ASSESSMENT OF THE IMPACT OF RECREATIONAL FISHING OF PRAWN STOCKS ON THE COMMERCIAL FISHERY FOR PRAWNS OFF NEW SOUTH WALES

FINAL REPORT TO THE FISHERIES RESEARCH & DEVELOPMENT CORPORATION

S.S. Montgomery and D.D. Reid

Project No. : 91/88

ISBN 0 7310 4941 1

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

LIST OF TABLES AND FIGURES

Opposite Page: Staff interviewing a prawner with a scoop net on Tuggerah Lakes during roving creel surveys (Photo J. Matthews, NSW Fisheries Research Institute)

NON-TECHNICAL SUMMARY

If wild stocks are to be managed effectively then information on the level of catch and fishing effort is needed from both the commercial and recreational harvesting sectors, so that managers can assess the impact of management options on fisheries.

The penaeid resources of New South Wales are the most economically important wild stocks managed solely by the NSW state government. Annual landings average about 2,000 tonnes and are worth around $32 million at the point of first sale. Approximately 42% and 31% of this production by weight and value respectively, comes from harvesting in estuaries. The catch in estuaries is comprised of significant quantities of eastern king, *Penaeus plebejus*, school *Metapeneaus macleayi*, and greasyback prawns *Metapenaeus bennettae*. The 2 most important species are the eastern king (42% and 58% by weight and value of production) and the school prawn (44% and 34%).

A comment by Ruello (1975) and data from an omnibus survey commissioned in 1981 by the then NSW Agriculture & Fisheries suggested that recreational fishers were significant harvesters of prawns in NSW. Funding was obtained from the then Fishing Industry Research and Development Council for a project to quantify in terms relative to the commercial catch, the catch of penaeids in NSW by recreational fishers.

We used roving creel survey techniques to provide estimates of catches of the three major penaeid species in four NSW coastal estuaries (Wallis Lake, Tuggerah Lakes, Lake Illawarra and Coila Lake) for the summer seasons of 1991-92, 1992-93 and 1993-94. Roving creel surveys were used to ensure representative samples. There were many more access points to each estuary than could have been covered by scientific staff.

We assume when using roving creel survey techniques that these provide data that are an unbiased estimate of mean catch per unit effort (CPUE) for the fishery. Because interviews were done whilst the fisher is still fishing, fishers who fish longer have a greater probability of being interviewed. If these individuals were

only the best or worst fishers, then estimates of CPUE would be biased. We therefore tested this assumption by comparing estimates of CPUE between completed and uncompleted prawning trips (roving creel surveys) and found no differences between estimates. We concluded therefore that roving creel surveys were an appropriate technique to use on estuaries in NSW to collect information on prawning effort and CPUE in the recreational fishery for prawns.

The roving creel surveys were stratified by moon-phase, day-type, tidal state and time of night. Subsamples of interviews provided information on the length and species of prawns caught. A total of 3,360 interviews were done over the whole survey period and 10,835 prawns were sampled. Estimates of commercial catches were obtained from monthly returns by commercial fishermen. Overall, recreational catches were estimated to be 28% of the total commercial prawn catches from these estuaries over the three years of the study, with recreational catches representing 57% (±5%) of the commercial catch for Lake Illawarra, 30% (±3%), for Tuggerah Lakes, 17% (±3%), for Wallis Lake and 10% (±2%) for Coila Lake.

The species composition of the recreational catch differed from the commercial catch, with the recreational fishery taking almost exclusively king prawns in Wallis Lake, Lake Illawarra and Coila Lake. In Tuggerah Lakes the recreational catch was made up of equal proportions of eastern king and school prawns. The commercial fishery in Lake Illawarra and Wallis Lake took a much greater proportion of school prawns, with 30 - 50% of the annual catches being this species.

The lengths of eastern king prawns in samples were similar between commercial and recreational catches but those of school prawns in Tuggerah Lakes (the only estuary where a comparison could be made for this species) were longer in samples from recreational than commercial catches. There were marked differences in catch rates between tidal and non-tidal areas for Tuggerah Lake, but no differences in catch rates between tidal and non-tidal areas in Lake Illawarra. Catch rates also varied between methods. The catch rate of 2m wide hauling (drag) nets was five times that of scoop-nets used in the same subareas. Recreational prawning in Wallis Lake was done predominantly on the ebb-tide in the dark of the moon.

This study demonstrated that night time surveys of recreational fisheries for penaeids can produce estimates of catch with acceptable levels of variance. Considering the difficulties of surveying fishers at night, the techniques used in this study should work equally as well during day time.

There can be little doubt that the quantity of prawns caught by the recreational fishery will impact upon the level of catch of the commercial fishery and the prawn resources. Most of the catch of school and eastern king prawns in estuaries are immature individuals. There is the risk therefore that this harvest may affect levels of recruitment to the spawning stocks. The impact of the recreational catch will probably be greatest upon the eastern king prawn resource and the commercial catch for this species because this species comprised the major proportion of the recreational catch. Eastern king prawns are probably the most susceptible of the penaeid species off NSW to over-exploitation, it is likely to have a lower natural mortality (because it is longer living) and is exploited in estuaries whilst being an immature animal. The recreational fishery for prawns in NSW needs to be considered by managers when developing management options for the eastern king, school and greasyback prawn fisheries of NSW.

It is likely that the methodology used in this study could be used to survey the recreational fisheries for other penaeid resources in estuaries. This study provides a guide to the level of sampling required to extend the coverage to an estimate of the recreational catch in NSW. The relatively low variation in mean CPUE over a full season within an estuary indicates that estimates of the state-wide catch could be achieved by concentrating survey effort on counts of prawners, with relatively low survey effort directed to interviews.

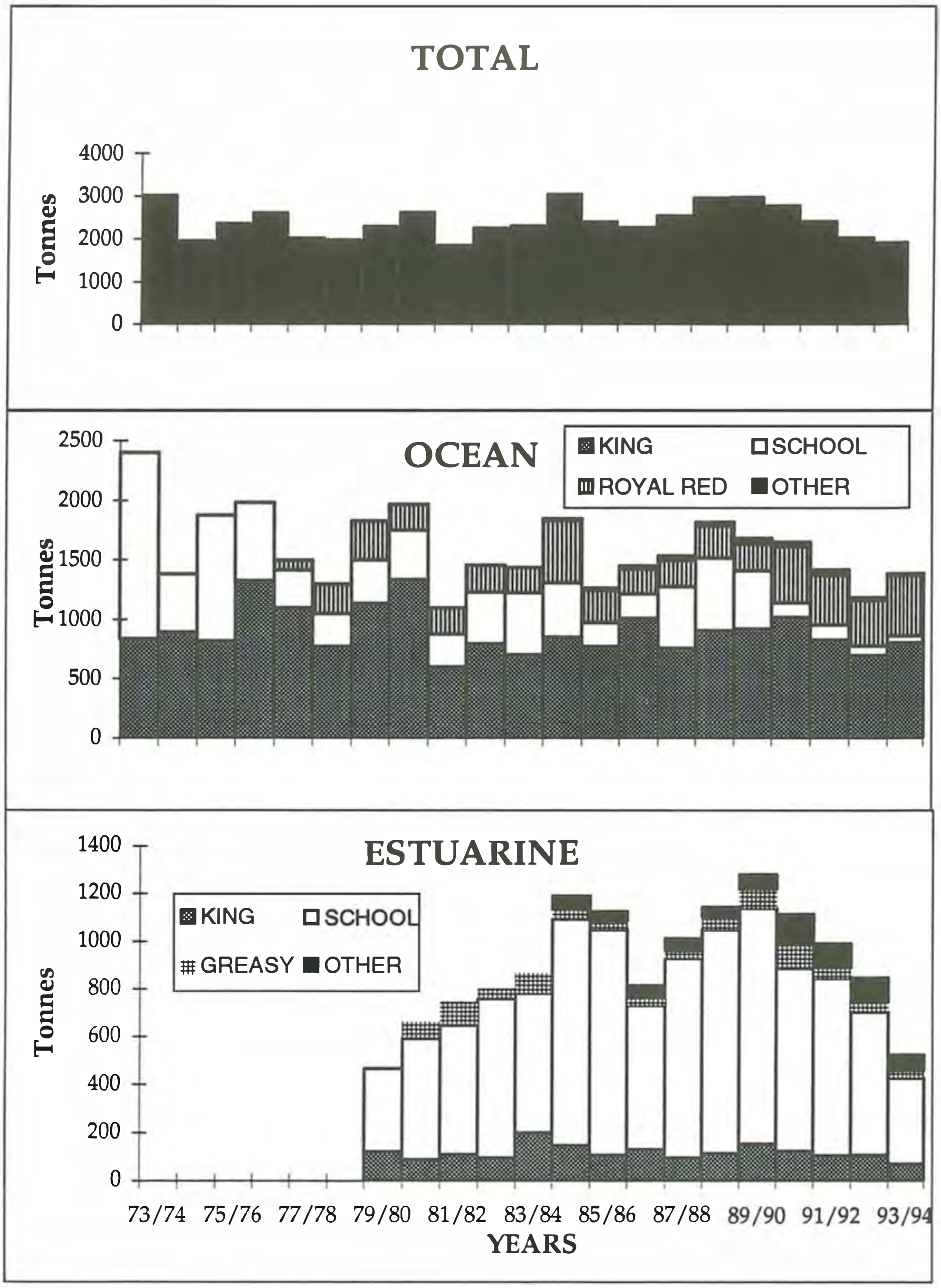


FIG. 1. Annual production by weight of prawns caught by the commercial fishery in New South Wales. No data were available for the estuarine catch prior to 1979-80. Data for 1993-94 are approximately 97% completed on the "LCATCH" database.

BACKGROUND INFORMATION

In 1993-94 commercial fisheries around Australia landed about 20,000 tonnes of species of the family Penaeidae, worth A$ 278 million (Anon 1995). Recreational fisheries for some of these species occur in all states except South Australia (Kailola et al. 1993), yet little appears to be known about the capacity of these fisheries to harvest wild stocks of prawns. This dearth of information is of concern when one considers that most stocks of penaeids around Australia are being heavily exploited.

The penaeid resources of New South Wales are the most economically important wild stocks managed solely by the state government. Annual landings average about 2,000 tonnes, being worth around $32 million at the point of first sale. Approximately 42% and 31% of this production by weight and value respectively, comes from harvesting in estuaries (Montgomery and McDonall 1988; Fig 1). The catch is comprised of significant quantities of eastern king prawns, *Penaeus plebejus*, school *Metapeneaus macleayi*, greasyback *Metapenaeus bennettae*, and royal red prawns *Haliporoides sibogae*. The 2 most important species are the eastern king (42% and 58% by weight and value of production) and the school prawn (44% and 34%).

Eastern king, school and greasyback prawns are endemic to the waters off Australia (Grey et al. 1983; Kailola et al. 1993). These species are found along the east coast of Australia within the boundaries of around 21° S to 42° S for eastern king, and 25° S to 38° S for school and greasyback. Royal red prawns live in the Indian and Western Pacific oceans in the waters off New Zealand, Madagascar, Japan and Australia. The life cycles of eastern king, and school prawns have both an estuarine and oceanic phase whilst greasyback and royal red prawns live entirely within estuarine and oceanic waters, respectively. With the exception of eastern king prawns, each species appears to constitute several discrete stocks within NSW (Ruello 1977). Eastern king prawns on the other hand form one stock along the east coast of Australia (Mulley and Latter 1981; Montgomery 1990).

Data from an omnibus survey commissioned in 1981 by the then NSW Agriculture & Fisheries, suggested that the catch of prawns by the recreational fishery in NSW was between 1000 and 2000 tonnes. This is greater than the reported landings over the same period from estuaries by the commercial fishery. The number of respondents in the survey was, however, very small, thus estimates of catch and effort from the survey were subject to very large error. Nonetheless, the results suggested that recreational fishers were significant harvesters of prawns in NSW.

We therefore approached the then Fishing Industry Research and Development Council for funding for a project that would provide information on the catch of the recreational fishery for prawns expressed as a relative proportion of the commercial catch.

OBJECTIVE

To determine the impact of the recreational prawn fishery in NSW on the commercial fisheries for the same species.

FIG. 2. The most popular type of gear used by recreational fishers to catch prawns is the scoop net. The gear used though varies in technology (see text).

FIG. 3. Other types gear used by recreational prawners are the scissor net (a) and the drag net (b).

The gear used by prawners with scoop nets varies in technology; from an above water torch and net (left), to some form of floating device to hold prawns and a 6 volt battery that powers an underwater light (bottom).

a

Push or Scissor net.

b

Drag nets are hauled on foot by 2 people in shallow water.

INTRODUCTORY TECHNICAL INFORMATION

The Recreational Fishery

The recreational fishery for prawns occurs in estuaries only, and operates from spring to autumn, from Noosa Heads in southern Queensland (26° S) to George's Bay in Tasmania (41° S). Eastern king and school prawns are the main species caught. A variety of gear types are used to catch the prawns. Regulations governing the dimensions for these gears in NSW are outline in the Fisheries Management Act 1994 of NSW (Appendix 1). The gears used are:

(i) Scoop Net. Scoop netting is the most popular method used by recreational prawners and is used whilst either wading in shallow areas or over the side of a boat. A sock of net is supported on a hand held frame. Prawners use lights to spot prawns moving in the water column. The type of gear used varies between prawners. Some prawners use above surface torches whilst others tow small floating objects that carry a 6 volt motorcycle battery to power underwater lights (e.g. front cover and (Figure 2a).

(ii) Scissor or Push Net. This is a bag of net supported by a frame in the shape of a pair of scissors. It is pushed across the bottom in shallow water (Figure 3a).

(iii) Haul or Drag Net. The net is similar in design to a pocket net, with a weighted footrope and buoyant headline. The footrope and headline are separated by a stake at each end of the net. The net is dragged through shallow water by 2 people (one holding each stake), then pulled onshore to sort the catch (Figure 3b).

The Commercial Fishery

The commercial fishery for prawns in estuaries operates from spring to autumn, and extends from Swain's Reef in Queensland (21° S) to Gippsland Lakes in eastern Victoria (38° S). Eastern king and school prawns are exploited both offshore and in estuaries, while greasyback and royal red prawns are exploited only in estuaries and oceans, respectively. Prawns are exploited year round in oceanic waters.
A variety of gear were used by commercial fishers operating in the estuaries studied during this project. Regulations concerning the dimensions for these gears and areas where these can be used is outline in the Fisheries Management Act 1994 of NSW (Appendix 1). These are:

(i) Running net. A wall of net is set into a slight current, usually between the shore and a vessel, in areas of shallow water. The prawns are "run" along the net to the vessel and then lifted onboard.

(ii) Hauling net. The net has 2 long wings and a section in which to concentrate and retain the catch. The wings of the net have a spreading device (*Dan leno*) between the headline and footrope to stop the net pulling together when it is hauled. The negatively buoyant net is set from a vessel by running the rope connected to one end out from and perpendicular to the shoreline; then the net is set parallel to the shore, and finally the rope connected to the other end of the net is run out on the way back to shore.

(iii) Snigging net. The net is similar in shape and is set in a similar manner to a haul net. The gear is set in a "pear" shape from a vessel. One rope is connected to a Dan buoy and run out from a vessel, then the net is set and the other rope run out back to the Dan buoy. The first rope is picked up again. The net is towed forward until it is closed (when the ropes are parallel) and is then winched on board the vessel.

(iv) Pocket net. This is a trawl shaped net but with a longer pocket leading to the codend. The net is used at night during the run out tide in channels with a strong current. It is held in place by stakes driven into the sediment during the slack neap tide. The headline is tied near the top of the stake, then weights are tied to the footrope and slid down the stakes to keep the headline and footrope separated. Prawns swim into the net with the current and are forced into the codend by the current's strength. The codend is lifted periodically onboard a dinghy to empty out the prawns.

Survey Techniques

Information on catch and fishing effort is collected from a range of sources that are dependent (e.g. log books and records of landings) or independent of the fishing industry (e.g. surveys by telephone or mail and intercept surveys).

Intercept surveys are one of the most common types of independent surveys used to collect data on recreational fisheries (see Malvestuto et al. 1978, 1983; Hayne 1991; Robson 1991; Pollock et al. 1994). Fishers can be interviewed by staff when they have completed their fishing trip (known as access point surveys) or whilst they are fishing (known as roving creel surveys). Access point surveys have the advantage of interviewing fishers at the end of their trip so that information on the total catch is collected, provided that the coverage of the fishery is complete. These are limited to those situations where fishers enter the fishery at few access sites (e.g. boat ramps) so that research staff can interview sufficient fishers to obtain representative sample sizes. Data collected by roving creel survey techniques suffer from the disadvantage that total catch must be estimated through extrapolation. It is assumed when calculating total catch that the mean catch rate of fishers does not vary over the time available for fishing. Roving creel survey techniques do have the advantage however, of being useful in those situations where fishers enter the fishery through more access points than can be covered by staff to provide a sample size of interviews that is considered representative for the fishery.

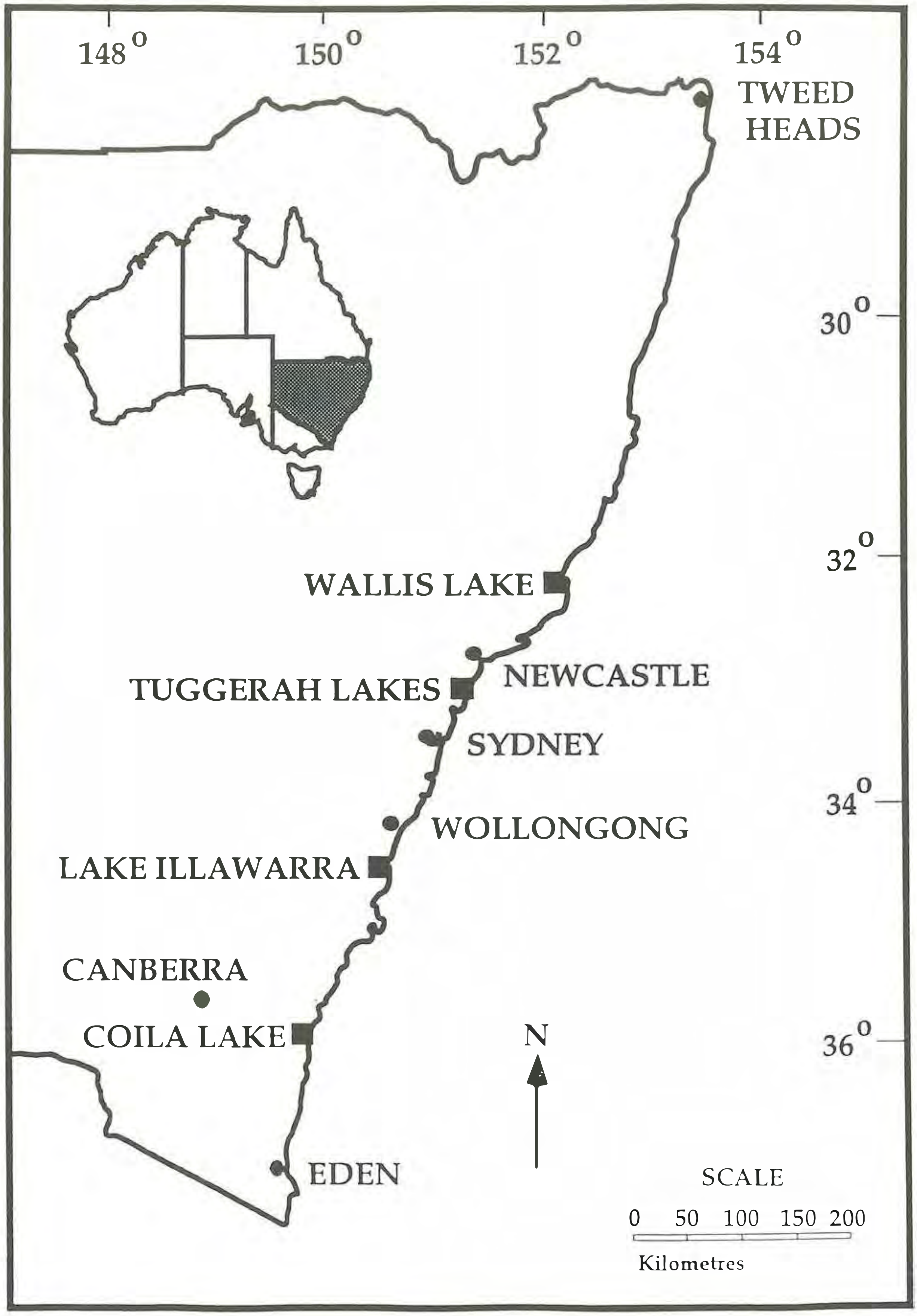


FIG. 4. Map of New South Wales showing areas of major urbanisation (●) and estuaries included in this study (■).

METHODOLOGY

Details of the methods used during this project are given in Montgomery and Reid (Appendix 2), Reid and Montgomery (Appendix 3) and West (Appendix 4). We have provided a summary of these below.

Choice of study sites.

The four estuaries chosen for this study are shown on Figure 4. More detailed maps of each estuary can be found in Appendix 4 (pg. 29). The estuaries studied were:

(i) Wallis Lake (32°17' S) has a plan area of approximately 100 km^2;

(ii) Tuggerah Lakes (33°17' S) consists of three interconnected estuaries, namely, Tuggerah, Budgewoi and Munmorah Lakes, with a total plan area of approximately 80 km^2;

(iii) Lake Illawarra (34°33' S) has a plan area of 34 km^2, and

(iv) Coila Lake (36°01' S) has a plan area of approximately 8 km^2.

Estuaries were selected on the criteria of:

(i) The importance of each estuary to the commercial prawn fishery operating in estuaries for the whole of NSW. Information on the catch by species of prawn, by estuary was collated from the NSW Fisheries' "LCATCH" database. This is made up of records from Form 19 that details by month and estuary each commercial fisher's catch by species (kg) and the total number of days fished. Commercial fishers are compelled by law to complete on a Form 19 details of their fishing practice for the previous month. This is then verified by the NSW Fisheries' fisheries officer responsible for that district.

(ii) Whether the location of the estuary was within that area of NSW identified from the omnibus survey as contributing 80% of the catch of prawns by recreational prawners.

(iii) The relative importance of each estuary to the recreational fishery for prawns. Fisheries Officers of the NSW Fisheries stationed at coastal districts were asked to rank in importance in terms of recreational catch and effort, the estuaries in their district.

Information on recreational catch and effort

We used roving creel surveys because there were more access points to each estuary than could have been covered by scientific staff so that representative numbers of prawners were interviewed.

Roving creel surveys were done on a random stratified design by staff from a private consulting company (Kewagama Research; see Appendix 4.). The staff at Kewagama Research were experienced in doing surveys of recreational fishers. We were able therefore to use experienced personnel and at the same time give the surveys a certain independence by having interviews not directly associated with NSW Fisheries.

The main assumption of roving creel surveys is that these data give an unbiased estimate of catch per unit effort (CPUE) for completed trips and therefore the fishery. Because interviews are done whilst the fisher is still fishing, those who fish longer have a greater probability of being interviewed. If these individuals are better or worse fishers, then estimates of CPUE will be biased. We therefore tested this assumption by doing access point and roving creel surveys at the same time on Tuggerah Lakes and Lake Illawarra. Differences in CPUE between access point and roving creel survey techniques were tested for significance using a paired t-Test.

A complete description of the roving creel survey design used in this project can be found in Reid and Montgomery (Appendix 3) and the report on the methodology used in surveys from Kewagama Research (Appendix 4). Surveys of recreational prawners commenced in January 1991 and concluded in March 1994. The months covered in the study were January 1991 - March 1992; November 1992 - March 1993; and November 1993 - March 1994.

The stratification variables for the design were day-type (weekend+public holiday/weekday), moon-phase (dark/light), tidal state (ebb/flood/slack) and time of night (before/after midnight). The *a priori* stratification of sampling effort was for approximately two-thirds of nights to be chosen from the dark period, and approximately two-thirds of shifts to include the period of the ebb-tide. Field staff were rostered to carry out intercept surveys on 11 nights per month, with 7 in the lunar 'dark' and 4 in the lunar 'light' period. The 'dark' was defined as 7 days before and after the new moon, plus the date of the new moon. The 'light' was the remainder of the lunar month. Shifts were of 4 h duration on the larger lakes (Wallis, Tuggerah and Illawarra) and 2.25 hours on Lake Coila. Time-blocks for the rosters were from last light (equivalent to nautical twilight defined by Lomb (1993)) to first light.

Subareas were defined for each estuary. These were chosen on the basis that prawning was known to occur in the area and that head-counts of prawners operating in each subarea could be counted in 10 minutes. The procedure for each survey shift was based on progressive count methods (Hoenig *et. al.* 1993). It was not feasible to do more than one head count in each subarea per shift because of the relative little time available during the ebb tide at night compared to the time taken to traverse the estuaries. In each subarea, a head-count of prawners and interviews were completed, with a maximum of 30 minutes total time being allowed for each subarea. The starting position and direction of travel were randomly allocated for each shift. For each month of the survey period, one night in the dark of the moon period was allocated to a head count of prawners for the whole estuary, to provide information on the coverage of the survey subareas in accounting for the effort for the entire estuary.

During interviews, prawners were asked for information on the number of nets being used, number of people in the fishing party, number of people actually prawning, and the time the person started prawning. This was recorded together with the time of interview. The catch was weighed with a spring balance to the nearest 0.01 kg and for a subset of interviews in each subarea (about 30% of the total interviews), a subsample of 10 randomly chosen prawns (approximately 100g) were processed to determine species composition and distribution of lengths.

For each lunar month, for each cell of the stratification - the prawner counts were multiplied by the appropriate factors to give an estimate of the total number of prawners over all available nights of the month. Lengths of prawns in samples were pooled to give annual distributions of lengths of prawns caught for each species.

Information on commercial catch and effort

Information on catch and fishing effort were extracted from the "LCATCH" database of NSW Fisheries and collated by year and method.

Information on the sex and species composition, and sizes of prawns caught by the commercial fishery were collected in the field by staff from the NSW Fisheries Research Institute. In the 1992/93 and 1993/94 seasons, on nights chosen randomly from the roster for the creel surveys, staff took 2-3 random samples (500 g) per night from the catches of commercial fishers operating on each estuary. The total weight of each species caught in the estuary was recorded by fisher and method, for each night. Prawns in samples were separated by species and sex and had their length measured as the straight line distance between the base of the eye orbit and the centre of the posterior margin of the carapace (carapace length, CL). Lengths of prawns were weighted to the total catch by the fisher and method. These were then summed to give annual distributions of lengths.

RESULTS

The results of this project are contained in the manuscripts by Montgomery and Reid (Appendix 2) and Reid and Montgomery (Appendix 3) which will be submitted to peer reviewed scientific journals. We have provided a summary of these below.

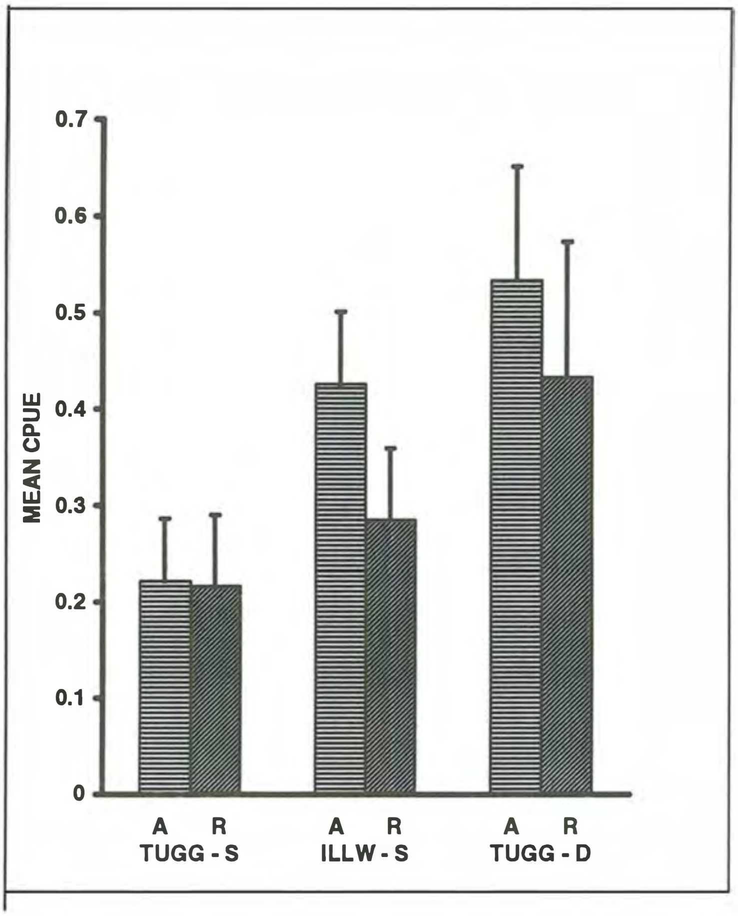


FIG. 5. Mean CPUE (Kg per prawner per hour) (± S.E.) calculated from data collected by access (A) and roving creel surveys (R) of the same prawners using scoop (S) or drag (D) nets on Tuggerah Lake (TUGG) and Lake Illawarra (ILLW).

Patterns in recreational catch, effort and CPUE

The results presented by Montgomery and Reid (Appendix 2) showed that roving creel surveys gave an unbiased estimate of mean CPUE for recreational prawners. There were no differences in mean CPUE between data from surveys of prawners who had completed their prawning trip and those done whilst people were prawning (Fig. 5). We concluded that roving creel surveys were an appropriate technique to use on estuaries in NSW to collect information on prawning effort and CPUE in the recreational fishery for prawns.

A total of 3,360 interviews were done during roving creel surveys on the four estuaries. Comparisons of monthly head-counts of prawners for the whole estuary with those for each subarea during roving creel surveys showed that our surveys covered close to 100% of the prawning effort during each lunar month. Further, response rates by prawners to interviews were virtually 100% during each survey.

Most prawners operating on each estuary were residents of the local area (Table 1). Prawners from Sydney made up a significant proportion of the people prawning at Wallis Lake and Tuggerah Lakes but were not a large proportion of the population prawning on Lake Illawarra. Those from Newcastle comprised a large proportion of the prawning population at Wallis Lake, but surprisingly were not a large proportion of those prawning on nearby Tuggerah Lakes. The prawning population at Lake Illawarra was made up mainly of local residents, whilst Canberra residents were a significant proportion of the people prawning on Coila Lake.

Table 1. Spatial distribution of residing area of prawners by number and percentage as determined from postcode information collected during interviews on roving creel surveys.

	Wallis		Lake Tuggerah		Illawarra		Coila	
	no.	%	no.	%	no.	%	no.	%
Local*	626	41.2	1497	69.1	1629	80.4	478	64.9
Sydney metropolitan area	254	16.7	399	18.4	122	6.0	32	4.3
Newcastle area	514	33.8	135	6.2	9	0.4	1	0.1
Wollongong area	4	0.3	4	0.2	-	-	11	1.5
Canberra area	1	0.1	10	0.5	8	0.4	157	21.3
Other NSW	113	7.4	91	4.2	252	12.4	41	5.6
Interstate	7	0.5	18	0.8	4	0.2	15	2.0
Overseas	0	0.0	1	0.0	2	0.1	0	0.0
No code	0	0.0	11	0.5	0	0.0	1	0.1
Total	1519		2166		2026		736	
* Postcodes considered within the local area	2420-2439		2250-2269		2500-2529		2530-2549	

Table 2 provides details on the number of prawners operating per night on each estuary for all strata in the survey season of 1993-94, whilst Figure 6 shows the number of prawners by method. Similar patterns in numbers of prawners operating by each method were found in each season of surveys (Fig. 6; Appendices 5.1 to 5.3). Scoop netting was the dominant method used by recreational prawners on each estuary to catch prawns (Fig. 6). No less than 80% of the effort on each estuary was by some form of scoop netting. Drag netting was the next most popular method. Over the whole survey period, only 17 interviews were recorded of people who used scissor nets.

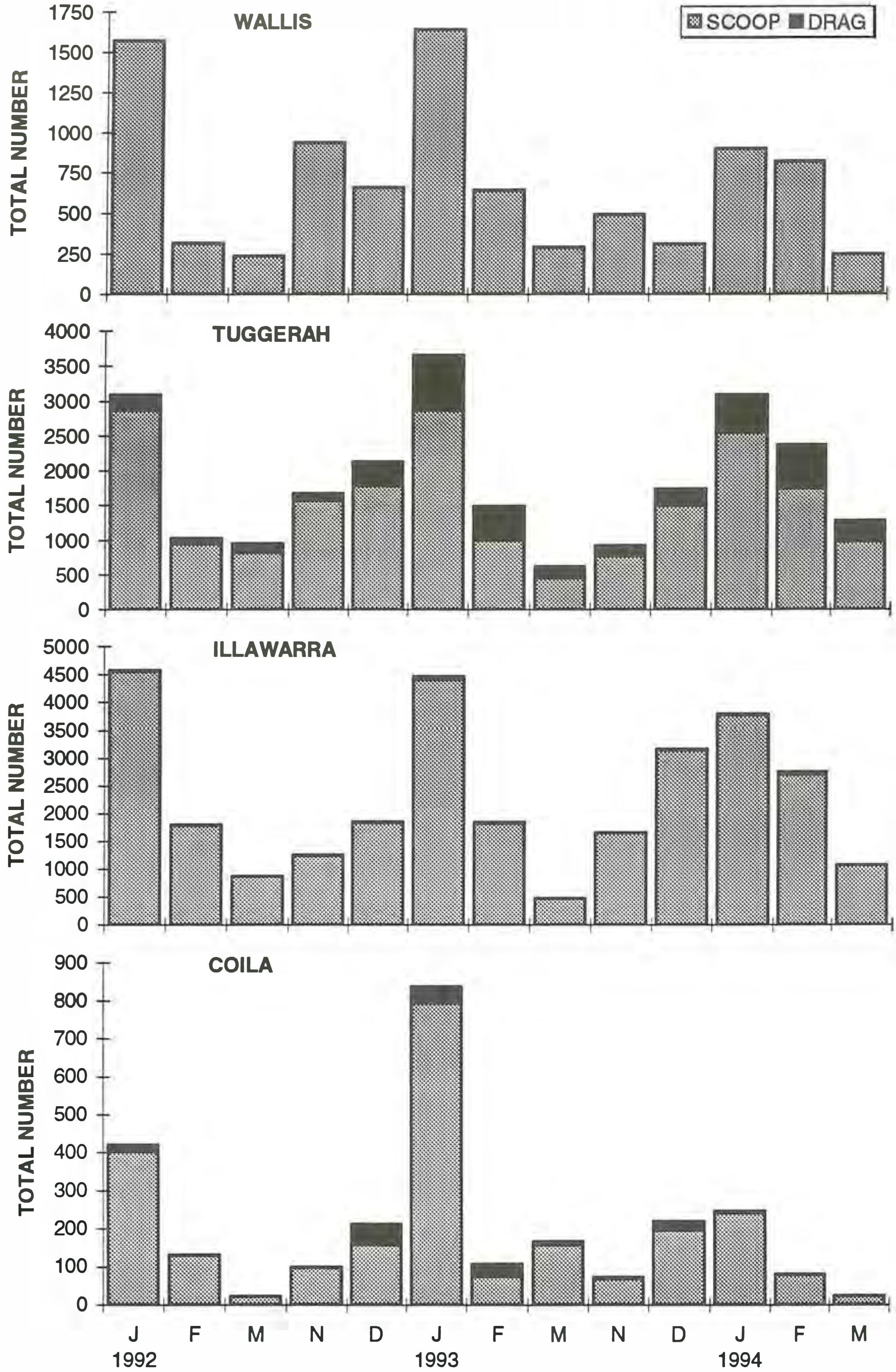


FIG. 6. Estimated total numbers of prawners using scoop-nets or drag-nets each month during the survey period.

Table 2. Estimated mean number of prawners per night by moon-phase (M), day-type (D), tide (T) and fishing method for the 1993-94 season. D = dark and L = light moon phases.

Location	M	D	T	No. of shore-scoopers				No. of boat-scoopers				No. of drag-netters			
				N	mean	se	Total	N	mean	se	Total	N	mean	se	Total
Wallis tidal	D	WD	RI	10	0.00	0.00	0	7	0.00	0.00	0	10	0.00	0.00	0
	D	WD	RO	25	0.36	0.17	19	18	21.17	4.42	1101	25	0.00	0.00	0
	D	WE	RI	5	0.00	0.00	0	3	0.00	0.00	0	5	0.00	0.00	0
	D	WE	RO	9	0.56	0.44	12	6	36.83	14.57	810	9	0.00	0.00	0
	L	WD	RI	4	0.00	0.00	0	3	0.00	0.00	0	4	0.00	0.00	0
	L	WD	RO	13	0.00	0.00	0	11	2.64	1.63	158	13	0.00	0.00	0
	L	WE	RI	3	0.00	0.00	0	2	0.00	0.00	0	3	0.00	0.00	0
	L	WE	RO	5	0.20	0.20	6	5	18.40	10.80	534	5	0.00	0.00	0
							37				2603				0
Tuggerah tidal	D	WD	RI	7	0.43	0.43	22	7	0.00	0.00	0	7	0.00	0.00	0
	D	WD	RO	18	56.06	15.12	2915	18	5.39	3.07	280	18	0.00	0.00	0
	D	WE	RI	3	1.33	1.33	29	3	0.00	0.00	0	3	0.00	0.00	0
	D	WE	RO	6	80.00	26.64	1760	6	4.67	1.69	103	6	0.00	0.00	0
	L	WD	RI	3	0.00	0.00	0	3	0.00	0.00	0	3	0.00	0.00	0
	L	WD	RO	11	19.64	9.33	1178	11	0.09	0.09	5	11	0.00	0.00	0
	L	WE	RI	2	3.00	3.00	87	2	0.00	0.00	0	2	0.00	0.00	0
	L	WE	RO	5	33.60	24.47	974	5	2.80	2.80	81	5	0.00	0.00	0
							6967				470				0
Tuggerah non-tidal	D	WD	n.a	25	9.32	2.44	485	25	0.00	0.00	0	25	20.96	5.50	1090
	D	WE	n.a	9	5.33	2.25	117	9	0.00	0.00	0	9	17.56	7.24	386
	L	WD	n.a	15	2.20	1.50	132	15	0.00	0.00	0	15	2.13	0.95	128
	L	WE	n.a	7	7.71	2.02	224	7	0.00	0.00	0	7	7.71	2.81	224
							957				0				1828
Illawarra tidal	D	WD	RI	7	0.00	0.00	0	7	0.00	0.00	0	7	0.00	0.00	0
	D	WD	RO	18	65.22	9.88	3391	18	6.83	1.62	355	18	0.00	0.00	0
	D	WE	RI	3	0.00	0.00	0	3	0.00	0.00	0	3	0.00	0.00	0
	D	WE	RO	6	67.33	26.32	1481	6	6.33	2.95	139	6	0.00	0.00	0
	L	WD	RI	2	0.00	0.00	0	2	0.00	0.00	0	2	0.00	0.00	0
	L	WD	RO	12	23.25	8.08	1395	12	2.00	1.12	120	12	0.00	0.00	0
	L	WE	RI	2	0.00	0.00	0	2	0.00	0.00	0	2	0.00	0.00	0
	L	WE	RO	4	22.00	8.86	638	4	0.00	0.00	0	4	0.00	0.00	0
							6906				614				0
Illawarra non-tidal	D	WD	n.a	25	10.08	3.07	524	25	20.60	6.01	1071	25	0.16	0.16	8
	D	WE	n.a	9	8.78	4.26	193	9	23.56	12.11	518	9	0.44	0.44	10
	L	WD	n.a	14	5.00	2.25	300	14	5.65	3.14	339	14	0.29	0.29	17
	L	WE	n.a	6	4.50	3.72	131	6	2.33	2.33	68	6	0.00	0.00	0
							1148				1996				35
Coila	D	WD	n.a	25	5.88	1.92	306	25	0.00	0.00	0	25	0.44	0.26	23
	D	WE	n.a	9	1.67	0.69	37	9	0.00	0.00	0	9	0.00	0.00	0
	L	WD	n.a	14	3.21	2.48	193	14	0.00	0.00	0	14	0.00	0.00	0
	L	WE	n.a	7	3.71	1.66	108	7	0.00	0.00	0	7	0.14	0.14	4
							643				0				27

At least 80% of prawning effort on each estuary occurred during the run-out tide (Table 2). In Wallis Lake effort was concentrated almost exclusively to tidally affected areas whist in the other estuaries effort was distributed across tidal and non tidal areas. On weekends in the dark period on Wallis Lake there were approximately double the number of prawners that were there on weekend light periods, while for weekdays, the dark period had ten-fold the number of prawners counted in the light period. There was a similar pattern in the other estuaries, with number of prawners in the dark period being approximately double that of the light (Table 2). In all estuaries, January was the month with the greatest effort (Fig. 6).

Estimates of annual mean CPUE for each season and estuary are shown in Table 3 whilst Appendix 5.4 provides estimates of mean CPUE for separate strata. When comparing mean CPUE between estuaries, we were limited to scoop netting because this was the only method with representative sample sizes from each estuary. The major difference in mean CPUE between the four study sites was the significantly greater values for Wallis Lake (Table 3). The CPUE for scoop netting in Wallis Lake over the whole survey period was almost double that for the tidal areas in the other Lakes (Table 3). In 1992-93, the CPUE for Coila Lake was similar to that of Wallis Lake but was less than that for the other 3 estuaries over the remainder of the whole survey period (Table 3).

The mean CPUE for scoop-netting in the tidal subareas in Tuggerah Lakes was almost double that of the non-tidal subareas for the total survey period (Table 3). In Lake Illawarra though, mean CPUE did not differ between tidal and non tidal areas.

There was no clear pattern in mean CPUE for scoop netting between dark and light lunar phases of the moon within each estuary or between years (Table 3). Significant differences in mean CPUE between dark and light phases were found in Wallis Lake (1992-93, 1993-94), in the tidal areas of Tuggerah Lakes (1991-92) and Lake Illawarra (1991-92, 1993-94) and in Coila Lake in 1992-93. In the non tidal subareas of Tuggerah Lakes in 1991-92, mean CPUE for drag nets was greater during the light than the dark phases.

Table 3. Mean CPUE (kg per prawner per h) for dark and light moon-phases (see text) in tidal and non-tidal subareas of each estuary

Location	Year	Moon phase	Scoop			Drag		
			N	mean	se	N	mean	se
Wallis tidal	1991/2	D	106	0.39	0.06			
	1991/2	L	3	0.25	0.01			
	1992/3	D	206	0.49	0.03			
	1992/3	L	67	0.31	0.04			
	1993/4	D	206	0.46	0.03			
	1993/4	L	43	0.3	0.06			
	Total		631	0.43	0.02			
Tuggerah tidal	1991/2	D	88	0.18	0.02			
	1991/2	L	19	0.32	0.04			
	1992/3	D	119	0.3	0.05			
	1992/3	L	54	0.17	0.03			
	1993/4	D	120	0.23	0.03			
	1993/4	L	43	0.3	0.09			
	Total		443	0.24	0.02			
Tuggerah non-tidal	1991/2	D	49	0.17	0.04	26	0.87	0.18
	1991/2	L	6	0.14	0.11	8	0.36	0.09
	1992/3	D	37	0.09	0.02	63	0.61	0.1
	1992/3	L	38	0.07	0.02	33	0.39	0.09
	1993/4	D	44	0.07	0.01	75	0.48	0.06
	1993/4	L	19	0.06	0.01	24	0.3	0.06
	Total		193	0.1	0.01	229	0.52	0.04
Illawarra tidal	1991/2	D	70	0.18	0.03			
	1991/2	L	21	0.54	0.07			
	1992/3	D	241	0.27	0.02			
	1992/3	L	102	0.23	0.02			
	1993/4	D	210	0.24	0.02			
	1993/4	L	112	0.17	0.02			
	Total		756	0.24	0.01			
Illawarra non-tidal	1991/2	D	42	0.26	0.07	2	0.56	0.19
	1991/2	L	11	0.42	0.20	1	0.94	-
	1992/3	D	161	0.22	0.01	7	0.29	0.11
	1992/3	L	76	0.28	0.04	1	0.2	-
	1993/4	D	225	0.19	0.01	2	0.2	0.13
	1993/4	L	66	0.18	0.02	1	0.55	-
	Total		581	0.22	0.01	14	0.37	0.08
Coila	1991/2	D	42	0.13	0.03	7	0.17	0.03
	1991/2	L	10	0.08	0.02	1	0.28	-
	1992/3	D	155	0.48	0.04	13	0.73	0.48
	1992/3	L	59	0.19	0.04	5	0.66	0.66
	1993/4	D	124	0.08	0.02	5	0.05	0.03
	1993/4	L	48	0.04	0.01	0	-	-
	Total		439	0.24	0.02	31	0.47	0.22

Drag-nets were used only in the non-tidal areas of estuaries. Comparisons between scoop netting and drag netting were possible only for Tuggerah Lakes because this was the only estuary in which both methods were commonly used. Drag-netting had a significantly greater mean CPUE than scoop netting ($P<0.05$) for each of the survey years for both light and dark lunar phases. The mean CPUE over the whole survey period was 0.51 kg/prawner h for drag-nets and 0.12 for scoop-nets. There were no differences in mean CPUE between boat-based and shore-based scoop netting. Mean CPUE and standard error (SE) for boat-based and shore-based scoop netting in Lake Illawarra over the whole survey period were 0.23 (± 0.01) and 0.23 (± 0.01), respectively. Comparable values for Tuggerah Lakes were 0.27 (± 0.03) and 0.24 (± 0.02), respectively.

Comparison of commercial and recreational catches

Estimates of monthly catch for the commercial and recreational fisheries are shown in Figure 7. Table 4 gives the annual catch for the recreational fishery as a proportion of the commercial catch. Annual catch for the recreational fishery expressed as a proportion of the commercial catch fluctuated greatly (Table 4), although these showed less inter-annual variation than the commercial catches for Wallis, Tuggerah and Illawarra Lakes (Fig. 7). Coila Lake differed from the others in that the closure of its mouth in January 1993 led to large catches in 1992-93, but relatively few prawns were caught in 1993-94.

The recreational catch was comprised almost exclusively of eastern king prawns in Wallis, Illawarra and Coila Lakes, while in Tuggerah Lakes the proportions of eastern king and school prawns were similar, with greasyback prawns comprising 10-22% of the catch (Fig. 8). The brown tiger prawn, *Penaeus esculentus* was the only other prawn species found during surveys of recreational prawners; 6 individuals were identified from the total of 10,835 prawns measured in subsamples. The commercial catches showed much higher proportions of school prawns in Wallis Lake (33-52%) and Lake Illawarra (35-53%; Fig 9b).

Greasyback prawns comprised 26-38% of catches in Wallis Lake with negligible catches of this species in the other lakes, apart from Tuggerah Lakes with 13% in 1993-94.

Annual distributions of lengths of eastern king prawns in samples from each estuary are shown in Figure 9a, and those for school prawns from Tuggerah Lakes are shown in Figure 9b. There were less than 50 school and greasyback prawns in pooled samples for the other estuaries; too few to warrant constructing similar distributions. The sizes of eastern king prawns in samples were similar between commercial and recreational catches for Wallis, Tuggerah and Illawarra lakes, however for Coila Lake, the distributions showed differences in both 1992-93 and 1993-94. In 1992-93 the recreational catches had relatively more longer prawns, while the converse was the case in 1993-94. School prawns in samples from recreational catches contained relatively more longer prawns (hence longer mean length) than those from commercial catches (Fig. 9b).

Table 4. Seasonal estimates of prawn catch (tonnes) by recreational (r) and commercial (c) fishers. Approximate standard errors are shown as (±SE).

	Tuggerah			Wallis			Illawarra			Coila		
	r	c	r/c(%)	r	c	r/c(%)	r	c	r/c(%)	r	c	r/c(%)
Jan-Mar 92	5.74 (±0.92)	17.98	31.9 (±5.1)	4.52 (±1.72)	32.71	13.8 (±5.3)	8.95 (±1.93)	15.27	58.6 (±12.6)	0.42 (±0.13)	5.10	8.2 (±2.5)
Nov 92-Mar 93	12.52 (±2.01)	64.86	19.3 (±3.1)	10.22 (±2.64)	67.19	15.2 (±3.9)	12.80 (±1.58)	19.03	67.3 (±8.3)	3.04 (±0.69)	31.38	9.0 (±2.2)
Nov 93- Mar 94	17.41 (±3.12)	37.42	46.5 (±8.3)	6.62 (±1.31)	23.75	27.9 (±5.5)	13.68 (±1.64)	27.49	49.8 (±6.0)	0.24 (±0.07)	0.85	28.2 (±8.2)
Total	35.67 (±3.82)	120.3	29.7 (±3.2)	21.36 (±3.41)	123.7	17.3 (±2.8)	35.43 (±2.99)	61.79	57.3 (±4.8)	3.70 (±0.71)	37.33	9.9 (±1.9)

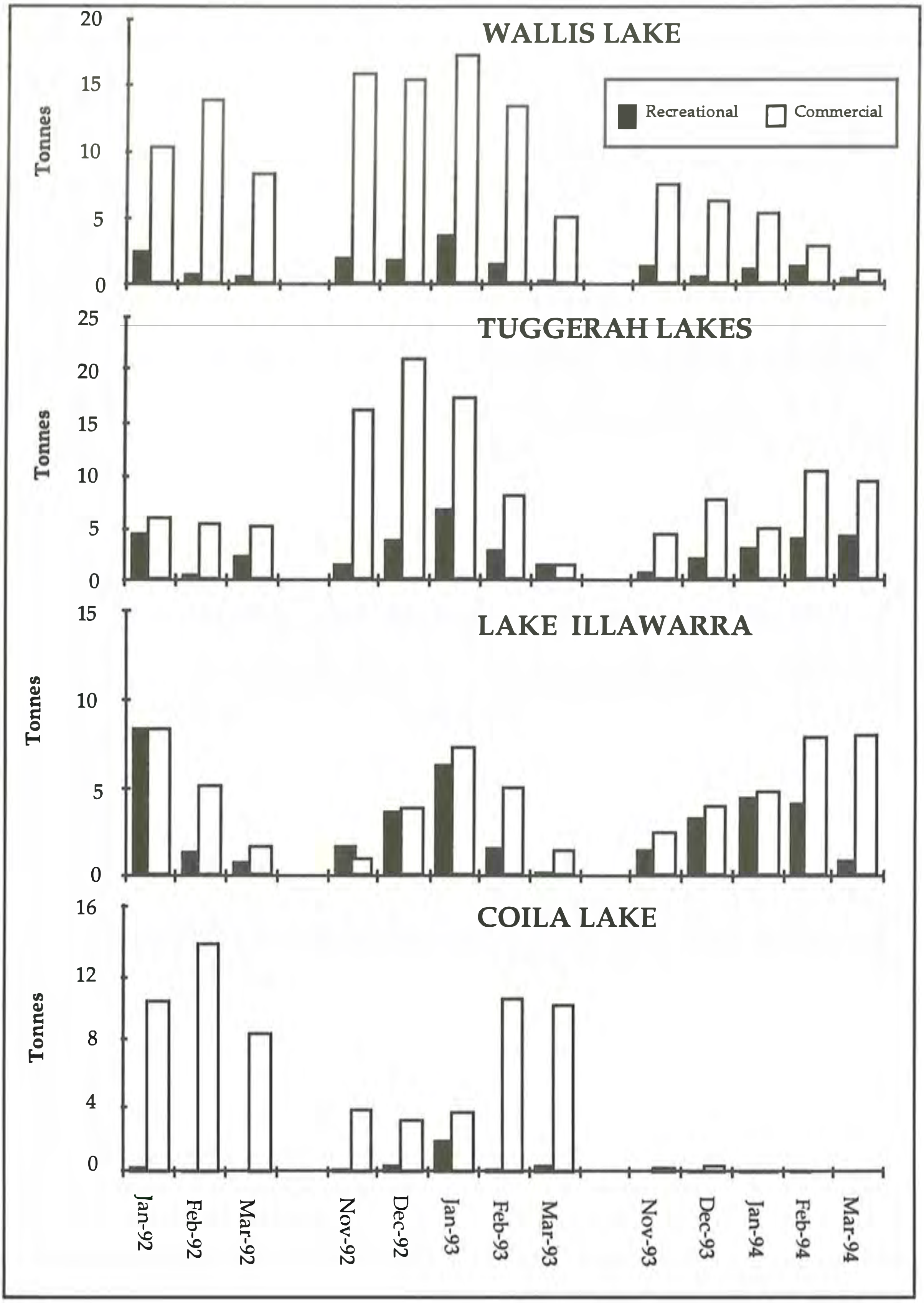


FIG. 7. Estimates of total catch of prawns by commercial and recreational fishers operating in the 4 estuaries studied.

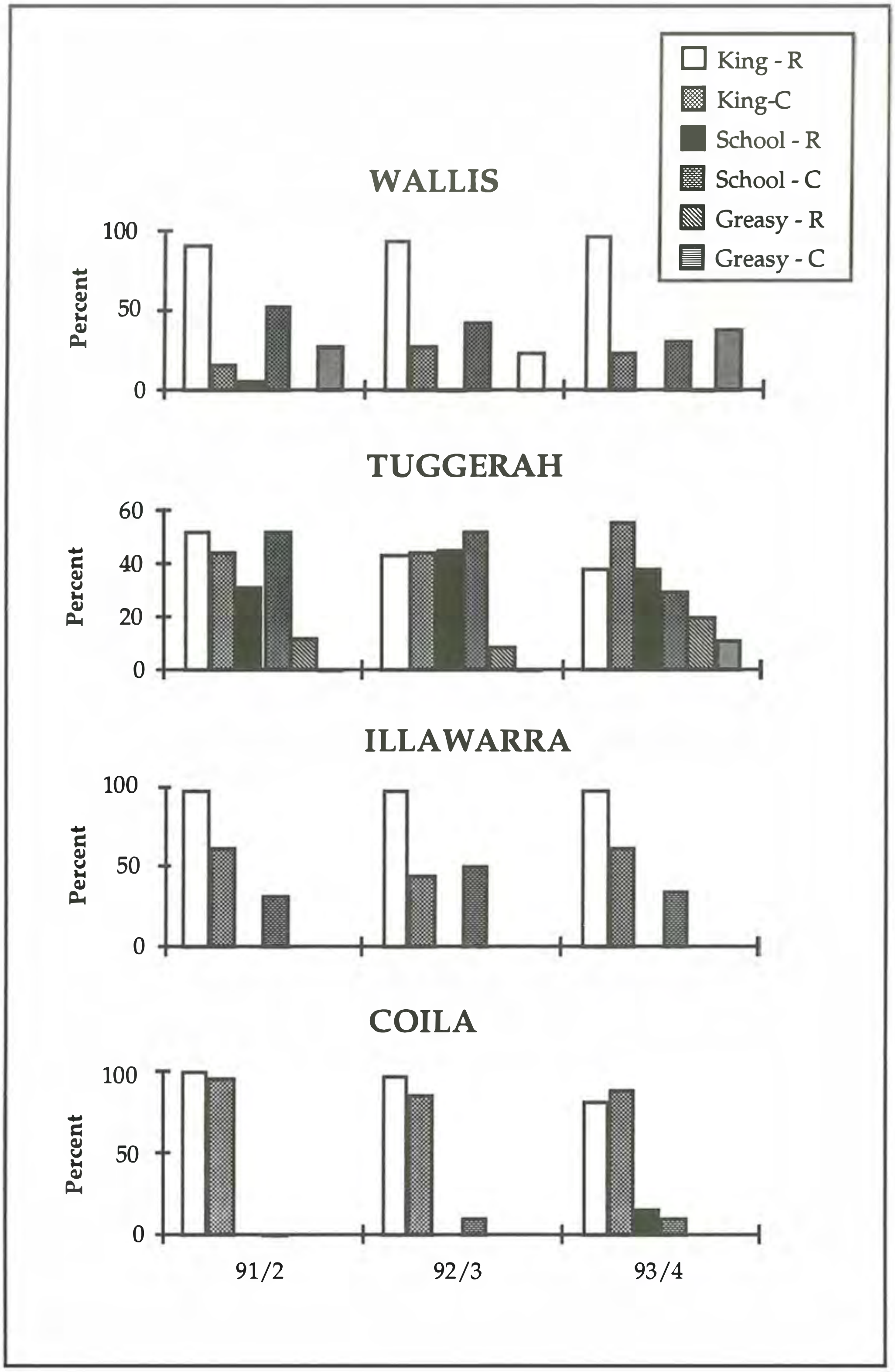


FIG. 8. Species composition of prawns in samples taken from the recreational (R) and commercial catches (C) of fishers operating on each estuary in the study.

FIG. 9a. Annual distributions of lengths of eastern king prawns in samples taken from the catches of recreational and commercial fishers over the survey period.

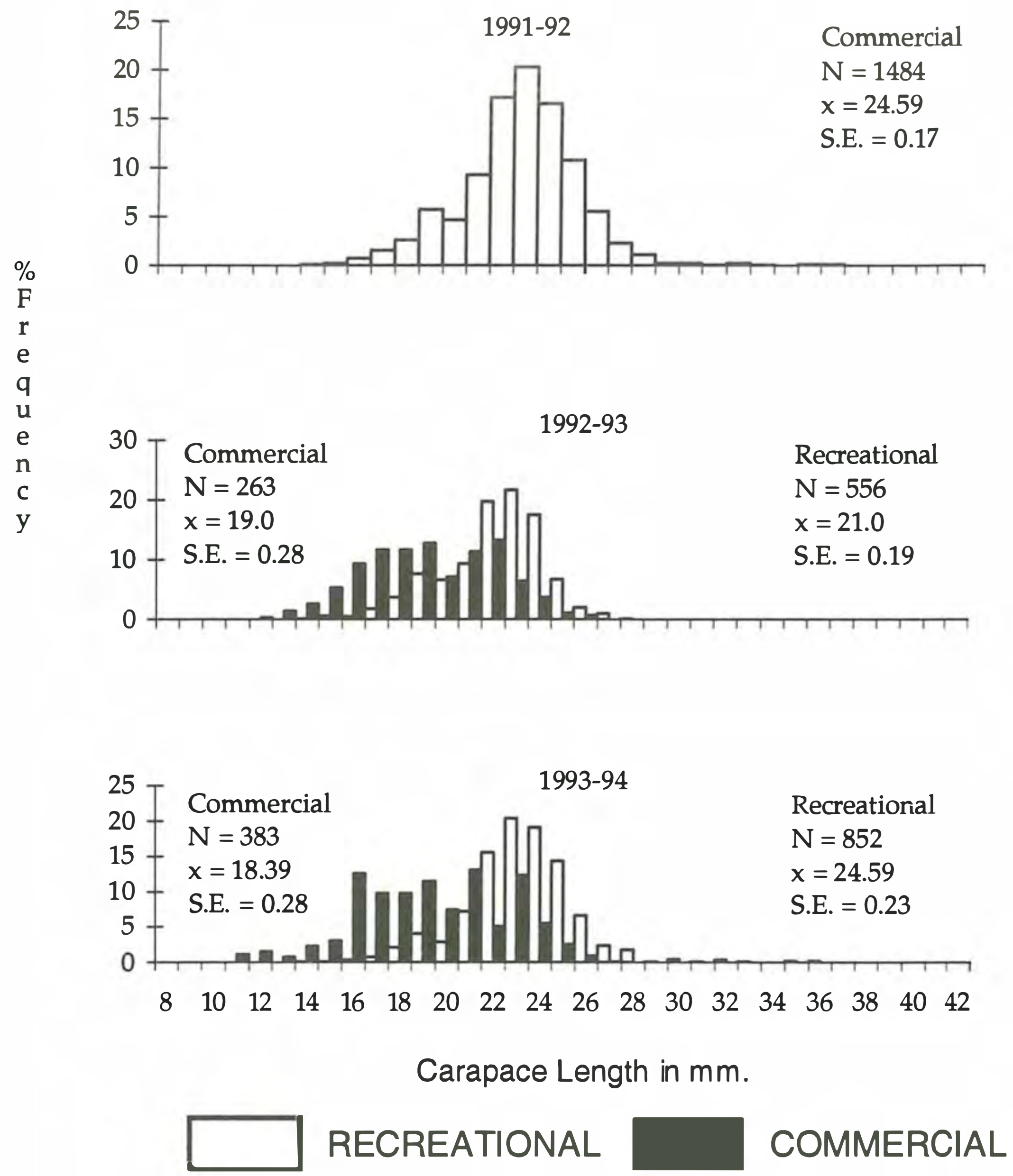


FIG. 9b. Annual distributions of lengths of school prawns in samples taken from the catches of recreational and commercial fishers operating in Tuggerah lakes over the survey period.

DISCUSSION

This project has provided estimates of catch with acceptable levels of variance for recreational fisheries for prawns in four estuaries. In doing so it has demonstrated that it is possible to do independent surveys at night of fisheries for penaeids. Results from this project have shown that recreational prawners are significant harvesters of the eastern king, school and greasyback prawn stocks in NSW.

Recreational prawners used either scoop netting or drag netting to catch prawns. Differences in catch rates between prawners operating drag nets and those using scoop nets can be attributed largely to the non passive nature of the former gear. As the name implies, drag nets are dragged across the bottom and so disturb those prawns not actively swimming in the water column. This gear also covers a greater area per unit time than the scoop net.

The great variability in the proportion of recreational to commercial catch between estuaries may be a function of the area of shallow grounds available for prawning. Juvenile prawns live in the shallow areas in estuaries (Young 1978; Young and Carpenter 1977), but are spatially distributed through the estuary principally by differences in tolerances to salinity (e.g. Coles and Greenwood 1983). Wide expanses of shallow areas provide recreational prawners with the opportunity to harvest more efficiently than in deeper estuaries (e.g. Wallis Lake). Prawners not only cover more area but are able to exploit the entire water column. This is particularly the case near the mouth of intermittently opening estuaries (Roy 1984) where prawners target prawns as they migrate to oceanic waters to mature (e.g. Ruello 1977; Montgomery 1990). Prawners in Tuggerah Lakes and Lake Illawarra were able to cover large areas of the Lake by wading, whereas in Wallis Lake prawners were limited to fishing from a boat because this estuary was far deeper than the other two.

The proportion of the recreational catch to commercial catch may be biased upwards through unreported landings from the commercial fishery, though this is thought not to have been significant. Information on levels of catch in the commercial fishery came from the "LCATCH" database of NSW Fisheries and was not validated for quantities of prawn caught. Results of two tagging studies done in Tuggerah Lakes to assess the exploitation rate on prawns by commercial and recreational fishers also suggested that recreational fisheries were significant harvesters of prawns. Recapture rates were 9 and 7%, and 5 and 2% for commercial and recreational fisheries, respectively.

The prominence of eastern king prawns in the catches of recreational prawners is probably associated with differences in behaviour between species. Penn (1983) discussed the effects on catchability of prawn behaviour. He categorised eastern king prawns as being nocturnal, strongly burrowing and most catchable at night. Racek (1959) and Ruello (1975) also found eastern king prawns to be most active at night and to emigrate in the surface waters of night ebb tides to oceanic waters during spring-summer. School prawns on the other hand do not burrow as deeply as eastern king prawns, are more active during the day time than the former species, and move in the bottom or mid-water (Racek 1959; Ruello 1975). Greasyback prawns peak in activity levels at dawn and dusk (Racek 1959). These behavioural differences appear to be related to light intensity (Wassenberg and Hill 1994).

Recreational prawners predominantly use scoop nets to catch prawns moving in the water column at night. This practise renders eastern king prawns more susceptible than school prawns to capture by these fishers because eastern king prawns move in the water column at night whereas school prawns move along the substrate. Commercial fishers use some more active types of gear than recreational prawners and operate both during the day and night. Consequently there is more likelihood that the proportion of school prawns in their catches will be greater than in recreational catches. School prawns are more susceptible to capture by active types of gear, particularly during day time, because they do not burrow as deep in the substrate as eastern king prawns and so are more easily disturbed by fishing gear.

The impact upon prawn stocks of harvesting in estuaries is probably greater than suggested by the contribution the estuary catch of each species makes to the total catch of prawns in NSW. Firstly, the proportion of the catch taken in estuaries in terms of numbers caught will be greater than the proportion by weight because individuals in estuaries are smaller than those from oceanic waters. Secondly, harvesting prawns in estuaries targets immature individuals. The size at first maturity for female eastern king prawns is approximately 42 mm CL (Courtney et al. in press) whilst that for school prawns is around 22 mm CL but varies between stocks (Ruello 1973 and Glaister 1977). These are longer than the lengths of most individuals caught in estuaries. Catching relatively large quantities of immature prawns has the potential to affect recruitment to the spawning stock.

This impact will vary between species because school prawns comprise discrete stocks (Ruelllo 1977) whereas eastern king prawns are a unit stock (Montgomery 1990) along the east coast of Australia. Little else is known about the dynamics of school prawn populations other than that production is associated to river discharge (Ruello 1973, Glaister 1978). The effects upon the spawning stock of eastern king prawns of changes in recruitment from different estuaries is very complex. Fishing pressure is not uniform off the east coast of Australia, so that as individuals grow and move northwards they are exposed to different levels of natural and fishing mortality. Gordon et al. (in press) combined the concept of the Baranov (1918) catch equation with the compartmentalised approach of Glaister et al. (1990) to assess the effects upon yield of eastern king prawns of variations in recruitment from different estuaries. Essentially this effect depends upon the rate of movement of eastern king prawns along the coast of NSW. The longer it takes prawns from an estuary to reach offshore prawn grounds where fishing pressure is high, the less impact this recruitment will have upon the stock because the bulk of the recruits are lost from yield through natural mortality.

The most important biological question for prawns relevant to management, is optimum size at first capture. This has both an economic and biological aspect. The size may vary between prawns from different estuaries. In the case of school prawns it will be because of differences in growth and mortality between stocks, whilst for eastern king prawns, it will be a "trade off" between rate of movement, mortality and growth. Simulations using the yield per recruit models of Beverton and Holt (1957) and Gordon et al. (in press) showed that greater yield per recruit of eastern king prawns would be obtained if optimum size at first capture was longer than is currently the case (15-20 mm CL; Montgomery unpublished data).

There can be little doubt that the quantity of prawns caught by the recreational fishery will impact upon the level of catch of the commercial fishery and the prawn resources. This project is an example of using roving creel survey techniques in hours of darkness to estimate the level of catch in a fishery. Malvestuto (1983) and Hayne (1991) list as a disadvantage the fact that roving creel surveys cannot be done at night. This may be the general case as we have been unable to find any examples of studies that have used intercept survey methods to estimate the catch of fishers operating at night. The recreational fishery for prawns in NSW may be the exception because prawners use battery powered lights to spot prawns in the water column and are therefore easily identified by the bobbing of their light. Further, we are unaware of any other study in the peer reviewed literature that has surveyed a fishery for penaeids. We conclude that roving creel surveys have been used successfully at night to show that the recreational fishery is a significant harvester of penaeids in NSW. The methodology used in this study may be applicable to other penaeid fisheries in Australia and internationally.

RECOMMENDATIONS AND IMPLICATIONS

The basic piece of information required by managers to manage a resource is the level of catch by user groups of the particular resource. This study has been successful in demonstrating that surveys of recreational fisheries for penaeids that operate at night can be done to provide estimates of catch with acceptable levels of variance. Considering the difficulties of surveying fishers at night, the techniques used in this study should work equally as well during day time. Results in this study have shown clearly that recreational fishers are significant users of the prawn resources of NSW.

The recreational fishery for prawns in NSW needs to be considered by managers when developing management options for the eastern king, school and greasyback prawn fisheries of NSW. Overall, the estimate of catch by the recreational fishery for prawns in the estuaries studied was 30% of the commercial fishery operating in the same estuaries. The importance of the recreational fishery as harvesters of prawns has added significance when it is considered that eastern king prawns comprised the major proportion of the catch. Eastern king prawns are the longest lived of the penaeid resources off NSW and therefore would be expected to have a lower natural mortality and, as a consequence, be more susceptible to over-exploitation than the other penaeids.

The significance of harvesting prawns whilst in estuaries is even greater when catch is considered as numbers of prawns. School and eastern king prawns in estuaries are smaller than those in oceanic waters so that it takes more individuals from estuaries make up the same weight as that from the oceanic catch. Further, eastern king prawns in estuaries are immature individuals, so significant harvesting is taking place before individuals have had a chance to spawn.

Clearly, the most important question relevant to management of prawn stocks, is optimum size at first capture. This size may vary between prawns from different estuaries. We recommend that investigations be done to determine whether sizes at first capture for prawns in estuaries need to be increased.

Penaeids are one of the most economically important groups of seafood resources in Australia. As such it is important for managers to have information on the level of catch by both recreational and commercial user groups. It is likely that the methodology used in this study could be used to survey the recreational fisheries for other penaeid resources in estuaries in Australia. This study provides a guide to the level of sampling required to extend the coverage to an estimate of the recreational catch in NSW. The relatively low variation in mean CPUE over a full season within an estuary indicates that estimates of the state wide catch could be achieved by concentrating survey effort on counts of prawners, with relatively low survey effort directed to interviews.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the cooperation of the many recreational and commercial prawners encountered during this project.

Doing roving creel surveys at night is something few have attempted. We wish to thank Mr L. West from Kewagama Research for his input into the survey design and the professional manner in which his company did these surveys. Special thanks go to the field staff he employed to do the interviews in the field; namely; K. Garn, D. Wright, D. Castle, L. Lovasz, S. Munro, R. Petersen, G. Thomas and M. Tucker.

Thanks go also to staff at the NSW Fisheries Research Institute, who did the access point surveys; particularly Mr M. Beatson who supervised this work. Mr A. Grinberg from NSW Fisheries provided database support which facilitated data analysis for the project. Technical support during the project was provided by M. Beatson, P. Brett, C. Blount, M. Tanner, S. Wagland and L. Raines, all from NSW Fisheries.

Manuscripts were reviewed by Drs A. Steffe and R. West from the NSW Fisheries Research Institute, who are acknowledged for their helpful comments.

Finally we would like to thank the Director of NSW Fisheries Research, Dr R.E. Kearney and the board of the Fishing Industry Research & Development Corporation for having the vision to support this research.

REFERENCES

BEVERTON, R.J.H., AND S.J. Holt S.J. 1957. On the dynamics of exploited fish populations. U.K. Min. Agric. Fish. Fish. Invest. (Ser II), 19: 1-533.

COLES, R.G., AND J.G. GREENWOOD 1983. Seasonal movement and size distribution of three commercially important Australian prawn species (Crustacea: Penaeidae) within an estuarine system. Aust. J. Mar. Freshwat. Res. 34: 727-743.

COURTNEY, A.J., S.S. MONTGOMERY, D.J. DIE, N.L. ANDREW, M. COSGROVE, AND C. BLOUNT. In PRESS. Reproductive biology of the eastern king prawn, *Penaeus plebejus* and spawning stock dynamics in coastal waters of east Australia. I Maturation. Mar. Biol.

GLAISTER, J.P. 1977. Ecological studies on Metapenaeus macleayi (Haswell) (Crustacea, Decapoda, Penaeidae) in the Clarence River region, northern NSW. Msc. Thesis UNSW 1-116 pp.

GLAISTER, J.P. 1978. The impact of river discharge on distribution and production of the school prawn Metapenaeus macleayi (Haswell) (Crustacea: Penaeidae) in the Clarence River region, northern NSW. Aust. J. Mar. Freshwat. Res. 29: 311-323.

GORDON, G.N.G., N.L. ANDREW, AND S.S. MONTGOMERY (In Press). A deterministic compartmental model for the eastern king prawn (Penaeus plebejus) fishery in New South Wales. Aust. J. Mar. Freshwat. Res.

GREY, D.L, W. DALL, and A. BAKER 1983. A guide to the Australian penaeid prawns. NT Govt, Printing Office 1-140.

HAYNE, D.W. 1991. The access point survey: procedures and comparison with roving clerk creel survey. Am. Fish. Soc. Symp. 12: 123-138.

HOENIG, J.M., D.S. ROBSON, C.M., JONES, and POLLOCK, K.H. 1993. Scheduling counts in instantaneous and progressive count methods for estimating sportfishing. N. Am. J. Fish. Man. 13: 723-736.

KAILOLA, P.J., WILLIAMS, M.J., STEWART, P.C., REICHELT, R.E., McNEE, A. AND GRIEVE, C. 1993. Australian Fisheries Resources. BRS Dept. Prim. Ind. 1-422.

LOMB, N. 1993. 1994 Sydney Sky Guide. Observatory. 1-80.

MALVESTUTO, S.P. 1983. Sampling the recreational fishery. p. 397-419. In L.A. Nielsen AND D.L. Johnson [ed] Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

MALVESTUTO, S.P., W.D. DAVIES, AND W.L. SHELTON 1978. An evaluation of the roving creel survey with nonuniform probability sampling. Trans. Am. Fish. Soc. 107: 255-262.

MONTGOMERY, S.S and V.C. McDONALL 1988. A summary of the research conducted on estuarine prawn trawl fisheries in New South Wales and recommendations for their future management. NSW Fish. Res. Int. Rep. 46: 1-177.

MONTGOMERY S.S. 1990. Movements of juvenile eastern king prawns Penaeus plebejus, and identification of stock along the east coast of Australia. Fish. Res. 9: 189-208.

POLLOCK, K.H., C.M. JONES, AND T.L. BROWN [ED] 1994. Angler survey methods and their applications in fisheries management. Am. Fish. Soc. Symp. 25: 1-371.

RACEK, A.A. 1959. Prawn investigations in eastern Australia. Res. Bull. St. Fish. N. S. W. 6: 1-57.

ROY, P.S. 1984. New South Wales estuaries: their origin and evolution. In B.G. Thom [ed] Coastal geomorphology in Australia. Academic Press, New York. 99-121.

RUELLO, N.V. 1975. Geographical distribution, growth and breeding migration of the eastern Australian king prawn Penaeus plebejus Hess. Aust. J. Mar. and Freshwat. Res. 26, 343-354.

RUELLO, N.V. 1977. Migration and stock studies on the Australian school prawn Metapenaeus macleayi. Mar. Biol. 41:185-190.

ROBSON, D.S. 1991. The roving creel survey. Am. Fish. Soc. Symp. 12: 19-24.

YOUNG, P.C. 1978. Moreton Bay, Queensland: A nursery area for juvenile penaeid prawns. Aust. J. Mar. Freshw. Res. 29: 55-75.

YOUNG, P.C., AND S.M. CARPENTER 1977. Recruitment of postlarval penaeid prawns to nursery areas in Moreton Bay, Queensland. Australian J. Mar. Freshwat. Res. 28: 754-73.

WASSENBERG, T.J. and HILL, B.J. 1994. Laboratory study on the effect of light on the emergence behaviour of eight species of commercially important adult penaeid prawns. Aust. J. Mar. Freshw. Res. 45: 43-50.

APPENDIX 1

Regulations for fishing for prawns in the estuaries studied.

FISHERIES MANAGEMENT ACT 1994 -- REGULATION

(Fisheries Management (General) Regulation 1995)

NEW SOUTH WALES

PART 3 - FISHING GEAR

Division 3 - Lawful commercial nets

Prawn net (hauling)

29. (1) It is lawful to use a hauling net for taking prawns in the waters specified in the Table to this clause if the net (including hauling lines) complies with the description as set out in relation to those waters in that Table and the following conditions are complied with:

(a) The net is used only by the method of hauling.

(b) The net is not set or staked at any time.

(c) The net is landed on the tray of a boat or in sufficient depth of water to enable prohibited size fish that are taken in the net to escape.

(d) There is no seine net (prawns) on the boat from which the net is used.

(2) It is also lawful to use a try net in the waters specified in the Table to this clause to facilitate the taking of prawns by the means of a prawn net (hauling) if the try net complies with the following description:

The net is attached to a frame not exceeding 0.6 metre in width and 0. 5 metre in height, with a total length from the centre of the plane to the extremity of the net not exceeding 2 metres; mesh not less than 30 mm nor more than 36 mm.

(3) It is also lawful to use a hauling net to take other fish (other than a prohibited size class of fish) which are taken by the net when it is being lawfully used for taking prawns.

(4) For the purposes of this Regulation or any other instrument under the Act, a net described:

(a) in subclause (1) or in the Table to this clause may be referred to as a prawn net (hauling); and

(b) in subclause (2) may be referred to as a try net (prawns).

TABLE

PRAWN NET (HAULING)

1. (a) *Waters*—Tuggerah Lakes (other than that part described in Schedule 2).

   (b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 140 metres.

2. (a) *Waters*—Lake Illawarra (other than that part described in Schedule 2).

   (b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 220 metres.

3. (a) *Waters*—Botany Bay, Georges River, Shoalhaven River and St. Georges Basin.

   (b) *Description of net*—Total length not exceeding 90 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 220 metres.

4. (a) *Waters*—Lake Macquarie, together with all its inlets, bays, creeks and tributaries within the following boundaries: commencing at the southernmost extremity of Wangi Wangi Point, and bounded then by a straight line to the northernmost extremity of Galgabba or Stony Point, by the foreshore generally northerly to a point distant about 1,000 metres southerly from the southern

point of the junction of the waters of the entrance with those of the lake, then by a line drawn west about 800 metres, then by a line drawn northerly to a point about 800 metres west of the western extremity of Marks Point and then by that line to Marks Point, and then by the eastern, northern and western shore of Lake Macquarie and its tributaries to the point of commencement.

(b) *Description of net*—Total length not exceeding 20 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 65 metres.

5. (a) *Waters*—Myall Lakes, Booloombayte Lakes, the Broadwater (Myall Lakes) and Smith's Lake.

(b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 130 metres.

6. (a) *Waters*—That part of Wallis Lake included within the following boundaries: commencing at a post marked "FD" situated at the high water mark of Pipers Bay (the post being located by a line bearing 186 degrees from an electricity pole numbered 14808, situated at the eastern end of Pipers Bay Drive Forster), then bounded by a line bearing 217 degrees to a second post marked "FD" situated at the high water mark on the southern side of Big Island, then to a third post marked "FD" situated at the high water mark of Wallis Island, bearing 245 degrees from the second post, then southerly, westerly and northerly along the high water mark of Wallis Island to a jetty located on the western side of Wallis Island, then westerly along the length of the jetty to its end, then to a fourth post marked "FD", situated at the high water mark on the foreshore of Coomba Park, bearing 246 degrees and 30 minutes from the end of the jetty, then generally southerly, easterly and northerly by the high water mark of Wallis Lake to the point of commencement.

(b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 140 metres.

7. (a) *Waters*—Port Jackson (including the Parramatta and Lane Cove Rivers and Middle Harbour).

(b) *Description of net*—Total length not exceeding 60 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 130 metres.

8. (a) *Waters*—Wallagoot Lake and Blackfellows Lake.

(b) *Description of net*—Total length not exceeding 90 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 190 metres.

9. (a) *Waters*—Coila Lake and Wallaga Lake.

(b) *Description of net*—Total length not exceeding 75 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 130 metres.

10. (a) *Waters*—Tweed River and Terranora Inlet.

(b) *Description of net*—Total length not exceeding 40 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 220 metres.

11. (a) *Waters*—Any other waters (except inland waters and the Manning River).

(b) *Description of net*—Total length not exceeding 40 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 130 metres.

Prawn net (hauling): Manning River

30. (1) It is lawful to use a hauling net for taking prawns in the Manning River if the net (including hauling lines) complies with the description set out in subclause (2) and the conditions set out in subclauses (3), (4) and (5) are complied with.

(2) The net must comply with the following description:

(a) The total length of the net must not exceed 40 metres.

(b) The mesh throughout must not be less than 30 mm nor more than 36 mm.

(c) The net must have no attachments except spreader poles and hauling lines.

(d) The hauling line run on the first leg to the net must not be longer than 220 metres.

(e) The hauling line running from the net to the motor boat used to assist in shooting the net must not be longer than 90 metres, and not be shorter than 60 metres.

(3) The net must be used only by the method of hauling, and must not be set or staked at any time.

(4) The net must be shot and hauled as follows:

(a) One end of the hauling line run on the first leg to the net must be:

(i) attached to a fixed point on shore; or

(ii) anchored ashore; or

(iii) attached to an unpowered boat which itself is secured on shore.

(b) The line must then be cast from a motor boat, and the net then shot.

(c) The second hauling line must then be cast (or laid out) from the motor boat as the boat moves in a circular path so as to return to a landing-up point near the shore end of the first hauling line.

(d) The second hauling line must be attached to a point on the motor boat by the line's extremity only (that is, one end must be attached to the net, and the other end secured to the boat to prevent loss of the line overboard).

(e) The second hauling line must not be towed until all of it has been shot away free of tangles, knots or anything else which would effectively shorten it.

(f) Once the shooting and hauling of the net have commenced, they must continue until the hauling lines have been removed from the water and the net landed in such depth of water, or onto the tray of the boat in such a way, as to enable any prohibited size fish taken in the net to escape.

(g) Once any prohibited size fish have been allowed to escape, the net must be fully removed from the water.

(5) The net must be operated in accordance with the determination (if any) by the fisheries officer for the time being charged with the supervision of the Manning River as to the number of commercial fishers to constitute the crew operating the net.

(6) For the purposes of this Regulation or any other instrument under the Act, a net described in this clause may be referred to as a prawn net (hauling).

Prawn net (set pocket)

31. (1) It is lawful to use a set pocket net for taking prawns in the waters specified in the Table to this clause if the net complies with the description as set out in relation to those waters in that Table and the following conditions (in addition to those in subclause (2), if applicable) are complied with:

(a) The net is used only by the method of setting.

(b) Hauling lines are not attached to the net.

(c) The net must not be left unattended during the period it is set.

(2) If the net is used in the waters of the Clarence River, the following additional conditions must be complied with:

(a) The net must not be used in conjunction with a moored boat with the engine running unless the boat is licensed and is owned by a commercial fisher, or by a member of the crew of a commercial fisher, by whom or by which the net is being used.

(b) A person must not use a prawn net except during the following periods:

(i) on weekends during the dark (that is, the period commencing 3 days after a full moon and ending 3 days after the next new moon);

(ii) from sunset to sunrise on week days between 1 August in any year and 31 May in the next year;

(iii) from sunrise to sunset on week days between 1 December in any year and 31 May in the next year.

(c) Except in the area known as the South Arm Rocks:

(i) the inside peg of the net must not be set further than 5 metres from low-water mark; and

(ii) all pegs used in connection with the net must be painted white and show at least 1 metre above high-water mark.

(d) The net must be kept clear of the water when it is not in use.

(3) For the purposes of this Regulation or any other instrument under the Act, a net described in this clause may be referred to as a prawn net (set pocket).

TABLE

PRAWN NET (SET POCKET)

1. (a) *Waters*—That part of the Myall River from the junction of the Myall River with the Broadwater downstream to the road bridge between Tea Gardens and Hawk's Nest.

(b) *Description of net*—Total length not exceeding 20 metres; mesh throughout not less than 30 mm nor more than 36 mm.

2. (a) *Waters*—Those parts of Wallis Lake included within the following boundaries: (i) the whole of that part of Wollomba Channel in Wallis Lake within the following boundaries: commencing at the line of high-water mark at the southern point of the entrance to Wollomba River, and bounded then by a straight line southerly to the northern shore of First Island at the southeastern foreshore corner of Oyster Farm No. 77–3, by the northern shore of that island easterly to its extremity, and by a straight line southeasterly to the high-water mark of the northern shore of Cockatoo Island (being a point about 180 metres southwesterly from the southeastern foreshore corner of Oyster Farm No. 78–44), by the northern shore of that island generally easterly to the eastern foreshore corner of Oyster Farm No. 74–138, then by a straight line northeasterly to the northern shore of Grassy Island at the most northerly southeastern foreshore boundary of Oyster Lease No. 59–361, by the northern shore of that island easterly to its most eastern point, by a straight line north-northwesterly to the eastern extremity of Long Island, by the southern shore of that island generally westerly to its western extremity, by a straight line southwesterly to the eastern extremity of Sandy Island (such point being the most easterly foreshore corner of Oyster Farm No. 74–24), by the southern shore of that island generally westerly to its most western point, and then by a straight line westerly to the point of commencement; (ii) the whole of that part of Bulmer's Channel in Wallis Lake within the following boundaries: commencing at the northeastern corner of Oyster Lease No. 77–270 at the western end of Godwin Island, and bounded then by a straight line drawn west-northwesterly to the northeastern corner of Oyster Farm No. 72–11 on Cockatoo Island, by the southern shore of that island generally westerly to its most western point, by a line southeasterly to the most eastern point of

Northern Twin Island, by a line south-southwesterly to the most eastern foreshore corner of Oyster Farm No. 76–112, by the southeastern shore of that island generally southwesterly to the most eastern foreshore corner of Oyster Farm No. 68–31, by a straight line south-southwesterly to the high-water mark of Wallis Island at the westerly prolongation of the northern boundary of Portion 206, Parish of Forster, by the high-water mark of that island generally northeasterly and southeasterly to the southeastern foreshore corner of Oyster Farm No. 71– 360, section 1, and then by a line northeasterly to the point of commencement; (iii) the whole of that part of Stockyard Channel in Wallis Lake within the following boundaries: commencing at the northeastern corner of Oyster Lease No. 77– 270 at the western end of Godwin Island, and bounded then by a straight line drawn southwesterly to the southeastern foreshore corner of Oyster Farm No. 71– 360, section 1, on Wallis Island, by the high-water mark of that island generally southeasterly and southerly to the easterly prolongation of the southern boundary of Portion 221, Parish of Forster, by a straight line easterly to the most southerly corner of Oyster Farm No. 73–253, by a straight line northeasterly to the southeastern foreshore corner of Oyster Farm No. 73–216 on the southern end of Hadley Island, by the high-water mark of that island generally northwesterly and northeasterly to its northern extremity, by a line northerly to the northeastern foreshore corner of Oyster Farm No. 70–245 on the southern shore of Godwin Island, by the high-water mark of that island generally westerly, northwesterly, southwesterly and northerly to the northeastern corner of Oyster Farm No. 67–203, by a straight line westerly to the most western northeastern foreshore corner of Oyster Lease No. 81–43, and again by the high-water mark of Godwin Island generally southerly, westerly, northerly, southwesterly and northwesterly to the point of commencement.

(b) *Description of net*—Total length not exceeding 20 metres; mesh throughout not less than 30 mm nor more than 36 mm.

3. (a) *Waters*—The whole of Queen's Lake Entrance within the following boundaries: commencing at the northeastern corner of Oyster Farm No. 81–179, and bounded then by a line northerly to the western bank of Queen's Lake Entrance, by the western bank generally northwesterly to the western foreshore corner of Oyster Farm No. 83–95, by a line southwesterly to the eastern foreshore corner of Oyster Farm No. 67–6, by the foreshore generally southwesterly to the eastern foreshore corner of Oyster Farm No. 70–198, by a line drawn northeasterly through the most westerly point of an island at the western entrance to Queen's Lake Entrance, to the northern bank of Queen's Lake Entrance, then easterly and southerly, following the eastern bank of Queen's Lake Entrance generally southeasterly to a point east of the northeastern corner of Oyster Farm No. 81–179, and then by a line to the point of commencement.

(b) *Description of net*—Total length not exceeding 20 metres; mesh throughout not less than 30 mm nor more than 36 mm.

4. (a) *Waters*—That part of Watson Taylor Lake within the following boundaries: commencing at the northern point of Benson Inlet, then north along the eastern shore of Watson Taylor Lake to the northwestern corner of Portion 150, Parish of Camden Haven, County of Macquarie, then westerly to the northeast corner of Portion 70, Parish of Camden Haven, County of Macquarie, then southwest along the shore of Camden Haven Inlet and Moore's Island to the southwest tip of Moore's Island, then southwest to the northern corner of Grassy Island to the island's most southerly point, and then to the point of commencement.

(b) *Description of net*—Total length not exceeding 20 metres; mesh throughout not less than 30 mm nor more than 36 mm.

5. (a) *Waters*—Those parts of Tuggerah Lakes and Lake Illawarra (and ocean waters adjoining) described in Schedule 3.

(b) *Description of net*—Total length not exceeding 5 metres; mesh throughout not less than 30 mm nor more than 36 mm.

6 (a) *Waters*—That part of Cathie Creek within the following boundaries: the whole of that part of Cathie Creek north of a line bearing 110 degrees across the creek from a post (marked F^D) on the western bank of the creek to a Ti-tree (marked F^D) on the eastern bank of the creek, situated about 500 metres upstream from the Pacific Ocean.

(b) *Description of net*—Total length not exceeding 10 metres; length of pocket, from cod-end to cork line, not exceeding 10 metres; mesh throughout not less than 30 mm nor more than 36 mm.

7. (a) *Waters*—That part of Sussex Inlet within the following boundaries: the whole of the waters of that part of Sussex Haven and the adjacent waters of the Pacific Ocean within the following boundaries: commencing at the southeastern corner of Reserve 75,429 for Public Recreation notified in the Gazette on 14 November 1952, and bounded then by a line drawn easterly to the point of junction of the eastern shore of Sussex Haven with the shore of the Pacific Ocean, by a line parallel to the western shore of the entrance to Sussex Haven to a point east of the southernmost extremity of that entrance, by a line westerly, and then by that shore northwesterly to the point of commencement.

(b) *Description of net*—Total length not exceeding 5 metres; mesh throughout not less than 30 mm nor more than 36 mm.

8. (a) *Waters*—Limeburners Creek from its confluence with the Hastings River upwards to its source.

(b) *Description of net*—Total length not exceeding 20 metres; mesh throughout not less than 30 mm nor more than 36 mm.

9. (a) *Waters*—The whole of the main arm of the Clarence River seawards of the Ulmarra Ferry Crossing (excluding all creeks, tributaries, effluents and secondary or back channels of that river, that part of the left or northern bank between Brown's or Goodwood Island Wharf and the new (or eastern) opening in the Iluka Boat Harbour training wall and that part of the river which lies seawards of a line drawn from the north-westernmost corner of Portion 64, Parish of Taloumbi, to the north-westernmost corner of Freeburn Island and generally south of Freeburn Island and the main training wall that extends seawards from the easterly extremity of Freeburn Island).

(b) *Description of net*—Total length not exceeding 20 metres; mesh throughout not less than 30 mm nor more than 36 mm.

10. (a) *Waters*—Inlet cooling water canal to Munmorah Power Station.

(b) *Description of net*—Total length not exceeding 20 metres nor less than 18 metres; mesh throughout not less than 25 mm nor more than 30 mm.

11. (a) *Waters*—Smiths Lake.

(b) *Description of net*—Total length not exceeding 63 metres; length of pocket, bunt or bag not exceeding 9 metres; mesh throughout not less than 30 mm nor more than 36 mm; wings of net to be set at such an angle that the distance between the ends of the net does not exceed 45 metres.

Prawn running net

32. (1) It is lawful to use a running net for taking prawns in the waters specified in the Table to this clause if the net complies with the description as set out in relation to those waters in that Table and the following conditions are complied with:

(a) If the net is not staked, the net is used only by the method of casting or shooting the net and picking up and landing the whole of the net into a boat in the manner known as "running the net" within 1 hour of the commencement of the casting or shooting.

(b) In the case of a net that is being used for taking prawns in the waters of Lake Illawarra:

(i) the net must be operated by at least 2 commercial fishers; and

(ii) the net must not be operated by, or with the assistance of, any commercial fisher who is also operating, or assisting in the operation of, any other such net; and

(iii) the net must not be staked (that is, the net must be used only by the method referred to in paragraph (a)).

(c) In the case of a staked net:

(i) the net is not set earlier than 1 hour before sunset; and

(ii) the net is not set within 10 metres of the high water mark; and

(iii) the net is not staked by means of a star or 3 sided stake; and

(iv) no stakes are left in the water in the period between sunrise and 1 hour before sunset.

(2) It is also lawful to use a running net to take other fish (other than a prohibited size class of fish) which are taken by the net when it is being lawfully used for taking prawns.

(3) For the purposes of this Regulation or any other instrument under the Act, a net described in this clause may be referred to as a prawn running net.

TABLE

PRAWN RUNNING NET

1. (a) *Waters*—Conjurong or Conjola Lake, Burrill Lake, Wallaga Lake, Tuross Lake, Durras Water, Cuttagee Lake, Middle Lake, Lake Wollumboola, Swan Lake, Coila Lake, Corunna Lake, Tilba Lake, Mummuga or Dalmeny Lake, Lake Birroul or Brou Lake, including all their respective bays, inlets and creeks.

   (b) *Description of net*—Total length not exceeding 75 metres; mesh throughout not less than 25 mm nor more than 36 mm.

2. (a) *Waters*—St. Georges Basin, Lake Macquarie, Tuggerah Lakes and Lake Illawarra, including all their respective bays, inlets and creeks (but excluding those parts of Tuggerah Lakes and Lake Illawarra described in Schedule 2).

   (b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 25 mm nor more than 36 mm.

Seine net (prawns)

33. (1) It is lawful to use a seine net for taking prawns in the waters specified in the Table to this clause if the net (including hauling lines) complies with the description as set out in relation to those waters in that Table and the following conditions are complied with:

(a) The net is cast or shot in the following manner:

(i) a hauling line (to the end of which is attached a float or basket with a marker buoy affixed) is cast or shot from a boat;

(ii) that hauling line, the net and a second hauling line is then cast or shot from the boat as it moves in a circular direction resulting in the boat returning to the marker buoy.

(b) The net is hauled back on to a boat in such a way that both hauling lines are hauled to the same spot on the boat so as to avoid any trawling action.

(c) The hauling in of the net, once commenced, is to continue uninterrupted until all portions of the net, including the hauling lines, have been removed from the water.

(d) The net, if used in Borang Lake, is used with a boat having no engine or powered by an engine having no more than 12 kilowatts of motive power.

(e) There is no prawn net (hauling) on the boat from which the net is used.

(2) It is also lawful to use a try net in the waters specified in the Table to this clause to facilitate the taking of prawns by the means of a seine net (prawns) if the try net complies with the following description:

The net is attached to a frame not exceeding 0.6 metre in width and 0. 5 metre in height, with a total length from the centre of the frame to the extremity of the net not exceeding 2 metres; mesh not less than 30 mm nor more than 36 mm.

(3) For the purposes of this Regulation or any other instrument under the Act, a net described:

(a) in subclause (1) or in the Table to this clause may be referred to as a seine net (prawns); and

(b) in subclause (2) may be referred to as a try net (prawns).

TABLE

SEINE NET (PRAWNS)

1. (a) *Waters*—The whole of Lake Illawarra, including its bays, inlets and creeks (but excluding that part described in Schedule 2).

(b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 220 metres.

2. (a) *Waters*—The whole of Tuggerah Lakes, including its bays, inlets and creeks (but excluding that part described in Schedule 2).

(b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 140 metres.

3. (a) *Waters*—The whole of Lake Macquarie south of a line drawn between Wangi Wangi Point and Galgabba Point, including its bays, inlets and creeks.

(b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 280 metres.

4. (a) *Waters*—The whole of St. Georges Basin, including all its bays, inlets and creeks.

(b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 220 metres.

5. (a) *Waters*—The whole of Queen's Lake and Watson Taylors Lake, including all their respective bays, inlets and creeks.

(b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 140 metres.

6. (a) *Waters*—That part of Wallis Lake and Coolongolook and Wallingat Rivers covering an area south and east of the following boundaries: commencing at the southeastern corner of Portion 71, Parish of Forster, then by a line southwesterly to the most southeastern point of Wallis Island, then along the western foreshore of Wallis Island to a point directly east of the most easterly point of Regatta Island, then west to that point (Fisheries Division B.M. 18), then by the eastern foreshore of Regatta Island to the most northeasterly point of that island, then north to the most easterly point of Bandicoot Island (Fisheries Division B.M. 23), then west along Bandicoot Island to the most northwestern point on that island, then north by a line drawn to the northern bank of Wallis Lake (Fisheries Division B.M. 24), then west along the northern bank of Wallis Lake to the entrance of the Coolongolook River, then west along the northern foreshore of the Coolongolook River, excluding the whole of the waters of Minimbah and Duck Gully Creeks, to a point marked by a white post due north of the eastern extremity of Junction Point, then due south from that post to the eastern extremity of Junction Point, then extending across the Wallingat River on a bearing of 175 degrees to the northern foreshore corner of the jetty situated on the northwestern foreshore of Portion 66, Parish of Wallingat (and excluding all other waters of the Wallingat River)

(b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 140 metres.

7. (a) *Waters*—The whole of the Macleay River extending from the Jerseyville Bridge upstream to the Kempsey Railway Bridge.

(b) *Description of net*—Total length not exceeding 140 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 140 metres.

8. (a) *Waters*—The whole of Borang Lake.

(b) *Description of net*—Total length not exceeding 80 metres; mesh throughout not less than 30 mm nor more than 36 mm; length of each hauling line not exceeding 80 metres.

Otter trawl net (prawns)

34. (1) It is lawful to use an otter trawl net for taking prawns in the waters specified in the Table to this clause if the net complies with the description as set out in relation to those waters in that Table and the following conditions are complied with:

(a) The net is used only by the method of trawling.

(b) Not more than 2 nets are used at any one time in the Hawkesbury River (downstream from a line drawn between Juno Point and Eleanor Bluff), Clarence River, Botany Bay, Port Jackson, Jervis Bay or Coffs Harbour.

(c) Not more than 1 net is used at any one time in the Hunter River or in the Hawkesbury River upstream from a line drawn between Juno Point and Eleanor Bluff to the ferry crossing at Lower Portland.

(d) No string, rope, wire, cord, netting or other material is fixed to any meshes that are within 25 meshes of the draw or closing string of the cod-end of the net.

(2) Despite subclause (1) (d), an otter trawl net may have attached to it any of the following:

(a) a draw or closing string at the end of the cod-end;

(b) a frill of netting material, if the frill is not attached more than 5 meshes from the last row of meshes of the cod-end;

(c) a chafing piece, in accordance with clause 55 (2).

(3) It is also lawful to use an otter trawl net to take other fish which are taken by the net when it is being lawfully used for taking prawns if:

(a) the fish are not a prohibited size class of fish and are not of a species the taking of which is prohibited; or

(b) the fish are a prohibited size class of fish (other than abalone or crustaceans), are not of a prohibited size and are taken in waters (other than inland waters) north of a line drawn due east from the lighthouse situated at Smokey Cape; or

(c) the fish are a prohibited size class of fish (being crustaceans other than rock lobster) and are not of a prohibited size.

(4) For the purposes of this Regulation or any other instrument under the Act, a net described in this clause may be referred to as an otter trawl net (prawns).

TABLE

OTTER TRAWL NET (PRAWNS)

1. (a) *Waters*—All waters (other than inland waters and the Clarence River).

(b) *Description of net*—Total length not exceeding 11 metres (except in respect of a net used in ocean waters, in which case the total length of the net is not to exceed 33 metres or, if a maximum length for otter trawl nets (prawns) is specified in the boat licence for the boat from which the net is used, the length so specified); mesh of cod-end (or portion of the net capable of being used as a cod-end) not less than 40 mm nor more than 45 mm; mesh of net (other than cod-end or the portion of the net capable of being used as a cod-end) not less than 40 mm nor more than 60 mm; length of sweep attached to net (being the distance between the point of attachment to the otter boards and the net) not exceeding 5 metres or the distance from the trawl gallows to the stern of the boat (whichever is the greater); sweep to be secured to the net and the otter board so that it cannot exceed 5 metres in length or the distance from the trawl gallows to the stern of the boat (whichever is the greater).

2. (a) *Waters*—Clarence River.

(b) *Description of net*—Total length of net (when towed as single gear) not exceeding 11 metres; total length of either net (when towed as twin gear) not exceeding 7. 5 metres; mesh of cod-end (or portion of the net capable of being used as a cod-end) not less than 40 mm nor more than 45 mm; mesh of net (other than cod-end or the portion of the net capable of being used as a cod-end) not less than 40 mm nor more than 60 mm; length of sweep attached to net (being the distance between the point of attachment to the otter boards and the net) not exceeding 5 metres or the distance from the trawl gallows to the stern of the boat (whichever is the greater); sweep to be secured to the net and the otter board so that it cannot exceed 5 metres in length or the distance from the trawl gallows to the stern of the boat (whichever is the greater).

Division 4 - Lawful recreational nets

Hand-hauled prawn net

48. (1) It is lawful to use a hand-hauled net for taking prawns in the waters specified in the Table to this clause if the net complies with the description as set out in relation to those waters in that Table and the following conditions are complied with:

(a) The net is not staked or set, or joined or placed together with any other net.

(b) The net is continuously and manually propelled and not used as a stationary net.

(c) The net is not attached to a hauling line.

(2) It is also lawful to use a hand-hauled net to take other fish (other than a prohibited size class of fish) that are taken by the net when it is being lawfully used for taking prawns.

(3) For the purposes of this Regulation or any other instrument under the Act, a net described in this clause may be referred to as a hand-hauled prawn net.

TABLE

HAND-HAULED PRAWN NET

1. (a) *Waters*—Any waters (other than inland waters).

   (b) *Description of net*—Total length not exceeding 6 metres; mesh throughout not less than 30 mm nor more than 36 mm.

Push or scissors net (prawns)

49. (1) It is lawful to use a push or scissors net for taking prawns in the waters specified in the Table to this clause if the net complies with the description as set out in relation to those waters in that Table and the following conditions are complied with:

(a) The net is used only as a hand implement and is not staked or set, or joined or placed together with any other net.

(b) The net is continuously propelled and not used as a stationary net.

(c) The net is operated only by 1 person without assistance from any other person.

(d) Only 1 net is used by a person at any one time.

(2) It is also lawful to use a push or scissors net to take other fish (other than a prohibited size class of fish) that are taken by the net when it is being lawfully used for taking prawns.

(3) For the purposes of this Regulation or any other instrument under the Act, a net described in this clause may be referred to as a push or scissors net (prawns).

TABLE

PUSH OR SCISSORS NET (PRAWNS)

1. (a) *Waters*—Any waters (other than inland waters).

   (b) *Description of net*—Net attached to a scissors-type frame; length of lead or bottom line between the lower extremities of the poles not exceeding 2.75 metres; mesh not less than 30 mm nor more than 36 mm.

Dip or scoop net (prawns)

50. (1) It is lawful to use a dip or scoop net for taking prawns in the waters specified in the Table to this clause if the net complies with the description as set out in relation to those waters in that Table and the following conditions are complied with:

(a) The net is used as a hand implement only and not staked or set, or joined or placed together with any other net.

(b) Only 1 net is used by a person at any one time.

(2) It is also lawful to use a dip or scoop net to take other fish that are taken by the net when it is being lawfully used for taking prawns.

(3) For the purposes of this Regulation or any other instrument under the Act, a net described in this clause may be referred to as a dip or scoop net (prawns).

TABLE

DIP OR SCOOP NET (PRAWNS)

1. (a) *Waters*—Any waters (other than inland waters).

(b) *Description of net*—Net attached to a frame, hoop or ring not exceeding 0.6 metre in its greatest diameter, with a handle of not more than 1.2 metres in length, with a total length from the centre of the plane of the frame, hoop or ring to the extremity of the net not exceeding 1.25 metres; mesh not less than 20 mm.

APPENDIX 2

Montgomery, S.S. and D.D., Reid. A comparison of access point and roving creel survey techniques for estimating catch rate in recreational fisheries for penaeids.

A comparison of access point and roving creel survey techniques for estimating catch rate in recreational fisheries for penaeids .

S.S. Montgomery and D.D. Reid

NSW Fisheries Research Institute,

PO Box 21 Cronulla, NSW 2230

Australia.

Abstract

An important assumption of roving creel surveys is that mean catch per unit effort (CPUE) estimated from these data is an unbiased estimator of mean CPUE for completed trips. Some approaches to calculating catch from these data also assume that the mean proportion of the fishing trip that has been completed at the time of the roving creel interview is 0.5. We tested these assumptions for the night-time recreational fishery for penaeids in two estuaries in New South Wales (NSW), Australia, by doing access point and roving creel surveys on the same five nights over the summer prawning season of 1992-93. This was part of a larger main study involving a random stratified roving creel survey of prawners in four estuaries to estimate the catch of recreational prawners in NSW. There were no differences in estimates of mean CPUE between survey techniques (Student's t-Test; $\underline{P} < 0.05$). In some cases the mean proportion of a prawner's trip that had been completed at the time of interview during roving creel surveys was greater than 0.5. For these cases, estimators of total catch from roving creel surveys based on the doubling of catches from incomplete trips, would have overestimated total catch. Alternative estimators were used in our main study. This study demonstrated that it is possible to do roving creel surveys of recreational prawners in NSW at night and provide data that give unbiased estimates of mean CPUE for the recreational fishery.

Introduction

Information on the level of catch, effort and catch per unit effort (CPUE) by both recreational and commercial user groups is essential if wild stocks are to be managed effectively. Hilborn and Walters (1992) and Pollock et al. (1994) provide excellent reviews on the methods used to collect these data. These range from using sources that are dependent upon the fishing industry (e.g. log books and records of landings) to independent surveys of fishers by trained staff (e.g. surveys by telephone or mail and intercept surveys).

Intercept surveys are one of the most common types of independent surveys used to collect data on recreational fisheries (see Malvestuto et al. 1978, 1983; Hayne 1991; Robson 1991; Pollock et al. 1994). Fishers can be interviewed when they have completed their fishing trip (known as access point surveys) or whilst they are fishing (roving creel surveys). Access point surveys have the advantage of interviewing fishers at the end of their trip so that information on the total catch is collected, but are limited to those situations where fishers enter the fishery at few access sites (e.g. boat ramps). Data collected by roving creel survey techniques suffer from the disadvantage that total catch must be estimated by extrapolation of incomplete trip data. It is assumed when calculating total catch that (i) the mean (CPUE) does not depend on the time spent fishing and (ii) the mean proportion of the trip completed by fishers at the time of interview is 0.5 (e.g. Wade et al. 1991). Roving creel survey techniques do have the advantage however, of being useful in those situations where fishers enter the fishery through more access points than can be covered by staff to provide a sample size of interviews that is considered representative for the fishery.

If assumptions (i) and (ii) are violated then it is likely that estimates of catch, effort and CPUE will be biased (e.g. Malvestuto 1983; Pollock et al. 1994). Consequently, studies that use roving creel surveys need to test the underlying assumptions of this technique (e.g. Phippen and Bergersen 1991).

There are many examples were intercept surveys have been used to survey fishers during hours of daylight (e.g. Von Geldern 1972; Malvestuto and Davies 1978; Phippen and Bergersen 1991). We are unaware though of any studies in the peer reviewed literature that have attempted to use intercept survey techniques to estimate catch and mean CPUE for fisheries that operate at night. It is generally accepted that roving creel surveys are impossible to do during this period of darkness (Malvestuto 1983; Hayne 1991). Further, we are unaware of any study in the peer reviewed literature that has surveyed a fishery that targets species of the family Penaeidae (commonly referred to as shrimps or prawns).

In this paper we tested the null hypothesis that there was no difference in mean CPUE between data collected using access point and roving creel survey techniques. This formed part of a larger, main study to quantify the catch of the recreational fishery for prawns in New South Wales (NSW), Australia (Reid and Montgomery unpublished data). In this main study we elected to use roving creel survey techniques because the size of the estuaries and number of access points around them made it logistically too difficult to collect representative numbers of interviews using access point survey techniques. Consequently, we needed to know whether the mean CPUE calculated from data collected by roving creel surveys was an unbiased estimate of mean CPUE for completed trips by recreational prawners.

The Fishery

The commercial fishery lands approximately 3,000 tonnes of penaeids with a value of about $ 32 million per annum at the point of first sale. It is ranked second in economic importance amongst those managed solely by the state of New South Wales. Two species of prawn namely, eastern king, Penaeus plebejus and school Metapeneaus macleayi account for most of the catch, (36 and 55% and 33 and 24% by weight and value, respectively). These species are endemic to the east coast of Australia, being distributed between 21° S and 41° S. Both have a life history similar to that described by Garcia and Le Reste (1981) for a typical of penaeid, including both an estuarine and oceanic phase (Racek 1959; Ruello 1975; Young and Carpenter 1977; Ruello 1977; Coles and Greenwood 1983; Glaister et al. 1987; Montgomery 1990), though eastern king prawns in oceanic waters are known to move long distances in a northerly direction (Montgomery 1990). These are harvested in estuaries from September to April (inclusive) by commercial and recreational fishers and by commercial fishers year round in ocean waters.

The recreational fishery for prawns operates during the hours of darkness and almost exclusively on the ebb tide. Fishing operations are not species specific and the methods used are push or scissor nets, dip or scoop nets and hand-hauled (drag) nets (Fig. 1). Scoop and drag nets are the most popular amongst recreational prawners. All these types of gear are used whilst wading, but sccop-nets also are used from a boat. NSW Fisheries regulations cover method of use, maximum dimensions of nets and sizes of mesh used in nets.

Materials and Methods

Study Sites

Two of the four estuaries studied by Reid and Montgomery (unpublished data) were chosen for this study (Fig. 2). The Tuggerah Lakes system (33° 17′ S) consists of three interconnected lagoons and has a total plan area of approximately 80 km^2. The average depth of is about 1.6 m with the tidal range in the main body of water being less than 0.1 m. Lake Illawarra (34° 34′ S) has an area of 34 km^2 and a maximum water depth of 3.5 m but a significant area is less than 1 m deep. The tidal range reduces from 1.8 m at the entrance to the lake to approximately 0.2 m 1.5 km upstream. These estuaries were chosen on the basis that they were easily accessible from the NSW Fisheries Research Institute (34 °S) and were two of the most popular for recreational prawning in NSW. In the main study each estuary was divided into subareas on the basis that each subarea could be covered by survey staff in 30 minutes. We chose three subareas within Tuggerah Lakes and two subareas within Lake Illawarra to compare simultaneous access point and roving creel techniques (Fig. 2). These areas were chosen because of their popularity with recreational prawners, they covered the main methods used by prawners and offered only limited points of access to fishers so that all prawners in the sub area could be observed by staff at all times during the survey.

Procedures

Recreational prawners using scoop-nets were easily identified at night by the bobbing of their battery powered lights that they use to spot prawns moving in the water column. Those using drag-nets were generally recognised against the background of lighting from street lamps and houses and their use of easily accessible beaches as bases. Comparatively, fishers for fin fish at night do not use lights or very intermittently. The glow from the prawner's lights was also sufficient for survey staff to do head-counts without the use of any extra artificial illuminating devices.

The main study by Reid and Montgomery (unpublished data) was based upon a random stratified design using roving creel survey techniques over three spring-summer seasons, namely, 1991-92, 1992-93 and 1993-94. Staff from a private company specialising in surveys of recreational fisheries did surveys for four hours on nights allocated on the basis of a random start date and fixed skip interval. The start subarea and direction of travel by the creel survey clerk were also randomised. Thirty minutes was spent in each subarea. Surveys were generally done by staff in a boat or whilst wading. A count of prawners was done for 10 minutes immediately staff started in a new a subarea and the remainder of the 30 minute period was spent interviewing prawners. Prawners were asked for information on the number of nets being used, number of people in the fishing party, number of people actually prawning, and the time the party started prawning, which was recorded together with the time of interview. The catch was weighed with a spring balance to nearest 0.01kg.

At the end of each interview on the nights when both access point and roving creel surveys were being done, staff doing the roving creel surveys would give the interviewed prawner a numbered card. When the prawner had completed the fishing trip he/ she would take this card to staff doing access point surveys on shore. This prawner was then interviewed again and the information requested above was recorded in this case for a completed trip. The unique card number allowed us to associate information from incompleted with completed prawning trips for the same prawner.

Access point surveys were done by staff from the NSW Fisheries Research Institute on nights randomly chosen from the pool of nights scheduled for roving creel surveys. These started at sunset and continued until sunrise in each of the selected subareas. Earlier observations had shown that there was no recreational fishing for prawns during daylight hours.

Five nights were surveyed in the lunar months of January and February 1993, two of the most popular months for prawning by recreational fishers. Prawners were interviewed by staff when they had completed their fishing trip and were leaving the estuary. They were asked for information about the time they started prawning, where they had been prawning, the number of people in their party, the number in the party actually prawning, method of prawning used, number of units of each gear type used whilst prawning and the total amount of time spent prawning. The catch was then weighed as above and all this information was recorded with the roving creel interview number, where applicable.

At the end of each night's surveys therefore, we had three types of data:

(a) those from prawners interviewed by staff at access points only,

(b) those from prawners interviewed by staff doing roving creel surveys only,

(c) those from prawners interviewed in both the roving creel (incomplete trips) and access point (completed trips) surveys.

Data Analysis

We calculated mean CPUE (kg/prawner/h) from the access point and roving creel survey data using the estimators recommended by Pollock et al. (1994). Data from roving creel surveys were weighted by the proportions of the relevant factors in the stratified design. Data from type (c) for the same prawner were compared directly and those from type (a) were compared with those from type (c). Those calculated for individual prawners from dataset (c) were pooled between times within each subarea whilst types (a) and (b) were pooled across subareas and survey dates for each estuary. Where applicable prawning methods were analysed separatly. Data were tested for homogeneity of variances by Cochran's Test ($\underline{P} < 0.05$). Student t-Tests were used to test the null hypotheses that there were no differences in mean CPUE between techniques.

Our data also provided information on the estimated starting time for prawning (given by the prawner) and the time prawning finished (provided by the interviewer). We tested the assumption that the mean time of interview during roving creel surveys occurred half way through a prawner's fishing trip. The Student's -t-Test ($\underline{P} < 0.05$) was used to test the null hypothesis that the mean proportion of the trip prawners had completed at the time of interview during roving creel surveys did not differ from 50%.

Results

A total of 58 records from both estuaries contained information for both roving creel and access point surveys. Seven hundred and forty two records had interviews done by access point surveys only, whilst 186 records were for roving creel surveys only. There were no differences in mean CPUE between survey methods for each subarea and estuary (Table 1; Fig. 3), irrespective of whether type (c) or type (a) and (b) data were compared.

The mean proportion of the trip completed by prawners when interviewed during roving creel surveys differed (Students t-Test; $P < 0.05$) from 0.5 in subareas 204 (mean ± SE; 0.7420 ± 0.0739) and 308 (00.6976 ± 0.0673) but not in subareas 201 (0.5944 ± 0.0875), 210 (0.5037 ± 0.1038) and 310 (0.4215 ± 0.0744).

Discussion

This study showed that the estimator of mean catch per unit effort (CPUE) calculated from data collected from roving creel surveys of recreational prawners is an unbiased estimator of mean CPUE for completed trips by prawners. There was no difference in estimates of mean CPUE between survey methods in each estuary. Therefore, roving creel surveys will provide unbiased estimates of mean CPUE that can be used to estimate the catch of recreational prawners operating in the estuaries surveyed.

Our decision to use roving creel rather than access point surveys for the main study was based upon reasons of logistic efficiency and financial constraints. The access points to each estuary were numerous and prawning was concentrated within the few hours of run-out tide during night-time. This specific timing of fishing effort ruled out the use of newer approaches to exit surveys such as a bus-route design (for examples see Pollock et al. 1994) because the total time to cover the estuary was large compared to the available sampling time (Jones and Robson 1991).

We were limited in the areas that we could use in each estuary to compare techniques for the same reasons. The criteria that we used to select the subareas from the main survey for use in the access point surveys were that (i) the subarea had very limited access so that two survey clerks could interview most people who had completed prawning trips within the subarea; and (ii) the subareas were popular amongst recreational prawners so that we would get reasonable sample sizes.

If there is a relationship between the duration of the fishing trip and catch in data collected by roving creel surveys then mean CPUE calculated from these data will not be representative of the fishery (Malvestuto et al. 1978; Pollock et al. 1994). Lucas (1963) indentified what he termed "length of stay bias", whereby the probability of intercepting a fisher is proportional to length of the fisher's trip. If successful fishers stay longer they may be interviewed in disproportionate numbers and mean CPUE will overestimated. Conversely, if they stay for shorter periods than less successful fishers, mean CPUE will be underestimated. Estimates of catch will likewise be biased because these are calculated from mean CPUE (Robson 1961, Wade et al., 1991). Previous studies on finfish (Carlander 1958; Von Geldren 1972; Malvestuto et al., 1978 and Mac Kenzie 1991) also have found similar results to the present study, that roving creel surveys provide unbiased estimates of mean CPUE. Phippen and Bergersen (1991) however, found significant differences in mean CPUE between roving creel and access point surveys. But, these were not sufficiently different to greatly affect estimates of catch and therefore management decisions.

Some methods for estimating catch from data collected from roving creel surveys also rely on the assumption that the mean time of interview occurred half way through the duration of the fishing trip. Mean catch is then doubled to estimate the catch of completed trips (e.g. Wade et al. 1991). In our study we found that in some cases the mean time of interview occurred more than half way through the duration of the prawning trip. In these cases doubling the mean catch would have overestimated values of catch for completed trips.

The estimator of catch used in the main study does not use this form of extrapolation. Rather, as recommended by Pollock et al. (1994), catch is calculated as the product of the estimated mean CPUE from incompleted trips, mean number of prawners operating and the number of hours available for prawning.

Our study is an example of using creel survey techniques in hours of darkness to estimate the level of catch in a fishery. Malvestuto (1983) and Hayne (1991) list as a disadvantage the fact that roving creel surveys cannot be done at night. This may be the general case as we have been unable to find any examples of studies that have used intercept survey methods to estimate the catch of fishers operating at night. The recreational fishery for prawns in NSW may be the exception because prawners use battery powered lights to spot prawns in the water column and are therefore easily identified as prawners by the bobbing of their light. Roving creel surveys of recreational prawners operating in the estuaries of NSW will provide data that will give an unbiased estimate of mean CPUE and therefore can be reliably used to collect data from which to calculate the level of catch by this user group.

Acknowledgments

We wish to thank the staff of Kewagama Research who did the roving creel surveys and cooperated with us on those nights when were comparing survey techniques. Thanks go also to staff at the NSW Fisheries Research Institute, who did the access point surveys; particularly Mr M. Beatson who supervised this work. Finally we would like to thank the recreational prawners in our study area for their assistance. This manuscript has been improved following comments made on earlier drafts by.................

References

CARLANDER, K.D., C.J. DiCOSTANZO, AND R.J. JESSEN 1958. Sampling problems in creel census. Prog. Fish. Cult. 20: 73-81.

COLES, R.G., AND J.G. GREENWOOD 1983. Seasonal movement and size distribution of three commercially important Australian prawn species (Crustacea: Penaeidae) within an estuarine system. Aust. J. Mar. Freshwat. Res. 34: 727-743.

GARCIA, S., AND L. Le RESTE 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. FAO Fish. Tech. Pap. 203: 1-215.

GLAISTER, J.P., T. LAU, AND V.C. McDONALL 1987. Growth and migration of tagged eastern Australian king prawns Penaeus plebejus Hess. Aust. J. Mar. Freshwat. Res. 38: 225-241.

HAYNE, D.W. 1991. The access point survey: procedures and comparison with roving clerk creel survey. Am. Fish. Soc. Symp. 12: 123-138.

HILBORN, R., AND C.J. WALTERS 1992. Quantitative fisheries stock assessment; Choice, dynamics and uncertainty. Chapman and Hall 570 p.

JONES, C.M. AND D.S. ROBSON 1991. Improving precision in angler surveys: traditional access design versus bus route design. Am. Fish. Soc. Symp. 12: 177-188.

LUCAS, R.C. 1963. Bias in estimating recreationists' length of stay from sample interviews. For. 61: 912-914.

MACKENZIE, C. 1991. Comparison of northern pike catch and harvest rates from completed and uncompleted fishing trips. Am. Fish. Soc. Symp. 12: 51-60.

MALVESTUTO, S.P. 1983. Sampling the recreational fishery. p. 397-419. In L.A. Nielsen AND D.L. Johnson [ed] Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

MALVESTUTO, S.P., W.D. DAVIES, AND W.L. SHELTON 1978. An evaluation of the roving creel survey with nonuniform probability sampling. Trans. Am. Fish. Soc. 107: 255-262.

MONTGOMERY S.S. 1990. Movements of juvenile eastern king prawns Penaeus plebejus, and identification of stock along the east coast of Australia. Fish. Res. 9: 189-208.

PHIPPEN, K.W., AND E.P. BERGERSEN. 1987. Angling definitions and their effects on the accuracy of count-interview creel survey harvest estimates. N. Am. Fish. Man. 7: 488-492.

PHIPPEN, K.W., AND E.P. BERGERSEN 1991. Accuracy of a roving creel survey's harvest estimate and evaluation of possible sources of bias. Am. Fish. Soc. Symp. 12: 51-60.

POLLOCK, K.H., C.M. JONES, AND T.L. BROWN [ED] 1994. Angler survey methods and their applications in fisheries management. Am. Fish. Soc. Symp. 25: 1-371.

RACEK, A.A. 1959. Prawn investigations in eastern Australia. Res. Bull. St. Fish. N. S. W. 6: 1-57.

RUELLO, N.V. 1975. Geographical distribution, growth and breeding migration of the eastern Australian king prawn Penaeus plebejus Hess. Aust. J. Mar. and Freshwat. Res. 26, 343-354.

RUELLO, N.V. 1977. Migration and stock studies on the Australian school prawn Metapenaeus macleayi. Mar. Biol. 41:185-190.

ROBSON, D.S. 1991. The roving creel survey. Am. Fish. Soc. Symp. 12: 19-24.

von GELDERN, C.E. 1972. Angling quality at Folsom Lake, California, as determined by roving creel census. Calif. Fish. Gam. 58: 75-79.

YOUNG, P.C., AND S.M. CARPENTER 1977. Recruitment of postlarval penaeid prawns to nursery areas in Moreton Bay, Queensland. Australian J. Mar. Freshwat. Res 28: 754-73.

WADE, D.L., C.M. JONES, D.S. ROBSON, AND K.H. POLLOCK 1991. Computer simulation techniques to access bias in the roving-creel-survey estimator. Am. Fish. Soc. Symp. 12: 40-46.

Table 1. Summaries of Studen t-Tests comparing estimates of mean CPUE calculated from (A) completed and uncompleted prawning trips for the same prawners (datasets (a) and (b)), and (B) access point and roving creel surveys done on the same nights (dataset (c)). Cochran's statistic was non-significant in all comparisons.

ns = Non-significant ($\underline{P}$ < 0.05); ** = Significant ($\underline{P}$ > 0.01)

	Treatment	df	t	$\underline{P}$	
A					
	Tuggerah				
	Scoop-net	18	-0.1191	0.9065	ns
	Drag-net	7	-1.5842	0.1572	ns
	Illawarra				
	Scoop-net	30	-1.6735	0.1046	ns
B					
	Tuggerah				
	Scoop-net	12	-0.0017	0.9986	ns
	Drag-net	7	0.1648	0.8745	ns
	Illawarra				
	Scoop-net	30	0.5674	0.5809	ns

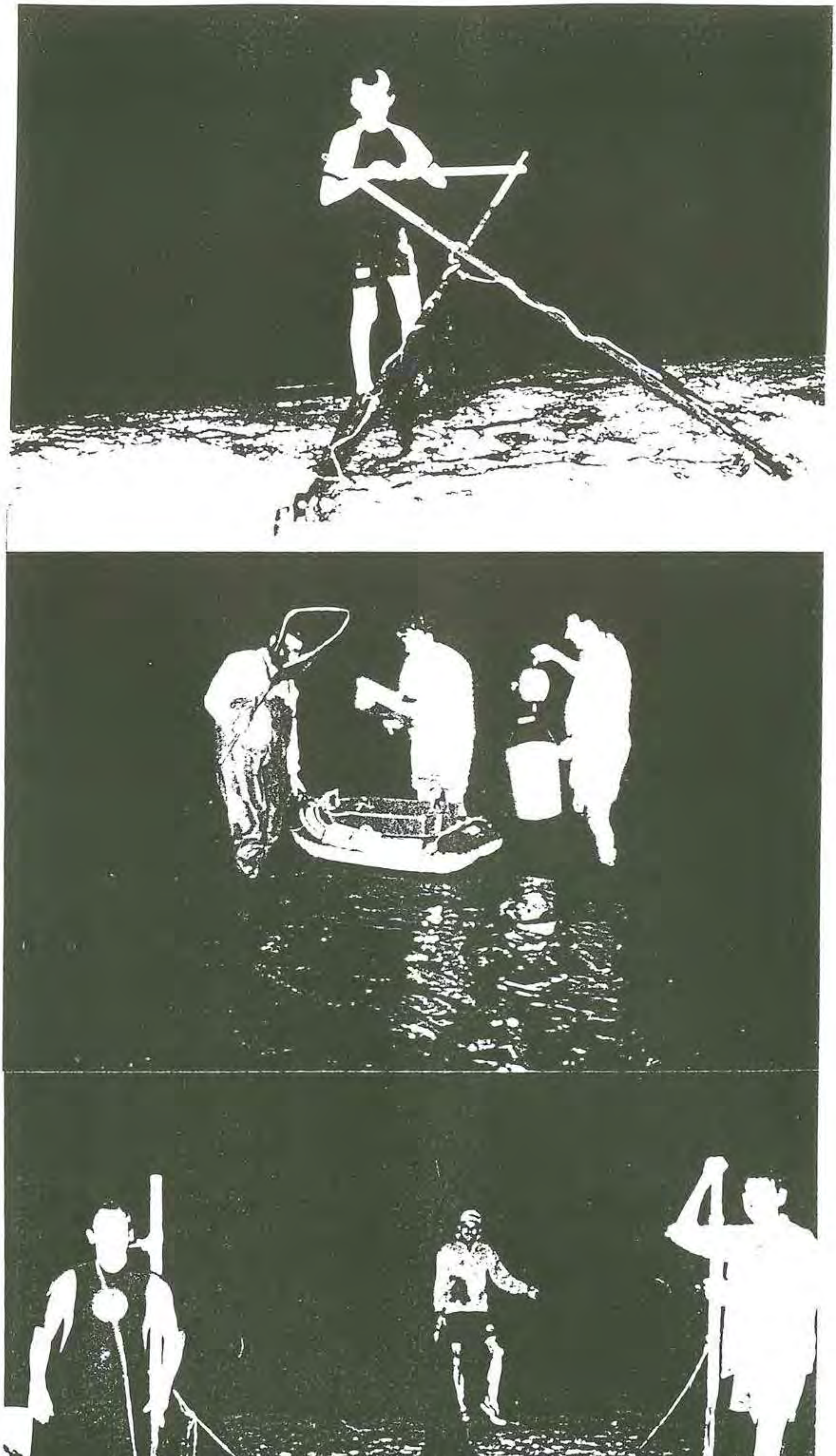
Captions to Figures

Figure 1. The main methods used by recreational prawners in NSW are a) a scissors or push net, b) scoop net (note that this prawner is being interviewed during a roving creel survey and c) hand-hauled or drag nets.

Figure 2 Map of the coast of NSW with indents of Australia and the two estuaries and subareas (◯) used in this study

Figure 3 Mean CPUE (kg per prawner per h) calculated from data collected by access (A) and roving creel (R) surveys of the same prawners using scoop (S) or drag (D) nets on Tuggerah Lake (TUGG) and Lake Illawarra (ILLW).

Figure 4. Mean CPUE (kg per prawner per h) calculated from data collected by access (A) and roving creel (R) surveys of recreational prawners using scoop (S) or drag (D) nets on Tuggerah Lake (TUGG) and Lake Illawarra (ILLW).



a

b

c

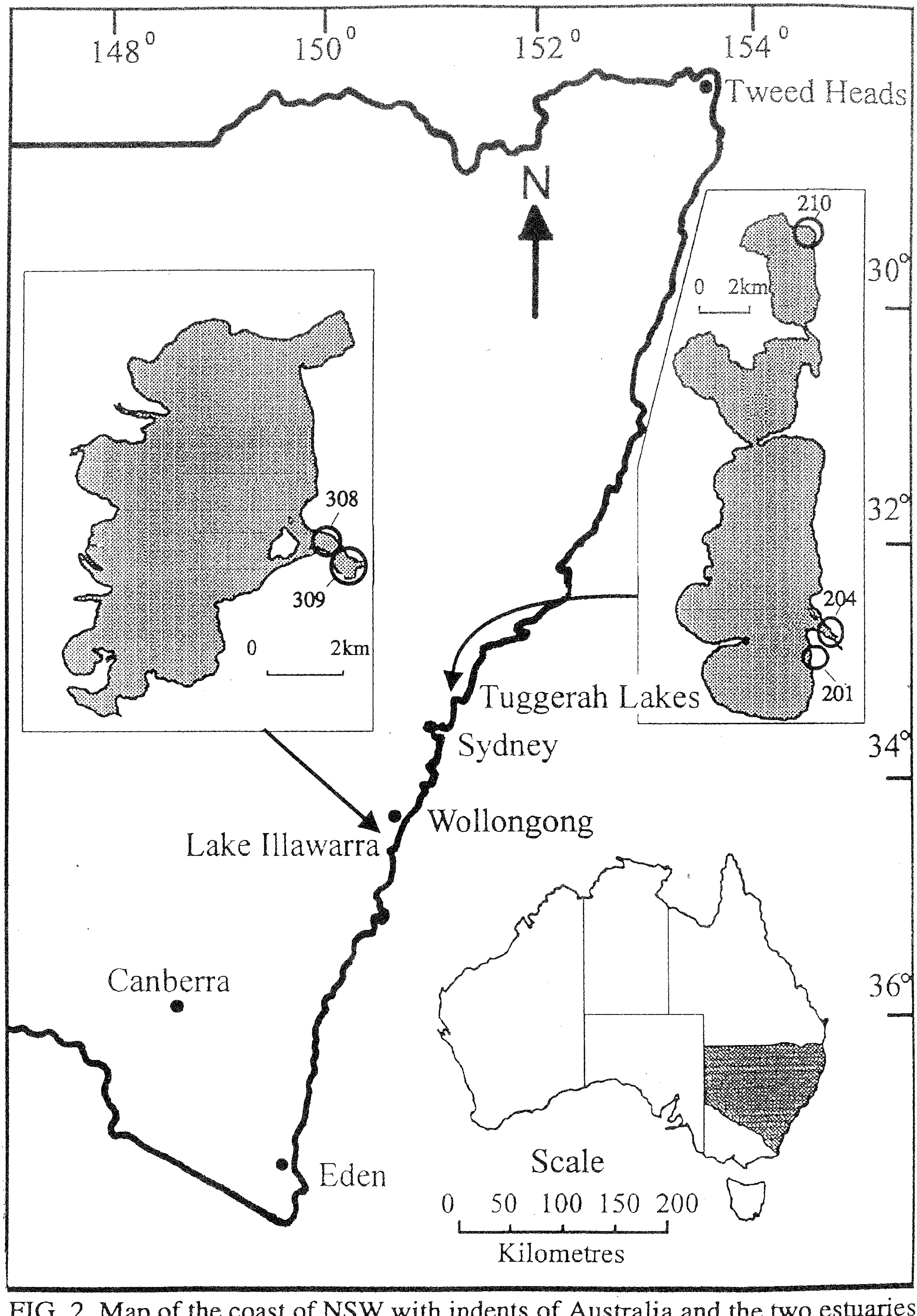


FIG. 2. Map of the coast of NSW with indents of Australia and the two estuaries and sub areas (◯) used in this study.

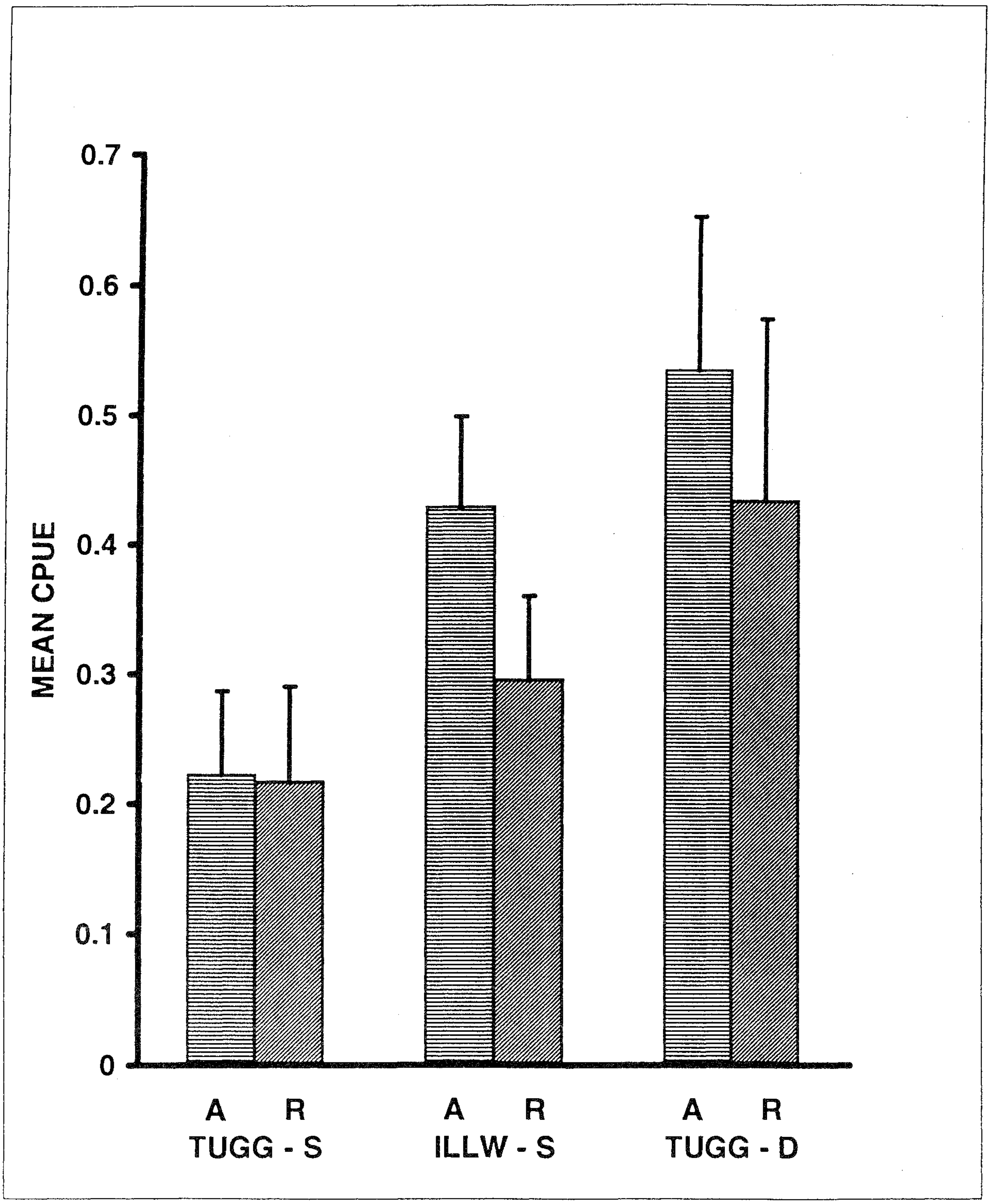


FIG 3

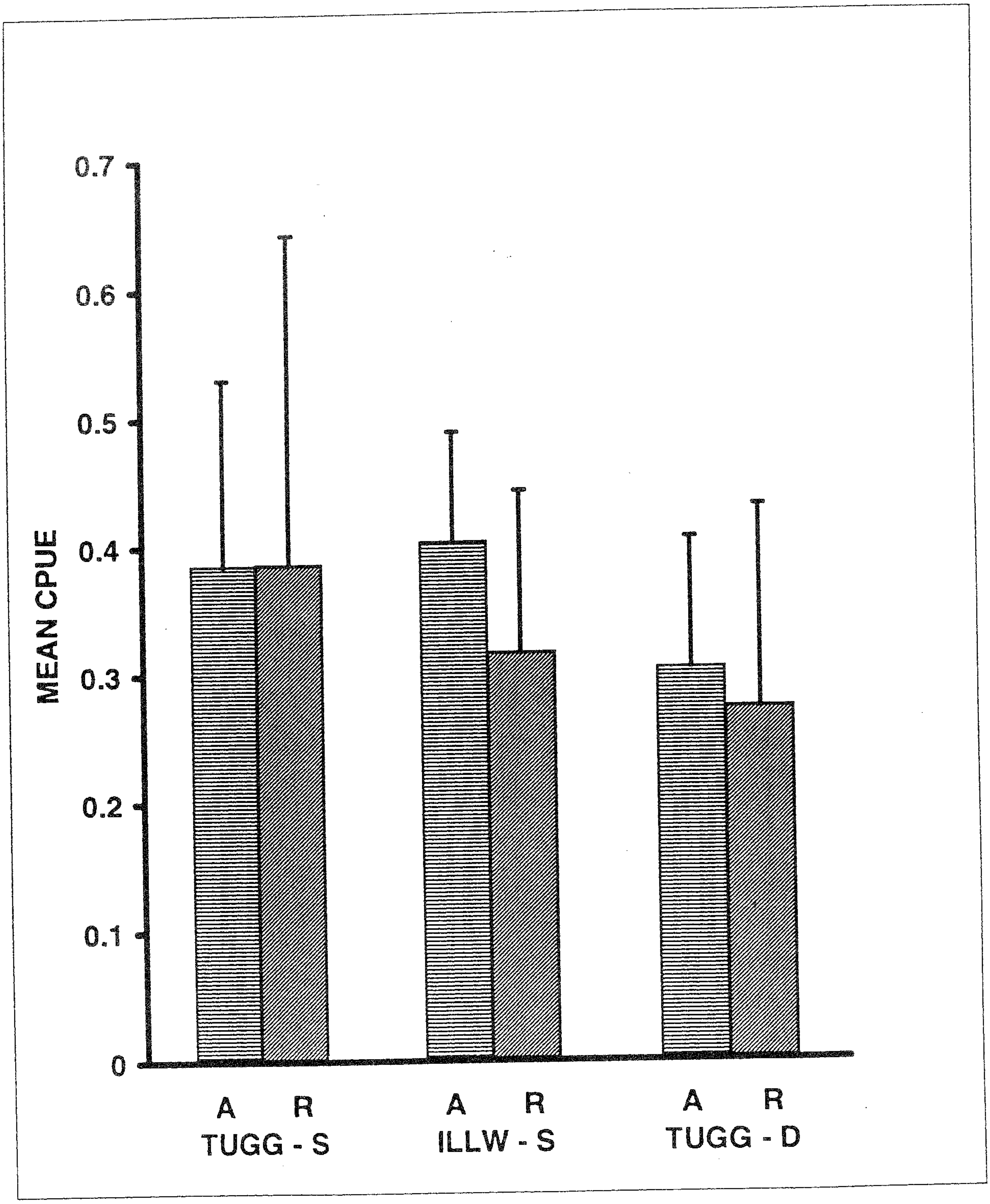


FIG 4

APPENDIX 3

Reid, D.D. and S.S., Montgomery. Comparison of recreational and commercial harvesting of penaeid prawns in New South Wales, Australia.

Comparison of recreational and commercial harvesting of penaeid prawns in New South Wales, Australia

D D Reid and S S Montgomery

Fisheries Research Institute, NSW Fisheries.

(Not to be cited without the written permission of the authors)

Abstract

A night-time intercept creel survey, based on stratification by moon-phase, day-type and tidal state provided estimates of recreational catches of the three major penaeid species for four New South Wales estuaries (Wallis Lake, Tuggerah Lakes, Lake Illawarra and Coila Lake) for lunar months in the spring-summer seasons of 1991/92, 1992/93 and 1993/94. Subsamples of interviews provided information which enabled estimation of the length frequency distribution of the recreational catch and the composition by species. Estimates of commercial catches were obtained from official records of landings by commercial fishermen. Overall, recreational catches were estimated to be 28% of the total commercial prawn catches from these estuaries over the three years of the study, with recreational catches representing 57%(±5%) of the commercial catch for Lake Illawarra, 30% (± 3%) for Tuggerah Lakes, 17%(±3%) for Wallis Lake and 10%(±2%) for Coila Lake. The species composition of the recreational catch differed from the commercial catch, with the recreational fishery taking almost exclusively eastern king prawns Penaeus plebejus in Wallis Lake, Lake Illawarra and Coila Lake, whereas the commercial fishery in Lake Illawarra and Wallis Lake took a much higher proportion of school prawns Peneaus macleayi, with 30 - 50% of the annual catches being this species. In Tuggerah Lakes, the proportions of eastern king and school prawns were similar for the commercial and recreational catches, but the proportion of greasyback prawns Metapenaeus bennettae was higher in the commercial catches. The size distributions of eastern king prawns were broadly similar for the recreational and commercial catches in all but Coila

Lake. The only substantial numbers of recreationally caught school prawns were in Tuggerah Lakes, and here the mean length of prawns from recreational catches was larger than for commercial catches. Catch rates varied between estuaries, with cpue for Wallis Lake (.43 kg h^{-1} ±.02) being almost double that of the tidal subareas of Tuggerah Lake (.24 kg h^{-1} ±.02) and Lake Illawarra (.24 kg h^{-1} ±.01). There were marked differences in catch rates between tidal and non-tidal areas for Tuggerah Lake, but not in Lake Illawarra. Catch rates also varied between methods, with the 2m wide hauling (drag) nets showing five times the catch rates of the small scoop-nets used in the same subareas of Tuggerah Lakes. Recreational prawning on the ebb-tide in the dark of the moon was strongly favoured by prawners, particularly in the areas of the estuaries affected by tides.

This study provides a guide to the level of sampling required to extend the coverage to an estimate of the statewide recreational catch. Precision of catch estimates can be optimised by concentrating survey effort on counts of prawners, with relatively low survey effort directed to interviews. The study also demonstrated that it is possible to assess Australian prawn fisheries by night-time roving creel surveys.

Introduction

If wild stocks are to be managed effectively then information on the level of catch and the fishing effort exerted to take that catch is needed from both the commercial and recreational harvesting sectors. This information is used by managers to assess the impact on fisheries of management options and can be useful when assessing the relative abundances of individuals in the population.

Hilborn and Walters (1992) and Pollock et al. (1994) provide excellent reviews on the methods used to collect these data. The methods use information that are either dependent (e.g. records of landings) or independent (e.g. telephone surveys) of the fishery being studied. Intercept surveys are one of the most common types of independent surveys used to collect data on recreational fisheries (see Malvestuto 1983, Malvestuto et al. 1978; Hayne 1991; Robson 1991; Pollock et al. 1994). Fishers can be interviewed by staff when they have completed their fishing trip (access point surveys) or whilst they are fishing (roving creel surveys). Access point surveys collect information on the total catch provided coverage of the fishery is complete (i.e a census), but are restricted to situations where fishers enter the fishery at few access sites (e.g. boat ramps) so that research staff can interview sufficient fishers to obtain representative sample sizes. Data collected by roving creel survey techniques suffer from the disadvantage that total catch must be estimated through extrapolation. It is assumed when calculating total catch that the mean catch rate of fishers does not vary over the time available for fishing. Roving creel survey techniques do have the advantage however, of being useful in those situations where fishers enter the fishery through more access points than can be covered by staff to provide a statistically adequate number of interviews.

There are few examples in the peer reviewed literature where information on patterns in catch, fishing effort and catch per unit effort (cpue) from both the commercial and recreational fisheries for a particular stock have been used together to assess the impact of management options on the stock (e.g. salmonids, Churchward and Hickley 1991; O'Connell et al. 1992; red drum, Vaughan and Hesler 1990). We could not find an example in the peer reviewed literature of a recreational fishery that had been surveyed at night time, yet fisheries for some species operate during the day and night. Data collected by surveys during daylight on fisheries that operate during day and night, may be biased if effort and catch rates vary between day and night.

Species of the family Penaeidae (commonly referred to as shrimps or prawns) are an example of marine resources that are harvested during day or night (Garcia and Le Reste 1981) throughout the World. These are valuable seafood resources around the world and in New South Wales (NSW), Australia, are the most economically important resource (approximately 16% by value at the point of first sale per annum of the seafood harvested in that state) managed solely by the state government of NSW. The catch is comprised principally of two species namely, eastern king, Penaeus plebejus and school Metapeneaus macleayi prawns. These account for 36 and 55% and 33 and 24% of the catch by weight and value, respectively (Montgomery and McDonall 1988). Both species are endemic to the east coast of Australia, being distributed between 21° S and 41° S. Both have a life history similar to that described by Garcia and Le Reste (1981) for a typical penaeid by including both an estuarine and oceanic phase (Racek 1959; Ruello 1975a,b, 1977; Young and Carpenter 1977; Glaister 1978 a,b; Glaister et. al. 1987, 1990; Coles and Greenwood 1983; Montgomery 1990). However eastern king prawns deviate from this general pattern by moving distances of over 1000 km in a northerly direction, once in oceanic waters (Montgomery 1990), whereas school prawns do not move as far away from the estuary from which they emigrated. Eastern king prawns constitute a unit stock along the east coast of Australia, whereas there are several stocks of school prawns. As a result the two species have different stock structures. Most of the eastern king prawn catch is taken at night, whilst school prawns are harvested during both day and night.

In this paper we present the results of a study done over 3 spring-summer seasons at night, to quantify in terms relative to the commercial catch, the catch of penaeids in NSW by recreational fishers. This information will allow managers to assess the impact on these resources of both commercial and recreational harvesting. Whilst this study was restricted to four estuaries, data from it has allowed us to make suggestions on the design of any future projects to survey recreational prawners in all the coastal estuaries of NSW.

The Fishery

Commercial fishing for prawns occurs in 55 estuaries in the state of New South Wales. While no records are kept for levels of recreational prawning activities, information from questionnaires completed by Fisheries Officers in 1991 showed that some recreational prawning occurred in all but 8 of 136 NSW estuaries, 34 of these being in the highest of three rankings given by Fisheries Officers.

Commercial

The commercial fishery for all species of prawns in NSW had reported landings in 1991/92 of 2392t with a value of ~$A21 million at the point of first sale . The catch from estuaries accounted for 41% of this production in 1991/92 (Pease and Scribner 1994). The fishery extends from Noosa Heads in southern Queensland (26°S) to Gippsland Lakes in Eastern Victoria (38°S). Eastern king and school prawns are exploited both offshore and in estuaries, while greasyback prawns are exploited only in estuaries. School prawns made up approximately 75% of the total prawn catch in estuaries and 13% of the oceanic catch, while eastern king prawns comprised 11% of the estuarine prawn catch and 59% of the prawn catch from oceanic waters in 1991/92 (Pease and Scribner 1994). Greasyback prawns made up approximately 5% of the estuarine prawn catch.

A variety of gear types are used to commercially fish for prawns in estuaries, namely running nets, hauling, seining, pocket nets and trawling (for descriptions of these gear types see Kailola et. al. 1993).

The management plan for this fishery is currently under review. One of the favoured options for management is to reduce fishing effort, and thereby sustain or improve yield. One of the potentially important factors in the resolution of management plans is the impact of the recreational fishery as a harvester of estuarine prawn stocks.

Recreational

The recreational prawn fishery operates during the hours of darkness. The fishing methods used by recreational prawners are hand-hauled (drag) nets, dip or scoop nets and push or scissor nets (Montgomery and Reid unpublished). Scoop nets are used from a boat or while wading, and the other nets are only used while wading. Regulations of the NSW Fisheries Management Act 1994 Department Regulations cover the method of use, maximum dimensions of the nets and minimum mesh size (20mm for scoop nets) or minimum and maximum mesh size (30-36mm for hand-hauled and 30-32mm for scissor nets).

The small amount of information on the level of catch in the recreational fishery indicated that substantial quantities of prawns were harvested by the recreational sector. Data from an omnibus survey carried out in 1981 (Pepperell 1985) suggested that the recreational fishery for prawns in NSW was substantial, landing between 1000 and 2000t per annum. This level of catch and exceeded the commercial estuarine catch at that time. However the number of respondents who were involved in recreational prawning activities was very small, thus the estimates of prawn catch and effort from this survey were subject to very large error. Further, Ruello (1975) estimated the recreational catch from Tuggerah Lakes in 1967 to be 450t ; much greater than the commercial catch (110t) in that year (Thresher *et. al.* 1993). These results suggested that recreational prawners harvested significant quantities of the prawn resources of NSW.

Methods

Study Sites

Four estuaries were chosen for the study, namely Wallis Lake, Tuggerah Lakes, Lake Illawarra and Coila Lake. These were identified from pilot telephone surveys of NSW Fisheries Officers, an omnibus survey done in 1981 (NSW Agriculture & Fisheries 1982) and official records of NSW Fisheries, as being amongst the most important estuaries for recreational and commercial prawning.

Wallis Lake (32°17'S 152°25'E), approximately 220 km north of Sydney, is a barrier estuary with a plan area of approximately 100km^2. Four rivers drain into this estuary. The tidal range varies from 1.7m near the estuary mouth to 0.12m at a point 4.35km from the mouth (Nielsen and Gordon 1986). Most of the estuary is less than 3m deep.

The Tuggerah Lakes system (33°17'S 151°30'E) consists of three interconnected lagoons - Tuggerah, Budgewoi and Munmorah Lakes, with a total plan area of ~80 km^2. The average depth is ~1.6m (Batley *et. al.* 1990), with the tidal range in the main water body being less than .1m (Collett *et. al.* 1981). Tidal exchange between the lakes and the sea is very small, being about 1% for Tuggerah Lake and less for Munmorah and Budgewoi Lakes (Batley *et. al.* 1990).

Lake Illawarra (34°33'S 150°50'E) has an area of 34 km^2, and a maximum water depth of 3.5m, with a significant area being less than 1m deep (Soros-Longworth & McKenzie 1976). The tidal range reduces from 1.8m at the lake entrance to ~0.20m at the Windang road bridge, 1.5 km away.

Coila Lake (36°01'S 150°07'E) has an area of ~8 km^2 and mean depth of 3m. Because this estuary opens intermittently to the ocean, the rate of tidal exchange is highly variable.The estuary was open to the ocean during the 1991/92 season and until January during the 1992/93 season.

Survey Design

All four estuaries in the study had many access points for recreational prawners, so an intercept (creel) survey was the only practicable method for obtaining the required information for the estimation of catch and effort. The surveys were carried out by a private contractor (Kewagama Research) between January 1992 and March 1994. The months covered in the study were January - March 1992; November 1992 - March 1993; and November 1993 - March 1994.

The stratification variables for the survey design were day-type (weekend+public holiday/weekday), moon-phase (dark/light), tidal state (ebb/flood/slack) time of night (before/after midnight). A further stratification by tidal/non-tidal classification of subareas was included for the data analysis (post-stratification). The *a priori* stratification of sampling effort was for approximately two-thirds of nights to be chosen from the dark period, and approximately two-thirds of shifts to include the period of the ebb-tide. The lunar month was divided into two periods, namely the 'dark', comprising the seven nights before and after the new moon, plus the night of the new moon; and (ii) the 'light', which comprised the remaining nights of the lunar month. Field staff were rostered to carry out intercept surveys on 11 nights per month, with 7 in the lunar 'dark' and 4 in the lunar 'light' period. Choice of sampling nights was based on a random starting date and fixed skip interval. Shifts were 4 h duration on the larger lakes (Wallis,Tuggerah and Illawarra) and 2.25 hours on Lake Coila. Time-blocks for the rosters were from last light (equivalent to 'civil' twilight defined by Lomb (1993)) to first light.

The procedure for each survey shift was based on progressive count methods (Hoenig et. al. 1993). Because of the distances involved in traversing the entire fishery in each estuary it was not feasible to have more than one head-count per shift. A maximum of 30 minutes was spent in each subarea. A head-count of prawners was done for the first 10 minutes, then the remainder of the 30 minutes was spent interviewing prawners. Those prawners interviewed had their catch weighed on a spring balance to the nearest .01 kg. Prawners were asked details of gear used (number of nets of each type and number of submersible and non-submersible lights). Subsamples of prawns (10 prawns wherever available, approximately 80 to 200g total weight) were taken from each of a subset of prawners (approximately 30% of interviews). The species and sex of prawns in the subsample were determined, and the carapace length of each prawn in the measured to the nearest mm. Other data recorded on the survey sheet were details of moon phase, tide and weather.

The starting position and direction of travel for the creel survey were randomly allocated for each shift. For each month of the survey period, one night in the dark of the moon period was randomly allocated to a head-count of prawners for the whole estuary, to provide an estimate of the extent to which the survey subareas accounted for the effort operating in the entire estuary.

The areas of each estuary for which the tidal influence can be separated from wind and other climatic effects cover only a small area in each of the four estuaries, extending only 0.5 to 1km beyond the entrance to Tuggerah and Illawarra Lakes, and a radial distance of 5km in Wallis Lake. In Coila Lake all subareas sampled were tidally affected when the lake was open, i.e. prior to January 1993.

For each data record from a tidally-influenced subarea, the time spent fishing on the runout tide during complete darkness as a proportion of the total time fishing, was computed by supplying the database with predicted times of low and high tides and commencement and cessation of darkness. The predicted times of darkness were derived from Lomb (1993) together with site specific data supplied by the Sydney Observatory (pers. comm. Paul Payne, Sydney Observatory, Sydney NSW 2000). Times for tidal states were calculated from tidal predictions and lags calculated on the basis of tide gauges in Wallis and Illawarra Lakes (Public Works Department NSW 1992; 1993). For Coila and Tuggerah Lakes, lag estimates were based on observations provided by the field staff.

Expansion of sample catch and effort data

Expansion of the survey data to give estimates of total catch and effort for all available days in the survey period required an estimate for the number of hours in the prawning night. For the period of the surveys, duration of darkness ranged from approximately 8.5 h in December and January to 9.5 h in November and March, however considering the overwhelming effect of tide on the number of prawners, the duration of the prawning night was assumed to be 6 h, because this was the approximate mean duration of the run-out tide in the tidal subareas.

Total recreational prawning effort was estimated for each combination of lunar phase, day-type, tidal/non-tidal subarea and fishing method. Total effort F_{ij} for stratum j in lunar month i, was obtained by calculating

$$F_{ij} = h_i \, d_{ij} \, \bar{x}_{ij} \,/\, D_{ij}$$

where h_i = number of hours available for fishing in a night (assumed 6h)

d_{ij} = total number of days from stratum j available in lunar month i

D_{ij} = number of surveyed days from stratum j in lunar month i

$\bar{x}_{ij}$ = mean number of prawners per night for stratum j in lunar month i

For estimating the mean catch rate ($\bar{R}_{ij}$, the mean cpue over individual catches) the same stratification as for F_{ij} was used, apart from the day-type stratum, which was omitted so that the sample sizes would be adequate for all strata combinations.

Catch C_{ij} for stratum j in month i was then estimated as the product of estimated catch rate and estimated effort for that stratum:

$$C_{ij} = F_{ij} \; \overline{R}_{ij}$$

Total catch for lunar month i (C_i) was calculated by summing C_{ij} over all j strata: $C_i = \sum_j F_{ij} \; \overline{R}_{ij}$

Approximate standard errors were computed by using the estimator for the variance of a product given in Goodman (1960), i.e.

$$\text{var } C_{ij} = \overline{R}_{ij}^{2} \text{ var}(F_{ij}) + F_{ij}^{2}\text{var}(\overline{R}_{ij}) + \text{var}(F_{ij}) \text{ var}(\overline{R}_{ij}).$$

An estimate of the variance of C_i was obtained by summing var(C_{ij}) over j (strata).

Results

A total of 3360 interviews were completed over the full survey period, and 1187 subsamples, comprising 10 835 prawns were processed for species and length data. The response rate from prawners approached by field staff for interview was extremely high, with only 7 complete refusals and 22 partial refusals of an interview over the whole survey period. The monthly head-counts for the entire estuary for each of the study sites confirmed that the subareas surveyed accounted for virtually 100% of the recreational prawning effort.

Estimates of Effort

The estimated numbers of prawners per night (by estuary, moon-phase, day-type and tide) for the 1993/94 season are given in Table 1. Patterns in the data for the other seasons were similar to those for the 1993/94 season.

Fishing effort in Wallis Lake was predominantly by scoop-nets from boats (98%), whilst in Tuggerah approximately 20% of total effort used drag-nets, with 80% scoop-nets (mainly shore-based); in Lake Illawarra effort was divided between scoop-nets from boats (35% of total) and scoop-nets used while wading (64%), with a small amount of drag-netting (<1%); and in Coila Lake 80% of effort was by scoop-nets while wading, the remainder by drag-nets (Figure 2). Only 17 prawners used scissor-nets; these were in Tuggerah Lakes.

Effort in Wallis Lake was concentrated almost exclusively in the tidal areas, with a negligible number of prawners counted in shifts based on the run-in tide (Table 1). On weekends in the dark period there were approximately double the number of prawners of weekend light periods, while for weekdays, the dark period had ten-fold the number of prawners counted in the light period (Table 1). There was a similar pattern in the other estuaries, with number of prawners in the dark period being approximately double that of the light. In all estuaries, January was the month with the greatest effort (Figure 2).

Because of the very small number of prawners active on the run-in tide, surveys scheduled for periods covering the run-in tide almost always encountered zero prawners (Table 1). The estimates of the mean percentage of time for which prawning was on the run-out tide show that for tidally affected areas, more than 90% of the time spent prawning until the time of interview was on the run-out tide. For the subareas with minimal tidal movement, the mean percentage of time spent prawning during the period of the run-out tide at the estuary entrance, was generally about 80%.

Estimates of Catch Rates

Estimates of annual mean catch rates (cpue; kg prawner-h^{-1}) by moon-phase and method for each estuary are shown in Table 2.

(i) Comparison between Estuaries

The major difference in cpue between the four study sites was the significantly higher cpue for Wallis Lake (Table 2). The cpue for scoop-netting in Wallis Lake was almost double that for the tidal areas in the other lakes. In 1992/93 the cpue for scoop-netting in Coila Lake was equal to that for Wallis, but in the other years the cpue for Coila Lake was the lowest of the three estuaries.

(iii) Comparison of 'tidal' and 'non-tidal' subareas

Tidal and non-tidal areas can only be compared for Illawarra and Tuggerah lakes, as the data available for non-tidal subareas of Wallis Lake were extremely limited, reflecting the low numbers of prawners in these subareas. All subareas in Coila Lake were tidally affected until the estuary entrance closed to the sea in January 1993.

For the total survey period, the mean cpue for scoop-netting in the tidal subareas of Tuggerah Lakes was almost double that of the non-tidal subareas (Table 2). On an individual year basis, cpue for scoop-netting in the tidal areas was greater than for non-tidal subareas in 1992/3 and 1993/4, but not in 1991/92. There were no significant differences in cpue for scoop-netting between tidal and non-tidal areas in Lake Illawarra (t_{1335}=1.57, p=0.12).

(iv) Lunar effects

The results of comparing mean cpue of the dark lunar period against the light (Table 2) were not consistent over the four estuaries: For Wallis and Coila Lakes, the mean cpue for the dark period of the moon was higher than that for the light period in each survey year. These differences were statistically significant (t-test, $P<.05$) for each comparison with at least 20 observations in each group. For Tuggerah Lakes, only the 1991/92 tidal subarea data showed a significant difference in cpue between the moon-phases, with the light period having greater cpue (t_{107}=2.98, P=.003). For the tidal subareas of Lake Illawarra, mean cpue was higher for the dark in 1993/94 (t_{320}=2.83, p=.005), but higher for the light period in 1991/2 (t_{89}=5.84, p=0.000).

(v) Drag-nets compared to scoop-nets

Drag-nets were used only in the non-tidal areas. Comparison between cpue for drag- and scoop-netting could only be made for Tuggerah Lakes because this was the only estuary in which both methods were commonly used (Table 2). The mean cpue over the total study period was 0.52 kg prawner-h^{-1} for drag-nets and 0.10 for scoop-nets. Drag-nets had a significantly higher mean cpue than scoop nets ($p<.05$) for each of the study years for both light and dark lunar phases.

(v) Shore-based compared to boat-based scoop-netting

The mean cpue of shore-based scoop-netting showed no significant difference from boat-based scoop-netting for Lake Illawarra over the full sampling period (mean=0.232 kg/prawner hour, se=0.012, N=331 for boat-based; mean=0.231, se=0.009 N= 1006 for shore-based). Similarly for Tuggerah Lakes there was no significant difference in mean cpue between shore- and boat-based scoopers (mean=0.238, se= 0.019, N=412 for shore-based; mean= 0.269, se=0.034 N=33 for boat-based scoopers).

Comparison of commercial and recreational catches

The estimated weights of the recreational and commercial catches for each of the four estuaries are given on an annual basis in Table 3 and on a monthly basis in Fig 3.

There were large fluctuations in the estimates of recreational catch as a proportion of commercial catch between years, although the recreational catches for Wallis, Tuggerah and Illawarra lakes showed much less inter-annual variation than the commercial catches. Coila Lake differed from the others in that the closure of its entrance in January 1993 led to large catches in 1992/93, but relatively few prawns were caught in the 1993/94 season.

The species compositions of recreational and commercial catches are shown in Figure 4. The recreational catch was comprised almost exclusively of eastern king prawns in Wallis, Illawarra and Coila Lakes, while in Tuggerah Lakes the proportions of eastern king and school prawns were almost equal, with greasyback prawns comprising 10-22% of the catch. Only one other prawn species was reported from the recreational survey, namely the brown tiger prawn Penaeus esculentus, for which 6 individuals were identified from the total of 10 835 prawns measured in subsamples. The commercial catches showed much higher proportions of school prawns in Wallis Lake (33-52%) and Lake Illawarra (35-53%).

Greasyback prawns comprised 26-38% of commercial catches in Wallis Lake with negligible catches of this species in the other lakes, apart from Tuggerah Lakes with 13% in 1993/4.

Length compositions of commercial and recreational catches are compared in Figure 5(a) eastern king prawns and 5(b) school prawns. For eastern king prawns, the length distributions for the commercial and recreational catches overlapped completely for each of Wallis, Tuggerah and Illawarra lakes, however for Coila Lake, the distributions were different in both 1992/93 and 1993/94. In 1992/93 recreational catches had relatively more of the longer prawns, while the converse was the case in 1993/94. Comparisons for school prawns were possible for samples from Tuggerah Lakes only, because this was the only estuary where prawn numbers were sufficient to consistently provide representative samples. For school prawns, the distributions overlapped, but recreational catches contained relatively more larger prawns. Mean lengths of prawns in samples from recreational catches were longer than those from commercial catches in both years for which data were available (Figure 5b).

Discussion

Comparisons of the estimates of recreational and commercial catches for the four estuaries indicate that the recreational component is a significant part of the total catch, particularly in Tuggerah and Illawarra Lakes, where many prawners are active.

This study has provided information on the variability of catch rates between years, between estuaries, between lunar months and phases within a lunar month for an estuary, and between prawning methods. The environmental conditions encountered during our surveys encapsulated the widest range of conditions which would affect catch rate and fishing effort. Flooding during 1991/92 meant that prawns were flushed to sea while prawners were discouraged by the extreme weather conditions. Similarly, extensive bushfires in January 1994 had an effect on prawning effort during that month, and possibly for the remainder of the season.

Differences in catch rates between prawners operating drag nets and those using scoop nets can be attributed largely to the non passive nature of the former gear. As the name implies, drag nets are dragged across the bottom and so disturb those prawns not actively swimming in the water column. This gear also covers a greater area per unit time than the scoop net.

The proportion of recreational catch to commercial catch varied greatly between estuaries, which may be a function of the availability of prawning grounds. Juvenile prawns live in the shallow areas in estuaries (Young 1978; Young and Carpenter 1977), but are spatially distributed through the estuary principally by differences in tolerances to salinity (e.g. Coles and Greenwood 1983). Wide expanses of shallow areas provide recreational prawners with the opportunity to harvest the available prawns more efficiently than in deeper estuaries (e.g. Wallis Lake). Prawners can not only cover more area but are able also to entire water column from the surface to the substrate. This is particularly the case near the mouths of intermittently opening estuaries (Roy 1984) where prawners target prawns as they migrate to oceanic waters to mature (e.g. Ruello 1977; Montgomery 1990). Prawners in Tuggerah Lakes and Lake Illawarra were able to cover large areas of the lake by wading whereas in Wallis Lake prawners were limited to fishing from a boat because the lake was far deeper than the other two.

The prominence of eastern king prawns in the catches of recreational prawners is probably associated with differences in behaviour between species. Penn (1983) discussed the effects on catchability of prawn behaviour. He categorised eastern king prawns as being nocturnal, strongly burrowing and most catchable at night. Racek (1959) and Ruello (1975) also found eastern king prawns to be most active at night and to emigrate in the surface waters of night ebb tides to oceanic waters during spring-summer. School prawns on the other hand do not burrow as deep as eastern king prawns, are more active during the day time than the former species, and move in the bottom or mid-water (Racek 1959; Ruello 1975). Greasyback prawns peak in activity levels at dawn and dusk (Racek 1959). These behavioral differences appear to be related to light intensity (Wassenberg and Hill 1994).

Their behavioural pattern makes eastern king prawns more susceptible to the recreational fishery than school prawns. Recreational prawners predominantly use scoop nets to catch prawns moving in the water column at night. These behavioural patterns also explain the differences in species composition between recreational and commercial catches. Commercial fishers not only use some more active types of gear than recreational prawners, but also operate both during the day and night. There is therefore a greater likelihood that their catches will contain more school prawns because of their day time fishing with active gear.

The impact upon the stock of harvesting eastern king prawns in estuaries is probably greater than suggested by the contribution the estuary catch of this species makes to the total commercial catch of eastern king prawns in NSW. Firstly, the proportion of the catch taken in estuaries in terms of numbers caught is greater than the proportion by weight because individuals in estuaries are smaller than those from oceanic waters. The 10-year mean catch

of eastern king prawns in estuaries by commercial fishers is around 14% by weight of the total commercial catch of this species (Montgomery and McDonall 1988), and we found in this study that the recreational catch was around 30% of the commercial catch in estuaries.
Secondly, harvesting eastern king prawns in estuaries targets immature animals. Sizes at first maturity for eastern king prawns is around 35 and 42 mm CL for males and females respectively (Glaister 1983; Courtney et al. in press); lengths that are longer than most individuals of this species caught in estuaries. This harvesting together with that for immature prawns in oceanic waters has the potential to affect recruitment to the spawning stock.

This project is an example of using roving creel survey techniques in hours of darkness to estimate the level of catch in a fishery. Malvestuto (1983) and Hayne (1991) list as a disadvantage the fact that roving creel surveys cannot be done at night. This may be the general case as we have been unable to find any examples of studies that have used intercept survey methods to estimate the catch of fishers operating at night. The recreational fishery for prawns in NSW may be the exception because prawners use battery powered lights to spot prawns in the water column and are therefore easily identified as prawners by the bobbing of their light. Further, we are unaware of any other study in the peer reviewed literature that has surveyed a fishery for penaeids. We conclude that roving creel surveys have been used successfully at night to show that recreational fishery is a significant harvester of penaeids in NSW. The methodology used in this study is possibly applicable to other penaeid fisheries in Australia and internationally.

Information obtained from this survey which enables planning for estimation of statewide estimates of catch and effort follows:

1. The precision of the total catch estimate is increased by putting as much survey resources as possible into the head-count data, while keeping an adequate level of sampling for catch rate estimation. While coefficients of

variation for cpue are generally of similar magnitude to those for number of prawners per night (80-120%), an interview takes far less sampling time than the head count, thus the sample sizes for estimating mean catch rates are much higher than those for estimating mean number of prawners per night, hence the standard errors of the former are relatively lower.

2. The important variables for stratification in surveys of recreational prawning are lunar month, lunar phase, tidal phase, day-type, tidal/non-tidal subareas and prawning methods.

3. There is a strong preference of prawners for the ebb-tide and dark period of the lunar cycle. Sampling can be limited to the period of the run-out tide, although there are significant numbers of recreational prawners active in the light period of the lunar cycle. Estimates of variability of prawner effort within and between lunar months and estuaries have also been provided.

4. Occasional observations of larger than expected effort coinciding with periods of large cpue, support the contention that prawners may be attracted to travel to an estuary by reports of large catch rates. This invalidates the assumption of independence between catch rates and the number of prawners. The confounding of high catch rates in January with the major school holiday period causes difficulties in testing data for such a relationship.

5. The major effects caused by closing of estuary entrances were ssen in the present study: The entrance to Coila Lake closed in January 1993. This led to high cpue in January to March 1993 (mean cpue 0.5 kg h^{-1} for scoop netters), then a reduction in cpue to approximately 0.1 kg h^{-1} in the 1993/94 season, when few of the prawns had survived from the previous season. Commercial prawners recorded very little effort in Coila Lake in the 1993/94 season. Many of the estuaries in NSW have intermittently opening entrances.

6. The study found large differences between estuaries in the mix of methods used by recreational prawners and in the species mix of the catch. These differences mean that the logistics of the survey operation have to be tailored to the requirements of each estuary.

REFERENCES

ADAM, P. 1986. Habitats of Wallis Lake. *In*: Wallis Lake - present and future. Occasional Papers Series. Australian Marine Science Association, New South Wales Branch. Publication 86/2.

ANON. 1995. Exports raise fisheries returns despite lower catches. Aust. Fish. 54(1): 14-16.

BATLEY, G., N. BODY, AND B.COOK. 1990. The ecology of the Tuggerah Lakes System - A review: With special reference to the impact of Munmorah Power Station - Stage 1 - Hydrology, aquatic macrophytes, heavy metals and nutrient dynamics. Report for the Electricity Commission, NSW. 185pp.

CARLANDER, K.D., C.J. DICOSTANZO, AND R.J. JESSEN. 1958. Sampling problems in creel census. Prog. Fish. Cult. 20: 73-81.

CHURCHWARD, A.S., AND P. HICKLEY. 1991. The Atlantic salmon fishery of the River Severn (UK) p.1-14. *In*: Cowx, I.G. [ed.] Catch effort sampling strategies - their application in freshwater fisheries management. Hartnolls Ltd., Bodmin, Cornwall.

COLES, R.G., AND J.G. GREENWOOD. 1983. Seasonal movement and size distribution of three commercially important Australian prawn species (Crustacea: Penaeidae) within an estuarine system. Aust. J. Mar. Freshwat. Res. 34: 727-743.

COLLETT, L.C., A.J. COLLINS, P.J. GIBBS, AND R.J. WEST. 1981. Shallow dredging as a strategy for the control of sublittoral macrophytes: A case study in Tuggerah Lakes, New South Wales. Aust. J. Mar. Freshwat. Res. 32: 563-71.

GARCIA, S. AND L. LE RESTE. 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. FAO Fish. Tech. Pap. 203: 1-215.

GLAISTER, J.P. 1978a. The impact of river discharge on distribution and production of the school prawn Metapenaeus macleayi (Haswell) (Crustacea : Penaeidae) in the Clarence River region, northern New South Wales. Aust. J. Mar. Freshwat. Res. 29: 311-323.

GLAISTER, J.P. 1978b. Movement and growth of tagged school prawns, Metapenaeus macleayi (Haswell) (Crustacea: Penaeidae), in the Clarence River region of northern New South Wales. Aust. J. Freshwat. Res. 29: 645-657.

GLAISTER, J.P., T. LAU, AND V.C. McDONALL. 1987. Growth and migration of tagged eastern Australian king prawns Penaeus plebejus Hess. Aust. J. Mar. Freshwat. Res. 38: 225-241.

GLAISTER, J.P., S.S. MONTGOMERY, AND V.C. McDONALL. 1990. Yield-per-recruit analysis of eastern king prawns Penaeus plebejus Hess, in Eastern Australia. Aust. J. Mar. Freshwat. Res. 41: 175-197.

GOODMAN, Leo A. 1960. On the exact variance of products. J. Am. Stat. Assoc. 708-713.

HAYNE, D.W. 1991. The access point survey: procedures and comparison with roving clerk creel survey. Am. Fish. Soc. Symp. 12: 123-138.

HILBORN, R., AND C.J. Walters. 1992. Quantitative fisheries stock assessment; Choice, dynamics and uncertainty. Chapman and Hall. 570 p.

HOENIG, J.M., D.S. ROBSON, C.M. JONES, AND K.H. POLLOCK. 1993. Scheduling counts in instantaneous and progressive count methods for estimating sportfishing effort. North American Journal of Fisheries Management. 13, 723-736.

KAILOLA, P.J., M.J. WILLIAMS, P.C. STEWART, R.E. REICHELT, A. McNEE, AND A. GRIEVE. 1993. Australian Fisheries Resources. BRS Dept. Prim. Ind. 422p.

LOMB, N. 1993. 1994 Sydney Sky Guide. Sydney Observatory. 80pp.

MACKENZIE, C. 1991. Comparison of northern pike catch and harvest rates from completed and uncompleted fishing trips. Am. Fish. Soc. Symp. 12: 51-60.

MALVESTUTO, S.P. 1983. Sampling the recreational fishery, p. 397-419. *In*: L.A. Nielsen AND D.L. Johnson [ed.] Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

MALVESTUTO, S.P., W.D. DAVIES, AND W.L. SHELTON. 1978. An evaluation of the roving creel survey with nonuniform probability sampling. Trans. Am. Fish. Soc. 107: 255-262.

MONTGOMERY S.S. 1990. Movements of juvenile eastern king prawns Penaeus plebejus, and identification of stock along the east coast of Australia. Fish. Res. 9: 189-208.

MONTGOMERY, S.S. 1990. Possible impacts of the greenhouse effect on commercial prawn populations and fisheries in New South Wales. Wetlands. 10: 35-39.

MONTGOMERY, S.S. AND V.C. McDONALL. 1988. A summary of the research conducted on the estuarine prawn trawl fisheries in New South Wales and recommendations for their future management.

LUCAS, R.C. 1963. Bias in estimating recreationists' length of stay from sample interviews. J. For. 61: 912-914.

NIELSEN, A.F AND A.D. GORDON. 1986. Behaviour and stability of tidal inlets - a case study of Wallis Lake. *In*: Wallis Lake - present and future. Occasional Papers Series. Australian Marine Science Association, New South Wales Branch. Publication No. 86/2.

O'CONNELL, M.F., J.B. DEMPSON, AND D.G. REDDIN. 1992. Evaluation of the impacts of major management changes in the Atlantic salmon (Salmo salar L.)

fisheries of Newfoundland and Labrador, Canada, 1984-1988. ICES J. Mar. Sci., 49:69-87.

PEASE, B.C., AND E.A. SCRIBNER. 1994. New South Wales Commercial Fisheries Statistics 1991/92.

PENN, J.W. 1984. The behaviour and hatchability of some commercially exploited penaeids and their relationships to stock and recruitment. *In*: J.A. Gulland and B.J.Rothschild [eds.] Penaeid shrimps: their biology and management. Fishing News Books, Farnham, Surrey, England, 1984, 173-186.

PEPPERELL, J.P. 1985. Expenditure on recreational fishing in New South Wales. Proc. 20th Assembly of Australian Freshwater Fishermen, Lake Eucumbene, 8-10th, March.

PHIPPEN, K.W., AND E.P. BERGERSEN. 1987. Angling definitions and their effects on the accuracy of count-interview creel survey harvest estimates. N. Am. Fish. Man. 7: 488-492.

PHIPPEN, K.W., AND E.P. BERGERSEN. 1991. Accuracy of a roving creel survey's harvest estimate and evaluation of possible sources of bias. Am. Fish. Soc. Sym

POLLOCK, K.H., C.M. JONES, AND T.L. BROWN [eds.] 1994. Angler survey methods and their applications in fisheries management. Am. Fish. Soc. Symp. 25: 1-371.

PUBLIC WORKS DEPARTMENT, NSW. 1992. NSW estuary and river water levels. Annual Summary 1991/92. Manly Hydraulics Laboratory, Report No. MHL625.

PUBLIC WORKS DEPARTMENT, NSW. 1993. NSW estuary and river water levels. Annual Summary 1992/93. Manly Hydraulics Laboratory, Report No. MHL659.

RACEK, A.A. 1959. Prawn investigations in Eastern Australia. State Fisheries Chief Secretary's Department, New South Wales. Research Bulletin No. 6.p.12-60.

ROBSON, D.S. 1991. The roving creel survey. Am. Fish. Soc. Symp. 12:-19-24.

ROBSON, D.S. 1991. The roving creel survey. Am. Fish. Soc. Symp. 12:-19-24.

ROY, P.S. 1984. New South Wales estuaries: their origin and evolution. *In*: Coastal Geomorphology in Australia. B.G. THOM (ed.) pp.99-121. Academic Press, New York.

RUELLO, N.V. 1975a. Geographical distribution, growth and breeding migration of the eastern Australian king prawn Penaeus plebejus Hess. Aust. J. Mar. and Freshwat. Res. 26, 343-354.

RUELLO, N.V. 1975b. An historical review and annotated bibliography of prawns and the prawning industry in Australia. *In* First Australian National Prawn Seminar, 1973. (Ed. P. C. Young). Australian Government Publishing Service, Canberra.

RUELLO, N. 1977. Migration and stock studies on the Australian school prawn Metapenaeus macleayi. Mar. Biol. 41: 185-90.

SOROS-LONGWORTH AND MCKENZIE. 1976. Lake Illawarra Waterway Planning Study. Report to NSW Department of Public Works. 136 pp.

THRESHER, A., T. WARD, AND C. CROSSLAND. 1993. An assessment of the impacts of Munmorah power station on the fauna of Tuggerah Lakes. Report to Pacific Power from CSIRO. CSIRO, Hobart, May 1993.

VAUGHAN, D.S., AND T.E. HELSER. 1990. Status of the red drum stock of the Atlantic coast: stack assessment report for 1989. NOAA Technical Memorandum NMFS-SEFC-263. 117p.

von GELDERN, C.E. 1972. Angling quality at Folsom Lake, California, as determined by roving creel census. Calif. Fish. Gam. 58: 75-79.

WADE, D.L., C.M. JONES, D.S. ROBSON, AND K.H. POLLOCK. 1991. Computer simulation techniques to access bias in the roving-creel-survey estimator. Am. Fish. Soc. Symp. 12: 40-46.

WASSENBERG, T.J AND B. J. HILL. 1994. Laboratory study on the effect of light on the emergence behaviour of eight species of commercially important adult penaeid prawns. Aust. J. Mar. Freshwater Res., 45, 43-50.

WEST et.al. 1985. An estuarine inventory for New South Wales, Australia. Department of Agriculture New South Wales. Fisheries Bulletin 2.

YOUNG, P.C. 1975. Preliminary observations on the environment and biology of juvenile king prawns (Penaeus plebejus) in Moreton Bay, Queensland. *In* First Australian National Prawn Seminar, 1973. (Ed. P. C. Young). Australian Government Publishing Service. Canberra.

YOUNG, P.C., AND S.M. CARPENTER. 1977. Recruitment of post-larval penaeid prawns to nursery areas in Moreton Bay, Queensland. Australian J. Mar. Freshwat. Res 28: 754-73.

Figures and Tables

Figures:

1. Locality map, showing areas of major urbanisation (●) and estuaries included in this study (■).

2. Estimates of monthly prawning effort by method for the four study sites.

3. Estimated catches of prawns by month, by commercial and recreational fishers for each of the four study sites.

4. Species composition of recreational and commercial catches from the four study sites.

5. Length frequency distribution of (a) eastern king prawns for samples from all four study sites; and (b) school prawns from Tuggerah Lakes; in commercial and recreational catches.

Tables:

1. Estimated mean number of prawners per night by moon-phase, day-type, tidal state and fishing method. Data are for 1993/4 season.

2. Mean cpue (kg prawner-h^{-1}) for the each of the four study sites by year and moon-phase.

3. Seasonal estimates of recreational and commercial catches of prawns for the four study sites

Table 1. Estimates of mean (per night) and total number of prawners by moon-phase (M), day-type (D), tide (T) and fishing method for the 1993-94 season (November 1993-March 1994). D=dark, L=light moon-phases; WD=week-day, WE=weekend or public holiday; RI=run-in, RO=run-out tide.

Location				No. of shore-scoopers			No. of boat-scoopers			No of drag-netters		
	M	D	T	mean	se	Total	mean	se	Total	mean	se	Total
Wallis tidal	D	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	0.36	0.17	19	21.17	4.42	1101	0.00	0.00	0
	D	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WE	RO	0.56	0.44	12	36.83	14.57	810	0.00	0.00	0
	L	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WD	RO	0.00	0.00	0	2.64	1.63	158	0.00	0.00	0
	L	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	0.20	0.20	6	18.40	10.80	534	0.00	0.00	0
						37			2603			0
Tuggerah tidal	D	WD	RI	0.43	0.43	22	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	56.06	15.12	2915	5.39	3.07	280	0.00	0.00	0
	D	WE	RI	1.33	1.33	29	0.00	0.00	0	0.00	0.00	0
	D	WE	RO	80.00	26.64	1760	4.67	1.69	103	0.00	0.00	0
	L	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WD	RO	19.64	9.33	1178	0.09	0.09	5	0.00	0.00	0
	L	WE	RI	3.00	3.00	87	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	33.60	24.47	974	2.80	2.80	81	0.00	0.00	0
						6967			470			0
Tuggerah non-tidal	D	WD	n.a	9.32	2.44	485	0.00	0.00	0	20.96	5.50	1090
	D	WE	n.a	5.33	2.25	117	0.00	0.00	0	17.56	7.24	386
	L	WD	n.a	2.20	1.50	132	0.00	0.00	0	2.13	0.95	128
	L	WE	n.a	7.71	2.02	224	0.00	0.00	0	7.71	2.81	224
						957			0			1828
Illawarra tidal	D	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	65.22	9.88	3391	6.83	1.62	355	0.00	0.00	0
	D	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WE	RO	67.33	26.32	1481	6.33	2.95	139	0.00	0.00	0
	L	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WD	RO	23.25	8.08	1395	2.00	1.12	120	0.00	0.00	0
	L	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	22.00	8.86	638	0.00	0.00	0	0.00	0.00	0
						6906			614			0
Illawarra non-tidal	D	WD	n.a	10.08	3.07	524	20.60	6.01	1071	0.16	0.16	8
	D	WE	n.a	8.78	4.26	193	23.56	12.11	518	0.44	0.44	10
	L	WD	n.a	5.00	2.25	300	5.65	3.14	339	0.29	0.29	17
	L	WE	n.a	4.50	3.72	131	2.33	2.33	68	0.00	0.00	0
						1148			1996			35
Coila	D	WD	n.a	5.88	1.92	306	0.00	0.00	0	0.44	0.26	23
	D	WE	n.a	1.67	0.69	37	0.00	0.00	0	0.00	0.00	0
	L	WD	n.a	3.21	2.48	193	0.00	0.00	0	0.00	0.00	0
	L	WE	n.a	3.71	1.66	108	0.00	0.00	0	0.14	0.14	4
						643			0			27

Table 2. Mean CPUE (kg per prawner per h) for dark and light moon-phases (see text) in tidal and non-tidal subareas of each estuary

Location	Year	Moon phase	Scoop			Drag		
			N	mean	se	N	mean	se
Wallis tidal	1991/2	D	106	0.3938	0.0560			
	1991/2	L	3	0.2502	0.0130			
	1992/3	D	206	0.4911	0.0330			
	1992/3	L	67	0.3140	0.0378			
	1993/4	D	206	0.4571	0.0323			
	1993/4	L	43	0.3011	0.0556			
	Total		631	0.4308	0.0187			
Tuggerah tidal	1991/2	D	88	0.1832	0.0195			
	1991/2	L	19	0.3206	0.0409			
	1992/3	D	119	0.2997	0.0459			
	1992/3	L	54	0.1653	0.0311			
	1993/4	D	120	0.2273	0.0303			
	1993/4	L	43	0.2985	0.0867			
	Total		443	0.2404	0.0180			
Tuggerah non-tidal	1991/2	D	49	0.1713	0.0351	26	0.8687	0.1804
	1991/2	L	6	0.1391	0.1136	8	0.3619	0.0887
	1992/3	D	37	0.0926	0.0173	63	0.6142	0.0975
	1992/3	L	38	0.0702	0.0150	33	0.3858	0.0904
	1993/4	D	44	0.0687	0.0133	75	0.4776	0.0638
	1993/4	L	19	0.0562	0.0135	24	0.3037	0.0566
	Total		193	0.1006	0.0113	229	0.5241	0.0432
Illawarra tidal	1991/2	D	70	0.1755	0.0270			
	1991/2	L	21	0.5395	0.0700			
	1992/3	D	241	0.2706	0.0226			
	1992/3	L	102	0.2272	0.0181			
	1993/4	D	210	0.2443	0.0179			
	1993/4	L	112	0.1683	0.0153			
	Total		756	0.2409	0.0101			
Illawarra non-tidal	1991/2	D	42	0.2636	0.0727	2	0.5556	0.1944
	1991/2	L	11	0.4216	0.2025	1	0.9378	-
	1992/3	D	161	0.2163	0.0132	7	0.2926	0.1077
	1992/3	L	76	0.2772	0.0347	1	0.1974	-
	1993/4	D	225	0.1940	0.0109	2	0.1971	0.1287
	1993/4	L	66	0.1821	0.0185	1	0.5508	-
	Total		581	0.2190	0.0100	14	0.3743	0.0795
Coila	1991/2	D	42	0.1340	0.0278	7	0.1711	0.0263
	1991/2	L	10	0.0827	0.0211	1	0.2802	-
	1992/3	D	155	0.4759	0.0395	13	0.7248	0.4755
	1992/3	L	59	0.1921	0.0403	5	0.6571	0.6571
	1993/4	D	124	0.0801	0.0157	5	0.0516	0.0300
	1993/4	L	48	0.0429	0.0129	0	-	-
	Total		439	0.2361	0.0163	31	0.4659	0.2236

Table 3. Seasonal estimates of prawn catch (tonnes) by recreational (r) and commercial (c) fishers. Approximate standard errors are shown as (± SE).

	Tuggerah			Wallis			Illawarra			Coila		
	r	c	r/c(%)	r	c	r/c(%)	r	c	r/c(%)	r	c	r/c(%)
Jan 92-Mar 92	5.74 (±0.92)	17.98	31.9 (±5.1)	4.52 (±1.72)	32.71	13.8 (±5.3)	8.95 (±1.93)	15.27	58.6 (±12.6)	0.42 (±0.13)	5.10	8.2 (±2.5)
Nov 92-Mar 93	12.52 (±2.01)	64.86	19.3 (±3.1)	10.22 (±2.64)	67.19	15.2 (±3.9)	12.80 (±1.58)	19.03	67.3 (±8.3)	3.04 (±0.69)	31.38	9.0 (±2.2)
Nov 93-Mar 94	17.41 (±3.12)	37.42	46.5 (±8.3)	6.62 (±1.31)	23.75	27.9 (±5.5)	13.68 (±1.64)	27.49	49.8 (±6.0)	0.24 (±0.07)	0.85	28.2 (±8.2)
Total	35.67 (±3.82)	120.3	29.7 (±3.2)	21.36 (±3.41)	123.7	17.3 (±2.8)	35.43 (±2.99)	61.79	57.3 (±4.8)	3.70 (±0.71)	37.33	9.9 (±1.9)

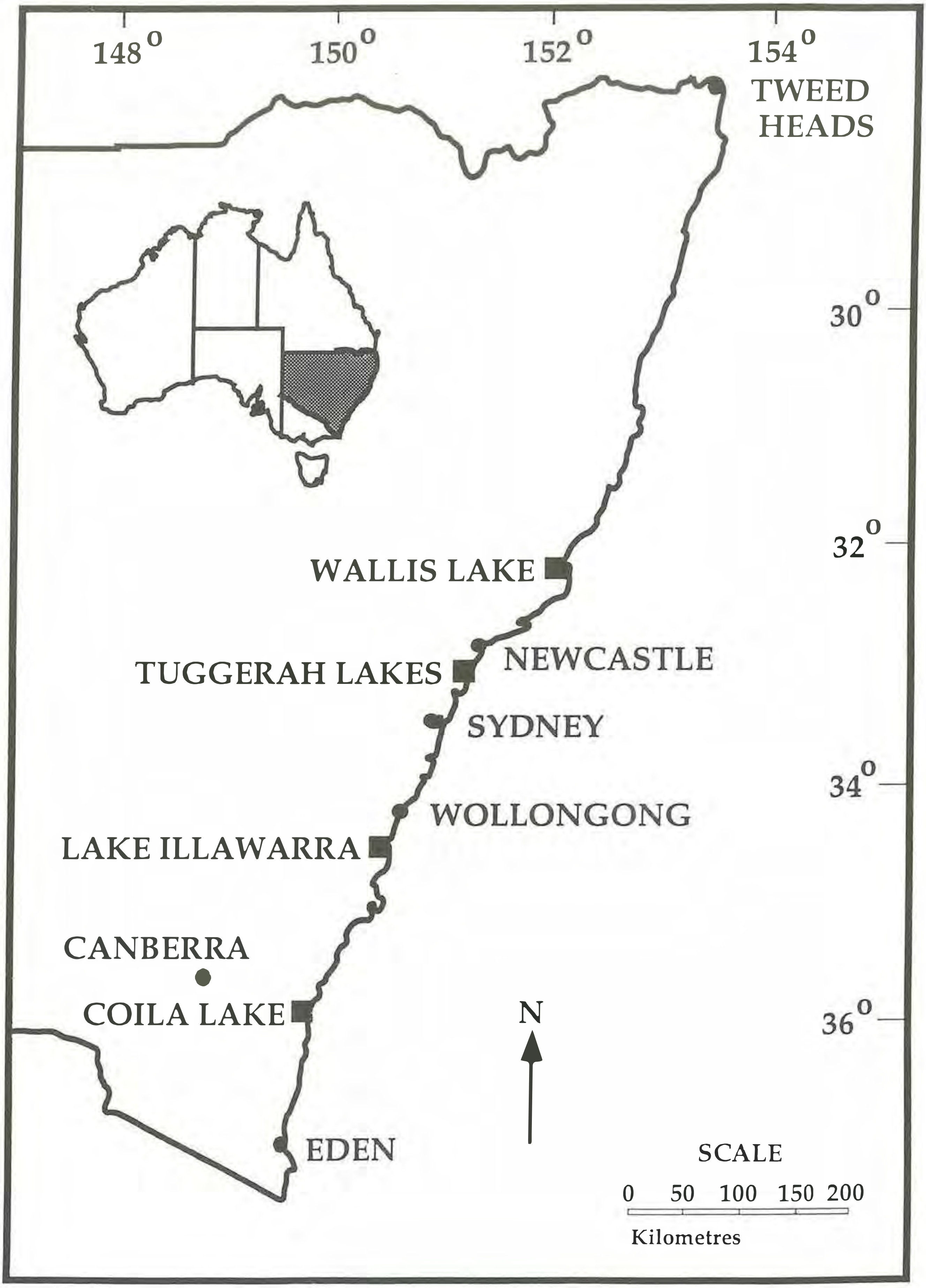


FIG. 1. Map of New South Wales showing areas of major urbanisation (●) and estuaries included in this study (■).

Fig 2

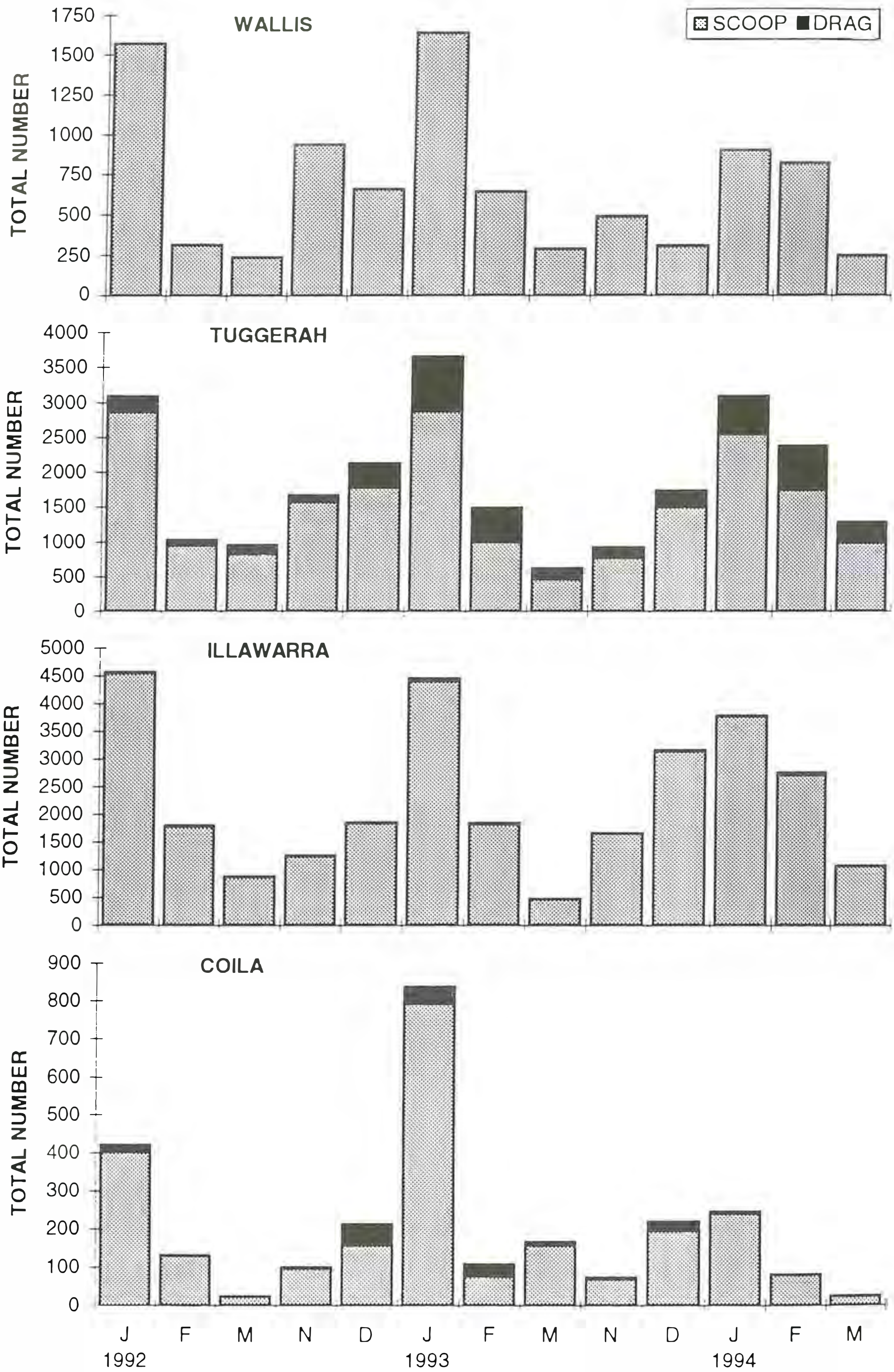

WALLIS
SCOOP
DRAG
TOTAL NUMBER
1750
1500
1250
1000
750
500
250
0
TUGGERAH
4000
3500
3000
2500
2000
1500
1000
500
ILLAWARRA
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
COILA
900
800
700
600
500
400
300
200
100
J F M N D J F M N D J F M
1992
1993
1994

Fig 3

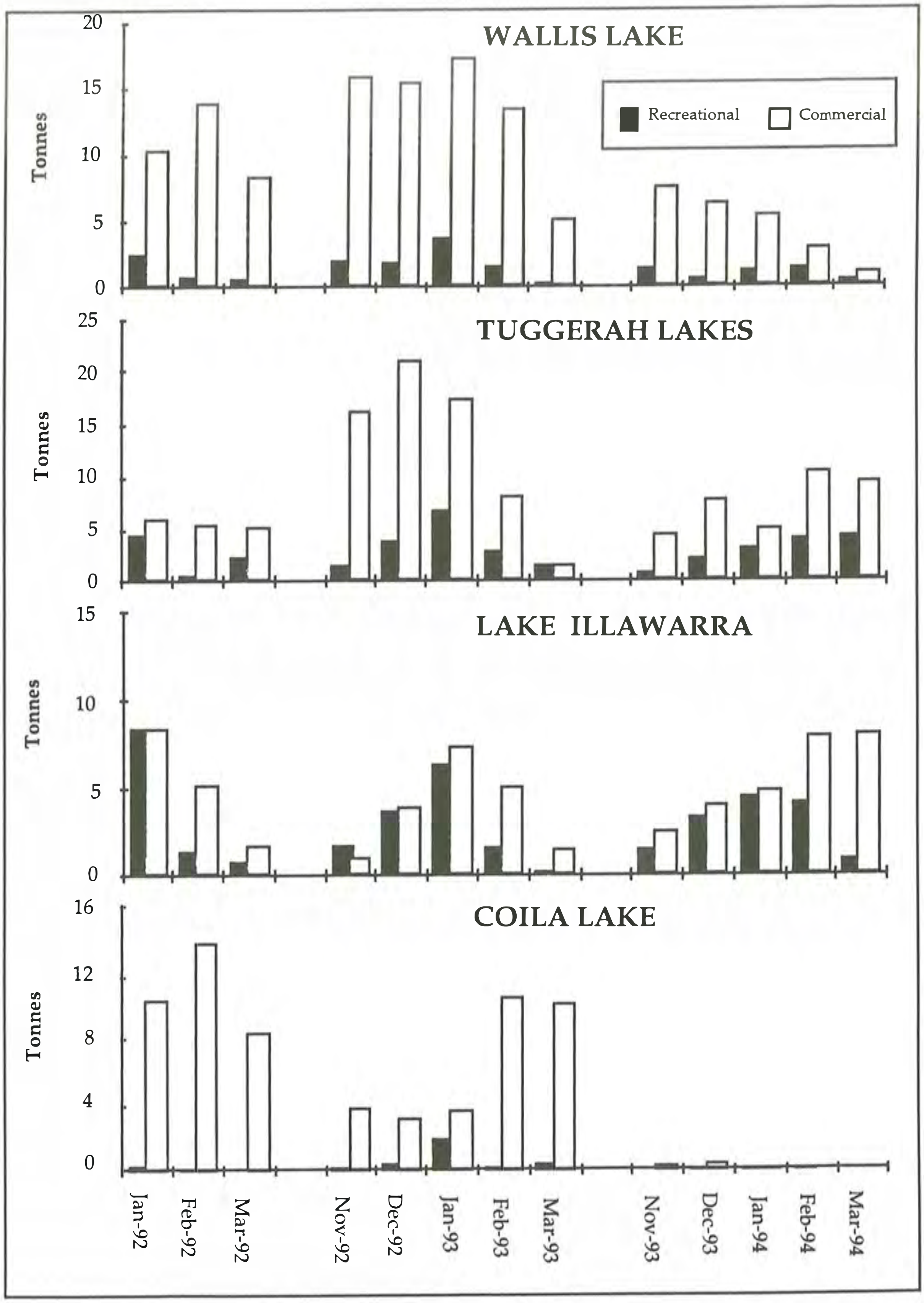
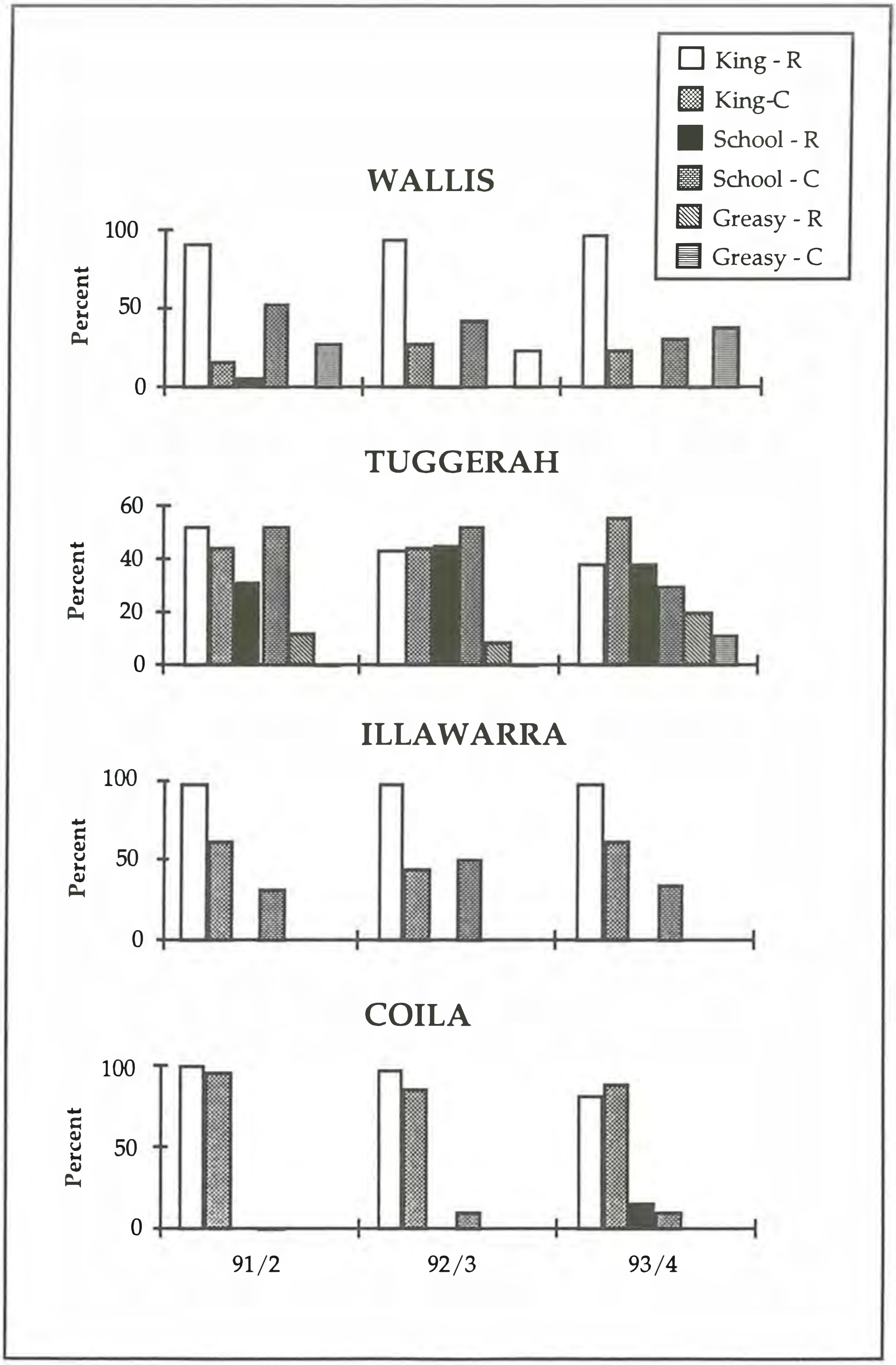

WALLIS LAKE
Recreational
Commercial
Tonnes
20
15
10
5
0
TUGGERAH LAKES
Tonnes
25
20
15
10
5
0
LAKE ILLAWARRA
Tonnes
15
10
5
0
COILA LAKE
Tonnes
16
12
8
4
0
Jan-92
Feb-92
Mar-92
Nov-92
Dec-92
Jan-93
Feb-93
Mar-93
Nov-93
Dec-93
Jan-94
Feb-94
Mar-94

Fig 4



King - R
King-C
School - R
School - C
Greasy - R
Greasy - C
WALLIS
Percent
100
50
0
TUGGERAH
60
40
20
ILLAWARRA
COILA
91/2
92/3
93/4

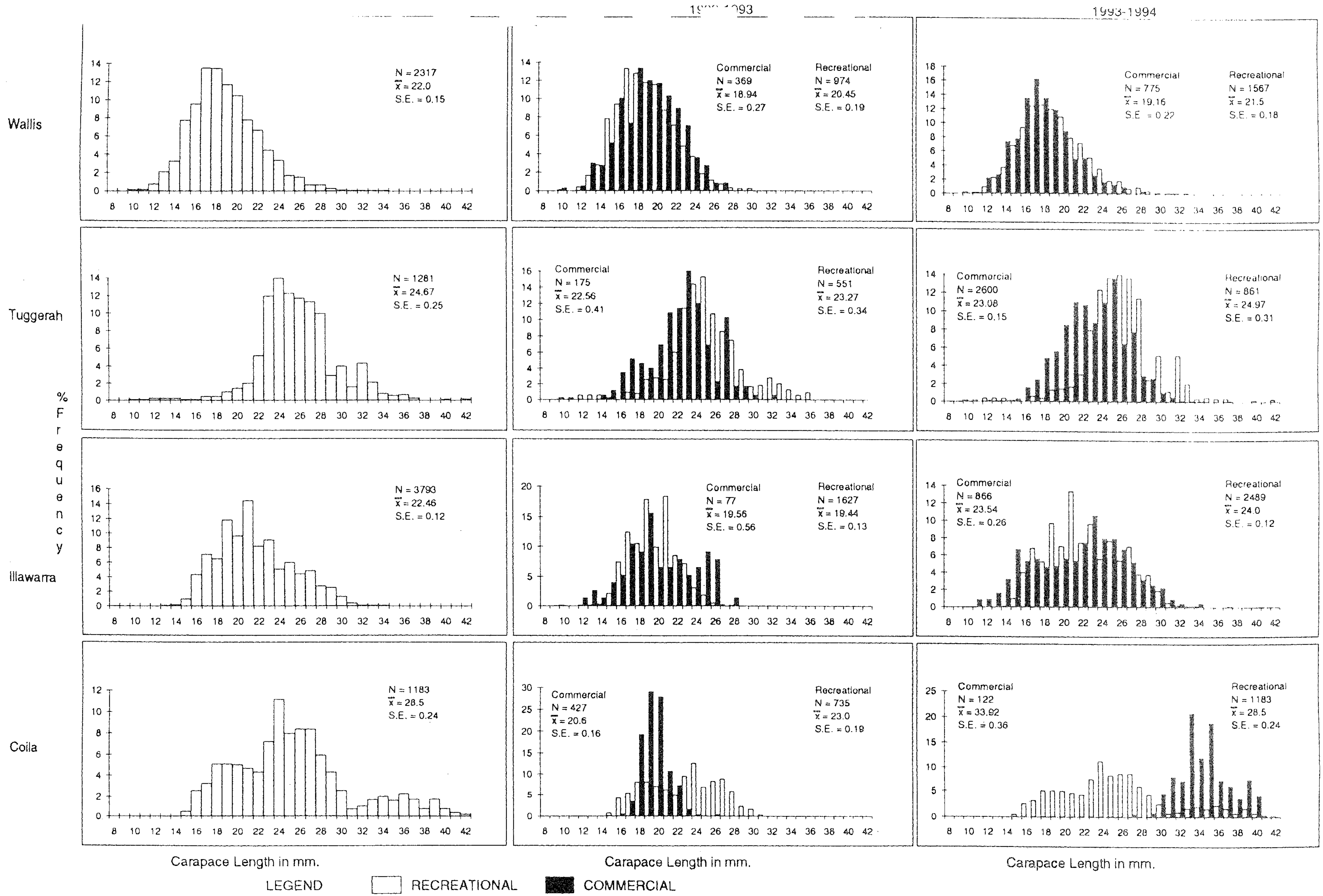
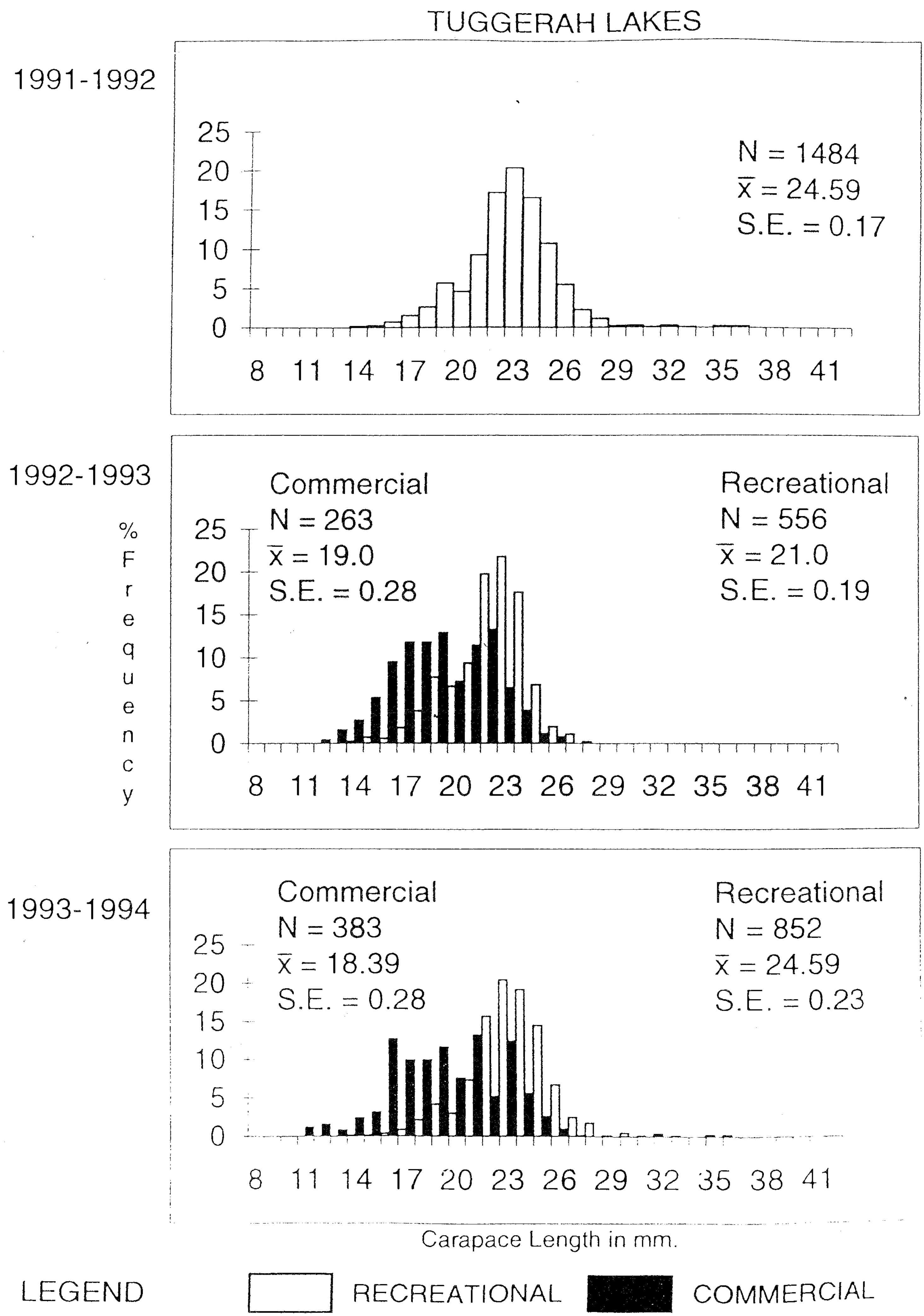

1993-1994
Wallis
Tuggerah
Illawarra
Coila
% Frequency
N = 2317
x̄ = 22.0
S.E. = 0.15
Commercial
N = 369
x̄ = 18.94
S.E. = 0.27
Recreational
N = 974
x̄ = 20.45
S.E. = 0.19
Commercial
N = 775
x̄ = 19.16
S.E. = 0.22
Recreational
N = 1567
x̄ = 21.5
S.E. = 0.18
N = 1281
x̄ = 24.67
S.E. = 0.25
Commercial
N = 175
x̄ = 22.56
S.E. = 0.41
Recreational
N = 551
x̄ = 23.27
S.E. = 0.34
Commercial
N = 2600
x̄ = 23.08
S.E. = 0.15
Recreational
N = 861
x̄ = 24.97
S.E. = 0.31
N = 3793
x̄ = 22.46
S.E. = 0.12
Commercial
N = 77
x̄ = 19.56
S.E. = 0.56
Recreational
N = 1627
x̄ = 19.44
S.E. = 0.13
Commercial
N = 866
x̄ = 23.54
S.E. = 0.26
Recreational
N = 2489
x̄ = 24.0
S.E. = 0.12
N = 1183
x̄ = 28.5
S.E. = 0.24
Commercial
N = 427
x̄ = 20.6
S.E. = 0.16
Recreational
N = 735
x̄ = 23.0
S.E. = 0.19
Commercial
N = 122
x̄ = 33.92
S.E. = 0.36
Recreational
N = 1183
x̄ = 28.5
S.E. = 0.24
Carapace Length in mm.
Carapace Length in mm.
Carapace Length in mm.
LEGEND
RECREATIONAL
COMMERCIAL

Fig 5b



TUGGERAH LAKES
1991-1992
N = 1484
x̄ = 24.59
S.E. = 0.17
1992-1993
Commercial
N = 263
x̄ = 19.0
S.E. = 0.28
Recreational
N = 556
x̄ = 21.0
S.E. = 0.19
% Frequency
1993-1994
Commercial
N = 383
x̄ = 18.39
S.E. = 0.28
Recreational
N = 852
x̄ = 24.59
S.E. = 0.23
0 5 10 15 20 25
8 11 14 17 20 23 26 29 32 35 38 41
Carapace Length in mm.
LEGEND
RECREATIONAL
COMMERCIAL

APPENDIX 4

West, L. (1994). Methodological Report.

Kewagama Research

Kewagama Research

(A division of Kewagama Holdings Pty. Ltd.)
A.C.N. 002101466

12 Blakesley Street,
Tewantin, Qld., 4565
Telephone: (074) 499 611
Facsimile: (074) 499 617

METHODOLOGICAL REPORT:

RECREATIONAL PRAWNING SURVEYS

COILA, ILLAWARRA, TUGGERAH & WALLIS LAKES

Three Summer Seasons
1991-92, 1992-93 & 1993-94

For: New South Wales Fisheries
Research Institute

DECEMBER 1994

Enquiries: Laurie West - Consultant Project Manager and Managing Director

TABLE OF CONTENTS

APPENDICES:

1 INTRODUCTION

The following report has been prepared for the NSW Fisheries Research Institute (FRI) in relation to consultant research work undertaken by Kewagama Research (KR) over the period November 1991 to April 1994.

In summary, this work involved the design and conduct of a program of *intercept* surveys of recreational prawning activities on four NSW estuaries - Coila Lake Lake Illawarra, Tuggerah Lakes and Wallis Lake. Conducted over three (summer) seasons, the surveys enable detailed estimates to be derived for recreational prawning catch and effort for these estuaries. During the project, completed survey questionnaires were despatched to FRI on a monthly basis with data entry, tabulation and analysis being undertaken by FRI staff.

The main purpose of this report is to provide users of the data with comprehensive details of study definitions and relevant methodologies, together with range and validity information for the various data elements contained in completed questionnaires. (The above information is contained in Sections 3 through 5).

Survey area maps and sample copies of questionnaires and monthly enumeration rosters (Workload Control Sheets) are contained in the Appendices. Several full sets of actual roster sheets for the entire survey have also been provided for each estuary as separate attachments.

As a first-of-its-kind study, the project presented substantial challenges in the design phase and although some difficulties were experienced in early stages of enumeration (e.g. problems with the precision of tidal predictions), we are pleased to report that the initial study design required little alteration during the project, resulting in excellent comparability of data gathered across the three (summer) seasons involved.

Other outcomes have also been pleasing, such as the excellent public co-operation that the study received (response rates of virtually 100% were achieved on each estuary) and most importantly, the high levels of *effort coverage* obtained in each case - close to 100% of total recreational prawning effort was provided by the comparatively small areas of each estuary that were routinely sampled each month.

2 ACKNOWLEDGMENTS

Clearly, the project has been most successful and we wish to acknowledge several important contributions to this outcome:-

- firstly, the project staff from FRI, principally, **Steven Montgomery and Dennis Reid**, in providing excellent support and technical assistance throughout the project - and especially during the substantial complexities and associated tedium of the development phase

- the role of KR's senior field supervisor, **Stuart Reston** is also acknowledged - particularly for his thoroughness in the design, recruitment and training phases of the project

- equally, the involvement of **Dr. Julian Pepperell** (consultant fisheries scientist) is very much appreciated. Among other things, his *devil's advocacy* role in the design phase has been extremely valuable and enabled several potential problem areas to be identified well in advance

- the role played by our local field staff on the four estuaries must also be acknowledged - not only in terms of their obvious diligence over three seasons of enumeration, but also in the early development stages, where their skills and experience proved most valuable. The professionalism and tenacity of these staff have undoubtedly been the key component to the success of this project:-

Coila Lake:	**Kevin Garn and David Wright**
Lake Illawarra:	**David Castle and Les Lovasz**
Tuggerah Lakes:	**Shirley Munro and Ray Petersen**
Wallis Lake:	**Gary Thomas and Martin Tucker**

3 PROCEDURAL SUMMARY

Details of sampling procedures and various study definitions are contained in Sections 4 and 5. The following is an overview discussion of relevant procedural aspects of the project (including various design philosophies/issues) and is presented in chronological order of project phase:-

3-1 Initial Design and Development

As mentioned earlier, the design phase of the project presented substantial challenges, not the least of which being the inherent operational difficulties associated with conducting headcounts of recreational prawners at night (and the fact that peak prawning activity tends to occur in the 'dark' phase of the moon, when natural visibility is at its worst).

The absence of relevant previous research (both in Australia and overseas) also meant that no previously tested methodologies were available to assist with instrument development, nor were there any existing datasets (catch, effort etc.) to enable comparisons of data obtained.

3-1.1 Study Objectives

The stated objectives of the study were:-

- to determine the number of recreational prawners and hours spent prawning in the four Lakes over the specified period
- to determine the distribution of catch per person per hour in these areas, in terms of both numbers and weight of each species over the specified period
- to determine the total prawn catch of recreational prawners by number and weight of each species, over the specified period
- to determine the size composition of the prawn catch of recreational prawners by species
- that all of the above parameters would be able to be analysed on the basis of night type, prawning location and differences between lunar months

3-1.2 Effort Concentrations in Time and Space

Due to the comparatively brief time-frame available in which to design the study (November/December, 1991), substantial resources were intensively deployed in the this phase. The main objective here was to obtain as much information as possible for each estuary concerning peak times (in terms of night, month and year), tide states, moon phase and the preferred localities where recreational prawning occurs - and to develop an appropriate field methodology which most cost-effectively and consistently addressed these aspects across all four estuaries.

To achieve this, a combination of traditional developmental research techniques (field pilot-testings etc.) were employed, together with less-conventional (qualitative research) techniques:-

- firstly, a qualitative assessment for each estuary was undertaken through discussions with a range of information sources (e.g. local fishing tackle shops, commercial operators/co-ops, the fishing inspector and recreational prawners themselves) resulting in a detailed and extremely consistent 'picture' emerging for each estuary in terms of the hypothesised patterns and concentrations of recreational prawning in terms of time, space, tide and moon phase.

- at that time, several field observations of prawning activity were also undertaken on each estuary covering the times/areas/tides etc. where activity was reported to be concentrated and also when/where little or no activity was expected. During this fieldwork, various issues concerning night counting and interviewing procedures were also explored.

As a result of this work, the hypotheses formed from the above-mentioned qualitative research were consistently confirmed for each estuary. Although this 'proof' only referred to effort concentrations for the time of year concerned, considerable confidence existed in terms of seasonality changes and therefore in opting for a survey design which focused largely on these peak times and the key geographic areas identified. (Note: details of all pilot-testing and results are contained in KR's memo to FRI of 30 December, 1991)

Of particular importance here was the strong hypothesis that for each estuary, virtually all prawning effort was concentrated in an extremely small proportion of the total area involved. Considerable efficiencies could therefore be gained in routinely and intensively sampling these areas from the outset of the study proper - as opposed to unnecessarily consuming project resources in conducting 'headcount' runs in very large areas where no activity existed.

Thus evolved the concept for the survey proper of sampling the 'known' areas of activity on a regular basis (initially 10 nights per lunar month - ultimately 11 per month) and within this, a disproportionately greater sampling in the hypothesised peak times (e.g. ebb tides, 'dark' phase of the moon). However, to monitor the *effort coverage* provided by the standard survey areas and to ensure that no significant shifts occurred over time, routine 'whole estuary' headcount runs were also conducted on a once-per-month basis throughout the project, at both 'peak' and 'non-peak' times. Note: as mentioned earlier, *coverage factors* of close to 100% were revealed as a result of this work, for all four estuaries. It should also be noted that prior to commencement of the survey proper, at least two 'whole estuary' headcount runs were conducted on each estuary, revealing coverage factors approaching 100% in each case. Furthermore, we note that over the course of the project, many other observations were made by local field staff (apart from scheduled work, e.g. a staff member would make a quick check of a remote area, when he/she happened to be in the vicinity) resulting in further confirmation of these results.

3-1.3 Night Vision and Other Design-related Issues

In terms of the actual methods employed in counting/interviewing work, the design phase also addressed several issues and options:-

- the use of military-grade *night-vision* equipment in headcounting work was thoroughly considered and several equipment options explored. From earlier experience with such equipment on conventional night creel survey work, it became quickly apparent that '1st generation' technology equipment was most inappropriate in this application, due mainly to problems with 'flaring' from prawning (and other) lights. The latest technology (although entirely suitable to the task) was rejected mainly on the basis of acquisition cost (over $100,000 for the four estuaries). Availability problems due to usage restrictions were also a factor

- after intensive testing on all four estuaries, it became evident that in areas where much of the prawning activity occurred, existing light sources (including prawning lights) were routinely sufficient to enable accurate headcounting to be readily undertaken without such equipment - including for those operating with submersible lights, or no lights at all

- however, the use of conventional binoculars with night-vision 'enhancement' capabilities (i.e. large lens diameters/wide field of view/modest magnification) also proved useful (especially in de-lineating prawners from anglers) and field staff were equipped with these for the survey proper

- the main problem area for headcounting concerned those areas where poor light sources exist (e.g the more remote areas/wide expanses of the estuaries) and prawners operating without lights in such areas (e.g. drag-netting). Although comparatively time-consuming, an effective methodology was developed here which enabled accurate headcounts to be obtained. In essence the procedure involved appropriate use of a combination of techniques, including: systematic low-speed coverage of the areas concerned; the careful use of any available 'background' light to reveal potential prawning parties; and only where necessary, the use of spotlighting to quickly scan/illuminate large areas of water/shoreline (thereby causing minimal annoyance to prawners/anglers). Importantly, the impact of the inefficiencies of this method upon overall resource usage was relatively insignificant, as it mainly affected the work in whole estuary headcount runs (conducted once per month only)

- an important additional feature of the study design concerns the application of 'simultaneous' counting and interviewing for each sub-area in routine sampling runs - i.e. up to 12 sub-areas were defined on each estuary, such that each could be fully counted and an adequate number of interviews conducted, in well less than the one-hour maximum, that is generally accepted as 'instantaneous' for creel survey headcounting purposes. This approach was shown to be more efficient than separate counting and interviewing runs, where significant 'back-tracking' problems existed. It also caused less disturbance/inconvenience to the public and enabled extremely precise sampling fractions to be obtained for interviews obtained in each sub-area, for each night

- consistent application of the survey instrument across the four estuaries was seen as highly desirable , e.g. to maximise comparability, routine sampling was conducted on the same nights each month, for each estuary. Identical lunar and tidal phase sampling was also sought for each estuary. However in several other respects, field procedures were necessarily tailor-made to each estuary, e.g. (i) the duration of the 'standard survey runs' varied substantially to provide adequate effort coverage, from 2.25 hours on Coila Lake to 4.5 hours on Wallis Lake and Tuggerah Lakes; and (ii) survey vessel usage also varied from virtually all shore-based work on Coila Lake, to the opposite situation on Wallis Lake, where prawning activity is largely boat-based. Further details and definitions concerning the study design are contained in Sections 3-5, 4 and 5

3-2 Recruitment

For all but Tuggerah Lakes, where KR's existing staff were employed, field interviewers were newly-recruited from the local areas concerned. This involved the application of our standardised recruitment procedures, which comprise: detailed display advertisements and 'classified' cross-references in local newspapers; written selection-testing of all applicants (literacy, numeracy, comprehension, map reading and species identification); and thorough interviewing/assessment by senior field staff of all applicants. Knowledge of the local estuary, boat ownership and handling skills etc. were also essential criteria for all applicants.

As has been our consistent experience in other creel survey recruitments, several high-calibre applicants emerged for each position, enabling excellent 'reserve' interviewers to be identified for each estuary, in case of losses during the project. No such losses occurred and the fact that reserve interviewers were only used on odd occasions when one member of an estuary's regular team was unavailable is further testimony to the overall quality and dedication of our field staff for the project.

3-3 Training

A comprehensive training session for all field interviewers was conducted in late November, 1991 at Tuggerah Lakes (a central point for all concerned). Using a combination of 'class-room' sessions, small-group practice and actual field practice sessions (at night), familiarity was gained with all field procedures and problems over the three days involved. It should also be noted that while staff received thorough training here, certain aspects of the study design were at that stage unresolved, (e.g. the precise structure of the survey areas for each estuary) and field staff subsequently assisted in the determination and refinement of these during December, 1991.

Further staff training work occurred during the course of the project with regular, less-formal sessions in the earlier stages of the project - including specific instruction/checking of prawn species identification and measurement procedures by FRI staff.

3-4 Enumeration of First Season

After further development work (practice interviewing, pilot-testing, time-trials etc.) during December, the survey proper commenced in the lunar month of January, 1992 and continued for the first season to include the lunar month of March 1992.

All staff were supplied with a range of equipment and apparel, including: uniforms; wet weather gear; wetsuit boots; clipboards; pens; waterproof stationery/ torches; official identity cards and signs for survey vessels; binoculars; high-quality spring and pan-balance scales for weighing catches; and precision 'dial' calipers for measuring prawn carapace lengths in sub-sample interviews.

In summary, the survey involved conducting combined count/interview runs for selected Sub-areas (the 'standard run') for each estuary on 10 nights per lunar month in accordance with a pre-determined roster (see Workload Control Sheets - Appendices G & H). The duration of the 'standard' run varied by estuary (from 2.25 hours up to 4.5 hours) to enable adequate coverage of the Sub-areas involved under varying conditions (weather, peak prawning activity etc).

In addition to this, *whole estuary headcount runs* were conducted once per month on each estuary to provide a measure of the coverage provided by the 'standard run' in terms of catch and effort. Due to the large expanses of water involved, these runs required substantial amounts of time to complete and on two estuaries (Tuggerah and Wallis), the work was conducted over two nights to obtain this coverage.

The overall results from initial counting/interviewing work were extremely pleasing with excellent coverage of total effort being provided by the 'standard' survey areas and exceptional response rates and roster adherence also being readily achieved. The number of interviews obtained each night, whilst adequate in the initial stages, understandably increased as field staff gained familiarity/efficiency in their work.

Similarly, our understanding of the tidal patterns on each estuary (a by no means simple matter) improved with time and it is fair to say that this issue represented the most significant operational/design problem encountered in the project. Clearly, there exists a range of data concerning tidal states on these estuaries (note: Coila Lake was mostly closed to the sea during all three seasons), but unfortunately, these were not sufficient (nor in some cases accurate) to enable adequate prediction of tide states in roster preparation work.

Nevertheless, the resultant marginal over-representation of 'make' tides (as opposed to ebb) which occurred in the early stages was accounted for in expansion of the raw survey data. Further discussion of this issue is contained in Section 4-3

3-5 Review of Study Design after First Season

As mentioned earlier, the initial study design required little alteration after the first season. The modifications that were made to the sampling framework did not affect year-to-year data comparability (certain Sub-areas were removed from routine sampling due to constant 'zero' counts - none were added). In fact, the changes provided increased data quality (and quantity) by enabling an extra night of routine sampling to be conducted each month on all four estuaries, within existing resources. It should also be noted that these changes were somewhat expected from the outset, but could only have occurred after analysis of the first season results, the design for which, was necessarily conservative:-

- with the exception of Coila Lake, certain Sub-Areas were excluded on each estuary from future routine sampling on the basis that they revealed (virtually) no prawning effort during the first season and this was expected to continue in subsequent seasons (for further details, see Sections 4-1 & 5-1)

- as a result of this, reductions in the duration of the 'standard' count/interview run on Illawarra, Tuggerah and Wallis Lakes enabled resource savings to be utilised in the form of an extra sampling night each month on all four estuaries (i.e. from 10 to 11 nights). This in turn necessitated minor amendment to the definitions of a Lunar Month and the Dark/Light Phases - see Section 4-3 for details). Minor alterations to roster structures were also made for Tuggerah and Wallis Lakes (see 5-1 for details)

- the continued confirmation from monthly *whole estuary counts* that the standard survey areas on each estuary provided virtually total coverage of all prawning effort, also enabled a reduction in the number of these headcount runs conducted in the 'dark' phase of the moon from once-per-month to every second month. However, to provide further verification of the *effort coverage* hypothesis, these resources were re-allocated to conducting headcount runs during the 'light' phase of the moon in the second and third seasons of the survey.

3-6 Enumeration of Second and Third Seasons

The overall enumeration of the remainder of the survey proceeded extremely well. As would be expected, the performance of interviewing staff improved consistently with time. The already high-quality work from interviewers in terms of response rates and clerical errors was more than maintained and with increasing experience (and effectively more interviewing time available through the removal of certain 'zero-count' Sub-areas) our interviewers were able to produce substantially higher sample-takes of interviews each night. In fact, on nights where comparatively smaller numbers of prawners were present, sampling fractions approaching 100% were achieved. Yet, on the busier nights (e.g. January school holidays, where larger proportions of roster times are consumed by the counting process), adequate sample-takes were consistently achieved in both absolute and proportional terms.

In terms of tidal predictions, significant improvements were also achieved over the first season, resulting in very few 'errors' in tidal outcomes over the latter two seasons.

Overall adherence to other aspects of the sampling plan was excellent. Adherence to specified roster schedules was exceptional throughout the whole study - at no stage did problems with survey vessels, punctuality or bad weather prevent completion of a scheduled sampling run. In fact, the only flaw in this regard occurred when the questionnaires for one night's routine sampling were unfortunately mislaid by field staff (previously notified to FRI staff - Lake Illawarra, 4 March 1994).

3-7 Quality Control Procedures

To maximise the quality of data obtained in the study, a range of quality control measures were routinely employed. Consistent application of the survey instrument was ensured, firstly through thorough training of field staff and also by regular supervision and liaison with field staff (including actual field observations of their work).

The clerical accuracy of all completed questionnaires was also checked, firstly by the interviewers themselves and secondly, by KR's field and office supervisors. (Note: where occasional errors were detected here, these were 'fed-back' to the interviewers concerned as part of an ongoing remedial/training process). In addition to this, it is understood that appropriate range, logic and validity editing has been undertaken as part of computer processing by FRI staff.

Also, un-announced field 'spot-checks' were conducted by KR's supervisory staff throughout the survey to ensure compliance by field staff with specified rosters.

Again, it is pleasing to report that all the above measures consistently revealed exceptional performance from all our field staff. Note: for security and operational efficiency, copies of all questionnaires for the survey were retained by KR's field staff and originals sent to our central office, which were in turn copied before despatch to FRI. Once all processing of the study is completed and on the advice of FRI, both copies held by KR will be 'destroyed under supervision'.

4 SAMPLING AND OTHER METHODOLOGICAL INFORMATION

4-1 Geographic Boundaries of the Survey Areas

For overall estimation purposes, the geographic boundaries of each of the four estuaries were defined as the entire lake (or lake system) to a point as close as possible to the entrance to the sea (in practical/operational safety terms). Any rivers/creeks which flow into these lakes were excluded. (Note: detailed maps showing the survey areas and sub-areas for each estuary are contained in Appendices A through D).

For analysis purposes, each estuary was dissected into an appropriate number of Sub-areas from the outset of the study. Each of these Sub-areas was allocated a unique identifying character, with numerics denoting the Sub-areas determined in the first season as forming the survey area for routine nightly sampling (peak prawning effort) and those with an alphabetic identifier being those parts of the estuary with little or no prawning effort expected. This numeric/alpha system is described in detail in Section 5-1.

4-2 Respondent, Species and Methods Criteria

As a survey of recreational prawning, the scope of the study was confined to prawning activity not associated with licensed commercial prawning operators in their normal (commercial) activities.

Importantly, while no difficulties were encountered during the survey in applying this definition, it should be noted that in theory, a commercial operator employing recreational prawning methods (e.g. scoop net) for non-commercial purposes would have been included in the study by this definition.

Therefore the primary field criterion was 'method-based' (scoop nets, scissor nets, drag nets etc.) and secondly, 'target-based'. Note: scoop-netting of crabs at night is a somewhat common practice, although mostly this seems to be conducted in conjunction with prawning. Cases where respondents were identified as only targeting crabs (or angling etc.), are provided for in Response Status coding (see 'Scope' exclusions in Section 5-3, Item (xi)).

In terms of age criteria, two definitions were employed. Firstly, for purposes of all headcounting (routine sampling or whole estuary counts), the age of the person prawning was not considered, for field practicality. However, during interviews, two 'counts' were recorded for each party interviewed whereby the first, refers to the total number in the party, regardless of age and the second, refers to the number actually prawning and aged five years or more. This age criterion is consistent with many other creel surveys and is appropriately set as the age, below which a child is usually unable to effectively participate in angling or prawning activity.

In terms of species in the scope of the study, four specific prawn species were identified as being of primary interest: greasy-back prawn (*Metapenaeus bennettae*); eastern king prawn (*Penaeus plebejus*); school prawn (*Metapenaeus macleayi*); and tiger prawn (*Penaeus merguiensis*). Other prawns (as defined) were included in the study and in very rare cases, these were reported when detected in interviewing/sampling work (e.g. Coral Prawn, "Killer Prawn").

4-3 Temporal Sampling (including tides and moon phases)

4-3.1 Sampling Nights, Times and Stratification - Routine Sampling Runs

The survey was conducted in the lunar months of January 92 - March 92 (1st season), November 92 - March 93 (2nd season) and November 93 - March 94 (3rd season). In the first season, a lunar month was defined (inclusively) as commencing seven nights prior to the night of the New Moon for that calendar month and ending eight nights prior to the New Moon in the following month. For subsequent seasons, this definition was altered to commencing nine nights before the new moon and ending ten nights before the new moon in the following month. (Note: this change enabled an additional routine sampling night to be [appropriately] included in the earlier part of the Dark Phase each month and resulted from information gathered during the first season regarding delays in tidal states on the three 'open' estuaries - Coila Lake was closed to the sea for a majority of the survey, details of which were routinely recorded on Workload Control Sheets).

Each lunar month was further dissected into its 'Dark' and 'Light' moon phase. In the first season the Dark Phase was defined (inclusively) as the first twelve nights of the lunar month (i.e. ending on the fourth night after the New Moon). The Light Phase was therefore from the fifth night (inclusive) after the New Moon onwards. In subsequent seasons, the Dark Phase was defined as the first fourteen nights of the lunar month (still ending on the fourth night after the New Moon, but commencing earlier due to the revised lunar month definition).

Although some recreational prawning activity can be (and occasionally is) undertaken during daylight hours, the survey was confined to night activity - defined as after 'last light' and before 'first light', per "Civil Twilight" times reported in *The Sydney Sky Guide, Sydney Observatory Almanac,* for the periods concerned (Reference example - 1992 edition: *ISSN 1035-9591*). Note: 'last/first light' times are approximately 30 minutes later/earlier than sunset and sunrise times.

In terms of routine sampling, an eight cell stratification matrix (covering moon phase, tide state and time of night) was applied for each lunar month for each estuary. For the first season, the 10 nights per month of routine sampling (numeric Sub-areas only) were stratified as follows (figures shown in (..) relate to the second and third seasons where 11 nights of sampling were undertaken each month):-

Stratification of Routine Sampling Nights (10/11) each Lunar Month

	Dark Phase		Light Phase		Total
	Ebb Tide[a]	Make Tide[a]	Ebb Tide[a]	Make Tide[a]	
Before Midnight	2(3)	1	2	1[b]	6(7)
After Midnight	2	1	1	-[b]	4
Total	4(5)	2	3	1	10(11)

Notes:

1. [a] Tide state is defined in terms of tidal 'flow' as opposed to 'levels' and relates to those Sub-areas where the flow is observable (viz: nearer to the mouth of the estuary) - see Section 5-1 for further details.

2. [b] In alternate months, the make tide run in the Light Phase was conducted after midnight

3. Precise expansion of the raw survey data to provide estimates of total catch and effort, therefore requires complete 'benchmark' data for the relevant sampling universes - in terms of hours of darkness contained within each cell of the stratification matrix. Note: these calculations have been undertaken by FRI staff for each estuary using appropriate 'tidal delay' data in each case

Selection of the actual nights for routine sampling each month was undertaken by applying a separate random start/skip interval method to the 'universe' of nights within each of the Dark and Light Phases of each month. For example, in the Dark Phase (always a sample interval of two applied), selections would either be 1,3,5,7, etc. or 2,4,6,8, etc. (note: numerics here are not dates but e.g. the first, third, fifth nights of the Dark Phase, as defined). For the Light Phase, usually a sample interval of 4 applied and a random start in the range of 1-4 (inclusive) would therefore apply. Note: selected sampling dates for a particular month were applied to all four estuaries for that month, for data comparability

Random allocations of selected nights to complete the quotas in the above stratification matrix were then undertaken, using a seemingly cumbersome, but necessary 'priority' procedure for each estuary.

This particular selection method was chosen as it minimised any clustering of sample nights and therefore the impact of any (clustered) weather patterns. It also provided a more practical outcome in terms of staff rosters (as it was, field staff in some cases were required to work five nights consecutively, due to *whole estuary counts* being conducted on intervening nights in the Dark Phase -see 4-3.3 below).

Note: for each estuary, a prescribed roster structure, including the order in which Sub-areas were to be enumerated (again, randomised), was provided each month. Complete details of selected sampling nights and related information are contained on these rosters (Workload Control Sheets - see Appendices G & H) and also as 'header' information on completed questionnaires (see Appendices E & F).

4-3.2 *Selection of Prawning Parties for Interview during Routine Sampling*

As mentioned earlier, survey enumeration involved combined count/interview runs whereby the number of recreational prawners in the Sub-area would firstly be counted and then interviews immediately conducted with an appropriate sample of these, before proceeding to the next Sub-area. Two types of interview were conducted: (i) the 'normal' interview where baseline catch and effort data were obtained and (ii) the 'subsample' interview where additional data was collected for a sample of (up to) ten prawns from the respondent's catch (carapace lengths by species, and aggregate weights of species).

For the **'Normal Interview'**, respondent/party selections were made using a random start/skip interval method within each Sub-area. At least one interview was sought in each Sub-area where one or more prawning parties existed. Second/ subsequent interviews were apportioned on a "partly proportional-to-size basis" whereby a second interview in each Sub-area would be sought from all Sub-areas, before any third or fourth interview. Effective 'field stratification' was also undertaken whereby interviewers ensured that less common events such as drag-netting, prawning from boat/shore (certain estuaries) were adequately represented. However, apart from such cases, interviewers were clearly briefed to at all times apply a "non-purposive" approach to selection work. For example, ease/difficulty of access to a prawning party or the likely co-operation (or otherwise) of a party, were never to be considered.

The above procedures were considered appropriate to ensure that an adequate distribution of interviews by area was obtained within the allotted time for each run. Understandably, this occasionally resulted in higher proportions (sampling fractions) of interviews from those Sub-areas towards the end of a run (note: Sub-area order was varied for this and other reasons).

As mentioned earlier, our field staff acquired considerable judgmental skill over time in terms of factors such as weather, visibility, likely effort concentrations etc. and produced consistently higher sample-takes of interviews as the study progressed.

IMPORTANT: the use of the 'simultaneous' count/interview method enables precise sampling fractions to be calculated (and therefore standard errors) for each Sub-area/night throughout the study.

For the **'Subsample Interview'**, selections were made from those selected for 'normal interviews' on the basis that at least five such interviews be completed per night for each estuary, where possible. Unless significant clustering of normal interviews occurred (or low effort levels existed), these five interviews were to be distributed across the Sub-areas, using a random start/sample interval method as appropriate, to select the Sub-areas for inclusion.

Within each selected Sub-area, a selection was then made on the basis of the first party interviewed (for 'normal interview') where a catch of 10 or more prawns was revealed (viz: 10 prawns was the required subsample size for these interviews). If a selected Sub-area did not produce an eligible interview, the subsample interview would be sought from the next Sub-area and so on. Accordingly, multiple subsample interviews were occasionally obtained for certain Sub-areas.

4-3.3 Sampling Nights and Times for Whole Estuary Counts

In the first season, these headcount runs were conducted on each estuary once per month in January, February and March 1992, on the night(s), closest to the night of the New Moon (and not previously selected for routine sampling purposes). For subsequent seasons three such counts were conducted on the same selection basis, in the (alternate) months of November 92(&93), January 93(&94) and March 93(&94). In terms of the times at which these count runs were conducted, we note that these runs were scheduled on each estuary to maximally embrace the peak prawning effort for the selected night, including scheduling for ebb tidal flows for those Sub-areas nearer to the mouth of the estuary.

As mentioned earlier, *whole estuary count runs* were also conducted in the Light Phase for certain months in the second season (February & April 93) and third season (December 93 & February 94). These were conducted to provide further data in relation to the coverage provided by routine sampling. Monthly selections were made on the basis of the night closest to the night of the Full Moon (and not selected for routine sampling). The timing of each 'run' was also scheduled to embrace the maximum effort for the selected night (including ebb tidal flows for Sub-areas near the mouth).

Note: in the very few cases where prawning activity was detected during *whole estuary counts* in Sub-areas other than those prescribed for routine sampling, field staff were instructed to conduct a conventional interview with these prawning parties to reveal any differences in catch/effort for these areas. Although some parties could not be accessed in such cases (shore-based prawning in shallow water vs. boat-based field staff), the results of such interviews must necessarily be reviewed with considerable caution and are effectively inconsequential due to the extraordinary coverage levels revealed through this work.

4-4 Response and other Sampling Considerations

As a strict rule, no substitution of selected nights, times or parties for interview was allowable in routine sampling work. However, in isolated cases, this did not apply to *whole estuary counts*, where extremely bad weather caused the appropriate re-scheduling of two such runs (primarily to obviate 'total zero' count situations and therefore avoid waste of field resources) .

In terms of public response, an exceptional overall result has been achieved in this study. Response rates of virtually 100% have been consistently obtained for each estuary and this is largely attributable to: use of an appropriately brief interview structure; a modest but effective public awareness campaign through local newspapers; and most importantly, the professionalism and skill of our field staff.

It should also be noted that the practices of concealing catches or 'conveniently' ceasing prawning activity as the survey team approaches (a concern in creel surveys generally and specifically, where bag/size limits exist) are considered to have been negligible. In fact, when asked to report on any suspected such cases, our field staff were only able to cite a few possible cases throughout the entire study.

Although of similar minority significance, it should be noted that in the early stages of the second season, some response difficulties were encountered with a party of regular local prawners on Lake Illawarra. However, the persistence/professionalism of our local field staff in continuing to attempt to interview them (whenever randomly selected) and in justifying the importance of their co-operation, eventually 'won through' with full co-operation being received for the remainder of the study.

A further isolated incident of concern to response quality involved the refusal by one party on Coila Lake in the second season to allow a very large catch of prawns to be weighed by our staff. As a result of this, field staff provided a best estimate of the weight involved and this was noted on the questionnaire and separately reported to FRI staff.

It is with some confidence therefore, that we suggest that overall response bias (and other non-sample error) associated with the study is absolutely minimal.

5 DETAILS OF DATA ELEMENTS - QUESTIONNAIRE FORMS

The following sub-sections provide a detailed discussion of each 'field' contained in the survey questionnaires, together with range and validity information as appropriate.

5-1 Data Elements Common to *Whole Estuary Count* Forms and *Count/Interview* Forms for Routine Sampling

The following information is mainly contained in the 'header' section of the two questionnaire types (see Appendices E and F for copies):-

(i)	**Estuary:**	one character, numeric only (valid codes: Wallis = 1; Tuggerah = 2; Illawarra = 3; Coila = 4)
(ii)	**Sub-area Number:**	two characters, zero-fill, alpha or numeric - valid codes below:
	Coila Lake:	total estuary - 01 to 05, plus A to E (inclusive) 1st season routine sampling - 01 to 05 2nd season routine sampling - 01 to 05 (no change)
	Lake Illawarra:	total estuary - 01 to 10, plus A to C (inclusive) 1st season routine sampling - 01 to 10 2nd season - 02 to 05, 07 to 10 (01 & 06 excluded)
	Tuggerah Lakes:	total estuary - 01 to 11, plus A to I (inclusive) 1st season routine sampling - 01 to 11 2nd season - 01 to 05, 09 to 11 (06 to 08 excluded)
	Wallis Lake:	total estuary - 01 to 12, plus A to I (inclusive) 1st season routine sampling - 01 to 12 2nd season - 02, 05 to 09, 11 & 12 (01, 03, 04, & 10 excluded)
(iii)	**Date (D/M/Y):**	six characters (3 x 2), zero fill, numeric only - day month, year of the selected night (i.e. the night hours beginning on [.....] basis*)

Note*: Even in cases where a scheduled run commenced after midnight, the date shown all Workload Control Sheets and questionnaires for that run refers to the previous day (i.e. date of commencement of the selected sample night)

(iv) Day Type: one character, numeric only (valid codes:
Weekday(WD) = 1,
Weekend/Public Holiday (WE/Hol) = 2

Note: with prawning activity occurring at night, it was determined that 'day type' classification should be based on the 'type' of the day following the selected night, as this more realistically reflects behavioural differences in this respect. Friday night selections were therefore classified to code 2 and Sunday nights to code 1, unless a Monday Public Holiday occurred the following day.

(v) NSW School Hols: one character, numeric only (valid codes
Yes = 1, No = 2)

Note: criteria for classifying selections at the start and end of a period of school holidays were as for Day Type (see note above)

(vi) Roster No: one character, numeric only (valid codes below)

Coila Lake:

ALL THREE SEASONS
Roster 1 - last light onwards for 2.25 hours
Roster 2 - 2215 hrs to 0030 hrs
Roster 3 - 0030 hrs to 0245 hrs
Roster 4 - 2.25 hrs before first light

Lake Illawarra:

ALL THREE SEASONS
Roster 1 - last light onwards for 3.5 hours
Roster 2 - 2245 hrs to 0215 hrs
Roster 3 - 3.5 hours before first light

Tuggerah & Wallis Lakes:

1ST SEASON
Roster 1 - last light onwards for 4.5 hours
Roster 2 - 4.5 hours before first light

2ND SEASON
Roster 1 - last light onwards for 4 hours
Roster 2 - 4 hours before first light

Note: no alteration was made for 'middle roster' types (e.g. Roster 2 Lake Illawarra), for variations caused by the reversion from Daylight saving towards the end of each season. However, last/first light times were of course adjusted for this. Note also: although provision existed on *whole estuary count* forms for Roster No#, the above code system was not employed. Instead, specific start times were shown on individual Workload Control Sheets.

(vii) C/I Period (or Count Period) ... from/to two fields x 4 characters, numeric only (valid ranges as per 24 hour clock and within [or close to] the corresponding range for the individual Roster No#). This is the actual time period for field work conducted on each particular form. Note: midnight = 0000 hrs and all times refer to official Daylight Saving or Eastern Standard Time as appropriate

(viii) Tide: the actual tidal flow state for each specific Sub-area as observed by field staff at the start of counting for that area. One character, numeric only (valid codes: Make tide (R/in) = 1; Ebb tide (R/out) = 2; Slack = 3; and not applicable* (N/A) = 4

Note*: on each estuary, certain Sub-areas were determined as 'non-tidal' i.e. the flow of water was negligible and could not be routinely assessed. The majority of Sub-areas on each estuary fell into this category (including all with an alphabetic Sub-area identifier). Those for which Tidal codes 1 to 3 were valid are: Coila - Sub-areas 01 - 05; Illawarra - Sub-areas 07 - 10; Tuggerah - Sub-areas 02 - 04; and Wallis - Sub-areas 05 - 09, 11 & 12. In all other cases, code 4 (only) is valid for this field

(ix) Moon: one character, numeric only (valid codes*: Dark Phase, Moon Up (D/U) = 1; Dark Phase, Moon Down (D/D) = 2; Light Phase, Moon Up (L/U) = 3; Light Phase, Moon Down (L/D) = 4

Note*: Dark/Light Phase of moon as defined earlier in 4-3.1. Moon up/down refers to whether the moon had risen or not at the start of that particular run/Sub-area and where any doubt existed (e.g. due to heavy cloud cover) this was sourced from data provided by the Sydney Observatory (see also under 4-3.1 earlier).

(x)	**Weather Observations:**	four fields, all one character, numeric only. Recorded from observations by field staff at the start of each run/Sub-area. Valid codes below:	
	Wind	less than 10 km/hr	= 1
		10 - 20 km/hr	= 2
		more than 20 km/hr	= 3
	Rain	Nil	= 1
		Light	= 2
		Medium/heavy	= 3
	Cloud (cover)	less than 33%	= 1
		33 - 66%	= 2
		more than 66%	= 3
	Temperature (air)	less than 20 °C	= 1
		20 - 25 °C	= 2
		more than 25 °C	= 3

Note: while the above observations did not necessarily involve empirical measurement, it should be noted that considerable time was devoted during interviewer training to maximise the consistency and absolute accuracy of this work (viz: certain field 'yardsticks' were applied e.g. below 20 km wind speed, only occasional small 'white water' on exposed areas).

(xi) Numbers of Prawners Counted by Type of Net Used, Boat vs. Shore-based and Prawning Light Type

In both *whole estuary counting* and *routine sampling* work, headcounts of recreational prawners (persons) were conducted for individual Sub-areas and according to the activities of each person/party (in terms of net type, etc.), counts were progressively 'cricket-scored' and ultimately totalled for each of nine discrete categories.

The nine categories (see questionnaires) are formed from three variables: boat versus shored-based (wading) activity; drag nets versus other net types (e.g. scoop net, push net, scissor net); prawning light usage and if so, whether above water (arrow upwards) or submersible (arrow downwards). For any (rare) cases not classifiable to one of these nine categories, an additional column was included ["All Others (specify)].

Each of these nine fields was originally set as two characters, numeric only. However, on some occasions during peak school holiday periods, counts for certain Sub-areas did exceed 99 prawners.

Note: as mentioned earlier, the field criteria employed in this counting work contained no reference to age of respondents and was primarily method-based (see earlier discussion under 4-2).

5-2 Other Information Relevant to *Whole Estuary Count* Forms

The information contained in 5-1 above embraces all substantive data elements contained on these questionnaires. It should be noted however, that for the larger estuaries, several questionnaire pages and separate nights of counting were required to complete a whole estuary count.

Also, before despatch of these questionnaires each month, calculations were routinely made and recorded on the front page for each estuary in terms of the *coverage factor* revealed from these counts. This *coverage factor* equates to the proportion, that the number of prawners counted in those Sub-areas covered by the routine sampling run (for that time), represented of the total prawners counted for all Sub-areas for the estuary. For example, on Coila Lake, the *coverage factor* was calculated by dividing the sum of all prawners in Sub-areas 01-05 by the sum of all prawners in Sub-areas 01-05 and A-E inclusive.

5-3 Other Information Relevant to Count/Interview Forms - Routine Sampling

The following information refers to data elements contained in the remainder of the count/interview form (see Appendix F). Note: this questionnaire was designed to enable (under most circumstances) all count and interview data for a sample night for an individual Sub-area to be contained on the one form. Note also: **all interviews were selected and conducted on a 'party basis'**, defined as one or more people engaged in (joint-effort) prawning activity and 'pooling' of the catch. If present, the prawning light was often a suitable additional determinant i.e. where more than one light existed, separate parties were considered to exist.

(i)	**Interview Number:**	a unique identifier (suffix) for each record - single character, numeric only. Structured codes 1 to 6 on the questionnaire. In rare cases where more than 6 interviews were obtained for a particular Sub-area, appropriate amendments have been made (7, 8, 9 etc.)
(ii)	**Boat or Shore/Wading:**	one character, numeric only (valid codes Boat = 1; Shore/Wading = 2)

Note: cases where prawners were operating from a vessel which was tied to a wharf or any other accessible shore-line area (as opposed to anchored or tied to e.g. an oyster lease/navigation pole) were classified as shore-based.

(iii)	**Nets (No. of ...):**	three x single character fields, numeric only, for the number of each type of drag, scoop or 'other' nets in use by the party at the time of interview. Note: 'other' nets include scissor and push nets. Also, zero-fill for appropriate cases
(iv)	**Prawn Lights (No. of ...):**	two x single character fields, numeric only, for the number of above-surface and submersible prawning lights in use by the party, at the time of interview. Note: torches and other conventional lighting were excluded here, unless being used specifically as prawning lights. Also, zero-fill for appropriate cases
(v)	**Total Number of People in party (all ages/whether prawning or not):**	two characters, numeric only - including all persons associated with each party's prawning activity - even infants/non-participants, but present in terms of e.g sitting on the shore/minding the catch
(vi)	**Number of People Actually Prawning (light/net/> or = 5 yrs):**	two characters, numeric only - equating to the number actually <u>involved</u> in prawning activity e.g using a net, light or holding the catch while wading at the time of interview.

Note: exclusion here of non-active party members and all aged less than 6 years creates an effective 'core' effort base. Note also: it is this figure which is most directly comparable with headcounts obtained for the Sub-area overall and therefore to be used in sample fraction calculation.

(vii)	**Time of Interview:**	four characters, numeric only - 24 hour clock used, Daylight Saving or Eastern Standard Time as appropriate. Recorded precisely by interviewers as 'start of interview' time (to the one minute level)
(viii)	**(And) when did you actually start prawning tonight?**	as per the above, but recorded to the degree of precision provided by the respondent - rarely better than the 5 minute level, but invariably reported at better than the 30 minute level - allowing for 'rounded' hourly effort calculations [and CPUE] of considerable reliability

Note: in terms of questioning respondents here, interviewers were instructed to probe briefly but thoroughly for any breaks in activity (and exclude/adjust times where appropriate). Maximally accurate start times were also sought, by quickly clarifying with the respondent any cases where vague start times (e.g. "*about three hours ago*") were initially reported. Usually this involved probing with ..... "*can you recall the time when you actually started prawning tonight?*" A common response to this probe would be e.g. "*well we left home a bit after eight ... about 15 minutes* (travel/set up time) *... probably about twenty past eight*".

Note also: the precision of reported start times was the subject of a separate (but parallel) study by FRI staff, whereby observations of actual commencement (and cessation) of prawning activity were made, enabling comparisons with reported/recalled start times by respondents.

(ix)	**Weight of Total Catch:**	four characters, numeric, recorded in kilograms (to two decimal points) - to the 100 gram level for larger catches* and to the 10 gram level for smaller catches* (where possible)

Note: *to enable precise weighing of the range of catch sizes, field staff were equipped with two sets of scales (i) a spring balance for catches ranging up to 10 kg (after this catches were necessarily divided) and (ii) a smaller pan balance for weighing subsamples (see (xiii) below) and smaller overall catches (usually up to around 300 grams). The weights of catches were recorded as precisely as possible, including deduction of the actual weight of any receptacle involved. However, for practical purposes (and security of catches) estimates of the weights of certain receptacles were made (e.g. the pocket/end of a [wet] prawn net in which prawns are kept while continuing prawning [wading]) - these were based on earlier actual test weights of commonly-used equipment. Also, weed, water and other foreign matter were routinely removed before weighing, to ensure a level of precision within the tolerances detailed above. Again, substantial practice/testing of these methods was undertaken before commencement of the study proper. Also, the precision of scales was tested at regular intervals throughout the study.

(x)	**(And) could you tell me your home postcode(s) please?**	three 'rows' in each of which, a three character postcode descriptor (numeric and equivalent to the first three digits of the Australian postcode*) and after the "x", a single character, numeric - the number of respondents in the party to whom that postcode (descriptor) relates

Note*: For example, three respondents with the postcodes of (say) 2160, 2162 and 2163 would be recorded on the one 'row' as 216 x 3. The second and third rows therefore provide for a total of up to three different postcode descriptors (as opposed to postcodes) for each party interviewed. Also, respondents with an overseas home address were classified according to the following postcode descriptors: UK = 994; Europe = 995; New Zealand = 996; Japan = 997; USA = 998; and elsewhere = 999.

(xi)	**Response Status:**	one character, numeric only - valid codes below
	Full Response (Full = 1):	where all required information was obtained for that interview
	Full Refusal (Ref = 2):	where all required information is declined for that interview (note: 'observed' data still recorded in these cases e.g. no. of people in party)
	Part Refusal (P/Ref = 3):	as for 2 above but only some information declined

Language (Lang = 4):	cases where the interview, or parts thereof, could not be completed due to foreign language or other communication difficulties
Scope Exclusions: (Scope = 5)	cases where the activities of all people in the party were out of the scope of the study e.g recreational anglers, those targeting crabs only, or commercial prawning operators

(xii) Comments (Quote I/view No#): a section for additional comments by the interviewer, where the Interview No# was cross-referenced in each such case

(xiii) Subsample Interview Number#

In accordance with procedures described earlier (see 4-3.2), subsample interviews were randomly selected from parties revealing prawn catches in the initial interview. Conducted as a continuation of that interview, a sample of 10 prawns (or less, in some cases where poor catches were prevalent) was randomly selected using a small sampling scoop, after 'stirring' of the catch.

The Subsample Interview Number (one character, alpha or numeric) provides a link to data collected in the initial interview for the selected party and equates to a repeating of the original Interview Number (see Item (i) above). Note: in cases where no Subsample Interview was sought for a particular Sub-area, this field remains blank and where an interview was sought but no eligible party existed, the alphabetic code (N) applies. Note: in some cases, two subsample interviews were conducted for certain Sub-areas and the additional data (and Interview No) recorded on the form, as appropriate.

(xiv) Subsample Interviews - Aggregate Weight by Species: six by three character fields, all numeric, zero-fill, for the aggregate weight (grams*) for each species (including 'other' and total) revealed in the Subsample. That is, the prawns were firstly sorted by species and then aggregate weights obtained for each species

Note*: using a precision pan balance, maximum accuracy was sought at all times. However, due to a number of factors (principally wind affecting the pan balance) a ten gram precision level should be assumed for this sampling work overall.

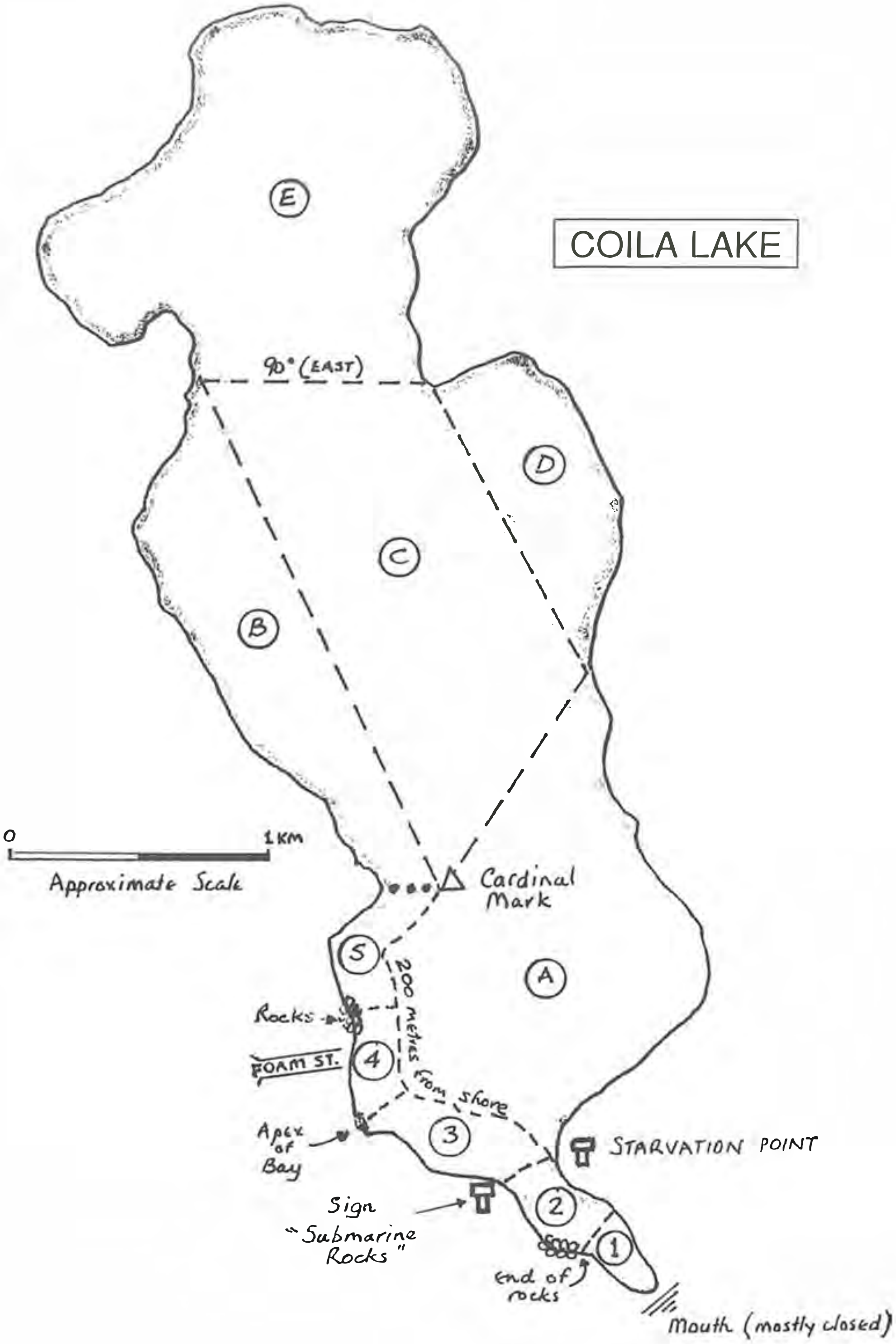
(xv)	**Subsample Interviews - Individual Carapace Lengths by Species**	length* in mms. (two characters, numeric), plus species code (one character, alpha) for up to 20 individual prawns (usually 10) in the subsample. Species codes: G = greasy-back; K = eastern king; S = school; T = tiger; O = other prawn; U = prawn species unknown

Note*: carapace lengths were measured using high quality vernier calipers (with analog dial) according to procedures specified by FRI (see Appendix I for graphic description).

APPENDIX *A*

Survey Area Map

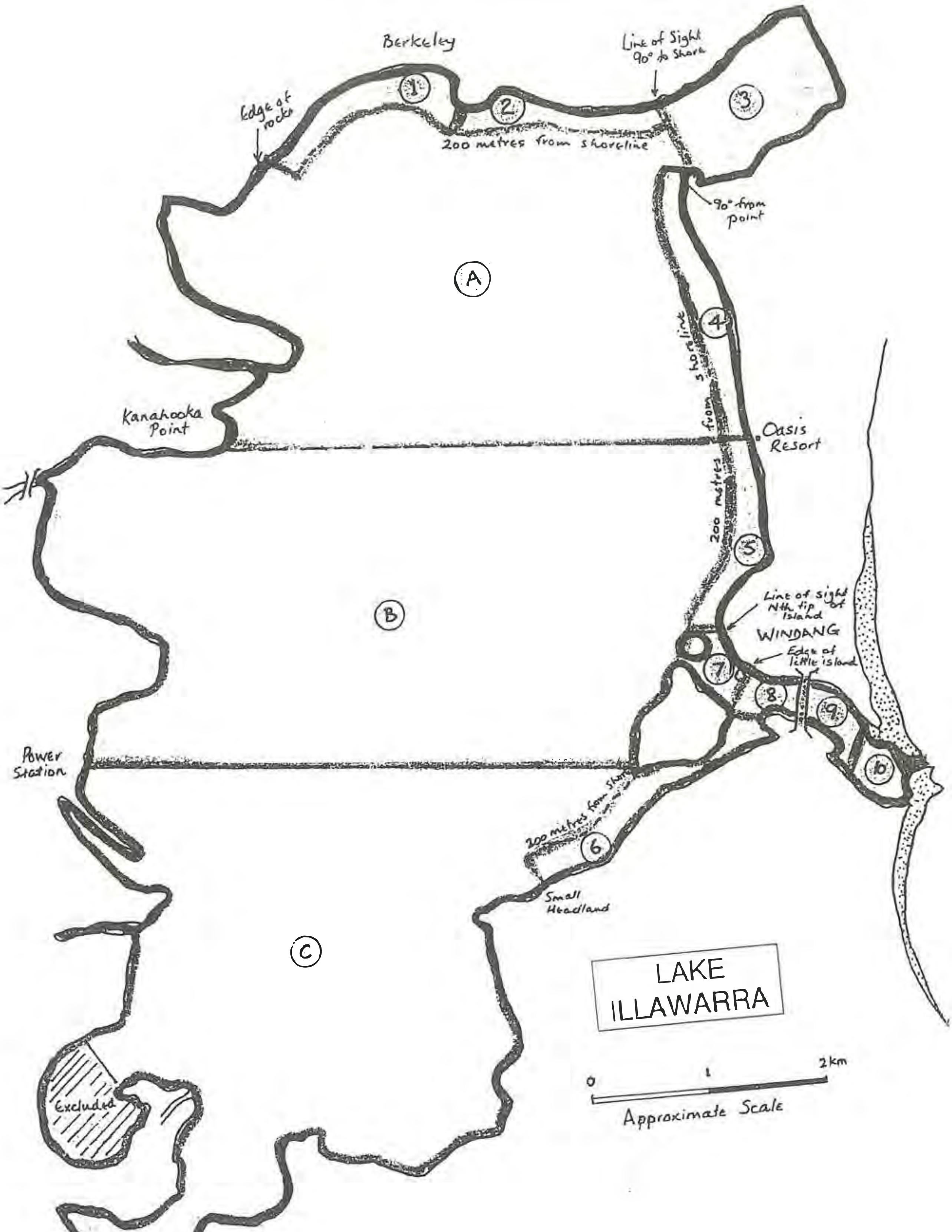
COILA LAKE


COILA LAKE
E
90° (EAST)
D
C
B
0
1KM
Approximate Scale
Cardinal Mark
5
A
200 metres from shore
Rocks
FOAM ST.
4
Apex of Bay
3
STARVATION POINT
Sign "Submarine Rocks"
2
1
End of rocks
Mouth (mostly closed)

APPENDIX *B*

Survey Area Map

LAKE ILLAWARRA

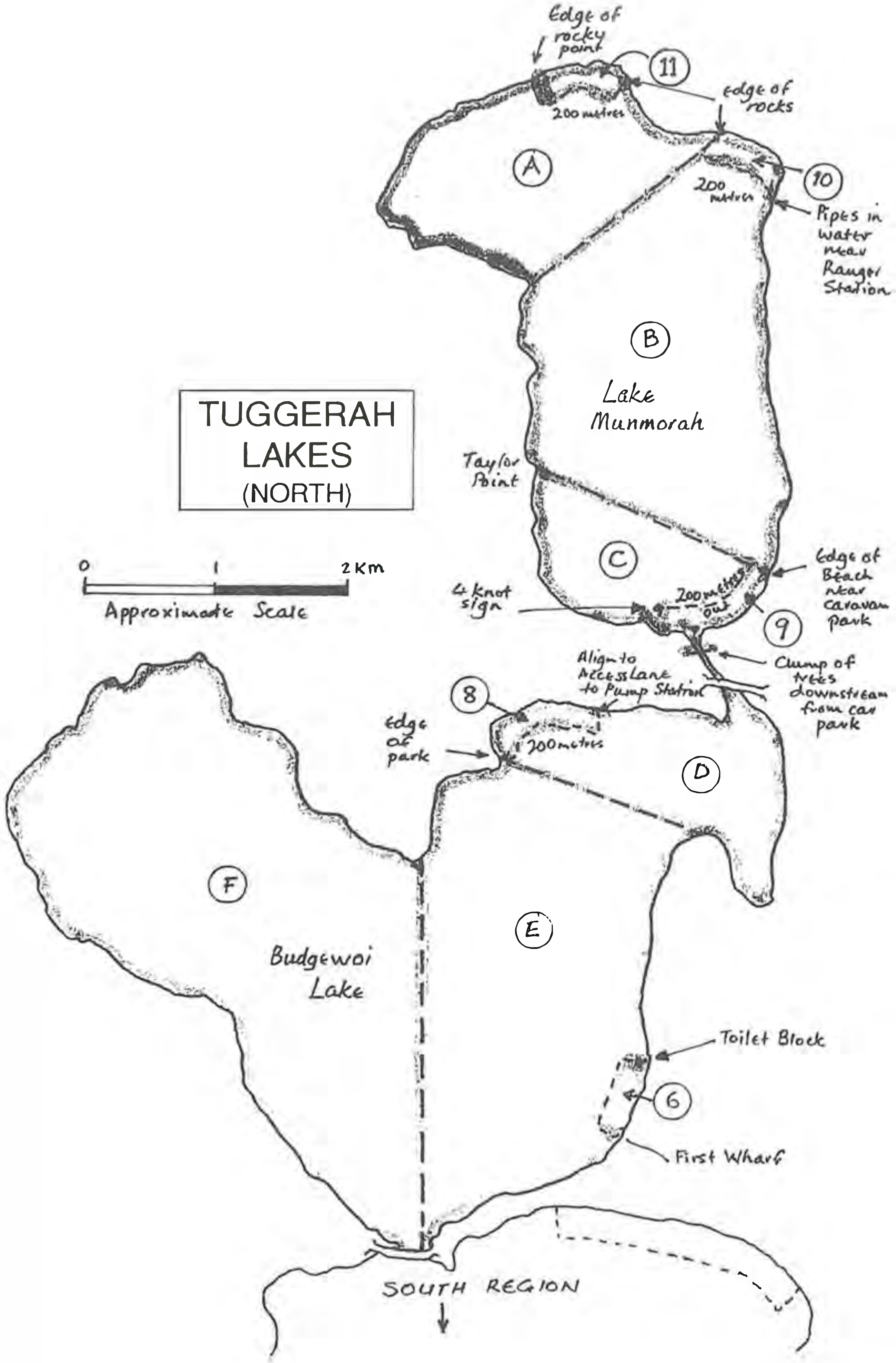


Berkeley
Line of Sight 90° to Shore
Edge of rocks
200 metres from shoreline
90° from point
A
200 metres from shoreline
Kanahooka Point
Oasis Resort
B
Line of sight Nth tip of Island
WINDANG
Edge of little island
Power Station
200 metres from shore
Small Headland
C
LAKE ILLAWARRA
Excluded
0
1
2km
Approximate Scale
1
2
3
4
5
6
7
8
9
10

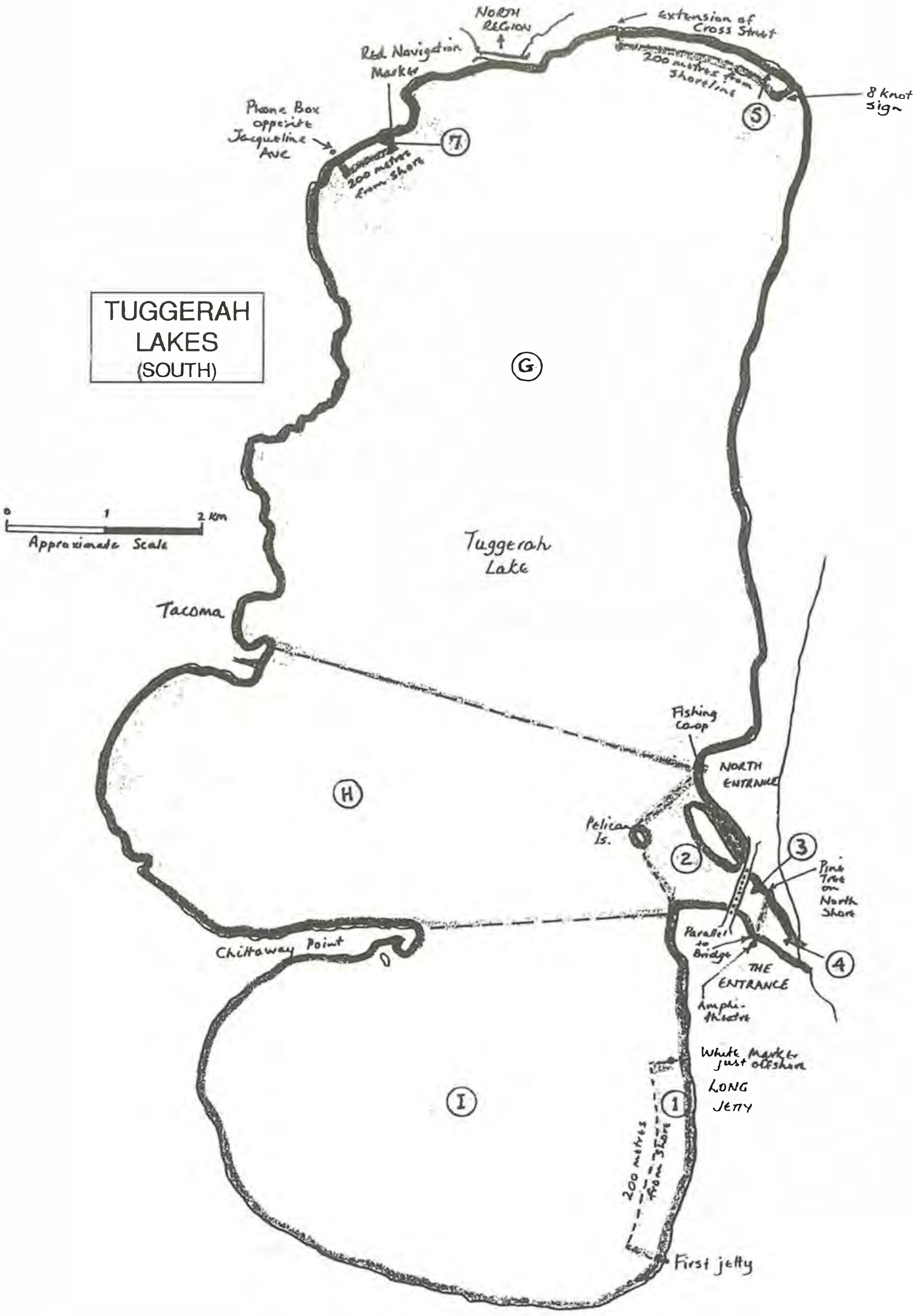
APPENDIX C

Survey Area Maps

TUGGERAH LAKES
(North and South)



TUGGERAH
LAKES
(NORTH)
0
1
2Km
Approximate Scale
Edge of rocky point
11
200 metres
edge of rocks
A
200 metres
10
Pipes in water near Ranger Station
B
Lake Munmorah
Taylor Point
C
Edge of Beach near caravan park
4 knot sign
200 metres out
9
Align to Accesslane to Pump Station
Clump of trees downstream from car park
8
Edge of park
200 metres
D
F
E
Budgewoi Lake
Toilet Block
6
First Wharf
SOUTH REGION

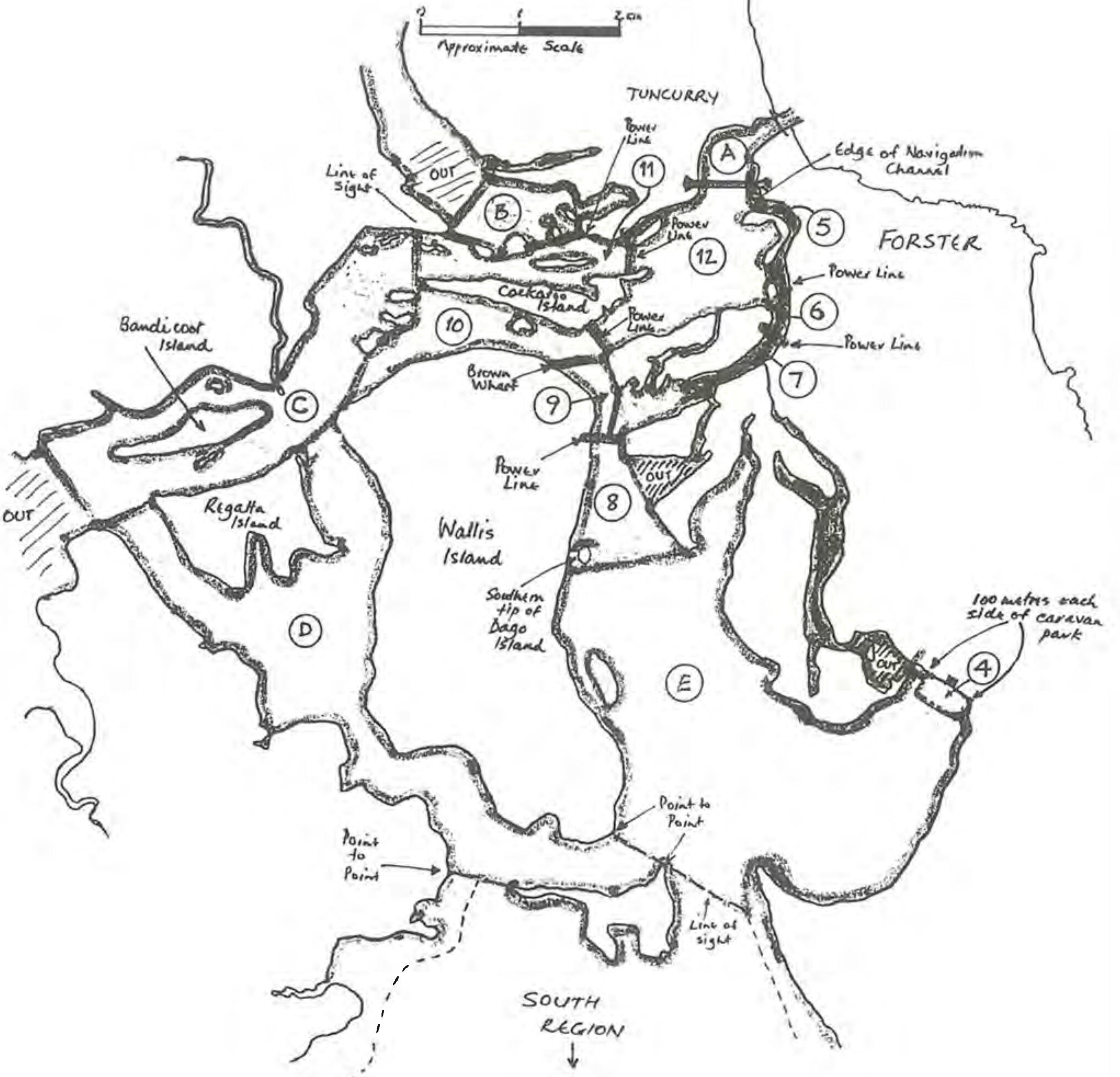

TUGGERAH LAKES (SOUTH)
NORTH REGION
extension of Cross Street
Red Navigation Marker
200 metres from Shoreline
8 Knot sign
Phone Box opposite Jacqueline Ave
200 metres from Shore
7
5
G
0 1 2 KM
Approximate Scale
Tuggerah Lake
Tacoma
Fishing Co-op
NORTH ENTRANCE
H
Pelican Is.
2
3
Pine Tree on North Shore
Parallel to Bridge
4
THE ENTRANCE
Chittaway Point
Amphi-theatre
White Marker just offshore
LONG JETTY
I
1
200 metres from Shore
First jetty

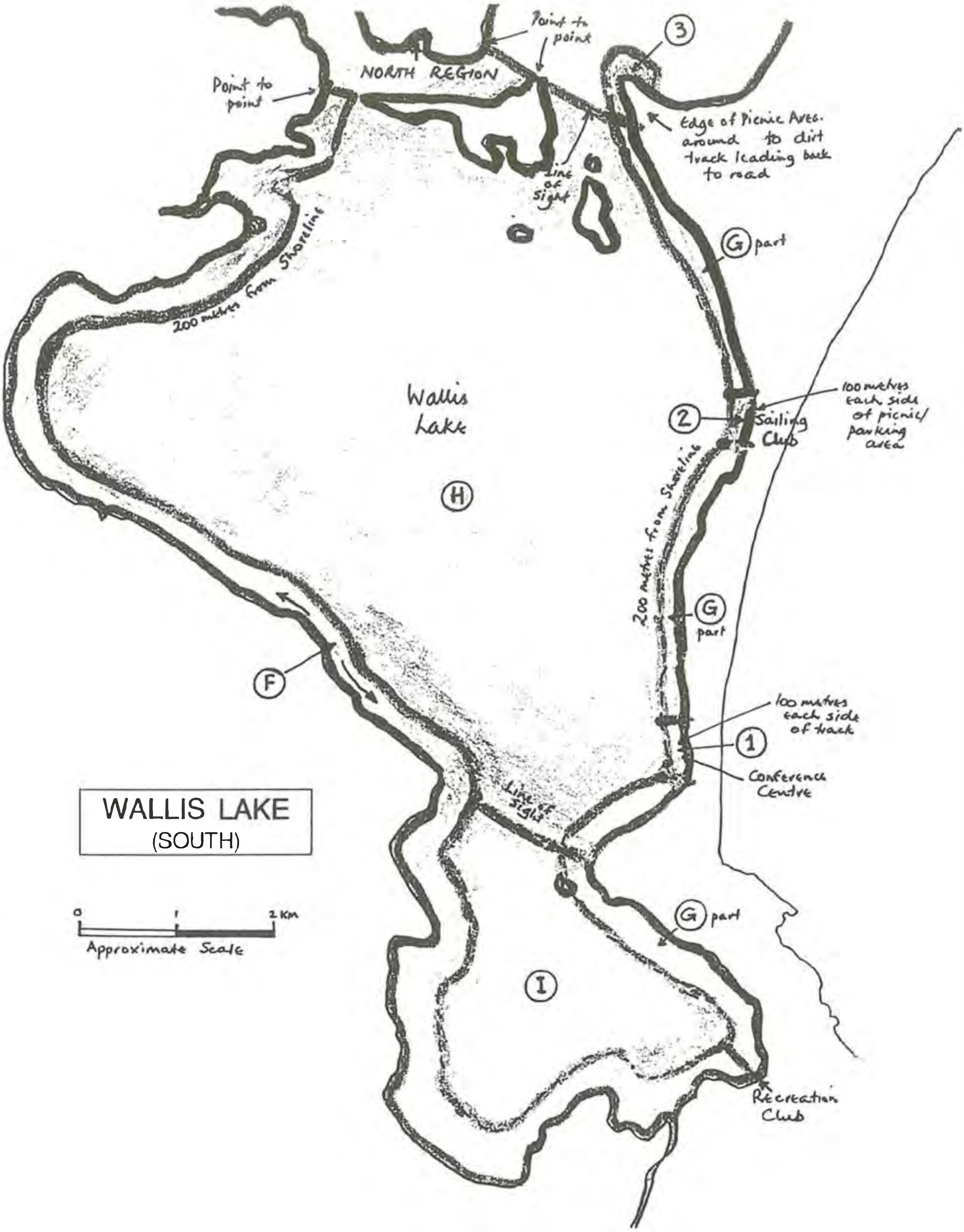
APPENDIX *D*

Survey Area Maps

WALLIS LAKE
(North and South)

WALLIS LAKE
(NORTH)




WALLIS LAKE
(SOUTH)
NORTH REGION
Point to point
Point to point
3
Edge of Picnic Area around to dirt track leading back to road
Line of Sight
G part
200 metres from Shoreline
Wallis Lake
H
2
Sailing Club
100 metres each side of picnic/parking area
200 metres from Shoreline
G part
F
100 metres each side of track
1
Conference Centre
Line of Sight
G part
I
Recreation Club
0
1
2 KM
Approximate Scale

APPENDIX *E*

Whole Estuary Count Form

Kewagama Research

RECREATIONAL PRAWNING SURVEY © 1991 - FULL COUNT FORM

Page ☐ of ☐

Estuary:	Date	Day Type	NSW School Hols	Roster No. #	Count Period	Tide	Moon	Wind	Rain	Cloud	Temp
Wallis 1 Tuggerah 2 Illawarra 3 Coila 4	Date ☐☐ Month ☐☐ Year ☐☐	WD 1 WE/Hol 2	Yes 1 No 2	☐	from ☐☐☐☐ to ☐☐☐☐	R/in 1 R/out 2 Slack 3 N/A 4	D/U 1 D/D 2 L/U 3 L/D 4	<10km 1 10-20 2 >20km 3	Nil 1 Light 2 Med-Heavy 3	<33° 1 33-66 2 >66° 3	<20° 1 20-25 2 >25° 3

Sub-Area No. #	BOAT (all net types)			SHORE (including wading) — Drag Net			SHORE (including wading) — Other Nets			All Others (specify)
	↑ Light	↓ Light	Nil	↑ Light	↓ Light	Nil	↑ Light	↓ Light	Nil	
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....

APPENDIX *F*

Count/Interview Questionnaire (Routine Sampling)

Kewagama Research

RECREATIONAL PRAWNING SURVEY © 1991

Page ☐ of ☐

Estuary:	Sub-Area Number #	Date	Day Type	NSW School Hols	Roster No. #	C/I Period	Tide	Moon	Wind	Rain	Cloud	Temp
Wallis 1 Tuggerah 2 Illawarra 3 Coila 4	☐☐	D ☐☐ M ☐☐ Y ☐☐	WD 1 WE/Hol 2	Yes 1 No 2	☐	from ☐☐☐☐ to ☐☐☐☐	R/in 1 R/out 2 Slack 3 N/A 4	D/U 1 D/D 2 L/U 3 L/D 4	<10km 1 10-20 2 >20km 3	Nil 1 Light 2 Med-Heavy 3	<33° 1 33-66 2 >66° 3	<20° 1 20-25 2 >25° 3

Count Record - Numbers of People

BOAT (all net types)			SHORE (including wading) Drag Net			SHORE (including wading) Other Nets			All Others (specify)
↑ Light	↓ Light	Nil	↑ Light	↓ Light	Nil	↑ Light	↓ Light	Nil	....
☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	....

Interview Number #	1	2	3	4	5	6
Boat or Shore/Wading	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2
Nets (No. of ...) • Drag • Scoop • Other	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐
Prawn Lights (No. of ...) • Above Surface • Submersible	☐ ☐	☐ ☐	☐ ☐	☐ ☐	☐ ☐	☐ ☐
Total number of people in party (all ages/whether prawning or not)	0☐	0☐	0☐	0☐	0☐	0☐
Number of people actually prawning (light/net/> 5yrs)	0☐	0☐	0☐	0☐	0☐	0☐
Time of Interview	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐
(And) when did you actually start prawning tonight? (Probe: continuous etc.)	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐
Weight of Total Catch	0☐ • ☐☐ kg 10g	0☐ • ☐☐ kg 10g	0☐ • ☐☐ kg 10g	0☐ • ☐☐ kg 10g	0☐ • ☐☐ kg 10g	0☐ • ☐☐ kg 10g
(And) Could you tell me your home postcode(s) please?	☐☐☐☐ x ☐☐☐☐ x ☐☐☐☐ x	☐☐☐☐ x ☐☐☐☐ x ☐☐☐☐ x	☐☐☐☐ x ☐☐☐☐ x ☐☐☐☐ x	☐☐☐☐ x ☐☐☐☐ x ☐☐☐☐ x	☐☐☐☐ x ☐☐☐☐ x ☐☐☐☐ x	☐☐☐☐ x ☐☐☐☐ x ☐☐☐☐ x
Response Status Full 1, Ref 2, P/Ref 3, Lang 4, Scope 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Comments (quote I'view No #): ....

....

....

....

Sub-sample Interview Number # 1 2 3 4 5 6 N	Sample Weights (grams)	Total	Greasy	King	School	Tiger	Other
		☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐

1	2	3	4	5	6	7	8	9	10
☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U	☐☐ G K S T O U

APPENDIX G

Workload Control
Sheet
(1st Season - 91/92)

RECREATIONAL PRAWNING SURVEY
WORKLOAD CONTROL SHEET

Estuary: COILA　　　　Month/Year: FEBRUARY, 1992

Day/Date (ie night hrs commencing on the p.m of ...)	Day Type WD (1) or WE/HOL (2)	NSW School Hols Yes (1) No (2)	Roster No.#	Area Order	Moon Phase D/ or L/	Other Comments
Tue 28/1	D	2	1	2	D	
Thu 30/1	D	2	2	1	D	
**Fri 31/1	E	2	N/A	N/A	D	** whole estuary count - 'last light' onwards
Sat 1/2	E	2	1	2	D	
Mon 3/2	D	2	4	1	D	
Wed 5/2	D	2	3	2	D	
Fri 7/2	E	2	2	1	D	
Tue 11/2	D	2	1	1	L	
Sat 15/2	E	2	2	2	L	
Wed 19/2	D	2	4	1	L	
Sun 23/2	D	2	1	2	L	

		COILA	ILLAWARRA	TUGGERAH	WALLIS
Roster	1.	last light + 2.25 hrs	last light + 3.5 hrs	last light + 4.5 hrs	last light + 4 hrs
	2.	2215 to 0030 hrs	2245 to 0215 hrs	4.5 hrs before 1st light	4.5 hrs before 1st light
	3.	0030 to 0245 hrs	3.5 hrs before 1st light		
	4.	2.25 hrs before 1st light			
Area Order	1.	1-5	1-10	1-11	1-12
	2.	5-1	10-1	11-1	12-1
	3.		6-10, 1-5	5-11, 1-4	5-12, 1-4
	4.		5-1, 10-6	4-1, 11-5	4-1,12-5

APPENDIX *H*

Workload Control
Sheet

(2nd & 3rd Seasons -
92/93 & 93/94)

RECREATIONAL PRAWNING SURVEY
WORKLOAD CONTROL SHEET

Estuary: WALLIS　　　　　　　　　　　　　　　　Month/Year: DECEMBER 1993

Day/Date (ie night hrs commencing on the p.m of ...)	Day Type WD (1) or WE/HOL (2)	NSW School Hols Yes (1) No (2)	Roster No.#	Area Order	Moon Phase D/ or L/	Tide* for 'flow' Sub-Areas (Ebb=E Make=M)	Other Comments
Sun 5/12	D	2	1	3	D	E	
Tue 7/12	D	2	1	2	D	E	
Thur 9/12	D	2	2	3	D	E	
Sat 11/12	E	2	2	4	D	E	
Mon 13/12	D	2	1	2	D	M	
Wed 15/12	D	2	3	1	D	E	
Fri 17/12	E	2	2	1	D	M	
Tue 21/12	D	1	1	2	L	E	
Sat 25/12	E	1	2	3	L	E	
Tue 28/12	D	1	N/A	N/A	L	-	Count - Nth Region Start 2300hrs, leave mouth last.
Wed 29/12	D	1	3	4	L	E	
Thur 30/12	D	1	N/A	N/A	L	-	Count - Sth Region Last Light onwards
Sun 2/1	E	1	2	1	L	M	

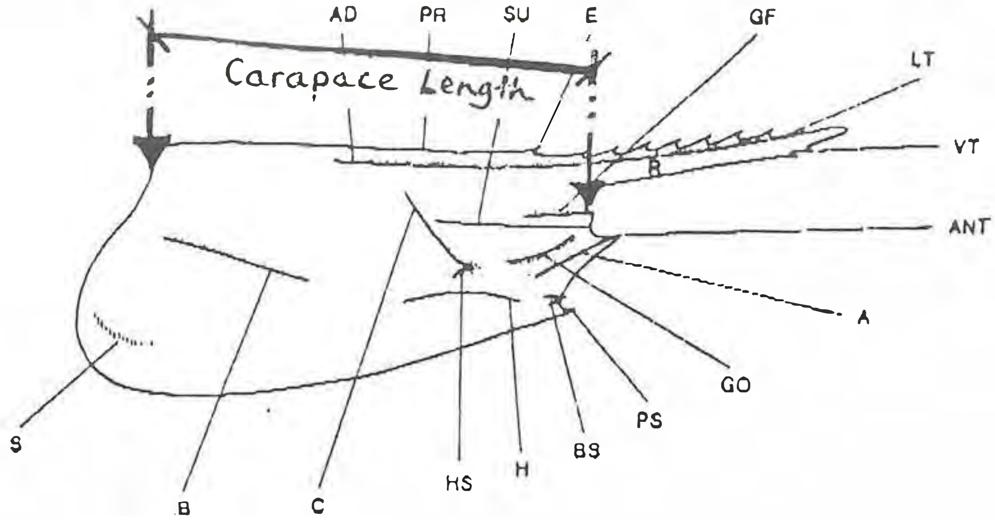
		COILA	ILLAWARRA	TUCGERAH	WALLIS
Roster	1.	last light + 2.25 hrs	last light + 3.5 hrs	last light + 4 hrs	last light + 4 hrs
	2.	2215 to 0030 hrs	2245 to 0215 hrs	2230 to 0230 hrs	2230 to 0230 hrs
	3.	0030 to 0245 hrs	3.5 hrs before 1st light	4 hrs before 1st light	4 hrs before 1st light
	4.	2.25 hrs before 1st light			
Area Order	1.	1-5	2-5, 7-10	1-5, 9-11	2, 5-9, 12, 11
	2.	5-1	10-7, 5-2	11-9, 5-1	11, 12, 9-5, 2
	3.		7-10, 2-5	9-11, 1-5	5-9, 12, 11, 2
	4.		5-2, 10-7	5-1, 11-9	2, 11, 12, 9-5

APPENDIX *I*

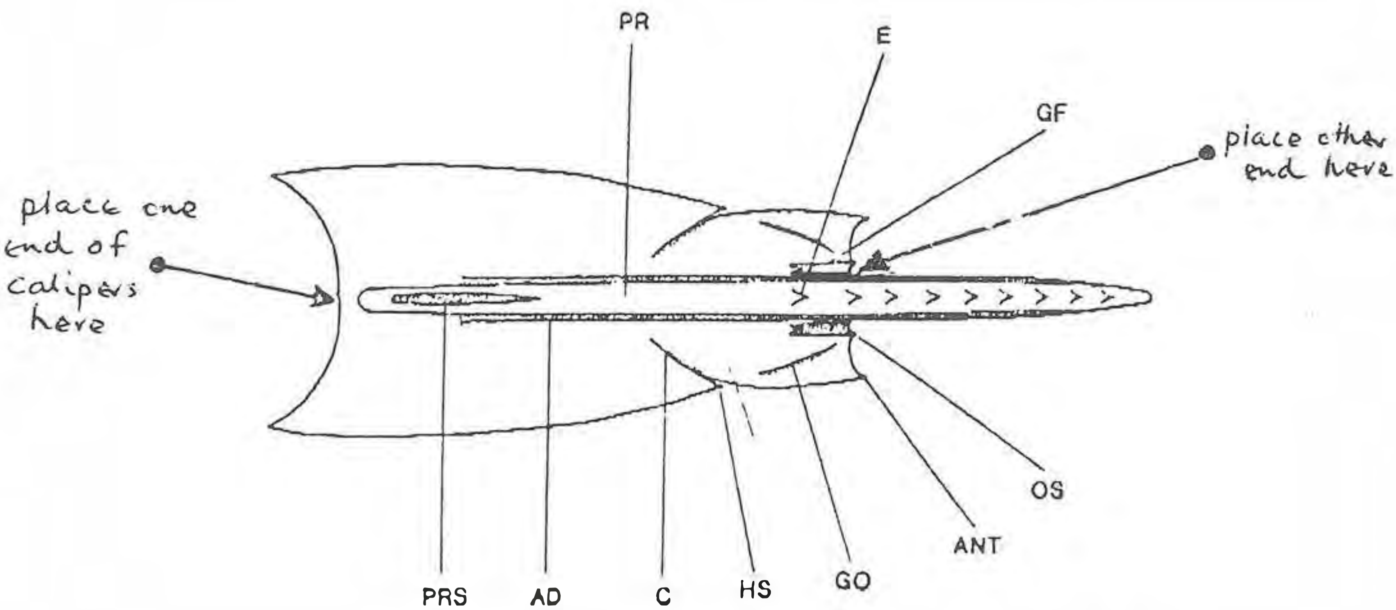
Measurement Procedures - Prawn Carapace Length

Carapace Length Measurement

A: Lateral View



B: Dorsal View



Key features of the carapace.

A. Lateral view.

B. Dorsal view.

A — antennal ridge and antennal groove (above); AD — adrostral ridge and groove; ANT — antennal spine; B — branchiocardiac ridge and groove; BS — branchiostegal spine; C — cervical ridge and groove; E — first (or epigastric) tooth; GF — gastrofrontal ridge and groove; GO — gastro-orbital ridge and groove; H — hepatic ridge and groove; HS — hepatic spine; LT — last or distal rostral tooth; OS — orbital spine; PR — postrostral ridge, PRS — postrostral groove; PS — pterygostomial spine; R — rostrum; S — serrated ridge (stridulating organ); SU — longitudinal suture; VT — ventral rostral tooth.

APPENDIX 5

Estimates of total effort and catch per unit effort by each strata for each season of surveys.

Location	M	D	T	No. of shore-scopers mean	se	Total	No. of boat-scoopers mean	se	Total	No. of drag-netters mean	se	Total
Wallis tidal	D	WD	RI	0.67	0.44	21	1.44	0.73	46	0.00	0.00	0
	D	WD	RO	0.21	0.21	7	23.36	6.07	748	0.00	0.00	0
	D	WE	RI	0.00	0.00	0	1.00	1.00	13	0.00	0.00	0
	D	WE	RO	1.14	0.86	15	82.75	50.39	1076	0.00	0.00	0
	L	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WD	RO	0.00	0.00	0	0.25	0.25	8	0.00	0.00	0
	L	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	0.00	0.00	0	6.67	6.67	87	0.00	0.00	0
						43			1977			0
Tuggerah tidal	D	WD	RI	9.60	4.87	307	2.40	2.40	77	0.00	0.00	0
	D	WD	RO	49.23	10.92	1575	1.69	0.82	54	0.00	0.00	0
	D	WE	RI	65.00		845	8.00		104	0.00	0.00	0
	D	WE	RO	54.00	26.41	702	6.00	6.00	78	0.00	0.00	0
	L	WD	RI	19.00		608	3.00		96	0.00	0.00	0
	L	WD	RO	3.00	1.29	96	0.00	0.00	0	0.00	0.00	0
	L	WE	RI			0			0			0
	L	WE	RO	8.00	8.00	104	6.00	6.00	78	0.00	0.00	0
						4238			487			0
Tuggerah non-tidal	D	WD	n.a	6.31	1.58	202	0.00	0.00	0	5.81	2.05	186
	D	WE	n.a	22.60	17.43	294	0.00	0.00	0	3.40	2.71	44
	L	WD	n.a	2.00	2.00	64	0.00	0.00	0	2.67	1.71	85
	L	WE	n.a	8.00	7.51	104	0.00	0.00	0	1.33	1.33	17
						664			0			333
Illawarra tidal	D	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	50.33	14.48	1611	6.53	2.44	209	0.00	0.00	0
	D	WE	RI			0			0			0
	D	WE	RO	101.40	44.25	1318	18.00	9.61	234	0.00	0.00	0
	L	WD	RI			0			0			0
	L	WD	RO	12.83	8.56	411	1.17	1.17	37	0.00	0.00	0
	L	WE	RI			0			0			0
	L	WE	RO	3.00	1.00	39	0.00	0.00	0	0.00	0.00	0
						3379			480			0
Illawarra non-tidal	D	WD	n.a	4.50	1.46	144	28.38	10.06	908	0.13	0.13	4
	D	WE	n.a	14.40	8.63	187	50.20	22.24	653	0.40	0.40	5
	L	WD	n.a	0.17	0.17	5	2.17	2.17	69	0.00	0.00	0
	L	WE	n.a	9.67	8.21	126	21.00	21.00	273	0.67	0.67	9
						462			1903			18
Coila	D	WD	n.a	16.67	3.13	213	0.00	0.00	0	0.56	0.44	18
	D	WE	n.a	14.83	7.01	193	0.00	0.00	0	0.50	0.29	7
	L	WD	n.a	0.17	0.17	5	0.00	0.00	0	0.00	0.00	0
	L	WE	n.a	7.25	4.75	87	0.00	0.00	0	2.00		26
						498			0			50

Appendix 5.1. Estimates of mean (per night) and total number of prawners by moon-phase (M), day-type (D), tide (T) and fishing method for the 1991-92 season (January-March 1992). D=dark, L=light moon-phases, WD=week-day, WE=weekend or public holiday, RI=run-in tide, RO=run-out tide.

Location	M	D	T	No. of shore-scoopers mean	se	Total	No. of boat-scoopers mean	se	Total	No. of drag-netters mean	se	Total
Wallis tidal	D	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	2.00	1.32	102	33.47	12.55	1707	0.00	0.00	0
	D	WE	RI	0.50	0.50	12	0.00	0.00	0	0.00	0.00	0
	D	WE	RO	0.50	0.33	12	48.00	19.23	1152	0.00	0.00	0
	L	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WD	RO	0.83	0.51	44	7.00	3.02	371	0.00	0.00	0
	L	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	0.50	0.50	10	14.00	9.30	280	0.00	0.00	0
						180			3510			0
Tuggerah tidal	D	WD	RI	1.29	0.84	66	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	39.21	13.22	2000	2.32	1.45	118	0.00	0.00	0
	D	WE	RI	15.50	10.47	372	4.50	4.50	108	0.00	0.00	0
	D	WE	RO	47.00	7.32	1128	3.33	1.74	80	0.00	0.00	0
	L	WD	RI			0			0	0.00	0.00	0
	L	WD	RO	15.82	6.18	838	1.36	1.00	72	0.00	0.00	0
	L	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	86.50	34.81	1730	1.00	1.00	20	0.00	0.00	0
						6134			398			0
Tuggerah non-tidal	D	WD	n.a	5.29	2.06	270	0.00	0.00	0	14.42	5.12	735
	D	WE	n.a	4.80	3.43	115	0.00	0.00	0	17.20	5.84	413
	L	WD	n.a	7.50	3.22	398	0.00	0.00	0	7.50	2.88	398
	L	WE	n.a	10.44	7.07	209	0.00	0.00	0	16.89	8.66	338
						991			0			1883
Illawarra tidal	D	WD	RI	1.20	1.20	61	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	45.47	9.13	2319	4.95	1.45	252	0.00	0.00	0
	D	WE	RI	14.67	14.67	352	2.67	2.67	64	0.00	0.00	0
	D	WE	RO	38.43	9.99	922	5.43	2.78	130	0.00	0.00	0
	L	WD	RI	26.00	22.59	1378	0.00	0.00	0	0.00	0.00	0
	L	WD	RO	21.70	8.09	1150	2.60	1.34	138	0.00	0.00	0
	L	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	41.57	19.08	831	1.43	0.97	29	0.00	0.00	0
						7014			613			0
Illawarra non-tidal	D	WD	n.a	5.92	1.81	302	15.38	5.13	784	1.04	0.70	53
	D	WE	n.a	6.30	2.82	151	17.80	7.65	427	0.20	0.20	5
	L	WD	n.a	3.67	1.14	194	7.58	4.19	402	0.00	0.00	0
	L	WE	n.a	2.89	1.37	58	16.67	9.97	333	0.89	0.89	18
						705			1947			76
Coila	D	WD	n.a	9.67	3.11	503	0.00	0.00	0	0.25	0.17	13
	D	WE	n.a	10.40	4.49	239	0.00	0.00	0	1.00	0.77	24
	L	WD	n.a	4.17	1.46	221	0.00	0.00	0	0.00	0.00	0
	L	WE	n.a	7.20	5.55	144	0.00	0.00	0	0.00	0.00	0
						1107			0			37

Appendix 5.2. Estimates of mean (per night) and total number of prawners by moon-phase (M), day-type (D), tide (T) and fishing method for the 1992-93 season (November 1992-March 1993). D=dark, L=light moon-phases, WD=week-day, WE=weekend or public holiday, RI=run-in tide, RO=run-out tide.

Location				No. of shore-scoopers			No. of boat-scoopers			No. of drag-netters		
	M	D	T	mean	se	Total	mean	se	Total	mean	se	Total
Wallis tidal	D	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	0.36	0.17	19	21.17	4.42	1101	0.00	0.00	0
	D	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WE	RO	0.56	0.44	12	36.83	14.57	810	0.00	0.00	0
	L	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WD	RO	0.00	0.00	0	2.64	1.63	158	0.00	0.00	0
	L	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	0.20	0.20	6	18.40	10.80	534	0.00	0.00	0
						37			2603			0
Tuggerah tidal	D	WD	RI	0.43	0.43	22	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	56.06	15.12	2915	5.39	3.07	280	0.00	0.00	0
	D	WE	RI	1.33	1.33	29	0.00	0.00	0	0.00	0.00	0
	D	WE	RO	80.00	26.64	1760	4.67	1.69	103	0.00	0.00	0
	L	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WD	RO	19.64	9.33	1178	0.09	0.09	5	0.00	0.00	0
	L	WE	RI	3.00	3.00	87	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	33.60	24.47	974	2.80	2.80	81	0.00	0.00	0
						6967			470			0
Tuggerah non-tidal	D	WD	n.a	9.32	2.44	485	0.00	0.00	0	20.96	5.50	1090
	D	WE	n.a	5.33	2.25	117	0.00	0.00	0	17.56	7.24	386
	L	WD	n.a	2.20	1.50	132	0.00	0.00	0	2.13	0.95	128
	L	WE	n.a	7.71	2.02	224	0.00	0.00	0	7.71	2.81	224
						957			0			1828
Illawarra tidal	D	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WD	RO	65.22	9.88	3391	6.83	1.62	355	0.00	0.00	0
	D	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	D	WE	RO	67.33	26.32	1481	6.33	2.95	139	0.00	0.00	0
	L	WD	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WD	RO	23.25	8.08	1395	2.00	1.12	120	0.00	0.00	0
	L	WE	RI	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
	L	WE	RO	22.00	8.86	638	0.00	0.00	0	0.00	0.00	0
						6906			614			0
Illawarra non-tidal	D	WD	n.a	10.08	3.07	524	20.60	6.01	1071	0.16	0.16	8
	D	WE	n.a	8.78	4.26	193	23.56	12.11	518	0.44	0.44	10
	L	WD	n.a	5.00	2.25	300	5.65	3.14	339	0.29	0.29	17
	L	WE	n.a	4.50	3.72	131	2.33	2.33	68	0.00	0.00	0
						1148			1996			35
Coila	D	WD	n.a	5.88	1.92	306	0.00	0.00	0	0.44	0.26	23
	D	WE	n.a	1.67	0.69	37	0.00	0.00	0	0.00	0.00	0
	L	WD	n.a	3.21	2.48	193	0.00	0.00	0	0.00	0.00	0
	L	WE	n.a	3.71	1.66	108	0.00	0.00	0	0.14	0.14	4
						643			0			27

Appendix 5.3. Estimates of mean (per night) and total number of prawners by moon-phase (M), day-type (D), tide (T) and fishing method for the 1993-94 season (November 1993-March 1994). D=dark, L=light moon-phases, WD=week-day, WE=weekend or public holiday, RI=run-in tide, RO=run-out tide.

Appendix 5.4a. Estimates of mean monthly cpue (kg/prawner/hour) for Wallis Lake. Data for tidal subareas are based on ebb-tide only.

Moon	Month	Tidal scoop-nets			Non-tidal scoop-nets		
Phase		mean	se	N	mean	se	N
	Jan-92	0.4054	0.1437	29	0.0314	0.0167	5
	Feb-92	0.2754	0.0651	22	0.0285	0.0091	4
Dark	Mar-92	0.4907	0.0870	44	0.0000	-	1
	Nov-92	0.6565	0.1142	28	0.6246	0.1240	4
	Dec-92	0.5545	0.0780	27	0.0558	0.0042	2
	Jan-93	0.3374	0.0531	58	0.0110	0.0062	4
	Feb-93	0.6200	0.0660	51	0.0090	0.0018	2
	Mar-93	0.4354	0.0904	28	0.0000	-	1
	Nov-93	0.6490	0.1046	35	0.2472	-	1
	Dec-93	0.4687	0.0780	31	0.0198	-	1
	Jan-94	0.2715	0.0364	49	0.0252	-	1
	Feb-94	0.3731	0.0540	42	0.0018	0.0018	2
	Mar-94	0.6119	0.0932	35			
Light	Jan-92	0.2502	0.0130	3			
	Feb-92						
	Mar-92						
	Nov-92	0.1796	0.0391	9			
	Dec-92	0.5144	0.1460	10			
	Jan-93	0.2798	0.0526	23			
	Feb-93	0.3729	0.0660	13			
	Mar-93	0.2543	0.1178	11			
	Nov-93	0.3447	0.1032	18			
	Dec-93	0.1428	-	1			
	Jan-94	0.2050	0.1019	5			
	Feb-94	0.1317	0.0605	7			
	Mar-94	0.3733	0.1011	13			

Appendix 5.4b. Estimates of mean monthly cpue (kg/prawner/hour) for Tuggerah Lakes. Data for tidal subareas are based on ebb-tide only.

Moon	Month	Tidal scoop-nets			Non-tidal scoop-nets			Non-tidal drag-nets		
Phase		mean	se	N	mean	se	N	mean	se	N
	Jan-92	0.2404	0.0635	17	0.1110	0.0403	25	0.3429	0.0626	12
	Feb-92	0.1441	0.0311	21	0.0889	0.0327	12	0.4445	0.0701	7
Dark	Mar-92	0.2068	0.0319	29	0.3794	0.0908	12	2.1945	0.2910	7
	Nov-92	0.2340	0.0493	25	0.1869	0.0880	4	0.4359	0.1268	12
	Dec-92	0.4086	0.1571	18	0.1919	0.0382	4	0.3305	0.0835	8
	Jan-93	0.4335	0.1680	23	0.0558	0.0122	13	0.7356	0.2581	20
	Feb-93	0.1811	0.0368	19	0.0667	0.0403	10	0.8984	0.1625	15
	Mar-93	0.4816	0.1009	18	0.0866	0.0241	6	0.3289	0.0993	8
	Nov-93	0.1368	0.0235	26	0.0472	0.0134	13	0.3766	0.1153	14
	Dec-93	0.3321	0.1049	26	0.0537	0.0172	9	0.2756	0.0375	17
	Jan-94	0.0739	0.0140	27	0.0933	0.0359	12	0.2330	0.0777	14
	Feb-94	0.2360	0.0409	14	0.0509	0.0199	5	0.6827	0.1050	18
	Mar-94	0.4105	0.0825	22	0.1108	0.0650	5	0.8590	0.2904	12
Light	Jan-92	0.3994	0.0899	6	0.0263	0.0164	5	0.4632	0.1890	2
	Feb-92	0.2358	0.0596	4	0.7032	.	1			
	Mar-92	0.0799	0.0201	11	0.1006	0.0311	5	0.3281	0.1067	6
	Nov-92	0.1308	0.0598	14	0.0312	0.0123	6			
	Dec-92	0.2468	0.0645	13	0.0840	0.0325	14	0.6777	0.1690	15
	Jan-93	0.0810	0.0189	9	0.0699	0.0400	7	0.1240	0.0238	11
	Feb-93	0.3153	0.0459	4	0.0783	0.0243	4	0.1619	0.1274	4
	Mar-93	0.0788	0.0086	5	0.0000	0.0000	2	0.1846	0.0471	3
	Nov-93	0.0611	0.0156	4	0.0198	.	1	0.7500	-	1
	Dec-93	0.5004	0.4583	5	0.0951	0.0216	4	0.1476	0.0232	4
	Jan-94	0.1036	0.0295	8	0.0417	0.0200	7	0.1854	0.0603	9
	Feb-94	0.8059	0.2388	10	0.0328	0.0232	5	0.4880	0.1705	5
	Mar-94	0.1764	-	1	0.1056	0.0810	2	0.3678	0.1240	5

Appendix 5.4c. Estimates of mean monthly cpue (kg/prawner/hour) for Lake Illawarra. Data for tidal subareas are based on ebb-tide only.

Moon Phase	Month	Tidal scoopers mean	Tidal scoopers se	Tidal scoopers N	Non-tidal scoopers mean	Non-tidal scoopers se	Non-tidal scoopers N	Non-tidal drag-nets mean	Non-tidal drag-nets se	Non-tidal drag-nets N
	Jan-92	0.2493	0.0644	23	0.4267	0.1517	19	0.3612	-	1
	Feb-92	0.2053	0.0819	10	0.1322	0.0632	8	0.7500	-	1
Dark	Mar-92	0.0635	0.0095	22	0.1270	0.0199	15			
	Nov-92	0.1926	0.0320	26	0.2000	0.0278	24	0.0378	-	1
	Dec-92	0.4413	0.0295	31	0.3039	0.0310	31	0.0000	-	1
	Jan-93	0.4021	0.0768	52	0.2544	0.0251	57	0.4021	0.11752	5
	Feb-93	0.2051	0.0258	29	0.1200	0.0141	45			
	Mar-93	0.0932	0.0102	41	0.1754	0.0390	4			
	Nov-93	0.1633	0.0179	27	0.2233	0.0597	23			
	Dec-93	0.2472	0.0246	50	0.1483	0.0113	82	0.0684	-	1
	Jan-94	0.2130	0.0236	37	0.2389	0.0248	54	0.3258	-	1
	Feb-94	0.2902	0.0353	26	0.2167	0.0183	48			
	Mar-94	0.2072	0.0386	23	0.1695	0.0409	18			
Light	Jan-92	0.0821	0.0221	4	0.4078	0.2903	7	0.9378	-	1
	Feb-92	0.7349	0.0419	14	0.0834	.	1			
	Mar-92	0.1947	0.0924	4	0.5666	0.3635	3			
	Nov-92	0.3357	0.0325	23	0.5772	0.0630	5			
	Dec-92	0.2605	0.0407	31	0.2505	0.0250	18			
	Jan-93	0.1434	0.0235	24	0.3746	0.0708	32			
	Feb-93	0.0760	0.0232	11	0.0844	0.0123	18	0.1974	-	1
	Mar-93	0.0827	0.0095	10	0.0554	0.0090	3			
	Nov-93	0.1572	0.0265	24	0.1061	0.0096	5			
	Dec-93	0.1223	0.0126	26	0.3912	.	1			
	Jan-94	0.2649	0.0394	35	0.1387	0.0223	26			
	Feb-94	0.1003	0.0081	15	0.2475	0.0318	29	0.5508	-	1
	Mar-94	0.2844	.	1	0.0622	0.0146	5			

Appendix 5.4d. Estimates of mean monthly cpue (kg/prawner/hour) for Coila Lake. Data for tidal subareas are based on ebb-tide only.

Moon Phase	Month	Tidal scoop-nets mean	Tidal scoop-nets se	Tidal scoop-nets N	Non-tidal scoop-nets mean	Non-tidal scoop-nets se	Non-tidal scoop-nets N	Non-tidal drag-nets mean	Non-tidal drag-nets se	Non-tidal drag-nets N
Dark	Jan-92				0.1482	0.0252	25	0.1374	0.0382	4
	Feb-92	0.0212	0.0107	3				0.2160	0.0128	3
	Mar-92				0.1475	0.0348	12			
	Nov-92				0.2725	0.0540	11	0.8640	-	1
	Dec-92	0.2646	0.0387	30				0.3233	0.1850	4
	Jan-93	0.9258	0.1003	39				1.5789	1.5789	4
	Feb-93				0.4071	0.0452	24	0.4749	0.3051	2
	Mar-93				0.4607	0.0646	25	0.0000	0.0000	2
	Nov-93				0.0289	0.0069	17	0.0498	-	1
	Dec-93				0.0824	0.0173	48	0.0521	0.0387	4
	Jan-94				0.0998	0.0183	35			
	Feb-94				0.0743	0.0149	11			
	Mar-94				0.0492	0.0181	8			
Light	Jan-92				0.1155	0.0193	6	0.2802	-	1
	Feb-92	0.0335	0.0218	4						
	Mar-92									
	Nov-92				0.3268	0.0536	5			
	Dec-92	0.2514	0.0783	13				0.8214	0.8214	4
	Jan-93	0.0879	0.0094	28				0.0000	-	1
	Feb-93				0.0126	0.0126	2			
	Mar-93				0.3871	0.0767	10			
	Nov-93				0.0132	0.0052	10			
	Dec-93				0.0143	0.0030	7			
	Jan-94				0.0773	0.0100	23			
	Feb-94				0.0067	0.0067	7			
	Mar-94				0.0000	-	1			