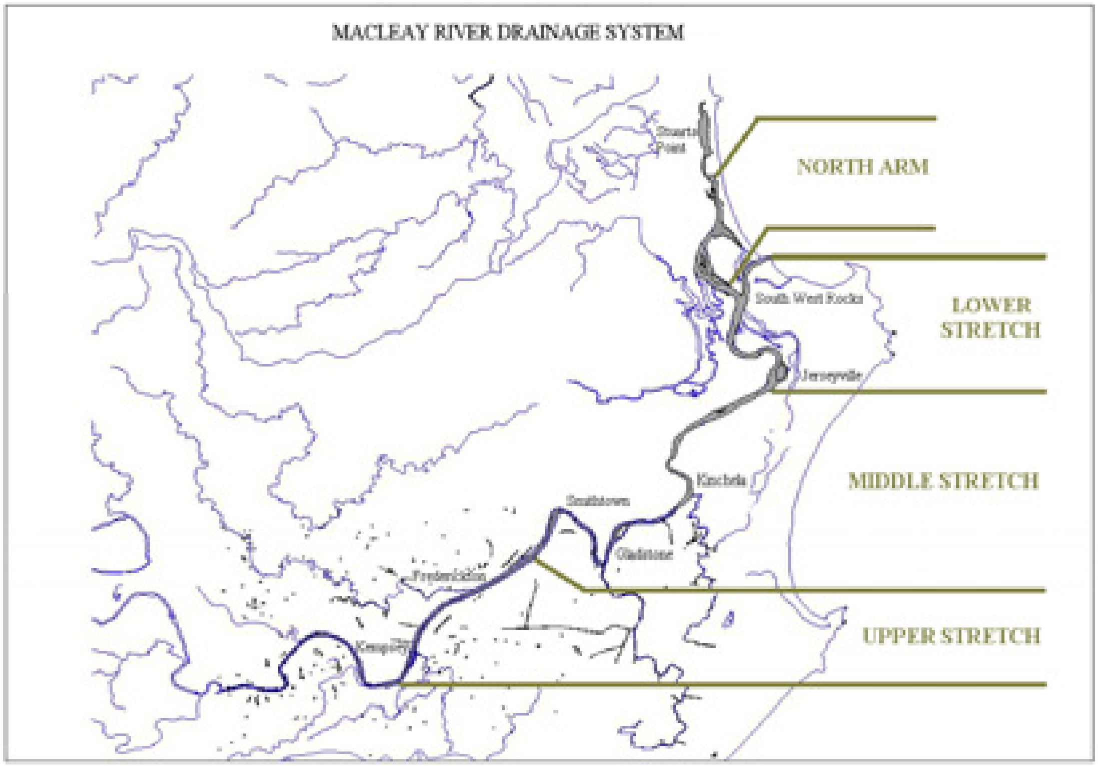

Figure 1. Map showing the categorisation of the lower Macleay River for the purposes of spatial and temporal comparisons, during the post-fish kill monitoring programme. Boundaries of the "Upper stretch", "Middle stretch", "Lower stretch" and "North Arm" are shown.

2.2. Spatial and temporal scales

For the purposes of spatial and temporal comparisons of results, the length of the lower Macleay River system in which monitoring took place was divided into four sections: the upper, middle and lower stretches, and the North Arm (Figure 1). The upper stretch extends downstream from Kempsey to just upstream of Smithtown; the middle stretch is from upstream of Smithtown to just upstream of Jerseyville; the lower stretch is from upstream of Jerseyville to the river mouth, and the North Arm extends approximately 7 km north from its junction with the main river channel near South West Rocks. Data from each of the 13 four-monthly sampling surveys completed during the monitoring programme (March 2001 to March 2002) were classified into the above spatial divisions, allowing valid temporal comparisons with each other. The dates of each sampling survey are shown in Table 1.

The sampling sites chosen for each of the fishing methods were those that were, under normal circumstances, fished regularly at the time of the year of the first (March 2001) survey by local commercial fishermen. The sampling sites defined in the first survey were re-sampled during subsequent surveys in order to maintain a scientifically rigorous sampling regime for monitoring the recovery through time of fauna in the river. The distribution of sampling units with respect to the spatial divisions applied in this survey for each of the sampling methods (mesh nets, traps, seines, etc.) is shown in Table 2. These tallies include any extra sampling that was done aside from the regular sampling regime (e.g. night mesh netting).

Table 1. Dates of each sampling survey done during the post-fish kill monitoring programme in the lower Macleay River.

SAMPLING SURVEY	DATES OF SAMPLING
MARCH 2001	27th March - 30th March , 2001
MAY 2001	30th April - 4th May , 2001
JUNE 2001	7th June - 11th June , 2001
JULY 2001	2nd July - 6th July , 2001
Late-JUL / early-AUG 2001	30th July - 3rd August , 2001
AUGUST 2001	27th August - 31st August , 2001
SEPTEMBER 2001	24th September - 28th September , 2001
OCTOBER 2001	22nd October - 26th October , 2001
NOVEMBER 2001	19th November - 23rd November , 2001
DECEMBER 2001	17th December - 21st December , 2001
JANUARY 2002	7th January - 11th January , 2001
FEBRUARY 2002	11th February - 15th February , 2001
MARCH 2002	11th March - 15th March , 2001

Table 2. Number of sampling units (replicates taken) in the upper (U), middle (M) and lower (L) stretches of the lower Macleay River, for each sampling method during each sampling survey in the post-fish kill monitoring programme.

SAMPLING SURVEY	SAMPLING METHOD					
	WATER QUALITY	MESH NETTING		CRAB TRAPPING	EEL TRAPPING	SCIENTIFIC SEINING
		DAY	NIGHT			
	U M L	U M L	U M L	Lower only	U M L	Lower only
MARCH 2001	1 2 2	2 3 3	- - -	40	- 6 10	11
MAY 2001	- - -	2 3 3	- - -	30	8 13 10	11
JUNE 2001	- - -	2 3 4	- - 1	28	8 16 8	11
JULY 2001	2 3 3	2 3 4	- - -	30	6 12 8	11
Late-JUL / Early AUG 2001	2 3 3	2 3 3	- - -	30	15 11 7	11
AUGUST 2001	2 3 3	2 3 3	- - -	29	4 15 13	11
SEPTEMBER 2001	2 3 3	2 3 3	- - -	30	15 11 7	11
OCTOBER 2001	2 3 3	2 3 3	- - -	30	8 10 8	11
NOVEMBER 2001	2 3 3	2 3 3	- - -	30	11 11 11	11
DECEMBER 2001	2 3 3	2 3 3	- - -	28	10 12 8	11
JANUARY 2002	2 3 3	2 3 3	- - -	33	9 11 10	11
FEBRUARY 2002	2 3 3	2 3 3	- - -	30	9 8 11	11
MARCH 2002	2 3 3	2 3 3	- - -	29	7 12 9	11
TOTALS	85	106	1	397	378	143

2.3. Water quality

During each sampling survey, water quality parameters were measured at approximately 2 metres depth at each mesh netting site in the river using a Horiba U10 Water Quality Meter: 2 in the upper stretch, 3 in the middle stretch and 3 in the lower stretch (Table 2, Figure 2). The three exceptions to this were the first three sampling surveys (March, May and June 2001). Water sampling was only done opportunistically during the March 2001 survey (i.e. not to the protocol described above), while problems with equipment prevented measurements being taken during the May and June 2001 surveys. Water quality parameters measured were dissolved oxygen (mg/L), pH (a measure of acidity/alkalinity), salinity (%), conductivity (mS/cm), turbidity (NTU) and water temperature (degrees C).

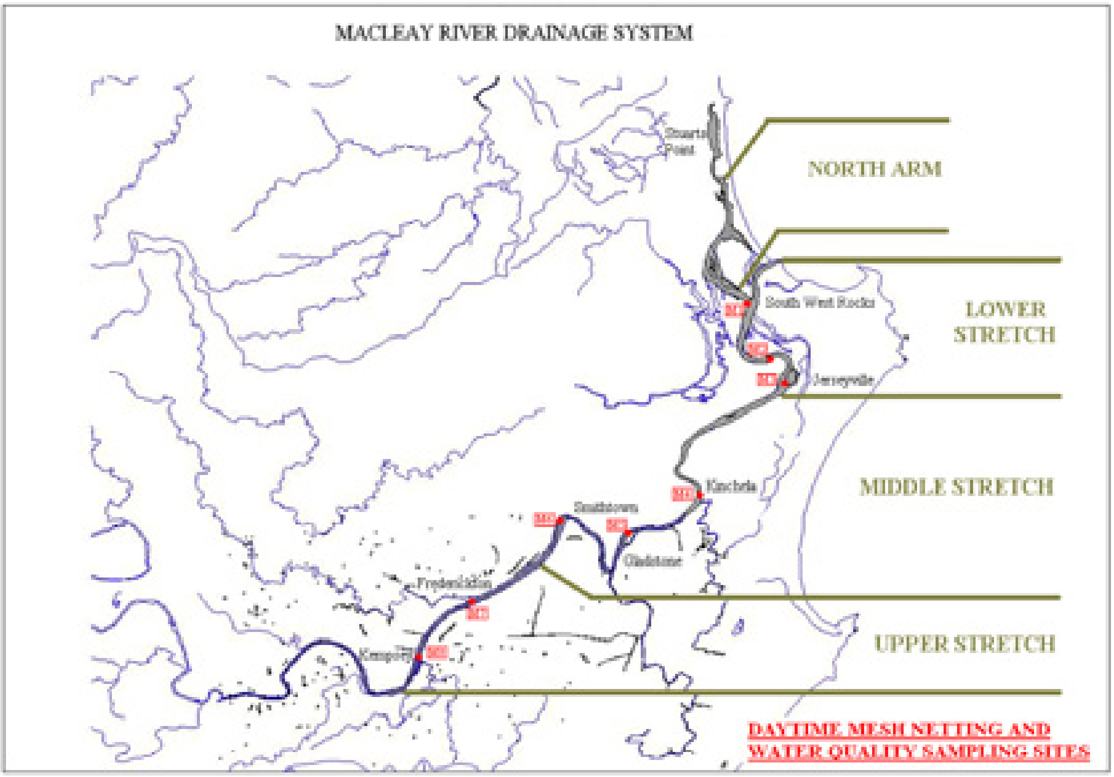

Figure 2. Map showing the regular daytime mesh netting and water quality sampling sites (M1 – M8) in the lower Macleay River sampled during the post-fish kill monitoring programme.

2.4. Mesh netting

Daytime mesh netting was done together with a local commercial mesh netting crew at 8 sites: 2 in the upper stretch, 3 in the middle stretch and 3 in the lower stretch (Table 2 & Figure 2). One mesh net set was done at each site. Two extra daytime mesh net sets were done near Little Spencers Creek in the lower stretch: one during the June 2001 survey and the other during the July 2001 survey. These 2 extra sets were not included in the graphs.

A commercial mesh net comprising a 100 metre length of 72mm mesh-size diver net, connected to a 150 metre length of 82mm mesh-size floating net and a 160 metre length of 104mm mesh-size floating net, was used for all daylight mesh netting. The 72mm section was 25 meshes deep, while the 82mm and 104mm sections were both 50 meshes deep. The net was set for approximately 10 minutes, during which time the fishing vessel was used to frighten any fish into swimming into the net.

All catches were counted and weighed by species. The smallest and largest individuals for each species were measured except in the case of commercially and/or recreationally important species, for which all individuals were measured.

Over and above the regular four-weekly downstream to upstream sequence of daytime mesh net sets in the main river channel, additional mesh netting was carried out at night in the lower stretch of the estuary during the June 2001 survey, using a mesh net composed of a 75 metre length of 178mm mesh-size diver net and a 75 metre length of 204mm mesh-size diver net. It was suggested that greater numbers of larger fish (e.g. mulloway) might be caught within a few kilometres of the mouth of the river (near South West Rocks), at night. Therefore, information gathered from this night set would compliment the information gleamed from the regular four-weekly daytime mesh netting operations.

2.5. Crab trapping

For all surveys, a total of between 28 and 40 crab traps were set, left overnight and retrieved the following morning as per normal commercial crab trapping operations (Table 2). These traps were spread among the middle stretch, lower stretch and the North Arm (Figure 1). The distribution of crab traps in relation to each section of the river is shown in Table 2. Logistical factors, such as tides and the efficient transport of traps, determined the numbers of traps used in each of the sections of the river during each of the surveys.

Two types of crab traps were used during the monitoring programme. Circular traps of approximately 90cm diameter and 30cm depth were used, as were “D”- traps (half-cylinder shape), which were approximately 90cm x 75cm x 50cm deep. There were two crab-entry funnels on each trap. For the purposes of this monitoring programme, it is assumed that the catchability of these two types of traps was identical.

The catches of mud crabs and associated by-catches were counted and weighed by species. The mud crabs were also sexed. All individuals for all of the species caught were measured.

2.6. Eel trapping

For all surveys, a total of between 16 and 33 eel traps were set, left overnight and retrieved the following morning as per normal commercial eel trapping operations (Table 2). These traps were spread among the upper, middle and lower stretches (Figure 1). The distribution of eel traps in relation to each section of the river is shown in Table 2. Logistical factors, such as tides and the efficient transport of traps determined the numbers of traps used in each of the sections of the river, during each of the surveys. It is important to note that no eel traps were set in the upper stretch during the first (March 2001) survey due to logistical constraints.

The eel traps used throughout the monitoring programme measured approximately 92 cm x 50 cm x 45 cm deep. There were two eel-entry funnels on each trap.

The catches of long-finned eels and associated by-catches were counted and weighed by species. The smallest and largest individuals for each of the species caught were measured.

2.7. Scientific seining

An 11 metre long scientific seine net with a 2.3 metre drop and a stretched mesh-size of 7mm was used at three sites in the lower stretch of the river (Jerseyville, Pelican Island and Kemps Corner) during each of the surveys in this monitoring programme (Figure 3). Four replicate shots were done at Jerseyville and Kemps Corner, while three replicate shots were done at Pelican Island. It was thought that the use of this small mesh seine net would catch small fish and crustaceans, hence providing evidence of recently settled juvenile fish in the river.

All catches were counted by species. The smallest and largest individuals for each of the species caught were measured.

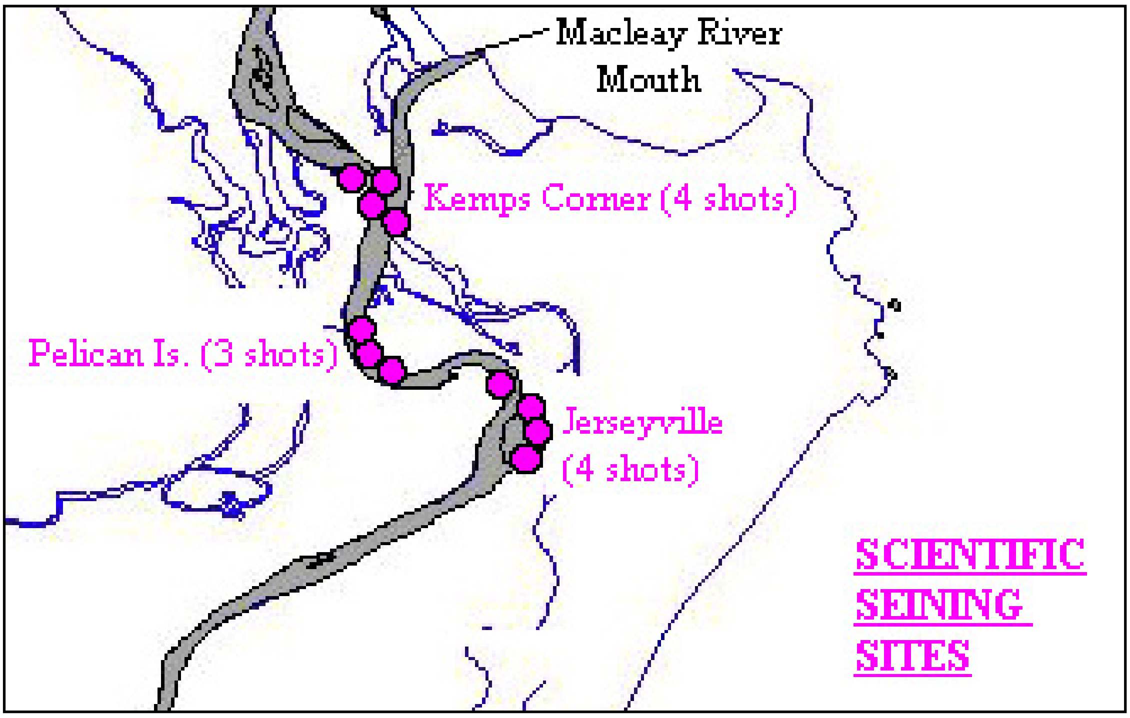

Figure 3. Map showing the scientific seining sites in the lower Macleay River sampled during the post-fish kill monitoring programme.

3. RESULTS

3.1. Water quality

Dissolved oxygen (DO) levels were very low in the middle and lower stretches in the lower Macleay River during the first (March 2001) survey, while DO levels were quite high in the upper stretch near Kempsey at that time (Figure 4a). Westlake and Copeland (2002) reported that the DO levels had returned to levels accepted as healthy throughout the main river channel approximately 3 to 4 weeks after the fish kill. Measurements taken during the July 2001 survey support this assertion (Figure 4a). In general, these improved levels were sustained during each of the remaining surveys of the monitoring programme (Figure 4a).

Water in the main river at the time of the first (March 2001) survey was quite acidic with measurements of between 5 to 6.7 throughout the river (Figure 4b). As in the case of dissolved oxygen, pH levels had returned to levels accepted as healthy (between 7 and 8) throughout the main river channel approximately 3 to 4 weeks after the fish kill (Westlake and Copeland, 2002). In general, pH levels were found to be more or less within this healthy range at the time of the July 2001 survey, and then for the remainder of the monitoring programme (Figure 4b).

Salinity levels were low in the lower stretch during the first (March 2001) survey (Figure 4c). Salinity levels had, however, increased to more or less expected levels at sites in the lower stretch by the July 2001 survey, and conductivity levels were also at expected levels by that time (Figure 4c and d). Salinity and conductivity levels remained very low in the middle stretch until the October 2001 survey, then fluctuated for the remainder of the monitoring programme, while water in the upper stretch of the river was predominantly fresh throughout the period of the monitoring programme (Figure 4c and d).

There did not appear to be any trend in the levels of turbidity among and during the surveys where measurements of turbidity were possible, such as the July/August, August and December 2001 surveys, as well as the January, February and March 2002 surveys (Figure 4e). In contrast, the trends in the temperatures recorded throughout the monitoring period showed that, in general, the water throughout the river became gradually warmer through the summer months (Figure 4f).

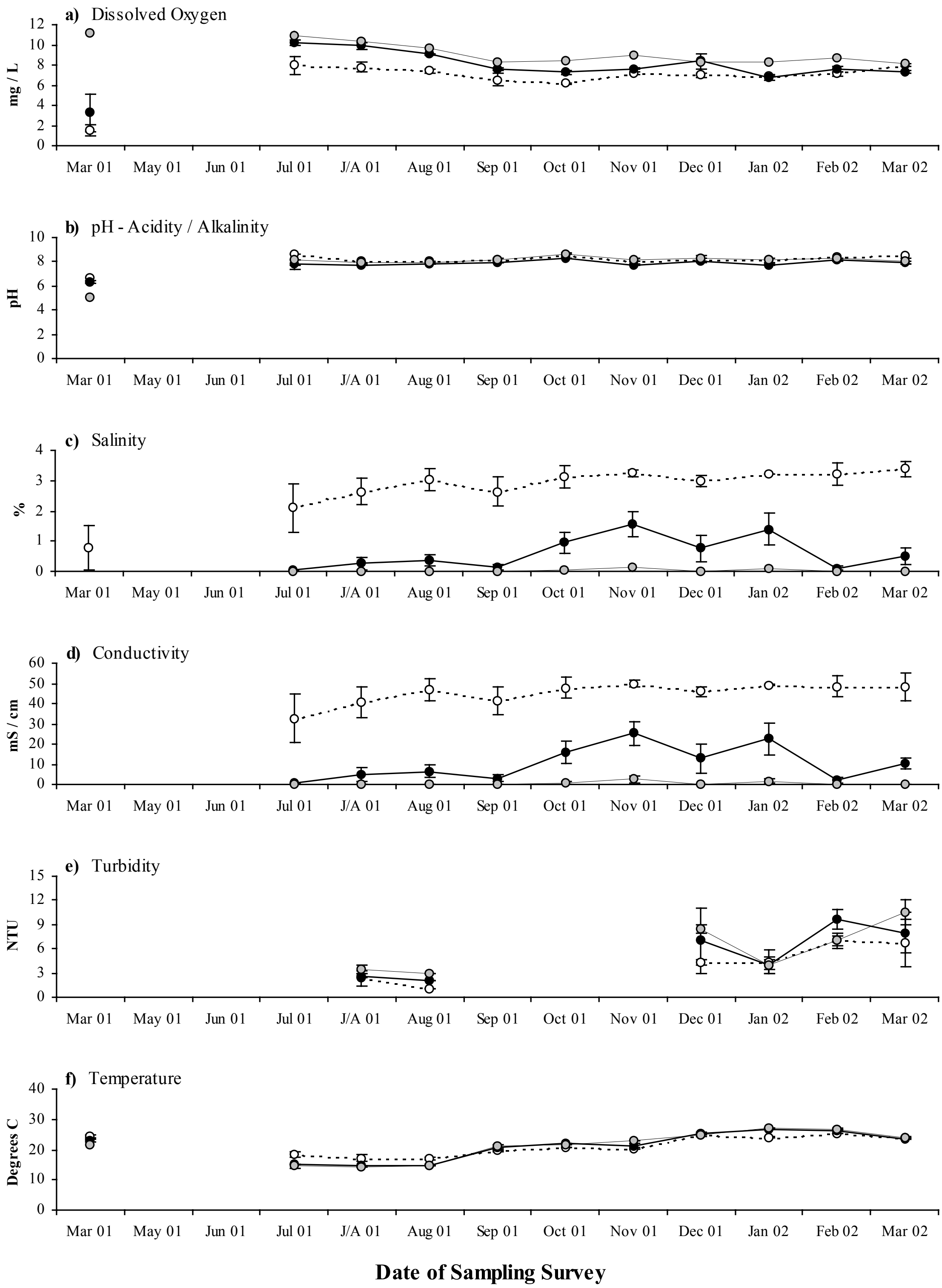

Figure 4. Results of water quality measurements taken in the main river channel of the lower Macleay River during the post-fish kill monitoring programme. Data are for the upper stretch (grey-filled data points), middle stretch (black-filled data points) and lower stretch (white-filled data points).

3.2. Mesh netting

An overall total of approximately 4,100 animals was caught in the mesh net sets during the regular daytime mesh netting (i.e. at the sites included in the standard mesh netting sampling design), during the post-fish kill monitoring programme. A wide range of species was caught during this regular daytime mesh netting, with pinkeye mullet and sea mullet comprising the majority of the overall catch (Table 3). Interestingly, a slight but steady decrease in the total numbers of species caught in mesh net sets in the river is evident through the duration of the monitoring programme (Figure 5).

Some of the commercially and/or recreationally important species that were caught reasonably regularly in mesh nets during the regular daytime mesh netting included pinkeye mullet, sea mullet, Australian bass, luderick and yellowfin bream (Table 3). Other commercially and/or recreationally important species that were recorded include flattail mullet, sand mullet, dusky flathead, sand whiting, giant trevally, silver biddy and blue swimmer crab. Non-commercially/recreationally important species caught regularly in the 82mm mesh net panels during the regular daytime mesh netting included whiptail ray, bullrout, freshwater herring and long-necked freshwater turtle (Table 3). Greater numbers of species were caught at sites in the lower and middle stretches than at sites in the upper stretch in the case of most of the surveys (Figure 5). For a full list of the species caught in mesh nets as part of the regular daytime mesh netting during the monitoring programme, refer to Table 3.

The average number of individuals (all animals) caught in mesh net sets was, in general, considerably greater during the earlier surveys (March, May and June 2001) than during any of the subsequent surveys (Figure 6), due to quite large catches of sea mullet (Figure 7) and pinkeye mullet (Figure 8) recorded during these first three surveys. Subsequently, the trends evident in catch rates were quite similar among the surveys completed after the June survey (Figure 6). Interestingly, catches per mesh net set were greater at sites in the upper stretch than those at sites in the middle and lower stretches in twelve of the thirteen surveys (Figure 6). This is most likely due to the pattern in the catches of pinkeye mullet, which were caught regularly in the upper stretch throughout the monitoring programme (Figure 8). In general, catches of fish during the regular daytime mesh netting (i.e. at the sites included in the standard mesh netting sampling design) were disappointing, especially in the case of surveys completed after the June 2001 survey (Figure 6).

As mentioned earlier, average catches of sea mullet per mesh net set were generally quite good during the first three surveys completed after the fish kill (Figure 7). Catch rates were considerably less during the July 2001 survey and all of the subsequent surveys, with no trend being evident in catches among these latter surveys (Figure 7).

There were some relatively large catches of Australian bass from mesh net sets in the upper and middle stretches during some of the surveys done before October 2001, although only a few were caught during each of the surveys done from the October survey onwards (Figure 9). In contrast, large numbers of luderick were caught in the mesh net sets in the lower stretch during the surveys done between June and August 2001, while very few were caught in the upper and middle stretches throughout the monitoring programme (Figure 10). Yellowfin bream were caught regularly, but in modest numbers, throughout the earlier part of the monitoring programme, although they had rapidly declined by August 2001, and none were recorded from the mesh net sets done during the last two surveys (February 2002 and March 2002) (Figure 11).

The extra daytime mesh net sets done near Little Spencers Creek in the lower stretch during the June and July 2001 surveys yielded reasonable catches of sea mullet, with 22 and 15 fish caught, respectively (Table 4). A couple of luderick and a dusky flathead were also caught during the June survey (Table 4).

The extra mesh net set done at night in the lower stretch of the river using larger mesh sizes during the June 2001 survey yielded only 2 mulloway, one being large (121 cm) and one being small (55 cm) (Table 5). Eight bull sharks were also caught in this night mesh net set (Table 5).

Table 3. The total number and length range (mm) of individuals caught during the regular daytime mesh netting operations (i.e. at the sites included in the standard mesh netting sampling design), for all taxa across all sampling surveys as part of the post-fish kill monitoring programme in the lower Macleay River. Note that the length range refers to total length in the case of the fish, carapace length in the case of the crustaceans and shell length in the case of the turtles.

Common name	Scientific name	Total no. caught	Length range (mm)
Pinkeye mullet	*Myxus petardi*	1,552	270 - 540
Sea mullet	*Mugil cephalus*	1,493	240 - 530
Australian bass	*Macquaria novemaculeata*	434	140 - 540
Luderick	*Girella tricuspidata*	202	230 - 370
Yellowfin bream	*Acanthopagrus australis*	110	160 - 320
Flattail mullet	*Liza argentea*	63	220 - 450
Sand mullet	*Myxus elongatus*	32	315 - 425
Sand whiting	*Sillago ciliata*	31	160 - 380
Whiptail ray	*Dasyatis sp.*	20	200 - 510
Dusky flathead	*Platycephalus fuscus*	18	225 - 800
Blue swimmer crab	*Portunus pelagicus*	15	38 - 66
Bullrout	*Notesthes robusta*	15	170 - 260
Freshwater herring	*Potamalosa richmondia*	13	210 - 310
Long tom	*Tylosurus gavialoides*	13	530 - 920
Long-necked freshwater turtle	*Chelodina longicollis*	13	80 - 170
Bull shark	*Carcharhinus leucas*	10	770 - 1130
Fantail mullet	*Valamugil georgii*	10	220 - 325
Giant trevally	*Caranx ignobilis*	10	255 - 290
Short-necked freshwater turtle	*Emydura macquarii*	9	90 - 180
Silver biddy	*Gerres subfasciatus*	8	150 - 210
Blue-spot stingray	*Dasyatis kuhlii*	3	350 - 385
Common stingray	*Dasyatis fluviorum*	3	240 - 400
Green turtle	*Chelonia mydas*	2	- -
Unidentified stingray	Dasyatididae *sp.*	2	1000 - 1000
Estuary perch	*Macquaria colonorum*	1	300
Goldfish	*Carassius auratus*	1	320
Mud crab	*Scylla serrata*	1	113
Globe fish	*Diodon nichthemerus*	1	255
Queenfish	*Scomberoides lysan*	1	195
Silver batfish	*Monodactylus argenteus*	1	125
Silver perch	*Bidyanus bidyanus*	1	310
Southern herring	*Herklotsichthys castelnaui*	1	155
Spotted scat	*Scatophagus argus*	1	251
Stargazer	*Ichthyoscopus lebeck*	1	165
Tailor	*Pomatomus saltatrix*	1	250
Striped scat	*Selenotoca multifasciata*	1	390

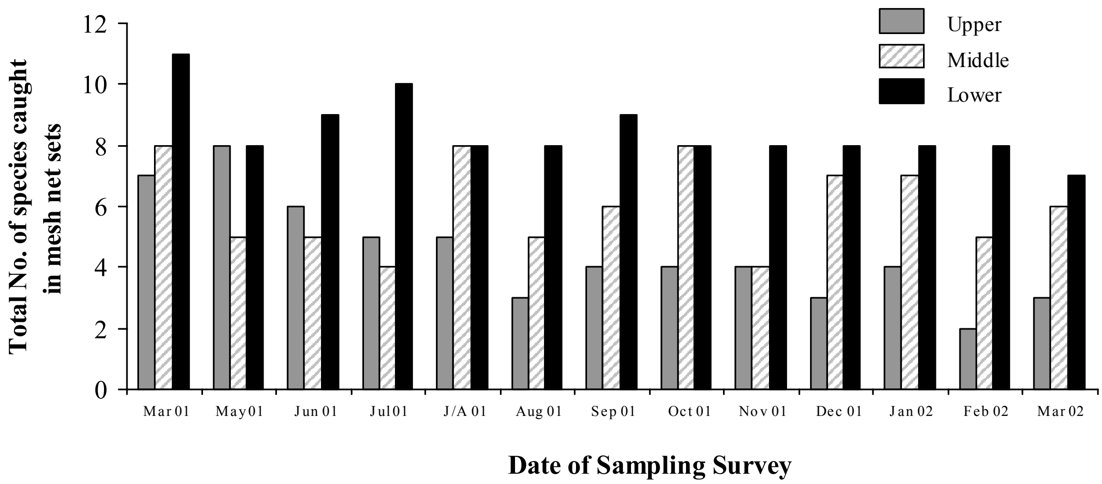

Figure 5. Number of species recorded from daytime mesh net sets in the upper, middle and lower stretches of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

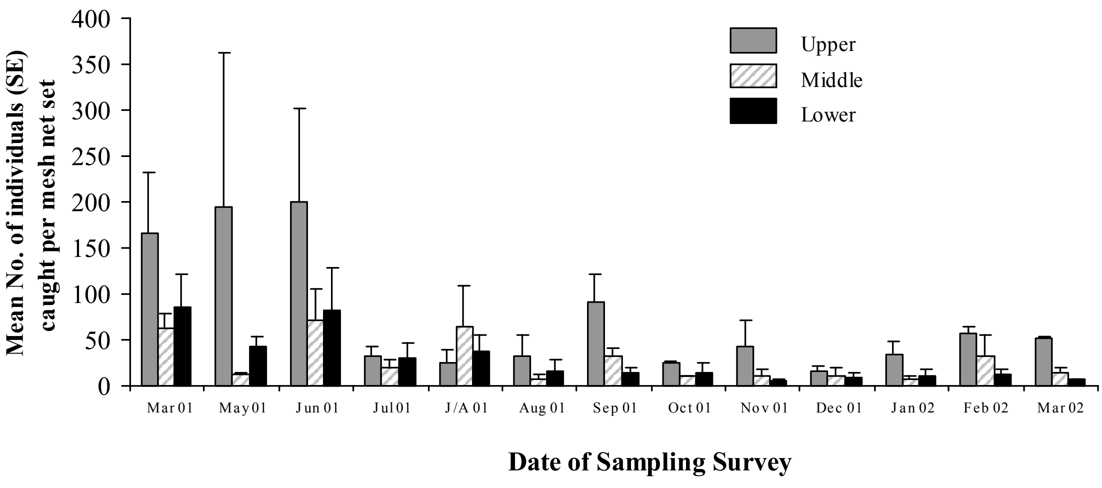

Figure 6. Mean number of individuals (SE) caught per daytime mesh net set in the upper, middle and lower stretches of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

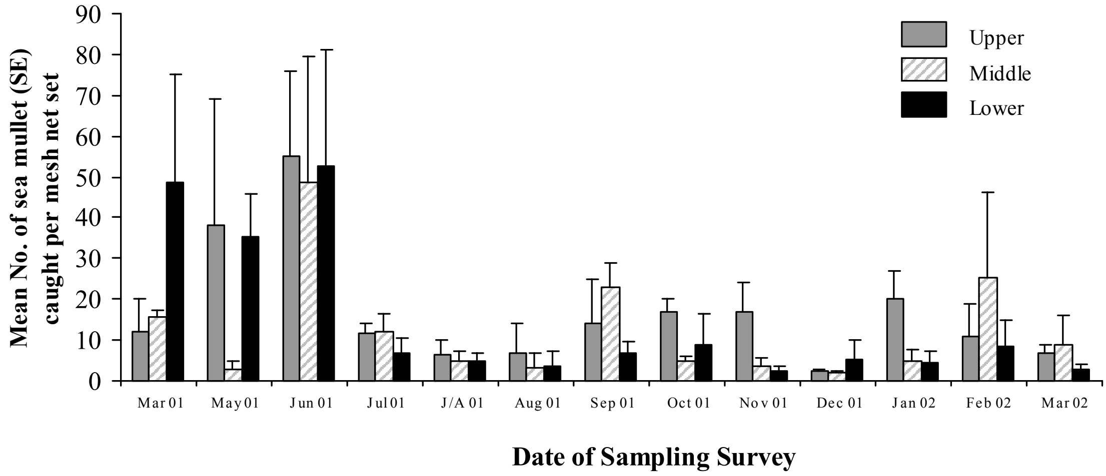

Figure 7. Mean number of sea mullet (SE) caught per daytime mesh net set in the upper, middle and lower stretches of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

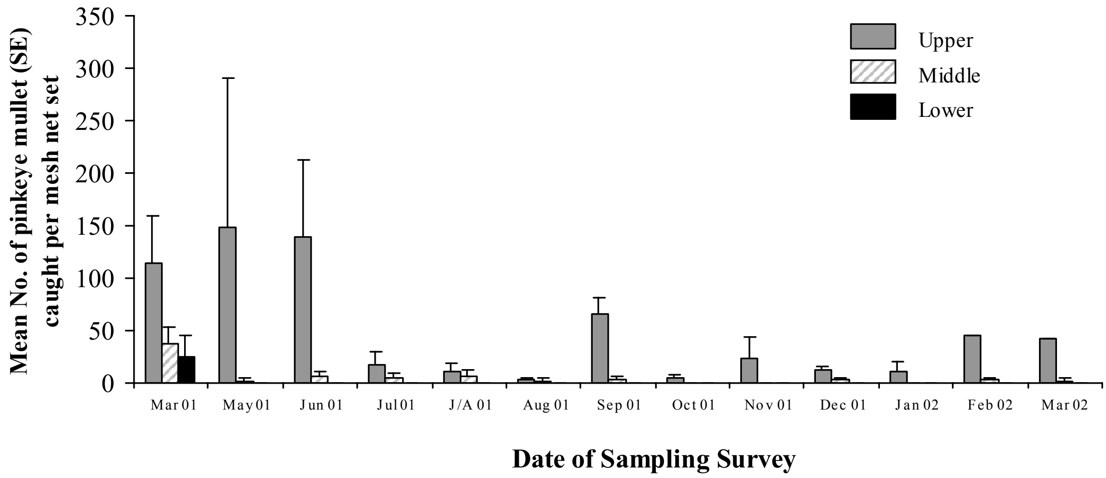

Figure 8. Mean number of pinkeye mullet (SE) caught per daytime mesh net set in the upper, middle and lower stretches of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

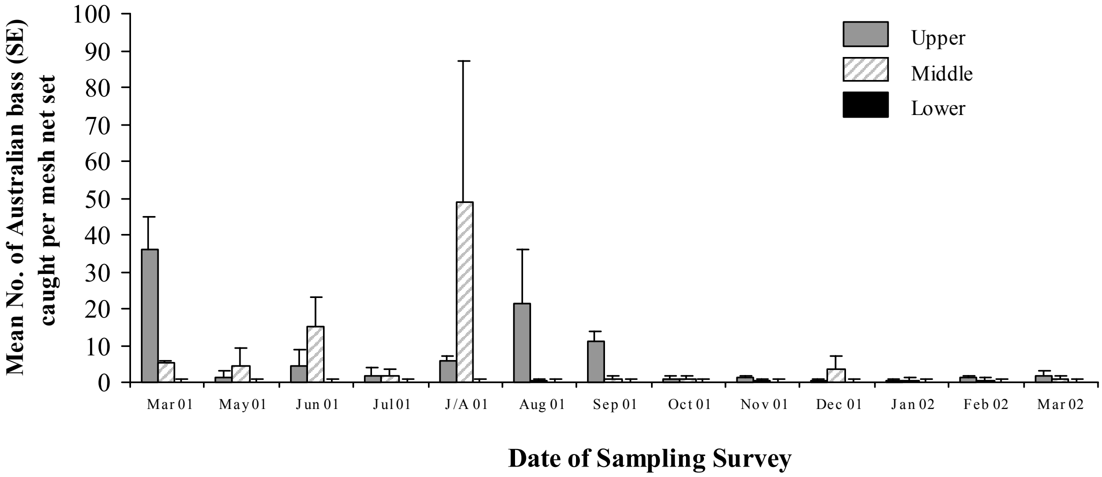

Figure 9. Mean number of Australian bass (SE) caught per daytime mesh net set in the upper, middle and lower stretches of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

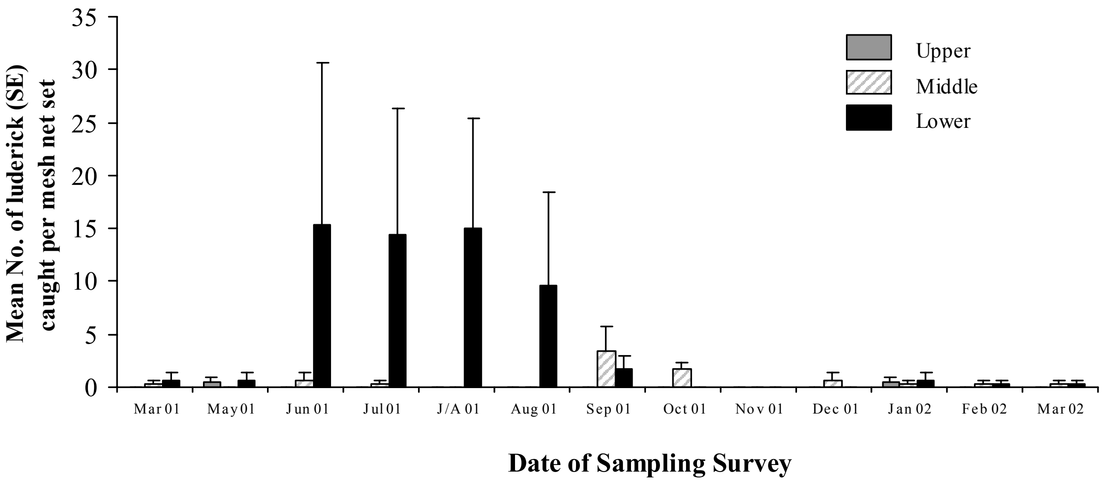

Figure 10. Mean number of luderick (SE) caught per daytime mesh net set in the upper, middle and lower stretches of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

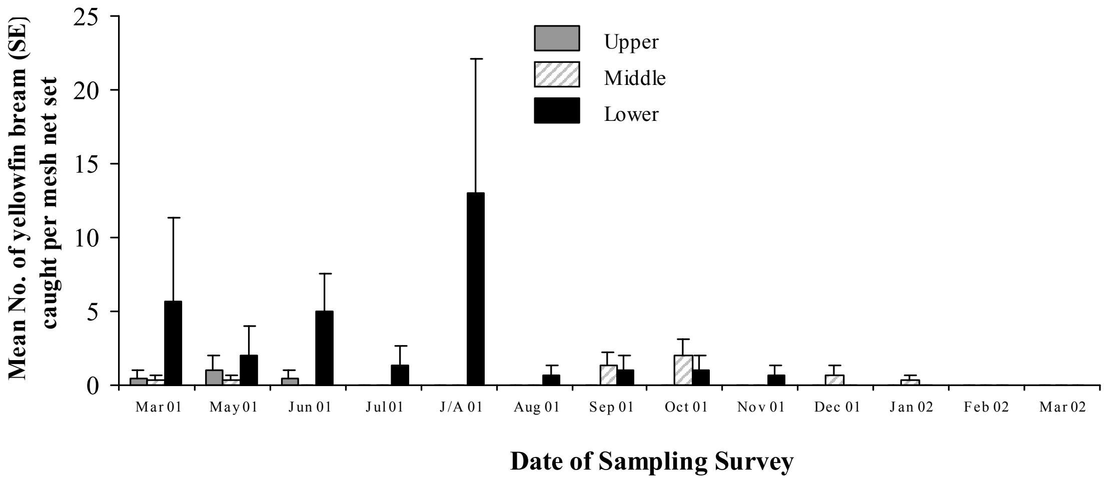

Figure 11. Mean number of yellowfin bream (SE) caught per daytime mesh net set in the upper, middle and lower stretches of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

Table 4. Catches of fish resulting from the extra daytime mesh net sets done near Little Spencers Creek in the lower stretch of the Macleay River during the post-fish kill monitoring programme. Note that the mesh net used in each of the sets was the same as that used for the regular daytime meshing throughout the monitoring programme.

Sampling Survey	Species	No. caught	Length range (mm)
JUNE 2001	Sea mullet	22	290 - 390
	Luderick	2	260 - 280
	Dusky flathead	1	600
JULY 2001	Sea mullet	15	310 - 425

Table 5. Catches of fish resulting from night mesh netting in the lower stretch of the Macleay River during the June 2001 survey as part of the post-fish kill monitoring programme.

Sampling method	Sampling site	Species	No. caught	Length range (mm)
Night mesh netting (approx. 240m of 178mm & 204mm mesh; approx. 30 min set)	Near Kemps Corner	Mulloway	2	55 - 121
		Bull shark	8	94 - 98

3.3. Crab trapping

A total of 288 mud crabs (175 male and 113 female) weighing approximately 174 kg was caught in the 397 crab traps successfully set and retrieved as part of the post-fish kill monitoring programme. These crabs ranged in size between 70mm and 140mm carapace length. The catch rates of mud crabs from crab trapping in the lower stretch and the North Arm were quite good during the first (March 2001) survey, although no crabs were caught in traps set in the middle stretch during that survey (Figure 12). Good catches of crabs did, however, come from traps set in the middle stretch as well as the lower stretch and the North Arm during the following (May 2001) survey (Figure 12). The number of crabs caught increased further to the higher levels recorded in the June and July 2001 surveys, after which the catch rates declined to levels generally lower than those recorded during the first (March 2001) survey (Figure 12). These comparatively lower catch rates were maintained until the completion of the monitoring programme, with the exception of the December 2001 survey, during which relatively high catch rates were recorded (Figure 12).

The major by-catch species recorded during the crab trapping operations throughout the monitoring programme was yellowfin bream (Table 6). No bream were caught in crab traps set in the middle stretch during the initial (March 2001) survey, although relatively good catches were recorded from traps set in the middle stretch during the two subsequent surveys (May and June 2001) (Figure 13). Apart from these particularly good catches and good catches recorded from traps set in the lower stretch during the July/August survey, catches of bream were generally low in each of the three sections of the river during surveys completed prior to the September 2001 survey (Figure 13). In general, very few bream were caught in crab traps during the surveys completed after the August 2001 survey (Figure 13).

Other species recorded as by-catch in crab traps included blue swimmer crab, sea mullet, bullrout and luderick (Table 6). For a full list of the species caught in the crab traps during the monitoring programme, refer to Table 6.

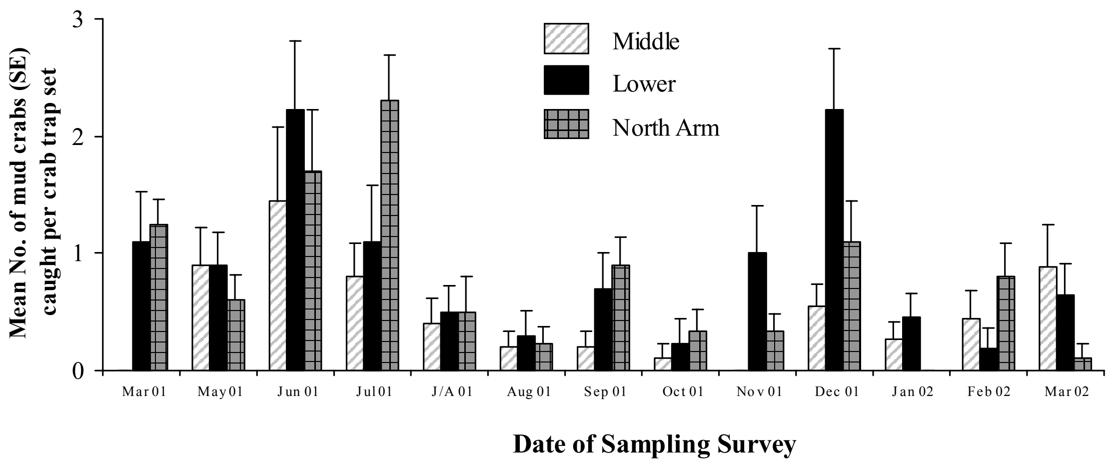

Figure 12. Mean number of mud crabs (SE) caught per crab trap set in the middle stretch, lower stretch and North Arm of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

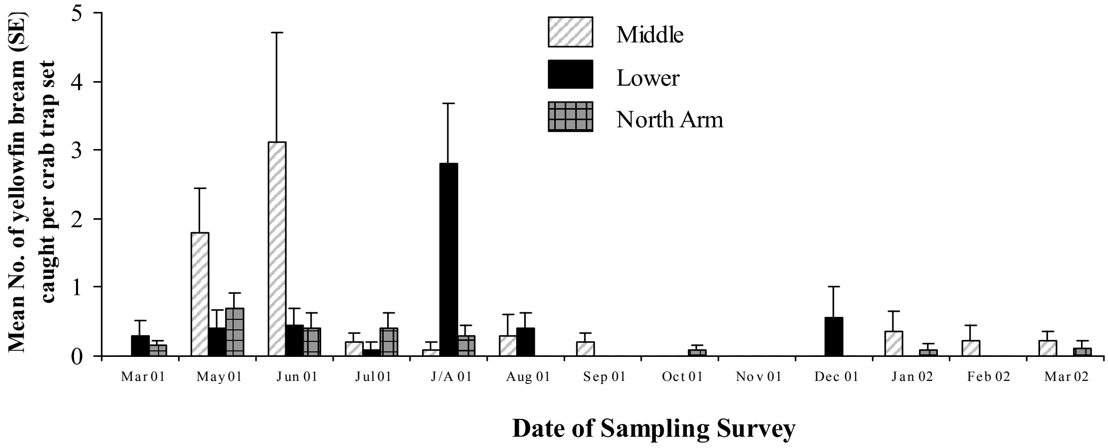

Figure 13. Mean number of yellowfin bream (SE) caught per crab trap set in the middle stretch, lower stretch and North Arm of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

Table 6. The total number and length range (mm) of individuals caught during all crab trapping operations for all taxa across all sampling surveys as part of the post-fish kill monitoring programme in the lower Macleay River. Note that the length range refers to total length in the case of the fish and carapace length in the case of the crustaceans.

Common name	**Scientific name**	**Total no. caught**	**Length range (mm)**
Mud crab	*Scylla serrata*	288	70 - 140
Yellowfin bream	*Acanthopagrus australis*	136	25 - 390
Blue swimmer crab	*Portunus pelagicus*	14	41 - 80
Sea mullet	*Mugil cephalus*	4	370 - 420
Bullrout	*Notesthes robusta*	2	200 - 280
Luderick	*Girella tricuspidata*	2	310 - 340
Australian bass	*Macquaria novemaculeata*	1	270
Octopus sp.	*Octopus sp.*	1	-
Pike eel	*Muraenesox bagio*	1	1200

3.4. Eel trapping

A total of 840 long-finned eels weighing approximately 555 kg was caught in the 378 eel traps successfully set and retrieved as part of the post-fish kill monitoring programme. These eels ranged between approximately 32 cm and 136 cm in length. Eel catches were quite high in the upper and middle stretches of the river early in the monitoring programme (March and May 2001), with the exception of the upper stretch, in which no eel trapping was done during the March 2001 survey (Figure 14). The catches of eels steadily declined from the May 2001 survey until the September 2001 survey, during which relatively low numbers of eels were caught (Figure 14). There was no clear trend in the catches of eels among the surveys done after the September 2001, except that the highest catch rates were recorded in the upper stretch during most of these surveys (Figure 14).

The major by-catch species recorded during the eel trapping operations throughout the monitoring programme was yellowfin bream (Table 7). In fact, more bream were caught in eel traps during the monitoring programme than eels (Table 7). The majority of these bream were small juveniles (<100 mm length) caught in relatively large numbers in the middle and lower stretches during the surveys done after the November 2001 survey. This is reflected in Figure 15. Catches of bream were relatively rare during surveys done before the December 2001 survey (Figure 15).

Other species recorded as by-catch in crab traps included tarwhine, mud crab, silver batfish and bullrout (Table 7). For a full list of the species caught in crab traps during the monitoring programme, refer to Table 7.

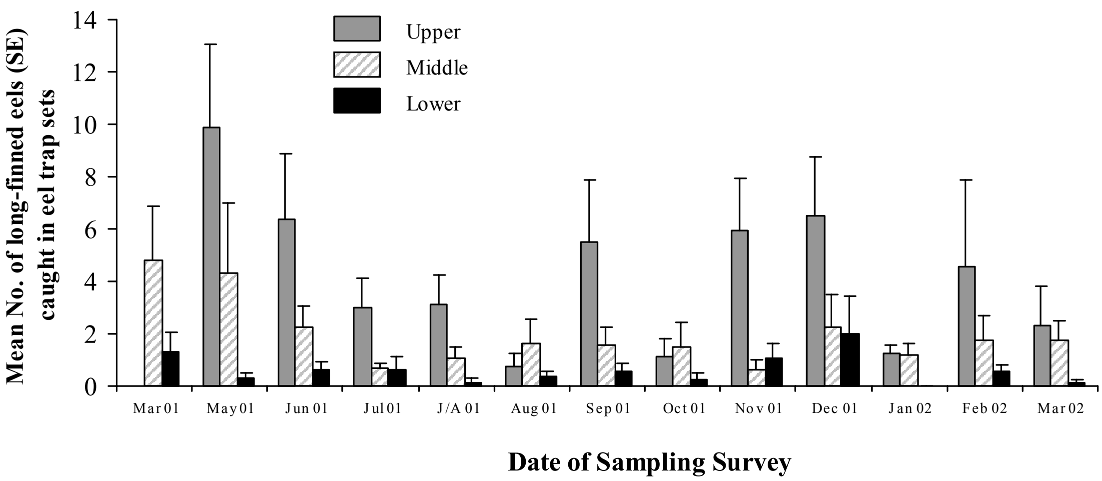

Figure 14. Mean number of long-finned eels (SE) caught per eel trap set in the upper, middle and lower stretches of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

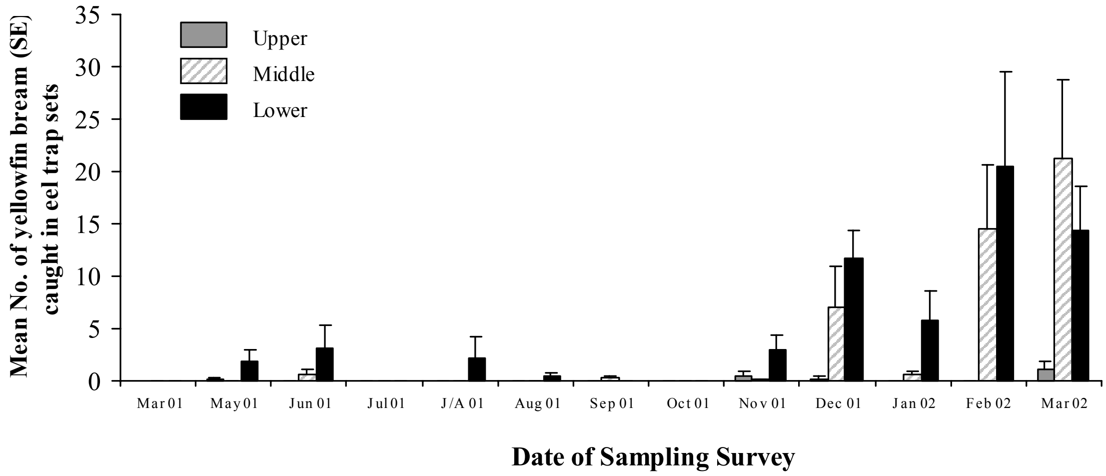

Figure 15. Mean number of yellowfin bream (SE) caught per eel trap set in the upper, middle and lower stretches of the lower Macleay River. Data are for each of the four-weekly surveys completed as part of the post-fish kill monitoring programme ("Mar 01" survey - "Mar 02" survey).

Table 7. The total number and length range (mm) of individuals caught during all eel trapping operations for all taxa across all sampling surveys as part of the post-fish kill monitoring programme in the lower Macleay River. Note that the length range refers to total length in the case of the fish, carapace length in the case of the crustaceans and shell length in the case of the turtles.

Common name	Scientific name	Total no. caught	Length range (mm)
Yellowfin bream	*Acanthopagrus australis*	1,097	26 - 251
Long-finned eel	*Anguilla reinhardtii*	840	322 - 1360
Tarwhine	*Rhabdosargus sarba*	25	66 - 138
Mud crab	*Scylla serrata*	20	54 - 112
Silver batfish	*Monodactylus argenteus*	17	35 - 78
Bullrout	*Notesthes robusta*	10	120 - 246
Striped trumpeter	*Pelates quadrilineatus*	5	91 - 120
Blue swimmer crab	*Portunus pelagicus*	2	58 - 64
Long-necked freshwater turtle	*Chelodina longicollis*	2	- -
Happy moments	*Siganus fuscescens*	1	134
Leatherjacket	Monacanthidae *sp.*	1	93
Luderick	*Girella tricuspidata*	1	210
Snapper	*Pagrus auratus*	1	87
Stripey	*Microcanthus strigatus*	1	48
Sweetlip	Haemulidae *sp.*	1	114

3.5. Scientific seining

A total of over 9,900 fish and crustaceans from 38 species was caught in scientific seine shots in the lower stretch of the lower Richmond River as part of the post-fish kill monitoring programme. There was no clear pattern in the mean numbers of individual fish and crustaceans (excluding glass shrimps) recorded per shot at sites in the lower stretch sampled during the monitoring programme (Figure 16). It is important to note that glass shrimps were excluded from the calculations of average numbers of individuals per shot in Figure 16 primarily due to the extreme variability in their abundances recorded during the surveys (some shots caught many thousands while other shots caught none), which tended to mask the overall trends discernible in the graphs. The four larger peaks in the mean numbers of individual fish and crustaceans (excluding glass shrimps) recorded per shot at Kemps Corner during the March 2001, October 2001, February 2001 and March 2002 surveys in Figure 16 were primarily due to exceptionally large catches of glass perch at this site during those surveys (Figure 17).

Interestingly, the mean number of species recorded per shot was relatively high during the first (March 2001) survey (Figure 18). Overall, there did not appear to be any clear trends evident with respect to the mean number of species recorded per shot during the monitoring programme.

Although very few small juvenile sand whiting were caught in the scientific seine shots done during the first (March 2001) survey, very large numbers of small sand whiting were caught in the seine nets during the two subsequent surveys (May and June 2001) (Figure 19). Catches of the small whiting were considerably less than those recorded during the May and June 2001 surveys, during the July 2001 survey and during all subsequent surveys (Figure 19). Similarly, only a couple of small juvenile dusky flathead were caught in the scientific seine shots during the first (March 2001) survey (Figure 20). Larger numbers of small flathead were, however, caught during the following (May 2001) survey (Figure 20). Catches of small dusky flathead were more or less consistent among all subsequent surveys (Figure 20).

Other species caught in considerable quantities in the scientific seine shots done during the monitoring programme included sand goby, very small school prawn, small flattail mullet, small sea mullet and sandy sprat. For a full list of the species caught in scientific seine shots during the monitoring programme, refer to Table 8.

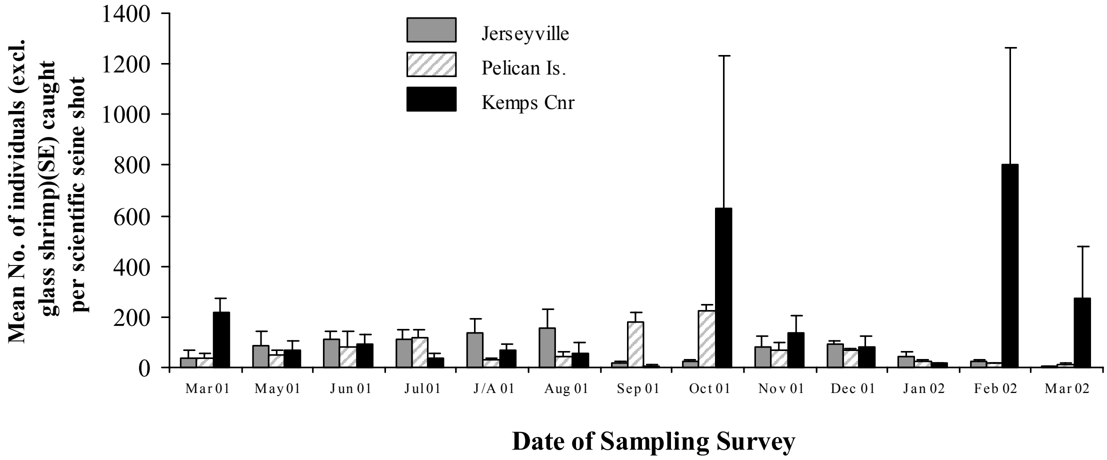

Figure 16. Mean number of individuals (excluding glass shrimps) (SE) caught per scientific seine shot at 3 sites (Kemps Corner, Pelican Island and Jerseyville) in the lower stretch of the lower Macleay River. Data are for the monthly surveys completed as part of the post-fish kill sampling programme ("Mar 01" survey - "Mar 02" survey).

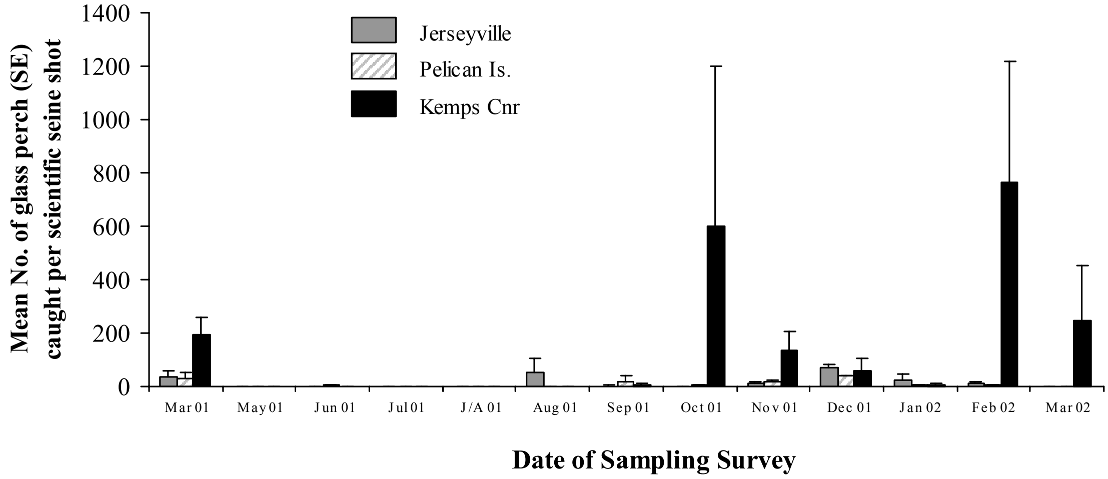

Figure 17. Mean number of glass perch (SE) caught per scientific seine shot at 3 sites (Kemps Corner, Pelican Island and Jerseyville) in the lower stretch of the lower Macleay River. Data are for the monthly surveys completed as part of the post-fish kill sampling programme ("Mar 01" survey - "Mar 02" survey).

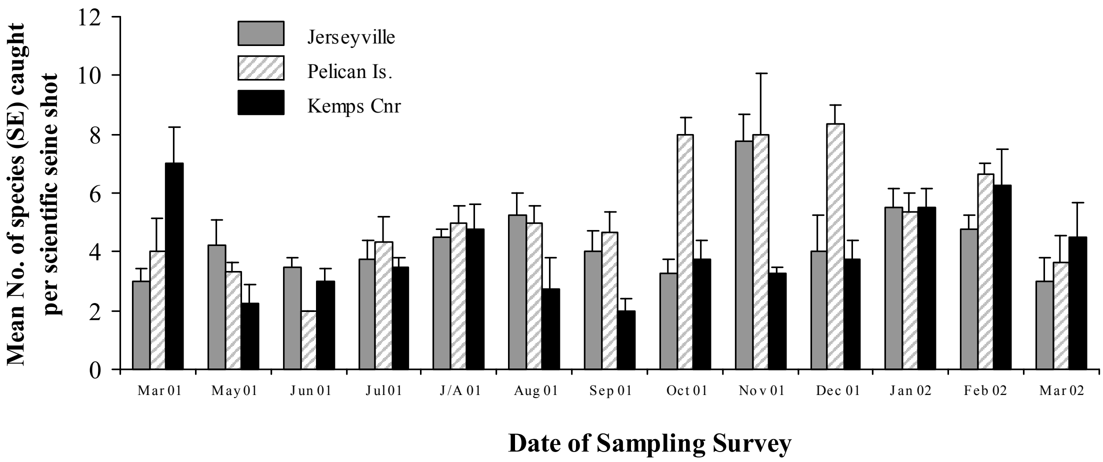

Figure 18. Mean number of species (SE) recorded per scientific seine shot at 3 sites (Kemps Corner, Pelican Island and Jerseyville) in the lower stretch of the lower Macleay River. Data are for the monthly surveys completed as part of the post-fish kill sampling programme ("Mar 01" survey - "Mar 02" survey).

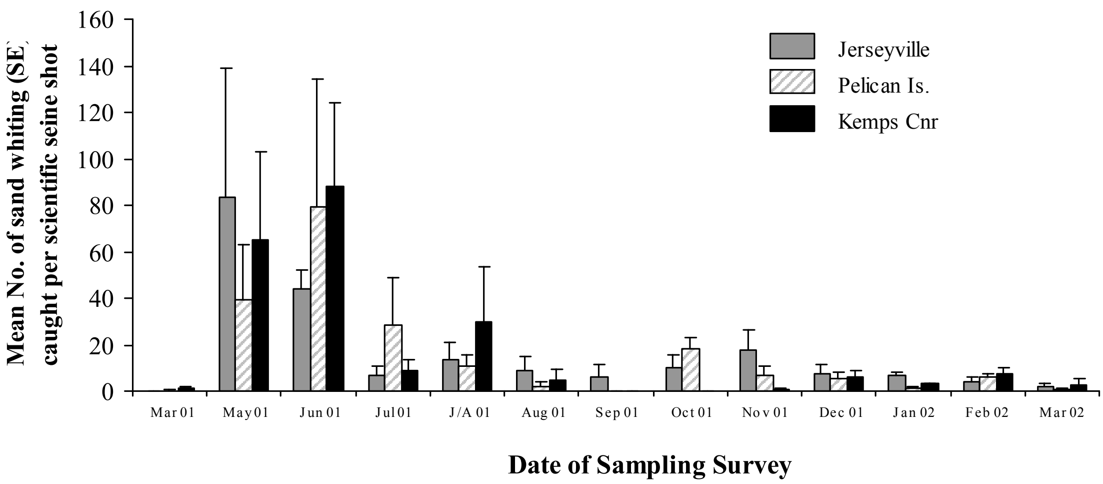

Figure 19. Mean number of sand whiting (SE) caught per scientific seine shot at 3 sites (Kemps Corner, Pelican Island and Jerseyville) in the lower stretch of the lower Macleay River. Data are for the monthly surveys completed as part of the post-fish kill sampling programme ("Mar 01" survey - "Mar 02" survey).

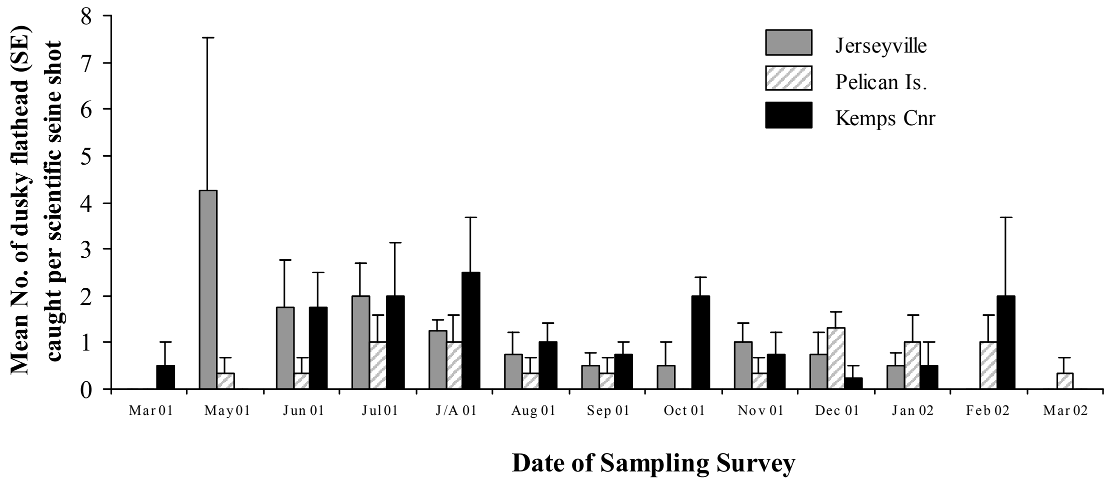

Figure 20. Mean number of dusky flathead (SE) caught per scientific seine shot at 3 sites (Kemps Corner, Pelican Island and Jerseyville) in the lower stretch of the lower Macleay River. Data are for the monthly surveys completed as part of the post-fish kill sampling programme (“Mar 01” survey - “Mar 02” survey).

Table 8. The total number and length range (mm) of individuals caught during scientific seining done as part of the post-fish kill monitoring programme in the lower Macleay River. Data are for all taxa across all sampling surveys. Note that the length range refers to total length in the case of the fish and carapace length in the case of the crustaceans.

Common name	Scientific name	Total no. caught	Length range (mm)
Glass shrimp	*Acetes sp.*	9,914	2 - 40
Glass perch	*Ambassis marianus*	9,282	3 - 74
Sand whiting	*Sillago ciliata*	2,318	16 - 169
Sand goby	*Favonigobius tamarensis*	2,310	12 - 60
School prawn	*Metapenaeus macleayi*	717	1 - 19
Flattail mullet	*Liza argentea*	684	13 - 165
Sea mullet	*Mugil cephalus*	306	10 - 137
Sandy sprat	*Hyperlophus vittatus*	300	22 - 78
Yellowfin bream	*Acanthopagrus australis*	140	12 - 165
Dusky flathead	*Platycephalus fuscus*	131	30 - 230
Rock prawn	*Macrobrachium sp.*	77	2 - 10
Empire gudgeon	*Hypseleotris compressa*	34	29 - 57
Large-toothed flounder	*Pseudorhombus arsius*	33	26 - 155
Tarwhine	*Rhabdosargus sarba*	32	12 - 61
Sand mullet	*Myxus elongatus*	27	38 - 106
Silver biddy	*Gerres subfasciatus*	24	15 - 105
Common toad	*Tetractenos hamiltoni*	20	26 - 116
Weeping toad	*Torquigener pleurogramma*	20	12 - 76
Unidentified goby	Gobiidae *sp.*	11	22 - 34
Cox's gudgeon	*Gobiomorphus coxii*	9	27 - 35
Pacific blue-eye	*Pseudomugil signifer*	7	13 - 28
Sea garfish	*Hyporhamphus australis*	7	75 - 90
Silver trevally	*Pseudocaranx dentex*	6	25 - 80
Mosquitofish	*Gambusia holbrooki*	5	20 - 36
Striped trumpeter	*Pelates quadrilineatus*	5	23 - 38
Bridled goby	*Arenigobius bifrenatus*	4	45 - 110
Pipefish	Syngnathidae *sp.*	3	93 - 123
Snapping shrimp	*Alpheus sp.*	3	5 - 10
Unidentified toadfish	Tetraodontidae *sp.*	3	10 - 15
Sea dragonet	*Repomucenus calcaratus*	2	70 - 115
Blue swimmer crab	*Portunus pelagicus*	1	11
Fortesque	*Centropogon australis*	1	46
Mado	*Atypichthys strigatus*	1	14
Mud flathead	*Suggrundus jugosus*	1	20
Pebble crab	*Ixa inermis*	1	16
Queenfish	*Scomberoides lysan*	1	46
Smooth toadfish	*Tetractenos glaber*	1	36
Stinkfish	*Foetorepus calauropomus*	1	87

4. DISCUSSION

4.1. General overview

Considering the urgent response to the Macleay River fish kill that was required by NSW Fisheries and other government agencies and local government groups, in general the sampling methods chosen and the sampling designs implemented sufficiently addressed the main aim of the monitoring programme - to provide the necessary biological information (i.e. on the distribution and relative abundances of fish and crustaceans) and water quality information required in order to make fisheries management decisions as to if, when and how the fishing closure imposed on the Macleay River should be lifted. The outstanding cooperation between the local interest groups and NSW Fisheries staff with respect to organising the monitoring programme was paramount to the successful implementation of the sampling surveys.

The continuation of monitoring well past the time of the re-opening of the river to fishing which occurred on 1 October 2001 provided valuable information regarding the response of the recovering populations of fish and crustaceans to the resumption of recreational and commercial fishing in the river. In addition, a better understanding of the rates of recovery of populations of fish and crustaceans in the river after such a fish kill event was facilitated by acquiring better information regarding the natural state of these populations in the river. Certainly the results from this monitoring programme, along with those reported by Westlake and Copeland (2002) regarding the causes and immediate effects of the fish kill, and Steffe and Macbeth (2002) regarding the extent of the recreational fish catch upon the re-opening of the river, provide a better understanding of the response of the biological communities in and around estuaries to major fish kill events such as this one. This in turn should allow for better planning of management responses to such events in the future.

One issue that raised concern was the catches in the regular daytime mesh netting, especially from the July 2001 survey onwards. It is most likely that the main contributing factor to these low catch rates was the necessarily rigid sampling regime, which was initially designed with the conditions in the river immediately following the fish kill, as well as the time of year of the earlier surveys, in mind. No plans for a long-term monitoring programme had been considered at that time. Refining the rigid sampling design to provide more flexibility with respect to the exact locations of mesh net sets might be a step in the right direction in formulating a response to similar situations in the future.

The responses of the populations of fish and crustaceans to the situation in the river after the fish kill varied by species. Following is a discussion of the temporal improvement in water quality in the river, as well as a detailed discussion of the responses exhibited by the various species encountered during the monitoring programme to this improvement.

4.2. Water quality

The water quality parameters measured during the monitoring programme indicated that the improvement in water quality detected throughout the main river channel a couple of months after the fish kill was maintained, and that the water quality from July 2001 onwards has remained generally quite good (Figure 4). These results are generally consistent with those documented by Westlake and Copeland (2002).

The water quality measurements that were taken during the initial (March 2001) survey indicated that the water in the upper stretch near Kempsey was oxygenated to high levels, although the water was quite acidic (Figures 4a and b), suggesting that water from the upper reaches of the Macleay system, which was not involved in the fish kill, was flowing into the lower Macleay River by that time. This is supported by the quite good catches of pinkeye mullet and bass that were recorded at sites in the upper stretch during that first survey (Figures 8 and 9, respectively). In contrast, the quality of the water in the middle and lower stretches of the river during that initial (March 2001) survey was relatively low, with low dissolved oxygen and quite low acidity (Figures 4a and b). Unfortunately, water quality was not measured during the May and June 2001 surveys, so a general estimate of the period of time taken for the water quality in the main river to improve to levels accepted as healthy was not possible. We do, however, know from measurements taken during the July 2001 survey that water quality in the main river had improved markedly by that time (Figure 4). Westlake and Copeland (2002) asserted that the water quality in the main river had improved to acceptable levels approximately 3 to 4 weeks after the fish kill.

4.3. Sea mullet

Catches of sea mullet in the regular daytime mesh net sets in the lower Macleay River during the first three surveys (March, May and June 2001) were quite good, although relatively low numbers of sea mullet were caught in the regular daytime mesh net sets completed since the June 2001 survey (Figure 7). This suggests that considerable recolonisation of the main river channel by this species had occurred shortly after the fish kill. These fish may have come from the upper reaches of the system, which was not affected by the fish kill, as well as from the ocean.

The relatively small catches of sea mullet in the mesh nets during the late-winter and spring months (July to November 2001) (Figure 7) may be attributed to a decrease in water temperature, particularly closer to the surface, which would be expected at that time of year. However, the fact that these small catches of sea mullet continued through into the summer months (Figure 7) suggests that other factors were also involved. It is possible that most of the mullet in the river may have been located in tributaries away from the main channel sites, which were not sampled as part of the regular daytime mesh netting. The fact that the water quality in many of the tributaries, such as Kinchela Creek and Belmore River, took much longer to improve than that in the main river (Westlake and Copeland, 2002), may explain why relatively good catches came from the regular daytime mesh netting during the earlier surveys (March to June 2001), than the surveys undertaken after June 2001.

Quite a few juvenile sea mullet were caught in the scientific seine nets during the monitoring programme (Tables 8), indicating that substantial larval and/or juvenile recruitment to the river of this species has occurred since the fish kill.

4.4. Yellowfin bream

Results from this post-fish kill monitoring programme indicated that the yellowfin bream population in the lower Richmond River has, in general, recovered since the March 2001 fish kill. Small numbers of yellowfin bream were caught in mesh net sets in the river during the earlier sampling surveys (Figure 11), suggesting that this species was fairly quick to begin recolonising the river. Bream catches resulting from the crab trapping (Figure 13) and eel trapping (Figure 15) also support this conclusion. In fact, quite a few bream were caught in crab traps in the middle stretch during the May and June 2001 surveys, which were undertaken only 6 weeks and 10 weeks after the fish kill, respectively (Figure 13).

The considerable reduction in catches in mesh nets and crab traps evident from August 2001 onwards (Figures 11 and 13) could have been due to the re-opening of the lower section of the river to limited recreational and commercial fishing on 1 July 2001, as the bream caught using these methods are usually of legal size or marginally sub-legal. Nevertheless, the relatively high catches of bream during the earlier surveys indicates that yellowfin bream were consistently present in the lower and middle stretches of the main river prior to the re-opening of the lower section of the river. In addition, the results reported in the recreational fishing survey, which was begun at the start of July, confirmed that the bream population in the lower stretch of the river downstream of Kinchela had recovered to levels considered sustainable to normal commercial and recreational fishing activities in the river by July (Steffe and Macbeth, 2002).

The aforementioned reduction in the numbers of bream caught in crab traps in the lower stretch of the river after the July 2001 survey may be due to a variety of factors. The resumption of recreational fishing downstream of Kinchela during July may have had an impact on the fish stocks throughout the lower stretch of the main river, especially considering the numbers of bream estimated to have been caught by recreational fishers after the opening of the river (Steffe and Macbeth, 2002). Alternatively, seasonal variation in the abundances of these fish, and/or in the catchability of the fish (i.e. in relation to spawning aggregations) may account for the observed temporal variation in abundance of bream in the river. A combination of these factors is likely.

The fact that some bream were caught in mesh net sets in the upper stretch during the first three surveys (March, May and June 2001) (Figure 11), indicates that at least some bream had recolonised the upper reaches of the river by that time. These bream may have either recolonised the main river from the ocean or, more likely, moved downstream from areas in the upper reaches of the system that were not affected by the fish kill.

Quite a few very small juvenile yellowfin bream (<50 mm length) were caught in the scientific seine shots in the lower stretch of the river during the August 2001 survey and in most of the subsequent surveys, confirming larval and/or juvenile recruitment of this species to the lower Richmond River since the fish kill. In addition, very high numbers of slightly larger juvenile bream (50 – 150 mm length) were caught in the eel traps set in the middle and lower stretches during surveys done during and after December 2001 (Figure 15), indicating that conditions in the river were conducive to successful growth of the juvenile bream that recruited to the river during the late-winter and spring of 2001.

4.5. Luderick

Results from the regular daytime meshing during the surveys done between June and August 2001 as part of this post-fish kill monitoring programme indicated that the population of luderick in the lower stretch of the lower Macleay River was certainly recovering in that part of the river (Figure 10). The subsequent reduction in luderick catches in the regular daytime mesh netting during the September 2001 survey, which then persisted throughout all the remaining surveys, could be due to a number of factors. As with bream, it is possible that the resumption of recreational fishing downstream of Kinchela during July may have had an impact on the stocks of luderick throughout the lower stretch of the main river, especially considering the very large numbers of luderick estimated to have been caught by recreational fishers after the opening of the river (Steffe and Macbeth, 2002). Alternatively, seasonal variation in the abundances, and/or the dispersion of spawning (or recently spawned) aggregations of luderick may account for the observed temporal variation in abundance of luderick in the river. A combination of all of these factors is quite likely. In any case, very high calculated estimates of luderick catches in the recreational fishing survey (started in July) confirmed that a large population of luderick existed in the lower stretch of the river downstream of Kinchela at that time (Steffe and Macbeth, 2002).

No small juvenile luderick were caught in the scientific seine shots done in the Lower Macleay River during the monitoring programme. This would be expected as small juvenile luderick are rarely, if ever, found over bare sandy substrate – they are usually associated with seagrass or rocky reef habitat (Gray et al., 1996), and the sites used for the scientific seining all had bare sand as the substrate.

4.6. Sand whiting

Catches of sand whiting in the daytime mesh netting in the lower and middle stretches of the lower Macleay River were low throughout the monitoring programme, although whiting were caught during early surveys (March and May 2001), suggesting that recolonisation of the lower part of the river by this species was occurring by that time. The estimates of sand whiting catches during the recreational fishing survey (July to October 2001, inclusive) certainly suggested that sand whiting were present in reasonably healthy numbers in the lower part of the river downstream of Kinchela at that time (Steffe and Macbeth, 2002).

Reasonably consistent catches of small juvenile sand whiting throughout the post-fish kill monitoring programme indicated a quite healthy larval recruitment of this species to the estuary. Juvenile sand whiting were caught in reasonable quantities in scientific seine shots in the lower stretch of the river during early surveys (March and May 2001) (Figure 19), indicating that sand whiting were quite quick to begin to recolonise the lower stretch of the river downstream of the Jerseyville boat harbour via larval and/or juvenile recruitment.

4.7. Dusky flathead

Catches of dusky flathead in daytime mesh net sets during the monitoring programme were restricted to a total of 18 individuals (Table 3), with the catches spread more or less evenly among the surveys done, suggesting that small numbers of this species were recolonising the main river quite soon after the fish kill. Most of these flathead were quite large individuals caught in the lower stretch, although a few were caught in the middle stretch. In any case, the estimates of dusky flathead catches during the recreational fishing survey (July to October 2001, inclusive) indicated that dusky flathead were present in numbers considered sustainable to normal commercial and recreational fishing activities in the lower part of the river downstream of Kinchela at that time (Steffe and Macbeth, 2002).

Although not present in large numbers, juvenile dusky flathead were caught regularly in the scientific seine shots in the lower stretch of the river throughout the monitoring period (Figure 20), indicating successful larval and/or juvenile recruitment of this species to the lower Macleay River since the fish kill.

4.8. Mulloway

The presence of at least some mulloway in the river was confirmed during the June 2001 survey, with two mulloway, one quite large, caught in night mesh sets near the mouth of the river (Table 5). Although only two mulloway were caught, the presence of these large predators suggests that there may have been smaller fish such as luderick and bream in the lower part of the river near the mouth at that time.

Quite a few mulloway were caught by recreational fishers around Jerseyville during the recreational fishing survey (July to October 2001, inclusive) indicating that mulloway were present further upstream of the site of the night mesh net set by July 2001 (Steffe and Macbeth, 2002).

4.9. Australian bass

The mesh netting in the upper and middle stretches of the river during surveys conducted before October 2001 resulted in quite variable catches of Australian bass from one survey to the next (Figure 9). However, relatively few bass were caught during surveys done during and subsequent to the October 2001 survey. This may have been due to natural seasonal variations in the distribution and abundance of this species within the river system. In any case, the population of Australian bass in the Macleay River did not seem to have been drastically affected by the conditions that resulted in the fish kill event (i.e. most were probably present upstream of the river stretch where the main fish kill occurred).

4.10. Mud crabs

Catches of mud crabs from the crab traps set in the lower Macleay River were quite good during the early surveys (March 2001 to July 2001) (Figure 12), suggesting that mud crabs may have recolonised the lower stretch of the river quite quickly or, alternatively, many crabs had survived the fish kill, as there were reports of mud crabs crawling up the banks of the river at the time of the fish kill. More likely it is a combination of both of these possibilities.

Mud crab catches during the spring months were substantially less than the catches during those earlier surveys (Figure 12). One possible explanation for this would be a reduction in the catchability of crabs in traps (as would be expected at this time of year) due to seasonal influences. Alternatively, increased fishing activities since the opening of the river to mud crab trapping may have reduced the mud crab population. In any case, catches during the December 2001 survey had returned to levels similar to those recorded during the early surveys (Figure 12), suggesting that populations of mud crabs did indeed recover relatively quickly after the fish kill and that the fluctuations in catch rates observed during the monitoring programme were most likely due to seasonal influences.

4.11. Long-finned eels

Catches of long-finned eels in eel traps set in the lower Macleay River during the first two surveys (March and May 2001) were quite good, although it is important to note that no traps were set in the upper stretch during the March 2001 survey, so no measure of abundance was possible for that section of the river at that time (Figure 14). This suggests that considerable recolonisation of the main river channel by this species had occurred shortly after the fish kill. These fish may have come from the upper reaches of the system, which was not affected by the fish kill.

There was a trend showing a steady decrease in the catches of long-finned eels from the May 2001 survey to the August 2001 survey (Figure 14), possibly due to a reduction in the catchability of eels in traps due to a reduction in the water temperatures in the river, as would be expected at that time of year. Alternatively, increased fishing activities removing eels from the system may have reduced the population. More likely it was a combination of both of these possibilities. In any case, catches of eels during surveys done after the August 2001 survey were quite variable, with some good catches being recorded at times, suggesting that the population of eels in the river had recovered since the fish kill.

4.12. Other species of commercial and recreational importance

Large numbers of pinkeye mullet mullet (a marginally commercially and recreationally important species) were caught in mesh net sets in the upper stretch of the lower Macleay River, especially during the earlier surveys that were done within a few months after the fish kill (Figure 8), suggesting that these fish may have recolonised that part of the river from the upper reaches of the system which was not affected by the fish kill. In addition, large numbers of small juvenile school prawns were caught in the scientific seine nets used in the lower stretch of the river (Table 8), suggesting that successful larval and/or juvenile recruitment of this species to the lower Macleay River had occurred since the fish kill.

Comparatively smaller numbers of a variety of other commercially and/or recreationally important species were caught in the Lower Richmond River during the monitoring programme. These species included tarwhine, sand mullet, flattail mullet, blue swimmer crab and large-toothed flounder.

Of particular interest was the confirmation of the presence of silver perch in the Macleay catchment drainage system as a result of the capture of one individual during the late-July / early-August survey. Silver perch occur naturally in the Murray / Darling catchment but are cultivated at various pond-based aquaculture facilities in the coastal catchments of NSW. It is most likely that the silver perch caught during the previous survey was an escapee from one of these aquaculture facilities.

4.13. Species of non-commercial/recreational importance

The non-commercially or recreationally important species caught in notable numbers in the main river channel during the monitoring programme were whiptail ray, bullrout, freshwater herring, silver batfish and freshwater turtles (Tables 3, 6 and 7). In addition, a wide variety of non-commercially or recreationally important species of fish and crustaceans were caught in the scientific seine nets in the lower stretch of the river. These species included glass shrimp, glass perch, sand goby and sandy sprat (Table 8). Certainly the variety of species caught in the scientific seine nets near the mouth of the river throughout the monitoring programme confirmed that the communities of fish and crustaceans present there exhibited considerable diversity with respect to the species present.

4.14. General conclusions

The question of whether the stocks of fish and crustaceans in the lower Macleay River had recovered to pre-fish kill levels cannot be answered directly because we do not have any detailed information describing the status of fish and crustacean stocks in the Macleay River immediately before the fish-kill event, and nor do we have comparable information about fish and crustacean communities in other non-impacted estuaries in the region that could be used as controls or reference sites. Therefore, we are restricted to making inferences about the recovery of the fish and crustacean populations from interpreting spatial and temporal trends in the distribution and abundance of fish and crustaceans apparent in the data collected as part of this monitoring programme.

In general, populations of fish and crustaceans in the Macleay River recovered to levels that could sustain normal commercial and recreational fishing practices, relative to the situation in the months immediately following the fish kill, by the time the fishing restrictions were lifted. Some species appeared to recover relatively quickly in the main river channel to levels that seem to have been more or less maintained since (e.g. mud crab, sea mullet, yellowfin bream, long-finned eel and pinkeye mullet), while some other species took longer to recover (e.g. luderick and sand whiting).

Increased commercial and recreational fishing activities (which have been allowed in some parts of the river since 1 July 2001), and normal recreational and commercial fishing activities (which have been allowed since 1 October 2001), may have been minor influencing factors in fluctuations detected in the relative abundances of some species subsequent to the lifting of fishing restrictions. However, it is important to consider that natural seasonal variations in the abundances of these fish, and/or in their catchability, are the most likely major influences on the results observed in this monitoring programme.

5. RECOMMENDATIONS

On the basis of the above findings, the following recommendations are made:

1. This post-fish kill monitoring programme provided invaluable information to scientists and fisheries managers with respect to the status of recovering populations of fish and crustaceans in the lower Macleay River following the fish-kill event of March 2001. A similar sampling programme should therefore be implemented if a similar fish kill (or an equivalent ecological emergency) was to occur in a NSW river and/or estuary in the future.

2. Fishery-independent sampling surveys should be done on a regular basis in NSW rivers and estuaries to provide data regarding the status of fish and crustacean populations at times of relative health of these rivers and estuaries. This would provide valuable baseline information that could be used for the purpose of comparison should another significant fish kill (or an equivalent ecological emergency) occur in a NSW river and/or estuary in the future.

3. Further work should be undertaken to develop a standard sampling design protocol for similar monitoring programmes that will probably be required in the future, which would require more detailed analyses of the techniques used and the data collected during this monitoring programme. The development of robust and reliable sampling regimes will result in more accurate overall assessments of the status of populations of fish and crustaceans in any given estuary and/or river.

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SECTION 3

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A Survey of Daytime Recreational Fishing Following a Large Fish-kill Event in the Lower Reaches of the Richmond River, NSW, Australia

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April 2002

ACKNOWLEDGEMENTS

We would like to thank the following persons:

- Doug Chapman for his invaluable work in creating the database and designing the machine-readable data collection sheets used during the survey.

- John Matthews for providing assistance with maps.

- Tracey McVea for formatting the final report.

- Megan Westlake, Simon Walsh and Craig Copeland for their help in co-ordinating the work of field staff and for providing technical support during the project.

- Paul Andrews, Daniel Clifton, Stuart Currie, Julie Dickson, Eli Dutton, Mieke Hummel, Emma Lewis, Anthony Moore, Samantha Pennick, Ben Phillips, Kris Pitman, Alan Robertson, Ben Robertson, Dean Stephen, Anna Tacey, Christopher Tippett, Simon Walsh, Megan Westlake and Chris Zschorn. The excellent work of this group of people during the data collection phase of the survey ensured a high level of data integrity.

- Steve Kennelly and Geoff Liggins for reviewing the draft manuscript and providing comments which improved the final report.

- Finally, we would like to thank all of the fishers that participated in the survey. The successful completion of this work was made possible by their continual co-operation and support.

EXECUTIVE SUMMARY

Major flooding in the upper reaches of the Richmond River occurred during early February 2001. The flood water inundated large areas of the floodplain which led to the decay of large amounts of vegetation and the mobilisation of highly reactive acid sulphate soils and sediments in the area. These two processes contributed directly to the marked reduction in dissolved oxygen levels in the river which in turn are believed to have been the cause of a large fish-kill which peaked around the 9th of February in the lower reaches of the Richmond River. The main species that were killed were yellowfin bream, dusky flathead, Australian bass, sea mullet, sand whiting, eels, school prawns and mud crabs. Lesser numbers of luderick, black sole, eeltail catfish, forktail catfish, and bullrout were also recorded in the fish-kill.

The NSW government responded to the fish-kill by: (a) closing the Richmond River (entrance to Coraki about 30 km upstream) and adjacent inshore ocean waters to all forms of fishing; (b) initiating biological monitoring of commercial fish and crustaceans; and (c) forming a Recovery Working Group to provide advice to the Minister on actions to be taken to enhance the recovery of fish stocks in the river, particularly with respect to river closures. In June 2001, the government decided to re-open part of the lower Richmond River, downstream of the Burns Point ferry crossing, to limited recreational and commercial fishing. Thus, when this recreational fishery re-opened on the 1st July, 2001 there was a need to collect quantitative information to describe the recreational fishery of the lower Richmond River. These data were essential for assessing the status of the recreational fisheries resources, the quality of the recreational fishery and to provide additional information regarding the rate of recovery of the populations of fish in the river since the fish-kill. The partial river closures were removed at the end of September 2001 to allow for the resumption of recreational and commercial fishing throughout the Richmond River.

Recreational fishing surveys of sound statistical design are essential for the collection of statistically unbiased information. We used stratified random sampling procedures as the basis of the survey design and integrated many data quality checks into the survey. Complemented survey methods were used to estimate the fishing effort; harvest and discard rates; and total harvest and discard for both the boat-based and shore-based fisheries in the Richmond River over a four-month survey period (July to October 2001 inclusive). The successful planning, organisation and execution of a large on-site survey of recreational fishing is a demanding and costly task. A community-based approach to the survey work, relying heavily on the support and involvement of local interest groups during all phases of the survey, proved highly successful.

We found that the recreational fishing population of the lower Richmond River was dominated by males - over 83% of both the boat-based fishers and shore-based fishers interviewed were male. We also found that the great majority of fishers interviewed were of local origin, ranging from 75% from the local area in the shore-based fishery to approximately 83% in the boat-based fishery.

We estimated that approximately 70,100 fisher hours of daytime recreational effort was expended in the lower Richmond River during the survey period - July to October 2001. The level of daytime recreational fishing effort showed a distinct monthly pattern with the highest level of effort in July, an intermediate level of effort in August and the lowest levels of effort in September and October. This monthly pattern of effort was similar to that recorded in a previous survey of a much larger area in the Richmond River, suggesting that these effort data are showing a seasonal trend.

We estimated that the daytime recreational harvest from the Richmond River fishery during the survey period consisted of approximately 29,800 fish, crabs and cephalopods (± 1,975 individuals - approximate SE) from 26 taxa. The bulk of this harvest was made up of luderick (≈13,680 fish -

≈ 7.3 tonnes), yellowfin bream (≈7,700 - ≈ 3.8 tonnes), dusky flathead (≈3,430 - ≈ 2.2 tonnes), sand mullet (≈1,630 - ≈ 0.1 tonnes), tailor (≈1,270 - ≈ 0.4 tonnes), and sand whiting (≈1,260 - ≈ 0.3 tonnes). These six taxa, by number, accounted for 97.3% of the daytime recreational harvest during the survey period. Comparisons made between these data and those collected during a previous survey in the Richmond River (1988 – 1989) indicate that there have not been any major changes in the structure of the recreational fishery since that time. Recreational anglers are still targeting and harvesting much the same species in the river and the monthly patterns of targeting and harvesting that we have documented are consistent with normal seasonal changes in this fishery. The size of the recreational harvest taken during the four month survey period can be put in context by comparing the size of the estimated recreational harvest to the estimates of total fish mortality associated with the fish-kill of February 2001. Westlake and Copeland (2002) estimated that around 300,000 yellowfin bream, 150,000 dusky flathead, 10,000 sand whiting and 5,000 luderick were killed in a 20 kilometer stretch of the lower Richmond River during the fish-kill event.

We estimated that recreational fishers (boat-based and shore-based) discarded approximately 50,900 fish, crabs and cephalopods (± 2,680 individuals - approximate SE) from 46 taxa whilst fishing in the lower Richmond River during the survey period. The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈30,060), dusky flathead (≈5,950), luderick (≈5,560), tailor (≈3,940), sand whiting (≈2,520) and southern herring (≈600). These six taxa, by number, accounted for 95.4% of the total daytime recreational discard. Recreational fishers indicated that the great majority (>90%) of discarded yellowfin bream, dusky flathead, luderick, tailor and sand whiting were below the legal minimum length. Although these discard data should be viewed with some caution because they are self-reported and less accurate than harvest data (which are collected by direct observation), they show that recreational fishers were catching and returning to the water large numbers of juvenile fish.

The four indicators of recreational fishing quality considered in this study were the proportion of unsuccessful fishing parties, non-directed harvest rates for the boat-based and shore-based fisheries, non-directed discard rates for the boat-based and shore-based fisheries and size-frequency distributions for some important taxa harvested by the recreational sector. The proportion of unsuccessful boat-based fishing parties ranged from approximately 31% to 59% on a monthly basis whilst the proportion of unsuccessful shore-based fishing parties was relatively higher ranging from approximately 61% to 80% on a monthly basis. In both fisheries the lowest proportion of unsuccessful fishing trips was recorded during July, immediately after the river was re-opened to recreational fishing, and progressively higher proportions of unsuccessful fishing parties were recorded in the following months. These data suggest that the quality of recreational fishing was best in July after the river had been re-opened to recreational fishing and that there had been a gradual decline in fishing quality in the following months. The reason for these trends in the boat and shore fisheries was probably a combination of seasonal fish abundances and the large amount of fishing effort that occurred immediately after the fishery was re-opened.

The harvest rates and discard rates we calculated and presented are based on the total non-directed fishing effort. The harvest rates observed during this four month survey are similar to comparable harvest rate data collected in other estuarine fisheries in NSW. These similarities suggest that the quality of recreational fishing was quite good for boat-based and shore-based fishers during the survey period in the lower Richmond River. A similar conclusion is reached when examining discard rate data. High rates of discard were reported for the main species of recreational interest during the survey period indicating that juvenile fish were abundant in the lower Richmond River during the survey period.

The size-frequency distributions presented are important baseline indicators which can be used to monitor future changes (if any) in the size structure of these species in the fishery. Overall, the proportions of undersized fish retained by recreational fishers in the lower Richmond River fishery (boat and shore-based) were comparable to rates measured in some other estuarine fisheries in NSW, suggesting a comparable availability of legal-sized fish in the population in the Richmond River. In addition, large individuals that were highly-prized by fishers were common in the recreational harvests, indicating that the quality of recreational fishing opportunities in this fishery were quite good.

In summary, the question of whether the recreational fishery (shore and boat-based) in the Richmond River has recovered from the impact of the February fish-kill event cannot be answered directly because we do not have any detailed information describing the status of riverine fish stocks or the recreational boat and shore fisheries in the Richmond River immediately before the fish-kill event nor do we have information about other non-impacted estuarine recreational fisheries in the region that could be used as controls or reference sites. Therefore, we are restricted to making inferences about the recovery of estuarine fish stocks and the status of the recreational fisheries from limited comparisons with previous studies and by examining a number of indicators of recreational fishing quality that have been derived from the current survey. The interpretation of the available evidence strongly suggests that the recreational fisheries in the lower Richmond River are still productive and providing quality recreational fishing opportunities despite the adverse impacts of the February 2001 fish-kill event.

1. INTRODUCTION

Major flooding in the upper reaches of the Richmond River occurred during early February 2001. The flood water inundated large areas of the floodplain which led to the decay of large amounts of vegetation and the mobilisation of highly reactive acid sulphate soils and sediments in the area. These two processes contributed directly to the marked reduction in dissolved oxygen levels in the river (Westlake and Copeland 2002) which in turn are believed to have been the cause of a large fish-kill which peaked around the 9th of February in the lower reaches of the Richmond River (Macbeth *et al.* 2002, Westlake and Copeland 2002). The main species that were killed were yellowfin bream, dusky flathead, Australian bass, sea mullet, sand whiting, eels, school prawns and mud crabs. Lesser numbers of luderick, black sole, eeltail catfish, forktail catfish, and bullrout were also recorded in the fish-kill (Macbeth *et al.* 2002, Westlake and Copeland 2002).

The NSW government responded to the fish-kill by: (a) closing the Richmond River (entrance to Coraki about 30 km upstream) and adjacent inshore ocean waters to all forms of fishing; (b) initiating biological monitoring of commercial fish and crustaceans; and (c) forming a Recovery Working Group to provide advice to the Minister on actions to be taken to enhance the recovery of fish stocks in the river, particularly with respect to river closures. In June 2001, the government decided to re-open part of the lower Richmond River, downstream of the Burns Point ferry crossing, to limited recreational and commercial fishing. This decision was taken after extensive consultation with the public and after detailed analysis of available biological and water quality information. Thus, when this recreational fishery re-opened on the 1st July, 2001 there was a need to collect quantitative information to describe the recreational fishery of the lower Richmond River. These data were essential for assessing the status of the recreational fisheries resources, the quality of the recreational fishery and to provide additional information regarding the rate of recovery of the populations of fish in the river since the fish-kill. The partial river closures were removed at the end of September 2001 to allow for the resumption of recreational and commercial fishing throughout the Richmond River.

1.1 Limitations of recreational fishing surveys for detecting environmental impacts

The assessment of environmental disturbance or impacts is difficult because it is often uncertain whether a causal relationship exists between the detrimental environmental event that has occurred (e.g. a flood followed by a fish-kill) and any changes that are measured at a later time. The changes in the recreational fishery detected after the fish-kill event include a component attributable to the detrimental flood event and a component due to natural fluctuations of fish populations that occur at various spatial and temporal scales. An appropriate experimental design is needed to discriminate between changes in the recreational fishery due to the fish-kill event and changes caused by natural fluctuations in fish abundance and catchability. Ideally, an experiment designed to test for the impacts of the fish-kill event would have included spatial replication at the level of rivers (i.e. other riverine fisheries would be used as controls or reference sites) and these multiple riverine fisheries would have been surveyed before and after the fish-kill event. This type of experimental design is referred to as a Before-After-Control-Impact (BACI) design in the scientific literature. Underwood (1991) provides a detailed description of this type of experimental design.

The recreational fishing survey we have done does not meet the rigorous requirements of a BACI experimental design. We do not have any data describing the recreational fishery immediately before the unexpected fish-kill event nor do we have data describing the status of other riverine recreational fisheries in the region that could be used as control sites. Thus, the current survey data can only be used to describe the status of the recreational fishery in the lower Richmond River after the fish-kill event. We are restricted to making inferences about the recovery of the fish stocks in the lower Richmond River from limited comparisons with some previous recreational fishing studies and by examining a number of indicators of recreational fishing quality derived from the present study.

1.2. Site description

The Richmond River ($28^0$53'S $153^0$35'E) is a large river on the north coast of New South Wales (NSW) on the east coast of Australia (Fig. 1). The Richmond River has a water area of approximately 19.1 km^2 and a total catchment area of approximately 6850 km^2 (Roy *et al.* 2001). The Richmond River is open permanently to the ocean with twin training breakwaters at its entrance. Roy *et al.* (2001) have classified the Richmond River as wave-dominated, barrier estuary. This type of estuary is characterised by having a tidal inlet that is constricted by wave deposited beach sand and a flood-tidal delta that is usually smaller than those found in tide-dominated estuaries (Roy *et al*. 2001). Wave dominated estuaries are more strongly influenced by river discharge than by tide with tidal ranges being approximately 5-10% less than in the ocean (Roy *et al*. 2001). The main river arm is approximately 170 km in length and the tidal limit is approximately 90 km from the ocean (DLWC website). The river contains approximately 4.9 km^2 of mangroves, approximately 0.2 km^2 of seagrass and approximately 0.1 km^2 of saltmarsh vegetation (Roy *et al*. 2001). The survey area in the lower Richmond River consisted of a relatively small part of the whole river, the Main River area being approximately 6.5 km in length and the North Creek area being approximately 6 km in length (Fig. 1).

1.2.1. Access for recreational fishers

The lower Richmond River, waters downstream of the Burns Point ferry crossing to the river mouth including North Creek and Fishery creek, was re-opened to limited recreational fishing on July 1, 2001. Additional new management measures were implemented during the following three month period which provided temporary restrictions to the recreational access to the fishery. Recreational fishing was allowed only between 06:00 to 19:00 hours. Each recreational fisher was permitted to have a daily bag limit of ten fish of any mix of species but with no more than five bream and one mulloway and not more of any species of finfish than allowed by an existing bag limit. Mullet taken for live bait were excluded from this personal bag limit with an additional 20 mullet less than 15 cm total length allowed. Recreational crab trapping was allowed in the re-opened area of the river. Existing legal size limits for all species remained the same.

The recreational fishery in the lower Richmond River can be readily accessed by fishers from boats and from the shore (Fig. 1). Boat-based fishers have access to the recreational fishery from five public boat ramps within the survey area (Fig.1) and from many other ramps located further upstream and outside the survey area. Private access to the fishery is quite restricted. There is extensive rural use of properties adjacent to the shoreline upstream of the survey area and large wetlands which preclude access for recreational fishers. There are very few moorings in the river and there is a small residential canal estate in the survey area (Fig. 1). Shoreline access to the recreational fishery is diffuse within the survey area, even though there are large areas of shoreline which are not very accessible because of the dense vegetation (e.g. mangroves in the North Creek area and along the southern shore of the river). Easy access to the fishery is available along the northern shoreline of the main river and along the length of the northern and southern breakwaters. The shoreline area beneath the Missingham bridge and the Munsies Point bridge are also popular fishing spots.

1.2.2. Access for commercial fishers

The lower Richmond River was also re-opened to limited commercial fishing on July 1, 2001. Stringent management measures were implemented during the following three-month period to hasten the recovery of fish stocks in the river. Beach haul fishing for mullet was allowed on the beach of the northern bank immediately downstream of the Missingham Bridge (Figure 1). Commercial fishing on the ocean beaches to the north and south of the river mouth was restricted to traveling schools of mullet and pilchards so as not to directly affect the recovery of the river. Commercial crab trapping was allowed within the re-opened area of the river. Existing legal size limits for all species remained the same.

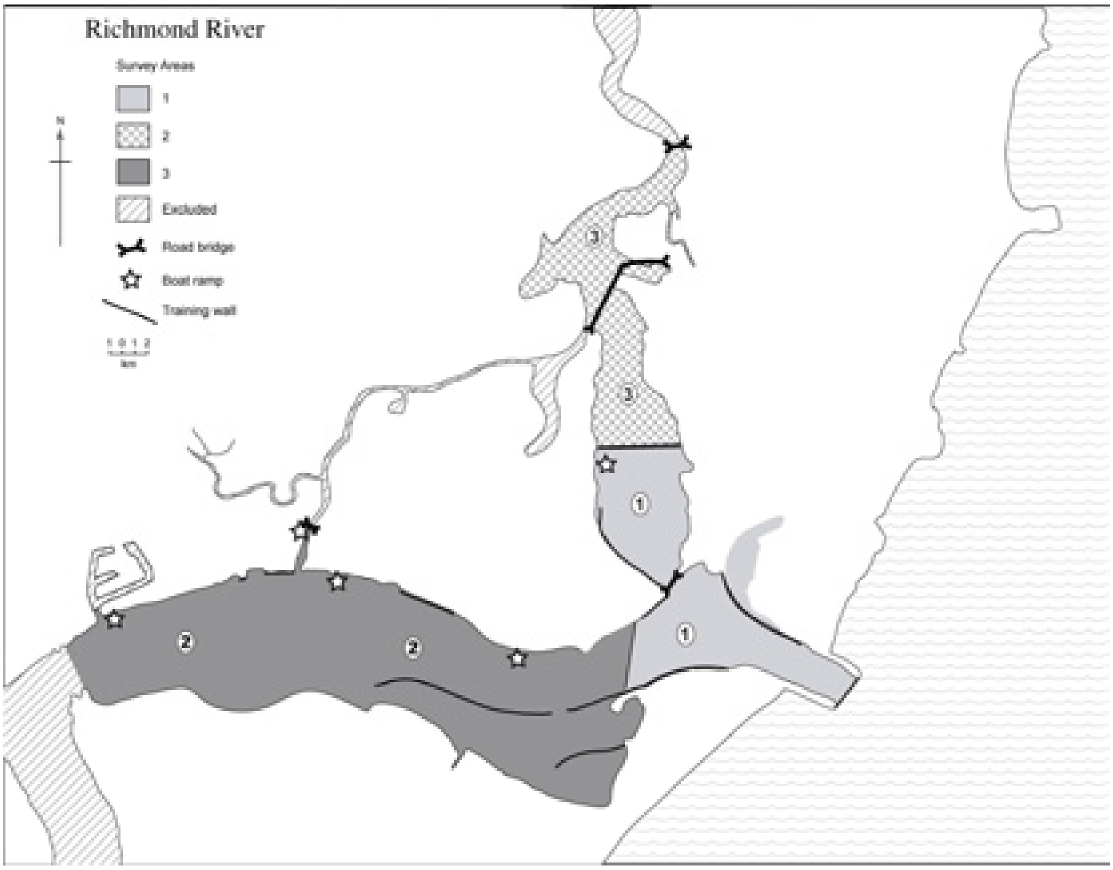

Figure 1. Map of the lower Richmond River showing the spatial extent of the survey and the boundaries used to divide the fishery into three areas: (1) the Entrance area; (2) North Creek area; and (3) the Main River area. The location of public boat ramps and training walls (break-waters) have been marked.

1.3. Aims

The principal aims of this project were:

1. To estimate the level of daytime recreational fishing effort in the lower reaches of the Richmond River during the four-month period, July to October 2001 inclusive.
2. To estimate daytime recreational harvest rates and discard rates in the lower reaches of the Richmond River.
3. To estimate the amount of daytime harvest and discarding by recreational fishers in the lower reaches of the Richmond River.
4. To describe the status of the shore-based and boat-based recreational fisheries in the lower reaches of the Richmond River following a major fish-kill event in early February 2001.

2. METHODS

2.1. General

We seek to communicate the findings of this work to a very diverse audience, which includes recreational and commercial fishers, scientists, managers and interested members of the general public. The published texts describing the many different types of survey designs and methods, their relative strengths and limitations, and their statistical treatment, all contain a considerable quantity of technical terms. Unfortunately, it is not possible to eliminate the use of this technical language without compromising the scientific meaning of the report. We provide a glossary of the technical terms used in this report (see Appendix 1) to assist any layperson in his/her attempt to read and understand the findings of this work. Wherever possible, we also try to define terms in the text when they are used for the first time. The term "catch" is used to refer to the number or weight of fish caught (kept and discarded), whilst the term "harvest" refers to that part of the catch that is retained, usually measured as the number or weight of fish kept. The term "discard" is used to refer to that part of the catch that is not kept, usually measured as the number of fish discarded. The reasons for discarding fish, crabs and cephalopods vary among fishers and include: (a) the small size of the animal (many species that are targeted by recreational fishers have minimum legal lengths specified in legislation, whereas, for all other species the discard size is determined by the judgement of individual fishers); (b) the animal is regarded by fishers to be of low edible quality or has poisonous flesh; (c) the bag limit has been achieved but the fisher wants to continue fishing; (d) the fishing ethic adopted by individual fishers (many fishers are involved in "catch and release" fishing).

Accurate and precise information which describes and quantifies the fishing effort, harvests, and harvest rates of recreational fishers is needed to understand changes in recreational fisheries throughout time. Recreational fishing surveys that have multiple objectives usually involve complex survey designs and these types of surveys can be very costly (Pollock *et al*. 1994). The choice of survey design is constrained by practical considerations, which are often site-specific, and by the limited finances available to the project. Thus, when decisions on sample sizes are made at the start of a survey, they are always influenced by the trade-off between desired levels of precision and the limited resources allocated to the survey. A statistically sound survey design based on the principles of stratified random sampling is essential to enable the cost-efficient collection of reliable survey data.

2.2. Survey design

We follow the terminology of Pollock *et al*. (1994) to describe the survey designs and estimation methods used to calculate harvest and discard rates, estimates of total fishing effort, total harvest and discard. We used on-site survey methods (surveys conducted at the fishing sites) because most of the information collected on-site can be verified by field staff. In contrast, off-site methods (surveys conducted away from fishing sites), such as telephone or diary surveys, depend largely on self-reported information which cannot be verified (Pollock *et al*. 1994). Another major advantage of on-site surveys is that the non-response or refusal rates recorded are usually much lower than the non-response rates recorded during off-site surveys (Pollock *et al*. 1994).

A complemented survey combines two or more contact methods for collecting effort and catch information from fishers (Pollock *et al*. 1994). Complemented survey methods were used to assess separately the shore-based recreational fishery and the boat-based recreational fishery. The shore-based fishery was assessed by using a roving(effort)-roving(harvest and discard) design combination. The boat-based fishery was assessed by using a roving(effort)-access(harvest and discard) design combination.

The sampling frame is a complete list of possible sampling units in the whole population and a clear and unambiguous definition of the sampling frame is needed to determine the scope of a survey (Cochran 1953, Yates 1965, Pollock *et al*. 1994). The sample frame can be divided into non-overlapping strata and a random sampling protocol is usually applied to select a sample from each stratum (Cochran 1953, Yates 1965, Pollock *et al*. 1994). This survey work is based on the principles of stratified random sampling. Pollock *et al*. (1994) summarised the advantages of stratification as:

(a) improving the overall precision of population estimates. An increase in precision (i.e. a reduction in variance) will occur when a relatively heterogeneous population is divided into non-overlapping strata of known size, that are relatively more homogeneous than the whole population;
(b) making the administration of the survey work easier because strata can be used to partition large frames that are difficult to sample into multiple, smaller units that can each be sampled more easily; and
(c) providing greater information yield. The creation of strata allows us to calculate population estimates for each separate stratum, thereby providing important information at a smaller scale, as well as providing overall estimates of population parameters for the entire population by combining the separate stratum totals and their associated variances.

2.3. Spatial sampling frame and stratification

The spatial sampling frame (geographical boundary) of this survey is illustrated in Figure 1. All excluded areas shown in Figure 1 are regarded as being outside the spatial sampling frame. The lower Richmond River survey area (Fig. 1) was stratified into three distinct areas: (a) the Entrance area; (b) the North Creek area; and (c) the Main River area.

2.3.1 Entrance area

The eastern extremity of the Entrance area (Fig. 1) was defined as being a line drawn between the seaward-most extremities of the North and South breakwaters at the river mouth. The boundary between the Entrance area and the Main River area (Fig. 1) was defined as a line drawn between the outermost part of a prominent sand spit on the northern shore (adjacent to the Kingsford Smith Park) and extending to the point at which the South breakwater meets the shoreline of Mobbs Bay (Fig. 1). The boundary between the Entrance area and the North Creek area was defined as a line extending east from Cawarra Park (north of the Cawarra street boat ramp) to the western-most point of the opposite shoreline of North Creek (Fig. 1). Shaws Bay was included as part of the Entrance area.

2.3.2. North Creek area

The southern boundary of this area was defined as a line extending east from Cawarra Park (north of the Cawarra street boat ramp) to the western-most point of the opposite shoreline of North Creek (Fig. 1). All tidal waters north of this boundary line were included in this area with the exception of the waters of North Creek Canal, which were excluded from the spatial survey frame. The waters of Prospect Lake and Chickiba Lake were included in this area.

2.3.3. Main river area

The boundary between the Main River area and the Entrance area (Fig. 1) was defined as a line drawn between the outermost part of a prominent sand spit on the northern river shore (adjacent to the Kingsford Smith Park) and extending to the point at which the South breakwater meets the shoreline of Mobbs Bay (Fig. 1). The western boundary of the Main River area was defined as the Burns Point Ferry crossing. (Figure 1). All waters upstream of the Burns Point Ferry crossing, the Ballina Quays (a small residential canal development), and the waters of North Creek Canal above the Pacific Highway roadbridge were excluded from the spatial survey frame. Mobbs Bay was included in this area.

2.4. Temporal sampling frame and stratification

The temporal sampling frame of the survey spanned a four-month period, commencing in July and concluding at the end of October 2001. We stratified the four-month survey period into months (July, August, September and October), and day-types within each month (Weekdays and Weekend days). Public holidays were classified as weekend days. Days were regarded as the primary sampling unit for all strata. By definition, a survey day started at sunrise and ended at sunset, however the fishery closure in place during July, August and September restricted the legally permitted fishing day to the period between 06:00 to 19:00 hours. When sunrise occurred before the start of the legally permitted fishing day we defined the length of the fishing day as being from 06:00 to sunset.

Basic sampling theory dictates that the accuracy and precision of overall population estimates can be improved by allocating more sampling units to a stratum that contains a large part of the recreational fishing effort and/or harvest (see Cochran 1953, Pollock *et al*. 1994). It has long been known that surveys will usually be most efficient (have least variance) when the distribution of sampling effort coincides with the distribution of fishing effort (Best and Boles 1956, Pollock *et al*. 1994). If effort and harvest are strongly correlated then it follows that by weighting sampling effort in proportion to the fishing effort there will also be an improvement in the precision of harvest estimates. We already knew from previous angler surveys that a disproportionate amount of the recreational fishing effort and harvest occurs on weekend days (Steffe et al. 1996a & 1996b, Steffe and Chapman 2002, Steffe unpublished data) thus it was logical to allocate proportionally more sampling units to the weekend day-type stratum than to the weekday day-type stratum.

2.5. Collecting data for the boat-based and shore-based recreational fisheries

Two independent datasets were collected and used to estimate recreational fishing effort, harvest rates and discard rates. These datasets consisted of: (1) progressive counts of recreational fishing effort; and (2) interviews with recreational fishing parties. These two datasets were used to obtain estimates of boat-based and shore-based recreational harvest and discard.

2.5.1. Progressive counts of recreational fishing effort

Estimates of recreational fishing effort for the boat-based fishery and the shore-based fishery were made with progressive counts on randomly selected survey days. Progressive counts were made separately of all boats and all shore-based persons that were observed to be involved in some type of recreational fishing activity. These recreational fishing activities included all forms of angling and the setting, checking and retrieval of crab nets, but excluded activities such as spearfishing, bait collecting and prawning. We specifically excluded boats traveling across the river and anglers moving along the shore from the counts (even when recreational fishing gear was visible) when it was not possible to determine their destination nor their intent to engage in any recreational fishing activity. In contrast, we included boats in the counts when they were engaged in drift fishing and they were observed traveling to start another "drift" upstream. Drift fishing was common in the river.

A series of shoreline vantage points spread throughout the survey area were used to construct a circuit for making progressive counts of fishing effort. The time needed to complete progressive counts during this circuit of the fishery was determined during a series of practice runs. Three replicate progressive counts were scheduled on each of the randomly selected survey days. The starting times for the replicate progressive counts were scheduled by picking one of a set of discrete possible starting times as recommended by Hoenig *et al*. (1993). The starting location and direction of travel were randomly selected for each scheduled progressive count. This progressive count method will, under very general conditions, provide unbiased estimates of fishing effort during the day (Hoenig *et al*. 1993). The collection of recreational effort data by means of these progressive counts was done on the same days as the interviews with recreational fishing parties. Importantly, the collection of progressive count and interview data were treated as separate jobs, meaning that scheduled progressive counts were not interrupted to interview fishers and that other survey staff were assigned to conduct interviews throughout the fishery during the entire fishing day which included the periods during which replicate progressive counting of fishing effort was done. This small organisational change in staff deployment effectively eliminated the "shadow bias" (see Wade *et al*. 1991) that occurs when progressive counts are interrupted so that interviews with fishers can be done. The number of replicate days sampled for each day-type stratum within each month is summarised in Table 1. The level of daily replication achieved represents sampling fractions of approximately 64% for the weekend day-type stratum and approximately 28% for the weekday stratum during the period of the survey (Table 1).

2.5.2. Interviews with recreational fishing parties

All interviews were done between 09:00 hours and sunset. We chose to restrict the interview coverage because data from a previous study had showed that less than 4% of recreational fishing trips were completed between sunrise and 09:00 hours making it cost-effective to start interviewing after 09:00 hours (Steffe *et al*. 1996a). It is important to note that most recreational fishing trips that begin in the period between sunrise and 09:00 hours are completed later in the day and would be covered by the sampling regime. Machine-readable interview forms were used to collect information from boat-based and shore-based fishing parties. Fishing parties were approached and asked to participate in the survey by providing information about their fishing trip, harvest and discard. Attempts were made to interview all recreational fishing parties encountered (shore-based and boat-based), however, during periods of high recreational activity it was necessary to systematically subsample every second or third fishing party (depending on the number of fishing parties available for interview). Refusals to provide information, or to show the fish retained, were recorded. We asked co-operative recreational fishers about their targeting preferences during their current fishing trip, the time they started fishing and their fishing locations. We also recorded the number of fishers in the fishing party (non-fishers were not included as part of a fishing party) and the sexes of all fishing party members. Home postcode information for all persons (fishers and non-fishers) in a fishing party was requested and the following six home postcodes (2471, 2477, 2478, 2479, 2480, 2481) were used to identify local fishers in the lower Richmond River. The retained catch was identified by field staff and, whenever possible, measurements of all fish (fork length), crabs (carapace length) and squid (mantle length) were taken to the nearest whole centimetre. When fishers were in a hurry to leave the ramp and it was not possible to measure all fish, crabs and squid, the survey personnel were instructed to record counts of the identified harvest and attempt to measure a sub-sample of the harvest. Fishers were also asked to recall the quantity and identity of all fish, crabs and cephalopods that they had caught and discarded during their trip. Whenever the nominated discard was a species that had a minimum legal length the fishers were asked additional questions to assess whether the discards had been larger or smaller than the minimum legal length.

Table 1. Sample sizes (number of days spent interviewing and the number of replicate progressive counts of effort), number of interviews, number of refusals and refusal rates for the boat and shore recreational fisheries in the Richmond River during the survey period (July 1 - October 31, 2001).

			No. DAYS SAMPLED		**BOAT FISHERY**			**SHORE FISHERY**		
Month/Year	Day-Type	No. Days in Stratum	Effort Counts	Interviews	Number of Interviews	Number of Refusals	Refusal Rate (%)	Number of Interviews	Number of Refusals	Refusal Rate (%)
July 2001	Weekday	22	6	6	119	2	1.7	384	2	0.5
	Weekend	9	6	6	267	3	1.1	389	1	0.3
	Total	**31**	**12**	**12**	**386**	**5**	**1.3**	**773**	**3**	**0.4**
August 2001	Weekday	23	6	6	96	1	1.0	298	0	0.0
	Weekend	8	6	6	218	2	0.9	291	0	0.0
	Total	**31**	**12**	**12**	**314**	**3**	**1.0**	**589**	**0**	**0.0**
September 2001	Weekday	20	6	6	45	1	2.2	197	1	0.5
	Weekend	10	6	6	112	1	0.9	281	1	0.4
	Total	**30**	**12**	**12**	**157**	**2**	**1.3**	**478**	**2**	**0.4**
October 2001	Weekday	22	6	6	50	3	6.0	224	0	0.0
	Weekend	9	5	6	108	2	1.9	247	2	0.8
	Total	**31**	**11**	**12**	**158**	**5**	**3.2**	**471**	**2**	**0.4**
Total	Weekday	87	24	24	310	7	2.3	1103	3	0.3
	Weekend	36	23	24	705	8	1.1	1208	4	0.3
	Total	**123**	**47**	**48**	**1,015**	**15**	**1.5**	**2,311**	**7**	**0.3**

Sampling effort was concentrated at the boat ramps used by recreational fishers within the survey area. This approach was adopted to maximise the number of interviews with boat-based fishing parties during late Winter and early Spring when low recreational effort levels were expected. The use of a bus-route method during this survey (see Robson and Jones 1989 for a description of this method) was considered but proved to be impractical because of the seasonal timing of the survey. We wanted to remove the possibility on low effort survey days of missing interviews with the few available boat-based fishing parties because the survey staff were waiting at another access point or in the process of traveling between boat ramps.

Boat-based fishing parties were approached at boat ramps when they returned from their fishing trip. The harvest rate and discard rate information collected during these access point interviews is based on completed trips (Malvestuto 1983, Hayne 1991, Pollock *et al*. 1994, Pollock *et al*. 1997). The access point survey method works best when there are few, well-defined, access sites (Pollock *et al*. 1994). The relatively small survey area contained five boat ramps which were all sampled but there are also many other access points further upstream that could have been used to provide access to the fishery. Similarly, private jetties and moorings could also have been used to access the fishery, however, there are relatively few private access points for boats along the lower Richmond River. Therefore, we assumed that the fishing activities of recreational fishers using the public boat ramps were representative of recreational fishing parties that used private access points and other boat ramps further upstream to enter and leave the fishery. Although we did not test this important assumption, we have no reason to expect that fishers using private access points and other upstream boat ramps would have behaved differently to those fishers that used the public boat ramps within the survey area because these populations of fishers (regardless of where they access the fishery) use the same methods to target the same species in the same fishing areas within the survey area.

The diffuse access across large stretches of shoreline and breakwater compelled us to use roving survey methods to assess the shore-based fishery. The shore-based fishery within the survey area was searched entirely at least once (usually many times) during each survey day by an interviewer, thus providing coverage of the entire shore-based fishery on each survey day. Shore-based fishing parties were approached during their fishing trips by field staff. Therefore, the harvest rate and discard rate information collected during these interviews was based on incomplete trips which documented only part of the total effort, harvest and discard for these fishing trips (Robson 1961 & 1991, Pollock *et al*. 1994). The use of a roving survey design introduced a sampling bias because the probability of interviewing a group is proportional to the duration of their fishing trip. That is, parties that fish for longer time periods are more likely to be encountered by field staff moving through the fishery, termed the "length-of-stay" bias (Robson 1991, Pollock *et al*. 1994, Pollock *et al*. 1997, Hoenig *et al*. 1997), which means that harvest rates and discard rates derived from roving survey methods tend to be based on samples that contain an over-representative number of longer trips and an under-representative number of short trips. Roving survey methods require the following assumptions be made: (a) the harvest rate and discard rate for the portion of fishing trip documented is the same as the harvest rate and discard rate for the entire trip; and (b) the harvest rate and discard rate of interviewed fishing parties is representative of the whole fishing population, which is the expected outcome for estimates derived from randomly selected samples (Malvestuto 1983, Phippen and Bergersen 1991, Pollock *et al*. 1994, Hoenig *et al*. 1997).

2.6. Estimation methods

We follow the general equations used by Pollock *et al*. (1994) for estimating total recreational fishing effort, recreational harvest and discard rates, and total recreational harvest and discard for the boat-based and shore-based fisheries and refer the reader to this book for worked examples. More detailed explanations of the statistical procedures used can be found in Cochran (1953), Robson (1960, 1961 & 1991), Yates (1965), Malvestuto (1983), Hayne (1991), Hoenig *et al*. (1993 & 1997) and Pollock *et al*. (1997).

2.6.1. Basic notation

j denotes the stratum being considered $(j = 1,...,J)$;

J denotes the total number of strata;

i denotes the sample day unit within the stratum $(i = 1,....,N_j)$;

N_j is the total population size (all possible sampling days) in stratum j;

n_j is the sample size in stratum j;

x_{ij} denotes the value of the ith unit of stratum j;

$\overline{x}_j$ is the sample mean for stratum j;

$$s_j^2 = \frac{\left[\sum_{i=1}^{n_j}\left(x_{ij} - \overline{x}_j\right)^2\right]}{\left(n_j - 1\right)}$$ is the sample variance for stratum j

2.6.2. Effort estimation for the boat-based and shore-based recreational fisheries

Estimation of total effort was done separately for the boat-based fishery (units of boat hours) and the shore-based fishery (units of fisher hours). The base level of effort estimation was a day-type stratum within a month for each of the three areas in the lower Richmond River (Entrance area, North Creek area and Main River area – see Figure 1). The effort estimates for each of the three river areas were combined to give separate day-type and monthly totals for the whole lower Richmond River survey area. A description of the equations used for estimating stratum totals, variances and standard errors are provided below.

Step 1 - The progressive counts of recreational fishing boats and shore-based fishers were expanded separately to estimate the daily effort for each fishing day that was sampled.

$$\hat{e}_i = \overline{P}_i \times T \qquad \text{(Equation 1)}$$

where:
$\hat{e}_i$ is the estimate of fishing effort for the ith sample day.
$\overline{P}_i$ is the mean value for replicated progressive counts done on the ith sample day. The mean number of boats per progressive count is used for the boat-based fishery. The mean number of shore fishers per progressive count is used for the shore-based fishery.
T is the length of the fishing day. We used the mean daylength period (units are hours) for each month (sunrise to sunset) whenever this period was contained within the legally permitted fishing day (06:00 to 19:00). When sunrise occurred before the start of the legally permitted fishing day we defined the length of the fishing day as being from 06:00 to sunset.

Step 2 - These daily effort estimates were then expanded for each day-type stratum within each month. This was done by multiplying the number of possible sample days in each base level stratum with the the mean of the daily estimates of effort.

$$\bar{e}_j = \frac{\sum \hat{e}_{ij}}{n_j} \quad \text{(Equation 2)}$$

where:
$\bar{e}_j$ is the estimated mean daily fishing effort for the j th day-type stratum within a month, in units of boats per day for the boat fishery and fishers per day for the shore fishery.
$\hat{e}_{ij}$ is the estimate of fishing effort for the i th sample day in the j th day-type stratum within a month.
n_j is the number of days sampled in the j th day-type stratum within a month.

$$\hat{E}_j = N_j \times \bar{e}_j \quad \text{(Equation 3)}$$

where:
$\hat{E}_j$ is the estimate of total effort for the j th day-type stratum within a month. In the boat fishery the units are boat hours and for the shore fishery the units are fisher hours.
See Basic notation and Equation 2 for definitions of the other terms.

Step 3 - Calculate the precision of the effort estimates. This is done for each fishery by estimating variances and standard errors for each stratum.

$$Var(\bar{e}_j) = \frac{s_j^2}{n_j} \quad \text{(Equation 4)}$$

where:
$Var(\bar{e}_j)$ is the estimated variance of the mean daily fishing effort for the j th day-type stratum within a month. This is calculated separately for each fishery.
s_j^2 is the sample variance of the daily estimates of fishing effort for the j th day-type stratum within a month.
n_j is the sample size as described in Equation 2.

$$SE(\bar{e}_j) = \sqrt{Var(\bar{e}_j)} \quad \text{(Equation 5)}$$

where:
$SE(\bar{e}_j)$ is the estimated standard error of the mean daily fishing effort.
$Var(\bar{e}_j)$ is the estimated variance of the mean daily fishing effort as described in Equation 4.

$$Var(\hat{E}_j) = N_j^2 \times Var(\bar{e}_j) \quad \text{(Equation 6)}$$

where:
$Var(\hat{E}_j)$ is the estimated variance of total effort for a stratum, and is calculated separately for each day-type within each month for each fishery.
See Basic notation and Equation 4 for definitions of the other terms.

$$SE(\hat{E}_j) = \sqrt{Var(\hat{E}_j)} \quad \text{(Equation 7)}$$

where:
$SE\left(\hat{E}_j\right)$ is the estimated standard error of total effort for a stratum.
$Var\left(\hat{E}_j\right)$ is the estimated variance of total effort for a stratum as described in Equation 6.

Step 4 - Calculate total fishing effort separately for the boat-based and shore-based fisheries. This was done by adding the effort estimates of the day-type strata together to obtain monthly totals.

$$\hat{E}_{Tot} = \sum_{j=1}^{J} \hat{E}_j \quad \text{(Equation 8)}$$

where:
$\hat{E}_{Tot}$ is the total monthly effort calculated by combining the effort estimates for each day-type stratum. The general form of the same equation was used when adding effort estimates for the three survey areas.
$\hat{E}_j$ is the estimate of total effort for the j th day-type stratum as defined in Equation 3.

Step 5 - Calculate the precision of effort estimates obtained by adding stratum totals. This is done by simply adding the estimated variances for each stratum and calculating a standard error for the estimates of monthly effort totals.

$$Var\left(\hat{E}_{Tot}\right) = \sum_{j=1}^{J} Var\left(\hat{E}_j\right) \quad \text{(Equation 9)}$$

where:
$Var\left(\hat{E}_{Tot}\right)$ is the estimated total monthly variance calculated by combining the estimated effort variances for each day-type stratum. The general form of the same equation was used when adding variance estimates for the three survey areas.

$$SE\left(\hat{E}_{Tot}\right) = \sqrt{Var\left(\hat{E}_{Tot}\right)} \quad \text{(Equation 10)}$$

where:
$SE\left(\hat{E}_{Tot}\right)$ is the estimated standard error for monthly effort totals when adding day-type strata. The general form of the same equation was used when adding effort estimates for the three survey areas and calculating the standard error for the combined effort estimate.
$Var\left(\hat{E}_{Tot}\right)$ is the estimated total variance as described in Equation 9.

Step 6 - Calculate total fishing effort (boat-based plus shore-based) for the entire survey area. The initial step in these calculations was to convert the effort estimates for the boat-based fishery into units of fisher hours. As before, the base level of effort estimation was for a day-type stratum within a month for each of the three survey areas (Entrance area, North Creek area and Main River area).

Please note: to simplify the notation in the following equations we have stopped adding the suffix j (which denotes the j th stratum) to all terms in the general equations even though these terms still refer implicitly to the j th stratum.

$\hat{E}_{new} = \hat{E}_{old} \times \bar{f}$ (Equation 11)

where:
$\hat{E}_{new}$ is the new estimate of effort for the boat-based fishery in units of fisher hours.
$\hat{E}_{old}$ is the old estimate of effort for the boat-based fishery in units of boat hours.
$\bar{f}$ is the mean number of fishers per boat in that stratum.

Step 7 - Calculate the variance and standard error of the new estimate of effort for the boat-based fishery.

$Var\left(\hat{E}_{new}\right) = \left\lfloor \hat{E}_{old}^{2} \times Var\left(\bar{f}\right)\right\rfloor + \left\lfloor \bar{f}^{2} \times Var\left(\hat{E}_{old}\right)\right\rfloor - \left\lfloor Var\left(\bar{f}\right) \times Var\left(\hat{E}_{old}\right)\right\rfloor$ (Equation 12)

where:
$Var\left(\hat{E}_{new}\right)$ is the estimated variance of the new estimate of effort for the boat-based fishery.
$Var\left(\bar{f}\right)$ has been calculated by using the general form of Equation 4.
$Var\left(\hat{E}_{old}\right)$ has been calculated by using the general form of Equation 6.
The terms $\hat{E}_{old}$ and $\bar{f}$ are described in Equation 11.

$SE\left(\hat{E}_{new}\right) = \sqrt{Var\left(\hat{E}_{new}\right)}$ (Equation 13)

where:
$SE\left(\hat{E}_{new}\right)$ is the estimated standard error of the new estimate of effort for the boat-based fishery.
$Var\left(\hat{E}_{new}\right)$ is described in Equation 12.

Step 8 - When estimates of effort totals for the boat-based fishery had been converted into the same units as those in the shore-based fishery, it was possible to combine stratum totals for the boat and shore fisheries to give estimates of monthly effort totals. Monthly effort estimates for the three spatial strata (Entrance area, North Creek area and Main River area) were then combined to give effort estimates for the whole survey area. This procedure of adding stratum estimates has already been described and calculations were done using the general form of Equation 8.

Step 9 - Calculate monthly estimates of variance and standard errors for the total fishery. This procedure has already been described and calculations are done using the general form of Equations 9 and 10.

2.6.3. Harvest rate and discard rate estimators for the boat-based fishery

When the objective is to estimate total harvest, and the interview data are based on completed trips, the correct harvest rate estimator to use is the "ratio of means" (Jones *et al*. 1995, Pollock *et al*. 1997). This estimator is essentially the ratio of mean harvest to mean effort on a given day. The "ratio of means" was used for estimating the harvest of the boat-based fishery. Pollock *et al*. (1997) have shown that this estimator has a statistical expectation that is equal to total harvest divided by total effort for the population of fishers when it is applied to completed trip interviews taken at access points to the fishery.

$$\hat{R}_{1(H)} = \frac{\sum_{k=1}^{n} H_k}{\sum_{k=1}^{n} L_k} \text{ (Equation 14)}$$

where:

$\hat{R}_{1(H)}$ is the "ratio of means" an estimated daily harvest rate based on complete trips. The units used to estimate recreational harvest for the boat-based fishery were the number of fish per boat hour (see Appendices 2.1 to 2.6), and the weight of fish per boat hour (which are not presented). We also converted harvest rates for the boat-based fishery to numbers of fish per fisher hour so that comparisons could be made with the shore-based fishery.

H_k is the complete harvest for the k th fishing unit. These fishing units can be boats, fishing parties, or fishers.

L_k is the complete trip length for the k th fishing unit.

n is the number of fishing units in the daily sample.

The explanation given above for harvest rate estimation is also valid for the estimation of discard rates.

$$\hat{R}_{1(D)} = \frac{\sum_{k=1}^{n} D_k}{\sum_{k=1}^{n} L_k} \text{ (Equation 15)}$$

where:

$\hat{R}_{1(D)}$ is the "ratio of means" an estimated daily discard rate based on complete trips. The units used to estimate recreational discard for the boat-based fishery were the number of fish discarded per boat hour (see Appendices 2.1 to 2.6), We also converted discard rates for the boat-based fishery to numbers of fish discarded per fisher hour so that comparisons could be made with the shore-based fishery.

D_k is the complete discard for the k th fishing unit. These fishing units can be boats, fishing parties, or fishers.

L_k is the complete trip length for the k th fishing unit.

n is the number of fishing units in the daily sample.

We calculated mean daily harvest rates $\overline{R}_{1(H)}$ and mean daily discard rates $\overline{R}_{1(D)}$ for each day-type stratum within a month. The estimated variances of the mean daily harvest rates $Var\left(\overline{R}_{1(H)}\right)$ and the estimated variances of the mean daily discard rates $Var\left(\overline{R}_{1(D)}\right)$ were calculated by using the general form of Equation 4, and the estimated standard errors of the mean daily harvest rates $SE\left(\overline{R}_{1(H)}\right)$ and the estimated standard errors of the mean daily discard rates $SE\left(\overline{R}_{1(D)}\right)$ were calculated using the general form of Equation 5.

2.6.4. Harvest rate and discard rate estimators for the shore-based fishery

When the objective is to estimate total harvest, and the interviews are based on incomplete trips, the correct harvest rate estimator to use is the "mean of ratios" (Jones *et al*. 1995, Pollock *et al*. 1997, Hoenig *et al*. 1997). This estimator is essentially the mean of the individual harvest rates for all fishers interviewed on a given day. The "mean of ratios" was used for estimating the harvest of the shore-based fishery. Hoenig *et al* (1997) used simulation procedures to show that the "mean of ratios" estimator has a large variance caused by the inclusion of high harvest rates resulting from very short, incomplete trips that have harvested some fish already. These authors found that the truncation (exclusion) of all short incomplete trips reduced the variance greatly without inducing an appreciable bias. Hoenig *et al*. (1997) recommended the truncation of short trips less than 20-30 minutes but noted that there was a trade-off between the level of truncation used and the number of interviews that were discarded. We examined the relationship between the harvest rate and the duration of the fishing trip for shore-based interviews to determine the most appropriate level of truncation. We found that by discarding all incomplete trips that had been in progress for less than 30 fisher minutes, we were able to remove the interviews with the most extreme harvest rates and hence minimise the variance of the harvest rate estimator. The adoption of this truncation criterion resulted in the loss of 292 shore-based interviews (approximately 12.6% of the usable shore-based interviews) from harvest calculations. We had routinely asked shore-based fishing parties about the intended finishing time for their current trip. We retained and used shore-based interviews with fishing parties that had completed their trips but had fished for less than 30 fisher minutes. We believe it is logical to keep and use the data from these complete short trips, regardless of the small amount of time fished or the amount of harvest taken, because it is these short trips that are under-represented in roving surveys due to "length-of-stay" bias.

Hoenig *et al*. (1997) showed that the mean of ratios estimator has an approximate statistical expectation of total harvest divided by total effort for the population of fishing units when it is applied to incomplete trip interviews with a truncation of short trips, taken by roving through the fishery. Thus, the mean of ratios estimator $\left(\hat{R}_2\right)$ used on incomplete trips with a truncation of short trips, provides an equivalent measure of fishing success to the ratio of means estimator $\left(\hat{R}_1\right)$ used on complete trips (Pollock *et al*. 1997, Hoenig *et al*. 1997).

$$\hat{R}_{2(H)} = \frac{1}{n}\sum_{k=1}^{n}\frac{H_k}{L_k} \quad \text{(Equation 16)}$$

where:

$\hat{R}_{2(H)}$ is the "mean of ratios" an estimated daily harvest rate with truncation of short incomplete trips. The units used to estimate recreational harvest for the shore-based fishery were the number of fish per fisher hour, and the weight of fish per fisher hour.

H_k is the incomplete harvest (the harvest recorded at the time of interview for the incomplete trip) for the k th fishing unit. These fishing units can be boats, fishing parties, or fishers.

L_k is the incomplete trip length (the length of the incomplete trip at the time of interview) for the k th fishing unit.

n is the number of fishing units in the daily sample.

The explanation given above for harvest rate estimation is also valid for the estimation of discard rates.

$\hat{R}_{2(D)} = \frac{1}{n}\sum_{k=1}^{n}\frac{D_k}{L_k}$ (Equation 17)

where:
$\hat{R}_{2(D)}$ is the "mean of ratios" an estimated daily discard rate with truncation of short incomplete trips. The units used to estimate recreational discard for the shore-based fishery were the number of fish discarded per fisher hour.
D_k is the incomplete discard (the discard recorded at the time of interview for the incomplete trip) for the k th fishing unit. These fishing units can be boats, fishing parties, or fishers.
L_k is the incomplete trip length (the length of the incomplete trip at the time of interview) for the k th fishing unit.
n is the number of fishing units in the daily sample.

We calculated mean daily harvest rates $\overline{R}_{2(H)}$ and mean daily discard rates $\overline{R}_{2(D)}$ for each day-type stratum within a month. The estimated variances of the mean daily harvest rates $Var\left(\overline{R}_{2(H)}\right)$ and the estimated variances of the mean daily discard rates $Var\left(\overline{R}_{2(D)}\right)$ were calculated by using the general form of Equation 4, and the estimated standard errors of the mean daily harvest rates $SE\left(\overline{R}_{2(H)}\right)$ and the estimated standard errors of the mean daily discard rates $SE\left(\overline{R}_{2(D)}\right)$ were calculated using the general form of Equation 5.

2.6.5. Monthly harvest rate estimation for boat and shore fisheries

The same logic and general equations are applied in the estimation of monthly harvest rates, monthly discard rates and their associated variances and standard errors. The contribution of each day-type stratum to the estimated monthly harvest rate and monthly discard rate was weighted by the relative size of each day-type stratum within the month (Pollock *et al*. 1994). This means that a greater weighting was given to the weekday stratum because there are more weekdays in a month than there are weekend days in a month.

$\overline{R}_{Month} = \left(\frac{N_{wd}}{N_{Month}} \times \overline{R}_{wd}\right) + \left(\frac{N_{we}}{N_{Month}} \times \overline{R}_{we}\right)$ (Equation 18)

where:
$\overline{R}_{Month}$ is a stratified mean daily rate (harvest or discard) for a month. The $\hat{R}_1$ estimators described in Equations 14 and 15 were used for the boat-based fishery, and the $\hat{R}_2$ estimators described in Equations 16 and 17 were used for the shore-based fishery. The units are the number of fish per fisher hour for the boat and shore fisheries.
N_{wd} is the number of weekdays in the month.
N_{we} is the number of weekend days (includes public holidays) in the month.
N_{Month} is the total number of days in the month (weekdays N_{wd} plus weekend days N_{we}).
$\overline{R}_{wd}$ is a mean daily rate (harvest or discard) for the weekday stratum. The $\hat{R}_1$ estimators described in Equations 14 and 15 were used for the boat-based fishery, and the $\hat{R}_2$ estimators described in Equations 16 and 17 were used for the shore-based fishery. The units are the number of fish per fisher hour for the boat and shore fisheries.

$\overline{R}_{we}$ is a mean daily rate (harvest or discard) for the weekend day stratum. The $\hat{R}_1$ estimators described in Equations 14 and 15 were used for the boat-based fishery, and the $\hat{R}_2$ estimators described in Equations 16 and 17 were used for the shore-based fishery. The units are the number of fish per fisher hour for the boat and shore fisheries.

The estimates of variance for the stratified mean daily harvest rates and stratified mean daily discard rates for each month were calculated using the following general equation.

$$Var\left(\overline{R}_{Month}\right) = \left[\left(\frac{N_{wd}}{N_{Month}}\right)^2 \times Var\left(\overline{R}_{wd}\right)\right] + \left[\left(\frac{N_{we}}{N_{Month}}\right)^2 \times Var\left(\overline{R}_{we}\right)\right] \quad \text{(Equation 19)}$$

where:
$Var\left(\overline{R}_{Month}\right)$ is an estimated variance for the stratified mean daily rate (harvest or discard) for a month.
$Var\left(\overline{R}_{wd}\right)$ is an estimated variance for the mean daily rate (harvest or discard) for the weekday stratum in a month. This variance of a mean can be calculated by using the general form of Equation 4.
$Var\left(\overline{R}_{we}\right)$ is an estimated variance for the mean daily rate (harvest or discard) for the weekend day stratum in a month. This variance of a mean can be calculated by using the general form of Equation 4.
The other terms used have been described in Equation 18.

The estimates of standard errors for the stratified mean daily harvest rates and stratified mean daily discard rates for each month were calculated using the following general equation.

$$SE\left(\overline{R}_{Month}\right) = \sqrt{Var\left(\overline{R}_{Month}\right)} \quad \text{(Equation 20)}$$

where:
$SE\left(\overline{R}_{Month}\right)$ is the standard error of a stratified mean daily rate (harvest or discard) for a month.
$Var\left(\overline{R}_{Month}\right)$ is the variance of a stratified mean daily rate (harvest or discard) for a month. This term has been described in Equation 19.

2.6.6. Harvest and discard estimation for the boat-based and shore-based fisheries

The complemented survey designs used to assess the recreational fisheries used different on-site, contact methods to estimate effort and catch. Harvest and discard estimation in the boat-based fishery used interviews of completed trips, whereas the shore-based fishery used interviews of incomplete trips. The text in this section provides a detailed explanation of harvest estimation and the calculation of variances and standard errors. The same logic and general equations are also applied in the estimation of discard and its associated estimates of precision.

Step 1 - Daily harvest calculations are made for each survey day within each day-type stratum in a month. These daily harvest calculations are done because effort counts were done on the same days as interviews with recreational fishing parties.

$\hat{H}_i = \hat{e}_i \times \hat{R}_i$ (Equation 21)

where:
$\hat{H}_i$ is an estimate of harvest for the i th sample day. The base level of estimation was for each day-type stratum within a month. Harvest units are either numbers of fish, or the weight of fish.
$\hat{e}_i$ is an estimate of fishing effort for the i th sample day. Units are in boat hours for the boat-based fishery and in fisher hours for the shore-based fishery.
$\hat{R}_i$ is an estimate of harvest rate for the i th sample day. The $\hat{R}_{1(H)}$ estimator (see Equation 14) is used for the boat-based fishery and units are either numbers of fish per boat hour, or the weight of fish per boat hour. The $\hat{R}_{2(H)}$ estimator (see Equation 16) is used for the shore-based fishery and units are either numbers of fish per fisher hour, or the weight of fish per fisher hour.

Step 2 - These daily harvest estimates were then expanded for each day-type stratum within each month. This was done by multiplying the number of possible sample days in each base level stratum with the mean of the daily estimates of harvest.

$$\overline{H}_j = \frac{\sum \hat{H}_{ij}}{n_j} \text{ (Equation 22)}$$

where:
$\overline{H}_j$ is the estimated mean daily harvest for the j th day-type stratum within a month, in units of numbers of fish per day or weight of fish per day.
$\hat{H}_{ij}$ is the estimate of harvest for the i th sample day in the j th day-type stratum within a month.
n_j is the number of days sampled in the j th day-type stratum within a month.

$$\hat{H}_j = N_j \times \overline{H}_j \qquad \text{(Equation 23)}$$

where:
$\hat{H}_j$ is the estimate of harvest for the j th day-type stratum within a month, in units of numbers of fish or weight of fish.
See Basic notation and Equation 22 for definitions of the other terms.

Step 3 - Calculate the precision of the harvest estimates for each day-type stratum in a month. This is done for each fishery by estimating variances and standard errors for each stratum.

$$Var\left(\overline{H}_j\right) = \frac{s_j^2}{n_j} \text{ (Equation 24)}$$

where:
$Var\left(\overline{H}_j\right)$ is the estimated variance of the mean daily harvest for the j th day-type stratum within a month. This is calculated separately for each fishery.
s_j^2 is the sample variance of the daily estimates of harvest for the j th day-type stratum within a month.
n_j is the sample size as described in Equation 2.

$SE\left(\overline{H}_j\right) = \sqrt{Var\left(\overline{H}_j\right)}$ (Equation 25)

where:
$SE\left(\overline{H}_j\right)$ is the estimated standard error of the mean daily harvest.
$Var\left(\overline{H}_j\right)$ is the estimated variance of the mean daily harvest as described in Equation 24.

$Var\left(\hat{H}_j\right) = N_j^2 \times Var\left(\overline{H}_j\right)$ (Equation 26)

where:
$Var\left(\hat{H}_j\right)$ is the estimated variance of total harvest for a stratum, and is calculated separately for each day-type within each month for each fishery.
See Basic notation and Equation 24 for definitions of the other terms.

$SE\left(\hat{H}_j\right) = \sqrt{Var\left(\hat{H}_j\right)}$ (Equation 27)

where:
$SE\left(\hat{H}_j\right)$ is the estimated standard error of total harvest for a stratum.
$Var\left(\hat{H}_j\right)$ is the estimated variance of total harvest for a stratum as described in Equation 26.

We did not attempt to make expanded estimates of harvest for any taxa that were considered to have been “rare” throughout the survey period - defined as any taxon that had been recorded from three or less interviews during the survey period, regardless of the number of individuals harvested in those trips. This definition of rarity was applied separately to the boat-based and shore-based fisheries. All taxa which did not meet the criterion for rarity were classified as common taxa and expanded estimates of harvest were made for these taxa.

Survey personnel had, where possible, measured all identified fish, crabs and cephalopods that were seen during interviews with fishing parties. It was not always possible to obtain measurements, usually because fishers were in a hurry to leave the ramp. Thus, during many interviews, survey personnel were only able to collect measurements for a sub-sample of the entire harvest, or were only able to record counts of identified fish, crabs and cephalopods.

We did not measure the weight of fish during interviews but converted the length measurements into weights using length to weight keys. This was done for all taxa for which we had suitable length to weight conversion keys (Appendix 3). The remaining unmeasured component of the harvest (i.e. those fish seen during interviews but only counted) were assigned the median weight for that taxon as calculated from the pooled interview data. We used a median weight rather than a mean weight (as is traditionally done in angler surveys) because many of the estimated weight frequency distributions were highly skewed, making the median a better estimate of the centre of the population (Sokal and Rohlf 1969). In some cases, the use of a mean would have resulted in higher estimates of harvest. We calculated medians separately for the boat-based and shore-based fisheries. When no measurements had been made for a taxon in a particular fishery (e.g. the boat fishery), we used the available measurements from the other fishery (e.g. the shore fishery). In some cases, measurements were not available for some taxa and so we could not estimate weights.

Harvest estimates for the weekday and weekend day strata were combined to give monthly totals. A description of the equations used for estimating stratum totals, variances and standard errors is provided for effort estimation. The general form of the equations used in the estimation of effort and the associated variances and standard errors has been used for harvest estimation.

2.7. Comparisons with other recreational fishing studies done in NSW

Fisheries managers and the general public have a reasonable expectation that meaningful comparisons should be made between the current study and previous work done on other estuarine recreational fisheries in NSW. We have compared harvest rate data collected during: (a) this survey (monthly estimates for boat and shore fisheries); (b) a concurrent recreational fishing survey in the lower Macleay River (monthly estimates for shore and boat fisheries); (c) a survey of recreational fishing in Lake Macquarie done during 1999/2000 (seasonal estimates for boat and shore fisheries); and (d) a survey of boat-based recreational fishing in Tuross Lake done during 1999/2000 (seasonal estimates for the boat fishery only). The different survey designs used during these four surveys has precluded more detailed comparisons.

The published harvest rate estimates from a previous recreational fishing survey done in the Richmond River (West and Gordon 1994) could not be compared meaningfully with the data from the current study because their data summaries were aggregated at very different temporal scales (eg. annual estimates of harvest rate were provided separately for boat and shore fisheries but no seasonal or monthly estimates were given for the boat and shore fisheries) or at different spatial scales (eg. monthly estimates of harvest rate were provided but these were calculated after combining data for the boat and shore fisheries). West and Gordon (1994) did provide monthly estimates of angling effort for the Richmond River (boat and shore fisheries combined) and these summary data were useful for describing monthly and seasonal patterns of fishing effort for the whole recreational fishery.

2.8. Quality assurance

A survey can be useless if the data collected are of poor quality (Yates 1965, Pollock *et al*. 1994). We incorporated important quality assessment and control procedures into all phases of the survey so that the highest possible level of data quality and integrity could be attained. A brief description of these procedures are provided below.

2.8.1. Survey preparation phase

2.8.1.1. Design and pre-testing of survey forms

We had previously used similar data collection forms and interview procedures in other recreational fishing surveys. A feature of the previous surveys was the extensive field testing of survey forms that was done to ensure clearly worded, unambiguous questions and the development of a simple survey protocol. The forms used in this current survey were based on the previously used form designs. The old data collection forms were simplified to meet the needs of the current survey. We pre-tested the new data collection forms to confirm the logic of the questions and their functionality by conducting a series of mock interviews with persons having no involvement in this project. This pre-testing step was useful for further improving the form designs and was completed prior to the start of staff training.

2.8.1.2. Training of survey personnel

There were 19 people involved in data collection during this survey. NSW Fisheries staff provided comprehensive training to all persons involved in the survey, which included detailed documentation of survey protocols, procedures and fish identification. All persons were provided with explanations of the aims of the survey and the importance of the information that was being collected. Field staff were provided with work rosters which specified survey dates and work times and all persons involved in interviewing recreational fishing parties were provided with clear instructions on standard interview procedures, protocols for recording data on the interview forms, and on the use of the fish identification kit. Additional training based on hypothetical examples likely to be encountered during the course of the survey was also provided to all interviewers. The importance of using a systematic sampling procedure to subsample recreational fishing parties during busy periods was stressed to all interviewers and strict instructions were given to them to not preferentially interview fishers known to them or parties that were known to be cooperative.

2.8.1.3. Field identification kit for fish, crabs and cephalopods

We developed a detailed field identification kit for fish and invertebrates that were likely to be caught by recreational fishers during the survey. This kit was used to standardise the level of taxonomic precision among interviewers working at different sites in the Richmond River. The use of the identification kit also facilitated the conduct of interviews and as such was an important part of the interview procedure.

2.8.1.4. Information leaflets

Information leaflets which stated the objectives of the study and provided a brief explanation of the need for collecting survey data were distributed by field staff. These leaflets generated much local interest and were useful for informing the general public about the importance of the survey work. The distribution of these information leaflets helped gain the support and cooperation of the local fishing community and thereby were critical in improving the integrity of the survey data.

2.8.2. Survey operation phase

2.8.2.1. Supervision of survey personnel

Random checks of survey personnel were carried out during the survey period to provide a cost-effective way of ensuring data quality. We also maintained regular contact with nominated group leaders by telephone. In this way we were able to provide a regular flow of information to all field staff.

2.8.2.2. Preliminary scrutiny of data collection forms

Preliminary checks of progressive count data sheets and interview forms were made as they were received and we identified any missing or unusual data, such as, large numbers of fishing boats in particular areas of the river, very large harvests, fish having very small or very large sizes, and the occurrence of uncommon species. The individuals that had collected the unusual data were then contacted and asked to confirm or explain them. This scrutiny helped to maintain high levels of data integrity by identifying and correcting data problems at the earliest possible time.

2.8.3. Data entry, checking and manipulation phase

2.8.3.1. Data entry and data checking procedures

Machine-readable data forms were designed and used during this project. After the initial vetting of the data forms, the sheets were scanned and the digital images of the forms were examined using Intelligent/Optical Character Recognition (ICR/OCR) software (Teleform Elite Version V - Cardiff software). A trained operator checked and either verified or corrected all data that were queried by the ICR/OCR data entry process. Random checks of data subsets were then done to validate the effectiveness of the data entry system. Prior to any analyses, the data were subjected to a wide range of data outlier checks to identify any unusual data and detect any reading or logic errors which had been missed during the preliminary checks.

2.8.3.2. Data manipulation procedures

We verified the correctness of the computations used to derive the estimates of harvest rates, discard rates, weights of fish, effort, harvest, discard and their associated measures of precision by undertaking random checks on some subsets of the data.

3. RESULTS

3.1. Recreational fishing effort

3.1.1. Whole fishery (boat and shore fisheries combined)

We estimated that approximately 70,100 fisher hours of daytime recreational effort was expended in the lower Richmond River during the survey period - July to October 2001 inclusive (Table 2). Most recreational fishing effort, approximately 42,300 fisher hours representing 60.3% of total effort, occurred in the Main River area (Table 3). The Entrance area received approximately 19,000 fisher hours representing 27.2% of the total effort (Table 4), and approximately 8,700 fisher hours of effort representing 12.5% of total effort were recorded for the North Creek area (Table 5). The level of daytime recreational fishing effort showed a distinct monthly pattern (Table 2). The highest level of effort was found in July (approximately 26,100 fisher hours representing 37.2% of the total effort), an intermediate level of effort was recorded in August (approximately 18,800 fisher hours representing 26.8% of the total effort) and the lowest levels of effort were recorded in September (approximately 11,700 fisher hours representing 16.7% of the total effort), and October (approximately 13,500 fisher hours representing 19.3% of the total effort). Tables 2 to 5 also provide estimates of daytime effort for each day-type stratum within each month.

Table 2. Estimates of daytime recreational fishing effort (fisher hours) for the three areas in the Richmond River (Entrance, North Creek and Main River) combined. Data are presented for all temporal strata and for the boat-based and shore-based fisheries.

Month/Year	Day-Type	Boat Effort (fisher hrs)		SE	Shore Effort (fisher hrs)		SE	Total Effort (fisher hrs)		SE
July 2001	Weekday	4,624	±	914	11,852	±	1,297	16,476	±	1,587
	Weekend	4,037	±	904	5,565	±	843	9,602	±	1,236
	Total	**8,661**	±	**1,285**	**17,417**	±	**1,547**	**26,078**	±	**2,011**
August 2001	Weekday	3,299	±	520	7,188	±	808	10,487	±	961
	Weekend	3,100	±	485	5,173	±	390	8,273	±	622
	Total	**6,399**	±	**711**	**12,360**	±	**897**	**18,759**	±	**1,145**
September 2001	Weekday	1,298	±	300	3,994	±	650	5,292	±	716
	Weekend	2,782	±	218	3,652	±	185	6,434	±	286
	Total	**4,080**	±	**371**	**7,646**	±	**675**	**11,726**	±	**771**
October 2001	Weekday	2,202	±	319	5,633	±	832	7,835	±	890
	Weekend	2,007	±	468	3,669	±	415	5,676	±	625
	Total	**4,209**	±	**566**	**9,302**	±	**929**	**13,511**	±	**1,088**
Total	Weekday	11,423	±	1,139	28,666	±	1,857	40,089	±	2,179
	Weekend	11,926	±	1,148	18,059	±	1,034	29,985	±	1,545
	Total	**23,349**	±	**1,617**	**46,725**	±	**2,126**	**70,074**	±	**2,671**

Table 3. Estimates of daytime recreational fishing effort (fisher hours) for the Main River area of the Richmond River. Data are presented for all temporal strata and for the boat-based and shore-based fisheries.

Month/Year	Day-Type	Boat Effort (fisher hrs)		SE	Shore Effort (fisher hrs)		SE	Total Effort (fisher hrs)		SE
July 2001	Weekday	3,436	±	848	6,064	±	936	9,500	±	1,263
	Weekend	2,981	±	868	2,972	±	736	5,953	±	1,137
	Total	**6,417**	±	**1,213**	**9,035**	±	**1,190**	**15,452**	±	**1,700**
August 2001	Weekday	2,147	±	441	3,494	±	625	5,641	±	765
	Weekend	2,269	±	428	3,241	±	322	5,510	±	536
	Total	**4,416**	±	**615**	**6,735**	±	**703**	**11,151**	±	**934**
September 2001	Weekday	943	±	272	2,107	±	609	3,050	±	667
	Weekend	1,986	±	147	2,055	±	131	4,041	±	196
	Total	**2,929**	±	**309**	**4,162**	±	**623**	**7,091**	±	**696**
October 2001	Weekday	1,398	±	221	3,667	±	735	5,065	±	768
	Weekend	1,349	±	421	2,198	±	368	3,547	±	559
	Total	**2,747**	±	**475**	**5,865**	±	**822**	**8,612**	±	**950**
Total	Weekday	7,924	±	1,018	15,332	±	1,476	23,256	±	1,793
	Weekend	8,585	±	1,065	10,466	±	893	19,051	±	1,390
	Total	**16,509**	±	**1,473**	**25,798**	±	**1,725**	**42,307**	±	**2,269**

Table 4. Estimates of daytime recreational fishing effort (fisher hours) for the Entrance area of the Richmond River. Data are presented for all temporal strata and for the boat-based and shore-based fisheries.

Month/Year	Day-Type	Boat Effort (fisher hrs)		SE	Shore Effort (fisher hrs)		SE	Total Effort (fisher hrs)		SE
July 2001	Weekday	898	±	323	3,606	±	833	4,504	±	894
	Weekend	778	±	242	1,811	±	395	2,589	±	463
	Total	**1,676**	±	**404**	**5,417**	±	**922**	**7,093**	±	**1,007**
August 2001	Weekday	691	±	195	2,244	±	414	2,935	±	458
	Weekend	609	±	214	1,304	±	190	1,913	±	286
	Total	**1,300**	±	**289**	**3,549**	±	**456**	**4,849**	±	**540**
September 2001	Weekday	209	±	121	1,409	±	199	1,618	±	232
	Weekend	480	±	126	1,260	±	121	1,740	±	175
	Total	**689**	±	**174**	**2,669**	±	**233**	**3,358**	±	**291**
October 2001	Weekday	629	±	213	1,420	±	307	2,049	±	374
	Weekend	520	±	196	1,157	±	183	1,677	±	269
	Total	**1,149**	±	**290**	**2,577**	±	**358**	**3,726**	±	**460**
Total	Weekday	2,427	±	450	8,679	±	1,000	11,106	±	1,097
	Weekend	2,387	±	398	5,533	±	490	7,920	±	631
	Total	**4,814**	±	**601**	**14,212**	±	**1,114**	**19,026**	±	**1,266**

Table 5. Estimates of daytime recreational fishing effort (fisher hours) for the North Creek area of the Richmond River. Data are presented for all temporal strata and for the boat-based and shore-based fisheries.

Month/Year	Day-Type	Boat Effort (fisher hrs)		SE	Shore Effort (fisher hrs)		SE	Total Effort (fisher hrs)		SE
July 2001	Weekday	290	±	104	2,182	±	335	2,472	±	351
	Weekend	278	±	79	782	±	114	1,060	±	138
	Total	**568**	±	**131**	**2,964**	±	**354**	**3,532**	±	**377**
August 2001	Weekday	461	±	195	1,449	±	302	1,910	±	359
	Weekend	222	±	76	627	±	113	849	±	136
	Total	**683**	±	**209**	**2,076**	±	**322**	**2,759**	±	**384**
September 2001	Weekday	146	±	40	478	±	105	624	±	112
	Weekend	316	±	101	336	±	51	652	±	113
	Total	**462**	±	**109**	**814**	±	**116**	**1,276**	±	**160**
October 2001	Weekday	175	±	85	546	±	237	721	±	252
	Weekend	138	±	59	314	±	57	452	±	82
	Total	**313**	±	**103**	**860**	±	**244**	**1,173**	±	**265**
Total	Weekday	1,072	±	240	4,655	±	520	5,727	±	573
	Weekend	954	±	160	2,060	±	178	3,014	±	240
	Total	**2,026**	±	**289**	**6,715**	±	**550**	**8,741**	±	**621**

3.1.2. Boat-based fishery

We estimated that approximately 23,300 fisher hours of daytime recreational boat-based effort was expended in the lower Richmond River during the survey period - July to October 2001 inclusive (Table 2). This represented 33.3% of the effort for the total fishery (boat and shore combined). The highest amounts of boat-based effort were recorded from the Main River area (approximately 16,500 fisher hours representing 70.7% of the boat-based effort - Table 3) and the Entrance area (approximately 4,800 fisher hours representing 20.6% of the boat-based effort - Table 4) and the North Creek area received lower levels of boat-based effort (approximately 2,000 fisher hours representing 8.7% of the boat-based effort - Table 5). The level of daytime boat-based fishing effort showed a distinct monthly pattern (Table 2). The highest level of effort was found in July (approximately 8,700 fisher hours representing 37.1% of the total boat effort), an intermediate level of effort was recorded in August (approximately 6,400 fisher hours representing 27.4% of the total boat effort) and the lowest levels of effort were recorded in September (approximately 4,100 fisher hours representing 17.5% of the total boat effort), and October (approximately 4,200 fisher hours representing 18.0% of the total boat effort). Tables 2 to 5 also provide estimates of daytime boat-based effort for each day-type stratum within each month. Supplementary daytime effort information for the boat-based fishery is provided in units of boat hours, the original units used to in the calculations of boat-based effort and harvest (see Appendix 4).

3.1.3. Shore-based fishery

We estimated that approximately 46,700 fisher hours of daytime recreational shore-based effort was expended in the lower Richmond River during the survey period - July to October 2001 inclusive (Table 2). This represented 66.7% of the effort for the total fishery (boat and shore combined). The highest amount of shore-based effort was recorded from the Main River area (approximately 25,800 fisher hours representing 55.2% of the shore-based effort - Table 3), and the Entrance area (approximately 14,200 fisher hours representing 30.4% of the shore-based effort

- Table 4) and the North Creek area received lower levels of shore-based effort (approximately 6,700 fisher hours representing 14.4% of the shore-based effort - Table 5). The level of daytime shore-based fishing effort showed a distinct monthly pattern (Table 2). The highest level of effort was found in July (approximately 17,400 fisher hours representing 37.3% of the total shore effort), an intermediate level of effort was recorded in August (approximately 12,400 fisher hours representing 26.4% of the total shore effort) and the lowest levels of effort were recorded in September (approximately 7,600 fisher hours representing 16.4% of the total shore effort), and October (approximately 9,300 fisher hours representing 19.9% of the total shore effort). Tables 2 to 5 also provide estimates of daytime shore-based effort for each day-type stratum within each month.

3.2. Demography of the fishing population

The populations of boat-based and shore-based fishers were dominated by males (Table 6). Over the survey period, we found that 83.8% of the boat-based fishers that had been interviewed were males. Similarly, we found that 83.3% of the shore-based fishers that had been interviewed were males. There was an apparent increase in the proportion of female fishers during the final two months (September and October) of the survey period in both fisheries (Table 6). In the shore-based fishery a consistent pattern was evident when comparing the sex-based composition of the fishing populations between day-type strata. A higher proportion of female fishers were observed in the fishing population on weekend days. A similar pattern was found in the boat-based fishery except for the month of October during which the proportion of female fishers observed during weekend days was slightly lower than the proportion of female fishers recorded during weekdays (Table 6).

Over the survey period, we found that the great majority of fishers were of local origin (Table 7). This was true for both the boat-based fishery (83.4% locals) and for the shore-based fishery (75.0% locals). The proportion of visiting fishers in the boat-based fishing population ranged between 11.6% and 23.2% on a monthly basis (Table 7). In the boat fishery, the lowest proportion of visiting fishers was recorded during August and the highest proportion of visiting fishers was recorded during October (Table 7). The proportion of visiting fishers in the shore-based fishing population ranged between 23.4% and 27.1% on a monthly basis (Table 7). In the shore fishery, there was no apparent monthly trend in the proportion of visiting fishers in the fishing population (Table 7).

Table 6. Numbers and percentages of male and female fishers for the boat and shore recreational fisheries in the Richmond River during the survey period (July 1 - October 31, 2001).

		BOAT FISHERY				SHORE FISHERY			
Month/Year	Day-Type	No. Male	% Male	No. Female	% Female	No. Male	% Male	No. Female	% Female
July 2001	Weekday	216	89.6	25	10.4	513	87.1	76	12.9
	Weekend	485	83.0	99	17.0	582	81.7	130	18.3
	Total	**701**	**85.0**	**124**	**15.0**	**1,095**	**84.2**	**206**	**15.8**
August 2001	Weekday	154	89.5	18	10.5	380	87.2	56	12.8
	Weekend	397	82.7	83	17.3	427	81.6	96	18.4
	Total	**551**	**84.5**	**101**	**15.5**	**807**	**84.2**	**152**	**15.8**
September 2001	Weekday	64	90.1	7	9.9	265	84.9	47	15.1
	Weekend	209	80.4	51	19.6	434	82.7	91	17.3
	Total	**273**	**82.5**	**58**	**17.5**	**699**	**83.5**	**138**	**16.5**
October 2001	Weekday	84	80.0	21	20.0	349	82.5	74	17.5
	Weekend	200	81.3	46	18.7	376	79.7	96	20.3
	Total	**284**	**80.9**	**67**	**19.1**	**725**	**81.0**	**170**	**19.0**
Total	Weekday	518	87.9	71	12.1	1,507	85.6	253	14.4
	Weekend	1,291	82.2	279	17.8	1,819	81.5	413	18.5
	Total	**1,809**	**83.8**	**350**	**16.2**	**3,326**	**83.3**	**666**	**16.7**

Table 7. Numbers and percentages of local and visiting fishers for the boat and shore recreational fisheries in the Richmond River during the survey period (July 1 - October 31, 2001).

		BOAT FISHERY				SHORE FISHERY			
Month/Year	Day-Type	No. Local	% Local	No. Visitors	% Visitors	No. Local	% Local	No. Visitors	% Visitors
July 2001	Weekday	178	73.0	66	27.0	405	69.2	180	30.8
	Weekend	516	87.3	75	12.7	585	82.7	122	17.3
	Total	**694**	**83.1**	**141**	**16.9**	**990**	**76.6**	**302**	**23.4**
August 2001	Weekday	149	86.6	23	13.4	304	69.9	131	30.1
	Weekend	430	89.0	53	11.0	402	76.0	127	24.0
	Total	**579**	**88.4**	**76**	**11.6**	**706**	**73.2**	**258**	**26.8**
September 2001	Weekday	52	73.2	19	26.8	200	62.5	120	37.5
	Weekend	218	83.5	43	16.5	422	79.2	111	20.8
	Total	**270**	**81.3**	**62**	**18.7**	**622**	**72.9**	**231**	**27.1**
October 2001	Weekday	74	69.2	33	30.8	325	74.2	113	25.8
	Weekend	198	80.2	49	19.8	376	78.3	104	21.7
	Total	**272**	**76.8**	**82**	**23.2**	**701**	**76.4**	**217**	**23.6**
Total	Weekday	453	76.3	141	23.7	1,234	69.4	544	30.6
	Weekend	1,362	86.1	220	13.9	1,785	79.4	464	20.6
	Total	**1,815**	**83.4**	**361**	**16.6**	**3,019**	**75.0**	**1,008**	**25.0**

3.3. Targeting preferences

The main targeting preferences nominated by boat-based fishing parties over the survey period were grouped into 9 categories (Table 8). Many boat-based fishing parties indicated that they did not have any specific target preference. Fishing parties nominating “anything” as their main target were ranked highest during the survey period (Table 8). Flathead, luderick, bream and whiting were other popular main targets of boat-based fishing parties. Fishing parties that had nominated any of these four main target categories, or the generalist category “anything” made up 98.7% of the boat-based fishing population during the survey period (Table 8). Tailor, crabs, mulloway and garfish were also nominated as main target categories by boat-based fishing parties. These four target categories accounted for 1.3% of the boat-based fishing population during the survey period (Table 8). Some monthly trends in the targeting preferences of boat-based fishing parties were evident. The proportion of generalist fishing parties in the boat fishery was lowest in July, the month in which the fishery was re-opened, with relatively higher proportions recorded during the other months (Table 8). There was a steady increase in the proportion of fishing parties targeting “flathead” during the course of the survey period (Table 8). In contrast, there was a steady decrease in the proportion of fishing parties targeting “luderick” during the course of the survey (Table 8). The proportion of fishing parties targeting “bream” were highest during July and August with relatively lower proportions of “bream” targeting were recorded during September and October (Table 8). The proportion of boat-based fishing parties targeting “whiting” were relatively low during the first three months of the survey period with a marked proportional increase in the targeting of “whiting” being recorded during October (Table 8).

The main targeting preferences nominated by shore-based fishing parties over the survey period were grouped into 10 target categories (Table 9). A large proportion of shore-based fishing parties indicated that they did not have any specific target preference. Fishing parties nominating “anything” as their main target were ranked highest during all months surveyed (Table 9). Bream, luderick, flathead and whiting were other popular main targets of shore-based fishing parties. Fishing parties that had nominated any of these four main target categories, or the generalist category “anything” made up 97.0% of the shore-based fishing population during the survey period (Table 9). Mulloway, mullet, tailor, southern herring and wrasse were also nominated as main target categories by shore-based fishing parties. These four target categories accounted for 3.0% of the shore-based fishing population during the survey period (Table 9). Some monthly trends in the targeting preferences of shore-based fishing parties were evident. The proportion of generalist fishing parties in the shore fishery was lowest in July and August, with relatively higher proportions recorded during September and October (Table 9). There was a steady decrease in the proportion of fishing parties targeting “bream” during the survey period (Table 9). In contrast, the proportion of shore-based fishing parties targeting “luderick” were relatively high during July, August and September with a marked decline in the proportion of “luderick” targeting recorded during October (Table 9). The proportion of fishing parties targeting “flathead” showed no apparent trend during the first three months of the survey period, however, there was a notable increase in the proportion of shore-based fishing parties targeting “flathead” during October (Table 9). The proportion of shore-based fishing parties targeting “whiting” increased steadily during each month of the survey period (Table 9).

Table 8. Main target categories nominated by boat-based fishing parties in the Richmond River fishery during the survey period (July 1 - October 31, 2001).

Boat-Based	July 2001		August 2001		September 2001		October 2001		Total	
Target Category	No.	%	No.	%	No.	%	No.	%	No.	%
Anything	115	30.3	121	38.9	55	35.7	69	45.4	360	36.1
Flathead	98	25.8	84	27.0	62	40.3	61	40.1	305	30.6
Luderick	85	22.4	58	18.6	25	16.2	3	2.0	171	17.2
Bream	73	19.2	42	13.5	10	6.5	11	7.2	136	13.6
Whiting	2	0.5	4	1.3	1	0.6	6	3.9	13	1.3
Tailor	4	1.1	1	0.3	-	-	-	-	5	0.5
Crabs	2	0.5	-	-	-	-	1	0.7	3	0.3
Mulloway	1	0.3	1	0.3	1	0.6	-	-	3	0.3
Garfish	-	-	-	-	-	-	1	0.7	1	0.1
Total	**380**		**311**		**154**		**152**		**997**	

Table 9. Main target categories nominated by shore-based fishing parties in the Richmond River fishery during the survey period (July 1 - October 31, 2001).

Shore-Based	July 2001		August 2001		September 2001		October 2001		Total	
Target Category	No.	%	No.	%	No.	%	No.	%	No.	%
Anything	306	39.9	230	39.1	213	44.8	221	47.2	970	42.2
Bream	201	26.2	144	24.5	79	16.6	65	13.9	489	21.3
Luderick	154	20.1	144	24.5	89	18.7	41	8.8	428	18.6
Flathead	75	9.8	42	7.1	52	10.9	88	18.8	257	11.2
Whiting	10	1.3	12	2.0	27	5.7	36	7.7	85	3.7
Mulloway	9	1.2	5	0.9	7	1.5	4	0.9	25	1.1
Mullet	3	0.4	5	0.9	4	0.8	9	1.9	21	0.9
Tailor	6	0.8	6	1.0	3	0.6	3	0.6	18	0.8
Southern herring	2	0.3	-	-	1	0.2	1	0.2	4	0.2
Crimson-banded wrasse	1	0.1	-	-	-	-	-	-	1	<0.1
Total	**767**		**588**		**475**		**468**		**2,298**	

3.4. Indicators of recreational fishing quality

An assessment of a recreational fishery can be improved if reliable indicators of fishing quality are available. We present four indicators of recreational fishing quality for the boat-based and shore-based fisheries in the lower Richmond River. These are: (1) the proportion of unsuccessful fishing parties; (2) recreational harvest rates; (3) recreational discard rates; and (4) the size-frequency distributions for some important taxa harvested by the recreational sector.

3.4.1. Proportion of unsuccessful fishing parties

We found that a high proportion of boat-based fishing parties were unsuccessful during their fishing trips. That is, these fishing parties failed to catch any fish, crab or cephalopods that they regarded as being worthy of keeping. The proportion of unsuccessful boat-based fishing parties ranged from approximately 31% to 59% on a monthly basis (Fig. 2). The proportion of unsuccessful boat-based fishing parties was approximately 43% over the entire survey period. The proportion of unsuccessful boat-based fishing parties was lowest during July, higher in August and the highest proportions were recorded during September and October (Fig. 2).

Shore-based fishing parties were less successful than boat-based parties. The proportion of unsuccessful shore-based fishing parties ranged from approximately 61% to 80% on a monthly basis (Fig. 2). The proportion of unsuccessful shore-based fishing parties was approximately 70% over the entire survey period. The proportion of unsuccessful shore-based fishing parties was lowest during July, higher in August and the highest proportions were recorded during September and October (Fig. 2).

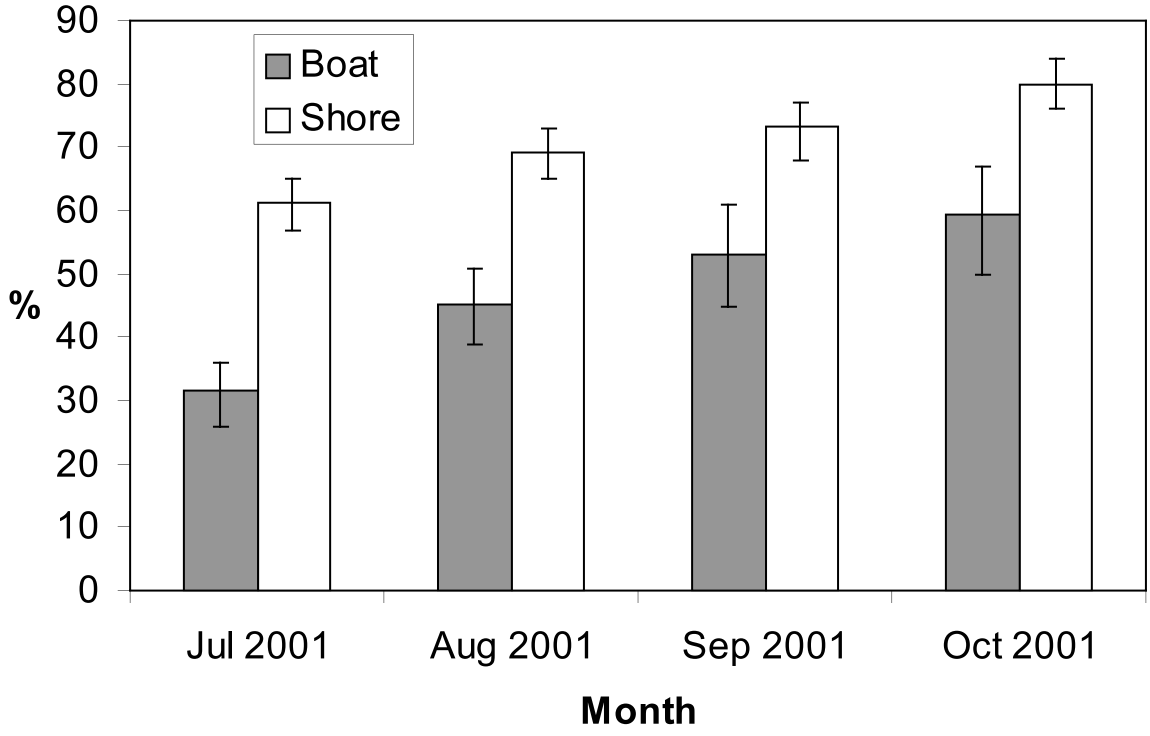

Figure 2. The proportion of unsuccessful boat-based and shore-based fishing parties (± 95% C.I.) for each month of the survey period (July 1 - October 31, 2001). Sample sizes are presented in Table 1.

3.4.2. Recreational harvest rates

The harvest rates reported in this document are based on calculations made using total fishing effort (non-directed effort) for a stratum. We present harvest rates for six important species. The harvest rate information is presented separately for the boat-based and shore-based fisheries, for each day-type stratum and for each month. In this way, temporal trends within the whole fishery can be examined. We also provide supplementary harvest rate information for the boat-based fishery in units of number of fish per boat hour (see Appendices 2.1 to 2.6). These appendices report the harvest rates for the boat-based fishery in the original units that were used in the calculations of boat-based effort and harvest, and are useful for other workers that may want to make comparisons between boat-based fisheries from other locations and/or survey periods.

3.4.2.1. *Yellowfin bream*

Bream were an important component of the harvest for both boat-based and shore-based fishing parties. The highest harvest rates for bream taken by boat-based fishers were recorded during July (Table 10). A decline in bream harvest rates in the boat fishery was observed during August and September which was followed by a small increase during October but the bream harvest rate in October was still much lower than that recorded during July (Table 10).

Bream harvest rates in the shore fishery were highest during July and there was a steady decline in harvest rate recorded during the next three months (Table 10). This trend was similar to the pattern observed in the boat fishery.

Table 10. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for yellowfin bream (*Acanthopagrus australis*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Richmond River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.125	±	0.029	0.426	±	0.109
	Weekend	0.084	±	0.015	0.425	±	0.051
	Total	**0.113**	**±**	**0.021**	**0.426**	**±**	**0.078**
August 2001	Weekday	0.082	±	0.015	0.401	±	0.064
	Weekend	0.049	±	0.011	0.313	±	0.047
	Total	**0.073**	**±**	**0.011**	**0.378**	**±**	**0.049**
September 2001	Weekday	0.037	±	0.035	0.139	±	0.071
	Weekend	0.019	±	0.006	0.194	±	0.024
	Total	**0.031**	**±**	**0.023**	**0.157**	**±**	**0.048**
October 2001	Weekday	0.065	±	0.019	0.335	±	0.077
	Weekend	0.042	±	0.012	0.219	±	0.033
	Total	**0.059**	**±**	**0.014**	**0.301**	**±**	**0.055**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.188	±	0.050	0.689	±	0.089
	Weekend	0.148	±	0.006	0.513	±	0.076
	Total	**0.177**	**±**	**0.035**	**0.638**	**±**	**0.067**
August 2001	Weekday	0.138	±	0.036	0.401	±	0.085
	Weekend	0.115	±	0.026	0.429	±	0.078
	Total	**0.132**	**±**	**0.028**	**0.408**	**±**	**0.066**
September 2001	Weekday	0.064	±	0.032	0.298	±	0.042
	Weekend	0.065	±	0.043	0.292	±	0.048
	Total	**0.064**	**±**	**0.026**	**0.296**	**±**	**0.032**
October 2001	Weekday	0.026	±	0.010	0.352	±	0.087
	Weekend	0.051	±	0.022	0.265	±	0.035
	Total	**0.033**	**±**	**0.010**	**0.327**	**±**	**0.062**

3.4.2.2. Luderick

Relatively high harvest rates were achieved in both the shore and boat fisheries during the first three months of the survey period with a peak observed in September (Table 11). The September peak in harvest rate for luderick was followed by a marked decline in harvest rate during October. This trend was the same for both the boat and shore fisheries (Table 11).

Table 11. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for luderick (*Girella tricuspidata*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Richmond River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.302	±	0.072	0.064	±	0.018
	Weekend	0.201	±	0.041	0.078	±	0.025
	Total	**0.272**	±	**0.052**	**0.068**	±	**0.014**
August 2001	Weekday	0.197	±	0.067	0.034	±	0.014
	Weekend	0.208	±	0.046	0.061	±	0.019
	Total	**0.200**	±	**0.051**	**0.041**	±	**0.011**
September 2001	Weekday	0.431	±	0.130	0.196	±	0.095
	Weekend	0.087	±	0.045	0.055	±	0.030
	Total	**0.316**	±	**0.088**	**0.149**	±	**0.064**
October 2001	Weekday	0.004	±	0.004	-		-
	Weekend	0.004	±	0.004	0.003	±	0.003
	Total	**0.004**	±	**0.003**	**0.001**	±	**0.001**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.237	±	0.072	0.098	±	0.020
	Weekend	0.268	±	0.050	0.075	±	0.009
	Total	**0.246**	±	**0.053**	**0.091**	±	**0.014**
August 2001	Weekday	0.295	±	0.038	0.124	±	0.040
	Weekend	0.168	±	0.062	0.071	±	0.025
	Total	**0.263**	±	**0.032**	**0.110**	±	**0.031**
September 2001	Weekday	0.383	±	0.100	0.153	±	0.037
	Weekend	0.166	±	0.064	0.058	±	0.020
	Total	**0.311**	±	**0.070**	**0.121**	±	**0.025**
October 2001	Weekday	0.070	±	0.026	0.052	±	0.021
	Weekend	0.055	±	0.027	0.027	±	0.014
	Total	**0.066**	±	**0.020**	**0.045**	±	**0.015**

3.4.2.3. Dusky flathead

Dusky flathead harvest rates in the boat fishery showed no apparent trend and were similar in all months of the survey period (Table 12). The shore fishery was characterised by relatively lower harvest rates than the boat fishery. The highest harvest rate for dusky flathead in the shore fishery was recorded during July, with slightly lower harvest rates being recorded in the last three months of the survey period (Table 12).

Table 12. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for dusky flathead (*Platycephalus fuscus*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Richmond River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.082	±	0.024	0.180	±	0.036
	Weekend	0.090	±	0.020	0.179	±	0.020
	Total	**0.084**	**±**	**0.018**	**0.180**	**±**	**0.026**
August 2001	Weekday	0.086	±	0.026	0.154	±	0.043
	Weekend	0.081	±	0.015	0.183	±	0.036
	Total	**0.084**	**±**	**0.020**	**0.161**	**±**	**0.033**
September 2001	Weekday	0.059	±	0.026	0.273	±	0.070
	Weekend	0.081	±	0.022	0.144	±	0.036
	Total	**0.066**	**±**	**0.019**	**0.230**	**±**	**0.048**
October 2001	Weekday	0.083	±	0.022	0.208	±	0.054
	Weekend	0.078	±	0.018	0.174	±	0.044
	Total	**0.081**	**±**	**0.016**	**0.198**	**±**	**0.040**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.026	±	0.008	0.025	±	0.006
	Weekend	0.048	±	0.017	0.049	±	0.021
	Total	**0.033**	**±**	**0.008**	**0.032**	**±**	**0.007**
August 2001	Weekday	0.018	±	0.007	0.030	±	0.014
	Weekend	0.033	±	0.017	0.064	±	0.017
	Total	**0.022**	**±**	**0.007**	**0.039**	**±**	**0.011**
September 2001	Weekday	0.019	±	0.008	0.027	±	0.018
	Weekend	0.023	±	0.007	0.034	±	0.012
	Total	**0.021**	**±**	**0.006**	**0.029**	**±**	**0.013**
October 2001	Weekday	0.014	±	0.007	0.027	±	0.014
	Weekend	0.028	±	0.011	0.038	±	0.008
	Total	**0.018**	**±**	**0.006**	**0.030**	**±**	**0.010**

3.4.2.4. Sand whiting

Relatively few sand whiting were taken by boat-based fishers during the survey period and accordingly the harvest rates recorded were relatively low (Table 13). There was no apparent monthly trend in these harvest rate data for the boat fishery. In contrast, the harvest rates for the shore fishery increased each month during the survey period (Table 13). The sand whiting harvest rate recorded during July was markedly lower than the harvest rates recorded in the other three months of the survey period (Table 13).

Table 13. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for sand whiting (*Sillago ciliata*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Richmond River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.008	±	0.005	0.011	±	0.005
	Weekend	0.008	±	0.002	0.011	±	0.003
	Total	**0.008**	±	**0.003**	**0.011**	±	**0.004**
August 2001	Weekday	0.039	±	0.034	0.029	±	0.012
	Weekend	0.003	±	0.002	0.011	±	0.004
	Total	**0.030**	±	**0.025**	**0.024**	±	**0.009**
September 2001	Weekday	-		-	-		-
	Weekend	0.018	±	0.010	0.027	±	0.010
	Total	**0.006**	±	**0.003**	**0.009**	±	**0.003**
October 2001	Weekday	0.006	±	0.006	0.040	±	0.016
	Weekend	0.013	±	0.007	0.036	±	0.011
	Total	**0.008**	±	**0.005**	**0.039**	±	**0.012**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.006	±	0.003	0.007	±	0.002
	Weekend	0.006	±	0.005	0.022	±	0.009
	Total	**0.006**	±	**0.003**	**0.011**	±	**0.003**
August 2001	Weekday	0.040	±	0.021	0.048	±	0.032
	Weekend	0.011	±	0.010	0.032	±	0.014
	Total	**0.032**	±	**0.016**	**0.044**	±	**0.024**
September 2001	Weekday	0.045	±	0.028	0.070	±	0.021
	Weekend	0.015	±	0.005	0.116	±	0.051
	Total	**0.035**	±	**0.019**	**0.085**	±	**0.022**
October 2001	Weekday	0.046	±	0.018	0.043	±	0.010
	Weekend	0.022	±	0.010	0.042	±	0.013
	Total	**0.039**	±	**0.013**	**0.043**	±	**0.008**

3.4.2.5. Tailor

The highest harvest rates for tailor taken by boat-based fishers were recorded during July (Table 14). The tailor harvest rate in the boat fishery was relatively low during August and September. No tailor were recorded in the harvest of boat-based fishers during October (Table 14). The highest harvest rates for tailor taken by shore-based fishers were recorded during July (Table 14). Shore-based harvest rates for tailor were relatively lower than the July estimates during the last three months of the survey period (Table 14).

Table 14. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for tailor (*Pomatomus saltatrix*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Richmond River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.041	±	0.020	0.116	±	0.056
	Weekend	0.020	±	0.007	0.091	±	0.026
	Total	**0.035**	±	**0.014**	**0.108**	±	**0.041**
August 2001	Weekday	0.009	±	0.005	0.056	±	0.017
	Weekend	0.025	±	0.020	0.058	±	0.019
	Total	**0.013**	±	**0.006**	**0.056**	±	**0.014**
September 2001	Weekday	-		-	0.031	±	0.020
	Weekend	0.001	±	0.001	0.064	±	0.025
	Total	**<0.001**	±	**<0.001**	**0.042**	±	**0.016**
October 2001	Weekday	-		-	0.024	±	0.012
	Weekend	-		-	0.033	±	0.016
	Total	-		-	**0.027**	±	**0.010**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.031	±	0.018	0.049	±	0.027
	Weekend	0.012	±	0.004	0.039	±	0.015
	Total	**0.026**	±	**0.013**	**0.046**	±	**0.020**
August 2001	Weekday	0.016	±	0.012	0.014	±	0.008
	Weekend	0.020	±	0.007	0.132	±	0.072
	Total	**0.017**	±	**0.009**	**0.045**	±	**0.020**
September 2001	Weekday	0.001	±	0.001	0.011	±	0.008
	Weekend	0.004	±	0.003	0.082	±	0.059
	Total	**0.002**	±	**0.001**	**0.035**	±	**0.020**
October 2001	Weekday	0.019	±	0.019	0.021	±	0.015
	Weekend	-		-	0.047	±	0.038
	Total	**0.014**	±	**0.014**	**0.029**	±	**0.015**

3.4.2.6. Mulloway

Relatively few mulloway were taken by boat-based fishers during the survey period and accordingly the harvest rates recorded were relatively low (Table 15). There was no apparent monthly trend in these harvest rate data for the boat fishery. Mulloway were classified as a rare taxon in the shore fishery and as such we did not estimate harvest rates or make expanded estimates of harvest for this species in the shore fishery.

Table 15. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for mulloway (*Argyrosomus japonicus*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Richmond River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	-		-	-		-
	Weekend	0.001	±	0.001	0.002	±	0.002
	Total	**<0.001**	±	**<0.001**	**0.001**	±	**0.001**
August 2001	Weekday	-		-	-		-
	Weekend	-		-	0.002	±	0.002
	Total	-		-	**0.001**	±	**0.001**
September 2001	Weekday	0.002	±	0.002	-		-
	Weekend	-		-	-		-
	Total	**0.001**	±	**0.001**	-		-
October 2001	Weekday	0.006	±	0.004	0.004	±	0.004
	Weekend	0.001	±	0.001	0.001	±	0.001
	Total	**0.005**	±	**0.003**	**0.003**	±	**0.003**

b. SHORE FISHERY

Mulloway were classified as a rare taxon in the shore fishery and as such we did not estimate harvest rates or discard rates for this species in the shore fishery.

3.4.3. Recreational discard rates

The discard rates reported in this document are based on calculations made using total fishing effort (non-directed effort) for a stratum. We present discard rates for six important species. The discard rate information is presented separately for the boat-based and shore-based fisheries, for each day-type stratum and for each month. In this way, temporal trends within the whole fishery can be examined. We also provide supplementary discard rate information for the boat-based fishery in units of number of fish per boat hour (see Appendices 2.1 to 2.6). These appendices report the discard rates for the boat-based fishery in the original units that were used in the calculations of boat-based effort and discard, and are useful for other workers that may want to make comparisons between boat-based fisheries from other locations and/or survey periods.

3.4.3.1. Yellowfin bream

Bream were regularly discarded by both boat-based and shore-based fishing parties. Recreational boat-based fishers indicated that 4.5% of the estimated 2700 discarded bream had been of legal size. Similarly, recreational shore-based fishers indicated that 2.9% of the estimated 2000 discarded bream had been of legal size. The highest discard rates for bream taken by boat-based fishers were reported during July (Table 10). A decline in bream discard rates in the boat fishery was reported during August and September which was followed by a small increase during October but the bream discard rate in October was still much lower than that reported during July (Table 10). A similar monthly pattern was evident in the shore fishery. Bream discard rates in the shore fishery were highest during July, decreases in discard rate were reported during August and September, and the October discard rate was slightly higher than that estimated during the previous month (Table 10).

3.4.3.2. Luderick

Recreational boat-based fishers indicated that 14.9% of the estimated 440 discarded luderick had been of legal size. Similarly, recreational shore-based fishers indicated that 3.2% of the estimated 440 discarded luderick had been of legal size. The reported discard rates were always lower than the harvest rates achieved for luderick and this was true for all strata in both the boat and shore fisheries (Table 11). The highest discard rate of luderick by boat-based fishers was reported during September, lower discard rates were reported during July and August and a very low discard rate was reported in October (Table 11). A similar trend was apparent in the shore fishery. The highest discard rate was reported during September, slightly lower discard rates were reported during July and August, and the October discard rate was markedly lower than all previous months (Table 11).

3.4.3.3. Dusky flathead

Recreational boat-based fishers indicated that 8.3% of the estimated 1400 discarded dusky flathead had been of legal size. Similarly, recreational shore-based fishers indicated that 11.0% of the estimated 160 discarded dusky flathead had been of legal size. Dusky flathead discard rates in the boat fishery showed no apparent monthly trend and were similar in all months of the survey period (Table 12). The shore fishery was characterised by relatively lower discard rates than those reported for the boat fishery. The discard rates reported by shore-based fishers showed no apparent monthly trend (Table 12).

3.4.3.4. Sand whiting

Recreational boat-based fishers indicated that 2.0% of the estimated 150 discarded sand whiting had been of legal size. Similarly, recreational shore-based fishers indicated that 1.6% of the estimated 190 discarded sand whiting had been of legal size. The sand whiting discard rates reported by boat-based fishers were relatively low during the survey period and there was no apparent monthly trend in these discard rate data for the boat fishery (Table 13). In contrast, the discard rate reported by shore-based fishers was highest during September, intermediate during August and October, and the lowest discard rate in the shore fishery was reported during July (Table 13).

3.4.3.5. Tailor

Recreational boat-based fishers indicated that 7.3% of the estimated 530 discarded tailor had been of legal size. In contrast, recreational shore-based fishers indicated that none of the estimated 260 discarded tailor had been of legal size. The highest discard rates for tailor taken by boat-based fishers were reported during July followed by a steady decrease in reported monthly discard rates with the lowest discard rate in the boat fishery reported in October (Table 14). The reported tailor discard rate in the shore fishery was highest during July and August, a lower discard rate was reported during September and the lowest discard rate for the shore fishery was reported during October (Table 14).

3.4.3.6. Mulloway

Relatively few mulloway were caught by boat-based fishers during the survey period and accordingly the discard rates recorded were relatively low (Table 15). There was no apparent monthly trend in these discard rate data for the boat fishery. Mulloway were classified as a rare taxon in the shore fishery and as such we did not estimate discard rates or make expanded estimates of discard for this species in the shore fishery.

3.4.4. Size-frequency distributions

Appendix 5 contains descriptive statistics of all measurements taken for each taxon by boat-based and shore-based fishers during the survey period. Here, we present length frequency distributions for the five main taxa in the recreational fishery, aggregated for the whole fishery (boat and shore combined). The size-frequency distributions presented here are important baseline indicators which can be used to monitor future changes (if any) in the size structure of these species in the fishery. There are some noteworthy features evident in these size-frequency distributions (Figures 3a to 3e). First, large individuals that were highly-prized by recreational fishers were present in the recreational harvests indicating that the quality of recreational fishing opportunities during the survey period was quite good. Second, the proportions of under-sized yellowfin bream and luderick in the recreational harvest were extremely low indicating good compliance with fisheries regulations. Third, the proportion of under-sized tailor taken by shore-based fishers was relatively high indicating a compliance problem exists for at least part of the recreational fishing population. The proportions of under-sized dusky flathead and sand whiting in the recreational harvest were less than 15% which is comparable to rates measured in other NSW estuarine fisheries.

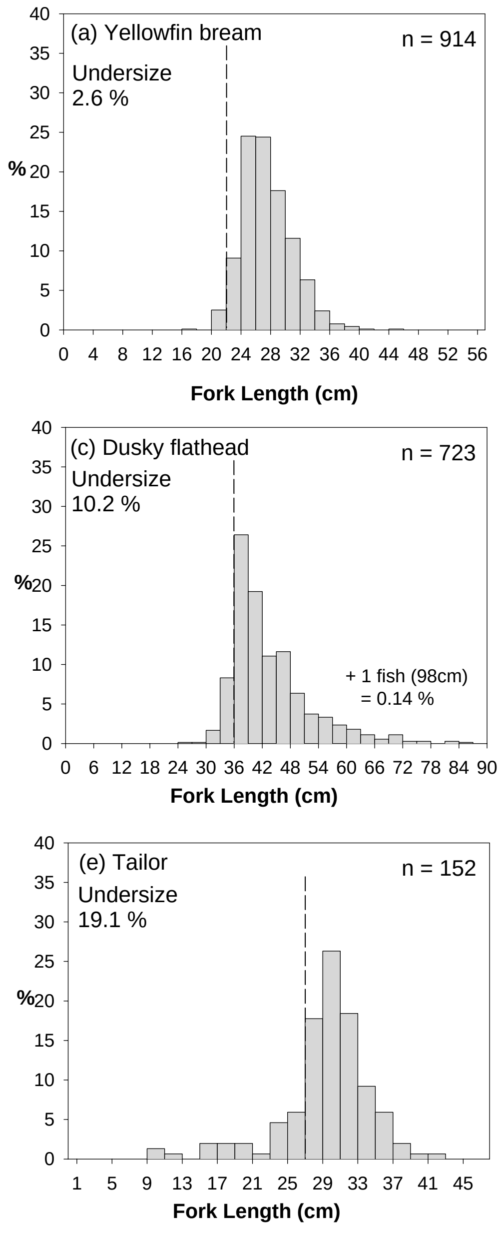

Figure 3. Length frequency distributions for: (a) Yellowfin bream (*Acanthopagrus australis*); (b) Luderick (*Girella tricuspidata*); (c) Dusky flathead (*Platycephalus fuscus*); (d) Sand whiting (*Sillago ciliata*); and (e) Tailor (*Pomatomus saltatrix*); taken by recreational fishers in the lower Richmond River during the survey period (July 1 to October 31, 2001). The length frequency data for the boat and shore fisheries have been pooled. The dashed line indicates the minimum legal length.

3.5. Recreational harvest

3.5.1. Whole fishery

We recorded 26 taxa in the retained catch of recreational fishers accessing the lower Richmond River fishery by boat and from the shore during the survey period (Table 16). We estimated that approximately 29,800 fish, crabs and cephalopods (± 1,975 individuals - approximate SE) were harvested by daytime recreational fishers from the lower Richmond River during the survey period (Table 16), and that this recreational harvest consisted almost exclusively of finfish (>99% of harvest) - (Table 16). The six most commonly harvested taxa, by number, during the survey period were luderick (≈13,680 - 45.9%), yellowfin bream (≈7,700 - 25.9%), dusky flathead (≈3,430 - 11.5%), sand mullet (≈1,630 - 5.5%), tailor (≈1,270 - 4.3%), and sand whiting (≈1,260 - 4.2%) - (Table 16). These six taxa, by number, accounted for 97.3% of the daytime recreational harvest during the survey period (Table 16).

We estimated that approximately 14.2 tonnes of fish, crabs and cephalopods (± 0.9 tonnes - approximate SE) were harvested by daytime recreational fishers from the lower Richmond River during the survey period (Table 17), and that this recreational harvest consisted almost exclusively of finfish (>99% of harvest) – (Table 17). The six most commonly harvested taxa, by weight, during the survey period were luderick (≈7.3 tonnes - 51.5%), yellowfin bream (≈3.8 tonnes – 27.0%), dusky flathead (≈2.2 tonnes – 15.4%), tailor (≈0.4 tonnes – 2.8%), sand whiting (≈0.3 tonnes – 2.1%), and sand mullet (≈0.1 tonnes - 0.6%) - (Table 17). These six taxa, by weight, accounted for 99.5% of the daytime recreational harvest during the survey period (Table 17).

Table 16. Monthly and total harvest estimates (number of individuals) and standard errors for taxa taken by recreational fishers in the Richmond River for the survey period (July 1 - October 31, 2001). The daytime harvest data for the boat and shore fisheries have been pooled.

	TOTAL HARVEST FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Luderick *Girella tricuspidata*	6,202 ±	1,059	4,085 ±	494	2,826 ±	544	567 ±	133	13,680 ±	1,296	45.9
Yellowfin bream *Acanthopagrus australis*	4,420 ±	778	2,147 ±	398	618 ±	233	519 ±	83	7,704 ±	908	25.9
Dusky flathead *Platycephalus fuscus*	1,548 ±	304	864 ±	194	462 ±	85	557 ±	131	3,431 ±	393	11.5
Sand mullet *Myxus elongatus*	853 ±	851	464 ±	439	157 ±	59	151 ±	68	1,625 ±	962	5.5
Tailor *Pomatomus saltatrix*	798 ±	241	395 ±	159	24 ±	12	51 ±	51	1,268 ±	294	4.3
Sand whiting *Sillago ciliata*	172 ±	57	482 ±	227	228 ±	89	380 ±	118	1,262 ±	277	4.2
Southern herring *Herklotsichthys castelnaui*	#7	-	35 ±	26	147 ±	114	568 ±	373	757 ±	391	2.5
Mulloway *Argyrosomus japonicus*	9 ±	8	-	-	7 ±	7	11 ±	8	27 ±	13	0.1
Large-toothed flounder *Pseudorhombus arsius*	-	-	-	-	#1	-	12 ±	8	13 ±	8	< 0.1
Snapper *Pagrus auratus*	-	-	-	-	-	-	#7	-	#7	-	< 0.1
Octopus* *Octopus spp.*	-	-	-	-	#2	-	#2	-	#4	-	< 0.1
Estuary perch *Macquaria colonorum*	-	-	#2	-	#1	-	-	-	#3	-	< 0.1
Flat-tail mullet *Liza argentea*	-	-	#3	-	-	-	-	-	#3	-	< 0.1
River garfish *Hyphorhamphus regularis*	-	-	-	-	-	-	#2	-	#2	-	< 0.1

Table 16 (continued)

	TOTAL HARVEST FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Sea mullet *Mugil cephalus*	-	-	#2	-	-	-	-	-	#2	-	< 0.1
Estuary catfish* *Cnidoglanis macrocephalus*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Mangrove jack* *Lutjanus argentimaculatus*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Mud crab *Scylla serrata*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Northern sand flathead *Platycephalus arenarius*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Red morwong *Cheilodactylus fuscus*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Shovelnose ray* Rhinobatidae	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Silver trevally *Pseudocaranx dentex*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Stingrays & stingarees* Dasyatidae & Urolophidae	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Tarwhine *Rhabdosargus sarba*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Wirrah *Acanthistius ocellatus*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Unidentified Eel*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Total Taxa	**12**		**14**		**13**		**13**		**26**		

* Associated estimates of expanded weight (kg) are not provided for this taxon in Table 17 because a suitable length to weight conversion key was not available.
# Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

Table 17. Monthly and total harvest estimates (kilograms) and standard errors for taxa taken by recreational fishers in the Richmond River for the survey period (July 1 - October 31, 2001). The daytime harvest data for the boat and shore fisheries have been pooled.

	TOTAL HARVEST FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	kg	SE	kg	SE	kg	SE	kg	SE	kg	SE	total
Luderick *Girella tricuspidata*	3,231 ±	527	2,211 ±	272	1,569 ±	304	311 ±	71	7,322 ±	670	51.5
Yellowfin bream *Acanthopagrus australis*	2,281 ±	412	975 ±	147	329 ±	121	248 ±	44	3,833 ±	456	27.0
Dusky flathead *Platycephalus fuscus*	858 ±	163	626 ±	172	301 ±	65	400 ±	95	2,185 ±	264	15.4
Tailor *Pomatomus saltatrix*	214 ±	52	164 ±	86	6 ±	3	7 ±	7	391 ±	101	2.8
Sand whiting *Sillago ciliata*	41 ±	14	107 ±	50	61 ±	24	87 ±	23	296 ±	61	2.1
Sand mullet *Myxus elongatus*	45 ±	44	23 ±	23	16 ±	7	6 ±	3	90 ±	50	0.6
Mulloway *Argyrosomus japonicus*	7 ±	5	-	-	29 ±	29	14 ±	9	50 ±	31	0.4
Southern herring *Herklotsichthys castelnaui*	#3	-	<1 ±	<1	1 ±	1	5 ±	3	10 ±	3	0.1
Large-toothed flounder *Pseudorhombus arsius*	-	-	-	-	#<1	-	3 ±	1	4 ±	1	< 0.1
Estuary perch *Macquaria colonorum*	-	-	#1	-	#1	-	-	-	#2	-	< 0.1
Mud crab *Scylla serrata*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Northern sand flathead *Platycephalus arenarius*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Red morwong *Cheilodactylus fuscus*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Silver trevally *Pseudocaranx dentex*	-	-	#1	-	-	-	-	-	#1	-	< 0.1

Table 17 (continued)

	TOTAL HARVEST FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	kg	SE	kg	SE	kg	SE	kg	SE	kg	SE	total
River garfish *Hyphorhamphus regularis*	-	-	-	-	-	-	#<1	-	#<1	-	< 0.1
Tarwhine *Rhabdosargus sarba*	#<1	-	-	-	-	-	-	-	#<1	-	< 0.1
Wirrah *Acanthistius ocellatus*	#<1	-	-	-	-	-	-	-	#<1	-	< 0.1
Flat-tail mullet *Liza argentea*	-	-	@	-	-	-	-	-	@	-	-
Sea mullet *Mugil cephalus*	-	-	@	-	-	-	-	-	@	-	-
Snapper *Pagrus auratus*	-	-	-	-	-	-	@	-	@	-	-

Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.
@ Estimates of weight (kg) are not provided for this taxon because no length measurements were made.

3.5.2. Boat fishery

We recorded 18 taxa in the retained catch of boat-based recreational fishers during the survey period (Table 18). We estimated that for boat-based recreational fishers, approximately 8,580 fish, crabs and cephalopods (± 750 individuals - approximate SE), were harvested in the daytime from the lower Richmond River during the survey period (Table 18). This represents 28.8%, by number, of the daytime harvest for the total fishery (boat and shore combined). The recreational harvest for the boat fishery consisted almost exclusively of finfish (>99% of harvest) - (Table 18). The six most commonly harvested taxa by boat-based fishers, by number, during the survey period were luderick (≈4,050 - 47.1%), dusky flathead (≈2,060 - 23.9%), yellowfin bream (≈1,790 - 20.9%), tailor (≈430 - 5.0%), sand whiting (≈180 - 2.1%), and mulloway (≈30 - 0.3%) - (Table 18). These six taxa, by number, accounted for 99.3% of the daytime recreational harvest of the boat-based fishery during the survey period (Table 18).

We estimated that for boat-based recreational fishers, approximately 4.6 tonnes of fish, crabs and cephalopods (± 0.4 tonnes - approximate SE), were harvested in the daytime from the lower Richmond River during the survey period (Table 19). This represents 32.4%, by weight, of the daytime harvest for the total fishery (boat and shore combined). The recreational harvest for the boat fishery consisted almost exclusively of finfish (>99% of harvest) - (Table 19). The six most commonly harvested taxa by boat-based fishers, by weight, during the survey period were luderick (≈2.3 tonnes - 49.7%), dusky flathead (≈1.2 tonnes - 26.1%), yellowfin bream (≈0.8 tonnes - 18.4%), tailor (≈0.2 tonnes - 3.5%), sand whiting (<0.1 tonnes - 1.1%), and mulloway (<0.1 tonnes - 1.0%) - (Table 19). These six taxa, by weight, accounted for 99.8% of the daytime recreational harvest of the boat-based fishery during the survey period (Table 19).

Table 18. Monthly and total harvest estimates (number of individuals) and standard errors for taxa taken by boat-based recreational fishers in the Richmond River for the survey period (July 1 - October 31, 2001).

	BOAT-BASED HARVEST															
	July 2001			August 2001			September 2001			October 2001			Total			%
Taxon	No.		SE	No.		SE	No.		SE	No.		SE	No.		SE	total
Luderick *Girella tricuspidata*	2,034	±	503	1,282	±	304	708	±	179	22	±	18	4,046	±	615	47.1
Dusky flathead *Platycephalus fuscus*	866	±	242	522	±	140	307	±	76	360	±	111	2,055	±	310	23.9
Yellowfin bream *Acanthopagrus australis*	1,079	±	247	422	±	86	105	±	46	184	±	31	1,790	±	268	20.9
Tailor *Pomatomus saltatrix*	278	±	73	149	±	90	2	±	2	-		-	429	±	116	5.0
Sand whiting *Sillago ciliata*	53	±	17	38	±	16	45	±	23	42	±	23	178	±	40	2.1
Mulloway *Argyrosomus japonicus*	8	±	8	-		-	7	±	7	11	±	8	26	±	13	0.3
Sand mullet *Myxus elongatus*	-		-	#15		-	#10		-	-		-	#25		-	0.3
Large-toothed flounder *Pseudorhombus arsius*	-		-	-		-	-		-	11	±	8	11	±	8	0.1
Snapper *Pagrus auratus*	-		-	-		-	-		-	#7		-	#7		-	0.1
Southern herring *Herklotsichthys castelnaui*	#7		-	-		-	-		-	-		-	#7		-	0.1
Estuary perch *Macquaria colonorum*	-		-	#2		-	#1		-	-		-	#3		-	< 0.1
Mangrove jack* *Lutjanus argentimaculatus*	#1		-	-		-	-		-	-		-	#1		-	< 0.1

Table 18 (continued)

	BOAT-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Mud crab *Scylla serrata*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Octopus* *Octopus spp.*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Red morwong *Cheilodactylus fuscus*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Shovelnose ray* Rhinobatidae	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Tarwhine *Rhabdosargus sarba*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Wirrah *Acanthistius ocellatus*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Total Taxa	**10**		**9**		**10**		**7**		**18**		

* Associated estimates of expanded weight (kg) are not provided for this taxon in Table 19 because a suitable length to weight conversion key was not available.
# Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

Table 19. Monthly and total harvest estimates (kilograms) and standard errors for taxa taken by boat-based recreational fishers in the Richmond River for the survey period (July 1 - October 31, 2001).

	BOAT-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	kg	SE	kg	SE	kg	SE	kg	SE	kg	SE	total
Luderick *Girella tricuspidata*	1,156 ±	283	714 ±	167	402 ±	104	14 ±	11	2,286 ±	345	49.7
Dusky flathead *Platycephalus fuscus*	492 ±	130	292 ±	80	174 ±	46	242 ±	72	1,200 ±	175	26.1
Yellowfin bream *Acanthopagrus australis*	497 ±	114	197 ±	42	65 ±	30	85 ±	15	844 ±	126	18.4
Tailor *Pomatomus saltatrix*	106 ±	27	53 ±	32	1 ±	1	-	-	160 ±	42	3.5
Sand whiting *Sillago ciliata*	12 ±	4	11 ±	6	13 ±	8	13 ±	6	49 ±	12	1.1
Mulloway *Argyrosomus japonicus*	5 ±	5	-	-	29 ±	29	14 ±	9	48 ±	31	1.0
Southern herring *Herklotsichthys castelnaui*	#3	-	-	-	-	-	-	-	#3	-	0.1
Large-toothed flounder *Pseudorhombus arsius*	-	-	-	-	-	-	2 ±	1	2 ±	1	< 0.1
Estuary perch *Macquaria colonorum*	-	-	#1	-	#1	-	-	-	#2	-	< 0.1
Mud crab *Scylla serrata*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Red morwong *Cheilodactylus fuscus*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Tarwhine *Rhabdosargus sarba*	#<1	-	-	-	-	-	-	-	#<1	-	< 0.1

Table 19 (continued)

	BOAT-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	kg	SE	kg	SE	kg	SE	kg	SE	kg	SE	total
Wirrah *Acanthistius ocellatus*	#<1	-	-	-	-	-	-	-	#<1	-	< 0.1
Sand mullet *Myxus elongatus*	-	-	@	-	@	-	-	-	@	-	-
Snapper *Pagrus auratus*	-	-	-	-	-	-	@	-	@	-	-

Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.
@ Estimates of weight (kg) are not provided for this taxon because no length measurements were made.

3.5.3. *Shore fishery*

We recorded 18 taxa in the retained catch of shore-based recreational fishers during the survey period (Table 20). We estimated that for shore-based recreational fishers, approximately 21,220 fish, crabs and cephalopods (± 1830 individuals - approximate SE), were harvested in the daytime from the lower Richmond River during the survey period (Table 20). This represents 71.2%, by number, of the daytime harvest for the total fishery (boat and shore combined). The recreational harvest for the shore fishery consisted almost exclusively of finfish (>99% of harvest) - (Table 20). The six most commonly harvested taxa by shore-based fishers, by number, during the survey period were luderick (≈9,630 - 45.4%), yellowfin bream (≈5,910 - 27.9%), sand mullet (≈1,600 - 7.5%), dusky flathead (≈1,380 - 6.5%), sand whiting (≈1,080 - 5.1%), and tailor (≈840 - 4.0%) - (Table 20). These six taxa, by number, accounted for 96.4% of the daytime recreational harvest of the shore-based fishery during the survey period (Table 20).

We estimated that for shore-based recreational fishers, approximately 9.6 tonnes of fish, crabs and cephalopods (± 0.8 tonnes - approximate SE), were harvested in the daytime from the lower Richmond River during the survey period (Table 21). This represents 67.6%, by weight, of the daytime harvest for the total fishery (boat and shore combined). The recreational harvest for the shore fishery consisted almost exclusively of finfish (>99% of harvest) - (Table 21). The six most commonly harvested taxa by shore-based fishers, by weight, during the survey period were luderick (≈5.0 tonnes – 52.4%), yellowfin bream (≈3.0 tonnes – 31.2%), dusky flathead (≈1.0 tonnes – 10.3%), sand whiting (≈0.2 tonnes – 2.6%), tailor (≈0.2 tonnes – 2.4%), and sand mullet (<0.1 tonnes – 0.9%) - (Table 21). These six taxa, by weight, accounted for 99.8% of the daytime recreational harvest of the shore-based fishery during the survey period (Table 21).

Table 20. Monthly and total harvest estimates (number of individuals) and standard errors for taxa taken by shore-based recreational fishers in the Richmond River for the survey period (July 1 - October 31, 2001).

	SHORE-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Luderick *Girella tricuspidata*	4,168 ±	932	2,803 ±	390	2,118 ±	513	545 ±	131	9,634 ±	1141	45.4
Yellowfin bream *Acanthopagrus australis*	3,341 ±	738	1,725 ±	388	513 ±	228	335 ±	77	5,914 ±	868	27.9
Sand mullet *Myxus elongatus*	853 ±	851	449 ±	439	147 ±	59	151 ±	68	1,600 ±	962	7.5
Dusky flathead *Platycephalus fuscus*	682 ±	184	342 ±	133	155 ±	38	197 ±	70	1,376 ±	241	6.5
Sand whiting *Sillago ciliata*	119 ±	55	444 ±	226	183 ±	86	338 ±	115	1,084 ±	274	5.1
Tailor *Pomatomus saltatrix*	520 ±	230	246 ±	131	22 ±	12	51 ±	51	839 ±	270	4.0
Southern herring *Herklotsichthys castelnaui*	-	-	35 ±	26	147 ±	114	568 ±	373	750 ±	391	3.5
Flat-tail mullet *Liza argentea*	-	-	#3	-	-	-	-	-	#3	-	< 0.1
Octopus* *Octopus spp.*	-	-	-	-	#1	-	#2	-	#3	-	< 0.1
Large-toothed flounder *Pseudorhombus arsius*	-	-	-	-	#1	-	#1	-	#2	-	< 0.1
River garfish *Hyphorhamphus regularis*	-	-	-	-	-	-	#2	-	#2	-	< 0.1
Sea mullet *Mugil cephalus*	-	-	#2	-	-	-	-	-	#2	-	< 0.1

Table 20 (continued)

	SHORE-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Estuary catfish* *Cnidoglanis macrocephalus*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Mulloway *Argyrosomus japonicus*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Northern sand flathead *Platycephalus arenarius*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Stingrays & stingarees* Dasyatidae & Urolophidae	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Silver trevally *Pseudocaranx dentex*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Unidentified eel*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Total Taxa	**8**		**11**		**10**		**11**		**18**		

* Associated estimates of expanded weight (kg) are not provided for this taxon in Table 21 because a suitable length to weight conversion key was not available.
# Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

Table 21. Monthly and total harvest estimates (kilograms) and standard errors for taxa taken by shore-based recreational fishers in the Richmond River for the survey period (July 1 - October 31, 2001).

	SHORE-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	kg	SE	kg	SE	kg	SE	kg	SE	kg	SE	total
Luderick *Girella tricuspidata*	2,075 ±	444	1,497 ±	215	1,167 ±	285	297 ±	70	5,036 ±	574	52.4
Yellowfin bream *Acanthopagrus australis*	1,784 ±	396	778 ±	141	264 ±	117	163 ±	41	2,989 ±	438	31.2
Dusky flathead *Platycephalus fuscus*	366 ±	98	334 ±	152	127 ±	46	158 ±	61	985 ±	197	10.3
Sand whiting *Sillago ciliata*	29 ±	13	96 ±	49	48 ±	22	74 ±	23	247 ±	60	2.6
Tailor *Pomatomus saltatrix*	108 ±	45	111 ±	80	5 ±	3	7 ±	7	231 ±	92	2.4
Sand mullet *Myxus elongatus*	45 ±	44	23 ±	23	16 ±	7	6 ±	3	90 ±	50	0.9
Southern herring *Herklotsichthys castelnaui*	-	-	<1 ±	<1	1 ±	1	5 ±	3	6 ±	3	0.1
Mulloway *Argyrosomus japonicus*	#2	-	-	-	-	-	-	-	#2	-	< 0.1
Northern sand flathead *Platycephalus arenarius*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Silver trevally *Pseudocaranx dentex*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Large-toothed flounder *Pseudorhombus arsius*	-	-	-	-	#<1	-	#<1	-	#<1	-	< 0.1
River garfish *Hyphorhamphus regularis*	-	-	-	-	-	-	#<1	-	#<1	-	< 0.1

Table 21 (continued)

	SHORE-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	kg	SE	kg	SE	kg	SE	kg	SE	kg	SE	total
Flat-tail mullet *Liza argentea*	-	-	@	-	-	-	-	-	@	-	< 0.1
Sea mullet *Mugil cephalus*	-	-	@	-	-	-	-	-	@	-	< 0.1

Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.
@ Estimates of weight (kg) are not provided for this taxon because no length measurements were made.

3.5.4. Monthly trends in recreational harvest

Information describing monthly trends in the pattern of recreational harvesting for the whole fishery are provided in Tables 16 and 17. Here we provide a brief description of the monthly trends evident for the six main species in the harvest, by number, for the whole fishery. The largest harvests of yellowfin bream and luderick were taken during July, the month after the river was re-opened, and the numbers of these two species harvested decreased in each of the following three months of the survey period (Table 16). The smallest level of harvest for yellowfin bream and luderick was recorded during October (Table 16). A different monthly pattern was evident for dusky flathead, sand mullet and tailor (Table 16). These three species were all harvested in greater numbers during July, with a decreased level of harvest during August and the lowest amount of harvest taken by recreational fishers recorded during September and October (Table 16). The harvest of sand whiting showed no apparent trend with the largest harvest levels recorded during August and October, and the lowest amounts of harvest were taken during July and September (Table 16). We also present information describing monthly trends in the pattern of recreational harvesting for the boat-based fishery (Tables 18 and 19), and the shore-based fishery (Tables 20 and 21). In this way, the reader may extract monthly information for particular species of interest.

3.6. Recreational discard

3.6.1. Whole fishery

Recreational fishers (boat-based and shore-based) reported discarding 46 taxa whilst fishing in the lower Richmond River during the survey period (Table 22). We estimated that approximately 50,900 fish, crabs and cephalopods (± 2,680 individuals - approximate SE) were discarded by daytime recreational fishers in the lower Richmond River during the survey period (Table 22), and that this recreational discard consisted almost exclusively of finfish (>99% of harvest) - (Table 22). The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈30,060 - 58.9%), dusky flathead (≈5,950 - 11.7%), luderick (≈5,560 - 10.9%), tailor (≈3,940 - 7.7%), sand whiting (≈2,520 - 5.0%), and southern herring (≈600 - 1.2%) - (Table 22). These six taxa, by number, accounted for 95.4% of the total daytime recreational discard during the survey period (Table 22). The great majority of discarded yellowfin bream (96.2%), dusky flathead (91.4%), luderick (91.0%), tailor (94.9%) and sand whiting (98.2%) were below the legal minimum length.

Table 22. Monthly and total discard estimates (number of individuals) and standard errors for taxa taken by recreational fishers in the Richmond River for the survey period (July 1 - October 31, 2001). The daytime harvest data for the boat and shore fisheries have been pooled.

	TOTAL DISCARD FOR WHOLE FISHERY															
	July 2001			August 2001			September 2001			October 2001			Total			%
Taxon	No.		SE	No.		SE	No.		SE	No.		SE	No.		SE	total
Yellowfin bream *Acanthopagrus australis*	15,660	±	2,099	7,582	±	953	2,935	±	270	3,881	±	550	30,058	±	2,385	58.9
Dusky flathead *Platycephalus fuscus*	2,234	±	421	1,737	±	287	882	±	140	1,093	±	235	5,946	±	578	11.7
Luderick *Girella tricuspidata*	2,358	±	378	1,536	±	333	1,260	±	266	403	±	108	5,557	±	580	10.9
Tailor *Pomatomus saltatrix*	1,808	±	456	1,138	±	342	510	±	189	483	±	223	3,939	±	641	7.7
Sand whiting *Sillago ciliata*	354	±	74	821	±	346	728	±	206	621	±	130	2,524	±	430	5.0
Southern herring *Herklotsichthys castelnaui*	145	±	98	74	±	39	17	±	17	367	±	367	603	±	382	1.2
Kelpfish *Chironemus marmoratus*	11	±	11	124	±	97	327	±	133	91	±	43	553	±	171	1.1
Stingrays & stingarees Dasyatidae & Urolophidae	190	±	85	155	±	47	61	±	25	136	±	78	542	±	127	1.1
Tarwhine *Rhabdosargus sarba*	23	±	18	3	±	3	181	±	130	148	±	74	355	±	150	0.7
Toadfish Tetraodontidae	174	±	105	83	±	36	20	±	11	54	±	21	331	±	114	0.7
Six-lined trumpeter *Pelates quadrilineatus*	-		-	31	±	31	30	±	22	23	±	23	84	±	44	0.2
Mullet Mugilidae	30	±	20	42	±	28	-		-	11	±	11	83	±	37	0.2
Silver sweep *Scorpis lineolatus*	-		-	42	±	30	27	±	27	-		-	69	±	40	0.1

Table 22 (continued)

	TOTAL DISCARD FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Eels Anguilliformes	46 ±	30	-	-	8 ±	6	11 ±	7	65 ±	32	0.1
Wirrah *Acanthistius ocellatus*	22 ±	12	-	-	-	-	20 ±	16	42 ±	20	0.1
Mulloway *Argyrosomus japonicus*	15 ±	15	3 ±	3	#1	-	19 ±	12	38 ±	20	0.1
Large-toothed flounder *Pseudorhombus arsius*	14 ±	8	9 ±	8	-	-	14 ±	7	37 ±	13	0.1
Swallowtail dart *Trachinotus coppingeri*	#9	-	-	-	-	-	-	-	#9	-	< 0.1
Trumpeter whiting *Sillago maculata*	-	-	-	-	#1	-	#7	-	#8	-	< 0.1
Estuary cod *Epinephelus spp.*	-	-	#2	-	-	-	#3	-	#5	-	< 0.1
Silver batfish *Monodactylus argenteus*	#1	-	-	-	-	-	#4	-	#5	-	< 0.1
Striped seapike *Sphyraena obtusata*	-	-	#5	-	-	-	-	-	#5	-	< 0.1
Octopus *Octopus spp.*	-	-	-	-	#2	-	#2	-	#4	-	< 0.1
Silver biddy *Gerres subfasciatus*	-	-	#1	-	#1	-	#2	-	#4	-	< 0.1
Silver trevally *Pseudocaranx dentex*	#2	-	-	-	#2	-	-	-	#4	-	< 0.1
Crimson-banded wrasse *Notolabrus gymnogenis*	-	-	#1	-	-	-	#2	-	#3	-	< 0.1

Table 22 (continued)

	TOTAL DISCARD FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Estuary catfish *Cnidoglanis macrocephalus*	#1	-	-	-	#1	-	#1	-	#3	-	< 0.1
Slimy mackerel *Scomber australasicus*	#3	-	-	-	-	-	-	-	#3	-	< 0.1
Black trevally (Spinefoot) *Siganus spp.*	-	-	#1	-	#1	-	-	-	#2	-	< 0.1
Fork-tail catfish *Arius graeffei*	#2	-	-	-	-	-	-	-	#2	-	< 0.1
Mangrove jack *Lutjanus argentimaculatus*	-	-		-	-	-	#2	-	#2	-	< 0.1
Moses perch *Lutjanus russelli*	-	-	#1	-	-	-	#1	-	#2	-	< 0.1
Red scorpioncod *Scorpaena cardinalis*	-	-	#2	-	-	-	-	-	#2	-	< 0.1
Snapper *Pagrus auratus*	-	-	#2	-	-	-	-	-	#2	-	< 0.1
Leatherjacket Monacanthidae	-	-	-	-	#2	-	-	-	#2	-	< 0.1
Black sole *Synaptura nigra*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Blind shark *Brachaelurus waddi*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Eastern blue groper *Achoerodus viridis*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Giant trevally *Caranx ignobilis*	#1	-	-	-	-	-	-	-	#1	-	< 0.1

Table 22 (continued)

	TOTAL DISCARD FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Half-banded seaperch *Ellerkeldia mccullochi*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Mud crab *Scylla serrata*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Netted sweetlips *Plectorhinchus flavomaculatus*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Northern sand flathead *Platycephalus arenarius*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Shovelnose ray Rhinobatidae	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Spotted butterfish *Scatophagus argus*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Emperor *Lethrinus spp.*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Total Taxa	**24**		**25**		**24**		**28**		**46**		

Expanded estimates of discard have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

3.6.2. *Boat fishery*

Recreational fishers in the boat-based fishery reported discarding 23 taxa whilst fishing in the lower Richmond River during the survey period (Table 23). We estimated that approximately 16,570 fish, crabs and cephalopods (± 1,240 individuals - approximate SE) were discarded by daytime boat-based recreational fishers in the lower Richmond River during the survey period (Table 23) and that this recreational discard consisted almost exclusively of finfish (>99% of harvest) - (Table 23). This boat-based discard represents 32.6%, by number, of the daytime discard for the total fishery (boat and shore combined). The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈8,280 - 49.9%), dusky flathead (≈4,260 - 25.7%), tailor (≈1,620 - 9.8%), luderick (≈1,430 - 8.6%), sand whiting (≈530 - 3.2%), and the category of stingrays and stingarees (≈230 - 1.4%) - (Table 23). These six taxa, by number, accounted for 98.6% of the daytime recreational discard for boat-based fishers during the survey period (Table 23).

Table 23. Monthly and total discard estimates (number of individuals) and standard errors for taxa taken by boat-based recreational fishers in the Richmond River for the survey period (July 1 - October 31, 2001).

	BOAT-BASED DISCARD										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Yellowfin bream *Acanthopagrus australis*	4,048 ±	945	2,452 ±	380	789 ±	154	988 ±	151	8,277 ±	1041	49.9
Dusky flathead *Platycephalus fuscus*	1,641 ±	376	1,190 ±	257	683 ±	127	745 ±	189	4,259 ±	509	25.7
Tailor *Pomatomus saltatrix*	868 ±	274	422 ±	119	203 ±	76	125 ±	69	1,618 ±	316	9.8
Luderick *Girella tricuspidata*	698 ±	189	290 ±	89	426 ±	166	11 ±	11	1,425 ±	267	8.6
Sand whiting *Sillago ciliata*	141 ±	54	147 ±	44	67 ±	23	173 ±	61	528 ±	95	3.2
Stingrays & stingarees Dasyatidae & Urolophidae	74 ±	28	94 ±	35	35 ±	22	23 ±	9	226 ±	51	1.4
Southern herring *Herklotsichthys castelnaui*	101 ±	95	-	-	-	-	-	-	101 ±	95	0.6
Tarwhine *Rhabdosargus sarba*	5 ±	3	3 ±	3	2 ±	2	44 ±	44	54 ±	44	0.3
Mulloway *Argyrosomus japonicus*	15 ±	15	3 ±	3	-	-	16 ±	12	34 ±	20	0.2
Large-toothed flounder *Pseudorhombus arsius*	12 ±	8	9 ±	8	-	-	5 ±	4	26 ±	12	0.2
Striped seapike *Sphyraena obtusata*	-	-	#5	-	-	-	-	-	#5	-	< 0.1
Slimy mackerel *Scomber australasicus*	#3	-	-	-	-	-	-	-	#3	-	< 0.1

Table 23 (continued)

	BOAT-BASED DISCARD										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Toadfish Tetraodontidae	#1	-	-	-	#2	-	-	-	#3	-	< 0.1
Silver trevally *Pseudocaranx dentex*	#2	-	-	-	-	-	-	-	#2	-	< 0.1
Snapper *Pagrus auratus*	-	-	#2	-	-	-	-	-	#2	-	< 0.1
Leatherjacket Monacanthidae	-	-	-	-	#2	-	-	-	#2	-	< 0.1
Black sole *Synaptura nigra*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Eels Anguilliformes	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Estuary cod *Epinephelus spp.*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Fork-tail catfish *Arius graeffei*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Northern sand flathead *Platycephalus arenarius*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Octopus *Octopus spp.*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Shovelnose ray Rhinobatidae	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Total Taxa	**16**		**12**		**12**		**9**		**23**		

Expanded estimates of discard have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

3.6.3. Shore fishery

Recreational fishers in the shore-based fishery reported discarding 39 taxa whilst fishing in the lower Richmond River during the survey period (Table 24). We estimated that approximately 34,330 fish, crabs and cephalopods (± 2,380 individuals - approximate SE) were discarded by daytime shore-based recreational fishers in the lower Richmond River during the survey period (Table 24), and that this recreational discard consisted almost exclusively of finfish (>99% of harvest) - (Table 24). This shore-based discard represents 67.4%, by number, of the daytime discard for the total fishery (boat and shore combined). The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈21,780 - 63.4%), luderick (≈4,130 - 12.0%), tailor (≈2,320 - 6.8%), sand whiting (≈2,000 - 5.8%), dusky flathead (≈1,690 - 4.9%) and kelpfish (≈550 - 1.6%) - (Table 24). These six taxa, by number, accounted for 94.5% of the daytime recreational discard for shore-based fishers during the survey period (Table 24).

Table 24. Monthly and total discard estimates (number of individuals) and standard errors for taxa taken by shore-based recreational fishers in the Richmond River for the survey period (July 1 - October 31, 2001).

	SHORE-BASED DISCARD															
	July 2001			August 2001			September 2001			October 2001			Total			%
Taxon	No.		SE	No.		SE	No.		SE	No.		SE	No.		SE	total
Yellowfin bream *Acanthopagrus australis*	11,612	±	1,874	5,130	±	874	2,146	±	222	2,893	±	529	21,781	±	2,146	63.4
Luderick *Girella tricuspidata*	1,660	±	327	1,246	±	321	834	±	207	392	±	108	4,132	±	514	12.0
Tailor *Pomatomus saltatrix*	940	±	365	716	±	321	307	±	173	358	±	212	2,321	±	557	6.8
Sand whiting *Sillago ciliata*	213	±	51	674	±	343	661	±	204	448	±	115	1,996	±	419	5.8
Dusky flathead *Platycephalus fuscus*	593	±	190	547	±	126	199	±	58	348	±	140	1,687	±	274	4.9
Kelpfish *Chironemus marmoratus*	11	±	11	124	±	97	327	±	133	91	±	43	553	±	171	1.6
Southern herring *Herklotsichthys castelnaui*	44	±	25	74	±	39	17	±	17	367	±	367	502	±	370	1.5
Toadfish Tetraodontidae	173	±	105	83	±	36	18	±	11	54	±	21	328	±	114	1.0
Stingrays & stingarees Dasyatidae & Urolophidae	116	±	80	61	±	32	26	±	12	113	±	78	316	±	117	0.9
Tarwhine *Rhabdosargus sarba*	18	±	18	-		-	179	±	130	104	±	59	301	±	144	0.9
Six-lined Trumpeter *Pelates quadrilineatus*	-		-	31	±	31	30	±	22	23	±	23	84	±	44	0.2
Mullet Mugilidae	30	±	20	42	±	28	-		-	11	±	11	83	±	37	0.2

Table 24 (continued)

	SHORE-BASED DISCARD										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Silver Sweep *Scorpis lineolatus*	-	-	42 ±	30	27 ±	27	-	-	69 ±	40	0.2
Eels Anguilliformes	45 ±	30	-	-	8 ±	6	11 ±	7	64 ±	32	0.2
Wirrah *Acanthistius ocellatus*	22 ±	12	-	-	-	-	20 ±	16	42 ±	20	0.1
Large-toothed flounder *Pseudorhombus arsius*	2 ±	2	-	-	-	-	9 ±	7	11 ±	7	< 0.1
Swallowtail dart *Trachinotus coppingeri*	#9	-	-	-	-	-	-	-	#9	-	< 0.1
Trumpeter whiting *Sillago maculata*	-	-	-	-	#1	-	#7	-	#8	-	< 0.1
Silver batfish *Monodactylus argenteus*	#1	-	-	-	-	-	#4	-	#5	-	< 0.1
Estuary cod *Epinephelus spp.*	-	-	#1	-	-	-	#3	-	#4	-	< 0.1
Mulloway *Argyrosomus japonicus*	-	-	-	-	#1	-	#3	-	#4	-	< 0.1
Silver biddy *Gerres subfasciatus*	-	-	#1	-	#1	-	#2	-	#4	-	< 0.1
Crimson-banded wrasse *Notolabrus gymnogenis*	-	-	#1	-	-	-	#2	-	#3	-	< 0.1
Estuary catfish *Cnidoglanis macrocephalus*	#1	-	-	-	#1	-	#1	-	#3	-	< 0.1

Table 24 (continued)

	SHORE-BASED DISCARD										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Octopus *Octopus spp.*	-	-		-	#1	-	#2	-	#3	-	< 0.1
Black trevally (Spinefoot) *Siganus spp.*	-	-	#1	-	#1	-	-	-	#2	-	< 0.1
Mangrove jack *Lutjanus argentimaculatus*	-	-		-	-	-	#2	-	#2	-	< 0.1
Moses perch *Lutjanus russelli*	-	-	#1	-	-	-	#1	-	#2	-	< 0.1
Red scorpioncod *Scorpaena cardinalis*	-	-	#2	-	-	-	-	-	#2	-	< 0.1
Silver trevally *Pseudocaranx dentex*	-	-	-	-	#2	-	-	-	#2	-	< 0.1
Blind shark *Brachaelurus waddi*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Eastern blue groper *Achoerodus viridis*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Fork-tail catfish *Arius graeffei*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Giant trevally *Caranx ignobilis*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Half-banded seaperch *Ellerkeldia mccullochi*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Mud crab *Scylla serrata*	-	-	-	-	-	-	#1	-	#1	-	< 0.1

Table 24 (continued)

	SHORE-BASED DISCARD										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Netted sweetlips *Plectorhinchus flavomaculatus*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Spotted Butterfish *Scatophagus argus*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Emperor *Lethrinus spp.*	-	-	#1	-	-	-	-	-	#1	-	< 0.1
Total Taxa	**20**		**20**		**21**		**28**		**39**		

Expanded estimates of discard have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

4. DISCUSSION

4.1. Overview of survey design

Recreational fishing surveys of sound statistical design are essential for the collection of statistically unbiased information. In the absence of reliable information, usually the result of flawed survey designs, the interpretation of survey data can become equivocal and management decisions cannot be justified scientifically. The theoretical framework for valid survey designs has been readily available for a long time (see Cochran 1953, Yates 1965) and these texts provide detailed descriptions of the logistic and statistical issues that need to be addressed when planning and running surveys. Detailed recommendations concerning the reporting of survey findings were published in 1948 by The United Nations Sub-Commission on Statistical Sampling (Yates 1965 reproduces the recommendations). These recommendations clearly identify many important issues that need to be addressed in order to evaluate the validity of survey findings. These issues include detailed descriptions of: (a) the survey aims; (b) the survey design, which includes the method of sample selection and the designation of sampling units; and (c) the survey frame (spatial and temporal). Further, it was recommended that when reporting survey results, the authors should provide sufficient information for an assessment of: (1) the survey accuracy - which can be done by minimising bias with good survey design, by providing evidence of the completeness of frame coverage and by quantifying the level of non-response errors such as refusal rates; (2) the survey precision - which can be done by reporting the precision of estimates derived from data; and (3) the integrity of survey data - which can be done by providing information about various quality assurance issues.

An assessment of a recreational fishery requires a specialised type of survey design but such assessments still require that randomly selected samples from a population of known size are used to estimate parameters for the entire population. Whilst, there have been recent advances in the theoretical understanding of recreational fishing survey designs and the statistical analysis of survey data (Robson and Jones 1989, Hoenig *et al*. 1993 and 1997, Pollock *et al*. 1994 and 1997, Jones *et al*. 1995), the theoretical basis of roving survey and access point survey designs, the most commonly used on-site survey methods, have been readily available for many years (Robson 1960 and 1961).

The use of complemented survey methods to estimate separately the effort, harvest and discard of the boat-based and shore-based fisheries separately in the lower Richmond River recognised that important differences existed between these two fisheries. We used stratified random sampling procedures as the basis of the survey design and integrated many data quality checks into the survey work (see Methods). In summary, this survey provides valuable baseline information about the boat-based and shore-based recreational fisheries in the lower Richmond River, collected using statistically sound survey methods which, if repeated, can be used to assess future changes in the fishery.

4.2. Demography of the recreational fishing population

We found that the recreational fishing population of the lower Richmond River was dominated by males. Over 83% of both the boat-based fishers and the shore-based fishers interviewed were male (Table 6). It is a well established fact that recreational fishing is a male dominated activity in Australia (see McGlennon 1995 for a review of national and statewide demographic characteristics of recreational fishing populations). A national study and all six statewide studies completed during the period 1978 to 1987 show that the proportion of male participants in the recreational fishing population ranged from approximately 67% to 75% (McGlennon 1995). The slightly higher proportions recorded during our on-site survey in the lower Richmond River were probably a reflection of the avidity of male fishers. It is well known that fishers are sampled in proportion to their avidity during on-site surveys and that off-site surveys, such as the telephone surveys used to collect statewide participation rates and demographics, sample fishers with equal probability (Pollock *et al*. 1994).

We found that the great majority of fishers interviewed were of local origin, ranging from 75% from the local area in the shore-based fishery to approximately 83% in the boat-based fishery (Table 7). It is not possible to use these data to assess whether the closure of the river to recreational fishing had an impact on tourist numbers in the area. However, these data are useful as a baseline for assessing future changes in the fishery.

4.3. Recreational effort, harvest and discard

We estimated that approximately 70,100 fisher hours of daytime recreational effort was expended in the lower Richmond River during the survey period - July to October 2001 inclusive (Table 2). The level of daytime recreational fishing effort showed a distinct monthly pattern (Table 2). The highest level of effort was found in July (approximately 26,100 fisher hours), an intermediate level of effort was recorded in August (approximately 18,800 fisher hours) and the lowest levels of effort were recorded in September (approximately 11,700 fisher hours), and October (approximately 13,500 fisher hours). These monthly effort estimates are similar to effort estimates made in 1988 and 1989 by West and Gordon (1994) for a much larger area of the Richmond River. West and Gordon (1994) provide monthly estimates of angling effort of approximately 21,500 angler hours for July, approximately 20,000 angler hours for August, approximately 9,500 angler hours for September and approximately 18,000 angler hours for October. A similar monthly pattern to that recorded in the current study is also apparent in the previous study by West and Gordon (1994) suggesting that these effort data are showing a seasonal trend.

We recorded 26 taxa in the retained catch of recreational fishers accessing the lower Richmond River fishery by boat and from the shore during the survey period (Table 16). We estimated that approximately 29,800 fish, crabs and cephalopods (± 1,975 individuals - approximate SE) were harvested by daytime recreational fishers from the lower Richmond River during the survey period (Table 16), and that this recreational harvest consisted almost exclusively of finfish (>99% of harvest) (Table 16). The six most commonly harvested taxa, by number, during the survey period were luderick (≈13,680 fish - ≈ 7.3 tonnes), yellowfin bream (≈7,700 - ≈ 3.8 tonnes), dusky flathead (≈3,430 - ≈ 2.2 tonnes), sand mullet (≈1,630 - ≈ 0.1 tonnes), tailor (≈1,270 - ≈ 0.4 tonnes), and sand whiting (≈1,260 - ≈ 0.3 tonnes) - (Tables 16 and 17). These six taxa, by number, accounted for 97.3% of the daytime recreational harvest during the survey period (Table 16). The species composition and the selective nature of the recreational harvest (i.e. six species making the bulk of the harvest) in the current study are consistent with the previous findings of West and Gordon (1994). The six main species in the recreational harvest during their survey in 1988 and 1989 were yellowfin bream, southern herring, dusky flathead, sand whiting, tailor and luderick and these species, by number, accounted for approximately 95% of the harvest (West and Gordon 1994). These comparisons indicate that there have not been any major changes in the structure of the recreational fishery since that time. Recreational anglers are still targeting and harvesting much the same species in the river and the monthly pattern of targeting and harvesting that we have documented are consistent with normal seasonal changes in this fishery as identified by West and Gordon (1994).

The size of the recreational harvest taken during the four month survey period can be put in context by considering the relative sizes of the fish mortality caused by the major flooding and subsequent deoxygenation of the river during February 2001. Westlake and Copeland (2002) have estimated the number of dead fish in a 20 km stretch of the lower Richmond River. They estimated the number of dead yellowfin bream at approximately 300,000 individuals, the number of dead dusky flathead at approximately 150,000 individuals, the number of dead sand whiting at approximately 10,000 individuals and the number of dead luderick at approximately 5,000 individuals (Westlake and Copeland 2002). In comparison, the number of these fish harvested by recreational fishers during the survey period were estimated as approximately 7,700 yellowfin bream, approximately 3,400 dusky flathead, approximately 1,300 sand whiting and approximately 13,700 luderick (Table 16). The numbers of recreationally harvested yellowfin bream, dusky flathead and sand whiting during the four month survey period were small relative to the magnitude of the fish-kill event during February. However, this was not the case for luderick. The number of luderick killed as a result of the February flooding was relatively small when compared to yellowfin bream, dusky flathead and sand whiting and was also substantially less than the estimate of recreational harvest. This suggests that a large population of luderick was resident in the lower Richmond River when it was re-opened to limited recreational fishing. A combination of factors which are not mutually exclusive may explain the apparent abundance of luderick in the river following the flood event. First, it is common for large schools of luderick to migrate between estuaries on the mid-north coast during the Winter and Spring seasons. Second, it is possible that the flood event had less impact on the riverine population of luderick relative to other species. The relative mortality estimates made by Westlake and Copeland (2002) for yellowfin bream, dusky flathead, sand whiting and luderick support this hypothesis. Third, the availability of food was not a limiting factor for luderick in the lower Richmond River after the flood event. Luderick are mainly herbivorous and it is believed that the algal food source of luderick in the lower Richmond River was not reduced greatly following the flood event. In contrast, the benthic food source of carnivorous and omnivorous fish such as yellowfin bream and dusky flathead were affected adversely by the flood event (Westlake and Copeland 2002).

Recreational fishers (boat-based and shore-based) reported discarding 46 taxa whilst fishing in the lower Richmond River during the survey period (Table 22). We estimated that approximately 50,900 fish, crabs and cephalopods (± 2,680 individuals - approximate SE) were discarded by daytime recreational fishers in the lower Richmond River during the survey period (Table 22), and that this recreational discard consisted almost exclusively of finfish (>99% of harvest) (Table 22). The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈30,060 - 58.9%), dusky flathead (≈5,950 - 11.7%), luderick (≈5,560 - 10.9%), tailor (≈3,940 - 7.7%), sand whiting (≈2,520 - 5.0%), and southern herring (≈600 - 1.2%) - (Table 22). These six taxa, by number, accounted for 95.4% of the total daytime recreational discard during the survey period (Table 22). The great majority of discarded yellowfin bream (96.2%), dusky flathead (91.4%), luderick (91.0%), tailor (94.9%) and sand whiting (98.2%) were below the legal minimum length. Discard data should be viewed with some caution because they are self-reported and less accurate than harvest data, which are collected by direct observation. Consequently, discard data suffer from additional biases such as rounding errors when reporting discard numbers, fish identification errors when reporting the species that were discarded, and recall problems when providing information about their discards. Even so, these discard data show that recreational fishers were catching and returning to the water large numbers of juvenile fish which suggests that the juveniles of these popular angling species were abundant in the lower Richmond River during the time of the survey.

4.4. Indicators of recreational fishing quality

Reliable indicators of recreational fishing quality for estuarine fisheries can provide a cost-effective means for monitoring and comparing the relative quality of important recreational fisheries. We have presented four indicators in this study: the proportion of unsuccessful fishing parties, non-directed harvest rates for the boat-based and shore-based fisheries, non-directed discard rates for the boat-based and shore-based fisheries and size-frequency distributions for some important taxa harvested by the recreational sector. The proportion of unsuccessful fishing parties is a measure of "lack of success" and it is believed that a strong positive correlation exists between the experience of fishers and the size of their harvests. That is, the least experienced fishers tend to catch fewer fish and the more experienced fishers tend to have larger harvests. Therefore, changes in the proportion of unsuccessful fishing parties through time would provide an indication of changes in a fishery (beneficial or detrimental) because they affect the largest and most inexperienced group of fishers in the recreational fishing population. The proportion of unsuccessful boat-based fishing parties ranged from approximately 31% to 59% on a monthly basis (Fig. 2) whilst the proportion of unsuccessful shore-based fishing parties was relatively higher ranging from approximately 61% to 80% on a monthly basis (Fig. 2). In both fisheries the lowest proportion of unsuccessful fishing trips was recorded during July, immediately after the river was re-opened to recreational fishing, and higher proportions of unsuccessful fishing parties were recorded in the following months (Fig. 2). These data suggest that the quality of recreational fishing was best in July after the river had been re-opened to recreational fishing and that there had been a gradual decline in fishing quality in the following months. The reason for these trends in the boat and shore fisheries was probably a combination of seasonal fish abundances and the large amount of fishing effort that occurred immediately after the fishery was re-opened.

The harvest rates and discard rates we calculated and presented are based on the total non-directed fishing effort. We provide harvest rate comparisons for luderick (Table 25), yellowfin bream (Table 26) and dusky flathead (Table 27) taken by boat-based and shore-based recreational fishers during this study, a concurrent survey done in the Macleay River (Steffe and Macbeth 2002), the recreational shore and boat fisheries in Lake Macquarie during the 1999 Winter and Spring seasons (Steffe and Chapman 2002), and the recreational boat-based fishery in Tuross Lake during the 1999 Winter and Spring seasons (Steffe and Chapman in prep.). It should be noted that seasonal harvest rate estimates will tend to be lower than the peak monthly harvest rate estimate because seasonal harvest rates incorporate any variability that occurs on smaller temporal scales (e.g. monthly or weekly variability). Even so, these seasonal harvest rates provide a general baseline that can be used to evaluate the relative size of the monthly harvest rates.

The harvest rates observed during this four month survey are similar to the comparable harvest rate data collected in other estuarine fisheries in New South Wales (see Tables 25, 26 and 27). The monthly harvest rates for luderick and dusky flathead taken by boat-based fishers in the lower Richmond River all fall within the range of harvest rates recorded from other estuaries (Tables 25 and 27). The harvest rate recorded for yellowfin bream in the lower Richmond River during July 2001 is the highest boat-based harvest rate for this species among the tabulated comparisons for the boat-based fisheries (Table 26). The monthly harvest rates for luderick, yellowfin bream and dusky flathead taken by shore-based fishers in the lower Richmond River all fall within the range of harvest rates recorded from other estuaries (Tables 25, 26 and 27). These similarities suggest that the quality of recreational fishing was quite good for boat-based and shore-based fishers during the survey period in the lower Richmond River. A similar conclusion is reached when examining discard rate data. High rates of discard were reported for the main species of recreational interest during the survey period (Tables 10 to 15) indicating that juvenile fish were abundant in the lower Richmond River. The use of harvest rates and discard rates as indicators of recreational fishing quality would be improved by using the directed fishing effort that is targeted at a particular species of interest. In this way, a multi-species fishery could be partitioned according to the targeting preferences of fishers and more accurate harvest rate comparisons could be made among sites and through time (Steffe and Murphy 1995).

The use of size-frequency distributions complements the interpretations made from harvest rate data. For example, it is conceivable that the harvest in a fishery, measured in terms of the number of fish taken, could remain constant through time but that the average size of the fish has become smaller. The regular monitoring of size-frequency distributions taken from the recreational fishery would allow the detection of this type of change in the fishery. The size frequency distributions of luderick, yellowfin bream, dusky flathead, sand whiting and tailor (Fig. 3) that were harvested by recreational fishers during the survey period are similar to size frequency distributions found in other NSW estuarine fisheries at the same time of year (West and Gordon 1994, Steffe and Chapman 2002). It is noteworthy that large individuals that were highly prized by fishers were commonly observed in the recreational harvest indicating that the quality of recreational fishing opportunities in this fishery were quite good (Fig. 3).

Size-frequency distributions of species having minimum legal length restrictions are also useful for evaluating compliance rates for the fishery. The proportion of undersized fish in the recreational harvest could also be used as an important indicator of fishing quality because the rate of compliance with regulations may be directly linked to the availability of legal sized fish to the recreational fishing population. For example, the proportion of undersized fish retained would be expected to be low when legal sized fish are abundant in a fishery, and conversely, in fisheries that contain relatively low numbers of legal sized fish it should be expected that compliance rates would be lower and that the proportion of undersized fish retained would be higher. The proportions of undersized fish retained by recreational fishers in the lower Richmond River fishery (boat and shore-based) were comparable to rates measured in some other estuarine fisheries in NSW (West and Gordon 1994, Steffe and Chapman 2002). We found that the proportions of under-sized yellowfin bream and luderick in the recreational harvest were extremely low (2.6% and 0.8% respectively), indicating good compliance with fisheries regulations. In contrast, the proportion of under-sized tailor taken by shore-based fishers was relatively high (19.1%), indicating that a compliance problem exists for at least part of the recreational fishing population. The proportions of under-sized dusky flathead and sand whiting in the recreational harvest were around 10%. The proportion of under-sized mulloway taken by fishers was relatively high but this figure is based on a small number of individual fish harvested and thus is representative only of the actions of a very small number of recreational fishers.

The use of these indicators is not intended to be an exhaustive analysis of the recreational survey data. We recommend that further analyses be done on the survey data to provide additional indicators, which could be used to assess future changes in the lower Richmond River fishery.

Table 25. Recreational harvest rate estimates (fish per fisher hour ± standard error) for Luderick (*Girella tricuspidata*) taken by: (a) boat-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie and in Tuross Lake during Winter and Spring 1999; (b) boat-based fishers in the Richmond River and Macleay River during the period July to October 2001; (c) shore-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie during Winter and Spring 1999; and (d) shore-based fishers in the Richmond River and Macleay River during the period July to October 2001.

A. BOAT FISHERY - LUDERICK

	LAKE MACQUARIE[1]									TUROSS LAKE[2]		
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL					
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.052**	±	**0.039**	-		-	**0.046**	±	**0.037**	**0.063**	±	**0.041**
Spring 1999	**0.115**	±	**0.113**	-		-	**0.058**	±	**0.053**	**0.086**	±	**0.039**

B. BOAT FISHERY - LUDERICK

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.272**	±	**0.052**	**0.973**	±	**0.106**
August 2001	**0.200**	±	**0.051**	**0.567**	±	**0.110**
September 2001	**0.316**	±	**0.088**	**0.210**	±	**0.036**
October 2001	**0.004**	±	**0.003**	**0.074**	±	**0.029**

C. SHORE FISHERY - LUDERICK

	LAKE MACQUARIE[1]								
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL		
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	-		-	**0.688**	±	**0.114**	**0.128**	±	**0.039**
Spring 1999	**0.016**	±	**0.016**	**0.736**	±	**0.116**	**0.184**	±	**0.062**

D. SHORE FISHERY - LUDERICK

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.246**	±	**0.053**	**0.350**	±	**0.046**
August 2001	**0.263**	±	**0.032**	**0.431**	±	**0.131**
September 2001	**0.311**	±	**0.070**	**0.029**	±	**0.013**
October 2001	**0.066**	±	**0.020**	**0.026**	±	**0.019**

[1] Steffe and Chapman (2002)
[2] Steffe and Chapman (in preparation)
[3] This study
[4] Steffe and Macbeth (2002)

Table 26. Recreational harvest rate estimates (fish per fisher hour ± standard error) for Yellowfin bream (*Acanthopagrus australis*) taken by: (a) boat-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie and in Tuross Lake during Winter and Spring 1999; (b) boat-based fishers in the Richmond River and Macleay River during the period July to October 2001; (c) shore-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie during Winter and Spring 1999; and (d) shore-based fishers in the Richmond River and Macleay River during the period July to October 2001.

A. BOAT FISHERY - YELLOWFIN BREAM

	LAKE MACQUARIE[1]									TUROSS LAKE[2]		
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL					
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.058**	±	**0.032**	**0.002**	±	**0.001**	**0.007**	±	**0.005**	**0.053**	±	**0.044**
Spring 1999	**0.025**	±	**0.011**	**0.036**	±	**0.022**	**0.052**	±	**0.021**	**0.066**	±	**0.038**

B. BOAT FISHERY - YELLOWFIN BREAM

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.113**	±	**0.021**	**0.096**	±	**0.023**
August 2001	**0.073**	±	**0.011**	**0.084**	±	**0.029**
September 2001	**0.031**	±	**0.023**	**0.029**	±	**0.008**
October 2001	**0.059**	±	**0.014**	**0.025**	±	**0.010**

C. SHORE FISHERY - YELLOWFIN BREAM

	LAKE MACQUARIE[1]								
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL		
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.010**	±	**0.005**	**0.007**	±	**0.004**	**0.014**	±	**0.008**
Spring 1999	**0.022**	±	**0.008**	**0.050**	±	**0.022**	**0.024**	±	**0.009**

D. SHORE FISHERY - YELLOWFIN BREAM

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.177**	±	**0.035**	**0.186**	±	**0.011**
August 2001	**0.132**	±	**0.028**	**0.152**	±	**0.027**
September 2001	**0.064**	±	**0.026**	**0.122**	±	**0.018**
October 2001	**0.033**	±	**0.010**	**0.090**	±	**0.023**

[1] Steffe and Chapman (2002)

[2] Steffe and Chapman (in preparation)

[3] This study

[4] Steffe and Macbeth (2002)

Table 27. Recreational harvest rate estimates (fish per fisher hour ± standard error) for Dusky flathead (*Platycephalus fuscus*) taken by: (a) boat-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie and in Tuross Lake during Winter and Spring 1999; (b) boat-based fishers in the Richmond River and Macleay River during the period July to October 2001; (c) shore-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie during Winter and Spring 1999; and (d) shore-based fishers in the Richmond River and Macleay River during the period July to October 2001.

A. BOAT FISHERY - DUSKY FLATHEAD

	LAKE MACQUARIE[1]									TUROSS LAKE[2]		
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL					
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.006**	±	**0.002**	**0.001**	±	**0.001**	-		-	**0.027**	±	**0.014**
Spring 1999	**0.021**	±	**0.011**	**0.022**	±	**0.015**	**0.031**	±	**0.017**	**0.133**	±	**0.034**

B. BOAT FISHERY - DUSKY FLATHEAD

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.084**	±	**0.018**	**0.049**	±	**0.022**
August 2001	**0.084**	±	**0.020**	**0.042**	±	**0.011**
September 2001	**0.066**	±	**0.019**	**0.052**	±	**0.014**
October 2001	**0.081**	±	**0.016**	**0.118**	±	**0.026**

C. SHORE FISHERY - DUSKY FLATHEAD

	LAKE MACQUARIE[1]								
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL		
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.011**	±	**0.009**	**<0.001**	±	**<0.001**	-		-
Spring 1999	-		-	-		-	**0.003**	±	**0.002**

D. SHORE FISHERY - DUSKY FLATHEAD

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.033**	±	**0.008**	**0.026**	±	**0.005**
August 2001	**0.022**	±	**0.007**	**0.022**	±	**0.007**
September 2001	**0.021**	±	**0.006**	**0.062**	±	**0.018**
October 2001	**0.018**	±	**0.006**	**0.025**	±	**0.008**

[1] Steffe and Chapman (2002)
[2] Steffe and Chapman (in preparation)
[3] This study
[4] Steffe and Macbeth (2002)

4.5. Status of the recreational fisheries in the lower Richmond River

Fisheries managers and the general public will inevitably ask whether the recreational fishery (shore and boat-based) in the Richmond River has recovered from the impact of the February fish-kill event. This important question cannot be answered directly because we do not have any detailed information describing the status of estuarine fish stocks or the recreational boat and shore fisheries in the Richmond River immediately before the fish-kill event nor do we have information about other non-impacted estuarine recreational fisheries in the region that could be used as controls or reference sites. Therefore, we are restricted to making inferences about the recovery of estuarine fish stocks and the status of the recreational fisheries from limited comparisons with previous studies and by examining a number of indicators of recreational fishing quality that have been derived from the current survey.

The available information indicates that a major flood in February 2001 led to deoxygenation of the water in the lower Richmond River and this was the direct cause of a large fish-kill event in the river (Westlake and Copeland 2002). We know that: (a) large numbers of important recreational and commercial fish species such as yellowfin bream, dusky flathead and sand whiting were killed by the anoxic conditions; (b) large numbers of hardy species such as mullet, eels and mudcrabs were also killed; and (c) large numbers of important prey animals such as school prawns and blood worms were killed. The evidence strongly suggests that most fish of recreational importance were flushed from the river system, migrated actively from the river system or were killed by the anoxic water during the period of the fish-kill. The government responded to this fish-kill event by closing the river to recreational and commercial fishing for a period of approximately four and a half months. The lower Richmond River was re-opened to limited recreational and commercial fishing at the start of July 2001.

The recreational fishing survey data indicate that: (a) the levels of monthly fishing effort recorded were similar to effort estimates reported from 1988 and 1989 in a much larger part of the Richmond River system; (b) the levels of monthly effort showed a seasonal pattern; (c) the monthly patterns of targeting and harvesting by boat-based and shore-based recreational fishers were consistent with expected seasonal changes in these fisheries; (d) the quality of recreational fishing was best during July after the river had been re-opened - presumably because of a combination of seasonal fish abundances and a high level of recreational fishing effort after a long period of fishery closure; (e) the species composition and the selective nature of the recreational harvest were consistent with the findings of previous survey work; (f) the harvest rates of the main angling species were similar to comparable data from other estuarine fisheries in NSW; (g) a large population of luderick was resident within the lower Richmond River when the fishery was re-opened; (h) highly-prized, large individuals were commonly observed in the recreational harvest of luderick, dusky flathead, yellowfin bream, tailor and sand whiting indicating that the quality of recreational fishing opportunities in this area were quite good; (i) large numbers of juvenile fish were caught and returned to the water by recreational fishers which suggests that the juveniles of these popular angling species were abundant in the lower Richmond River during the survey period; and (j) for the main angling target species, the proportions of under-sized fish retained by recreational fishers were similar to the rates measured in some other NSW estuarine fisheries.

The interpretation of the available evidence strongly suggests that the recreational fisheries in the lower Richmond River are still productive and providing quality recreational fishing opportunities despite the adverse impacts of the February 2001 fish-kill event. We recommend that statistical power analyses be done on the dataset collected during this study before starting any future surveys or monitoring of the recreational fishery in the lower Richmond River. Power analyses are based on four parameters of statistical inference: power, significance criterion, sample size, and effect size (Cohen 1988). The use of appropriate power analyses that specify the values of power, significance criterion and effect size should be done to determine, in a scientifically defensible way, the necessary sample size needed to detect future changes in the lower Richmond River fishery.

5. RECOMMENDATIONS

1. When based on statistically valid survey designs, on-site surveys of recreational fishing are valuable tools for collecting information to describe the status of a recreational fishery. We recommend the use of such surveys in conjunction with fishery-independent population assessment techniques should future fish-kill events occur.

2. On-site recreational fishing surveys should be repeated periodically to monitor the recreational fishery in the lower Richmond River. The intervals between surveys should be relatively short. It is our opinion that intervals of 3-5 years between surveys would be sufficient for monitoring changes in the recreational fishery.

3. Before future surveys or monitoring programmes are done in the lower Richmond River, it is recommended that statistical power analyses should be done of the recreational fishing dataset collected during this study. Power analyses are vital for determining scientifically defensible and cost-effective survey designs that have sufficient statistical power to detect changes in the recreational fishery throughout time.

4. The development of robust and reliable indicators of recreational fishing quality would lead to more cost-effective ways of monitoring estuarine fisheries throughout NSW. We recommend that additional work be done to develop robust and reliable indicators of fishing quality for all recreational fisheries in NSW. This would require more detailed analyses of: (a) the data collected during this survey; and (b) the survey data collected during previous recreational fishing surveys done in NSW.

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7. APPENDICES

Appendix 1. Glossary of technical terms. This is a modified version of the glossary provided by Pollock et al. (1994).

The terms in this glossary are defined in the context of recreational fishing, the focus of this report. Some terms may have slightly different (but analogous) meanings for recreational and commercial fishing.

Access point design: an on-site, intercept design that is used when fishers use defined access points to enter and leave the fishery. This method works best when there are few access points (e.g. boat ramps, wharves, breakwalls) and most fishers use these defined access points. The access point design can be used to estimate fishing effort, harvest rates and harvest and relies on complete trip interviews. (Compare *Roving design*.)

Accuracy: Degree of conformity to a true value. An accurate estimator has a small mean squared error, implying little or no bias and small standard error. (Compare *Precision.)*

Angler: Person participating in a line fishing activity. Recreational line fishing activities include trolling, drifting, fishing with lures or bait. (Compare *Fisher*.)

Angler survey: General term for any survey of anglers by an off-site method (mail, telephone, door-to-door) or an on-site method (access, roving, aerial). (Compare *Creel survey.)*

Avidity bias: Bias arising in on-site surveys when anglers are sampled in proportion to their fishing avidity (time spent fishing or frequency of fishing), not with equal probability.

Biased estimator: Estimator whose average value over many hypothetical repetitions of a study deviates from the true parameter value.

Catch rate: Number or weight of all fish caught (kept or released) per trip, per angler hour, or per some other unit of fishing effort. The catch per unit effort can be used as a measure of success rate. (Compare *Harvest rate*.)

Catch: Number or weight of all fish caught, whether the fish are kept or released. Sometimes the term is also used (less precisely) to mean harvest. (Compare *Harvest.)*

Census: Sampling of every unit in the sampled population.

Complemented survey: Survey combining two or more contact methods (e.g., a telephone survey to estimate effort and an access survey to estimate catch rate).

Complete trip interview: Interview conducted as an angler leaves the water at the end of fishing. (Compare *Incomplete trip interview.)*

Consistent estimator: Estimator that gets closer and closer to the true parameter value as the size of the sample increases.

Contact method: Any method used to contact fishers for a survey (mail, telephone, door-to-door, access, roving, or aerial).

Creel survey: On-site angler survey during which the harvests of fishers are examined by the survey agent.

Direct impact of fishing: The immediate, main effect caused by fishers on a population or stock. In any extractive fishery (recreational or commercial) this main, immediate impact can be assessed by estimating the harvest. (Compare *Indirect impact of fishing.*)

Directed fishing effort: Fishing effort directed at a particular species or group of species. (Compare *Non-directed fishing effort*.)

Directed harvest rate: A harvest rate that has been calculated using directed fishing effort and the associated harvest from that directed effort. (Compare *Non-directed harvest rate*.)

Discard: That part of the catch that is not kept. (Compare *Catch, Harvest.*)

Discard rate: Number of fish released (fish kept are not included) per trip, per angler hour, or per some other unit of fishing effort. The discard per unit effort can be used as a measure of success rate for the released component of the catch. (Compare *Catch rate, Harvest rate*.)

Effort: See *Fishing effort.*

Estimate: Realised value of an estimator calculated from a particular sample.

Estimation methods: General term to describe the methods used to calculate estimates of population parameters (e.g. effort, harvest rate, and harvest) and estimates of their precision (e.g. variances and standard errors). (Compare *Survey methods*.)

Estimator: Formula or sample statistic used to estimate a population parameter.

Fisher: Person participating in any fishing activity. Recreational fishing activities include all forms of line fishing, bait collecting, and the setting of crab traps. (Compare *Angler*.)

Fishing effort (fishing pressure): A measure of resource use by anglers or fishers. Typical units of effort are number of trips on the water, angler hours, party hours, and boat hours.

Fishing party: A group of anglers or fishers participating in a recreational fishing activity. A fishing party can consist of a single individual or a large number of persons fishing together.

Frame: See *Sampling frame.*

Harvest: Number or weight of the fish caught that are kept, not released. (Compare *Catch.*)

Harvest rate: Number or weight of fish retained (fish released are not included) per trip, per angler hour, or per some other unit of fishing effort. The harvest per unit effort can be used as a measure of success rate. (Compare *Catch rate*.)

Incomplete trip interview: Interview conducted before an angler has finished fishing. (Compare *Complete trip interview.)*

Indirect impact of fishing: An incidental, secondary effect caused by fishers on a population or stock. In any extractive fishery (recreational or commercial) these secondary impacts may include physical and genetic changes in population structures, post-release mortality of discards, and numerous effects on fish and fish habitats caused by factors such as pollution from outboard motors, anchoring in seagrass beds, loss of lead sinkers and fishing lines. (Compare *Direct impact of fishing.*)

Independence: See *Statistical independence*.

Instantaneous count: Count of anglers/fishers or boats made quickly from an aeroplane, a vantage point (bridge, hilltop, etc.), a fast-moving boat, or an automobile. (*Compare Progressive count.*)

Large individual: Being of more than common size.

Length-of-stay bias: Bias arising in roving surveys when anglers are interviewed with probability proportional to the length of their fishing trip, not with equal probability.

Mean: The arithmetic mean or average is calculated by summing all the individual observations (sampling units) of a sample and dividing this sum by the number of observations in the sample.

Median: The value of a variable (in an ordered array) that has an equal number of observations on either side of it. The median is used to divide a frequency distribution into two halves.

Non-directed fishing effort: The combined fishing effort regardless of targeting preferences. This term refers to the amalgamation of directed effort for different species and species groups and the effort of generalist fishers that had no specific target species. (Compare *Directed fishing effort*.)

Non-directed harvest rate: A harvest rate that has been calculated using non-directed fishing effort and the associated harvest from that non-directed effort. (Compare *Directed harvest rate*.)

Non-response bias: Bias arising when people refuse or are unable to answer a survey question. (See *Refusal rate*.)

Off-site survey: A recreational fishing survey that is carried out away from the fishing sites of a defined fishery. Off-site survey methods include mail, telephone, door-to-door, logbooks, diaries and catch cards. (Compare *On-site survey*.)

On-site survey: A recreational fishing survey that is carried out at the fishing sites within a defined fishery. On-site survey methods include access point, roving, and aerial surveys. (Compare *Off-site survey*.)

Parameter: Characteristic of the population under study.

Precision: Degree of variation. A precise estimator has a small standard error (or variance). (Compare *Accuracy.*)

Probability sampling: Sampling in which all possible samples have known probabilities of being drawn.

Progressive count: Count of anglers/fishers or boats made over time as a survey agent moves through a fishery area. Within each small subarea, the count may be instantaneous. (Compare *Instantaneous count*.)

Quality assurance: A continual process of checks and refinements aimed at maximising data integrity and hence also improving the credibility of survey results.

Random sampling: Independent sampling in which the replicate sampling units were selected at random for inclusion in the sample.

Recall bias: Bias arising when anglers/fishers inaccurately remember past events or the time in which they occurred.

Recreational fishing survey: General term for any survey of fishers by an off-site or on-site method. (Compare *Angler survey*.)

Refusal rate: The proportion of fishers or fishing parties that refused or were unable to answer survey questions. The refusal rate is an important measure of the non-response error within a survey. (See *Non-response bias*.)

Response error: Error arising because of recall, prestige, or rounding bias, or because an angler lied, misinterpreted a question, misidentified a species, or measured fish incorrectly.

Roving design: an on-site, intercept design that is used when access to a fishery is diffuse, occurring at too many points for the use of an access point survey. The roving design can be used to estimate fishing effort, harvest rates and harvest but relies on incomplete trip interviews. (Compare *Access point design*.)

Sample: Group of sampling units drawn from the sampled population.

Sample size: The number of sampling units in the sample.

Sampled population: Actual population from which information is collected. (Compare *Target population.*)

Sampling error: Error arising from improper sample selection, an incomplete sampling frame, duplications within the frame, avidity bias, or length-of-stay bias.

Sampling frame: Complete set or list of all sampling units.

Sampling unit: Basic unit of sampling (e.g., an angler/fisher, a fishing party, a fishing day or a particular combination of space and time).

Standard error: Square root of an estimator's variance.

Statistic: Characteristic of the sample drawn.

Statistical independence: The inherent assumption in all survey work that the sampling error associated with each sample is independent of the other samples. Random sampling is the mechanism used to safeguard against lack of independence problems.

Stratified sampling: Independent sampling within two or more defined subgroups of a sampled population. (See *Stratum*).

Stratum: A defined subgroup of a sampled population that does not overlap with any other subgroups and is of known size (See *Stratified sampling*.)

Survey error: General term embracing sampling, response, and non-response errors.

Survey methods: General term to describe the sampling methods used to survey the fishery (e.g. frame definition, levels of stratification, contact methods used, definition of basic sampling units, sample size). (Compare *Estimation methods*.)

Target population: Population about which information is desired. (Compare *Sampled population*.)

Unbiased estimator: Estimator whose average (or expected) value over many hypothetical repetitions of a study is the true parameter value.

Variance: The average (or expected) value of the squared deviations of an estimator from its expected value.

Appendix 2.1. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for yellowfin bream (*Acanthopagrus australis*) taken by boat-based fishers in the Richmond River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	0.264	±	0.063	0.895	±	0.250
	Weekend	0.176	±	0.029	0.927	±	0.141
	Total	**0.238**	±	**0.045**	**0.904**	±	**0.182**
August 2001	Weekday	0.163	±	0.040	0.744	±	0.106
	Weekend	0.108	±	0.025	0.677	±	0.105
	Total	**0.149**	±	**0.031**	**0.727**	±	**0.083**
September 2001	Weekday	0.060	±	0.057	0.226	±	0.119
	Weekend	0.044	±	0.013	0.449	±	0.053
	Total	**0.055**	±	**0.038**	**0.301**	±	**0.081**
October 2001	Weekday	0.143	±	0.038	0.664	±	0.122
	Weekend	0.100	±	0.034	0.522	±	0.107
	Total	**0.130**	±	**0.029**	**0.623**	±	**0.092**

Appendix 2.2. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for luderick (*Girella tricuspidata*) taken by boat-based fishers in the Richmond River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	0.624	±	0.146	0.137	±	0.040
	Weekend	0.414	±	0.070	0.173	±	0.057
	Total	**0.563**	±	**0.106**	**0.148**	±	**0.033**
August 2001	Weekday	0.357	±	0.122	0.062	±	0.026
	Weekend	0.441	±	0.091	0.129	±	0.040
	Total	**0.378**	±	**0.093**	**0.079**	±	**0.022**
September 2001	Weekday	0.596	±	0.158	0.285	±	0.128
	Weekend	0.206	±	0.105	0.128	±	0.066
	Total	**0.466**	±	**0.111**	**0.233**	±	**0.088**
October 2001	Weekday	0.005	±	0.005	-		-
	Weekend	0.009	±	0.009	0.006	±	0.006
	Total	**0.006**	±	**0.005**	**0.002**	±	**0.002**

Appendix 2.3. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for dusky flathead (*Platycephalus fuscus*) taken by boat-based fishers in the Richmond River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	0.164	±	0.042	0.366	±	0.071
	Weekend	0.196	±	0.045	0.392	±	0.059
	Total	**0.174**	±	**0.033**	**0.374**	±	**0.053**
August 2001	Weekday	0.160	±	0.045	0.277	±	0.076
	Weekend	0.169	±	0.025	0.396	±	0.077
	Total	**0.163**	±	**0.034**	**0.308**	±	**0.060**
September 2001	Weekday	0.081	±	0.033	0.485	±	0.189
	Weekend	0.192	±	0.051	0.342	±	0.088
	Total	**0.118**	±	**0.028**	**0.437**	±	**0.130**
October 2001	Weekday	0.162	±	0.044	0.415	±	0.098
	Weekend	0.177	±	0.047	0.383	±	0.088
	Total	**0.166**	±	**0.034**	**0.406**	±	**0.074**

Appendix 2.4. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for sand whiting (*Sillago ciliata*) taken by boat-based fishers in the Richmond River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	0.014	±	0.008	0.025	±	0.012
	Weekend	0.016	±	0.003	0.025	±	0.008
	Total	**0.015**	±	**0.006**	**0.025**	±	**0.009**
August 2001	Weekday	0.096	±	0.085	0.053	±	0.021
	Weekend	0.006	±	0.004	0.025	±	0.010
	Total	**0.073**	±	**0.063**	**0.046**	±	**0.016**
September 2001	Weekday	-		-	-		-
	Weekend	0.044	±	0.026	0.064	±	0.023
	Total	**0.015**	±	**0.009**	**0.021**	±	**0.008**
October 2001	Weekday	0.017	±	0.017	0.091	±	0.041
	Weekend	0.033	±	0.019	0.084	±	0.028
	Total	**0.022**	±	**0.013**	**0.089**	±	**0.030**

Appendix 2.5. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for tailor (*Pomatomus saltatrix*) taken by boat-based fishers in the Richmond River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	0.077	±	0.033	0.217	±	0.090
	Weekend	0.043	±	0.016	0.195	±	0.055
	Total	**0.067**	±	**0.024**	**0.211**	±	**0.066**
August 2001	Weekday	0.016	±	0.008	0.101	±	0.031
	Weekend	0.053	±	0.041	0.124	±	0.040
	Total	**0.026**	±	**0.012**	**0.107**	±	**0.025**
September 2001	Weekday	-		-	0.064	±	0.044
	Weekend	0.002	±	0.002	0.147	±	0.052
	Total	**0.001**	±	**0.001**	**0.092**	±	**0.034**
October 2001	Weekday	-		-	0.040	±	0.021
	Weekend	-		-	0.073	±	0.032
	Total	-		-	**0.050**	±	**0.017**

Appendix 2.6. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for mulloway (*Argyrosomus japonicus*) taken by boat-based fishers in the Richmond River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	-		-	-		-
	Weekend	0.002	±	0.002	0.004	±	0.004
	Total	**0.001**	±	**0.001**	**0.001**	±	**0.001**
August 2001	Weekday	-		-	-		-
	Weekend	-		-	0.004	±	0.004
	Total	-		-	**0.001**	±	**0.001**
September 2001	Weekday	0.003	±	0.003	-		-
	Weekend	-		-	-		-
	Total	**0.002**	±	**0.002**	-		-
October 2001	Weekday	0.010	±	0.006	0.008	±	0.008
	Weekend	0.002	±	0.002	0.003	±	0.003
	Total	**0.008**	±	**0.004**	**0.007**	±	**0.006**

Appendix 3. Length to weight conversion keys [W(grams) = a * L(cm)b] used to estimate weights for various taxa. Relevant details which describe the sample material used to calculate the length to weight key is provided. In all length to weights keys the sexes have been combined.

Common Name	Taxon	Sample Size	Size Range (cm)	Length to Weight Key W(grams) = a * $L(cm)^b$	Adjusted r^2	Region of Sample	Source of Key
Bass, Australian	*Macquaria novemaculeata*	845	5.0 – 47.6	$W=0.01122*FL^{3.091}$	0.971	Sydney Basin, NSW	Harris (1987)
Bream, Yellowfin	*Acanthopagrus australis*	758	15.0 – 40.5	$W=0.024787915*FL^{2.99584}$	0.980	NSW	Steffe *et al.* (1996a)
Crab, Blue Swimmer	*Portunus pelagicus*	186	1.3 – 9.3	$W=0.9219*CL^{2.8855}$	0.967	NSW	Ken Graham unpub. data
Crab, Mud	*Scylla serrata*	30	8.7 – 12.7	$W=15.9866*CL^{1.6375}$	0.346	NSW	Steffe & Chapman (2002)
Flathead, Dusky	*Platycephalus fuscus*	589	20.3 – 88.0	$W=0.0026864577*FL^{3.22910}$	0.992	NSW	Steffe *et al.* (1996a)
Flathead, Eastern blue-spotted	*Platycephalus caeruleopunctatus*	272	20.1 – 66.5	$W=0.0022403713*FL^{3.29590}$	0.995	NSW	Steffe *et al.* (1996a)
Flathead, Northern sand*	*Platycephalus arenarius*	-	- -	Eastern Blue-spotted Flathead Key Used	-	-	-
Flounder, Large-toothed	*Pseudorhombus arsius*	1061	15.0 – 31.5	$W=0.0053053006*FL^{3.18944}$	0.971	Botany Bay, NSW	Steffe *et al.* (1996a)
Garfish, Sea	*Hyporhamphus australis*	259	10.2 – 31.5	$W=0.0008*FL^{3.4561}$	0.971	Botany Bay, NSW	SPCC (1981)
Garfish, River*	*Hyporhamphus regularis*	-	- -	Sea Garfish Key Used	-	-	-
Herring, Southern	*Herklotsichthys castelnaui*	557	5.2 – 18.1	$W=0.0119*FL^{3.1687}$	0.962	Botany Bay, NSW	SPCC (1981)
Luderick	*Girella tricuspidata*	186	10.0 – 38.8	$W=0.0099659797*FL^{3.22212}$	0.990	Botany Bay, NSW	SPCC (1981)
Morwong, Blue	*Nemadactylus douglasii*	569	20.3 – 55.5	$W=0.024707568*FL^{2.59280}$	0.978	NSW	Steffe *et al.* (1996a)
Morwong, Red*	*Cheilodactylus fuscus*	-	- -	Blue Morwong Key Used	-	-	-
Mullet, Sand	*Myxus elongatus*	336	10.0 – 39.5	$W=0.0097*FL^{3.0967}$	0.963	Botany Bay, NSW	SPCC (1981)
Mulloway	*Argyrosomus japonicus*	141	21.7 – 139.0	$W=0.01355*FL^{2.94}$	Not Given	S. A.	Hall (1986)
Perch, Estuary	*Macquaria colonorum*	-	- -	Australian Bass Key Used	-	-	-
Tailor	*Pomatomus saltatrix*	1028	10.0 – 58.5	$W=0.0075039512*FL^{3.15753}$	0.994	NSW	Steffe *et al.* (1996a)
Tarwhine	*Rhabdosargus sarba*	730	10.0 – 30.5	$W=0.014914888*FL^{3.16297}$	0.986	NSW	Steffe *et al.* (1996a)
Trevally, Silver	*Pseudocaranx dentex*	43	19.5 – 39.0	$W=0.033516603*FL^{2.84574}$	0.991	NSW	Steffe *et al.* (1996a)
Whiting, Sand	*Sillago ciliata*	1198	10.0 – 39.5	$W=0.0040*FL^{3.3137}$	0.973	Botany Bay, NSW	SPCC (1981)
Wirrah	*Acanthistius ocellatus*	67	19.8 – 48.0	$W=0.013524151*FL^{3.09921}$	0.975	NSW	Steffe *et al.* (1996a)

This study - refers to addition material collected during the survey.
Steffe *et al.* (1996a). - refers to the amalgamation of material from a variety of sources and the recalculation of a length to weight key. These sources include material from market measuring, ramp measuring, and unpublished material taken from the Botany Bay project (SPCC, 1981), the Northern Rivers project and the Deep Ocean Outfall Monitoring project.
* Length to weight equation for this taxon was not available. Estimates of weight were obtained by using a length to weight key for a closely related taxon.
FL - Fork Length, ML - Mantle Length, CL - Carapace Length.

Appendix 4. Estimates of daytime recreational fishing effort (boat hours) for the boat-based fishery in the three areas in the Richmond River (Entrance, North Creek and Main River). Data are presented for all temporal strata and have also been combined to provide total effort estimates for the whole survey area.

		ENTRANCE			NORTH CREEK			MAIN RIVER			TOTAL		
Month/Year	Day-Type	Boat Effort (boat hrs)		SE	Boat Effort (boat hrs)		SE	Boat Effort (boat hrs)		SE	Boat Effort (boat hrs)		SE
July 2001	Weekday	436	±	156	141	±	50	1,668	±	407	2,245	±	439
	Weekend	352	±	109	126	±	35	1,349	±	391	1,827	±	408
	Total	**788**	±	**190**	**267**	±	**62**	**3,017**	±	**564**	**4,072**	±	**599**
August 2001	Weekday	384	±	107	256	±	108	1,193	±	240	1,833	±	284
	Weekend	272	±	95	99	±	34	1,013	±	190	1,384	±	215
	Total	**656**	±	**143**	**355**	±	**113**	**2,206**	±	**306**	**3,217**	±	**356**
September 2001	Weekday	129	±	74	90	±	24	582	±	162	801	±	180
	Weekend	207	±	54	136	±	43	856	±	53	1,199	±	87
	Total	**336**	±	**91**	**226**	±	**49**	**1,438**	±	**171**	**2,000**	±	**200**
October 2001	Weekday	281	±	94	78	±	38	624	±	89	983	±	135
	Weekend	230	±	86	61	±	26	597	±	185	888	±	206
	Total	**511**	±	**127**	**139**	±	**46**	**1,221**	±	**206**	**1,871**	±	**246**
Total	Weekday	1,230	±	224	565	±	127	4,067	±	507	5,862	±	569
	Weekend	1,061	±	177	422	±	70	3,815	±	475	5,298	±	512
	Total	**2,291**	±	**285**	**987**	±	**145**	**7,882**	±	**695**	**11,160**	±	**765**

Appendix 5. The number of individuals observed (N), the number of individuals measured (n), size range (cm), median length (cm), and mean length (cm) for all taxa measured during interviews with boat-based and shore-based recreational fishers in the Richmond River fishery during the survey period (July 1 - October 31, 2001).

	BOAT FISHERY					SHORE FISHERY					TOTAL FISHERY				
Common Name	N	n	Range	Median	Mean	N	n	Range	Median	Mean	N	n	Range	Median	Mean
Bream, Yellowfin	522	468	21 – 44	26.0	26.7	530	446	16 – 40	27.0	27.4	1052	914	16 – 44	27.0	27.0
Catfish, Estuary	-	-	- -	-	-	1	-	- -	-	-	1	-	- -	-	-
Crab, Mud	1	1	9	9.0	9.0	-	-	- -	-	-	1	1	9	9.0	9.0
Eel - unidentified	-	-	- -	-	-	1	-	- -	-	-	1	-	- -	-	-
Flathead, Dusky	672	604	27 – 82	40.0	42.9	131	119	25 – 98	40.0	43.5	803	723	25 – 98	40.0	43.0
Flathead, Northern sand	-	-	- -	-	-	1	1	47	47.0	47.0	1	1	47	47.0	47.0
Flounder, Large-toothed	4	4	25 – 28	25.5	26.0	2	2	25 – 31	28.0	28.0	6	6	25 – 31	25.5	26.7
Garfish, River	-	-	- -	-	-	2	2	23 – 25	24.0	24.0	2	2	23 – 25	24.0	24.0
Herring, Southern	7	1	28	28.0	28.0	84	3	8 – 10	8.0	8.7	91	4	8 – 28	9.0	13.5
Luderick	1243	924	20 – 46	30.0	29.7	981	792	21 – 40	29.0	29.0	2224	1716	20 – 46	29.0	29.4
Mangrove Jack	1	1	46	46.0	46.0	-	-	- -	-	-	1	1	46	46.0	46.0
Morwong, Red	1	1	35	35.0	35.0	-	-	- -	-	-	1	1	35	35.0	35.0
Mullet, Flat-tail	-	-	- -	-	-	3	-	- -	-	-	3	-	- -	-	-
Mullet, Sand	25	-	- -	-	-	93	24	10 – 40	16.0	17.5	118	24	10 – 40	16.0	17.5
Mullet, Sea	-	-	- -	-	-	2	-	- -	-	-	2	-	- -	-	-
Mulloway	7	7	33 – 82	49.0	51.6	1	1	- 55	55.0	55.0	8	8	33 – 82	51.5	52.0
Octopus	1	-	- -	-	-	3	-	- -	-	-	4	-	- -	-	-
Perch, Estuary	3	2	31 – 32	31.5	31.5	-	-	- -	-	-	3	2	31 – 32	31.5	31.5
Ray, Shovelnose	1	-	- -	-	-	-	-	- -	-	-	1	-	- -	-	-
Snapper	7	-	- -	-	-	-	-	- -	-	-	7	-	- -	-	-
Stingrays & stingarees	-	-	- -	-	-	1	-	- -	-	-	1	-	- -	-	-
Tailor	133	113	22 – 42	30.0	30.2	54	39	10 – 40	26.0	25.4	187	152	10 – 42	30.0	29.0
Tarwhine	1	1	25	25.0	25.0	-	-	- -	-	-	1	1	25	25.0	25.0
Trevally, Silver	-	-	- -	-	-	1	1	40	40.0	40.0	1	1	40	40.0	40.0
Whiting, Sand	60	51	23 – 37	28.0	28.5	82	73	20 – 39	27.0	27.6	142	124	20 – 39	27.0	28.0
Wirrah	1	1	27	27.0	27.0	-	-	- -	-	-	1	1	27	27.0	27.0

SECTION 4

Steffe, A.S. and Macbeth, W.G. (2002). A survey of daytime recreational fishing following a large fish-kill event in the lower reaches of the Macleay River, New South Wales, Australia. Pages 201 – 294 in: Kennelly, S.J. and McVea, T.A. (Eds) (2002). '*Scientific reports on the recovery of the Richmond and Macleay Rivers following fish kills in February and March 2001*'. NSW Fisheries Final Report Series. No. 39. ISSN 1440-3544.

A Survey of Daytime Recreational Fishing Following a Large Fish-kill Event in the Lower Reaches of the Macleay River, New South Wales, Australia

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April 2002

ACKNOWLEDGEMENTS

We would like to thank the following persons:

- Doug Chapman for his invaluable work in creating the database and designing the machine-readable data collection sheets used during the survey.

- John Matthews for providing assistance with maps.

- Tracey McVea for formatting the final report.

- Kerry Grezl, Victor Grezl and Allan Lyons for their help in co-ordinating the work of field staff and for providing technical support during the project.

- Heath Baker, Glen Barriskill, Reece Barriskill, Graham Beach, Glen Beers, Philip Bennett, Carol Bourne, Ian Cross, Kerry Grezl, Victor Grezl, Allan Lyons, Ken Lyons, Amanda Martin, Jenny McCaskie, Jeff Murphy, Dale Rigney, Colin Rowsell, Ethel Rowsell, Wayne Williams and Mathew Yalouris. The excellent work of this group of people during the data collection phase of the survey ensured a high level of data integrity.

- Steve Kennelly and Geoff Liggins for reviewing the draft manuscript and providing comments which improved the final report.

- Finally, we would like to thank all of the fishers that participated in the survey. The successful completion of this work was made possible by their continual co-operation and support.

EXECUTIVE SUMMARY

Major flooding in the upper reaches of the Macleay River occurred during the second week of March 2001. The flood water inundated large areas of the floodplain which led to the decay of large amounts of vegetation and the mobilisation of highly reactive acid sulphate soils and sediments in the area. These two processes contributed directly to the marked reduction in dissolved oxygen levels in the river which in turn are believed to have been the cause of a small fish-kill in the upper reaches of the Macleay system during the time of flooding and a much larger fish-kill in the lower reaches of the Macleay River which occurred during the period 15 to 19 March 2001. The main species that were killed were yellowfin bream, Australian bass, sea mullet, sand whiting, eels, dusky flathead, luderick, silver biddy, estuary cod, gudgeons, gobies, toadfish, mosquitofish, school prawns and mud crabs.

The NSW government responded to the fish-kill by: (a) closing the tidal waters of the Macleay River (approximately 54 km upstream of the entrance) and adjacent inshore ocean waters to all forms of fishing; (b) initiating biological monitoring of commercial fish and crustaceans; and (c) forming a Recovery Working Group to provide advice to the Minister on actions to be taken to enhance the recovery of fish stocks in the river, particularly with respect to river closures. In June 2001, the government decided to re-open part of the lower Macleay River, downstream of the township of Kinchela and including the Stuarts Point arm and the Clybucca Creek area, to limited recreational and commercial fishing. This decision was taken after extensive consultation with the public and after detailed analysis of available biological and water quality information. Thus, when this recreational fishery re-opened on the 1st July, 2001 there was a need to collect quantitative information to describe the recreational fishery of the lower Macleay River. These data were essential for assessing the status of the recreational fisheries resources, the quality of the recreational fishery and to provide additional information regarding the rate of recovery of the populations of fish in the river since the fish-kill. The partial river closures were removed at the end of September 2001 to allow for the resumption of recreational and commercial fishing throughout the Macleay River.

Recreational fishing surveys of sound statistical design are essential for the collection of statistically unbiased information. We used stratified random sampling procedures as the basis of the survey design and integrated many data quality checks into the survey. Complemented survey methods were used to estimate the fishing effort; harvest and discard rates; and total harvest and discard for both the boat-based and shore-based fisheries in the Macleay River over a four-month survey period (July to October 2001 inclusive). The successful planning, organisation and execution of a large on-site survey of recreational fishing is a demanding and costly task. A community-based approach to the survey work, relying heavily on the support and involvement of local interest groups during all phases of the survey, proved highly successful.

We found that the recreational fishing population of the lower Macleay River was dominated by males - 82% of the boat-based fishers and 79% of the shore-based fishers interviewed were male. We also found that approximately 48% of the fishers interviewed were of local origin, ranging from approximately 43% from the local area in the boat-based fishery to approximately 51% in the shore-based fishery.

We estimated that approximately 78,800 fisher hours of daytime recreational effort was expended in the lower Macleay River during the survey period - July to October 2001 inclusive. The level of daytime recreational fishing effort showed a distinct monthly pattern with the highest levels of effort recorded during July and August, and the lowest levels of effort recorded during September and October. This monthly pattern of effort was similar to that recorded in the Richmond River, suggesting that these effort data are showing a seasonal trend.

We estimated that the daytime recreational harvest from the Macleay River fishery during the survey period consisted of approximately 45,300 fish and crabs (± 4,205 individuals - approximate SE) from 16 taxa. The bulk of this harvest was made up of luderick (≈29,110 fish - ≈ 16.5 tonnes), yellowfin bream (≈9,250 - ≈ 4.7 tonnes), dusky flathead (≈3,760 - ≈ 1.9 tonnes), striped seapike (≈1,220 - ≈ 0.1 tonnes), tailor (≈670 - ≈ 0.3 tonnes), and sand mullet (≈600 - < 0.1 tonnes). These six taxa, by number, accounted for 98.5% of the daytime recreational harvest during the survey period. A limited comparison made between these data and a summary of information collected during a five month recreational fishing survey in 1990 in the lower Macleay River indicated that there have not been any major changes in the structure of the recreational fishery since that time. Recreational anglers are still targeting and harvesting much the same species in the river. Further comparisons made between this study, a concurrent survey in the lower Richmond River and data collected during 1988-1989 from the Richmond River suggest strongly that the monthly patterns of targeting and harvesting that we have documented are consistent with normal seasonal changes in this fishery.

The size of the recreational harvest taken during the four month survey period can be put in context by considering the relative sizes of the estimated recreational harvest with respect to the relative magnitude of the fish mortality caused by the fish-kill event of March 2001.

Westlake and Copeland (2002) have estimated the number of dead fish in a 1.5 km stretch of the lower Macleay River, near the town of South West Rocks, at approximately 180,000 individual fish of various species. In comparison, the number of fish and crabs harvested by recreational fishers during the survey period were estimated as approximately 45,300 individuals which is approximately one quarter of the size of the estimated mortality for a 1.5 km stretch of the lower Macleay River during the mid-March fish-kill event.

We estimated that daytime recreational fishers (boat-based and shore-based) discarded approximately 34,310 fish and crabs (± 2,060 individuals - approximate SE) from 26 taxa whilst fishing in the lower Macleay River during the survey period. The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈22,260 - 64.8%), luderick (≈5,200 - 15.2%), dusky flathead (≈3,590 - 10.5%), sand whiting (≈1,250 – 3.6%), tailor (≈1,040 – 3.0%), and silver batfish (≈470 - 1.4%) - (Table 23). These six taxa, by number, accounted for 98.5% of the total daytime recreational discard. Recreational fishers indicated that the great majority of discarded yellowfin bream (94.7%), sand whiting (97.6%), luderick (82.9%), dusky flathead (76.7%) and tailor (75.0%) were below the legal minimum length. Although these discard data should be viewed with some caution because they are self-reported and less accurate than harvest data (which are collected by direct observation), they show that recreational fishers were catching and returning to the water large numbers of juvenile fish.

The four indicators of recreational fishing quality considered in this study were the proportion of unsuccessful fishing parties, non-directed harvest rates for the boat-based and shore-based fisheries, non-directed discard rates for the boat-based and shore-based fisheries and size-frequency distributions for some important taxa harvested by the recreational sector. The proportion of unsuccessful boat-based fishing parties ranged from approximately 22% to 51% on a monthly basis whilst the proportion of unsuccessful shore-based fishing parties was relatively higher ranging from approximately 54% to 74% on a monthly basis. In both fisheries the lowest proportion of unsuccessful fishing trips was recorded during July, immediately after the river was re-opened to recreational fishing, and higher proportions of unsuccessful fishing parties were recorded in the following months. These data suggest that the quality of recreational fishing was best in July after the river had been re-opened to recreational fishing and that there had been a gradual decline in fishing quality in the following months. The reason for these trends in the boat and shore fisheries was probably a combination of seasonal fish abundances and the large amount of fishing effort that occurred immediately after the fishery was re-opened.

The harvest rates and discard rates we calculated and presented are based on the total non-directed fishing effort. The harvest rates of the main angling species measured during this four month survey were similar, and in some cases higher, than comparable harvest rate data collected in other estuarine fisheries in NSW. These findings suggest that the quality of recreational fishing was quite good for boat-based and shore-based fishers during the survey period in the lower Macleay River. A similar conclusion is reached when examining discard rate data. High rates of discard were reported for the main species of recreational interest during the survey period indicating that juvenile fish were abundant in the lower Macleay River during the survey period.

The size-frequency distributions presented are important baseline indicators which can be used to monitor future changes (if any) in the size structure of these species in the fishery. Overall, the proportions of undersized fish retained by recreational fishers in the lower Macleay River fishery (boat and shore-based) were comparable to rates measured in some other estuarine fisheries in NSW, suggesting a comparable availability of legal-sized fish in the population in the Macleay River. In addition, large individuals that were highly-prized by fishers were common in the recreational harvests, indicating that the quality of recreational fishing opportunities in this fishery were quite good.

In summary, the question of whether the recreational fishery (shore and boat-based) in the Macleay River has recovered from the impact of the March fish-kill event cannot be answered directly because we do not have any detailed information describing the status of riverine fish stocks or the recreational boat and shore fisheries in the Macleay River immediately before the fish-kill event nor do we have information about other non-impacted estuarine recreational fisheries in the region that could be used as controls or reference sites. Therefore, we are restricted to making inferences about the recovery of estuarine fish stocks and the status of the recreational fisheries from limited comparisons with previous studies and by examining a number of indicators of recreational fishing quality that have been derived from the current survey. The interpretation of the available evidence strongly suggests that the recreational fisheries in the lower Macleay River are still productive and providing quality recreational fishing opportunities despite the adverse impacts of the March 2001 fish-kill event.

1. INTRODUCTION

Major flooding in the upper reaches of the Macleay River occurred during the second week of March 2001. The flood water inundated large areas of the floodplain which led to the decay of large amounts of vegetation and the mobilisation of highly reactive acid sulphate soils and sediments in the area. These two processes contributed directly to the marked reduction in dissolved oxygen levels in the river (Westlake and Copeland 2002) which in turn are believed to have been the cause of a small fish-kill in the upper reaches of the Macleay system during the time of flooding and a much larger fish-kill in the lower reaches of the Macleay River which occurred during the period 15 to 19 March 2001 (Macbeth *et al.* 2002, Westlake and Copeland 2002). The main species that were killed were yellowfin bream, Australian bass, sea mullet, sand whiting, eels, dusky flathead, luderick, silver biddy, estuary cod, gudgeons, gobies, toadfish, mosquitofish, school prawns and mud crabs (Macbeth *et al.* 2002, Westlake and Copeland 2002).

The NSW government responded to the fish-kill by: (a) closing the tidal waters of the Macleay River (approximately 54 km upstream of the entrance) and adjacent inshore ocean waters to all forms of fishing; (b) initiating biological monitoring of commercial fish and crustaceans; and (c) forming a Recovery Working Group to provide advice to the Minister on actions to be taken to enhance the recovery of fish stocks in the river, particularly with respect to river closures. In June 2001, the government decided to re-open part of the lower Macleay River, downstream of the township of Kinchela and including the Stuarts Point arm and the Clybucca Creek area, to limited recreational and commercial fishing. This decision was taken after extensive consultation with the public and after detailed analysis of available biological and water quality information. Thus, when this recreational fishery re-opened on the 1st July, 2001 there was a need to collect quantitative information to describe the recreational fishery of the lower Macleay River. These data were essential for assessing the status of the recreational fisheries resources, the quality of the recreational fishery and to provide additional information regarding the rate of recovery of the populations of fish in the river since the fish-kill. The partial river closures were removed at the end of September 2001 to allow for the resumption of recreational and commercial fishing throughout the Macleay River.

1.1. Limitations of recreational fishing surveys for detecting environmental impacts

The assessment of environmental disturbance or impacts is difficult because it is often uncertain whether a causal relationship exists between the detrimental environmental event that has occurred (e.g. a flood followed by a fish-kill) and any changes that are measured at a later time. The changes in the recreational fishery detected after the fish-kill event include a component attributable to the detrimental flood event and a component due to natural fluctuations of fish populations that occur at various spatial and temporal scales. An appropriate experimental design is needed to discriminate between changes in the recreational fishery due to the fish-kill event and changes caused by natural fluctuations in fish abundance and catchability. Ideally, an experiment designed to test for the impacts of the fish-kill event would have included spatial replication at the level of rivers (i.e. other riverine fisheries would be used as controls or reference sites) and these multiple riverine fisheries would have been surveyed before and after the fish-kill event. This type of experimental design is referred to as a Before-After-Control-Impact (BACI) design in the scientific literature. Underwood (1991) provides a detailed description of this type of experimental design.

The recreational fishing survey we have done does not meet the rigorous requirements of a BACI experimental design. We do not have any data describing the recreational fishery immediately before the unexpected fish-kill event nor do we have data describing the status of other riverine recreational fisheries in the region that could be used as control sites. Thus, the current survey data can only be used to describe the status of the recreational fishery in the lower Macleay River after the fish-kill event. We are restricted to making inferences about the recovery of the fish stocks in the lower Macleay River from limited comparisons with some previous recreational fishing studies and by examining a number of indicators of recreational fishing quality derived from the present study.

1.2. Site description

The Macleay River ($30^0$52'S $153^0$01'E) is a large river on the mid-north coast of New South Wales (NSW) on the east coast of Australia (Fig. 1). The Macleay River has a water area of approximately 18.2 km^2 and a total catchment area of approximately 11385 km^2 (Roy *et al*. 2001). The Macleay River is open permanently to the ocean with twin training breakwaters at its entrance. Roy *et al*. (2001) have classified the Macleay River as wave-dominated, barrier estuary. This type of estuary is characterised by having a tidal inlet that is constricted by wave deposited beach sand and a flood-tidal delta that is usually smaller than those found in tide-dominated estuaries (Roy *et al*. 2001). Wave dominated estuaries are more strongly influenced by river discharge than by tide with tidal ranges being approximately 5-10% less than in the ocean (Roy *et al*. 2001). The main river arm is approximately 150 km in length and the tidal limit is approximately 54 km from the ocean (DLWC website). The river contains approximately 5.2 km^2 of mangroves, approximately 1.1 km^2 of seagrass and approximately 3.7 km^2 of saltmarsh vegetation (Roy *et al*. 2001). The survey area in the lower Macleay River consisted of a relatively large and convoluted part of the river system, the water distance from the entrance to Kinchela being approximately 23 km, the water distance from Kemps Corner and including a single circuit of the Clybucca Creek/Andersons Inlet loop being approximately 20 km and the Stuarts Point arm being approximately 8.5 km in length (Figure 1).

1.2.1. Access for recreational fishers

The lower Macleay River, waters downstream of the township of Kinchela to the river mouth including the Stuarts Point arm and the Clybucca Creek area, was re-opened to limited recreational fishing on July 1, 2001. Additional new management measures were implemented during the following three month period which provided temporary restrictions to the recreational access to the fishery. Recreational fishing was allowed only between 06:00 to 21:00 hours. Each recreational fisher was permitted to have a daily bag limit of ten fish of any mix of species but with no more than five bream and one mulloway and not more of any species of finfish than allowed by an existing bag limit. Mullet taken for live bait were excluded from this personal bag limit with an additional 20 mullet less than 15 cm total length allowed. Recreational crab trapping was allowed in the re-opened area of the river. Existing legal size limits for all species remained the same.

The recreational fishery in the lower Macleay River can be readily accessed by fishers from boats and from the shore (Fig. 1). Boat-based fishers have access to the recreational fishery from four public boat ramps within the survey area (Fig.1) and from many other ramps located further upstream and outside the survey area. Private access to the fishery is quite restricted. There is extensive rural use of properties adjacent to the shoreline upstream of the survey area and large wetlands exist throughout the system which preclude access for recreational fishers. There are very few moorings in the river. Shoreline access to the recreational fishery is diffuse within the survey area, even though there are large areas of shoreline which are not very accessible because of the dense vegetation (e.g. mangroves in the Clybucca Creek area and along most of the Stuarts Point arm). Easy access to the fishery is available along the southern shoreline of the main river and along the length of the breakwater. The shoreline area beneath the Jerseyville bridge was also a popular fishing spot.

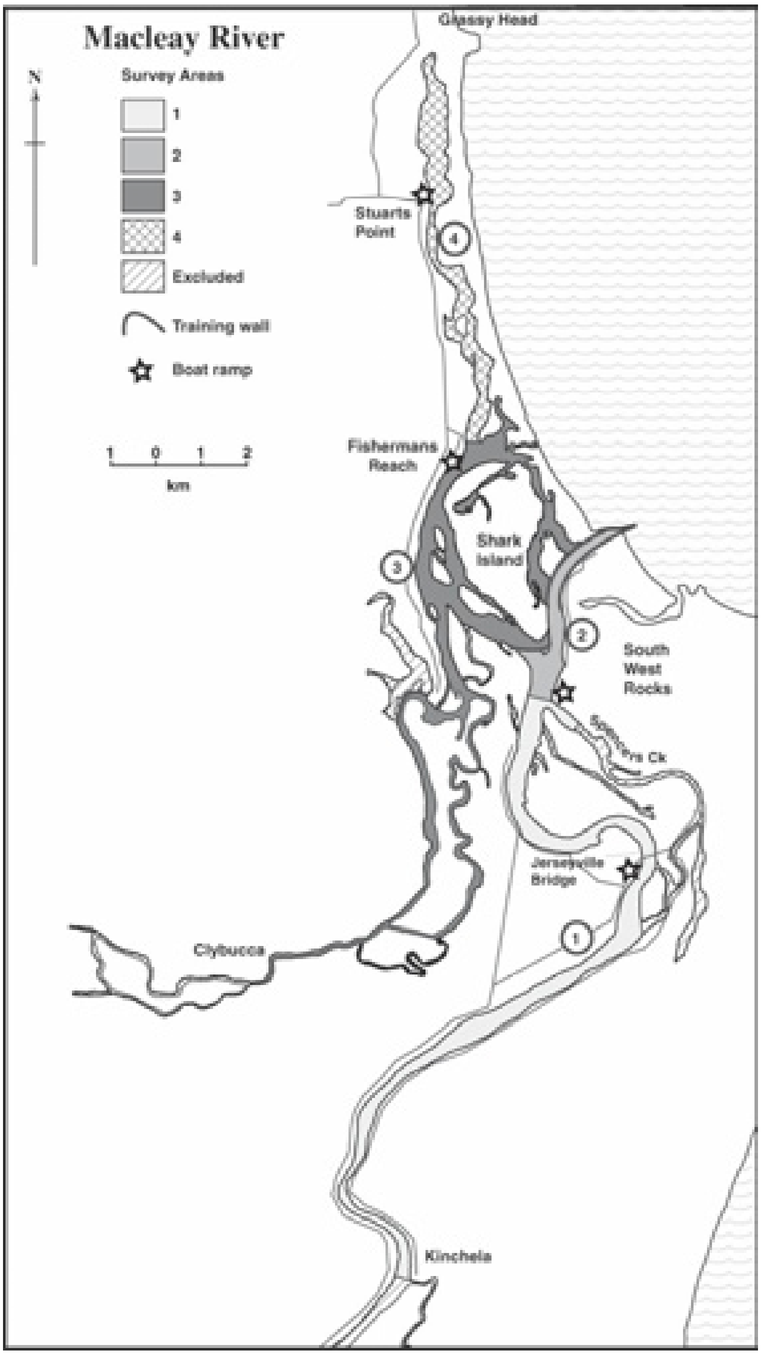

Figure 1. Map of the lower Macleay River showing the spatial extent of the survey and the boundaries used to divide the fishery into four areas: (1) the Main River area; (2) the Entrance area; (3) the Kemps Corner/Clybucca area; and (4) the Stuarts Point area. The location of public boat ramps and training walls (break-waters) have been marked.

1.2.2. Access for commercial fishers

The lower Macleay River was also re-opened to limited commercial fishing on July 1, 2001. Stringent management measures were implemented during the following three month period to hasten the recovery of fish stocks in the river. Commercial hauling operations on the ocean beaches to the north and south of the river mouth were restricted to travelling schools of fish such as sea mullet so as not to directly affect the recovery of the river. Commercial mesh netting (minimum mesh size 95mm) by the method of "splashing" which requires that the shooting of the net, splashing of water in the vicinity of the net and the retrieval of the net be done in a continuous operation, was permitted in the re-opened part of the river at night between 18:00 and 06:00 hours. A further condition associated with this commercial mesh netting was that no flathead were to be retained. Commercial crab and eel trapping was allowed within the re-opened area of the river. Existing legal size limits for all species remained the same.

1.3. Aims

The principal aims of this project were:

1. To estimate the level of daytime recreational fishing effort in the lower reaches of the Macleay River during the four month period, July to October 2001 inclusive.
2. To estimate daytime recreational harvest rates and discard rates in the lower reaches of the Macleay River.
3. To estimate the amount of daytime harvest and discarding by recreational fishers in the lower reaches of the Macleay River.
4. To describe the status of the shore-based and boat-based recreational fisheries in the lower reaches of the Macleay River following a major fish-kill event in mid March 2001.

2. METHODS

2.1. General

We seek to communicate the findings of this work to a very diverse audience which includes recreational and commercial fishers, scientists, managers and interested members of the general public. The published texts describing the many different types of survey designs and methods, their relative strengths and limitations, and their statistical treatment, all contain a considerable quantity of technical terms. Unfortunately, it is not possible to eliminate the use of this technical language without compromising the scientific meaning of the report. We provide a glossary of the technical terms used in this report (see Appendix 1) to assist any layperson in his/her attempt to read and understand the findings of this work. Wherever possible, we also try to define terms in the text when they are used for the first time. The term "catch" is used to refer to the number or weight of fish caught (kept and discarded), whilst the term "harvest" refers to that part of the catch that is retained, usually measured as the number or weight of fish kept. The term "discard" is used to refer to that part of the catch that is not kept, usually measured as the number of fish discarded. The reasons for discarding fish, crabs and cephalopods vary among fishers and include: (a) the small size of the animal (many species that are targeted by recreational fishers have minimum legal lengths specified in legislation, whereas, for all other species the discard size is determined by the judgement of individual fishers); (b) the animal is regarded by fishers to be of low edible quality or has poisonous flesh; (c) the bag limit has been achieved but the fisher wants to continue fishing; (d) the fishing ethic adopted by individual fishers (many fishers are involved in "catch and release" fishing).

Accurate and precise information which describes and quantifies the fishing effort, harvests, and harvest rates of recreational fishers is needed to understand changes in recreational fisheries throughout time. Recreational fishing surveys that have multiple objectives usually involve complex survey designs and these types of surveys can be very costly (Pollock *et al*. 1994). The choice of survey design is constrained by practical considerations which are often site-specific, and by the limited finances available to the project. Thus, when decisions on sample sizes are made at the start of a survey, they are always influenced by the trade-off between desired levels of precision and the limited resources allocated to the survey. A statistically sound survey design based on the principles of stratified random sampling is essential to enable the cost-efficient collection of reliable survey data.

2.2. Survey design

We follow the terminology of Pollock *et al*. (1994) to describe the survey designs and estimation methods used to calculate harvest and discard rates, estimates of total fishing effort, total harvest and discard. We used on-site survey methods (surveys conducted at the fishing sites) because most of the information collected on-site can be verified by field staff. In contrast, off-site methods (surveys conducted away from fishing sites), such as telephone or diary surveys, depend largely on self-reported information which cannot be verified (Pollock *et al*. 1994). Another major advantage of on-site surveys is that the non-response or refusal rates recorded are usually much lower than the non-response rates recorded during off-site surveys (Pollock *et al*. 1994).

A complemented survey combines two or more contact methods for collecting effort and catch information from fishers (Pollock *et al*. 1994). Complemented survey methods were used to assess separately the shore-based recreational fishery and the boat-based recreational fishery. The shore-based fishery was assessed by using a roving(effort)-roving(harvest and discard) design combination. The boat-based fishery was assessed by using a roving(effort)-access(harvest and discard) design combination.

The sampling frame is a complete list of possible sampling units in the whole population and a clear and unambiguous definition of the sampling frame is needed to determine the scope of a survey (Cochran 1953, Yates 1965, Pollock *et al*. 1994). The sample frame can be divided into non-overlapping strata and a random sampling protocol is usually applied to select a sample from each stratum (Cochran 1953, Yates 1965, Pollock *et al*. 1994). This survey work is based on the principles of stratified random sampling. Pollock *et al*. (1994) summarised the advantages of stratification as:

(a) improving the overall precision of population estimates. An increase in precision (i.e. a reduction in variance) will occur when a relatively heterogeneous population is divided into non-overlapping strata of known size, that are relatively more homogeneous than the whole population;

(b) making the administration of the survey work easier because strata can be used to partition large frames that are difficult to sample into multiple, smaller units that can each be sampled more easily; and

(c) providing greater information yield. The creation of strata allows us to calculate population estimates for each separate stratum, thereby providing important information at a smaller scale, as well as providing overall estimates of population parameters for the entire population by combining the separate stratum totals and their associated variances.

2.3. Spatial sampling frame and stratification

The spatial sampling frame (geographical boundary) of this survey is illustrated in Figure 1. All excluded areas shown in Figure 1 are regarded as being outside the spatial sampling frame. The lower Macleay River survey area (Fig. 1) was stratified into four distinct areas: (a) the Entrance area; (b) the Main River area; (c) the Kemps Corner/Clybucca area; and (d) the Stuarts Point area.

2.3.1. Entrance area

The eastern extremity of the Entrance area (Fig. 1) was defined as being a line drawn between the seaward-most extremities of the North and South breakwaters at the river mouth. The boundary between the Entrance area and the Main River area (Fig. 1) was defined as a line originating from the downstream edge of the mouth of Spencers Creek and extending across the river to the western bank (Fig. 1). The boundary between the Entrance area and the Kemps Corner/Clybucca area was defined as a line extending from the tip of the breakwater at Kemps Corner to the southern edge of Shark Island (Fig. 1). The popular fishing spots located along the southern breakwater were included in this area.

2.3.2. Main river area

The seaward boundary of this area was defined as a line originating from the downstream edge of the mouth of Spencers Creek and extending across the river to the western bank (Fig. 1). The upstream boundary of this area was defined as a line originating from the downstream edge of the mouth of Kinchela Creek and extending across the river to the western bank (Fig. 1). The waters of Kinchela Creek, the non-navigable parts of Spencers Creek and the small waterway behind the town of Jerseyville were excluded from this area.

2.3.3. Kemps Corner/Clybucca area

The boundary between the Kemps Corner/Clybucca area and the Entrance area was defined as a line extending from the tip of the breakwater at Kemps Corner to the southern edge of Shark Island (Fig. 1). The shallow sandbar near Fishermans Reach formed a natural barrier to boat traffic near the bottom of the tide. The southern edge of this sandbar was used as the boundary between the Kemps Corner/Clybucca area and the Stuarts Point area (Figure 1). All navigable waters around Shark Island and the Clybucca Creek/Andersons Inlet loop were included in this area. All waters behind the floodgates and behind the causeway at the end of Clybucca Creek were excluded from this area (Figure 1).

2.3.4. Stuarts Point area

The southern edge of the sandbar near Fishermans Reach was used as the boundary between the Kemps Corner/Clybucca area and the Stuarts Point area (Figure 1). The Stuarts Point area was characterised by extensive stands of mangroves, the small township of Stuarts Point and the caravan park located adjacent to the shoreline at Stuarts Point.

2.4. Temporal sampling frame and stratification

The temporal sampling frame of the survey spanned a four month period, commencing in July and concluding at the end of October 2001. We stratified the four month survey period into months (July, August, September and October), and day-types within each month (Weekdays and Weekend days). Public holidays were classified as weekend days. Days were regarded as the primary sampling unit for all strata. By definition, a survey day started at sunrise and ended at sunset, however the fishery closure in place during July, August and September restricted the legally permitted fishing day to the period between 06:00 to 21:00 hours. When sunrise occurred before the start of the legally permitted fishing day we defined the length of the fishing day as being from 06:00 to sunset.

Basic sampling theory dictates that the accuracy and precision of overall population estimates can be improved by allocating more sampling units to a stratum that contains a large part of the recreational fishing effort and/or harvest (see Cochran 1953, Pollock *et al*. 1994). It has long been known that surveys will usually be most efficient (have least variance) when the distribution of sampling effort coincides with the distribution of fishing effort (Best and Boles 1956, Pollock *et al*. 1994). If effort and harvest are strongly correlated then it follows that by weighting sampling effort in proportion to the fishing effort there will also be an improvement in the precision of harvest estimates. We already knew from previous angler surveys that a disproportionate amount of the recreational fishing effort and harvest occurs on weekend days (Steffe *et al*. 1996a & 1996b, Steffe and Chapman 2002, Steffe unpublished data) thus it was logical to allocate proportionally more sampling units to the weekend day-type stratum than to the weekday day-type stratum.

2.5. Collecting data for the boat-based and shore-based recreational fisheries

Two independent datasets were collected and used to estimate recreational fishing effort, harvest rates and discard rates. These datasets consisted of: (1) progressive counts of recreational fishing effort; and (2) interviews with recreational fishing parties. These two datasets were used to obtain estimates of boat-based and shore-based recreational harvest and discard.

2.5.1. Progressive counts of recreational fishing effort

Estimates of recreational fishing effort for the boat-based fishery and the shore-based fishery were made with progressive counts on randomly selected survey days. Progressive counts were made separately of all boats and all shore-based persons that were observed to be involved in some type of recreational fishing activity. These recreational fishing activities included all forms of angling and the setting, checking and retrieval of crab nets, but excluded activities such as spearfishing, bait collecting and prawning. We specifically excluded boats traveling across the river and anglers moving along the shore from the counts (even when recreational fishing gear was visible) when it was not possible to determine their destination nor their intent to engage in any recreational fishing activity. In contrast, we included boats in the counts when they were engaged in drift fishing and they were observed traveling to start another “drift” upstream. Drift fishing was common in the river.

We divided the survey area into two circuits for making progressive counts by boat: (a) the Entrance area, the Main River area and the Kemps Corner/Clybucca area; and (b) the Stuarts Point area (see Figure 1). This division of the fishery into two separate circuits was necessary because a large shallow expanse near Fishermans Reach was navigable only near the top of the tide. The time needed to complete progressive counts in each of the two circuits was determined during a series of runs. Two replicate progressive counts were scheduled on each of the randomly selected survey days. The starting times for the replicate progressive counts were scheduled by picking one of a set of discrete possible starting times as recommended by Hoenig *et al*. (1993). The starting location and direction of travel were randomly selected for each scheduled progressive count. This progressive count method will, under very general conditions, provide unbiased estimates of fishing effort during the day (Hoenig *et al*. 1993). The collection of recreational effort data by means of these progressive counts was done on the same days as the interviews with recreational fishing parties. Importantly, the collection of progressive count and interview data were treated as separate jobs, meaning that scheduled progressive counts were not interrupted to interview fishers and that other survey staff were assigned to conduct interviews throughout the fishery during the entire fishing day which included the periods during which replicate progressive counting of fishing effort was done. This small organisational change in staff deployment effectively eliminated the “shadow bias” (see Wade *et al*. 1991) that occurs when progressive counts are interrupted so that interviews with fishers can be done. The number of replicate days sampled for each day-type stratum within each month is summarised in Table 1. The level of daily replication achieved represents sampling fractions of approximately 64% for the weekend day-type stratum and approximately 28% for the weekday stratum during the period of the survey (Table 1).

Table 1. Sample sizes (number of days spent interviewing and the number of replicate progressive counts of effort), number of interviews, number of refusals and refusal rates for the boat and shore recreational fisheries in the Macleay River during the survey period (July 1 - October 31, 2001).

			No. DAYS SAMPLED		**BOAT FISHERY**			**SHORE FISHERY**		
Month/Year	Day-Type	No. Days in Stratum	Effort Counts	Interviews	Number of Interviews	Number of Refusals	Refusal Rate (%)	Number of Interviews	Number of Refusals	Refusal Rate (%)
July 2001	Weekday	22	6	6	136	0	0	243	2	0.8
	Weekend	9	6	6	183	2	1.1	379	4	1.1
	Total	**31**	**12**	**12**	**319**	**2**	0.6	**622**	**6**	1.0
August 2001	Weekday	23	6	6	99	2	2.0	134	0	0
	Weekend	8	6	6	175	0	0	218	0	0
	Total	**31**	**12**	**12**	**274**	**2**	0.7	**352**	**0**	0
September 2001	Weekday	20	6	6	63	0	0	71	0	0
	Weekend	10	6	6	119	0	0	100	2	2.0
	Total	**30**	**12**	**12**	**182**	**0**	0	**171**	**2**	1.2
October 2001	Weekday	22	6	6	86	1	1.2	100	0	0
	Weekend	9	6	6	83	0	0	76	0	0
	Total	**31**	**12**	**12**	**169**	**1**	0.6	**176**	**0**	0
Total	Weekday	87	24	24	384	3	0.8	548	2	0.4
	Weekend	36	24	24	560	2	0.4	773	6	0.8
	Total	**123**	**48**	**48**	**944**	**5**	0.5	**1,321**	**8**	0.6

2.5.2. Interviews with recreational fishing parties

All interviews were done between 09:00 hours and sunset. We chose to restrict the interview coverage because data from a previous study had showed that less than 4% of recreational fishing trips were completed between sunrise and 09:00 hours making it cost-effective to start interviewing after 09:00 hours (Steffe *et al*. 1996a). It is important to note that most recreational fishing trips that begin in the period between sunrise and 09:00 hours are completed later in the day and would be covered by the sampling regime. Machine-readable interview forms were used to collect information from boat-based and shore-based fishing parties. Fishing parties were approached and asked to participate in the survey by providing information about their fishing trip, harvest and discard. Attempts were made to interview all recreational fishing parties encountered (shore-based and boat-based), however, during periods of high recreational activity it was necessary to systematically subsample every second or third fishing party (depending on the number of fishing parties available for interview). Refusals to provide information, or to show the fish retained, were recorded. We asked co-operative recreational fishers about their targeting preferences during their current fishing trip, the time they started fishing and their fishing locations. We also recorded the number of fishers in the fishing party (non-fishers were not included as part of a fishing party) and the sexes of all fishing party members. Home postcode information for all persons (fishers and non-fishers) in a fishing party was requested and the following five home postcodes (2431, 2440, 2447, 2448, 2449) were used to identify local fishers in the lower Macleay River. The retained catch was identified by field staff and, whenever possible, measurements of all fish (fork length), crabs (carapace length) and squid (mantle length) were taken to the nearest whole centimetre. When fishers were in a hurry to leave the ramp and it was not possible to measure all fish, crabs and squid, the survey personnel were instructed to record counts of the identified harvest and attempt to measure a sub-sample of the harvest. Fishers were also asked to recall the quantity and identity of all fish, crabs and cephalopods that they had caught and discarded during their trip. Whenever the nominated discard was a species that had a minimum legal length the fishers were asked additional questions to assess whether the discards had been larger or smaller than the minimum legal length.

Sampling effort was concentrated at the boat ramps used by recreational fishers within the survey area. This approach was adopted to maximise the number of interviews with boat-based fishing parties during late Winter and early Spring when low recreational effort levels were expected. The use of a bus-route method during this survey (see Robson and Jones 1989 for a description of this method) was considered but proved to be impractical because of the seasonal timing of the survey. We wanted to remove the possibility on low effort survey days of missing interviews with the few available boat-based fishing parties because the survey staff were waiting at another access point or in the process of traveling between boat ramps.

Boat-based fishing parties were approached at boat ramps when they returned from their fishing trip. The harvest rate and discard rate information collected during these access point interviews is based on completed trips (Malvestuto 1983, Hayne 1991, Pollock *et al*. 1994, Pollock *et al*. 1997). The access point survey method works best when there are few, well-defined, access sites (Pollock *et al*. 1994). The survey area contained four boat ramps which were all sampled but there are also many other access points further upstream that could have been used to provide access to the fishery. Similarly, private jetties and moorings could also have been used to access the fishery, however, there are relatively few private access points for boats along the lower Macleay River. Holidaymakers and residents from the Stuarts Point caravan park often store their small fishing boats on the adjacent beach. These recreational fishers were surveyed by the person covering the boat ramp at Stuarts Point. Therefore, we assumed that the fishing activities of recreational fishers using the public boat ramps were representative of recreational fishing parties that used private access points and other boat ramps further upstream to enter and leave the fishery. Although we did not test this important assumption, we have no reason to expect that fishers using private access points and other upstream boat ramps would have behaved differently to those fishers that used the public boat ramps within the survey area because these populations of fishers (regardless of where they access the fishery) use the same methods to target the same species in the same fishing areas within the survey area.

The diffuse access across large stretches of shoreline and breakwater compelled us to use roving survey methods to assess the shore-based fishery. The shore-based fishery within the survey area was searched entirely at least once (usually many times) during each survey day by interviewers, thus providing coverage of the entire shore-based fishery on each survey day. Shore-based fishing parties were approached during their fishing trips by field staff. Therefore, the harvest rate and discard rate information collected during these interviews was based on incomplete trips which documented only part of the total effort, harvest and discard for these fishing trips (Robson 1961 & 1991, Pollock *et al*. 1994). The use of a roving survey design introduced a sampling bias because the probability of interviewing a group is proportional to the duration of their fishing trip. That is, parties that fish for longer time periods are more likely to be encountered by field staff moving through the fishery, termed the "length-of-stay" bias (Robson 1991, Pollock *et al*. 1994, Pollock *et al*. 1997, Hoenig *et al*. 1997), which means that harvest rates and discard rates derived from roving survey methods tend to be based on samples that contain an over-representative number of longer trips and an under-representative number of short trips. Roving survey methods require the following assumptions be made: (a) the harvest rate and discard rate for the portion of fishing trip documented is the same as the harvest rate and discard rate for the entire trip; and (b) the harvest rate and discard rate of interviewed fishing parties is representative of the whole fishing population, which is the expected outcome for estimates derived from randomly selected samples (Malvestuto 1983, Phippen and Bergersen 1991, Pollock *et al*. 1994, Hoenig *et al*. 1997).

2.6. Estimation methods

We follow the general equations used by Pollock *et al*. (1994) for estimating total recreational fishing effort, recreational harvest and discard rates, and total recreational harvest and discard for the boat-based and shore-based fisheries and refer the reader to this book for worked examples. More detailed explanations of the statistical procedures used can be found in Cochran (1953), Robson (1960, 1961 & 1991), Yates (1965), Malvestuto (1983), Hayne (1991), Hoenig *et al*. (1993 & 1997) and Pollock *et al*. (1997).

2.6.1. Basic notation

j denotes the stratum being considered $(j = 1,...,J)$;

J denotes the total number of strata;

i denotes the sample day unit within the stratum $(i = 1,....,N_j)$;

N_j is the total population size (all possible sampling days) in stratum j;

n_j is the sample size in stratum j;

x_{ij} denotes the value of the i th unit of stratum j;

$\bar{x}_j$ is the sample mean for stratum j;

$s_j^2 = \dfrac{\left[\sum_{i=1}^{n_j}\left(x_{ij} - \bar{x}_j\right)^2\right]}{\left(n_j - 1\right)}$ is the sample variance for stratum j

2.6.2. *Effort estimation for the boat-based and shore-based recreational fisheries*

Estimation of total effort was done separately for the boat-based fishery (units of boat hours) and the shore-based fishery (units of fisher hours). The base level of effort estimation was a day-type stratum within a month for each of the four areas in the lower Macleay River (Entrance area, Main River area, Kemps Corner/Clybucca area; and Stuarts Point area – see Figure 1). The effort estimates for each of the four river areas were combined to give separate day-type and monthly totals for the whole lower Macleay River survey area. A description of the equations used for estimating stratum totals, variances and standard errors are provided below.

Step 1 - The progressive counts of recreational fishing boats and shore-based fishers were expanded separately to estimate the daily effort for each fishing day that was sampled.

$$\hat{e}_i = \overline{P}_i \times T \qquad \text{(Equation 1)}$$

where:
$\hat{e}_i$ is the estimate of fishing effort for the i th sample day.
$\overline{P}_i$ is the mean value for replicated progressive counts done on the i th sample day. The mean number of boats per progressive count is used for the boat-based fishery. The mean number of shore fishers per progressive count is used for the shore-based fishery.
T is the length of the fishing day. We used the mean daylength period (units are hours) for each month (sunrise to sunset) whenever this period was contained within the legally permitted fishing day (06:00 to 21:00). When sunrise occurred before the start of the legally permitted fishing day we defined the length of the fishing day as being from 06:00 to sunset.

Step 2 - These daily effort estimates were then expanded for each day-type stratum within each month. This was done by multiplying the number of possible sample days in each base level stratum with the mean of the daily estimates of effort.

$$\overline{e}_j = \frac{\sum \hat{e}_{ij}}{n_j} \qquad \text{(Equation 2)}$$

where:
$\overline{e}_j$ is the estimated mean daily fishing effort for the j th day-type stratum within a month, in units of boats per day for the boat fishery and fishers per day for the shore fishery.
$\hat{e}_{ij}$ is the estimate of fishing effort for the i th sample day in the j th day-type stratum within a month.
n_j is the number of days sampled in the j th day-type stratum within a month.

$$\hat{E}_j = N_j \times \overline{e}_j \qquad \text{(Equation 3)}$$

where:
$\hat{E}_j$ is the estimate of total effort for the j th day-type stratum within a month. In the boat fishery the units are boat hours and for the shore fishery the units are fisher hours.
See Basic notation and Equation 2 for definitions of the other terms.

Step 3 - Calculate the precision of the effort estimates. This is done for each fishery by estimating variances and standard errors for each stratum.

$$Var(\overline{e}_j) = \frac{s_j^2}{n_j} \quad \text{(Equation 4)}$$

where:
$Var(\overline{e}_j)$ is the estimated variance of the mean daily fishing effort for the j th day-type stratum within a month. This is calculated separately for each fishery.
s_j^2 is the sample variance of the daily estimates of fishing effort for the j th day-type stratum within a month.
n_j is the sample size as described in Equation 2.

$$SE(\overline{e}_j) = \sqrt{Var(\overline{e}_j)} \quad \text{(Equation 5)}$$

where:
$SE(\overline{e}_j)$ is the estimated standard error of the mean daily fishing effort.
$Var(\overline{e}_j)$ is the estimated variance of the mean daily fishing effort as described in Equation 4.

$$Var(\hat{E}_j) = N_j^2 \times Var(\overline{e}_j) \quad \text{(Equation 6)}$$

where:
$Var(\hat{E}_j)$ is the estimated variance of total effort for a stratum, and is calculated separately for each day-type within each month for each fishery.
See Basic notation and Equation 4 for definitions of the other terms.

$$SE(\hat{E}_j) = \sqrt{Var(\hat{E}_j)} \quad \text{(Equation 7)}$$

where:
$SE(\hat{E}_j)$ is the estimated standard error of total effort for a stratum.
$Var(\hat{E}_j)$ is the estimated variance of total effort for a stratum as described in Equation 6.

Step 4 - Calculate total fishing effort separately for the boat-based and shore-based fisheries. This was done by adding the effort estimates of the day-type strata together to obtain monthly totals.

$$\hat{E}_{Tot} = \sum_{j=1}^{J} \hat{E}_j \quad \text{(Equation 8)}$$

where:
$\hat{E}_{Tot}$ is the total monthly effort calculated by combining the effort estimates for each day-type stratum. The general form of the same equation was used when adding effort estimates for the four survey areas.
$\hat{E}_j$ is the estimate of total effort for the j th day-type stratum as defined in Equation 3.

Step 5 - Calculate the precision of effort estimates obtained by adding stratum totals. This is done by simply adding the estimated variances for each stratum and calculating a standard error for the estimates of monthly effort totals.

$$Var\left(\hat{E}_{Tot}\right) = \sum_{j=1}^{J} Var\left(\hat{E}_j\right) \text{ (Equation 9)}$$

where:
$Var\left(\hat{E}_{Tot}\right)$ is the estimated total monthly variance calculated by combining the estimated effort variances for each day-type stratum. The general form of the same equation was used when adding variance estimates for the four survey areas.

$$SE\left(\hat{E}_{Tot}\right) = \sqrt{Var\left(\hat{E}_{Tot}\right)} \text{ (Equation 10)}$$

where:
$SE\left(\hat{E}_{Tot}\right)$ is the estimated standard error for monthly effort totals when adding day-type strata. The general form of the same equation was used when adding effort estimates for the four survey areas and calculating the standard error for the combined effort estimate.
$Var\left(\hat{E}_{Tot}\right)$ is the estimated total variance as described in Equation 9.

Step 6 - Calculate total fishing effort (boat-based plus shore-based) for the entire survey area. The initial step in these calculations was to convert the effort estimates for the boat-based fishery into units of fisher hours. As before, the base level of effort estimation was for a day-type stratum within a month for each of the four survey areas (Entrance area, Main River area, Kemps Corner/Clybucca area; and Stuarts Point area).

Please note: to simplify the notation in the following equations we have stopped adding the suffix j (which denotes the j th stratum) to all terms in the general equations even though these terms still refer implicitly to the j th stratum.

$$\hat{E}_{new} = \hat{E}_{old} \times \bar{f} \text{ (Equation 11)}$$

where:
$\hat{E}_{new}$ is the new estimate of effort for the boat-based fishery in units of fisher hours.
$\hat{E}_{old}$ is the old estimate of effort for the boat-based fishery in units of boat hours.
$\bar{f}$ is the mean number of fishers per boat in that stratum.

Step 7 - Calculate the variance and standard error of the new estimate of effort for the boat-based fishery.

$$Var\left(\hat{E}_{new}\right) = \left[\hat{E}_{old}^2 \times Var\left(\bar{f}\right)\right] + \left[\bar{f}^2 \times Var\left(\hat{E}_{old}\right)\right] - \left[Var\left(\bar{f}\right) \times Var\left(\hat{E}_{old}\right)\right] \text{ (Equation 12)}$$

where:
$Var\left(\hat{E}_{new}\right)$ is the estimated variance of the new estimate of effort for the boat-based fishery.
$Var\left(\bar{f}\right)$ has been calculated by using the general form of Equation 4.
$Var\left(\hat{E}_{old}\right)$ has been calculated by using the general form of Equation 6.
The terms $\hat{E}_{old}$ and $\bar{f}$ are described in Equation 11.

$$SE\left(\hat{E}_{new}\right) = \sqrt{Var\left(\hat{E}_{new}\right)}$$ (Equation 13)

where:
$SE\left(\hat{E}_{new}\right)$ is the estimated standard error of the new estimate of effort for the boat-based fishery.
$Var\left(\hat{E}_{new}\right)$ is described in Equation 12.

Step 8 - When estimates of effort totals for the boat-based fishery had been converted into the same units as those in the shore-based fishery, it was possible to combine stratum totals for the boat and shore fisheries to give estimates of monthly effort totals. Monthly effort estimates for the four spatial strata (Entrance area, Main River area, Kemps Corner/Clybucca area; and Stuarts Point area) were then combined to give effort estimates for the whole survey area. This procedure of adding stratum estimates has already been described and calculations were done using the general form of Equation 8.

Step 9 - Calculate monthly estimates of variance and standard errors for the total fishery. This procedure has already been described and calculations are done using the general form of Equations 9 and 10.

2.6.3. Harvest rate and discard rate estimators for the boat-based fishery

When the objective is to estimate total harvest, and the interview data are based on completed trips, the correct harvest rate estimator to use is the “ratio of means” (Jones *et al*. 1995, Pollock *et al*. 1997). This estimator is essentially the ratio of mean harvest to mean effort on a given day. The “ratio of means” was used for estimating the harvest of the boat-based fishery. Pollock *et al*. (1997) have shown that this estimator has a statistical expectation that is equal to total harvest divided by total effort for the population of fishers when it is applied to completed trip interviews taken at access points to the fishery.

$$\hat{R}_{1(H)} = \frac{\sum_{k=1}^{n} H_k}{\sum_{k=1}^{n} L_k}$$ (Equation 14)

where:
$\hat{R}_{1(H)}$ is the “ratio of means” an estimated daily harvest rate based on complete trips. The units used to estimate recreational harvest for the boat-based fishery were the number of fish per boat hour (see Appendices 2.1 to 2.6), and the weight of fish per boat hour (which are not presented). We also converted harvest rates for the boat-based fishery to numbers of fish per fisher hour so that comparisons could be made with the shore-based fishery.
H_k is the complete harvest for the k th fishing unit. These fishing units can be boats, fishing parties, or fishers.
L_k is the complete trip length for the k th fishing unit.
n is the number of fishing units in the daily sample.

The explanation given above for harvest rate estimation is also valid for the estimation of discard rates.

$$\hat{R}_{1(D)} = \frac{\sum_{k=1}^{n} D_k}{\sum_{k=1}^{n} L_k} \quad \text{(Equation 15)}$$

where:

$\hat{R}_{1(D)}$ is the "ratio of means" an estimated daily discard rate based on complete trips. The units used to estimate recreational discard for the boat-based fishery were the number of fish discarded per boat hour (see Appendices 2.1 to 2.6). We also converted discard rates for the boat-based fishery to numbers of fish discarded per fisher hour so that comparisons could be made with the shore-based fishery.

D_k is the complete discard for the k th fishing unit. These fishing units can be boats, fishing parties, or fishers.

L_k is the complete trip length for the k th fishing unit.

n is the number of fishing units in the daily sample.

We calculated mean daily harvest rates $\overline{R}_{1(H)}$ and mean daily discard rates $\overline{R}_{1(D)}$ for each day-type stratum within a month. The estimated variances of the mean daily harvest rates $Var\left(\overline{R}_{1(H)}\right)$ and the estimated variances of the mean daily discard rates $Var\left(\overline{R}_{1(D)}\right)$ were calculated by using the general form of Equation 4, and the estimated standard errors of the mean daily harvest rates $SE\left(\overline{R}_{1(H)}\right)$ and the estimated standard errors of the mean daily discard rates $SE\left(\overline{R}_{1(D)}\right)$ were calculated using the general form of Equation 5.

2.6.4. Harvest rate and discard rate estimators for the shore-based fishery

When the objective is to estimate total harvest, and the interviews are based on incomplete trips, the correct harvest rate estimator to use is the "mean of ratios" (Jones *et al*. 1995, Pollock *et al*. 1997, Hoenig *et al*. 1997). This estimator is essentially the mean of the individual harvest rates for all fishers interviewed on a given day. The "mean of ratios" was used for estimating the harvest of the shore-based fishery. Hoenig *et al* (1997) used simulation procedures to show that the "mean of ratios" estimator has a large variance caused by the inclusion of high harvest rates resulting from very short, incomplete trips that have harvested some fish already. These authors found that the truncation (exclusion) of all short incomplete trips reduced the variance greatly without inducing an appreciable bias. Hoenig *et al*. (1997) recommended the truncation of short trips less than 20-30 minutes but noted that there was a trade-off between the level of truncation used and the number of interviews that were discarded. We examined the relationship between the harvest rate and the duration of the fishing trip for shore-based interviews to determine the most appropriate level of truncation. We found that by discarding all incomplete trips that had been in progress for less than 30 fisher minutes, we were able to remove the interviews with the most extreme harvest rates and hence minimise the variance of the harvest rate estimator. The adoption of this truncation criterion resulted in the loss of 90 shore-based interviews (approximately 6.8% of the usable shore-based interviews) from harvest calculations. We had routinely asked shore-based fishing parties about the intended finishing time for their current trip. We retained and used shore-based interviews with fishing parties that had completed their trips but had fished for less than 30 fisher minutes. We believe it is logical to keep and use the data from these complete short trips, regardless of the small amount of time fished or the amount of harvest taken, because it is these short trips that are under-represented in roving surveys due to "length-of-stay" bias.

Hoenig *et al*. (1997) showed that the mean of ratios estimator has an approximate statistical expectation of total harvest divided by total effort for the population of fishing units when it is applied to incomplete trip interviews with a truncation of short trips, taken by roving through the fishery. Thus, the mean of ratios estimator $\left(\hat{R}_2\right)$ used on incomplete trips with a truncation of short trips, provides an equivalent measure of fishing success to the ratio of means estimator $\left(\hat{R}_1\right)$ used on complete trips (Pollock *et al*. 1997, Hoenig *et al*. 1997).

$$\hat{R}_{2(H)} = \frac{1}{n}\sum_{k=1}^{n}\frac{H_k}{L_k} \quad \text{(Equation 16)}$$

where:

$\hat{R}_{2(H)}$ is the "mean of ratios" an estimated daily harvest rate with truncation of short incomplete trips. The units used to estimate recreational harvest for the shore-based fishery were the number of fish per fisher hour, and the weight of fish per fisher hour.

H_k is the incomplete harvest (the harvest recorded at the time of interview for the incomplete trip) for the k th fishing unit. These fishing units can be boats, fishing parties, or fishers.

L_k is the incomplete trip length (the length of the incomplete trip at the time of interview) for the k th fishing unit.

n is the number of fishing units in the daily sample.

The explanation given above for harvest rate estimation is also valid for the estimation of discard rates.

$$\hat{R}_{2(D)} = \frac{1}{n}\sum_{k=1}^{n}\frac{D_k}{L_k} \quad \text{(Equation 17)}$$

where:

$\hat{R}_{2(D)}$ is the "mean of ratios" an estimated daily discard rate with truncation of short incomplete trips. The units used to estimate recreational discard for the shore-based fishery were the number of fish discarded per fisher hour.

D_k is the incomplete discard (the discard recorded at the time of interview for the incomplete trip) for the k th fishing unit. These fishing units can be boats, fishing parties, or fishers.

L_k is the incomplete trip length (the length of the incomplete trip at the time of interview) for the k th fishing unit.

n is the number of fishing units in the daily sample.

We calculated mean daily harvest rates $\overline{R}_{2(H)}$ and mean daily discard rates $\overline{R}_{2(D)}$ for each day-type stratum within a month. The estimated variances of the mean daily harvest rates $Var\left(\overline{R}_{2(H)}\right)$ and the estimated variances of the mean daily discard rates $Var\left(\overline{R}_{2(D)}\right)$ were calculated by using the general form of Equation 4, and the estimated standard errors of the mean daily harvest rates $SE\left(\overline{R}_{2(H)}\right)$ and the estimated standard errors of the mean daily discard rates $SE\left(\overline{R}_{2(D)}\right)$ were calculated using the general form of Equation 5.

2.6.5. Monthly harvest rate estimation for boat and shore fisheries

The same logic and general equations are applied in the estimation of monthly harvest rates, monthly discard rates and their associated variances and standard errors. The contribution of each day-type stratum to the estimated monthly harvest rate and monthly discard rate was weighted by the relative size of each day-type stratum within the month (Pollock *et al*. 1994). This means that a greater weighting was given to the weekday stratum because there are more weekdays in a month than there are weekend days in a month.

$$\overline{R}_{Month} = \left(\frac{N_{wd}}{N_{Month}} \times \overline{R}_{wd} \right) + \left(\frac{N_{we}}{N_{Month}} \times \overline{R}_{we} \right) \text{ (Equation 18)}$$

where:

$\overline{R}_{Month}$ is a stratified mean daily rate (harvest or discard) for a month. The $\hat{R}_1$ estimators described in Equations 14 and 15 were used for the boat-based fishery, and the $\hat{R}_2$ estimators described in Equations 16 and 17 were used for the shore-based fishery. The units are the number of fish per fisher hour for the boat and shore fisheries.

N_{wd} is the number of weekdays in the month.

N_{we} is the number of weekend days (includes public holidays) in the month.

N_{Month} is the total number of days in the month (weekdays N_{wd} plus weekend days N_{we}).

$\overline{R}_{wd}$ is a mean daily rate (harvest or discard) for the weekday stratum. The $\hat{R}_1$ estimators described in Equations 14 and 15 were used for the boat-based fishery, and the $\hat{R}_2$ estimators described in Equations 16 and 17 were used for the shore-based fishery. The units are the number of fish per fisher hour for the boat and shore fisheries.

$\overline{R}_{we}$ is a mean daily rate (harvest or discard) for the weekend day stratum. The $\hat{R}_1$ estimators described in Equations 14 and 15 were used for the boat-based fishery, and the $\hat{R}_2$ estimators described in Equations 16 and 17 were used for the shore-based fishery. The units are the number of fish per fisher hour for the boat and shore fisheries.

The estimates of variance for the stratified mean daily harvest rates and stratified mean daily discard rates for each month were calculated using the following general equation.

$$Var\left(\overline{R}_{Month}\right) = \left[\left(\frac{N_{wd}}{N_{Month}} \right)^2 \times Var\left(\overline{R}_{wd}\right) \right] + \left[\left(\frac{N_{we}}{N_{Month}} \right)^2 \times Var\left(\overline{R}_{we}\right) \right] \text{ (Equation 19)}$$

where:

$Var\left(\overline{R}_{Month}\right)$ is an estimated variance for the stratified mean daily rate (harvest or discard) for a month.

$Var\left(\overline{R}_{wd}\right)$ is an estimated variance for the mean daily rate (harvest or discard) for the weekday stratum in a month. This variance of a mean can be calculated by using the general form of Equation 4.

$Var\left(\overline{R}_{we}\right)$ is an estimated variance for the mean daily rate (harvest or discard) for the weekend day stratum in a month. This variance of a mean can be calculated by using the general form of Equation 4.

The other terms used have been described in Equation 18.

The estimates of standard errors for the stratified mean daily harvest rates and stratified mean daily discard rates for each month were calculated using the following general equation.

$$SE\left(\overline{R}_{Month}\right) = \sqrt{Var\left(\overline{R}_{Month}\right)} \text{ (Equation 20)}$$

where:

$SE\left(\overline{R}_{Month}\right)$ is the standard error of a stratified mean daily rate (harvest or discard) for a month.

$Var\left(\overline{R}_{Month}\right)$ is the variance of a stratified mean daily rate (harvest or discard) for a month. This term has been described in Equation 19.

2.6.6. Harvest and discard estimation for the boat-based and shore-based fisheries

The complemented survey designs used to assess the recreational fisheries used different on-site, contact methods to estimate effort and catch. Harvest and discard estimation in the boat-based fishery used interviews of completed trips, whereas the shore-based fishery used interviews of incomplete trips. The text in this section provides a detailed explanation of harvest estimation and the calculation of variances and standard errors. The same logic and general equations are also applied in the estimation of discard and its associated estimates of precision.

Step 1 - Daily harvest calculations are made for each survey day within each day-type stratum in a month. These daily harvest calculations are done because effort counts were done on the same days as interviews with recreational fishing parties.

$$\hat{H}_i = \hat{e}_i \times \hat{R}_i \text{ (Equation 21)}$$

where:

$\hat{H}_i$ is an estimate of harvest for the i th sample day. The base level of estimation was for each day-type stratum within a month. Harvest units are either numbers of fish, or the weight of fish.

$\hat{e}_i$ is an estimate of fishing effort for the i th sample day. Units are in boat hours for the boat-based fishery and in fisher hours for the shore-based fishery.

$\hat{R}_i$ is an estimate of harvest rate for the i th sample day. The $\hat{R}_{1(H)}$ estimator (see Equation 14) is used for the boat-based fishery and units are either numbers of fish per boat hour, or the weight of fish per boat hour. The $\hat{R}_{2(H)}$ estimator (see Equation 16) is used for the shore-based fishery and units are either numbers of fish per fisher hour, or the weight of fish per fisher hour.

Step 2 - These daily harvest estimates were then expanded for each day-type stratum within each month. This was done by multiplying the number of possible sample days in each base level stratum with the mean of the daily estimates of harvest.

$$\overline{H}_j = \frac{\sum \hat{H}_{ij}}{n_j} \text{ (Equation 22)}$$

where:

$\overline{H}_j$ is the estimated mean daily harvest for the j th day-type stratum within a month, in units of numbers of fish per day or weight of fish per day.

$\hat{H}_{ij}$ is the estimate of harvest for the i th sample day in the j th day-type stratum within a month.
n_j is the number of days sampled in the j th day-type stratum within a month.

$$\hat{H}_j = N_j \times \overline{H}_j \qquad \text{(Equation 23)}$$

where:
$\hat{H}_j$ is the estimate of harvest for the j th day-type stratum within a month, in units of numbers of fish or weight of fish.
See Basic notation and Equation 22 for definitions of the other terms.

Step 3 - Calculate the precision of the harvest estimates for each day-type stratum in a month. This is done for each fishery by estimating variances and standard errors for each stratum.

$$Var\left(\overline{H}_j\right) = \frac{s_j^2}{n_j} \quad \text{(Equation 24)}$$

where:
$Var\left(\overline{H}_j\right)$ is the estimated variance of the mean daily harvest for the j th day-type stratum within a month. This is calculated separately for each fishery.
s_j^2 is the sample variance of the daily estimates of harvest for the j th day-type stratum within a month.
n_j is the sample size as described in Equation 2.

$$SE\left(\overline{H}_j\right) = \sqrt{Var\left(\overline{H}_j\right)} \quad \text{(Equation 25)}$$

where:
$SE\left(\overline{H}_j\right)$ is the estimated standard error of the mean daily harvest.
$Var\left(\overline{H}_j\right)$ is the estimated variance of the mean daily harvest as described in Equation 24.

$$Var\left(\hat{H}_j\right) = N_j^2 \times Var\left(\overline{H}_j\right) \quad \text{(Equation 26)}$$

where:
$Var\left(\hat{H}_j\right)$ is the estimated variance of total harvest for a stratum, and is calculated separately for each day-type within each month for each fishery.
See Basic notation and Equation 24 for definitions of the other terms.

$$SE\left(\hat{H}_j\right) = \sqrt{Var\left(\hat{H}_j\right)} \quad \text{(Equation 27)}$$

where:
$SE\left(\hat{H}_j\right)$ is the estimated standard error of total harvest for a stratum.
$Var\left(\hat{H}_j\right)$ is the estimated variance of total harvest for a stratum as described in Equation 26.

We did not attempt to make expanded estimates of harvest for any taxa that were considered to have been "rare" throughout the survey period - defined as any taxon that had been recorded from three or less interviews during the survey period, regardless of the number of individuals harvested in those trips. This definition of rarity was applied separately to the boat-based and shore-based fisheries. All taxa which did not meet the criterion for rarity were classified as common taxa and expanded estimates of harvest were made for these taxa.

Survey personnel had, where possible, measured all identified fish, crabs and cephalopods that were seen during interviews with fishing parties. It was not always possible to obtain measurements, usually because fishers were in a hurry to leave the ramp. Thus, during many interviews, survey personnel were only able to collect measurements for a sub-sample of the entire harvest, or were only able to record counts of identified fish, crabs and cephalopods.

We did not measure the weight of fish during interviews but converted the length measurements into weights using length to weight keys. This was done for all taxa for which we had suitable length to weight conversion keys (Appendix 3). The remaining unmeasured component of the harvest (i.e. those fish seen during interviews but only counted) were assigned the median weight for that taxon as calculated from the pooled interview data. We used a median weight rather than a mean weight (as is traditionally done in angler surveys) because many of the estimated weight frequency distributions were highly skewed, making the median a better estimate of the centre of the population (Sokal and Rohlf 1969). In some cases, the use of a mean would have resulted in higher estimates of harvest. We calculated medians separately for the boat-based and shore-based fisheries. When no measurements had been made for a taxon in a particular fishery (e.g. the boat fishery), we used the available measurements from the other fishery (e.g. the shore fishery). In some cases, measurements were not available for some taxa and so we could not estimate weights.

Harvest estimates for the weekday and weekend day strata were combined to give monthly totals. A description of the equations used for estimating stratum totals, variances and standard errors is provided for effort estimation. The general form of the equations used in the estimation of effort and the associated variances and standard errors has been used for harvest estimation.

2.7. Comparisons with other recreational fishing studies done in NSW

Fisheries managers and the general public have a reasonable expectation that meaningful comparisons should be made between the current study and previous work done on other estuarine recreational fisheries in NSW. We have compared harvest rate data collected during: (a) this survey (monthly estimates for boat and shore fisheries); (b) a concurrent recreational fishing survey in the lower Richmond River (monthly estimates for shore and boat fisheries); (c) a survey of recreational fishing in Lake Macquarie done during 1999/2000 (seasonal estimates for boat and shore fisheries); and (d) a survey of boat-based recreational fishing in Tuross Lake done during 1999/2000 (seasonal estimates for the boat fishery only). The different survey designs used during these four surveys has precluded more detailed comparisons.

A five month recreational fishing survey was done in the lower Macleay River during March to July 1990 (NSW Fisheries unpublished data). Unfortunately, the different seasonal timing and the much smaller spatial coverage of that survey allows only limited comparisons to be made between that study and the current survey. The previous survey excluded the Stuarts Point area, most of Clybucca Creek and Andersons Inlet and most of the navigable waters behind Shark Island (NSW Fisheries unpublished data). The limited data summaries from the 1990 survey are aggregated for the entire five month period of the survey and no measure of precision is given (NSW Fisheries unpublished data), thereby precluding any detailed comparison.

2.8. Quality assurance

A survey can be useless if the data collected are of poor quality (Yates 1965, Pollock *et al*. 1994). We incorporated important quality assessment and control procedures into all phases of the survey so that the highest possible level of data quality and integrity could be attained. A brief description of these procedures are provided below.

2.8.1. Survey preparation phase

2.8.1.1. Design and pre-testing of survey forms

We had previously used similar data collection forms and interview procedures in other recreational fishing surveys. A feature of the previous surveys was the extensive field testing of survey forms that was done to ensure clearly worded, unambiguous questions and the development of a simple survey protocol. The forms used in this current survey were based on the previously used form designs. The old data collection forms were simplified to meet the needs of the current survey. We pre-tested the new data collection forms to confirm the logic of the questions and their functionality by conducting a series of mock interviews with persons having no involvement in this project. This pre-testing step was useful for further improving the form designs and was completed prior to the start of staff training.

2.8.1.2. Training of survey personnel

There were 21 people involved in data collection during this survey. NSW Fisheries staff provided comprehensive training to all persons involved in the survey, which included detailed documentation of survey protocols, procedures and fish identification. All persons were provided with explanations of the aims of the survey and the importance of the information that was being collected. Field staff were provided with work rosters which specified survey dates and work times and all persons involved in interviewing recreational fishing parties were provided with clear instructions on standard interview procedures, protocols for recording data on the interview forms, and on the use of the fish identification kit. Additional training based on hypothetical examples likely to be encountered during the course of the survey was also provided to all interviewers. The importance of using a systematic sampling procedure to subsample recreational fishing parties during busy periods was stressed to all interviewers and strict instructions were given to them to not preferentially interview fishers known to them or parties that were known to be cooperative.

2.8.1.3. Field identification kit for fish, crabs and cephalopods

We developed a detailed field identification kit for fish and invertebrates that were likely to be caught by recreational fishers during the survey. This kit was used to standardise the level of taxonomic precision among interviewers working at different sites in the Macleay River. The use of the identification kit also facilitated the conduct of interviews and as such was an important part of the interview procedure.

2.8.1.4. Information leaflets

Information leaflets which stated the objectives of the study and provided a brief explanation of the need for collecting survey data were distributed by field staff. These leaflets generated much local interest and were useful for informing the general public about the importance of the survey work. The distribution of these information leaflets helped gain the support and cooperation of the local fishing community and thereby were critical in improving the integrity of the survey data.

2.8.2. Survey operation phase

2.8.2.1. Supervision of survey personnel

Random checks of survey personnel were carried out during the survey period to provide a cost-effective way of ensuring data quality. We also maintained regular contact with nominated group leaders by telephone. In this way we were able to provide a regular flow of information to all field staff.

2.8.2.2. Preliminary scrutiny of data collection forms

Preliminary checks of progressive count data sheets and interview forms were made as they were received and we identified any missing or unusual data, such as, large numbers of fishing boats in particular areas of the river, very large harvests, fish having very small or very large sizes, and the occurrence of uncommon species. The individuals that had collected the unusual data were then contacted and asked to confirm or explain them. This scrutiny helped to maintain high levels of data integrity by identifying and correcting data problems at the earliest possible time.

2.8.3. Data entry, checking and manipulation phase

2.8.3.1. Data entry and data checking procedures

Machine-readable data forms were designed and used during this project. After the initial vetting of the data forms, the sheets were scanned and the digital images of the forms were examined using Intelligent/Optical Character Recognition (ICR/OCR) software (Teleform Elite Version V - Cardiff software). A trained operator checked and either verified or corrected all data that were queried by the ICR/OCR data entry process. Random checks of data subsets were then done to validate the effectiveness of the data entry system. Prior to any analyses, the data were subjected to a wide range of data outlier checks to identify any unusual data and detect any reading or logic errors which had been missed during the preliminary checks.

2.8.3.2. Data manipulation procedures

We verified the correctness of the computations used to derive the estimates of harvest rates, discard rates, weights of fish, effort, harvest, discard and their associated measures of precision by undertaking random checks on some subsets of the data.

3. RESULTS

3.1. Recreational fishing effort

3.1.1. Whole fishery (boat and shore fisheries combined)

We estimated that approximately 78,800 fisher hours of daytime recreational effort was expended in the lower Macleay River during the survey period - July to October 2001 inclusive (Table 2). Most recreational fishing effort, approximately 29,600 fisher hours representing 37.5% of total effort, occurred in the Entrance area (Table 3). The Kemps Corner / Clybucca area received approximately 22,400 fisher hours representing 28.4% of the total effort (Table 4), while the Stuarts Point area received approximately 16,400 fisher hours representing 20.8% of the total effort (Table 5), and approximately 10,500 fisher hours of effort representing 13.3% of total effort were recorded for the Main River area (Table 6). The level of daytime recreational fishing effort showed a distinct monthly pattern (Table 2). The highest level of effort was found in July (approximately 26,900 fisher hours representing 34.1% of the total effort), while a similarly high level of effort was also recorded in August (approximately 23,900 fisher hours representing 30.3% of the total effort). The lowest levels of effort were recorded in September (approximately 12,800 fisher hours representing 16.3% of the total effort), and October (approximately 15,200 fisher hours representing 19.3% of the total effort). Tables 2 to 6 also provide estimates of daytime effort for each day-type stratum within each month.

Table 2. Estimates of daytime recreational fishing effort (fisher hours) for the four areas in the Macleay River (Main River, Entrance, Kemps Cnr / Clybucca and Stuarts Point) combined. Data are presented for all temporal strata and for the boat-based and shore-based fisheries.

Month/Year	Day-Type	Boat Effort (fisher hrs)		SE	Shore Effort (fisher hrs)		SE	Total Effort (fisher hrs)		SE
July 2001	Weekday	6,502	±	1,027	11,422	±	1,366	17,924	±	1,709
	Weekend	3,758	±	443	5,178	±	562	8,936	±	716
	Total	**10,260**	±	**1,118**	**16,600**	±	**1,477**	**26,860**	±	**1,853**
August 2001	Weekday	4,854	±	572	12,141	±	1,476	16,995	±	1,583
	Weekend	2,444	±	358	4,487	±	506	6,931	±	620
	Total	**7,298**	±	**675**	**16,629**	±	**1,561**	**23,927**	±	**1,700**
September 2001	Weekday	2,328	±	554	3,792	±	546	6,120	±	778
	Weekend	3,096	±	404	3,626	±	499	6,722	±	642
	Total	**5,424**	±	**686**	**7,418**	±	**740**	**12,842**	±	**1,009**
October 2001	Weekday	5,528	±	897	4,964	±	696	10,492	±	1,136
	Weekend	2,898	±	388	1,829	±	236	4,727	±	454
	Total	**8,426**	±	**978**	**6,793**	±	**735**	**15,219**	±	**1,223**
Total	Weekday	19,212	±	1,579	32,320	±	2,197	51,532	±	2,706
	Weekend	12,196	±	799	15,121	±	936	27,317	±	1,231
	Total	**31,408**	±	**1,770**	**47,440**	±	**2,388**	**78,848**	±	**2,973**

Table 3. Estimates of daytime recreational fishing effort (fisher hours) for the Entrance area of the Macleay River. Data are presented for all temporal strata and for the boat-based and shore-based fisheries.

Month/Year	Day-Type	Boat Effort (fisher hrs)		SE	Shore Effort (fisher hrs)		SE	Total Effort (fisher hrs)		SE
July 2001	Weekday	1,729	±	454	6,329	±	1,197	8,058	±	1,280
	Weekend	786	±	147	2,434	±	395	3,220	±	421
	Total	**2,515**	±	**477**	**8,762**	±	**1,260**	**11,277**	±	**1,348**
August 2001	Weekday	1,107	±	287	5,912	±	1,263	7,019	±	1,295
	Weekend	514	±	74	2,416	±	399	2,930	±	406
	Total	**1,621**	±	**297**	**8,329**	±	**1,325**	**9,950**	±	**1,357**
September 2001	Weekday	238	±	106	1,575	±	364	1,813	±	379
	Weekend	482	±	102	1,799	±	328	2,281	±	343
	Total	**720**	±	**147**	**3,374**	±	**490**	**4,094**	±	**511**
October 2001	Weekday	744	±	230	2,612	±	556	3,356	±	602
	Weekend	365	±	136	558	±	63	923	±	150
	Total	**1,109**	±	**268**	**3,170**	±	**560**	**4,279**	±	**620**
Total	Weekday	3,818	±	594	16,428	±	1,863	20,246	±	1,955
	Weekend	2,147	±	236	7,207	±	653	9,354	±	695
	Total	**5,965**	±	**639**	**23,634**	±	**1,974**	**29,599**	±	**2,075**

Table 4. Estimates of daytime recreational fishing effort (fisher hours) for the Kemps Corner / Clybucca area of the Macleay River. Data are presented for all temporal strata and for the boat-based and shore-based fisheries.

Month/Year	Day-Type	Boat Effort (fisher hrs)		SE	Shore Effort (fisher hrs)		SE	Total Effort (fisher hrs)		SE
July 2001	Weekday	2,317	±	676	2,072	±	302	4,389	±	741
	Weekend	1,386	±	319	731	±	157	2,117	±	356
	Total	**3,703**	±	**748**	**2,802**	±	**341**	**6,505**	±	**822**
August 2001	Weekday	2,248	±	436	3,167	±	449	5,415	±	625
	Weekend	1,000	±	315	933	±	258	1,933	±	407
	Total	**3,248**	±	**537**	**4,100**	±	**517**	**7,348**	±	**746**
September 2001	Weekday	749	±	227	972	±	292	1,721	±	369
	Weekend	1,318	±	304	593	±	204	1,911	±	366
	Total	**2,067**	±	**379**	**1,565**	±	**356**	**3,632**	±	**520**
October 2001	Weekday	2,712	±	843	588	±	176	3,300	±	861
	Weekend	1,301	±	265	298	±	108	1,599	±	286
	Total	**4,013**	±	**884**	**887**	±	**207**	**4,900**	±	**908**
Total	Weekday	8,026	±	1,187	6,799	±	639	14,825	±	1,348
	Weekend	5,005	±	603	2,555	±	380	7,560	±	713
	Total	**13,031**	±	**1,331**	**9,354**	±	**744**	**22,385**	±	**1,525**

Table 5. Estimates of daytime recreational fishing effort (fisher hours) for the Stuarts Point area of the Macleay River. Data are presented for all temporal strata and for the boat-based and shore-based fisheries.

Month/Year	Day-Type	Boat Effort (fisher hrs)		SE	Shore Effort (fisher hrs)		SE	Total Effort (fisher hrs)		SE
July 2001	Weekday	2,179	±	617	1,368	±	436	3,547	±	755
	Weekend	1,309	±	250	949	±	240	2,258	±	347
	Total	**3,488**	±	**665**	**2,317**	±	**498**	**5,805**	±	**831**
August 2001	Weekday	1,213	±	230	950	±	126	2,163	±	262
	Weekend	597	±	49	448	±	47	1,045	±	68
	Total	**1,810**	±	**236**	**1,398**	±	**134**	**3,208**	±	**271**
September 2001	Weekday	1,183	±	480	583	±	195	1,766	±	519
	Weekend	920	±	203	544	±	95	1,464	±	224
	Total	**2,103**	±	**522**	**1,128**	±	**217**	**3,231**	±	**565**
October 2001	Weekday	1,860	±	174	800	±	267	2,660	±	319
	Weekend	1,050	±	224	452	±	138	1,502	±	263
	Total	**2,910**	±	**283**	**1,252**	±	**300**	**4,162**	±	**413**
Total	Weekday	6,435	±	833	3,702	±	561	10,137	±	1,005
	Weekend	3,876	±	395	2,393	±	297	6,269	±	494
	Total	**10,311**	±	**922**	**6,095**	±	**635**	**16,406**	±	**1,120**

Table 6. Estimates of daytime recreational fishing effort (fisher hours) for the Main River area of the Macleay River. Data are presented for all temporal strata and for the boat-based and shore-based fisheries.

Month/Year	Day-Type	Boat Effort (fisher hrs)		SE	Shore Effort (fisher hrs)		SE	Total Effort (fisher hrs)		SE
July 2001	Weekday	277	±	103	1,653	±	389	1,930	±	403
	Weekend	277	±	101	1,065	±	279	1,342	±	297
	Total	**554**	±	**145**	**2,719**	±	**479**	**3,273**	±	**500**
August 2001	Weekday	286	±	46	2,112	±	606	2,398	±	608
	Weekend	333	±	145	690	±	167	1,023	±	221
	Total	**619**	±	**152**	**2,802**	±	**629**	**3,421**	±	**647**
September 2001	Weekday	158	±	117	661	±	208	819	±	239
	Weekend	376	±	138	690	±	301	1,066	±	331
	Total	**534**	±	**181**	**1,351**	±	**366**	**1,885**	±	**408**
October 2001	Weekday	212	±	107	965	±	269	1,177	±	289
	Weekend	182	±	110	520	±	145	702	±	182
	Total	**394**	±	**153**	**1,484**	±	**306**	**1,878**	±	**342**
Total	Weekday	933	±	195	5,391	±	797	6,324	±	820
	Weekend	1,168	±	250	2,966	±	466	4,134	±	529
	Total	**2,101**	±	**317**	**8,356**	±	**923**	**10,457**	±	**976**

3.1.2. Boat-based fishery

We estimated that approximately 31,400 fisher hours of daytime recreational boat-based effort was expended in the lower Macleay River during the survey period - July to October 2001 inclusive (Table 2). This represented 39.8% of the effort for the total fishery (boat and shore combined). The highest amounts of boat-based effort were recorded from the Kemps Corner / Clybucca area (approximately 13,000 fisher hours representing 41.5% of the boat-based effort - Table 4) and the Stuarts Point area (approximately 10,300 fisher hours representing 32.8% of the boat-based effort - Table 5), while relatively low levels of boat-based effort were recorded from the Entrance area (approximately 5,965 fisher hours representing 19.0% of the boat-based effort - Table 3) and the Main River area (approximately 2,100 fisher hours representing 6.7% of the boat-based effort - Table 6). The level of daytime boat-based fishing effort showed a distinct monthly pattern (Table 2). The highest level of effort was found in July (approximately 10,300 fisher hours representing 32.7% of the total boat effort). Intermediate levels of effort were recorded in August (approximately 7,300 fisher hours representing 23.2% of the total boat effort) and October (approximately 8,400 fisher hours representing 26.8% of the total boat effort), while the lowest level of effort was recorded in September (approximately 5,400 fisher hours representing 17.3% of the total boat effort). Tables 2 to 6 also provide estimates of daytime boat-based effort for each day-type stratum within each month. Supplementary daytime effort information for the boat-based fishery is provided in units of boat hours, the original units used to in the calculations of boat-based effort and harvest (see Appendix 4).

3.1.3. Shore-based fishery

We estimated that approximately 47,400 fisher hours of daytime recreational shore-based effort was expended in the lower Macleay River during the survey period - July to October 2001 inclusive (Table 2). This represented 60.2% of the effort for the total fishery (boat and shore combined). The highest amount of shore-based effort was recorded from the Entrance area - approximately 23,600 fisher hours representing 49.8% of the shore-based effort (Table 3). Substantially lower levels of shore-based effort were recorded from the Kemps Corner / Clybucca area (approximately 9,400 fisher hours representing 19.7% of the shore-based effort - Table 4), the Main River area (approximately 8,400 fisher hours representing 17.6% of the shore-based effort - Table 6) and the Stuarts Point area (approximately 6,100 fisher hours representing 12.8% of the shore-based effort - Table 5). The level of daytime shore-based fishing effort showed a distinct monthly pattern (Table 2). The highest levels of effort were found in July (approximately 16,600 fisher hours representing 35.0% of the total shore effort) and August (approximately 16,600 fisher hours representing 35.1% of the total shore effort), while much lower levels of effort were recorded in September (approximately 7,400 fisher hours representing 15.6% of the total shore effort), and October (approximately 6,800 fisher hours representing 14.3% of the total shore effort). Tables 2 to 6 also provide estimates of daytime shore-based effort for each day-type stratum within each month.

3.2. Demography of the fishing population

The populations of boat-based and shore-based fishers were dominated by males (Table 7). Over the survey period, we found that 82.0% of the boat-based fishers that had been interviewed were males. Similarly, we found that 79.0% of the shore-based fishers that had been interviewed were males. There was an apparent increase in the proportion of female fishers during the final two months (September and October) of the survey period in the boat-based fishery, and the final three months (August, September and October) of the survey period in the shore-based fishery (Table 7). In the shore-based fishery a consistent pattern was evident when comparing the sex-based composition of the fishing populations between day-type strata. A higher proportion of female fishers were observed in the fishing population on weekend days. A similar pattern was found in the boat-based fishery except for the month of October during which the proportion of female fishers observed during weekend days was slightly lower than the proportion of female fishers recorded during weekdays (Table 7).

Over the survey period, we found that around half of the fishers in the shore-based fishery (51.3%) were of local origin (Table 8). In contrast, slightly less than half of the boat-based fishers (42.8%) were of local origin (Table 8). The proportion of visiting fishers in the boat-based fishing population ranged between 52.4% and 65.0% on a monthly basis (Table 8). In the boat fishery, the lowest proportion of visiting fishers was recorded during August and the highest proportion of visiting fishers was recorded during October (Table 8). The proportion of visiting fishers in the shore-based fishing population ranged between 45.7% and 62.6% on a monthly basis (Table 8). In the shore fishery, the highest proportion of visiting fishers was recorded during October, while the proportions recorded during the three preceding months were similar (Table 8).

Table 7. Numbers and percentages of male and female fishers for the boat and shore recreational fisheries in the Macleay River during the survey period (July 1 - October 31, 2001).

		BOAT FISHERY				SHORE FISHERY			
Month/Year	Day-Type	No. Male	% Male	No. Female	% Female	No. Male	% Male	No. Female	% Female
July 2001	Weekday	217	87.9	30	12.1	337	85.3	58	14.7
	Weekend	293	81.6	66	18.4	552	79.3	144	20.7
	Total	**510**	**84.2**	**96**	**15.8**	**889**	**81.5**	**202**	**18.5**
August 2001	Weekday	141	85.5	24	14.5	167	78.4	46	21.6
	Weekend	277	83.7	54	16.3	294	76.0	93	24.0
	Total	**418**	**84.3**	**78**	**15.7**	**461**	**76.8**	**139**	**23.2**
September 2001	Weekday	105	82.0	23	18.0	85	78.7	23	21.3
	Weekend	202	78.9	54	21.1	139	75.5	45	24.5
	Total	**307**	**79.9**	**77**	**20.1**	**224**	**76.7**	**68**	**23.3**
October 2001	Weekday	146	75.6	47	24.4	159	81.1	37	18.9
	Weekend	157	79.7	40	20.3	95	69.9	41	30.1
	Total	**303**	**77.7**	**87**	**22.3**	**254**	**76.5**	**78**	**23.5**
Total	Weekday	609	83.1	124	16.9	748	82.0	164	18.0
	Weekend	929	81.3	214	18.7	1,080	77.0	323	23.0
	Total	**1,538**	**82.0**	**338**	**18.0**	**1,828**	**79.0**	**487**	**21.0**

Table 8. Numbers and percentages of local and visiting fishers for the boat and shore recreational fisheries in the Macleay River during the survey period (July 1 - October 31, 2001).

		BOAT FISHERY				**SHORE FISHERY**			
Month/Year	Day-Type	No. Local	% Local	No. Visitors	% Visitor	No. Local	% Local	No. Visitors	% Visitor
July 2001	Weekday	97	39.6	148	60.4	185	45.6	221	54.4
	Weekend	174	48.9	182	51.1	411	59.0	286	41.0
	Total	**271**	**45.1**	**330**	**54.9**	**596**	**54.0**	**507**	**46.0**
August 2001	Weekday	60	36.1	106	63.9	88	40.9	127	59.1
	Weekend	177	53.3	155	46.7	228	58.9	159	41.1
	Total	**237**	**47.6**	**261**	**52.4**	**316**	**52.5**	**286**	**47.5**
September 2001	Weekday	39	30.2	90	69.8	48	44.9	59	55.1
	Weekend	116	46.2	135	53.8	110	59.8	74	40.2
	Total	**155**	**40.8**	**225**	**59.2**	**158**	**54.3**	**133**	**45.7**
October 2001	Weekday	48	24.9	145	75.1	58	29.4	139	70.6
	Weekend	89	44.9	109	55.1	67	48.9	70	51.1
	Total	**137**	**35.0**	**254**	**65.0**	**125**	**37.4**	**209**	**62.6**
Total	Weekday	244	33.3	489	66.7	379	41.0	546	59.0
	Weekend	556	48.9	581	51.1	816	58.1	589	41.9
	Total	**800**	**42.8**	**1,070**	**57.2**	**1,195**	**51.3**	**1,135**	**48.7**

3.3. Targeting preferences

The main targeting preferences nominated by boat-based fishing parties over the survey period were grouped into 8 categories (Table 9). Fishing parties nominating "luderick" as their main target were ranked highest overall during the survey period (Table 9). Many boat-based fishing parties indicated that they did not have any specific target preference, with fishing parties nominating "anything" as their main target ranked second during the survey period (Table 9). Flathead, bream and mulloway were other popular main targets of boat-based fishing parties. Fishing parties that had nominated any of these five main target categories, including the generalist category "anything", made up 99.1% of the boat-based fishing population during the survey period (Table 9). Whiting, tailor and crabs were also nominated as main target categories by boat-based fishing parties. These three target categories accounted for 0.9% of the boat-based fishing population during the survey period (Table 9). Some monthly trends in the targeting preferences of boat-based fishing parties were evident. There was a steady, yet substantial decrease in the proportion of fishing parties targeting "luderick" during the course of the survey (Table 9). In contrast, the proportion of generalist fishing parties in the boat fishery was lowest in July, the month in which the fishery was re-opened, with relatively higher proportions recorded during the other months, the highest being recorded in September (Table 9). There was an increase in the proportion of fishing parties targeting "flathead" during the course of the survey period, with by far the highest being recorded in October (Table 9). The proportion of fishing parties targeting "bream" were highest during July, while relatively lower proportions of "bream" targeting were recorded during August, September and October (Table 9). The proportion of boat-based fishing parties targeting "mulloway" were relatively low throughout the survey period (Table 9).

The main targeting preferences nominated by shore-based fishing parties over the survey period were grouped into 11 target categories (Table 10). A large proportion of shore-based fishing parties indicated that they did not have any specific target preference. Fishing parties nominating "bream" as their main target were ranked highest overall during the survey period (Table 10). Many shore-based fishing parties indicated that they did not have any specific target preference, with fishing parties nominating "anything" as their main target ranked second during the survey period (Table 10). Luderick, flathead and mulloway were other popular main targets of shore-based fishing parties. Fishing parties that had nominated any of these five main target categories, including the generalist category "anything", made up 99.0% of the shore-based fishing population during the survey period (Table 10). Mullet, whiting, tailor, garfish, seapike and tarwhine were also nominated as main target categories by shore-based fishing parties. These six target categories accounted for 1.0% of the shore-based fishing population during the survey period (Table 10). Some monthly trends in the targeting preferences of shore-based fishing parties were evident. There was a steady decrease in the proportion of fishing parties targeting "bream" during the survey period (Table 10). In contrast, the proportion of generalist fishing parties in the shore fishery was lowest in July, steadily increasing during the course of the survey period (Table 10). The proportion of shore-based fishing parties targeting "luderick" were relatively high during July and August, with a marked decline in the proportion of "luderick" targeting recorded during September and October (Table 10). The proportion of fishing parties targeting "flathead" showed the opposite, with the lowest proportions recorded during July and August, while the highest proportions were recorded during September and October (Table 10). The proportions of shore-based fishing parties targeting "mulloway" were highest in July and October, and very low in August and September (Table 10).

Table 9. Main target categories nominated by boat-based fishing parties in the Macleay River fishery during the survey period (July 1 - October 31, 2001).

Boat-Based	July 2001		August 2001		September 2001		October 2001		Total	
Target Category	No.	%	No.	%	No.	%	No.	%	No.	%
Luderick	171	54.1	115	42.8	42	23.2	11	6.5	339	36.3
Anything	31	9.8	57	21.2	74	40.9	56	33.3	218	23.3
Flathead	40	12.7	52	19.3	36	19.9	68	40.5	196	21.0
Bream	64	20.3	39	14.5	25	13.8	24	14.3	152	16.3
Mulloway	9	2.8	6	2.2	2	1.1	4	2.4	21	2.2
Whiting	1	0.3	-	-	2	1.1	2	1.2	5	0.5
Tailor	-	-	-	-	-	-	2	1.2	2	0.2
Crabs	-	-	-	-	-	-	1	0.6	1	0.1
Total	**316**		**269**		**181**		**168**		**934**	

Table 10. Main target categories nominated by shore-based fishing parties in the Macleay River fishery during the survey period (July 1 - October 31, 2001).

Shore-Based	July 2001		August 2001		September 2001		October 2001		Total	
Target Category	No.	%	No.	%	No.	%	No.	%	No.	%
Bream	269	43.7	137	38.9	60	35.5	34	19.3	500	38.1
Anything	133	21.6	111	31.5	73	43.2	105	59.7	422	32.1
Luderick	170	27.6	85	24.1	15	8.9	4	2.3	274	20.9
Flathead	13	2.1	10	2.8	17	10.1	19	10.8	59	4.5
Mulloway	28	4.5	6	1.7	3	1.8	8	4.5	45	3.4
Mullet	-	-	1	0.3	1	0.6	2	1.1	4	0.3
Whiting	1	0.2	-	-	-	-	3	1.7	4	0.3
Tailor	2	0.3	-	-	-	-	-	-	2	0.2
Garfish	-	-	-	-	-	-	1	0.6	1	0.1
Striped seapike	-	-	1	0.3	-	-	-	-	1	0.1
Tarwhine	-	-	1	0.3	-	-	-	-	1	0.1
Total	**616**		**352**		**169**		**176**		**1,313**	

3.4. Indicators of recreational fishing quality

An assessment of a recreational fishery can be improved if reliable indicators of fishing quality are available. We present four indicators of recreational fishing quality for the boat-based and shore-based fisheries in the lower Macleay River. These are: (1) the proportion of unsuccessful fishing parties; (2) recreational harvest rates; (3) recreational discard rates; and (4) the size-frequency distributions for some important taxa harvested by the recreational sector.

3.4.1. Proportion of unsuccessful fishing parties

We found that quite a high proportion of boat-based fishing parties were unsuccessful during their fishing trips. That is, these fishing parties failed to catch any fish, crab or cephalopods that they regarded as being worthy of keeping. The proportion of unsuccessful boat-based fishing parties ranged from approximately 22% to 51% on a monthly basis (Fig. 2). The proportion of unsuccessful boat-based fishing parties was approximately 36% over the entire survey period. The proportion of unsuccessful boat-based fishing parties was lowest during July, higher in August and the highest proportions were recorded during September and October (Fig. 2).

Shore-based fishing parties were less successful than boat-based parties. The proportion of unsuccessful shore-based fishing parties ranged from approximately 54% to 74% on a monthly basis (Fig. 2). The proportion of unsuccessful shore-based fishing parties was approximately 61% over the entire survey period. The proportion of unsuccessful shore-based fishing parties was lowest during July, higher in August and the highest proportions were recorded during September and October (Fig. 2).

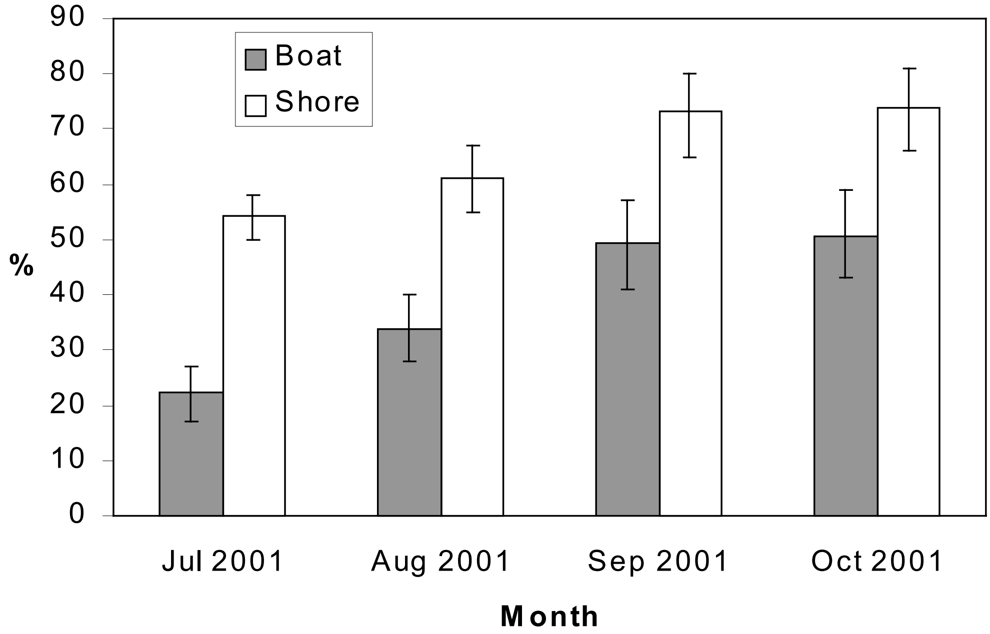

Figure 2. The proportion of unsuccessful boat-based and shore-based fishing parties (± 95% C.I.) for each month of the survey period (July 1 - October 31, 2001). Sample sizes are presented in Table 1.

3.4.2. Recreational harvest rates

The harvest rates reported in this document are based on calculations made using total fishing effort (non-directed effort) for a stratum. We present harvest rates for six important species. The harvest rate information is presented separately for the boat-based and shore-based fisheries, for each day-type stratum and for each month. In this way, temporal trends within the whole fishery can be examined. We also provide supplementary harvest rate information for the boat-based fishery in units of number of fish per boat hour (see Appendices 2.1 to 2.6). These appendices report the harvest rates for the boat-based fishery in the original units that were used in the calculations of boat-based effort and harvest, and are useful for other workers that may want to make comparisons between boat-based fisheries from other locations and/or survey periods.

3.4.2.1. Yellowfin bream

Bream were an important component of the harvest for both boat-based and shore-based fishing parties. The highest harvest rates for bream taken by boat-based fishers were recorded during July (Table 11). A decline in bream harvest rates in the boat fishery was observed throughout the remainder of the survey (Table 11). Similarly, bream harvest rates in the shore fishery were highest during July and there was a steady decline in harvest rate recorded during the next three months (Table 11). The bream harvest rates were generally higher in the shore-based fishery than in the boat-based fishery (Table 11).

Table 11. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for Yellowfin bream (*Acanthopagrus australis*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Macleay River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.080	±	0.029	0.157	±	0.045
	Weekend	0.136	±	0.038	0.271	±	0.075
	Total	**0.096**	±	**0.023**	**0.190**	±	**0.039**
August 2001	Weekday	0.088	±	0.039	0.143	±	0.050
	Weekend	0.073	±	0.014	0.229	±	0.066
	Total	**0.084**	±	**0.029**	**0.165**	±	**0.041**
September 2001	Weekday	0.014	±	0.010	0.102	±	0.028
	Weekend	0.059	±	0.013	0.117	±	0.022
	Total	**0.029**	±	**0.008**	**0.107**	±	**0.020**
October 2001	Weekday	0.031	±	0.014	0.172	±	0.014
	Weekend	0.010	±	0.005	0.227	±	0.046
	Total	**0.025**	±	**0.010**	**0.188**	±	**0.017**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.168	±	0.013	0.495	±	0.074
	Weekend	0.229	±	0.018	0.529	±	0.110
	Total	**0.186**	±	**0.011**	**0.505**	±	**0.061**
August 2001	Weekday	0.153	±	0.035	0.274	±	0.100
	Weekend	0.150	±	0.029	0.270	±	0.065
	Total	**0.152**	±	**0.027**	**0.273**	±	**0.076**
September 2001	Weekday	0.106	±	0.014	0.296	±	0.052
	Weekend	0.154	±	0.045	0.362	±	0.052
	Total	**0.122**	±	**0.018**	**0.318**	±	**0.039**
October 2001	Weekday	0.090	±	0.027	0.320	±	0.073
	Weekend	0.089	±	0.045	0.313	±	0.089
	Total	**0.090**	±	**0.023**	**0.318**	±	**0.058**

3.4.2.2. *Luderick*

High harvest rates of luderick were achieved in both the shore and boat fisheries during the first two months of the survey period with particularly high harvest rates recorded in the boat-based fishery during July (Table 12). The high harvest rates for luderick in July and August were followed by a marked decline in harvest rates during September and October. This trend was the same for both the boat and shore fisheries (Table 12).

Table 12. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for Luderick (*Girella tricuspidata*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Macleay River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	1.081	±	0.137	0.170	±	0.050
	Weekend	0.709	±	0.140	0.160	±	0.055
	Total	**0.973**	**±**	**0.106**	**0.167**	**±**	**0.039**
August 2001	Weekday	0.575	±	0.144	0.062	±	0.020
	Weekend	0.545	±	0.102	0.058	±	0.021
	Total	**0.567**	**±**	**0.110**	**0.061**	**±**	**0.015**
September 2001	Weekday	0.187	±	0.048	0.017	±	0.008
	Weekend	0.255	±	0.049	0.032	±	0.016
	Total	**0.210**	**±**	**0.036**	**0.022**	**±**	**0.007**
October 2001	Weekday	0.066	±	0.038	0.003	±	0.002
	Weekend	0.092	±	0.037	0.026	±	0.022
	Total	**0.074**	**±**	**0.029**	**0.009**	**±**	**0.006**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.350	±	0.050	0.108	±	0.036
	Weekend	0.352	±	0.103	0.131	±	0.030
	Total	**0.350**	**±**	**0.046**	**0.115**	**±**	**0.027**
August 2001	Weekday	0.526	±	0.175	0.037	±	0.034
	Weekend	0.159	±	0.069	0.048	±	0.035
	Total	**0.431**	**±**	**0.131**	**0.040**	**±**	**0.027**
September 2001	Weekday	0.008	±	0.006	-		-
	Weekend	0.071	±	0.038	0.091	±	0.073
	Total	**0.029**	**±**	**0.013**	**0.030**	**±**	**0.024**
October 2001	Weekday	0.037	±	0.027	-		-
	Weekend	-		-	0.020	±	0.020
	Total	**0.026**	**±**	**0.019**	**0.006**	**±**	**0.006**

3.4.2.3. Dusky flathead

Dusky flathead harvest rates in the boat fishery showed no apparent trend in the first three months of the survey, while the harvest rate increased substantially during October (Table 13). The highest harvest rate for dusky flathead in the shore fishery was recorded during September, with lower harvest rates being recorded in the other three months of the survey period (Table 13).

Table 13. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for Dusky flathead (*Platycephalus fuscus*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Macleay River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.053	±	0.030	0.050	±	0.019
	Weekend	0.039	±	0.010	0.057	±	0.013
	Total	**0.049**	**±**	**0.022**	**0.052**	**±**	**0.014**
August 2001	Weekday	0.036	±	0.014	0.084	±	0.018
	Weekend	0.061	±	0.012	0.084	±	0.033
	Total	**0.042**	**±**	**0.011**	**0.084**	**±**	**0.016**
September 2001	Weekday	0.045	±	0.019	0.071	±	0.022
	Weekend	0.066	±	0.015	0.093	±	0.011
	Total	**0.052**	**±**	**0.014**	**0.078**	**±**	**0.015**
October 2001	Weekday	0.117	±	0.035	0.134	±	0.064
	Weekend	0.119	±	0.022	0.108	±	0.025
	Total	**0.118**	**±**	**0.026**	**0.126**	**±**	**0.046**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.029	±	0.006	0.013	±	0.006
	Weekend	0.020	±	0.010	0.021	±	0.011
	Total	**0.026**	**±**	**0.005**	**0.016**	**±**	**0.005**
August 2001	Weekday	0.017	±	0.008	0.001	±	0.001
	Weekend	0.034	±	0.012	0.002	±	0.001
	Total	**0.022**	**±**	**0.007**	**0.001**	**±**	**0.001**
September 2001	Weekday	0.053	±	0.020	0.048	±	0.036
	Weekend	0.079	±	0.035	0.027	±	0.018
	Total	**0.062**	**±**	**0.018**	**0.041**	**±**	**0.025**
October 2001	Weekday	0.014	±	0.006	0.040	±	0.018
	Weekend	0.051	±	0.024	0.070	±	0.032
	Total	**0.025**	**±**	**0.008**	**0.048**	**±**	**0.016**

3.4.2.4. *Sand whiting*

Relatively few sand whiting were taken by boat-based fishers during the survey period and accordingly the harvest rates recorded were relatively low (Table 14). There was no apparent monthly trend in these harvest rate data for the boat fishery. The harvest rates for the shore fishery were very low during July, while no sand whiting were recorded in the harvest of boat-based fishers during August and September (Table 14). Interestingly, the sand whiting harvest rate recorded in the shore fishery during October was markedly higher (Table 14).

Table 14. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for Sand whiting (*Sillago ciliata*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Macleay River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.006	±	0.005	0.010	±	0.005
	Weekend	0.001	±	0.001	0.014	±	0.007
	Total	**0.004**	**±**	**0.003**	**0.011**	**±**	**0.004**
August 2001	Weekday	-		-	-		-
	Weekend	0.001	±	0.001	0.011	±	0.005
	Total	**<0.001**	**±**	**<0.001**	**0.003**	**±**	**0.001**
September 2001	Weekday	0.001	±	0.001	0.002	±	0.002
	Weekend	0.005	±	0.003	0.016	±	0.007
	Total	**0.003**	**±**	**0.001**	**0.007**	**±**	**0.003**
October 2001	Weekday	-		-	0.020	±	0.011
	Weekend	0.011	±	0.007	0.007	±	0.004
	Total	**0.003**	**±**	**0.002**	**0.016**	**±**	**0.008**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.001	±	0.001	0.006	±	0.004
	Weekend	-		-	0.007	±	0.006
	Total	**0.001**	**±**	**0.001**	**0.007**	**±**	**0.003**
August 2001	Weekday	-		-	0.005	±	0.005
	Weekend	-		-	<0.001	±	<0.001
	Total	-		-	**0.004**	**±**	**0.004**
September 2001	Weekday	-		-	-		-
	Weekend	-		-	0.011	±	0.011
	Total	-		-	**0.004**	**±**	**0.004**
October 2001	Weekday	0.032	±	0.016	0.101	±	0.052
	Weekend	0.047	±	0.036	0.013	±	0.005
	Total	**0.036**	**±**	**0.015**	**0.075**	**±**	**0.037**

3.4.2.5. Tailor

The harvest rates for tailor taken by boat-based fishers were relatively low in the boat fishery during each month of the survey period, with no apparent monthly trend in these data (Table 15). The highest harvest rates for tailor taken by shore-based fishers were recorded during July, while very few tailor were caught by shore-based fishers during August (Table 15). No tailor were recorded in the harvest of shore-based fishers during September and October (Table 15).

Table 15. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for Tailor (*Pomatomus saltatrix*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Macleay River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.001	±	0.001	0.007	±	0.006
	Weekend	0.005	±	0.003	0.017	±	0.011
	Total	**0.002**	±	**0.001**	**0.010**	±	**0.005**
August 2001	Weekday	-		-	0.006	±	0.006
	Weekend	0.003	±	0.001	0.007	±	0.005
	Total	**0.001**	±	**<0.001**	**0.006**	±	**0.005**
September 2001	Weekday	-		-	0.002	±	0.002
	Weekend	0.004	±	0.003	0.011	±	0.010
	Total	**0.001**	±	**0.001**	**0.005**	±	**0.004**
October 2001	Weekday	-		-	0.005	±	0.004
	Weekend	0.002	±	0.002	0.010	±	0.006
	Total	**0.001**	±	**0.001**	**0.006**	±	**0.003**

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)		SE
July 2001	Weekday	0.005	±	0.002	0.012	±	0.009
	Weekend	0.067	±	0.063	0.021	±	0.015
	Total	**0.023**	±	**0.018**	**0.015**	±	**0.008**
August 2001	Weekday	-		-	0.020	±	0.016
	Weekend	0.003	±	0.002	0.028	±	0.028
	Total	**0.001**	±	**<0.001**	**0.022**	±	**0.014**
September 2001	Weekday	-		-	0.006	±	0.004
	Weekend	-		-	-		-
	Total	-		-	**0.004**	±	**0.003**
October 2001	Weekday	-		-	-		-
	Weekend	-		-	-		-
	Total	-		-	-		-

3.4.2.6. Mulloway

Relatively few mulloway were taken by boat-based fishers during the survey period and accordingly the harvest rates recorded were relatively low (Table 16). There was no apparent monthly trend in these harvest rate data for the boat fishery. Similarly, few mulloway were taken by shore-based fishers during the survey period, with no apparent monthly trend in the harvest rate data (Table 16). No mulloway were recorded in the harvest of shore-based fishers during September (Table 16).

Table 16. Recreational harvest rate and discard rate estimates (fish per fisher hour ± standard error) for Mulloway (*Argyrosomus hololepidotus*) taken by (a) boat-based fishers, and (b) shore-based fishers, in the Macleay River during the survey period (July 1 - October 31, 2001).

a. BOAT FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)	SE
July 2001	Weekday	-		-		
	Weekend	0.008	±	0.005		
	Total	**0.002**	±	**0.001**		
August 2001	Weekday	-		-	See	
	Weekend	0.003	±	0.002	note	
	Total	**0.001**	±	**<0.001**	below	
September 2001	Weekday	-		-		
	Weekend	0.004	±	0.002		
	Total	**0.001**	±	**0.001**		
October 2001	Weekday	0.004	±	0.004		
	Weekend	-		-		
	Total	**0.003**	±	**0.003**		

b. SHORE FISHERY

Month/Year	Day-Type	Harvest Rate (fish/fisher hr)		SE	Discard Rate (fish/fisher hr)	SE
July 2001	Weekday	0.015	±	0.008		
	Weekend	0.002	±	0.002		
	Total	**0.011**	±	**0.006**		
August 2001	Weekday	0.005	±	0.005	See	
	Weekend	-		-	note	
	Total	**0.004**	±	**0.004**	below	
September 2001	Weekday	-		-		
	Weekend	-		-		
	Total	-		-		
October 2001	Weekday	-		-		
	Weekend	0.003	±	0.003		
	Total	**0.001**	±	**0.001**		

Note: Mulloway were classified as a rare taxon with respect to discards in the boat and shore fisheries and as such we did not estimate discard rates for this species in the boat or shore fishery.

3.4.3. Recreational discard rates

The discard rates reported in this document are based on calculations made using total fishing effort (non-directed effort) for a stratum. We present discard rates for six important species. The discard rate information is presented separately for the boat-based and shore-based fisheries, for each day-type stratum and for each month. In this way, temporal trends within the whole fishery can be examined. We also provide supplementary discard rate information for the boat-based fishery in units of number of fish per boat hour (see Appendices 2.1 to 2.6). These appendices report the discard rates for the boat-based fishery in the original units that were used in the calculations of boat-based effort and discard, and are useful for other workers that may want to make comparisons between boat-based fisheries from other locations and/or survey periods.

3.4.3.1. Yellowfin bream

Bream were regularly discarded by both boat-based and shore-based fishing parties. Recreational boat-based fishers indicated that 6.5% of the estimated 1300 discarded bream had been of legal size. Similarly, recreational shore-based fishers indicated that 3.8% of the estimated 1100 discarded bream had been of legal size. The highest discard rates for bream taken by boat-based fishers were reported during July and October (Table 11). There were slightly lower bream discard rates in the boat fishery during August, while the lowest monthly bream discard rate was reported during September (Table 11). Bream discard rates in the shore fishery were highest during July, while lower discard rates were reported during August, September and October (Table 11).

3.4.3.2. Luderick

Recreational boat-based fishers indicated that 18.0% of the estimated 530 discarded luderick had been of legal size. Similarly, recreational shore-based fishers indicated that 14.0% of the estimated 150 discarded luderick had been of legal size. The reported discard rates were lower than the harvest rates achieved for luderick for all strata in the boat fishery and most strata in the shore fishery (Table 12). Discard rates exceeded harvest rates in the shore fishery during the weekend day-type stratum in both September and October (Table 12). The highest discard rates for luderick reported by boat-based fishers occurred during July (Table 12). A decline in luderick discard rates in the boat fishery was apparent throughout the remainder of the survey (Table 12). Similarly, luderick discard rates in the shore fishery were highest during July and there was a steady decline in the monthly discard rates reported during the next three months (Table 12).

3.4.3.3. Dusky flathead

Recreational boat-based fishers indicated that 24.7% of the estimated 570 discarded dusky flathead had been of legal size. In contrast, recreational shore-based fishers indicated that 12.1% of the estimated 70 discarded dusky flathead had been of legal size. Dusky flathead monthly discard rates in the boat fishery were lowest during July, intermediate during August and September and highest during October (Table 13). The shore fishery was characterised by relatively lower discard rates than those reported for the boat fishery. The discard rates reported by shore-based fishers were higher during the second half of the survey period (Table 13).

3.4.3.4. Sand whiting

Recreational boat-based fishers indicated that none of the estimated 80 discarded sand whiting were of legal size, while shore-based fishers indicated that 6.4% of the estimated 50 discarded sand whiting in the shore fishery had been of legal size. The sand whiting discard rates reported by boat-based fishers were relatively low during the survey period and there was no apparent monthly trend in these discard rate data for the boat fishery (Table 14). The monthly discard rates reported by shore-based fishers during the first three months of the survey were as low as those recorded for the boat-based fishery, while a relatively higher discard rate was reported during October (Table 14).

3.4.3.5. Tailor

Recreational boat-based fishers indicated that 31.7% of the estimated 60 discarded tailor had been of legal size. In contrast, recreational shore-based fishers indicated that 15.0% of the estimated 40 discarded tailor had been of legal size. The monthly discard rates for tailor reported by boat-based fishers were relatively low during the survey period and there was no apparent monthly trend in these discard rate data for the boat fishery (Table 15). The tailor discard rates reported by shore-based fishers during July and August were higher than all of the monthly discard rates reported in the boat fishery (Table 15). Shore-based fishers reported lower discard rates during September, while no tailor were reported as being discarded in the shore-based fishery during October (Table 15).

3.4.3.6. Mulloway

Boat-based fishers caught relatively few mulloway during the survey period and the number of reported discards was also extremely low. For example, none of the 5 mulloway reported as discard in the boat-based fishery were of legal size, while no mulloway were reported as being discarded in the shore-based fishery. As a consequence, mulloway were classified as a rare taxon with respect to discards in the shore fishery and as such we did not estimate discard rates or make expanded estimates of discard for this species in the shore fishery (Table 16).

3.4.4. Size-frequency distributions

Appendix 5 contains descriptive statistics of all measurements taken for each taxon by boat-based and shore-based fishers during the survey period. Here, we present length frequency distributions for the five main taxa in the recreational fishery, aggregated for the whole fishery (boat and shore combined). The size-frequency distributions presented here are important baseline indicators which can be used to monitor future changes (if any) in the size structure of these species in the fishery. There are some noteworthy features evident in these size-frequency distributions (Figures 3a to 3e). First, large individuals that were highly-prized by recreational fishers were present in the recreational harvests indicating that the quality of recreational fishing opportunities during the survey period were quite good. Second, the proportions of under-sized yellowfin bream, luderick, tailor and mulloway in the recreational harvest were extremely low indicating good compliance with fisheries regulations. Finally, the proportions of under-sized dusky flathead and sand whiting in the recreational harvest were less than 15% which is comparable to rates measured in other NSW estuarine fisheries.

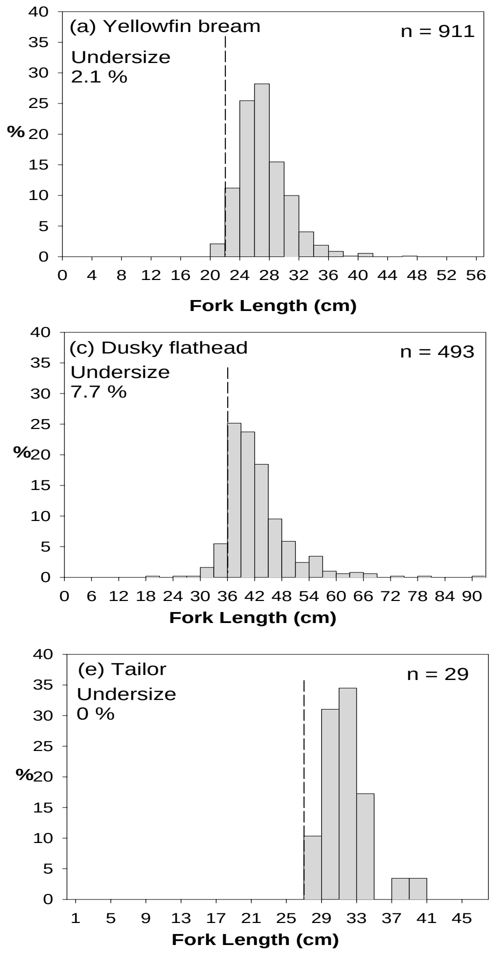

Figure 3. Length frequency distributions for: (a) Yellowfin bream (*Acanthopagrus australis*); (b) Luderick (*Girella tricuspidata*); (c) Dusky flathead (*Platycephalus fuscus*); (d) Sand whiting (*Sillago ciliata*); and (e) Tailor (*Pomatomus saltatrix*); taken by recreational fishers in the lower Macleay River during the survey period (July 1 to October 31, 2001). The length frequency data for the boat and shore fisheries have been pooled. The dashed line indicates the minimum legal length.

3.5. Recreational harvest

3.5.1. Whole fishery

We recorded 16 taxa in the retained catch of recreational fishers accessing the lower Macleay River fishery by boat and from the shore during the survey period (Table 17). We estimated that approximately 45,300 fish and crustaceans (± 4,205 individuals - approximate SE) were harvested by daytime recreational fishers from the lower Macleay River during the survey period (Table 17) and that this recreational harvest consisted almost exclusively of finfish (>99% of harvest) - (Table 17). The six most commonly harvested taxa, by number, during the survey period were luderick (≈29,110 – 64.2%), yellowfin bream (≈9,250 - 20.4%), dusky flathead (≈3,760 - 8.3%), striped seapike (≈1,220 - 2.7%), tailor (≈670 - 1.5%), and sand mullet (≈600 – 1.3%) - (Table 17). These six taxa, by number, accounted for 98.5% of the daytime recreational harvest during the survey period (Table 17).

We estimated that approximately 25.2 tonnes of fish and crustaceans (± 2.4 tonnes - approximate SE) were harvested by daytime recreational fishers from the lower Macleay River during the survey period (Table 18) and that this recreational harvest consisted almost exclusively of finfish (>99% of harvest) – (Table 18). The six most commonly harvested taxa, by weight, during the survey period were luderick (≈16.5 tonnes – 65.4%), yellowfin bream (≈4.7 tonnes – 18.8%), dusky flathead (≈1.9 tonnes – 7.5%), mulloway (≈1.6 tonnes – 6.3%), tailor (≈0.3 tonnes – 1.0%), and striped seapike (≈0.1 tonnes - 0.6%) - (Table 18). These six taxa, by weight, accounted for 99.6% of the daytime recreational harvest during the survey period (Table 18).

Table 17. Monthly and total harvest estimates (number of individuals) and standard errors for taxa taken by recreational fishers in the Macleay River for the survey period (July 1 - October 31, 2001). The daytime harvest data for the boat and shore fisheries have been pooled.

	TOTAL HARVEST FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Luderick *Girella tricuspidata*	15,167 ±	2200	11,676 ±	3320	1,428 ±	283	837 ±	269	29,108 ±	4002	64.2
Yellowfin bream *Acanthopagrus australis*	4,201 ±	500	3,120 ±	459	1,078 ±	145	848 ±	208	9,247 ±	724	20.4
Dusky flathead *Platycephalus fuscus*	1,048 ±	340	684 ±	162	911 ±	205	1,118 ±	195	3,761 ±	471	8.3
Striped seapike *Sphyraena obtusata*	46 ±	41	5 ±	5	637 ±	637	535 ±	340	1,223 ±	723	2.7
Tailor *Pomatomus saltatrix*	631 ±	503	21 ±	11	12 ±	10	8 ±	8	672 ±	503	1.5
Sand mullet *Myxus elongatus*	160 ±	106	295 ±	288	143 ±	143	-	-	598 ±	338	1.3
Mulloway *Argyrosomus japonicus*	219 ±	88	89 ±	81	10 ±	6	41 ±	34	359 ±	124	0.8
Sand whiting *Sillago ciliata*	66 ±	39	5 ±	5	27 ±	16	212 ±	90	310 ±	100	0.7
Australian salmon *Arripis trutta*	#4	-	-	-	-	-	#1	-	#5	-	< 0.1
Small-toothed flounder *Pseudorhombus jenynsii*	#1	-	#2	-	#1	-	-	-	#4	-	< 0.1
Southern herring *Herklotsichthys castelnaui*	#4	-	-	-	-	-	-	-	#4	-	< 0.1
Flat-tail mullet *Liza argentea*	-	-	-	-	-	-	#2	-	#2	-	< 0.1
Australian bass *Macquaria novemaculeata*	#1	-	-	-	-	-	-	-	#1	-	< 0.1

Table 17 (continued)

	TOTAL HARVEST FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Blue-swimmer crab *Portunus pelagicus*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Sea mullet *Mugil cephalus*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Silver biddy *Gerres subfasciatus*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Total Taxa	**13**		**9**		**9**		**11**		**16**		

Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

Table 18. Monthly and total harvest estimates (kilograms) and standard errors for taxa taken by recreational fishers in the Macleay River for the survey period (July 1 - October 31, 2001). The daytime harvest data for the boat and shore fisheries have been pooled.

	TOTAL HARVEST FOR WHOLE FISHERY															
	July 2001			August 2001			September 2001			October 2001			Total			%
Taxon	kg		SE	kg		SE	kg		SE	kg		SE	kg		SE	total
Luderick *Girella tricuspidata*	8,614	±	1,312	6,496	±	1,776	838	±	173	511	±	146	16,459	±	2,219	65.4
Yellowfin bream *Acanthopagrus australis*	1,964	±	231	1,665	±	261	561	±	95	548	±	182	4,738	±	404	18.8
Dusky flathead *Platycephalus fuscus*	549	±	171	362	±	98	399	±	95	588	±	111	1,898	±	245	7.5
Mulloway *Argyrosomus japonicus*	877	±	384	457	±	409	70	±	53	173	±	153	1,577	±	584	6.3
Tailor *Pomatomus saltatrix*	244	±	194	8	±	4	3	±	3	6	±	6	261	±	194	1.0
Striped seapike *Sphyraena obtusata*	6	±	5	1	±	1	75	±	75	63	±	40	145	±	85	0.6
Sand whiting *Sillago ciliata*	16	±	9	1	±	1	8	±	4	48	±	19	73	±	22	0.3
Australian salmon *Arripis trutta*	#9		-	-		-	-		-	#7		-	#16		-	0.1
Sand mullet *Myxus elongatus*	4	±	3	4	±	3	2	±	2	-		-	10	±	5	< 0.1
Sea mullet *Mugil cephalus*	-		-	-		-	-		-	#3		-	#3		-	< 0.1
Australian bass *Macquaria novemaculeata*	#1		-	-		-	-		-	-		-	#1		-	< 0.1
Blue-swimmer crab *Portunus pelagicus*	-		-	-		-	-		-	#1		-	#1		-	< 0.1
Flat-tail mullet *Liza argentea*	-		-	-		-	-		-	#1		-	#1		-	< 0.1

Table 18 (continued)

	TOTAL HARVEST FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	kg	SE	kg	SE	kg	SE	kg	SE	kg	SE	total
Small-toothed flounder *Pseudorhombus jenynsii*	#<1	-	#<1	-	#<1	-	-	-	#1	-	< 0.1
Silver biddy *Gerres subfasciatus*	#<1	-	-	-	-	-	-	-	#<1	-	< 0.1
Southern herring *Herklotsichthys castelnaui*	#<1	-	-	-	-	-	-	-	#<1	-	< 0.1

Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

3.5.2. Boat fishery

We recorded 12 taxa in the retained catch of boat-based recreational fishers during the survey period (Table 19). We estimated that for boat-based recreational fishers, approximately 20,180 fish and crustaceans (± 2,230 individuals - approximate SE) were harvested in the daytime from the lower Macleay River during the survey period (Table 19). This represents 44.5%, by number, of the daytime harvest for the total fishery (boat and shore combined). The recreational harvest for the boat fishery consisted almost exclusively of finfish (>99% of harvest) - (Table 19). The six most commonly harvested taxa by boat-based fishers, by number, during the survey period were luderick (≈15,400 – 76.3%), yellowfin bream (≈2,260 – 11.2%), dusky flathead (≈2,260 – 11.2%), sand whiting (≈110 – 0.5%), mulloway (≈80 - 0.4%) and tailor (≈50 – 0.3%) - (Table 19). These six taxa, by number, accounted for 99.9% of the daytime recreational harvest of the boat-based fishery during the survey period (Table 19).

We estimated that for boat-based recreational fishers, approximately 11.4 tonnes of fish and crustaceans (± 1.3 tonnes - approximate SE) were harvested in the daytime from the lower Macleay River during the survey period (Table 20). This represents 45.3%, by weight, of the daytime harvest for the total fishery (boat and shore combined). The recreational harvest for the boat fishery consisted almost exclusively of finfish (>99% of harvest) - (Table 20). The six most commonly harvested taxa by boat-based fishers, by weight, during the survey period were luderick (≈8.7 tonnes – 76.3%), dusky flathead (≈1.1 tonnes – 9.8%), yellowfin bream (≈1.1 tonnes – 9.7%), sand whiting (0.4 tonnes – 3.6%), mulloway (<0.1 tonnes – 0.2%) and tailor (<0.1 tonnes – 0.2%) - (Table 20). These six taxa, by weight, accounted for 99.9% of the daytime recreational harvest of the boat-based fishery during the survey period (Table 20).

Table 19. Monthly and total harvest estimates (number of individuals) and standard errors for taxa taken by boat-based recreational fishers in the Macleay River for the survey period (July 1 - October 31, 2001).

	BOAT-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Luderick *Girella tricuspidata*	9,150	± 1,774	4,398	± 1,183	1,238	± 272	610	± 200	15,396	± 2,159	76.3
Yellowfin bream *Acanthopagrus australis*	1,105	± 255	693	± 249	215	± 56	249	± 126	2,262	± 382	11.2
Dusky flathead *Platycephalus fuscus*	635	± 325	294	± 43	376	± 117	951	± 188	2,256	± 395	11.2
Sand whiting *Sillago ciliata*	51	± 36	5	± 5	27	± 16	27	± 17	110	± 43	0.5
Mulloway *Argyrosomus japonicus*	32	± 18	8	± 5	10	± 6	33	± 33	83	± 39	0.4
Tailor *Pomatomus saltatrix*	29	± 15	5	± 3	12	± 10	8	± 8	54	± 20	0.3
Striped seapike *Sphyraena obtusata*	#5	-	-	-	-	-	-	-	#5	-	<0.1
Southern herring *Herklotsichthys castelnaui*	#4	-	-	-	-	-	-	-	#4	-	<0.1
Australian salmon *Arripis trutta*	#3	-	-	-	-	-	#1	-	#4	-	<0.1
Small-toothed flounder *Pseudorhombus jenynsii*	-	-	#2	-	#1	-	-	-	#3	-	<0.1
Silver biddy *Gerres subfasciatus*	#1	-	-	-	-	-	-	-	#1	-	<0.1
Blue-swimmer crab *Portunus pelagicus*	-	-	-	-	-	-	#1	-	#1	-	<0.1
Total Taxa	**10**		**7**		**7**		**8**		**12**		

Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

Table 20. Monthly and total harvest estimates (kilograms) and standard errors for taxa taken by boat-based recreational fishers in the Macleay River for the survey period (July 1 - October 31, 2001).

	BOAT-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	kg	SE	kg	SE	kg	SE	kg	SE	kg	SE	total
Luderick *Girella tricuspidata*	5,113 ±	1,059	2,401 ±	594	750 ±	170	428 ±	130	8,692 ±	1,233	76.3
Dusky flathead *Platycephalus fuscus*	292 ±	155	152 ±	28	172 ±	58	501 ±	105	1,117 ±	198	9.8
Yellowfin bream *Acanthopagrus australis*	492 ±	113	333 ±	114	111 ±	31	174 ±	109	1,110 ±	197	9.7
Sand whiting *Sillago ciliata*	137 ±	80	49 ±	31	70 ±	53	152 ±	152	408 ±	182	3.6
Mulloway *Argyrosomus japonicus*	12 ±	8	1 ±	1	8 ±	4	7 ±	4	28 ±	10	0.2
Tailor *Pomatomus saltatrix*	12 ±	6	3 ±	1	3 ±	3	6 ±	6	24 ±	9	0.2
Australian salmon *Arripis trutta*	#7	-	-	-	-	-	#7	-	#14	-	0.1
Blue-swimmer crab *Portunus pelagicus*	-	-	-	-	-	-	#1	-	#1	-	<0.1
Small-toothed flounder *Pseudorhombus jenynsii*	-	-	#<1	-	#<1	-	-	-	#1	-	<0.1
Striped seapike *Sphyraena obtusata*	#1	-	-	-	-	-	-	-	#1	-	<0.1
Silver biddy *Gerres subfasciatus*	#<1	-	-	-	-	-	-	-	#<1	-	<0.1
Southern herring *Herklotsichthys castelnaui*	#<1	-	-	-	-	-	-	-	#<1	-	<0.1

Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

3.5.3. Shore fishery

We recorded 13 taxa in the retained catch of shore-based recreational fishers during the survey period (Table 21). We estimated that for shore-based recreational fishers, approximately 25,120 fish (± 3,570 individuals - approximate SE) were harvested in the daytime from the lower Macleay River during the survey period (Table 21). This represents 55.5%, by number, of the daytime harvest for the total fishery (boat and shore combined). The recreational harvest for the shore fishery consisted exclusively of finfish (Table 21). The six most commonly harvested taxa by shore-based fishers, by number, during the survey period were luderick (≈13,710 - 54.6%), yellowfin bream (≈6,990 - 27.8%), dusky flathead (≈1,510 - 6.0%), striped seapike (≈1,220 – 4.8%), tailor (≈620 – 2.4%), and sand mullet (≈600 – 2.4%) - (Table 21). These six taxa, by number, accounted for 98.0% of the daytime recreational harvest of the shore-based fishery during the survey period (Table 21).

We estimated that for shore-based recreational fishers, approximately 13.8 tonnes of fish (± 2.0 tonnes - approximate SE), were harvested in the daytime from the lower Macleay River during the survey period (Table 22). This represents 54.7%, by weight, of the daytime harvest for the total fishery (boat and shore combined). The recreational harvest for the shore fishery consisted exclusively of finfish (Table 22). The six most commonly harvested taxa by shore-based fishers, by weight, during the survey period were luderick (≈7.8 tonnes – 56.3%), yellowfin bream (≈3.6 tonnes – 26.3%), mulloway (≈1.2 tonnes – 8.5%), dusky flathead (≈0.8 tonnes – 5.7%), tailor (≈0.2 tonnes – 1.7%), and striped seapike (≈0.1 tonnes – 1.0%) - (Table 22). These six taxa, by weight, accounted for 99.5% of the daytime recreational harvest of the shore-based fishery during the survey period (Table 22).

Table 21. Monthly and total harvest estimates (number of individuals) and standard errors for taxa taken by shore-based recreational fishers in the Macleay River by shore-based recreational fishers in the Macleay River.

	SHORE-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Luderick *Girella tricuspidata*	6,017	± 1,301	7,278	± 3,103	190	± 78	227	± 180	13,712	± 3,370	54.6
Yellowfin bream *Acanthopagrus australis*	3,096	± 430	2,427	± 386	863	± 134	599	± 165	6,985	± 615	27.8
Dusky flathead *Platycephalus fuscus*	413	± 102	390	± 156	535	± 168	167	± 53	1,505	± 257	6.0
Striped seapike *Sphyraena obtusata*	41	± 41	5	± 5	637	± 637	535	± 340	1,218	± 723	4.8
Tailor *Pomatomus saltatrix*	602	± 503	16	± 11	-	-	-	-	618	± 503	2.4
Sand mullet *Myxus elongatus*	160	± 106	295	± 288	143	± 143	-	-	598	± 338	2.4
Mulloway *Argyrosomus japonicus*	187	± 86	81	± 81	-	-	8	± 8	276	± 118	1.1
Sand whiting *Sillago ciliata*	15	± 15	-	-	-	-	185	± 89	200	± 90	0.8
Flat-tail mullet *Liza argentea*	-	-	-	-	-	-	#2	-	#2	-	<0.1
Australian bass *Macquaria novemaculeata*	#1	-	-	-	-	-	-	-	#1	-	<0.1
Australian salmon *Arripis trutta*	#1	-	-	-	-	-	-	-	#1	-	<0.1
Sea mullet *Mugil cephalus*	-	-	-	-	-	-	#1	-	#1	-	<0.1
Small-toothed flounder *Pseudorhombus jenynsii*	#1	-	-	-	-	-	-	-	#1	-	<0.1
Total Taxa	**11**		**7**		**5**		**8**		**13**		

Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

Table 22. Monthly and total harvest estimates (kilograms) and standard errors for taxa taken by shore-based recreational fishers in the Macleay River for the survey period (July 1 - October 31, 2001).

	SHORE-BASED HARVEST										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	kg	SE	kg	SE	kg	SE	kg	SE	kg	SE	total
Luderick *Girella tricuspidata*	3,501 ±	774	4,095 ±	1,674	88 ±	34	83 ±	66	7,767 ±	1,845	56.3
Yellowfin bream *Acanthopagrus australis*	1,472 ±	201	1,332 ±	235	450 ±	90	374 ±	145	3,628 ±	353	26.3
Mulloway *Argyrosomus japonicus*	740 ±	375	408 ±	408	-	-	21 ±	21	1,169 ±	555	8.5
Dusky flathead *Platycephalus fuscus*	257 ±	73	210 ±	94	227 ±	75	87 ±	36	781 ±	145	5.7
Tailor *Pomatomus saltatrix*	232 ±	194	5 ±	4	-	-	-	-	237 ±	194	1.7
Striped seapike *Sphyraena obtusata*	5 ±	5	1 ±	1	75 ±	75	63 ±	40	144 ±	85	1.0
Sand whiting *Sillago ciliata*	4 ±	4	-	-	-	-	41 ±	19	45 ±	19	0.3
Sand mullet *Sillago ciliata*	4 ±	3	4 ±	3	2 ±	2	-	-	10 ±	5	0.1
Sea mullet *Mugil cephalus*	-	-	-	-	-	-	#3	-	#3	-	<0.1
Australian salmon *Arripis trutta*	#2	-	-	-	-	-	-	-	#2	-	<0.1
Australian bass *Macquaria novemaculeata*	#1	-	-	-	-	-	-	-	#1	-	<0.1
Flat-tail mullet *Liza argentea*	-	-	-	-	-	-	#1	-	#1	-	<0.1
Small-toothed flounder *Pseudorhombus jenynsii*	#<1	-	-	-	-	-	-	-	#<1	-	<0.1

Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

3.5.4. Monthly trends in recreational harvest

Information describing monthly trends in the pattern of recreational harvesting for the whole fishery are provided in Tables 17 and 18. Here we provide a brief description of the monthly trends evident for the six main species in the harvest, by number, for the whole fishery. The largest monthly harvest of luderick was taken during July, the month after the river was re-opened (Table 17). Harvests of luderick remained high during August, although the harvests recorded during September and October were considerably lower (Table 17). Similarly, the largest monthly harvest of yellowfin bream was taken during July, which was followed by a steady decrease in harvest during each of the following three months of the survey period (Table 17). The smallest levels of harvest for luderick and yellowfin bream were recorded during October (Table 17). A different monthly pattern was evident for dusky flathead (Table 17). The largest harvests of dusky flathead were taken during July and October, while decreased levels of harvest were recorded during August and September (Table 17). In contrast, the largest harvests of striped seapike were taken during September and October, while much lower levels of harvest were recorded during the first two months of the survey (Table 17). As was the case for luderick and yellowfin bream, the largest harvest of tailor was taken during July (Table 17). However, relatively few tailor were harvested during August, September and October (Table 17). The harvest of sand mullet showed no apparent trend with the largest harvest level recorded during August, relatively lower amounts of harvest taken during July and September, and no sand mullet recorded during October (Table 17). We also present information describing monthly trends in the pattern of recreational harvesting for the boat-based fishery (Tables 19 and 20), and the shore-based fishery (Tables 21 and 22). In this way, the reader may extract monthly information for particular species of interest.

3.6. Recreational discard

3.6.1. Whole fishery

Recreational fishers (boat-based and shore-based) reported discarding 26 taxa whilst fishing in the lower Macleay River during the survey period (Table 23). We estimated that approximately 34,310 fish and crustaceans (± 2,060 individuals - approximate SE) were discarded by daytime recreational fishers in the lower Macleay River during the survey period (Table 23) and that this recreational discard consisted almost exclusively of finfish (>99% of harvest) - (Table 23). The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈22,260 - 64.8%), luderick (≈5,200 - 15.2%), dusky flathead (≈3,590 - 10.5%), sand whiting (≈1,250 – 3.6%), tailor (≈1,040 – 3.0%), and silver batfish (≈470 - 1.4%) - (Table 23). These six taxa, by number, accounted for 98.5% of the total daytime recreational discard during the survey period (Table 23). The great majority of discarded yellowfin bream (94.7%) and sand whiting (97.6%) were below the legal minimum length. Interestingly, lower proportions of discarded luderick (82.9%), dusky flathead (76.7%) and tailor (75.0%) were below the legal minimum length.

Table 23. Monthly and total discard estimates (number of individuals) and standard errors for taxa taken by recreational fishers in the Macleay River for the survey period (July 1 - October 31, 2001). The daytime harvest data for the boat and shore fisheries have been pooled.

	TOTAL DISCARD FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Yellowfin bream *Acanthopagrus australis*	9,878	± 1,451	5,708	± 1,327	3,015	618	3,660	± 781	22,261	± 1,715	64.8
Luderick *Girella tricuspidata*	3,643	± 1,065	1,029	± 473	380	227	150	± 118	5,202	± 877	15.2
Dusky flathead *Platycephalus fuscus*	923	± 294	585	± 118	867	314	1,215	± 412	3,590	± 477	10.5
Sand whiting *Sillago ciliata*	264	± 119	112	± 99	84	57	786	± 422	1,246	± 361	3.6
Tailor *Pomatomus saltatrix*	441	± 241	445	± 293	97	70	58	± 28	1,041	± 329	3.0
Silver batfish *Monodactylus argenteus*	342	± 217	30	± 28	-	-	95	± 87	467	± 221	1.4
Mullet Mugilidae	60	± 60	69	± 44	-	-	69	± 52	198	± 90	0.6
Stingrays & stingarees Dasyatidae & Urolophidae	18	± 15	85	± 85	43	± 40	6	± 4	152	± 87	0.4
Tarwhine *Rhabdosargus sarba*	62	± 33	-	-	3	± 3	-	-	65	± 33	0.2
Large-toothed flounder *Pseudorhombus arsius*	20	± 15	20	± 13	#1	-	11	± 11	52	± 23	0.2
Mulloway *Argyrosomus japonicus*	#4	-	#1	-	-	-	-	-	#5	-	< 0.1
Longtom BELONIDAE	-	-	#4	-	-	-	-	-	#4	-	< 0.1
Estuary cod *Epinephelus spp.*	#2	-	-	-	-	-	#1	-	#3	-	< 0.1

Table 23 (continued)

	TOTAL DISCARD FOR WHOLE FISHERY										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Black trevally (spinefoot) *Siganus spp.*	-	-	-	-	#1	-	#1	-	#2	-	< 0.1
Mud crab *Scylla serrata*	#1	-	-	-	-	-	#1	-	#2	-	< 0.1
Painted grinner *Trachinocephalus myops*	-	-	-	-	#2	-	-	-	#2	-	< 0.1
Silver trevally *Pseudocaranx dentex*	-	-	#1	-	#1	-	-	-	#2	-	< 0.1
Toadfish Tetraodontidae	#1	-	-	-	#1	-	-	-	#2	-	< 0.1
Bullrout *Notesthes robusta*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Giant trevally *Caranx ignobilis*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Hammerhead shark *Sphyrna spp.*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Moses perch *Lutjanus russelli*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
River garfish *Hyphorhamphus regularis*	-	-	-	-	-	-	#1	-	#1	-	< 0.1
Striped catfish *Plotosus lineatus*	-	-	-	-	#1	-	-	-	#1	-	< 0.1
Wirrah *Acanthistius ocellatus*	#1	-	-	-	-	-	-	-	#1	-	< 0.1
Unidentified fish	#3	-	-	-	-	-	-	-	#3	-	< 0.1
Total Taxa	**17**		**12**		**15**		**14**		**26**		

Expanded estimates of discard have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

3.6.2. *Boat fishery*

Recreational fishers in the boat-based fishery reported discarding 24 taxa whilst fishing in the lower Macleay River during the survey period (Table 24). We estimated that approximately 11,860 fish and crustaceans (± 1,040 individuals - approximate SE) were discarded by daytime boat-based recreational fishers in the lower Macleay River during the survey period (Table 24) and that this recreational discard consisted almost exclusively of finfish (>99% of harvest) - (Table 24). This boat-based discard represents 34.6%, by number, of the daytime discard for the total fishery (boat and shore combined). The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈5,670 - 47.8%), dusky flathead (≈2,750 - 23.2%), luderick (≈2,650 - 22.4%), sand whiting (≈370 - 3.1%), tailor (≈300 - 2.6%) and silver batfish (≈40 - 0.4%) - (Table 24). These six taxa, by number, accounted for 99.5% of the daytime recreational discard for boat-based fishers during the survey period (Table 24).

Table 24. Monthly and total discard estimates (number of individuals) and standard errors for taxa taken by boat-based recreational fishers in the Macleay River for the survey period (July 1 - October 31, 2001).

	BOAT-BASED DISCARD										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Yellowfin bream *Acanthopagrus australis*	2,402	± 573	1,117	± 241	660	± 174	1,489	± 201	5,668	± 676	47.8
Dusky flathead *Platycephalus fuscus*	660	± 195	564	± 105	561	± 136	965	± 335	2,750	± 424	23.2
Luderick *Girella tricuspidata*	1,909	± 624	443	± 102	177	± 83	124	± 92	2,653	± 645	22.4
Sand whiting *Sillago ciliata*	136	± 50	23	± 11	56	± 29	156	± 100	371	± 116	3.1
Tailor *Pomatomus saltatrix*	135	± 71	40	± 28	70	± 53	58	± 28	303	± 97	2.6
Silver batfish *Monodactylus argenteus*	17	± 13	19	± 17	-	-	7	± 7	43	± 23	0.4
Stingrays & stingarees Dasyatidae & Urolophidae	3	± 3	4	± 4	30	± 27	6	± 4	43	± 28	0.4
Large-toothed flounder *Pseudorhombus arsius*	-	-	#7	-	#1	-	-	-	#8	-	<0.1
Mulloway *Argyrosomus japonicus*	#4	-	#1	-	-	-	-	-	#5	-	<0.1
Longtom BELONIDAE		-	#3	-	-	-	-	-	#3	-	<0.1
Estuary cod *Epinephelus spp.*	#2	-	-	-	-	-	-	-	#2	-	<0.1
Painted grinner *Trachinocephalus myops*	-	-	-	-	#2	-	-	-	#2	-	<0.1

Table 24 (continued)

	BOAT-BASED DISCARD										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Black trevally (spinefoot) *Siganus spp.*	-	-	-	-	#1	-	-	-	#1	-	<0.1
Bullrout *Notesthes robusta*	-	-	-	-	#1	-	-	-	#1	-	<0.1
Giant trevally *Caranx ignobilis*	#1	-	-	-	-	-	-	-	#1	-	<0.1
Hammerhead shark *Sphyrna spp.*	-	-	-	-	#1	-	-	-	#1	-	<0.1
Moses perch *Lutjanus russelli*	-	-	-	-	-	-	#1	-	#1	-	<0.1
Mud crab *Scylla serrata*	-	-	-	-	-	-	#1	-	#1	-	<0.1
Silver trevally *Pseudocaranx dentex*	-	-	-	-	#1	-	-	-	#1	-	<0.1
Striped catfish *Plotosus lineatus*	-	-	-	-	#1	-	-	-	#1	-	<0.1
Tarwhine *Rhabdosargus sarba*	#1	-	-	-	-	-	-	-	#1	-	<0.1
Toadfish Tetraodontidae	-	-	-	-	#1	-	-	-	#1	-	<0.1
Wirrah *Acanthistius ocellatus*	#1	-	-	-	-	-	-	-	#1	-	<0.1
Unidentified fish	#2	-	-	-	-	-	-	-	#2	-	<0.1
Total Taxa	**13**		**10**		**14**		**9**		**24**		

Expanded estimates of discard have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

3.6.3. Shore fishery

Recreational fishers in the shore-based fishery reported discarding 18 taxa whilst fishing in the lower Macleay River during the survey period (Table 25). We estimated that approximately 22,440 fish and crustaceans (± 1,780 individuals - approximate SE) were discarded by daytime shore-based recreational fishers in the lower Macleay River during the survey period (Table 25) and that this recreational discard consisted almost exclusively of finfish (>99% of harvest) - (Table 25). This shore-based discard represents 65.4%, by number, of the daytime discard for the total fishery (boat and shore combined). The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈16,590 – 73.8%), luderick (≈2,550 - 11.4%), sand whiting (≈880 – 3.9%), dusky flathead (≈840 – 3.7%), tailor (≈740 – 3.3%) and silver batfish (≈420 - 1.9%) - (Table 25). These six taxa, by number, accounted for 98.0% of the daytime recreational discard for shore-based fishers during the survey period (Table 25).

Table 25. Monthly and total discard estimates (number of individuals) and standard errors for taxa taken by shore-based recreational fishers in the Macleay River for the survey period (July 1 - October 31, 2001).

	SHORE-BASED DISCARD										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Yellowfin bream *Acanthopagrus australis*	7,476 ±	878	4,591 ±	1,086	2,355 ±	444	2,171 ±	580	16,593 ±	1,576	73.8
Luderick *Girella tricuspidata*	1,734 ±	441	586 ±	371	203 ±	144	26 ±	26	2,549 ±	594	11.4
Sand whiting *Sillago ciliata*	128 ±	69	89 ±	88	28 ±	28	630 ±	322	875 ±	342	3.9
Dusky flathead *Platycephalus fuscus*	263 ±	99	21 ±	13	306 ±	178	250 ±	77	840 ±	218	3.7
Tailor *Pomatomus saltatrix*	306 ±	170	405 ±	265	27 ±	17	-	-	738 ±	315	3.3
Silver batfish *Monodactylus argenteus*	325 ±	204	11 ±	11	-	-	88 ±	80	424 ±	219	1.9
Mullet Mugilidae	60 ±	60	69 ±	44	-	-	69 ±	52	198 ±	90	0.9
Stingrays & stingarees Dasyatidae & Urolophidae	15 ±	12	81 ±	81	13 ±	13	-	-	109 ±	82	0.5
Tarwhine *Rhabdosargus sarba*	61 ±	33	-	-	3 ±	3	-	-	64 ±	33	0.3
Large-toothed flounder *Pseudorhombus arsius*	20 ±	15	13 ±	13	-	-	11 ±	11	44 ±	23	0.2
Estuary cod *Epinephelus spp.*	-	-	-	-	-	-	#1	-	#1	-	<0.1
Black trevally (spinefoot) *Siganus spp.*	-	-	-	-	-	-	#1	-	#1	-	<0.1

Table 25 (continued)

	SHORE-BASED DISCARD										
	July 2001		August 2001		September 2001		October 2001		Total		%
Taxon	No.	SE	No.	SE	No.	SE	No.	SE	No.	SE	total
Longtom BELONIDAE	-	-	#1	-	-	-	-	-	#1	-	<0.1
Mud crab *Scylla serrata*	#1	-	-	-	-	-	-	-	#1	-	<0.1
River garfish *Hyphorhamphus regularis*	-	-	-	-	-	-	#1	-	#1	-	<0.1
Silver trevally *Pseudocaranx dentex*	-	-	#1	-	-	-	-	-	#1	-	<0.1
Toadfish Tetraodontidae	#1	-	-	-	-	-	-	-	#1	-	<0.1
Unidentified fish	#1	-	-	-	-	-	-	-	#1	-	<0.1
Total Taxa	**13**		**11**		**7**		**10**		**18**		

Expanded estimates of discard have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.

4. DISCUSSION

4.1. Overview of survey design

Recreational fishing surveys of sound statistical design are essential for the collection of statistically unbiased information. In the absence of reliable information, usually the result of flawed survey designs, the interpretation of survey data can become equivocal and management decisions cannot be justified scientifically. The theoretical framework for valid survey designs has been readily available for a long time (see Cochran 1953, Yates 1965) and these texts provide detailed descriptions of the logistic and statistical issues that need to be addressed when planning and running surveys. Detailed recommendations concerning the reporting of survey findings were published in 1948 by The United Nations Sub-Commission on Statistical Sampling (Yates 1965 reproduces the recommendations). These recommendations clearly identify many important issues that need to be addressed in order to evaluate the validity of survey findings. These issues include detailed descriptions of: (a) the survey aims; (b) the survey design, which includes the method of sample selection and the designation of sampling units; and (c) the survey frame (spatial and temporal). Further, it was recommended that when reporting survey results, the authors should provide sufficient information for an assessment of: (1) the survey accuracy - which can be done by minimising bias with good survey design, by providing evidence of the completeness of frame coverage and by quantifying the level of non-response errors such as refusal rates; (2) the survey precision - which can be done by reporting the precision of estimates derived from data; and (3) the integrity of survey data - which can be done by providing information about various quality assurance issues.

An assessment of a recreational fishery requires a specialised type of survey design but such assessments still require that randomly selected samples from a population of known size are used to estimate parameters for the entire population. Whilst, there have been recent advances in the theoretical understanding of recreational fishing survey designs and the statistical analysis of survey data (Robson and Jones 1989, Hoenig *et al*. 1993 and 1997, Pollock *et al*. 1994 and 1997, Jones *et al*. 1995), the theoretical basis of roving survey and access point survey designs, the most commonly used on-site survey methods, have been readily available for many years (Robson 1960 and 1961).

The use of complemented survey methods to estimate separately the effort, harvest and discard of the boat-based and shore-based fisheries separately in the lower Macleay River recognised that important differences existed between these two fisheries. We used stratified random sampling procedures as the basis of the survey design and integrated many data quality checks into the survey work (see Methods). In summary, this survey provides valuable baseline information about the boat-based and shore-based recreational fisheries in the lower Macleay River, collected using statistically sound survey methods which, if repeated, can be used to assess future changes in the fishery.

4.2. Demography of the recreational fishing population

We found that the recreational fishing population of the lower Macleay River was dominated by males - 82% of the boat-based fishers and 79% of the shore-based fishers interviewed were male (Table 7). It is a well established fact that recreational fishing is a male dominated activity in Australia (see McGlennon 1995 for a review of national and statewide demographic characteristics of recreational fishing populations). A national study and all six statewide studies completed during the period 1978 to 1987 show that the proportion of male participants in the recreational fishing population ranged from approximately 67% to 75% (McGlennon 1995). The slightly higher proportions recorded during our on-site survey in the lower Macleay River were probably a reflection of the avidity of male fishers. It is well known that fishers are sampled in proportion to their avidity during on-site surveys and that off-site surveys, such as the telephone surveys used to collect statewide participation rates and demographics, sample fishers with equal probability (Pollock *et al*. 1994).

We found that approximately 48% of the fishers interviewed were of local origin, ranging from approximately 43% from the local area in the boat-based fishery to approximately 51% in the shore-based fishery (Table 8). It is not possible to use these data to assess whether the closure of the river to recreational fishing had an impact on tourist numbers in the area. However, these data are useful as a baseline for assessing future changes in the fishery.

4.3. Recreational effort, harvest and discard

We estimated that approximately 78,800 fisher hours of daytime recreational effort was expended in the lower Macleay River during the survey period - July to October 2001 inclusive (Table 2). The highest levels of effort were found in July (approximately 26,900 fisher hours) and August (approximately 23,900 fisher hours), while the lowest levels of effort were recorded in September (approximately 12,800 fisher hours) and October (approximately 15,200 fisher hours). This monthly pattern of effort is similar to the monthly effort trend found in the Richmond River. A concurrent survey in the lower Richmond River found highest monthly effort in July, an intermediate level of effort in August and the lowest levels of effort were recorded during September and October 2001 (Steffe and Macbeth 2002). Similarly, West and Gordon (1994) surveyed a much larger part of the Richmond River during 1988 and 1989 and reported monthly estimates of angling effort of approximately 21,500 angler hours for July, approximately 20,000 angler hours for August, approximately 9,500 angler hours for September and approximately 18,000 angler hours for October. The apparent similarities in monthly effort patterns in all three studies suggests that these effort data are showing a seasonal trend.

We recorded 16 taxa in the retained catch of recreational fishers accessing the lower Macleay River fishery by boat and from the shore during the survey period (Table 17). We estimated that approximately 45,300 fish and crustaceans (± 4,205 individuals - approximate SE) were harvested by daytime recreational fishers from the lower Macleay River during the survey period (Table 17) and that this recreational harvest consisted almost exclusively of finfish (>99% of harvest) - (Table 17). The six most commonly harvested taxa, by number, during the survey period were luderick (≈29,110 fish - ≈ 16.5 tonnes), yellowfin bream (≈9,250 - ≈ 4.7 tonnes), dusky flathead (≈3,760 - ≈ 1.9 tonnes), striped seapike (≈1,220 - ≈ 0.1 tonnes), tailor (≈670 - ≈ 0.3 tonnes), and sand mullet (≈600 - < 0.1 tonnes) - (Tables 17 and 18). These six taxa, by number, accounted for 98.5% of the daytime recreational harvest during the survey period (Table 17). The species composition and the selective nature of the recreational harvest (i.e. six species making the bulk of the harvest) in the current study are consistent with the findings of other surveys (West and Gordon 1994, Steffe and Macbeth 2002, NSW Fisheries unpublished data). The six main species in the recreational harvest of the lower Richmond River during the same period were luderick, yellowfin bream, dusky flathead, sand mullet, tailor and sand whiting and these six taxa, by number, accounted for 97.3% of the daytime recreational harvest (Steffe and Macbeth 2002). The six main species in the recreational harvest during the Richmond River survey in 1988 and 1989 were yellowfin bream, southern herring, dusky flathead, sand whiting, tailor and luderick and these species, by number, accounted for approximately 95% of the harvest (West and Gordon 1994). The six main species in the recreational harvest during the March to July 1990 period were yellowfin bream, luderick, dusky flathead, mulloway, southern herring and sand whiting and these species, by number, accounted for 98.3% of the harvest (NSW Fisheries unpublished data).

These comparisons indicate that great similarities exist between the recreational fisheries in the Richmond and Macleay Rivers. The limited comparison between the 1990 survey data and the current study suggests that there have not been any major changes in the structure of the recreational fishery in the lower Macleay River. Recreational anglers are still targeting and harvesting much the same species in the river and the monthly patterns of targeting and harvesting that we have documented are consistent with normal seasonal changes observed in the lower Richmond River.

The size of the recreational harvest taken during the four month survey period can be put in context by considering the relative sizes of the fish mortality caused by the major flooding and subsequent deoxygenation of the lower reaches of the Macleay river during the middle of March 2001. Westlake and Copeland (2002) consulted local Fisheries officers, local council staff, commercial and recreational fishers and members of the general public to determine the size of the fish-kill in the lower Macleay River. Westlake and Copeland (2002) have estimated the number of dead fish in a 1.5 km stretch of the lower Macleay River, near the town of South West Rocks, at approximately 180,000 individual fish of various species. The Macleay River fish-kill event was apparently smaller than that in the Richmond River which was estimated to have killed over two million fish, prawns, crabs and bloodworms (Westlake and Copeland 2002). Anecdotal accounts provided by local fishers indicate that the fish-kill event was concentrated in the main reach of the Macleay River and that some other areas in the river were not affected greatly. For example, local fishers observed large schools of apparently healthy fish, mainly mullet and luderick, in the Stuarts Point arm during the time of the major fish-kill in the lower Macleay River.

In comparison, the number of fish and crabs harvested by recreational fishers during the survey period were estimated as approximately 45,300 individuals (Table 17) which is approximately one quarter of the size of the mortality estimate provided by Westlake and Copeland (2002) for a 1.5 km stretch of the lower Macleay River in mid-March 2001. The two main species taken by recreational fishers, by number, during the survey period were luderick (64.2% of total harvest) and yellowfin bream (20.4% of total harvest) – (Table 17). The highest monthly estimates of harvest for luderick and yellowfin bream were recorded during July with harvest levels declining in the subsequent months. This suggests that large populations of luderick and yellowfin bream were resident in the lower Macleay River when it was re-opened to limited recreational fishing. A combination of factors which are not mutually exclusive may explain the apparent abundance of luderick and yellowfin bream in the river following the flood event. First, it is common for large schools of luderick and yellowfin bream to migrate between estuaries on the mid-north coast during the Winter and Spring seasons. Second, it is possible that the water quality remained good in some areas within the Macleay river system during the time of the major fish-kill in the main arm of the river and that these areas of good water quality were used by fish as refuges. Fish surviving in these refuge areas could have recolonised the main river channel as soon as there was an improvement in water quality. The anecdotal accounts provided by local fishers of large schools of fish in the Stuarts Point arm support this refuge area hypothesis. Third, the availability of food was not a limiting factor for luderick in the lower Macleay River after the flood event. Luderick are mainly herbivorous and it is believed that the algal food source of luderick in the lower Macleay River was not reduced greatly following the flood event. In contrast, the benthic food source of carnivorous and omnivorous fish such as yellowfin bream and dusky flathead may have been reduced by the fish-kill event and this in turn could have had an adverse effect on localised fish abundance. Westlake and Copeland (2002) provided evidence of mass mortality of prawns and blood worms, important food sources for many species of fish, during the Richmond River fish-kill. We believe it is plausible to suggest that the populations of prawns and worms would also have been impacted adversely in the lower Macleay River during the time of the large fish-kill (see Macbeth *et al.* 2002), however, the magnitude of any potential reduction in the populations of these taxa remains unknown.

Recreational fishers (boat-based and shore-based) reported discarding 26 taxa whilst fishing in the lower Macleay River during the survey period (Table 23). We estimated that approximately 34,310 fish and crabs (± 2,060 individuals - approximate SE) were discarded by daytime recreational fishers in the lower Macleay River during the survey period (Table 23) and that this recreational discard consisted almost exclusively of finfish (>99% of harvest) - (Table 23). The six most commonly discarded taxa, by number, during the survey period were yellowfin bream (≈22,260 - 64.8%), luderick (≈5,200 - 15.2%), dusky flathead (≈3,590 - 10.5%), sand whiting (≈1,250 – 3.6%), tailor (≈1,040 – 3.0%), and silver batfish (≈470 - 1.4%) - (Table 23). These six taxa, by number, accounted for 98.5% of the total daytime recreational discard during the survey period (Table 23). The great majority of discarded yellowfin bream (94.7%), sand whiting (97.6%), luderick (82.9%), dusky flathead (76.7%) and tailor (75.0%) were below the legal minimum length. Discard data should be viewed with some caution because they are self-reported and less accurate than harvest data, which are collected by direct observation. Consequently, discard data suffer from additional biases such as rounding errors when reporting discard numbers, fish identification errors when reporting the species that were discarded, and recall problems when providing information about their discards. Even so, these discard data show that recreational fishers were catching and returning to the water large numbers of juvenile fish which suggests that the juveniles of these popular angling species were abundant in the lower Macleay River during the time of the survey.

4.4. Indicators of recreational fishing quality

Reliable indicators of recreational fishing quality for estuarine fisheries can provide a cost-effective means for monitoring and comparing the relative quality of important recreational fisheries. We have presented four indicators in this study: the proportion of unsuccessful fishing parties, non-directed harvest rates for the boat-based and shore-based fisheries, non-directed discard rates for the boat-based and shore-based fisheries and size-frequency distributions for some important taxa harvested by the recreational sector. The proportion of unsuccessful fishing parties is a measure of "lack of success" and it is believed that a strong positive correlation exists between the experience of fishers and the size of their harvests. That is, the least experienced fishers tend to catch fewer fish and the more experienced fishers tend to have larger harvests. Therefore, changes in the proportion of unsuccessful fishing parties through time would provide an indication of changes in a fishery (beneficial or detrimental) because they affect the largest and most inexperienced group of fishers in the recreational fishing population. The proportion of unsuccessful boat-based fishing parties ranged from approximately 22% to 51% on a monthly basis (Fig. 2) whilst the proportion of unsuccessful shore-based fishing parties was relatively higher ranging from approximately 54% to 74% on a monthly basis (Fig. 2). In both fisheries the lowest proportion of unsuccessful fishing trips was recorded during July, immediately after the river was re-opened to recreational fishing, and higher proportions of unsuccessful fishing parties were recorded in the following months (Fig. 2). These data suggest that the quality of recreational fishing was best in July after the river had been re-opened to recreational fishing and that there had been a gradual decline in fishing quality in the following months. The reason for these trends in the boat and shore fisheries was probably a combination of seasonal fish abundances and the large amount of fishing effort that occurred immediately after the fishery was re-opened.

The harvest rates and discard rates we calculated and presented are based on the total non-directed fishing effort. We provide harvest rate comparisons for luderick (Table 26), yellowfin bream (Table 27) and dusky flathead (Table 28) taken by boat-based and shore-based recreational fishers during this study, a concurrent survey done in the Richmond River (Steffe and Macbeth 2002), the recreational shore and boat fisheries in Lake Macquarie during the 1999 Winter and Spring seasons (Steffe and Chapman 2002), and the recreational boat-based fishery in Tuross Lake during the 1999 Winter and Spring seasons (Steffe and Chapman in prep.). It should be noted that seasonal harvest rate estimates will tend to be lower than the peak monthly harvest rate estimate because seasonal harvest rates incorporate any variability that occurs on smaller temporal scales (e.g. monthly or weekly variability). Even so, these seasonal harvest rates provide a general baseline that can be used to evaluate the relative size of the monthly harvest rates.

The harvest rates observed during this four month survey are similar to the comparable harvest rate data collected in other estuarine fisheries in New South Wales (see Tables 26, 27 and 28). The boat-based harvest rate for luderick in the lower Macleay River during July 2001 is the highest harvest rate for this species among the tabulated comparisons for the boat-based fisheries (Table 26). The monthly harvest rates for yellowfin bream and dusky flathead taken by boat-based fishers in the lower Macleay River all fall within the range of harvest rates recorded from other estuaries (Tables 27 & 28). The monthly harvest rates for luderick taken by shore-based fishers in the lower Macleay were relatively high but within the range of harvest rates recorded from other estuaries (Table 26). The shore-based harvest rate for yellowfin bream during July 2001 in the lower Macleay River is the highest harvest rate for this species among the tabulated comparisons for the shore-based fisheries (Table 27), however, this harvest rate was only marginally higher than that recorded in the Richmond River during the same month. Dusky flathead harvest rates for shore-based fishers tended to be relatively low across all estuaries (Table 28). The highest shore-based harvest rate for dusky flathead among the tabulated comparisons was recorded during September 20001 in the lower Macleay River (Table 28). The harvest rate similarities among estuarine fisheries suggest that the quality of recreational fishing was quite good for boat-based and shore-based fishers during the survey period in the lower Macleay River. A similar conclusion is reached when examining discard rate data. High rates of discard were reported for the main species of recreational interest during the survey period (Tables 10 to 15) indicating that juvenile fish were abundant in the lower Macleay River. The use of harvest rates and discard rates as indicators of recreational fishing quality would be improved by using the directed fishing effort that is targeted at a particular species of interest. In this way, a multi-species fishery could be partitioned according to the targeting preferences of fishers and more accurate harvest rate comparisons could be made among sites and through time (Steffe and Murphy 1995).

The use of size-frequency distributions complements the interpretations made from harvest rate data. For example, it is conceivable that the harvest in a fishery, measured in terms of the number of fish taken, could remain constant through time but that the average size of the fish has become smaller. The regular monitoring of size-frequency distributions taken from the recreational fishery would allow the detection of this type of change in the fishery. The size frequency distributions of luderick, yellowfin bream, dusky flathead, sand whiting and tailor (Fig. 3) that were harvested by recreational fishers during the survey period are similar to size frequency distributions found in other NSW estuarine fisheries at the same time of year (West and Gordon 1994, Steffe and Chapman 2002). It is noteworthy that large individuals that were highly-prized by fishers were commonly observed in the recreational harvest indicating that the quality of recreational fishing opportunities in this fishery were quite good (Fig. 3).

Size-frequency distributions of species having minimum legal length restrictions are also useful for evaluating compliance rates for the fishery. The proportion of undersized fish in the recreational harvest could also be used as an important indicator of fishing quality because the rate of compliance with regulations may be directly linked to the availability of legal sized fish to the recreational fishing population. For example, the proportion of undersized fish retained would be expected to be low when legal sized fish are abundant in a fishery, and conversely, in fisheries that contain relatively low numbers of legal sized fish it should be expected that compliance rates would be lower and that the proportion of undersized fish retained would be higher. The proportions of undersized fish retained by recreational fishers in the lower Macleay River fishery (boat and shore-based) were comparable to rates measured in some other estuarine fisheries in NSW (West and Gordon 1994, Steffe and Chapman 2002). We found that the proportions of under-sized yellowfin bream and luderick in the recreational harvest were extremely low (2.1% and 1.0% respectively), indicating good compliance with fisheries regulations (Fig. 3a & 3b). We did not record any under-sized tailor in the recreational harvest but this figure is based on a small number of fish (Fig. 3e). The proportions of under-sized dusky flathead and sand whiting in the recreational harvest were around 8% (Fig. 3c & 3d).

The use of these indicators is not intended to be an exhaustive analysis of the recreational survey data. We recommend that further analyses be done on the survey data to provide additional indicators, which could be used to assess future changes in the lower Macleay River fishery.

Table 26. Recreational harvest rate estimates (fish per fisher hour ± standard error) for Luderick (*Girella tricuspidata*) taken by: (a) boat-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie and in Tuross Lake during Winter and Spring 1999; (b) boat-based fishers in the Richmond River and Macleay River during the period July to October 2001; (c) shore-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie during Winter and Spring 1999; and (d) shore-based fishers in the Richmond River and Macleay River during the period July to October 2001.

A. BOAT FISHERY - LUDERICK

	LAKE MACQUARIE[1]									TUROSS LAKE[2]		
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL					
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.052**	±	**0.039**	-		-	**0.046**	±	**0.037**	**0.063**	±	**0.041**
Spring 1999	**0.115**	±	**0.113**	-		-	**0.058**	±	**0.053**	**0.086**	±	**0.039**

B. BOAT FISHERY - LUDERICK

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.272**	±	**0.052**	**0.973**	±	**0.106**
August 2001	**0.200**	±	**0.051**	**0.567**	±	**0.110**
September 2001	**0.316**	±	**0.088**	**0.210**	±	**0.036**
October 2001	**0.004**	±	**0.003**	**0.074**	±	**0.029**

C. SHORE FISHERY - LUDERICK

	LAKE MACQUARIE[1]								
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL		
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	-		-	**0.688**	±	**0.114**	**0.128**	±	**0.039**
Spring 1999	**0.016**	±	**0.016**	**0.736**	±	**0.116**	**0.184**	±	**0.062**

D. SHORE FISHERY - LUDERICK

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.246**	±	**0.053**	**0.350**	±	**0.046**
August 2001	**0.263**	±	**0.032**	**0.431**	±	**0.131**
September 2001	**0.311**	±	**0.070**	**0.029**	±	**0.013**
October 2001	**0.066**	±	**0.020**	**0.026**	±	**0.019**

[1] Steffe and Chapman (2002)
[2] Steffe and Chapman (in preparation)
[3] Steffe and Macbeth (2002)
[4] This study

Table 27. Recreational harvest rate estimates (fish per fisher hour ± standard error) for Yellowfin Bream (*Acanthopagrus australis*) taken by: (a) boat-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie and in Tuross Lake during Winter and Spring 1999; (b) boat-based fishers in the Richmond River and Macleay River during the period July to October 2001; (c) shore-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie during Winter and Spring 1999; and (d) shore-based fishers in the Richmond River and Macleay River during the period July to October 2001.

A. BOAT FISHERY - YELLOWFIN BREAM

	LAKE MACQUARIE[1]									TUROSS LAKE[2]		
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL					
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.058**	±	**0.032**	**0.002**	±	**0.001**	**0.007**	±	**0.005**	**0.053**	±	**0.044**
Spring 1999	**0.025**	±	**0.011**	**0.036**	±	**0.022**	**0.052**	±	**0.021**	**0.066**	±	**0.038**

B. BOAT FISHERY - YELLOWFIN BREAM

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.113**	±	**0.021**	**0.096**	±	**0.023**
August 2001	**0.073**	±	**0.011**	**0.084**	±	**0.029**
September 2001	**0.031**	±	**0.023**	**0.029**	±	**0.008**
October 2001	**0.059**	±	**0.014**	**0.025**	±	**0.010**

C. SHORE FISHERY - YELLOWFIN BREAM

	LAKE MACQUARIE[1]								
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL		
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.010**	±	**0.005**	**0.007**	±	**0.004**	**0.014**	±	**0.008**
Spring 1999	**0.022**	±	**0.008**	**0.050**	±	**0.022**	**0.024**	±	**0.009**

D. SHORE FISHERY - YELLOWFIN BREAM

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.177**	±	**0.035**	**0.186**	±	**0.011**
August 2001	**0.132**	±	**0.028**	**0.152**	±	**0.027**
September 2001	**0.064**	±	**0.026**	**0.122**	±	**0.018**
October 2001	**0.033**	±	**0.010**	**0.090**	±	**0.023**

[1] Steffe and Chapman (2002)

[2] Steffe and Chapman (in preparation)

[3] Steffe and Macbeth (2002)

[4] This study

Table 28. Recreational harvest rate estimates (fish per fisher hour ± standard error) for Dusky Flathead (*Platycephalus fuscus*) taken by: (a) boat-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie and in Tuross Lake during Winter and Spring 1999; (b) boat-based fishers in the Richmond River and Macleay River during the period July to October 2001; (c) shore-based fishers in the northern Lake, southern Lake, and Swansea Channel areas of Lake Macquarie during Winter and Spring 1999; and (d) shore-based fishers in the Richmond River and Macleay River during the period July to October 2001.

A. BOAT FISHERY - DUSKY FLATHEAD

	LAKE MACQUARIE[1]									TUROSS LAKE[2]		
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL					
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.006**	±	**0.002**	**0.001**	±	**0.001**	**-**		**-**	**0.027**	±	**0.014**
Spring 1999	**0.021**	±	**0.011**	**0.022**	±	**0.015**	**0.031**	±	**0.017**	**0.133**	±	**0.034**

B. BOAT FISHERY - DUSKY FLATHEAD

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.084**	±	**0.018**	**0.049**	±	**0.022**
August 2001	**0.084**	±	**0.020**	**0.042**	±	**0.011**
September 2001	**0.066**	±	**0.019**	**0.052**	±	**0.014**
October 2001	**0.081**	±	**0.016**	**0.118**	±	**0.026**

C. SHORE FISHERY - DUSKY FLATHEAD

	LAKE MACQUARIE[1]								
	NORTHERN LAKE			SOUTHERN LAKE			SWANSEA CHANNEL		
Season/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
Winter 1999	**0.011**	±	**0.009**	**<0.001**	±	**<0.001**	**-**		**-**
Spring 1999	**-**		**-**	**-**		**-**	**0.003**	±	**0.002**

D. SHORE FISHERY - DUSKY FLATHEAD

	RICHMOND RIVER[3]			MACLEAY RIVER[4]		
Month/Year	Harvest Rate (fish/fisher hr)		SE	Harvest Rate (fish/fisher hr)		SE
July 2001	**0.033**	±	**0.008**	**0.026**	±	**0.005**
August 2001	**0.022**	±	**0.007**	**0.022**	±	**0.007**
September 2001	**0.021**	±	**0.006**	**0.062**	±	**0.018**
October 2001	**0.018**	±	**0.006**	**0.025**	±	**0.008**

[1] Steffe and Chapman (2002)

[2] Steffe and Chapman (in preparation)

[3] Steffe and Macbeth (2002)

[4] This study

4.5. Status of the recreational fisheries in the lower Macleay River

Fisheries managers and the general public will inevitably ask whether the recreational fishery (shore and boat-based) in the Macleay River has recovered from the impact of the March fish-kill event. This important question cannot be answered directly because we do not have any detailed information describing the status of estuarine fish stocks or the recreational boat and shore fisheries in the Macleay River immediately before the fish-kill event nor do we have information about other non-impacted estuarine recreational fisheries in the region that could be used as controls or reference sites. Therefore, we are restricted to making inferences about the recovery of estuarine fish stocks and the status of the recreational fisheries from limited comparisons with previous studies and by examining a number of indicators of recreational fishing quality that have been derived from the current survey.

The available information indicates that a major flood in March 2001 led to deoxygenation of the water in the lower Macleay River and this was the direct cause of a large fish-kill event in the river (Westlake and Copeland 2002). We know that: (a) large numbers of important recreational and commercial fish species such as yellowfin bream, dusky flathead, luderick, sand whiting and Australian bass were killed by the anoxic conditions; (b) large numbers of hardy species such as mullet, eels and mudcrabs were also killed; (c) large numbers of important prey animals such as school prawns were killed. The evidence strongly suggests that most fish of recreational importance were flushed from the river system, migrated actively away from areas of poor water quality or were killed by the anoxic water during the period of the fish-kill. The government responded to this fish-kill event by closing the river to recreational and commercial fishing for a period of approximately three and a half months. The lower Macleay River was re-opened to limited recreational and commercial fishing at the start of July 2001.

The recreational fishing survey data indicate that: (a) the levels of monthly fishing effort recorded were similar to effort estimates recorded during a concurrent survey in the lower Richmond River and to estimates reported from 1988 and 1989 data in a much larger part of the Richmond River system; (b) the levels of monthly effort showed a seasonal pattern; (c) the monthly patterns of targeting and harvesting by boat-based and shore-based recreational fishers were consistent with expected seasonal changes in these fisheries; (d) the quality of recreational fishing was best during July after the river had been re-opened presumably because of a combination of seasonal fish abundances and a high level of recreational fishing effort after a long period of fishery closure; (e) the species composition and the selective nature of the recreational harvest were consistent with the findings of previous survey work; (f) the harvest rates of the main angling species were similar, and in some cases higher, than comparable data from other estuarine fisheries in NSW; (g) large populations of luderick and yellowfin bream were resident within the lower Macleay River when the fishery was re-opened; (h) highly-prized, large individuals were commonly observed in the recreational harvest of luderick, dusky flathead and yellowfin bream indicating that the quality of recreational fishing opportunities in this area were quite good; (i) large numbers of juvenile fish were caught and returned to the water by recreational fishers which suggests that the juveniles of these popular angling species were abundant in the lower Macleay River during the survey period; and (j) for the main angling target species, the proportions of under-sized fish retained by recreational fishers were similar to the rates measured in some other NSW estuarine fisheries.

The interpretation of the available evidence strongly suggests that the recreational fisheries in the lower Macleay River are still productive and providing quality recreational fishing opportunities despite the adverse impacts of the March 2001 fish-kill event. We recommend that statistical power analyses be done on the dataset collected during this study before starting any future surveys or monitoring of the recreational fishery in the lower Macleay River. Power analyses are based on four parameters of statistical inference: power, significance criterion, sample size, and effect size (Cohen 1988). The use of appropriate power analyses that specify the values of power, significance criterion and effect size should be done to determine, in a scientifically defensible way, the necessary sample size needed to detect future changes in the lower Macleay River fishery.

5. RECOMMENDATIONS

When based on statistically valid survey designs, on-site surveys of recreational fishing are valuable tools for collecting information to describe the status of a recreational fishery. We recommend the use of such surveys in conjunction with fishery-independent population assessment techniques should future fish-kill events occur.

On-site recreational fishing surveys should be repeated periodically to monitor the recreational fishery in the lower Macleay River. The intervals between surveys should be relatively short. It is our opinion that intervals of 3-5 years between surveys would be sufficient for monitoring changes in the recreational fishery.

Before future surveys or monitoring programmes are done in the lower Macleay River, it is recommended that statistical power analyses should be done of the recreational fishing dataset collected during this study. Power analyses are vital for determining scientifically defensible and cost-effective survey designs that have sufficient statistical power to detect changes in the recreational fishery throughout time.

The development of robust and reliable indicators of recreational fishing quality would lead to more cost-effective ways of monitoring estuarine fisheries throughout NSW. We recommend that additional work be done to develop robust and reliable indicators of fishing quality for all recreational fisheries in NSW. This would require more detailed analyses of: (a) the data collected during this survey; and (b) the survey data collected during previous recreational fishing surveys done in NSW.

6. REFERENCES

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7. APPENDICES

Appendix 1. Glossary of technical terms. This is a modified version of the glossary provided by Pollock *et al.* (1994).

The terms in this glossary are defined in the context of recreational fishing, the focus of this report. Some terms may have slightly different (but analogous) meanings for recreational and commercial fishing.

Access point design: an on-site, intercept design that is used when fishers use defined access points to enter and leave the fishery. This method works best when there are few access points (e.g. boat ramps, wharves, breakwalls) and most fishers use these defined access points. The access point design can be used to estimate fishing effort, harvest rates and harvest and relies on complete trip interviews. (Compare *Roving design*.)

Accuracy: Degree of conformity to a true value. An accurate estimator has a small mean squared error, implying little or no bias and small standard error. (Compare *Precision.)*

Angler: Person participating in a line fishing activity. Recreational line fishing activities include trolling, drifting, fishing with lures or bait. (Compare *Fisher*.)

Angler survey: General term for any survey of anglers by an off-site method (mail, telephone, door-to-door) or an on-site method (access, roving, aerial). (Compare *Creel survey.)*

Avidity bias: Bias arising in on-site surveys when anglers are sampled in proportion to their fishing avidity (time spent fishing or frequency of fishing), not with equal probability.

Biased estimator: Estimator whose average value over many hypothetical repetitions of a study deviates from the true parameter value.

Catch rate: Number or weight of all fish caught (kept or released) per trip, per angler hour, or per some other unit of fishing effort. The catch per unit effort can be used as a measure of success rate. (Compare *Harvest rate*.)

Catch: Number or weight of all fish caught, whether the fish are kept or released. Sometimes the term is also used (less precisely) to mean harvest. (Compare *Harvest.)*

Census: Sampling of every unit in the sampled population.

Complemented survey: Survey combining two or more contact methods (e.g., a telephone survey to estimate effort and an access survey to estimate catch rate).

Complete trip interview: Interview conducted as an angler leaves the water at the end of fishing. (Compare *Incomplete trip interview.)*

Consistent estimator: Estimator that gets closer and closer to the true parameter value as the size of the sample increases.

Contact method: Any method used to contact fishers for a survey (mail, telephone, door-to-door, access, roving, or aerial).

Creel survey: On-site angler survey during which the harvests of fishers are examined by the survey agent.

Direct impact of fishing: The immediate, main effect caused by fishers on a population or stock. In any extractive fishery (recreational or commercial) this main, immediate impact can be assessed by estimating the harvest. (Compare *Indirect impact of fishing.*)

Directed fishing effort: Fishing effort directed at a particular species or group of species. (Compare *Non-directed fishing effort*.)

Directed harvest rate: A harvest rate that has been calculated using directed fishing effort and the associated harvest from that directed effort. (Compare *Non-directed harvest rate*.)

Discard: That part of the catch that is not kept. (Compare *Catch, Harvest.*)

Discard rate: Number of fish released (fish kept are not included) per trip, per angler hour, or per some other unit of fishing effort. The discard per unit effort can be used as a measure of success rate for the released component of the catch. (Compare *Catch rate, Harvest rate*.)

Effort: See *Fishing effort.*

Estimate: Realised value of an estimator calculated from a particular sample.

Estimation methods: General term to describe the methods used to calculate estimates of population parameters (e.g. effort, harvest rate, and harvest) and estimates of their precision (e.g. variances and standard errors). (Compare *Survey methods*.)

Estimator: Formula or sample statistic used to estimate a population parameter.

Fisher: Person participating in any fishing activity. Recreational fishing activities include all forms of line fishing, bait collecting, and the setting of crab traps. (Compare *Angler*.)

Fishing effort (fishing pressure): A measure of resource use by anglers or fishers. Typical units of effort are number of trips on the water, angler hours, party hours, and boat hours.

Fishing party: A group of anglers or fishers participating in a recreational fishing activity. A fishing party can consist of a single individual or a large number of persons fishing together.

Frame: See *Sampling frame.*

Harvest: Number or weight of the fish caught that are kept, not released. (Compare *Catch.*)

Harvest rate: Number or weight of fish retained (fish released are not included) per trip, per angler hour, or per some other unit of fishing effort. The harvest per unit effort can be used as a measure of success rate. (Compare *Catch rate*.)

Incomplete trip interview: Interview conducted before an angler has finished fishing. (Compare *Complete trip interview.)*

Indirect impact of fishing: An incidental, secondary effect caused by fishers on a population or stock. In any extractive fishery (recreational or commercial) these secondary impacts may include physical and genetic changes in population structures, post-release mortality of discards, and numerous effects on fish and fish habitats caused by factors such as pollution from outboard motors, anchoring in seagrass beds, loss of lead sinkers and fishing lines. (Compare *Direct impact of fishing.*)

Independence: See *Statistical independence*.

Instantaneous count: Count of anglers/fishers or boats made quickly from an aeroplane, a vantage point (bridge, hilltop, etc.), a fast-moving boat, or an automobile. (*Compare Progressive count.*)

Large individual: Being of more than common size.

Length-of-stay bias: Bias arising in roving surveys when anglers are interviewed with probability proportional to the length of their fishing trip, not with equal probability.

Mean: The arithmetic mean or average is calculated by summing all the individual observations (sampling units) of a sample and dividing this sum by the number of observations in the sample.

Median: The value of a variable (in an ordered array) that has an equal number of observations on either side of it. The median is used to divide a frequency distribution into two halves.

Non-directed fishing effort: The combined fishing effort regardless of targeting preferences. This term refers to the amalgamation of directed effort for different species and species groups and the effort of generalist fishers that had no specific target species. (Compare *Directed fishing effort*.)

Non-directed harvest rate: A harvest rate that has been calculated using non-directed fishing effort and the associated harvest from that non-directed effort. (Compare *Directed harvest rate*.)

Non-response bias: Bias arising when people refuse or are unable to answer a survey question. (See *Refusal rate*.)

Off-site survey: A recreational fishing survey that is carried out away from the fishing sites of a defined fishery. Off-site survey methods include mail, telephone, door-to-door, logbooks, diaries and catch cards. (Compare *On-site survey*.)

On-site survey: A recreational fishing survey that is carried out at the fishing sites within a defined fishery. On-site survey methods include access point, roving, and aerial surveys. (Compare *Off-site survey*.)

Parameter: Characteristic of the population under study.

Precision: Degree of variation. A precise estimator has a small standard error (or variance). (Compare *Accuracy.*)

Probability sampling: Sampling in which all possible samples have known probabilities of being drawn.

Progressive count: Count of anglers/fishers or boats made over time as a survey agent moves through a fishery area. Within each small subarea, the count may be instantaneous. (Compare *Instantaneous count*.)

Quality assurance: A continual process of checks and refinements aimed at maximising data integrity and hence also improving the credibility of survey results.

Random sampling: Independent sampling in which the replicate sampling units were selected at random for inclusion in the sample.

Recall bias: Bias arising when anglers/fishers inaccurately remember past events or the time in which they occurred.

Recreational fishing survey: General term for any survey of fishers by an off-site or on-site method. (Compare *Angler survey*.)

Refusal rate: The proportion of fishers or fishing parties that refused or were unable to answer survey questions. The refusal rate is an important measure of the non-response error within a survey. (See *Non-response bias*.)

Response error: Error arising because of recall, prestige, or rounding bias, or because an angler lied, misinterpreted a question, misidentified a species, or measured fish incorrectly.

Roving design: an on-site, intercept design that is used when access to a fishery is diffuse, occurring at too many points for the use of an access point survey. The roving design can be used to estimate fishing effort, harvest rates and harvest but relies on incomplete trip interviews. (Compare *Access point design*.)

Sample: Group of sampling units drawn from the sampled population.

Sample size: The number of sampling units in the sample.

Sampled population: Actual population from which information is collected. (Compare *Target population.*)

Sampling error: Error arising from improper sample selection, an incomplete sampling frame, duplications within the frame, avidity bias, or length-of-stay bias.

Sampling frame: Complete set or list of all sampling units.

Sampling unit: Basic unit of sampling (e.g., an angler/fisher, a fishing party, a fishing day or a particular combination of space and time).

Standard error: Square root of an estimator's variance.

Statistic: Characteristic of the sample drawn.

Statistical independence: The inherent assumption in all survey work that the sampling error associated with each sample is independent of the other samples. Random sampling is the mechanism used to safeguard against lack of independence problems.

Stratified sampling: Independent sampling within two or more defined subgroups of a sampled population. (See *Stratum*).

Stratum: A defined subgroup of a sampled population that does not overlap with any other subgroups and is of known size (See *Stratified sampling*.)

Survey error: General term embracing sampling, response, and non-response errors.

Survey methods: General term to describe the sampling methods used to survey the fishery (e.g. frame definition, levels of stratification, contact methods used, definition of basic sampling units, sample size). (Compare *Estimation methods*.)

Target population: Population about which information is desired. (Compare *Sampled population*.)

Unbiased estimator: Estimator whose average (or expected) value over many hypothetical repetitions of a study is the true parameter value.

Variance: The average (or expected) value of the squared deviations of an estimator from its expected value.

Appendix 2.1. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for yellowfin bream (*Acanthopagrus australis*) taken by boat-based fishers in the Macleay River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	0.148	±	0.053	0.287	±	0.079
	Weekend	0.265	±	0.071	0.531	±	0.132
	Total	**0.182**	±	**0.043**	**0.358**	±	**0.068**
August 2001	Weekday	0.161	±	0.072	0.236	±	0.078
	Weekend	0.142	±	0.027	0.443	±	0.129
	Total	**0.157**	±	**0.054**	**0.290**	±	**0.067**
September 2001	Weekday	0.029	±	0.021	0.213	±	0.057
	Weekend	0.125	±	0.025	0.250	±	0.043
	Total	**0.061**	±	**0.016**	**0.225**	±	**0.041**
October 2001	Weekday	0.065	±	0.027	0.391	±	0.019
	Weekend	0.026	±	0.012	0.544	±	0.120
	Total	**0.054**	±	**0.020**	**0.435**	±	**0.037**

Appendix 2.2. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for luderick (*Girella tricuspidata*) taken by boat-based fishers in the Macleay River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	1.924	±	0.195	0.307	±	0.089
	Weekend	1.345	±	0.206	0.305	±	0.098
	Total	**1.756**	±	**0.151**	**0.306**	±	**0.069**
August 2001	Weekday	1.014	±	0.286	0.104	±	0.032
	Weekend	1.056	±	0.195	0.110	±	0.038
	Total	**1.025**	±	**0.218**	**0.106**	±	**0.026**
September 2001	Weekday	0.390	±	0.095	0.037	±	0.017
	Weekend	0.563	±	0.112	0.074	±	0.039
	Total	**0.448**	±	**0.073**	**0.050**	±	**0.017**
October 2001	Weekday	0.171	±	0.106	0	±	0
	Weekend	0.190	±	0.075	0.049	±	0.039
	Total	**0.177**	±	**0.078**	**0.018**	±	**0.012**

Appendix 2.3. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for dusky flathead (*Platycephalus fuscus*) taken by boat-based fishers in the Macleay River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	0.098	±	0.053	0.092	±	0.035
	Weekend	0.076	±	0.020	0.112	±	0.024
	Total	**0.091**	±	**0.038**	**0.098**	±	**0.026**
August 2001	Weekday	0.058	±	0.018	0.137	±	0.027
	Weekend	0.119	±	0.022	0.164	±	0.065
	Total	**0.074**	±	**0.015**	**0.144**	±	**0.026**
September 2001	Weekday	0.093	±	0.043	0.149	±	0.047
	Weekend	0.146	±	0.031	0.207	±	0.029
	Total	**0.111**	±	**0.030**	**0.168**	±	**0.033**
October 2001	Weekday	0.259	±	0.066	0.291	±	0.125
	Weekend	0.276	±	0.056	0.264	±	0.068
	Total	**0.264**	±	**0.050**	**0.283**	±	**0.091**

Appendix 2.4. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for sand whiting (*Sillago ciliata*) taken by boat-based fishers in the Macleay River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	0.011	±	0.008	0.018	±	0.009
	Weekend	0.001	±	0.001	0.028	±	0.013
	Total	**0.008**	±	**0.006**	**0.021**	±	**0.008**
August 2001	Weekday	-		-	-		-
	Weekend	0.002	±	0.002	0.022	±	0.010
	Total	**0.001**	±	**0.001**	**0.006**	±	**0.002**
September 2001	Weekday	0.003	±	0.003	0.004	±	0.004
	Weekend	0.012	±	0.008	0.034	±	0.014
	Total	**0.006**	±	**0.003**	**0.014**	±	**0.006**
October 2001	Weekday	-		-	0.047	±	0.025
	Weekend	0.027	±	0.017	0.018	±	0.012
	Total	**0.008**	±	**0.005**	**0.039**	±	**0.018**

Appendix 2.5. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for tailor (*Pomatomus saltatrix*) taken by boat-based fishers in the Macleay River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	0.002	±	0.002	0.012	±	0.010
	Weekend	0.009	±	0.005	0.031	±	0.019
	Total	**0.004**	±	**0.002**	**0.018**	±	**0.009**
August 2001	Weekday	-		-	0.010	±	0.010
	Weekend	0.005	±	0.003	0.015	±	0.009
	Total	**0.001**	±	**0.001**	**0.011**	±	**0.008**
September 2001	Weekday	-		-	0.005	±	0.005
	Weekend	0.009	±	0.006	0.029	±	0.026
	Total	**0.003**	±	**0.002**	**0.013**	±	**0.009**
October 2001	Weekday	-		-	0.010	±	0.007
	Weekend	0.005	±	0.005	0.025	±	0.016
	Total	**0.001**	±	**0.001**	**0.014**	±	**0.007**

Appendix 2.6. Recreational harvest rate and discard rate estimates (fish per boat hour ± standard error) for mulloway (*Argyrosomus japonicus*) taken by boat-based fishers in the Macleay River during the survey period (July 1 - October 31, 2001).

Month/Year	Day-Type	Harvest Rate (fish/boat hr)		SE	Discard Rate (fish/boat hr)		SE
July 2001	Weekday	-		-	-		-
	Weekend	0.016	±	0.010	0.007	±	0.006
	Total	**0.005**	±	**0.003**	**0.002**	±	**0.002**
August 2001	Weekday	-		-	-		-
	Weekend	0.006	±	0.004	0.001	±	0.001
	Total	**0.001**	±	**0.001**	**<0.001**	±	**<0.001**
September 2001	Weekday				-		-
	Weekend	0.009	±	0.004	-		-
	Total	**0.003**	±	**0.001**	-		-
October 2001	Weekday	0.007	±	0.007	-		-
	Weekend	-		-	-		-
	Total	**0.005**	±	**0.005**	-		-

Appendix 3. Length to weight conversion keys [W(grams) = a * L(cm)b] used to estimate weights for various taxa. Relevant details which describe the sample material used to calculate the length to weight key is provided. In all length to weights keys the sexes have been combined.

Common Name	Taxon	Sample Size	Size Range (cm)	Length to Weight Key W(grams) = a * L(cm)^b	Adjusted r^2	Region of Sample	Source of Key
Bass, Australian	*Macquaria novemaculeata*	845	5.0 – 47.6	W=0.01122*FL$^{3.091}$	0.971	Sydney Basin, NSW	Harris (1987)
Biddy, Silver	*Gerres subfasciatus*	Unpublished NSW Fisheries data used to estimate weights					
Bream, Yellowfin	*Acanthopagrus australis*	758	15.0 – 40.5	W=0.024787915*FL$^{2.99584}$	0.980	NSW	Steffe *et al.* (1996a)
Crab, Blue swimmer	*Portunus pelagicus*	186	1.3 – 9.3	W=0.9219*CL$^{2.8855}$	0.967	NSW	Ken Graham unpub. data
Flathead, Dusky	*Platycephalus fuscus*	589	20.3 – 88.0	W=0.0026864577*FL$^{3.22910}$	0.992	NSW	Steffe *et al.* (1996a)
Flounder, Small-toothed	*Pseudorhombus jenynsii*	138	15.0 – 33.4	W=0.0014768963*FL$^{3.62935}$	0.961	Botany Bay, NSW	Steffe *et al.* (1996a)
Herring, Southern	*Herklotsichthys castelnaui*	557	5.2 – 18.1	W=0.0119*FL$^{3.1687}$	0.962	Botany Bay, NSW	SPCC (1981)
Luderick	*Girella tricuspidata*	186	10.0 – 38.8	W=0.0099659797*FL$^{3.22212}$	0.990	Botany Bay, NSW	SPCC (1981)
Mullet, Flat-tail	*Liza argentea*	657	10.5 – 35.8	W=0.0291*FL$^{2.7951}$	0.837	Botany Bay, NSW	SPCC (1981)
Mullet, Sand	*Myxus elongatus*	336	10.0 – 39.5	W=0.0097*FL$^{3.0967}$	0.963	Botany Bay, NSW	SPCC (1981)
Mullet, Sea	*Mugil cephalus*	216	6.9 – 43.8	W=0.0078*FL$^{3.2097}$	0.970	Botany Bay, NSW	SPCC (1981)
Mulloway	*Argyrosomus japonicus*	141	21.7 – 139.0	W=0.01355*FL$^{2.94}$	Not Given	S. A.	Hall (1986)
Salmon, Australian	*Arripis trutta*	8232	4.0 – 77.0	W=0.0132678*FL$^{3.0485}$	Not Given	Australia	Malcolm (1966)
Seapike, Long-finned	*Dinolestes lewini*	87	13.0 – 43.5	W=0.0024685959*FL$^{3.30752}$	0.995	NSW	Steffe *et al.* (1996a)
Seapike, Striped*	*Sphyraena obtusata*	-	- -	Long-finned Seapike Key Used		-	-
Tailor	*Pomatomus saltatrix*	1028	10.0 – 58.5	W=0.0075039512*FL$^{3.15753}$	0.994	NSW	Steffe *et al.* (1996a)
Whiting, Sand	*Sillago ciliata*	1198	10.0 – 39.5	W=0.0040*FL$^{3.3137}$	0.973	Botany Bay, NSW	SPCC (1981)

This study - refers to addition material collected during the survey.
Steffe *et al.* (1996a). - refers to the amalgamation of material from a variety of sources and the recalculation of a length to weight key. These sources include material from market measuring, ramp measuring, and unpublished material taken from the Botany Bay project (SPCC 1981), the Northern Rivers project and the Deep Ocean Outfall Monitoring project.
* Length to weight equation for this taxon was not available. Estimates of weight were obtained by using a length to weight key for a closely related taxon.
FL - Fork Length, ML - Mantle Length, CL - Carapace Length.

Appendix 4. Estimates of daytime recreational fishing effort (boat hours) for the boat-based fishery in the four areas in the Macleay River (Main River, Entrance, Kemps Cnr / Clybucca and Stuarts Point). Data are presented for all temporal strata and have also been combined to provide total effort estimates for the whole survey area.

		ENTRANCE			KEMPS/CLYBUCCA			STUARTS POINT			MAIN RIVER			TOTAL		
Month/Year	Day-Type	Boat Effort (boat hrs)		SE	Boat Effort (boat hrs)		SE	Boat Effort (boat hrs)		SE	Boat Effort (boat hrs)		SE	Boat Effort (boat hrs)		SE
July 2001	Weekday	950	±	248	1,273	±	369	1,197	±	337	152	±	56	3,572	±	561
	Weekend	397	±	73	700	±	160	661	±	125	140	±	51	1,898	±	221
	Total	**1,347**	±	**258**	**1,973**	±	**402**	**1,858**	±	**359**	**292**	±	**76**	**5,470**	±	**603**
August 2001	Weekday	655	±	168	1,330	±	253	718	±	134	169	±	27	2,872	±	333
	Weekend	272	±	38	529	±	166	316	±	24	176	±	76	1,293	±	188
	Total	**927**	±	**172**	**1,859**	±	**302**	**1,034**	±	**136**	**345**	±	**81**	**4,165**	±	**382**
September 2001	Weekday	224	±	46	613	±	139	428	±	92	175	±	64	1,440	±	184
	Weekend	117	±	52	369	±	110	583	±	235	78	±	58	1,147	±	271
	Total	**341**	±	**70**	**982**	±	**177**	**1,011**	±	**253**	**253**	±	**86**	**2,587**	±	**328**
October 2001	Weekday	329	±	101	1,200	±	369	823	±	67	94	±	47	2,446	±	392
	Weekend	154	±	57	549	±	109	443	±	93	77	±	46	1,223	±	161
	Total	**483**	±	**116**	**1,749**	±	**385**	**1,266**	±	**115**	**171**	±	**66**	**3,669**	±	**424**
Total	Weekday	2,158	±	319	4,416	±	597	3,166	±	380	590	±	101	10,330	±	783
	Weekend	940	±	113	2,147	±	278	2,003	±	283	471	±	118	5,561	±	429
	Total	**3,098**	±	**339**	**6,563**	±	**658**	**5,169**	±	**474**	**1,061**	±	**155**	**15,891**	±	**892**

Appendix 5. The number of individuals observed (N), the number of individuals measured (n), size range (cm), median length (cm), and mean length (cm) for all taxa measured during interviews with boat-based and shore-based recreational fishers in the Macleay River fishery during the survey period (July 1 - October 31, 2001).

	BOAT FISHERY					SHORE FISHERY					TOTAL FISHERY				
Common Name	N	n	Range	Median	Mean	N	n	Range	Median	Mean	N	n	Range	Median	Mean
Bass, Australian	-	-	- -	-	-	1	1	43	43.0	43.0	1	1	43	43.0	43.0
Biddy, Silver	1	1	12	12.0	12.0	-	-	- -	-	-	1	1	12	12.0	12.0
Bream, Yellowfin	481	443	20 – 40	26.0	26.4	476	468	20 – 47	26.0	27.0	957	911	20 – 47	26.0	26.7
Crab, Blue Swimmer	1	1	10	10.0	10.0	-	-	- -	-	-	1	1	10	10.0	10.0
Flathead, Dusky	452	412	20 – 90	40.0	41.8	90	81	30 – 68	41.0	42.6	542	493	20 – 90	40.0	41.9
Flounder, Small-toothed	3	3	22 – 28	26.0	25.3	1	1	26	26.0	26.0	4	4	22 – 28	26.0	25.5
Herring, Southern	4	4	5 – 8	7.0	6.8	-	-	- -	-	-	4	4	5 – 8	7.0	6.8
Longtom, Stout	1	1	70	70.0	70.0	-	-	- -	-	-	1	1	70	70.0	70.0
Luderick	3234	2970	20 – 48	29.0	29.5	634	575	23 – 43	30.0	29.7	3868	3545	20 – 48	29.0	29.6
Mullet, Flat-tail	-	-	- -	-	-	2	2	26 – 27	26.5	26.5	2	2	26 – 27	26.5	26.5
Mullet, Sand	-	-	- -	-	-	19	7	8 – 15	10.0	11.0	19	7	8 – 15	10.0	11.0
Mullet, Sea	-	-	- -	-	-	1	1	53	53.0	53.0	1	1	53	53.0	53.0
Mulloway	22	20	52 – 105	71.0	75.0	12	12	50 – 90	69.5	70.4	34	32	50 – 105	71.0	73.3
Salmon, Australian	4	4	50 – 75	52.0	57.3	1	1	51	51.0	51.0	5	5	50 – 75	52.0	56.0
Seapike, Striped	5	5	21 – 30	26.0	26.4	27	-	- -	-	-	32	5	21 – 30	26.0	26.4
Tailor	15	14	27 – 40	31.0	31.9	28	15	28 – 34	31.0	30.9	43	29	27 – 40	31.0	31.3
Whiting, Sand	25	24	25 – 33	27.0	27.9	13	12	20 – 33	29.0	27.6	38	36	20 – 33	27.0	27.8

SECTION 5

Miller, M. (2002). Survey of prawn trawl by-catch in the Richmond River Oceanic Fishing Closure (April – July 2001). Pages 295 – 322 in: Kennelly, S.J. and McVea, T.A. (Eds) (2002). *'Scientific reports on the recovery of the Richmond and Macleay Rivers following fish kills in February and March 2001'.* NSW Fisheries Final Report Series. No. 39. ISSN 1440-3544.

Survey of Prawn Trawl By-catch in the Richmond River Oceanic Fishing Closure (April – July 2001)

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April 2002

EXECUTIVE SUMMARY

At the beginning of February 2001 a flood event occurred in the Richmond River Catchment causing a severe fish kill in the lower reaches of the estuary. The river and adjacent off-shore waters were closed to all fishing following this fish kill.

As a component of the overall surveys done by NSW Fisheries to examine at the recovery of the river after such a large kill, investigations into the abundances of recreational and commercial species in the offshore fishing closure outside the mouth of the estuary were done using an ocean prawn trawler during the months of April, June and July.

Survey sites were chosen throughout the entire closure area, with the results indicating high by-catch to school prawn ratios. The main recreational and commercial species observed in high numbers were juvenile mulloway with lesser numbers of juvenile and small adults of tarwhine, silver biddy and large-toothed flounder.

Overall there were not a large proportion of estuarine fish species captured at these sites during each of the months surveyed, but the closure did seem to be beneficial in protecting juvenile mulloway after the flood and for the spawning of school prawns before they migrated away from the system and became susceptible to capture outside the closure.

In conclusion, it appears as though this oceanic closure subsequent to the fish kill may have had benefits to future stocks of mulloway and school prawns in the region.

1. INTRODUCTION

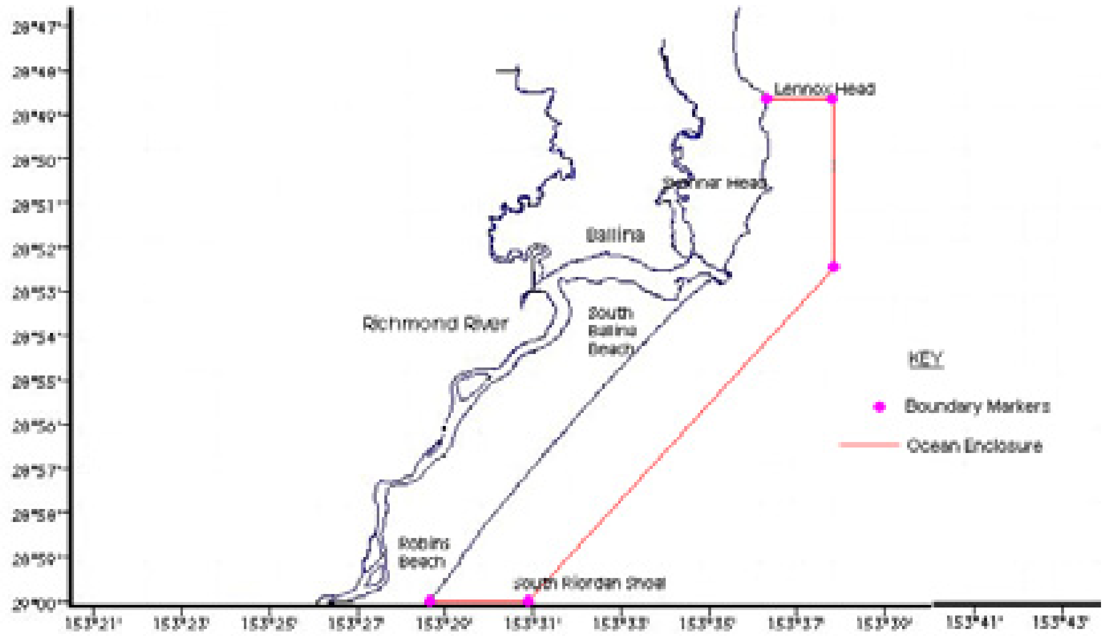
At the beginning of February 2001, a severe flooding event occurred in the upper reaches of the Richmond River Catchment. Runoff from the surrounding flood plains brought with it a large body of de-oxygenated water, resulting in a major fish kill which occurred in the lower reaches of the river approximately a week later, peaking on or around 9 February.

The river and adjacent inshore waters were closed to all fishing following this event fish kill for an initial period of three weeks from 9 February 2001. This was extended to a three month fishing closure from Ballina Bar upstream to Coraki Junction and the mean high water mark at Lennox Head, extending 5km seaward off the Ballina Bar, then southwards 16.5km to the northern tip of South Riordan Shoals, and finally back to the mean high water mark at the southern end of South Ballina Beach (see Map 1, for exact coordinates see Appendix 1).

During the period of this closure, NSW Fisheries regularly surveyed the river to determine the recovery of fish and crustacean stocks in the system, providing the necessary biological and water quality information required to make fisheries management decisions as to when or if the closure on this river and adjacent ocean waters should be lifted. During April, June and July, as part of the post-fish kill investigations, a survey using a commercial prawn trawler was conducted in the ocean closure area located off the Richmond River to examine the relative abundances of commercial and recreational fish and crustacean species present within this area. This report outlines this latter work.

2. MATERIALS AND METHODS

The prawn trawler LFB 'Kiama', based at Ballina, was used to survey fish and crustacean abundances in the ocean closure located off the mouth of the Richmond River (refer to Map 1).



Map 1. Ocean Closure – Richmond River

Scientific observers were placed on board the prawn trawler during April, June and July 2001 to conduct these surveys. The April and July trips were performed during daylight hours and the June trip was performed at night. A May survey was not possible as the prawn trawler was unavailable. It was, in fact, catching school prawns outside the closure at Evans Head and Lennox Head, which were then experiencing large catches of school prawns – thought by fishers to be a consequence of the flooding.

Sites in the survey were chosen so that they were spread evenly throughout the area from the northern to the southern-most part of the closure (see Maps 2, 3 and 4). Details of each shot, including sampling time, shot duration, coordinates, at the start and finish of each shot, depth, and number of codends used were recorded (see Tables 1, 2 and 3). After hauling each shot on board and emptying the contents onto the sorting tray, the catch was sorted by the crew and observers according to retained commercial / recreational fish and crustacean species as well as discarded by-catch (see Photos 1, 2, 3 and 4). If the entire catch of a particular species could not be counted, data were collected from a representative sample, with the total weight taken to enable a total count to be estimated. Data being collected from each tow were: the total weight of retained and discarded by-catches, and the numbers and weights of retained commercial / recreational species and their sizes (total lengths).

A species list was generated from the overall catch. Length frequency information for each of the most abundant commercial and recreational fish species captured was generated as % frequencies for those species in the catch from each shot. A ratio of school prawn to total by-catch weight in the catch was calculated.

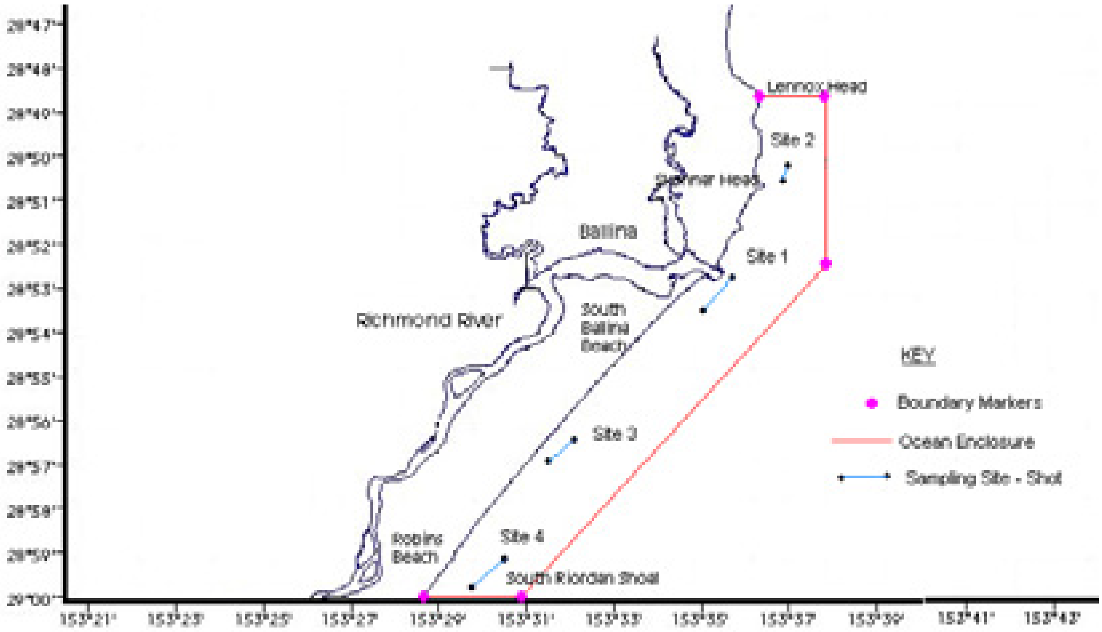
Photo 1. Preparation for the first shot of the day Ballina Bar.

Photo 2. A collection of species captured from a shot made during the survey.

Photo 3. Hauling the catch aboard the ‘Kiama’.

Photo 4. Sorting of the catch into species.

2.1. April survey operational information

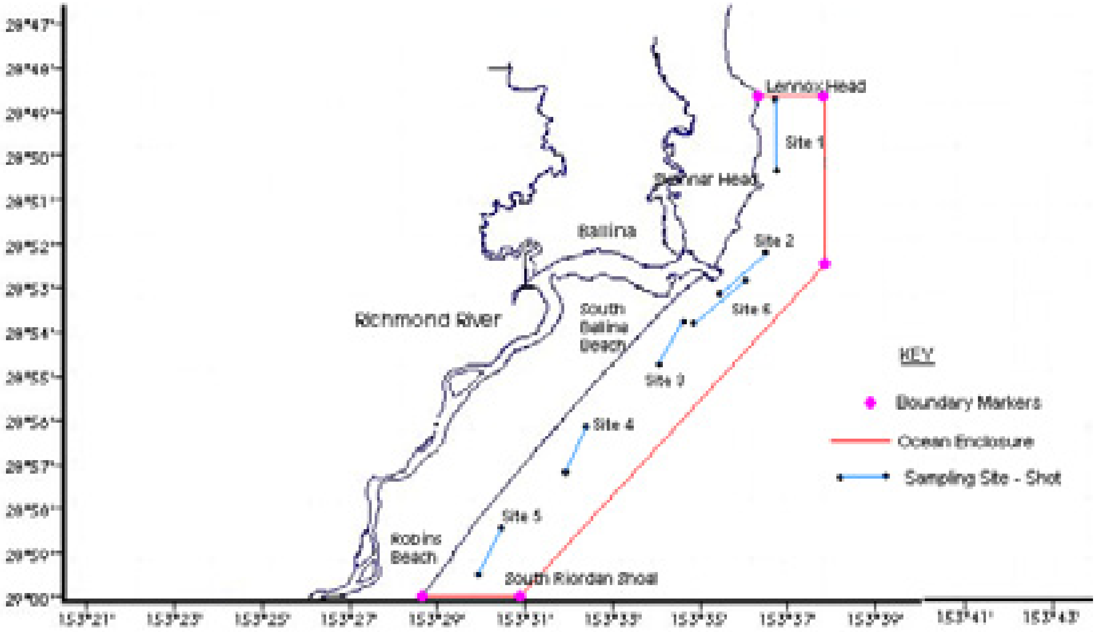


Map 2. Sites sampled during the April survey within the Ocean Closure.

Table 1. Sites 1 to 4 – time, shot duration, and start / finish coordinates of each shot, number of codends used and depth range for each site.

Site	Time (am)	Shot Duration (mins)	Start	Finish	N^{o} of Codends Used	Depth (fathoms)
1	7.15am	24	28*52'.92 S, 153*35'.59 E	28*53'.52 S, 153*34'.99 E	3	7 - 11
2	9.30am	10	28*50'.35 S,153*36'.90 E	28*50'.75 S,153*36'.80 E	1	10 - 12
3	10.30am	15	28*56'.46 S,153*32.09 E	28*57'.00 S,153*31'.66 E	3	6 - 8
4	11.30am	20	28*58'.94 S,153*30'.60 E	28*59'.83 S,153*29'.75 E	1	10 - 12

2.2. June survey operational information

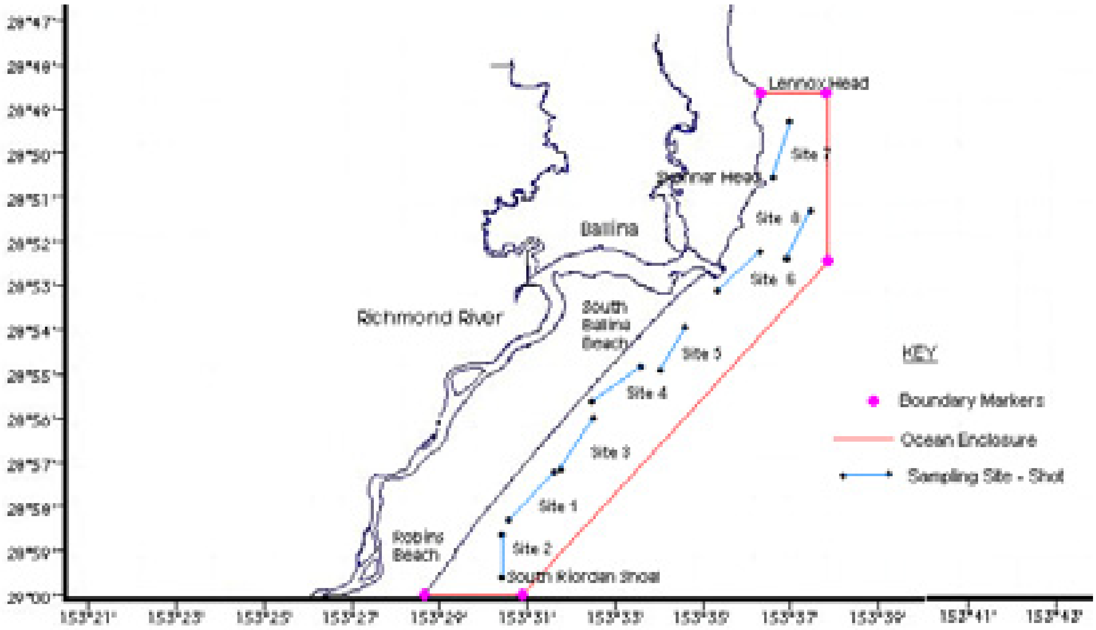


Map 3. Sites sampled during the June survey within the Ocean Closure.

Table 2. Sites 1 to 6 - time, shot duration, and start / finish coordinates of each shot, number of codends used and depth range for each site.

Site	Time (am)	Shot Duration (mins)	Start	Finish	N° of Codends Used	Depth (fathoms)
1	19.30pm	30	28*49'.77 S, 153*36'.74 E	28*50'.95 S, 153*36'.88 E	3	9 - 11
2	21.00pm	30	28*52'.38 S,153*36'.14 E	28*53'.24 S,153*35'.24 E	3	8 - 9
3	22.30pm	30	28*53'.99 S,153*34.75 E	28*54'.95 S,153*33'.83 E	3	12
4	12.00pm	30	28*56'.25 S,153*32'.19 E	28*57'.21 S,153*31'.41 E	3	7
5	0130am	30	28*58'.69 S,153*30'.58 E	28*59'.65 S,153*29'.86 E	3	10 - 12
6	0430am	30	28*53'.66 S,153*34'.64 E	28*52'.95 S,153*35'.76 E	3	8 - 9

2.3. July survey operational information



Map 4. Sites sampled during the July survey within the Ocean Closure.

Table 3. Sites 1 to 8 - time, shot duration, and start / finish coordinates of each shot, number of codends used and depth range for each site.

Site	Time (am)	Shot Duration (mins)	Start	Finish	N° of Codends Used	Depth (fathoms)
1	8.45am	30	28*58'.21 S, 153*30'.49 E	28*57'.20 S, 153*31'.28 E	3	5
2	9.45am	30	28*59'.70 S,153*29'.81 E	28*58'.72 S,153*30'.59 E	3	10
3	11.00am	30	28*57'.16 S,153*31.61 E	28*56'.10 S,153*32'.29 E	3	7
4	12.30pm	30	28*55'.84 S,153*32'.49 E	28*54'.90 S,153*33'.27 E	3	3 - 4
5	13.15pm	30	28*55'.09 S,153*33'.80 E	28*54'.11 S,153*24'.64 E	3	12
6	14.30pm	30	28*53'.31 S,153*35'.12 E	28*52'.29 S,153*36'.00 E	3	8 - 9
7	15.45pm	30	28*50'.67 S,153*36'.86 E	28*49'.53 S,153*36'.98 E	3	11
8	16.30pm	30	28*51'.47 S,153*37'.27 E	28*52'.70 S,153*37'.02 E	3	20

2.4. LFB 'Kiama' gear information

The 48ft prawn trawler 'Kiama' uses a Caterpillar 3306, 230hp engine. The otter boards used throughout the survey were rectangular 'Humphrey Boards', of dimensions 7ft by 3 ft. Triple-trawl gear was used, with the outside nets comprised of 1 3/4" mesh and the middle part of the net comprising of 2" mesh. The total headrope length was 43.8m, with the middle net measuring 16.5m and the outer nets both measuring 13.65m, respectively. Positioned in each of the codends was a by-catch reduction device (BRD) measuring 210mm by 297mm, with a minimum diagonal measurement of 55mm. The ground gear used was 8mm stainless ground chain (see Photo 5).

Photo 5. The prawn trawler LFB 'Kiama'.

3. RESULTS

A complete species list for the three surveys from the Ocean Prawn Trawl Closure is given in Table 4. From the three surveys the majority of the catch was identified to species, but those organisms for which identification or handling was difficult were assigned to higher taxonomic groupings.

Table 4. List of species sampled from the Ocean Closure.

Family	*Scientific Name*	Common Name	April	June	July
Finfishes:					
APOGONIDAE	*Apogon atripes*	Bulls-eye cardinalfish		*	*
APOGONIDAE	*Vincentia novaehollandiae*	Eastern gobbleguts		*	*
ARACANIDAE	*Anoplocapros inermis*	Eastern smooth boxfish			*
BOTHIDAE	*Pseudorhombus arsius*	Large-toothed flounder	*	*	*
BOTHIDAE	*Pseudorhombus jenynsii*	Small-toothed flounder	*	*	
CARANGIDAE	*Gnathanodon speciosus*	Golden trevally		*	
CARANGIDAE	*Pseudocaranx dentex*	Silver trevally	*		
CARANGIDAE	*Trachurus novaezelandiae*	Yellowtail	*	*	*
CARCHARHINIDAE	*Rhizoprionodon acutus*	Milk shark	*		
CHAETODONTIDAE	*Chaetodon guentheri*	Gunther's butterflyfish			*
CLUPEIDAE	*Herklotsichthys castelnaui*	Southern herring	*		
CYNOGLOSSIDAE	*Paraplagusia unicolor*	Lemon tongue sole			*
DASYATIDIDAE	*Dasyatis fluviorum*	Estuary stingray	*	*	
DINOLESTIDAE	*Dinolestes lewini*	Longfin pike			*
DIODONTIDAE	*Dicotylichthys punctulatus*	Three-bar porcupinefish			*
ENOPLOSIDAE	*Enoplosus armatus*	Old wife			*
FISTULARIIDAE	*Fistularia commersonii*	Smooth flutemouth			*
GERREIDAE	*Gerres subfasciatus*	Silver biddy	*	*	*
HARPODONTIDAE	*Saurida undosquamis*	Large-scaled grinner			*
HEMIRAMPHIDAE	*Hyporhamphus australis*	Eastern garfish		*	
HYPNIDAE	*Hypnos monopterygium*	Coffin ray	*	*	*
MICROCANTHIDAE	*Microcanthus strigatus*	Stripey			*
MONACANTHIDAE	*Meuschenia sp.*	Leatherjacket		*	
MONODACTYLIDAE	*Schuettea scalaripinnis*	Ladder-finned pomfret			*
MUGILOIDIDAE	*Parapercis sp.*	Grubfish	*	*	
MULLIDAE	*Upeneichthys lineatus*	Blue-lined goatfish		*	*
MULLIDAE	*Upeneus tragula*	Bar-tail goatfish			*
ORECTOLOBIDAE	*Orectolobus maculatus*	Spotted wobbegong			*
PEMPHERIDIDAE	*Pempheris sp.*	Bullseye	*		
PLATYCEPHALIDAE	*Platycephalus caeruleopunctatus*	Eastern blue-spotted flathead		*	*
PLATYCEPHALIDAE	*Platycephalus endrachtensis*	Bar-tail flathead	*		
PLATYCEPHALIDAE	*Platycephalus arenarius*	Northern sand flathead	*		
PLATYCEPHALIDAE	*Platycephalus fuscus*	Dusky flathead	*	*	
PLOTOSIDAE	*Cnidoglanis macrocephalus*	Estuary catfish	*	*	
PLOTOSIDAE	*Plotosus lineatus*	Striped catfish	*		
POMATOMIDAE	*Pomatomus saltatrix*	Tailor	*		*
RHINOBATIDAE	*Aptychotrema rostrata*	Shovelnose ray	*	*	*
SCIAENIDAE	*Argyrosomus japonicus*	Mulloway	*	*	*
SCIAENIDAE	*Atractoscion aequidens*	Teraglin	*		
SCOMBRIDAE	*Scomber australasicus*	Slimy mackerel			*
SCORPAENIDAE	*Centropogon australis*	Fortesque	*		*
SCORPAENIDAE	*Notesthes robusta*	Bullrout	*	*	*
SCORPIDIDAE	*Scorpis lineolata*	Silver sweep			*
SILLAGINIDAE	*Sillago flindersi*	Red spot whiting			*
SILLAGINIDAE	*Sillago robusta*	Stout whiting	*	*	*
SPARIDAE	*Rhabdosargus sarba*	Tarwhine	*		*
SOLEIDAE	*Aesopia microcephalus*	Black sole	*	*	*
SOLEIDAE	*Zebrias scalaris*	Many-banded sole	*	*	*
TETRAODONTIDAE	*Arothron manillensis*	Narrow-lined puffer		*	
TETRAODONTIDAE	*Tetractenos glaber*	Smooth toadfish			*
TERAPONTIDAE	*Pelates sexlineatus*	Striped trumpeter	*	*	*
TRICHIURIDAE	*Trichiurus lepturus*	Hairtail	*		
TRIGLIDAE	*Chelidonichthys kumu*	Red gurnard			*
UROLOPHIDAE	*Trygonoptera testacae*	Common stingaree	*	*	*

Table 4 (continued)

Family	*Scientific Name*	Common Name	April	June	July
Crustaceans:					
LEUCOSIIDAE	*Ixa inermis*	Horned pebble crab			*
PENAEIDAE	*Metapenaeus macleayi*	School prawn	*	*	*
PENAEIDAE	*Penaeus esculentus*	Tiger prawn	*		
PENAEIDAE	*Penaeus plebejus*	Eastern king prawn	*		
PORTUNIDAE	*Portunus pelagicus*	Blue swimmer crab	*	*	
PORTUNIDAE	*Portunus sanguinolentus*	Three spot crab	*	*	*
PORTUNIDAE	*Ovalipes australiensis*	Sand crab	*		*
STOMATOPODA (ORDER)	*Squilla sp.*	Mantis shrimp		*	
Molluscs:					
LOLIGINIDAE	*Loliolus sp.*	Bottle squid	*	*	*
LOLIGINIDAE	*Loligo sp.*	Slender squid		*	*
OCTOPODA (ORDER)	*Octopus sp.*	Octopus	*	*	*
SEPIIDAE	*Sepia sp.*	Cuttlefish	*		*

3.1. April survey

Weights of the total by-catch, retained commercial catch and discarded by-catch are shown in Table 5.

Table 5. Weights (kg) of the catch taken from all sites.

Catch	Site 1	Site 2	Site 3	Site 4	Total (kg)
Retained Commercial Catch (kg)	80.8	4.75	94.15	12.95	192.65
Discarded By-catch (kg)	59.8	13.63	85.86	34.25	193.54
Total Weight of Catch (kg)	140.6	18.38	180.01	47.2	386.19

The commercial species retained from Sites 1 – 4 included School Prawns (*Metapenaeus macleayi*), Tiger Prawns (*Penaeus esculentus*), Eastern King Prawns (*Penaeus plebejus*), Blue Swimmer Crabs (*Portunus pelagicus*), Stout Whiting (*Sillago robusta*), Yellowtail (*Trachurus novaezelandiae*) and Bottle Squid (*Loliolus sp.*).

The total amount of prawns caught from all sites was 19.65 kg. The total amount of by-catch amounted to 366.54 kg, a prawn to by-catch ratio (from all sites) of:

1 kg of prawns to 18.65 kg of by-catch.

Stout Whiting (*Sillago robusta*), Yellowtail (*Trachurus novaezelandiae*), Northern Sand Flathead (*Platycephalus arenarius*), Mulloway (*Argyrosomus japonicus*) and Silver Biddy (*Gerres subfasciatus*) were recorded as the most abundant retained fin-fish captured from each shot. Each species was measured and weighed, with results for their size ranges given as % frequency of the total catch for that species from each site. School Prawns (*Metapenaeus macleayi*) and Bottle

Squid (*Loliolus sp.*) were the two most abundant retained crustaceans and molluscs. The length frequencies for these species are shown in Figures 1 - 4.

Total weight and % of total catch was calculated for the five most abundant fin-fish species from all sites. This is shown in Table 6.

Table 6. The seven most abundant commercial species as a % of the total catch.

Common Name	Scientific Name	Weight (kg)	Numbers	Total Catch Weight (kg)	% of total catch
Stout whiting	*Sillago robusta*	157.2	3934	386.19	40.71
Mulloway	*Argyrosomus japonicus*	13.7	774	386.19	3.55
Northern sand flathead	*Platycephalus arenarius*	9.1	392	386.19	2.36
Yellowtail	*Trachurus novaezelandiae*	7	201	386.19	1.81
Silver biddy	*Gerres subfasciatus*	6.42	173	386.19	1.66
School prawns	*Metapenaeus macleayi*	19.65	-	386.19	5.09
Bottle squid	*Loliolus sp.*	8.8	-	386.19	2.28

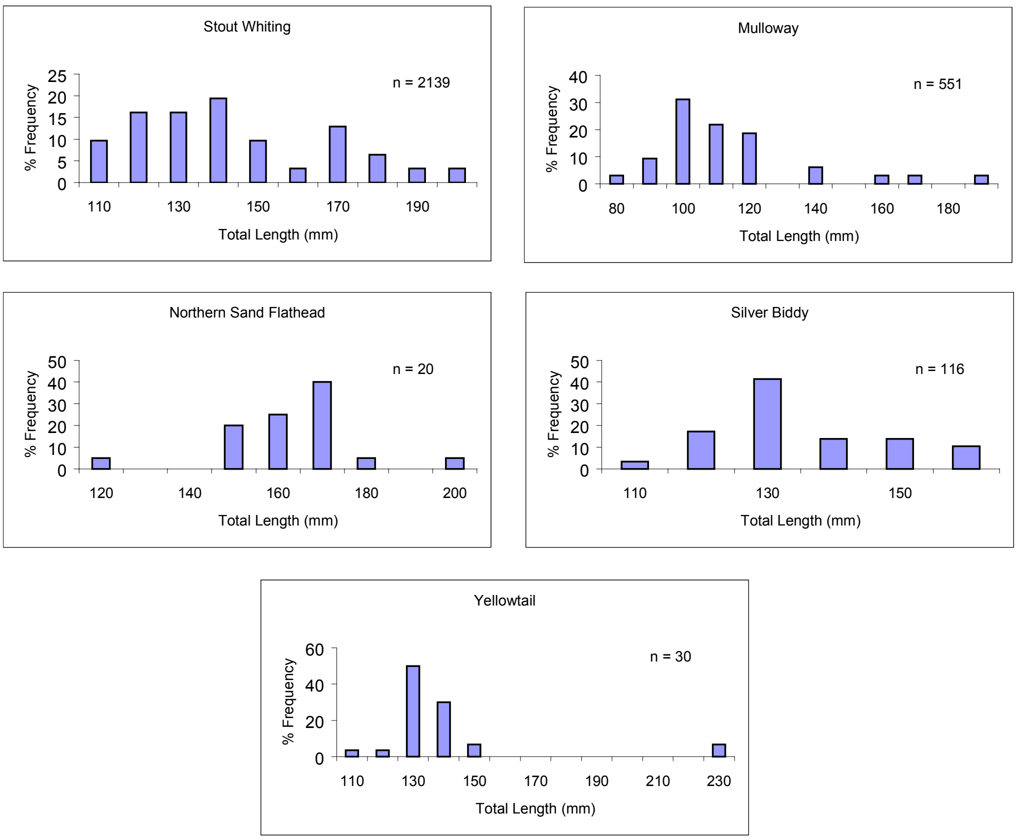


Figure 1. Length frequencies for the most abundant fin-fish from Site 1.

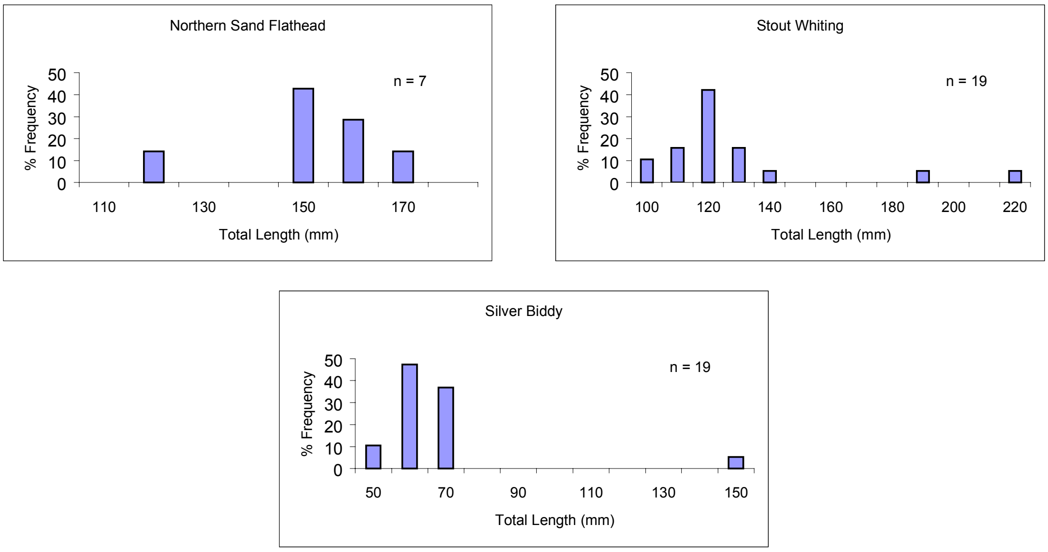


Figure 2. Length frequencies for the most abundant fin-fish from Site 2.

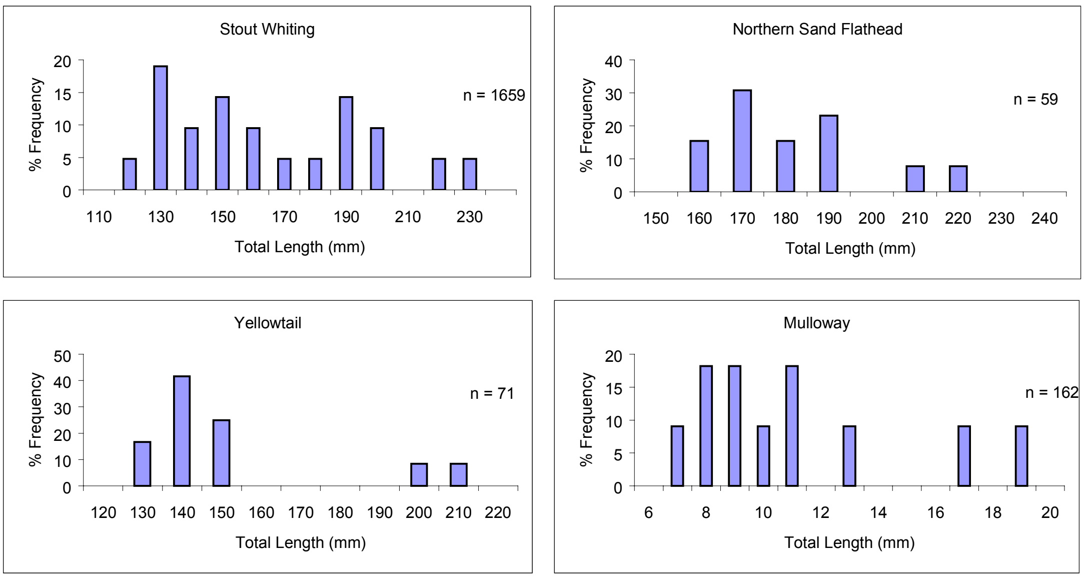


Figure 3. Length frequencies for the most abundant fin-fish from Site 3.

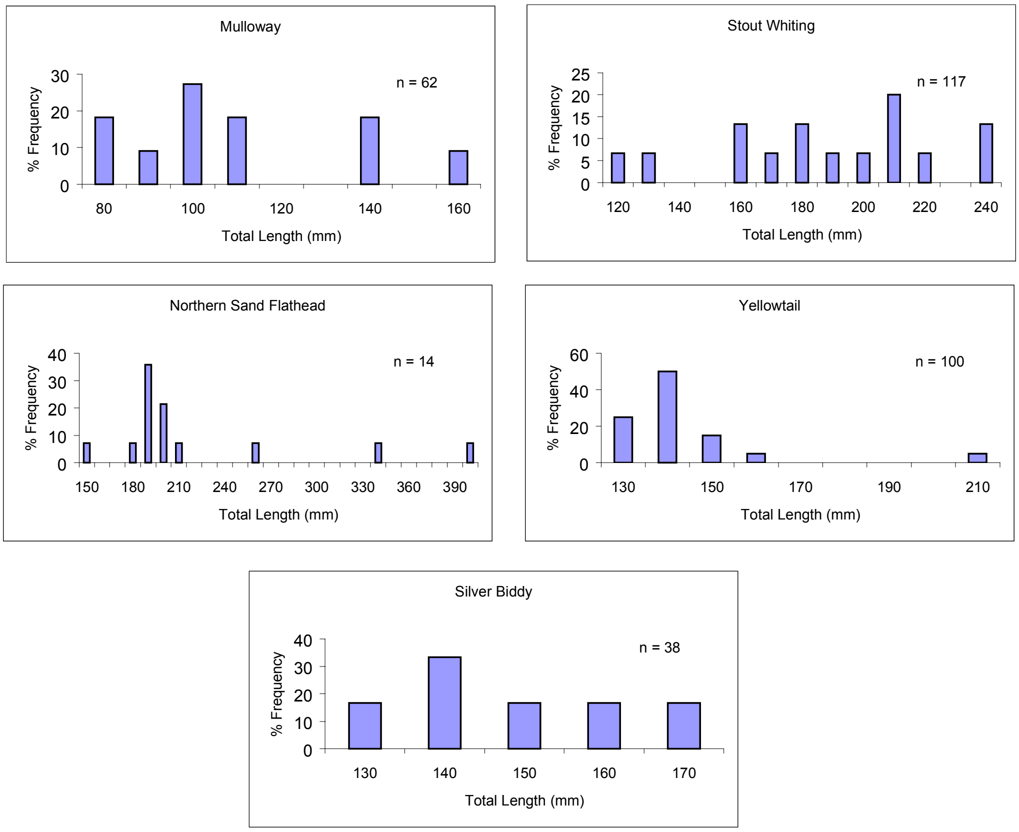


Figure 4. Length frequency of the most abundant fin-fish from Site 4.

3.2. June survey

The total by-catch, retained commercial catch and discarded by-catch were measured and weighted (kg), and are shown in Table 7.

Table 7. Weights (kg) of the catch from all sites.

Catch	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Total (kg)
Retained Commercial Catch (kg)	37.05	58.2	69.12	34.9	55.05	62.4	316.72
Discarded By-catch (kg)	65.42	36.67	50.39	23.45	50.31	109.7	335.94
Total Weight of Catch (kg)	102.47	94.87	119.51	58.35	105.36	172.1	652.66

The commercial species retained from Sites 1 – 6 included School Prawns (*Metapenaeus macleayi*), Blue Swimmer Crabs (*Portunus pelagicus*), Stout Whiting (*Sillago robusta*), Red-spot Whiting (*Sillago flindersi*), Yellowtail (*Trachurus novaezelandiae*), Eastern Garfish (*Hyporhamphus australis*), Bottle Squid (*Loliolus sp.*) and Octopus (*Octopus sp.*).

The total quantity of prawns caught from all sites was 7.65 kg. The total by-catch amounted to 645.01 kg giving a prawn to by-catch ratio (from all sites) of:

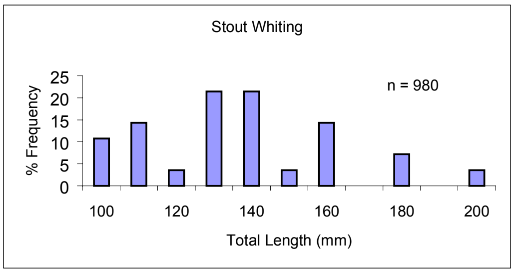
1 kg of prawns to 84.32 kg of by-catch.

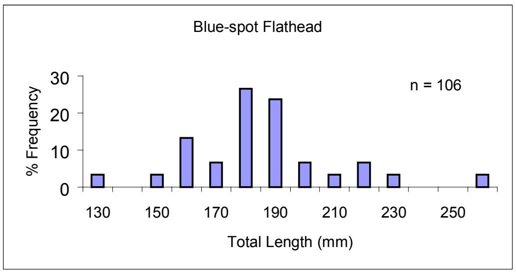
Stout Whiting (*Sillago robusta*), Eastern Blue-spot Flathead (*Platycephalus caeruleopunctatus*), Mulloway (*Argyrosomus japonicus*), Large-toothed Flounder (*Pseudorhombus arsius*) were recorded as the most abundant retained commercial / recreational fin-fish captured from each shot. A non-commecial / non-recreational species, the Many-banded Sole (*Zebrias scalaris*), represented 2.09% of the catch. Each species was measured and weighed, with results for their size ranges being given as % frequency of the total catch for that species from each site. School Prawns (*Metapenaeus macleayi*) and Bottle Squid (*Loliolus sp.*) were the two most abundant retained crustaceans and molluscs. The length frequencies for the fin-fish species are shown in Figures 5 - 8.

Total weights and % of total catch were calculated for the four most abundant retained fin-fish species from all sites. This is shown in Table 8.

Table 8. The four most abundant commercial species as a % of the total catch.

Common Name	Scientific Name	Weight (kg)	Numbers	Total Catch Weight (kg)	% of total catch
Stout whiting	*Sillago robusta*	295	8991	652.66	45.20
Eastern blue-spotted flathead	*Platycephalus caeruleopunctatus*	20	430	652.66	3.06
Many-banded sole	*Zebrias scalaris*	13.65	396	652.66	2.09
Large-toothed flounder	*Pseudorhombus arsius*	7.2	40	652.66	1.10
Mulloway	*Argyrosomus japonicus*	7.07	145	652.66	1.08
Bottle squid	*Loliolus sp.*	9.5	1571	652.66	1.46
School prawns	*Metapenaeus macleayi*	7.65	1286	652.66	1.17





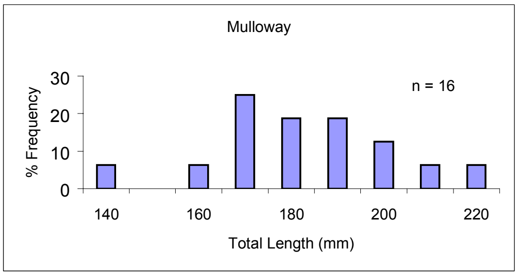


Figure 5. Length frequencies for the most abundant fin-fish from Site 1.

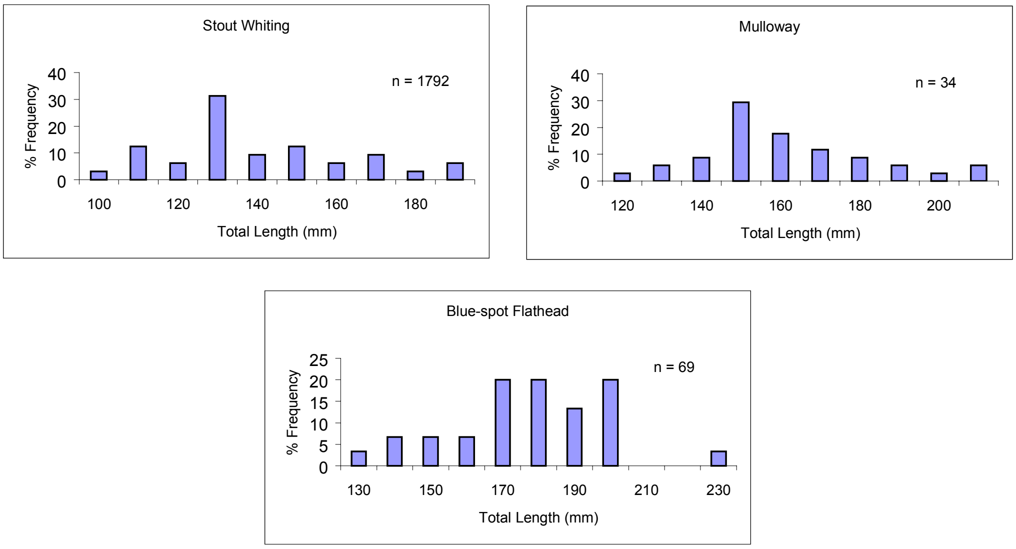


Figure 6. Length frequencies for the most abundant fin-fish from Site 2.

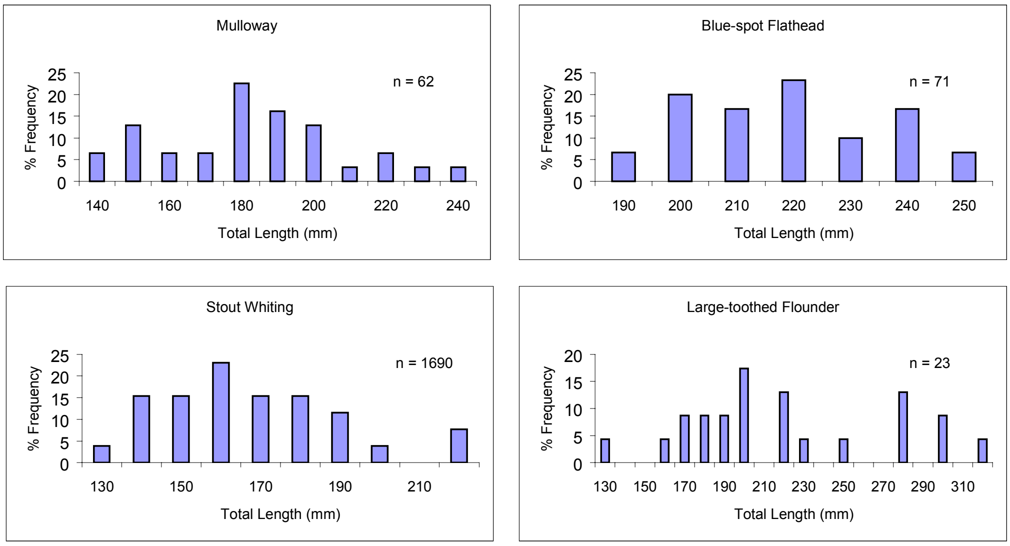


Figure 7. Length frequencies for the most abundant fin-fish from Site 3.

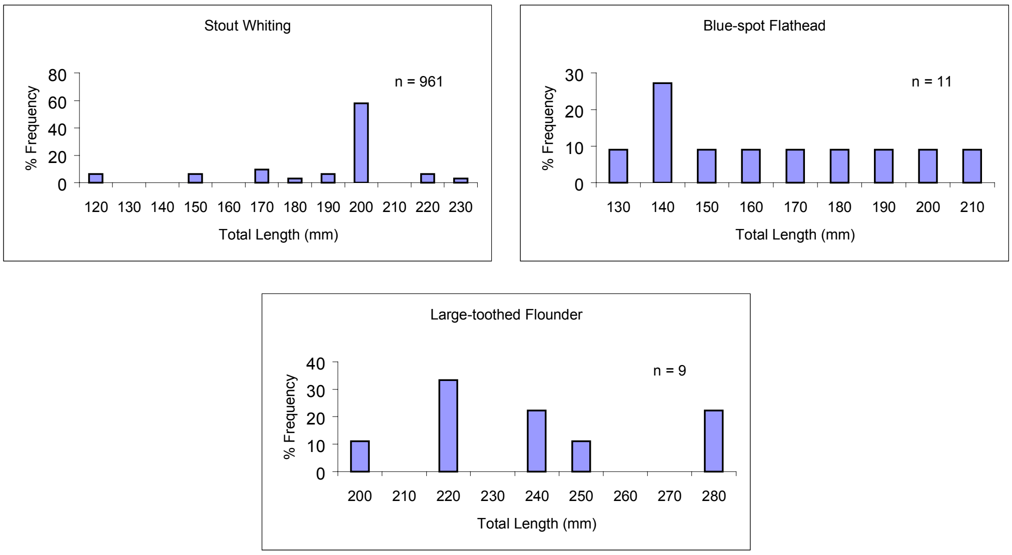


Figure 8. Length frequencies for the most abundant fin-fish from Site 4.

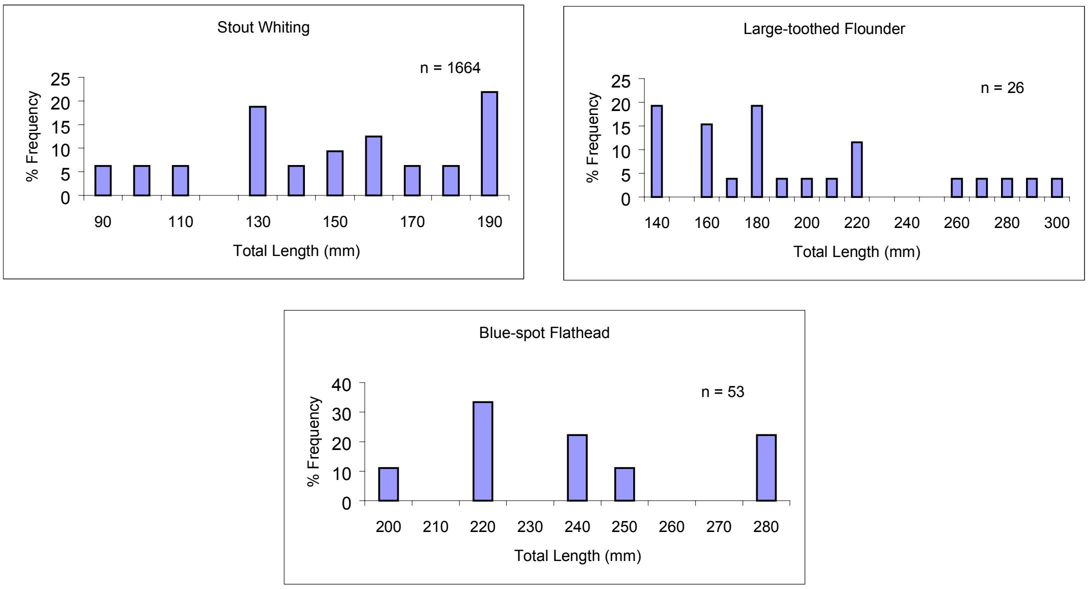
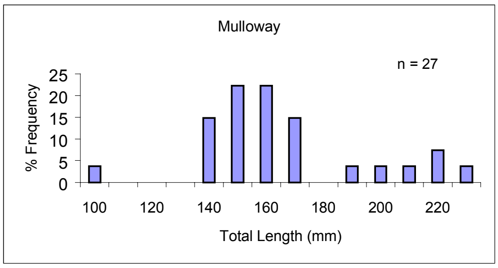
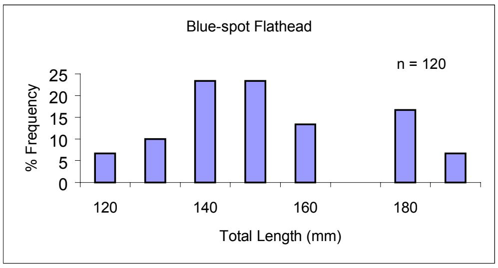


Figure 9. Length frequencies for the most abundant fin-fish from Site 5.





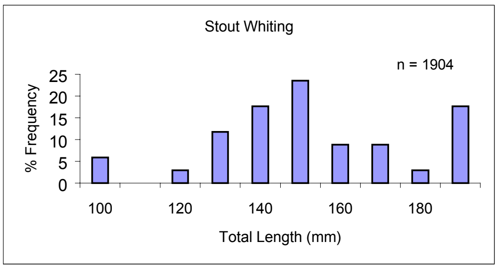


Figure 10. Length frequencies for the most abundant fin-fish from Site 6.

3.3. July survey

The total by-catch, retained commercial catch and discarded by-catch were measured and weighted (kg), and are shown in Table 9.

Table 9. Weights (kg) of the catch from all sites.

Catch	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Total (kg)
Retained Commercial Catch (kg)	33.35	173.72	44.37	0.96	19.4	1.98	25.45	0.15	299.378
Discarded By-catch (kg)	12.7	37.92	19.46	22.16	25.16	20.51	25.16	16.36	179.425
Total Weight of Catch (kg)	46.05	211.64	63.83	23.12	44.56	22.49	50.61	16.51	478.803

The commercial species retained from Sites 1 – 8 included Stout Whiting (*Sillago robusta*), Red-spot Whiting (*Sillago flindersi*), Slimy Mackeral (*Scomber australasicus*), Yellowtail (*Trachurus novaezelandiae*), Bottle Squid (*Loliolus sp.*), Octopus (*Octopus sp.*), Cuttlefish (*Sepia sp.*) and Blue Swimmer Crabs (*Portunus pelagicus*).

One School Prawn (*Metapenaeus macleayi*) measuring a carapace length of 21mm was captured in Site 7, from a total catch amounting to 487.81 kg. It was unnecessary to determine a prawn to by-catch ratio.

Stout Whiting (*Sillago robusta*), Eastern Blue-spot Flathead (*Platycephalus caeruleopunctatus*), Silver Biddy (*Gerres subfasciatus*), Mulloway (*Argyrosomus japonicus*), Large-toothed Flounder (*Pseudorhombus arsius*), Tarwhine (*Rhabdosargus sarba*), Red-spot Whiting (*Sillago flindersi*) and Yellowtail (*Trachurus novaezelandiae*) were recorded as the most abundant retained commercial / recreational fin-fish captured from each shot. Each species was measured and weighed, with results for their size ranges being given as % frequency of the total catch for that species from each site. School Prawns (*Metapenaeus macleayi*) and Bottle Squid (*Loliolus sp.*) were the two most abundant retained crustaceans and molluscs. The length frequencies for these species are shown in Figures 11 - 18.

Total weight and % of total catch was calculated for the eight most abundant fin-fish species from all sites. This is shown in Table 10.

Table 10. The eight most abundant commercial species as a % of the total catch.

Common Name	Scientific Name	Weight (kg)	Numbers	Total Catch Weight (kg)	% of total catch
Stout whiting	*Sillago robusta*	293.1	6616	478.80	61.22
Eastern blue-spotted flathead	*Platycephalus caeruleopunctatus*	17.78	295	478.80	3.71
Silver biddy	*Gerres subfasciatus*	7.15	213	478.80	1.49
Mulloway	*Argyrosomus japonicus*	5.94	49	478.80	1.24
Large-toothed flounder	*Pseudorhombus arsius*	5.76	44	478.80	1.20
Tarwhine	*Rhabdosargus sarba*	4.72	68	478.80	0.99
Red spot whiting	*Sillago flindersi*	2.23	106	478.80	0.47
Yellowtail	*Trachurus novaezelandiae*	2.01	50	478.80	0.42

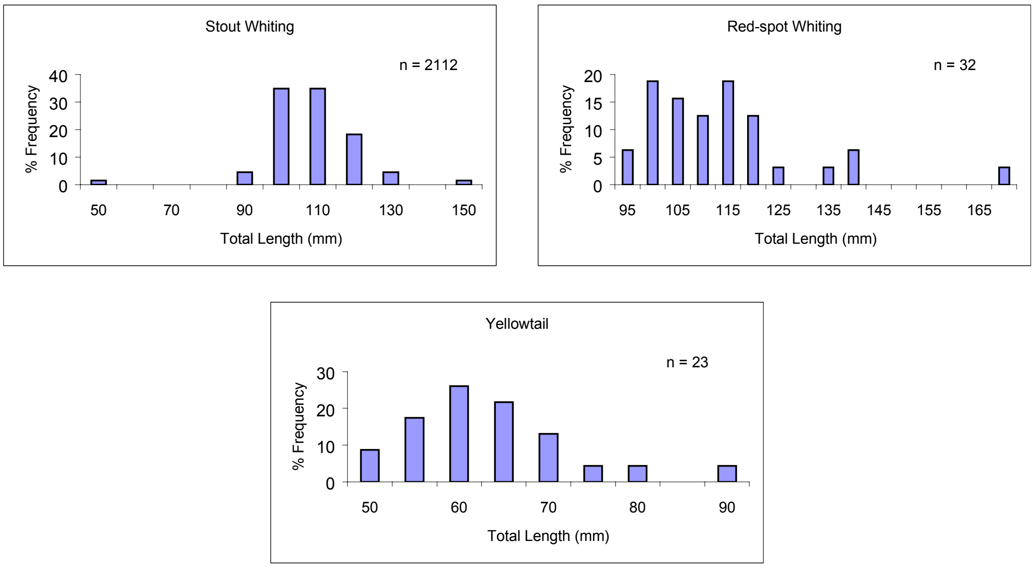


Figure 11. Length frequencies for the most abundant fin-fish from Site 1.

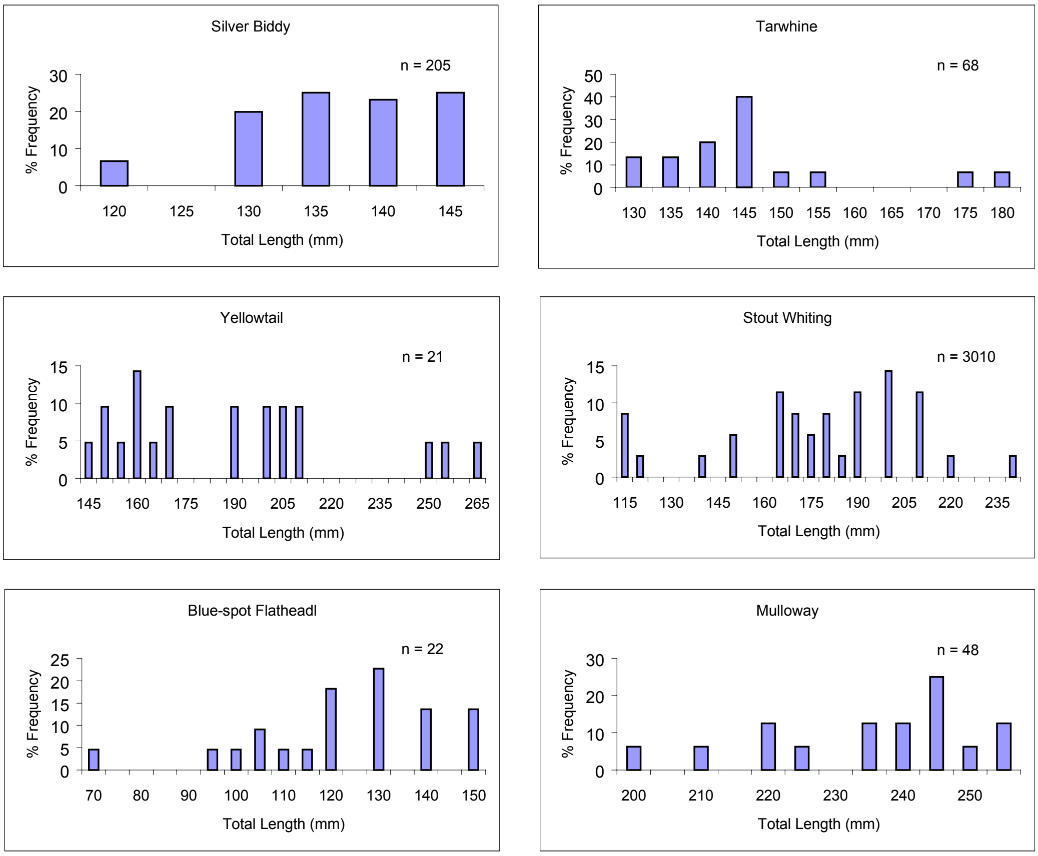


Figure 12. Length frequencies for the most abundant fin-fish from Site 2.

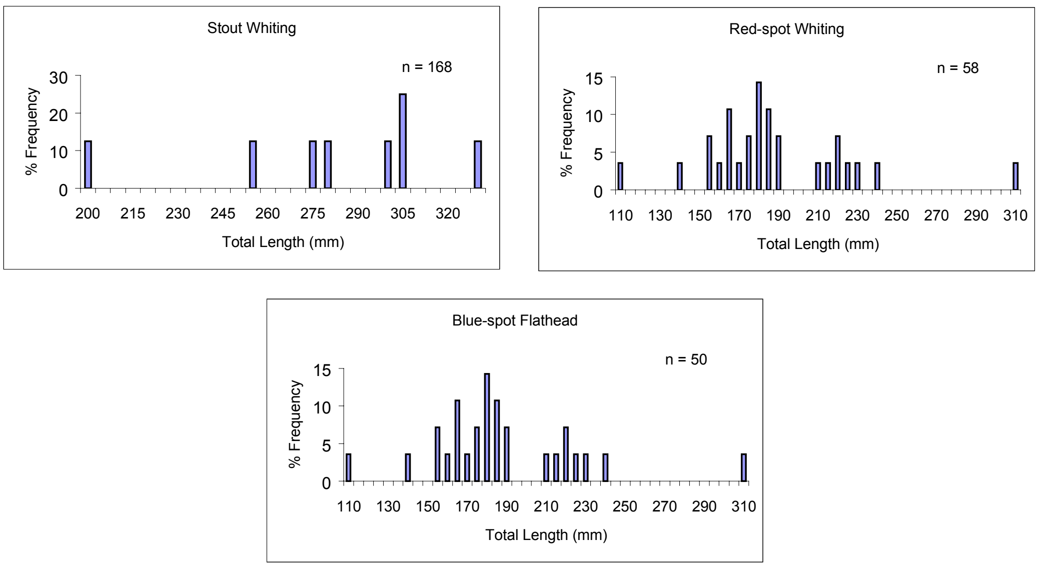


Figure 13. Length frequencies for the most abundant fin-fish from Site 3.

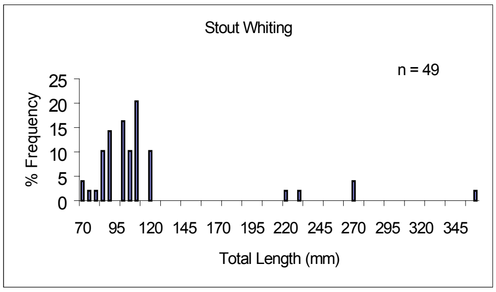


Figure 14. Length frequencies for the most abundant fin-fish from Site 4.

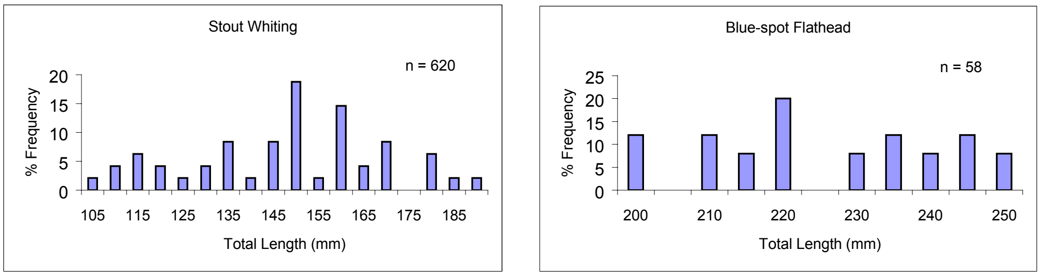


Figure 15. Length frequencies for the most abundant fin-fish from Site 5.

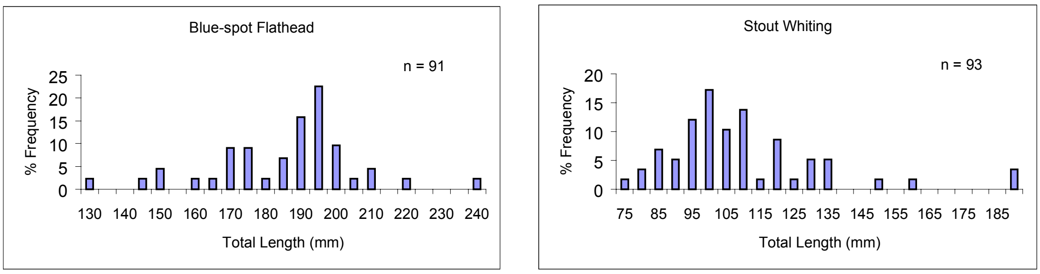


Figure 16. Length frequencies for the most abundant fin-fish from Site 6.

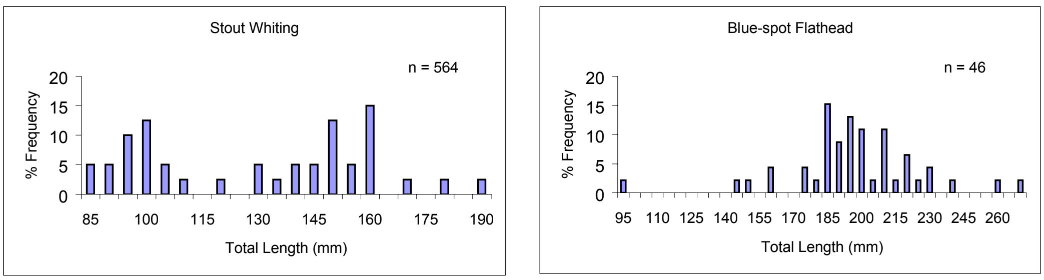


Figure 17. Length frequencies for the most abundant fin-fish from Site 7.

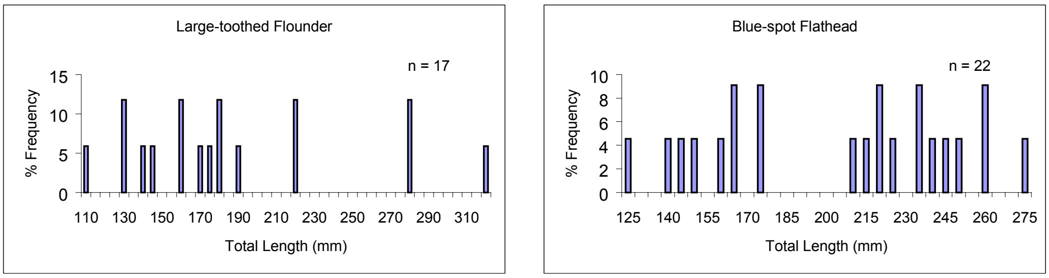


Figure 18. Length frequencies for the most abundant fin-fish from Site 8.

4. DISCUSSION

The oceanic closure implented off the Richmond River following the 2001 flood event was found to contain a large number of fin-fish species and relatively few prawns. A total of 54 fin-fish, 8 crustaceans and 5 molluscs were captured from the three surveys, of which 52% species are regarded as potential commercial or recreational species (see Table 1). The difference between the discarded by-catch and retained commercial catch from the April and June surveys was 4.21 kg and 19.22 kg respectively. In July however, the opposite occurred where the retained commercial catch exceeded the discarded by-catch by 119.95 kg (see Tables 5, 7 and 9).

The most abundant fin-fish species caught in April were Stout Whiting (*Sillago robusta*) and Mulloway (*Argyrosomus japonicus*), making up 42.93% and 3.74% of the total catch respectively. School Prawns and Bottle Squid made up 5.37% and 2.4% of the catch respectively. In June, Stout Whiting (*S. robusta*) and Eastern Blue-spot Flathead (*Platycephalus caeruleopunctatus*) made up 45.19% and 3.06% of the catch respectively, whilst School Prawn and Bottle Squid numbers dropped significantly to 1.17% and 1.46% of the total catch respectively. The July results indicated that Stout Whiting (*S. robusta*) numbers rose significantly to 61.22% of the total catch, an increase of 18.29% of the catch compared with April. Eastern Blue-spot Flathead (*P. caeruleopunctatus*) remained steady in numbers, only increasing slightly to 3.71%. Both School Prawn and Bottle Squid numbers decreased to insignificant numbers, where only one individual school prawn and 97 Bottle Squid were captured throughout the closure (together representing just 0.0012% of the total catch in July.

The prawn to by-catch ratio proved to be large during the entire survey. April results indicated over one and half times the ratio found during studies done in an earlier study by Kennelly et al. (1998) where the by-catch to prawn ratio was found to be 1 kg of prawns to 10.4 kg of by-catch for the off-shore Eastern King Prawn fishery. The June results showed over eight times the prawn to by-catch ratio in comparison to the earlier work. A similar ratio was unable to be calculated in July due to a lack of prawns.

Length frequencies were derived for the total lengths of the individual most abundant commercial and recreational fin-fish species from each site surveyed. In April, Sites 1 – 3 showed a large proportion of the population of Stout Whiting (*S. robusta*) ranged from 120 – 170mm, but catches at Site 4 indicated that a larger cohort of fish of lengths 170 – 240mm inhabited the lower southern region of the closure. Mulloway (*Argyrosomus japonicus*) catches showed that the greatest portion of the catch were in the size range from 70 – 140mm at all sites. Silver Biddy catches contained a large proportion of fish between 110 – 170mm. Yellowtail catches showed a cohort of fish from all sites between 110 – 150mm. June results indicated that the majority of the Stout Whiting (*S. robusta*) captured were from a cohort that ranged from 100 up to 200mm. Eastern Blue-spot Flathead (*P. caeruleopunctatus*) showed a steady range of sizes of fish from 160 to 280mm. Mulloway (*A. japonicus*) numbers declined, but those captured showed the greatest numbers in the size range between 140 – 240mm. Large-toothed Flounder (*Pseudorhombus arsius*) ranged from 160 – 260mm from the small number of fish sampled. The July survey showed three size cohorts of Stout Whiting (*S. robusta*) from the very large sample that was captured. The smaller cohort of fish measured 85mm – 130mm, the medium sized fish measured 160 – 210 mm and the large cohort measured 275 – 340mm. Red-spot Whiting (*Sillago flindersi*) were captured for the first time in July and displayed two cohorts of fish. Smaller fish measured between 95 and 125mm and medium sized fish measured 150 – 190mm. A small population of larger fish were captured measuring 210 – 240mm. Two sizes of Yellowtail (*Trachurus novaezelandiae*) were captured, smaller fish measured between 50 – 70mm and larger fish ranged from 145 – 265mm. Eastern blue-spot flathead (*P. caeruleopunctatus*) showed a range of sizes from 110 – 230mm, with a few larger specimens being taken at Site 8, in the deeper water. The only large catches of Mulloway (*A. japonicus*), Tarwhine (*Rhabdosargus sarba*) and Silver Biddy (*Gerres subfasciatus*) were captured in the far southern region of the closure from Site 2. Fish were between 200 – 260mm for the Mulloway. The main part of the population of Tarwhine was between 130 – 155mm, and the Silver Biddy ranged from 120 to 145mm.

From this survey, the extension of the already existing juvenile Eastern King Prawn closure located off the Richmond River Bar showed that only a low percentage of high value commercial species, namely School Prawns, inhabited this closure during the period of the study. The water turbidity at the time of the survey was much clearer within the closure than outside it. This may have implications for School Prawn and Bottle Squid populations as they may have been buried in the sand, thus producing lower numbers in our samples compared with what may have been present. Over the months, as water clarity improved, a decrease in the quantities of high value species occurred, while populations of other low value species, such as Stout Whiting and Eastern blue-spot flathead, increased.

The night survey in June showed no significant differences in fin-fish catches from the previous survey that had occurred in April, although, as mentioned above, a drop in the percentage of the total catch of School Prawns and Bottle Squid had occurred.

It is worth noting that during the period of 17 April to 15 May, the Prawn Trawl Fleet was working the ocean closure borders outside Evans Head and Lennox Head, capturing a total of 46,944 kg of School Prawns (Pers. Comm – Ballina Fishermans Co-operative March 2002).

5. CONCLUSION

The survey reported here has several limitations, the most important being the fact that only three individual days of sampling were done, one in each month. This precludes any definitive statements about temporal trends in the data. Despite this, however, the data clearly show very low catches of School Prawns made inside the closure, and relatively high by-catch to prawn catch ratios. This leads one to conclude that the ocean closure off the mouth of the Richmond River was a beneficial management tool during this flood event and should be considered during future such events.

This closure, which protected those commercial / recreational (especially by-catch) species present in this area, should have helped to facilitate the redistribution and recovery of the fish stocks in the lower Richmond River estuary, especially in the case of the juveniles of estuarine species such as Mulloway, Tarwhine, Silver biddy and Large-toothed flounder. In addition, the existence of this closure should have allowed for the spawning of school prawns before they migrated to areas where they could be captured outside the protective closure zone.

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