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A 12-month survey of recreational fishing in the Swan-Canning Estuary Basin of Western Australia during 1998-99

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Cover photograph: Leesa King

FISHERIES
WESTERN AUSTRALIA

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The primary function of the Fisheries Research Division is to provide scientific advice to government in the formulation of management policies for developing and sustaining Western Australian fisheries.

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A 12-MONTH SURVEY OF RECREATIONAL FISHING IN THE SWAN-CANNING ESTUARY BASIN OF WESTERN AUSTRALIA DURING 1998-99

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Abstract

A survey of recreational boat-based and shore-based fishing in the Swan-Canning Estuary Basin was conducted between August 1998 and July 1999. During the survey 1,302 interviews were conducted at boat ramps. The majority of these (62%) were not involved in fishing or crabbing activities, with a further 18 per cent fishing in the adjacent ocean. Of the remainder, 139 boats had been crabbing and 154 angling (29 were both crabbing and angling) within the Swan-Canning Estuary Basin. In addition to the interviews at boat ramps, 378 shore-based fishing parties were interviewed.

The survey estimated the total annual boat-based recreational fishing effort as 22,265 fisher days, with 44 per cent of this effort targeting blue swimmer crabs. The total annual shore-based recreational fishing effort was estimated to be 8,073 fisher days, with only 9 per cent of this effort targeting blue swimmer crabs.

The estimated total recreational catch of blue swimmer crabs from the Swan-Canning Estuary Basin was 20,875 crabs or 7.3 tonnes. This consisted of a boat-based catch of 20,176 crabs and a shore-based catch of 699 crabs. Most crabs (94%) kept by recreational fishers were male.

The most common fish species kept by anglers in the Swan-Canning Estuary Basin are (in order of number kept) common blowfish, tailor, whiting other than King George, Australian herring, black bream, flathead, trumpeter and flounder.

There was a very high level of compliance with fishing regulations amongst all anglers and boat-based crabbers. However, 5.4 per cent of shore-based crabbing parties interviewed were found to have kept undersize crabs.

Less than one per cent of boats with two or more people on board achieved the daily boat limit of 48 crabs. However, a larger proportion (7.1%) of boats with only one person on board achieved their daily bag limit of 24 crabs. No anglers caught their daily bag limit of any fish species.

Summary

- A survey of recreational boat-based and shore-based fishing in the Swan-Canning Estuary Basin was conducted between August 1998 and July 1999. During the survey 1,302 interviews were conducted at boat ramps. The majority of these (62%) were not involved in fishing or crabbing activities, with a further 18 per cent fishing in the adjacent ocean. Of the remainder, 139 boats had been crabbing and 154 angling (29 were both crabbing and angling) within the Swan-Canning Estuary Basin. In addition to the interviews at boat ramps, 378 shore-based fishing parties were interviewed.
- The main species caught by recreational fishers in the Swan-Canning Estuary Basin between August 1998 and July 1999 were (in order of number kept) blue swimmer crabs (55%), common blowfish, tailor, whiting other than King George, Australian herring, black bream, flathead, trumpeter and flounder.
- The recreational catch for blue swimmer crabs is significant. The estimated recreational catch for August 1998 to July 1999 of 7.3 tonnes comprises 23 per cent of the combined commercial and recreational catch.
- The survey indicated that very few boats with two or more people on board (0.9%) achieve the daily boat limit of 48 crabs. A slightly larger proportion of boats with only one person on board (7.1%) achieve their daily bag limit of 24 crabs.
- The summer months are the most popular time for boat-based recreational crabbing and angling in the Swan-Canning Estuary Basin.
- There was generally a very high level of compliance with fishing regulations amongst all anglers and boat-based crabbers. However, 5.4 per cent of shore-based crabbing parties were found to have kept undersize crabs. No fishers exceeded the bag limits.
- Further monitoring of the recreational catch and effort in the Swan-Canning Estuary Basin is necessary to better assess the impact of recreational fishing on fish stocks. This information is necessary for the improved management of this important fishery.

1.0 INTRODUCTION

The Swan-Canning Estuary Basin, located in Perth, is one of the most popular estuaries for recreational fishing in the south-west of Western Australia. Blue swimmer crabs (*Portunus pelagicus*) are commonly caught by recreational boat-based fishers in the estuary basin, while many boat and shore based anglers target fish species such as tailor, black bream, flathead and Australian herring.

Participation in recreational fishing is increasing. A survey by the Australian Bureau of Statistics (ABS) in July 1987 estimated that of the 284,100 persons who had participated in recreational fishing in Western Australia during the previous 12 months, 77,300 had been crabbing (Anon. 1989). A more recent survey (Baharthah and Sumner, 1999) estimated that 544,300 Western Australians participate in recreational fishing at least once per year.

With such high participation rates in recreational fishing and limited resources available for exploitation, it is important to know the recreational catch and fishing effort for areas of potential high usage such as the Swan-Canning Estuary Basin. This information can be used to develop resource sharing strategies to ensure the sustainability of fishing activities and the conservation of fish stocks and fish habitats within the estuary basin.

Commercial crab catches in the Swan-Canning Estuary Basin have remained relatively stable over the last five years, but little is known about the recreational crab or fish catch and effort over the same period. The commercial and recreational effort expended on key species and the catch of these species is important for managing stocks of fish and crabs. This survey was, therefore, undertaken to estimate the recreational catch of fish and crabs and fishing effort for the Swan-Canning Estuary Basin.

The estuary basin, which was surveyed from the ocean to the Coode Street Jetty on the Swan River and Mount Henry Bridge on the Canning River, contains eight major public boat ramps (Figure 1). Creel surveys have been conducted in the region in previous years, however, these focussed on ocean based fishing and did not specifically take account of estuary fishing (Ayvazian *et al*., 1997; Sumner and Williamson, 1999).

2.0 METHODS

Information on the shore-based and boat-based recreational catch and fishing effort was obtained from creel surveys. Commercial catch and effort data was obtained from compulsory returns provided by these fishers.

2.1 Survey design

Catch and fishing effort information for recreational boat-based and shore-based fishing were required for the management of stocks of both fish and crab species caught in the Swan-Canning Estuary. However, since the primary focus of this study was blue swimmer crabs, recording the catch of fish species was a secondary objective. For this reason the study was restricted to the estuary basin, an area downstream from the Mount Henry Bridge on the Canning River and the Causeway on the Swan River.

The bus route method (Robson and Jones, 1989; Jones *et al*., 1990) was used to estimate the total catch and fishing effort for persons angling or crabbing from recreational trailer boats launched at boat ramps. A roving creel survey was used to estimate the catch and fishing effort from shore-based anglers and crabbers using drop nets from the shore.

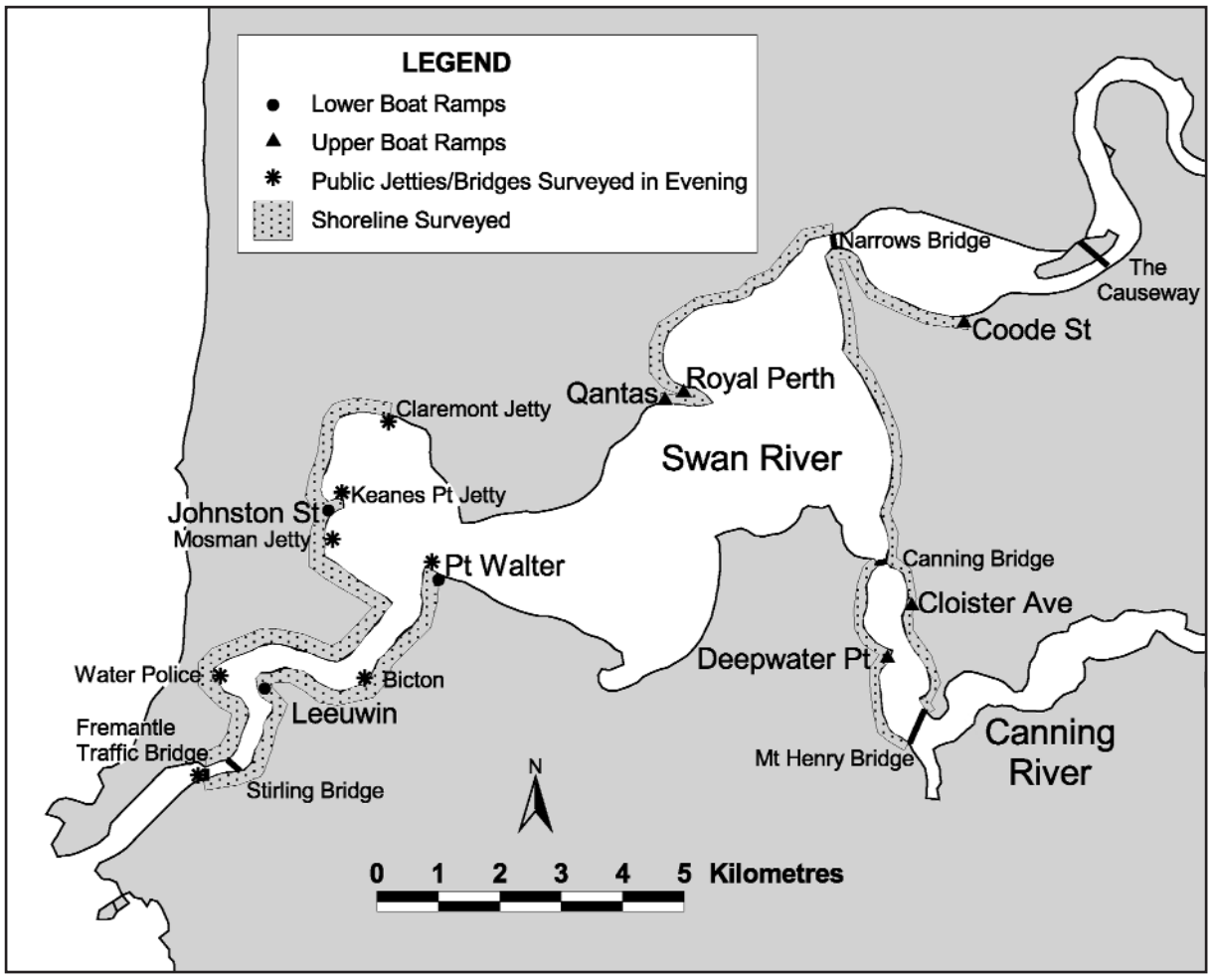

Figure 1 The Swan-Canning Estuary Basin showing sampling locations mentioned in the text

2.2 Spatial and temporal stratification

The survey spanned a 12-month period, commencing in August 1998 and concluding at the end of July 1999.

The survey was stratified by season (spring, summer, autumn or winter), time of day (morning or afternoon) and weekdays or weekends (including public holidays). Separate total catch estimates were made for each of these 16 strata (four seasons x two for mornings and afternoons x two for weekends and weekdays). The boat-based fishing effort estimates were further stratified by ramp, creating 128 strata (eight ramps), to account for the varying proportion of boats at each ramp which were crabbing or angling within the estuary basin, fishing outside the estuary basin or not fishing at all. These estimates were then combined to obtain the total recreational catch and effort for the estuary basin during the survey period.

The interviewers commenced work before fishers started returning to the boat ramps. Almost all recreational boats return to the boat ramps before dusk when the interviewer finished work at the last ramp visited. Periods of low fishing activity, such as during the night, could not be covered with the available resources. Although the incidental night-time crab catch by divers in the Swan-Canning Estuary Basin was therefore not included, anecdotal information obtained from Fisheries Officers and local recreational fishers suggested that, although night fishing occurred at certain times of year, the catch and fishing effort was insignificant and did not warrant special attention. The personal safety of interviewers working at night was also a concern.

An interviewer worked one shift (morning or afternoon) on each of the scheduled survey days. From November to March shifts were six hours, either 7:00 am to 1:00 pm or 1:00 pm to 7:00 pm. Due to fewer hours of daylight this was reduced to 5.5 hours, 7:00 am to 12:30 pm or 12:30 pm to 6:00 pm during April, May, September and October; and then further reduced to 4.5 hours 8:00 am to 12:30 pm or 12:30 pm to 5:00 pm during the winter months of June, July and August.

2.3 Sampling design

Boat-based fishing – bus route method

A creel survey was used to estimate the recreational boat-based catch for all species. The bus route method, where a survey interviewer visits all boat ramps in a pre-determined area on the one day, was used for boat-based fishing.

Two bus routes were set up (referred to as ‘upper’ and ‘lower’) to cover all boat ramps in the Swan-Canning Estuary Basin. Having the two areas, three boat ramps on the lower Swan and five on the upper Swan-Canning, meant that the survey interviewer could visit all boat ramps in the designated area each shift (Figure 1). The number of shifts conducted per month depended upon the season. More shifts were allocated to the seasons where most effort occurred, based on prior information on recreational fishing patterns (Sumner, unpublished data). Prior information suggested that fishing effort varied between the upper and lower ramps. More shifts were therefore allocated to the area where most effort occurred. An equal proportion of shifts were allocated to mornings and afternoons and weekdays and weekends (including public holidays). The number of survey shifts allocated per month varied from eight to 22, which is effectively four to 11 full days (Table 1).

Month	Number of upper shifts	Number of lower shifts	Total number of shifts
January	12	10	22
February	10	8	18
March	8	8	16
April	6	8	14
May	6	6	12
June	4	4	8
July	4	4	8
August	4	4	8
September	4	6	10
October	4	6	10
November	6	8	14
December	8	8	16

Table 1 Monthly allocation of survey shifts

The bus route schedules were constructed as described by Pollock *et al*., (1994). The start and wait time at boat ramps as well as the travel time between ramps were rounded to the nearest minute. A Mathcad (Mathsoft 1995) worksheet was developed by the authors to generate the randomised schedules.

The survey interviewer followed a pre-determined schedule specifying the boat ramps to visit and the sampling time for each boat ramp. The route was chosen to minimise the distance travelled between boat ramps. The starting location and direction of travel was chosen randomly. The bus route commenced either between ramps or at a ramp. The bus route method was constrained so that a shift could not commence part way through the wait time at a ramp, although the probability of commencing at a ramp or travelling remained unchanged. On average, visits to each site were likely to occur over all daylight hours throughout each season. A similar modification of the bus route method was used by McGlennon and Kinloch (1997).

The initial allocation of wait time to each ramp was proportional to ramp use based on anecdotal information from Fisheries Officers and local fishers. This was revised after two months once data from the survey became available (Table 2).

Area	Ramp	Proportion of time
Upper	Royal Perth	0.27
Upper	Qantas	0.14
Upper	Deepwater Point	0.27
Upper	Cloister Avenue	0.05
Upper	Coode Street	0.27
Lower	Leeuwin	0.35
Lower	Point Walter	0.35
Lower	Johnston Street	0.30

Table 2 Allocation of time to survey ramps

The eight boat launching ramps within the Swan-Canning Estuary Basin were divided into two areas, three boat ramps on the lower Swan and five on the upper Swan-Canning, so that a survey interviewer could visit all boat ramps in the designated area each shift (Figure 1, Table 2).

Within each season, a random sample of survey days was chosen. When it was not possible for recreational anglers to fish due to severe weather conditions, the survey was not conducted and it was

assumed that there was zero catch and effort for the shift. This decision was made by the survey interviewer on the day after assessing and recording the weather conditions and confirming that no recreational boats had been launched. On a small number of occasions, additional survey days were allocated to allow for severe weather conditions. It was assumed that the number of days when recreational fishing was not possible due to severe weather was representative of the season.

Catch, effort, biological and demographic information were collected from boat-based fishers when they returned to the boat ramp. One form was used to record the environmental conditions, boat launches and retrievals while the interviewer was at a boat ramp (Appendix A). Only recreational boat trailers were counted at the boat ramps; these could be distinguished from trailers used by professional fishers. A second form was used to record the time spent fishing, catch and other information for individual boats (Appendix B). For boat-based fishers the catch was recorded at the completion of the day's fishing and represented the entire catch for the duration of the trip. The catch of each species was identified, counted, measured and where possible the sex recorded. For crabs, the carapace width (CW) was measured to the nearest millimetre while the total length in millimetres was recorded for fish.

Field staff were instructed to measure all fish or crabs that were seen during interviews. However, since it was more important to collect as much basic catch information from as many anglers as possible, when several boats returned to a ramp at the same time it was not always possible to measure all the crabs and fish in the catch. When this happened, a random sample of the crabs or fish of each species was measured. A random sample, rather than all of the catch, was also measured when fishers were in a hurry to leave the ramp.

Shore-based fishing – roving creel survey

A roving creel survey was used for the survey of shore-based fishers. These included anglers and crabbers using drop nets from the shore.

Effort information for shore-based fishers was collected during the bus route surveys. Progressive counts of shore-based fishers were made while the interviewer drove from one boat ramp to the next according to a randomised time schedule. The boat ramps were used as checkpoints along the route. Although this covered most shore-based fishing locations the shoreline between Claremont Jetty and Qantas boat ramp and between Point Walter and Canning Bridge was not surveyed (Figure 1). The schedule design allowed time for a small number of interviews between check points. This enabled most shore-based fishers to be interviewed when encountered. The interview questionnaire used for boat-based fishers (Appendix B) was also used to record time spent fishing, catch and other information for shore-based fishers.

On the 'lower' bus route, the survey of shore-based fishers was extended to include the catch and effort for fishers fishing from jetties and bridges around dusk. At the conclusion of an afternoon shift on the lower bus route the interviewer visited each of the six jetties/bridges indicated in Figure 1. An instantaneous count of fishers was made on arrival at each bridge/jetty before interviews were undertaken using the interview questionnaire shown in Appendix C.

2.4 Estimation of total catch and effort for boat-based fishers

The fishing effort (boat hours) for a day was estimated from the counts of the number of trailers at the boat ramps. This was converted to fisher days by taking into account the average number of fishers per boat and average time spent fishing. Catch rates were estimated from information on the time spent fishing and catch obtained by interviewing anglers and crabbers when they returned to the boat ramp at the completion of the fishing trip. The total catch was estimated by multiplying the catch rate by the estimate of fishing effort in fisher hours. Separate catch and effort calculations were performed for estuarine crabbing and angling (Appendix D).

The unit of effort (number of trailers counted at the boat ramps) for each season was adjusted to correct for the number of recreational boats not involved in fishing activities. The trailer counts were multiplied by the proportion of boats interviewed that were participating in recreational fishing in the estuary basin.

Fishing effort by fishers from boats that were launched before the start of a morning shift (7:00 am or 8:00 am in winter) and returned after the start of a morning shift was also taken into account. The ratio of effort occurring prior to the start of a morning shift to that occurring after the start of a morning shift was estimated and a correction factor (f) applied to the effort estimate in the mornings for each season (Appendix D).

Where possible the whole weight of the catch, in kilograms, was estimated from length to weight relationships for each species (Appendix E).

2.5 Estimation of total catch and effort for shore-based fishers

The hours of fisher effort for the day were calculated by multiplying the progressive counts by the average number of hours in the fishing day. Catch rates were estimated from information on the time spent fishing and catch obtained by interviewing anglers and crabbers while they were still fishing. The total catch was estimated by multiplying the catch rate by the estimate of fishing effort in fisher hours. Separate catch and effort calculations were performed for estuarine crabbing and angling (Appendix F).

The whole weight of the catch, in kilograms, was estimated from length-weight relationships for each species (Appendix E).

3.0 RESULTS

During the survey 1,302 interviews were conducted at boat ramps. The majority of these (62%) were not involved in fishing or crabbing activities, with a further 18 per cent fishing in the adjacent ocean. Of the remainder, 139 boats had been crabbing and 154 angling (29 were both crabbing and angling) within the Swan-Canning Estuary Basin.

Blue swimmer crabs were the target species for 42 per cent of recreational boat-based fishers interviewed in the Swan-Canning Estuary Basin. Of the remaining boat-based fishers, 47 per cent targeted fish such as tailor, black bream and flathead while 11 per cent targeted both blue swimmer crabs and fish.

In addition to the interviews at boat ramps, 378 shore-based fishing parties were interviewed. Thirty-seven of these groups were crabbing and 374 were angling (33 were both crabbing and angling).

3.1 Recreational fishing effort

3.1.1 Boat-based effort

Results indicate that most fishing occurred during the two survey periods of the day, referred to as a morning or afternoon shift. However, fishing also occurred both before and after the survey period as indicated by the boat launch and retrieval times. Fishing by boats that were launched before the start of a morning shift (7:00 am in spring, summer and autumn or 8:00 am in winter) and returned after the start of a morning shift was taken into account. The ratio of fishing effort occurring prior to the start of a morning shift to that occurring after the start of a morning shift was estimated and a correction factor (*f*) applied to the effort estimate in the mornings for each season (Table 3 and Appendix D).

Season	Ratio of effort prior to start to after start	Correction factor (*f*)
Summer	0.314	1.314
Autumn	0.131	1.131
Winter	0.365	1.365
Spring	0.156	1.156

Table 3 Correction factor for fishing effort occurring before the start of a morning shift

Most boats had returned to the ramp before the end of an afternoon shift (7:00 pm during January, February, March, November and December, 6:00 pm during April, May, September and October and 5:00 pm during June, July and August). The number of boats returning after this time of the day, based on the number of trailers remaining, was relatively small (around four per ramp on average between November and March) (Figure 2).

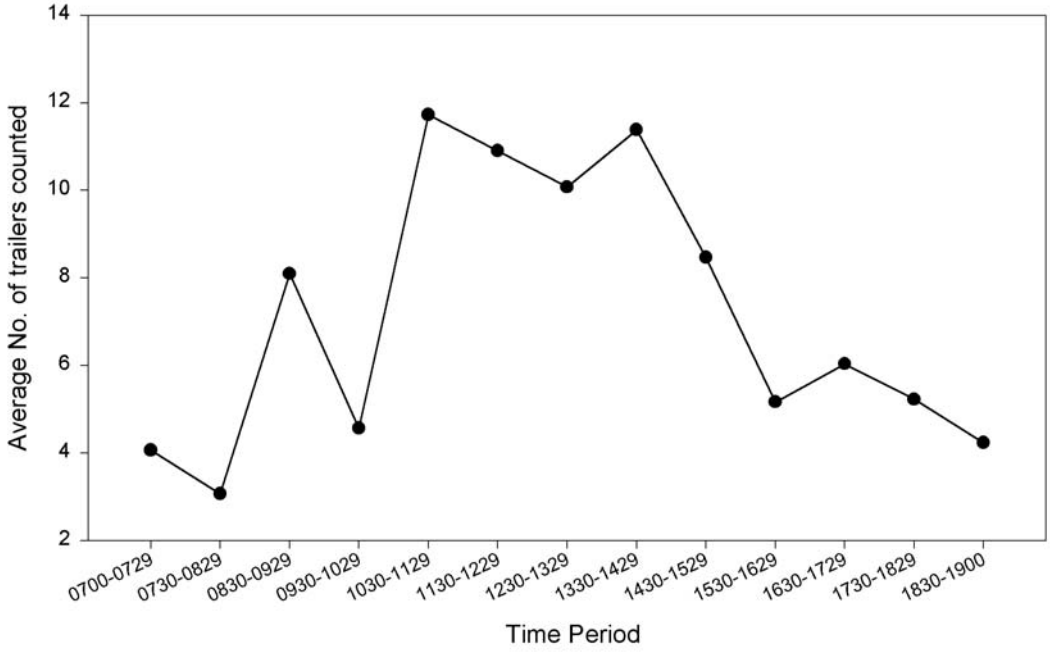

Figure 2 Average number of trailers counted on arrival/departure at all ramps (November to March)

Boat-based crabbing effort

Boat-based crabbers used drop nets to catch crabs. No boat-based divers targeting crabs were recorded.

The recreational boat-based crabbing effort was greatest in summer with 63% of the annual crabbing effort occurring during this period (December to February). Autumn was the next most popular season for boat-based crabbing followed by spring. Very little crabbing took place during winter (Figure 3). The majority of boat-based crabbing took place from the lower boat ramps, although during summer more of the crabbing effort (57%) was from the upper boat ramps. Very few people went crabbing from the upper boat ramps during the remainder of the year (Figure 3).

The recreational crabbing effort varied from 455 fisher days during winter to 5,209 fisher days for summer (Figure 3).

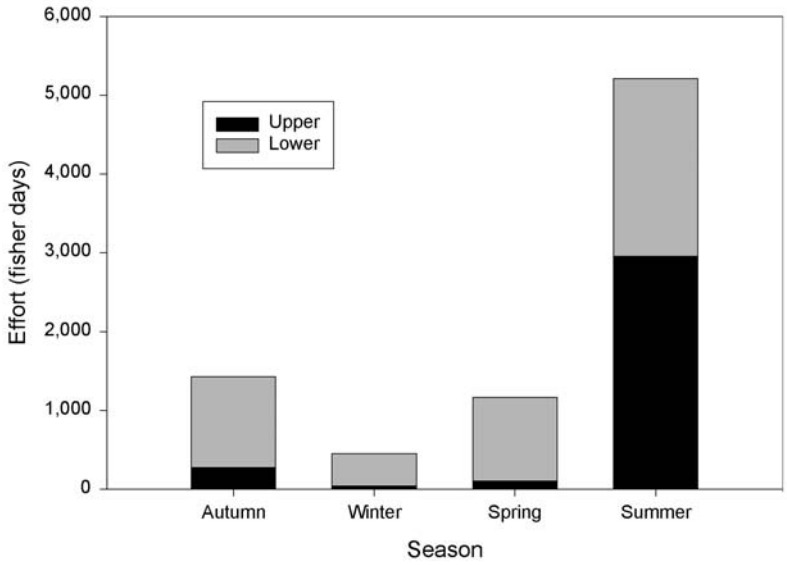

Figure 3 Recreational boat-based crabbing effort

The estimated total annual recreational boat-based crabbing effort for the Swan-Canning Estuary Basin was 8,258 fisher days (15,402 boat hours).

Boat-based angling effort

Anglers were considered to be people targeting fish using one or more fishing lines.

Summer is the most popular season for angling in the Swan-Canning Estuary Basin. The effort is considerably less during autumn, winter and spring (Figure 4).

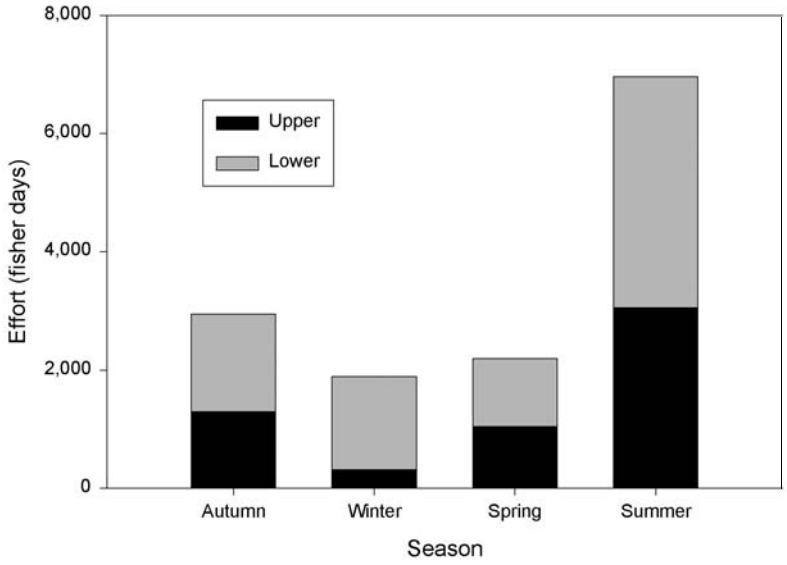

Figure 4 Recreational boat-based angling effort

The lower boat ramps were more popular with estuary anglers. The upper ramps are less popular, particularly in winter, although they are used by estuary anglers throughout the year (Figure 4).

The estimated annual recreational boat-based angling effort for the Swan-Canning Estuary Basin was 14,007 fisher days (19,287 boat hours).

3.1.2 Shore-based effort

Shore-based crabbing effort

All shore-based crabbers encountered were fishing from jetties and bridges using drop nets. No shore-based crabbers with scoop nets or divers targeting crabs were recorded.

The majority of shore-based crabbing (52%) took place in spring, with a total of 382 fisher days. There was a similar amount of effort in both autumn and summer and no shore-based crabbing recorded during winter (Figure 5).

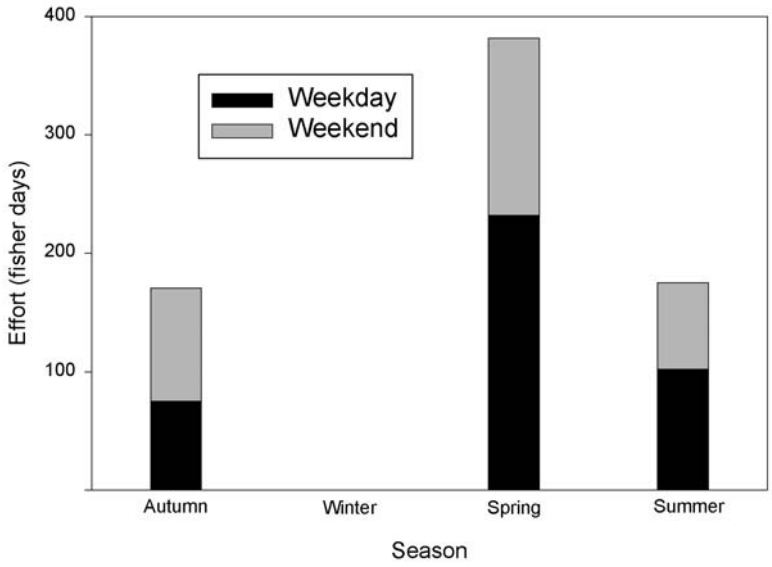

Figure 5 Recreational shore-based crabbing effort

The estimated total annual recreational shore-based crabbing effort for the Swan-Canning Estuary Basin was 728 fisher days (1,583 fisher hours).

Shore-based angling effort

Autumn is the most popular season for shore-based estuary angling in the Swan-Canning Estuary Basin followed by summer (Figure 6).

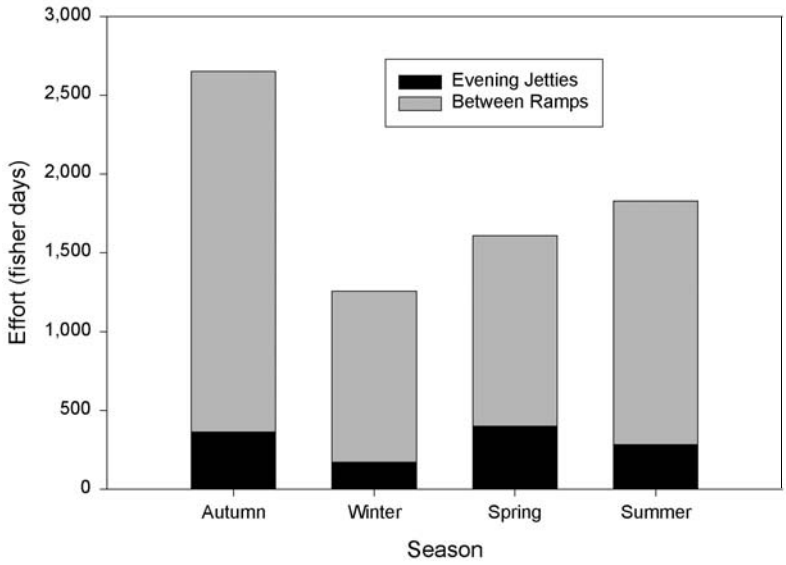

Figure 6 Recreational shore-based angling effort

The estimated annual recreational shore-based angling effort for the Swan-Canning Estuary Basin was 7,345 fisher days (20,666 fisher hours).

3.2 Recreational catch of blue swimmer crabs

3.2.1 Size frequency

The size frequency for blue swimmer crabs displayed in Figure 7 shows the carapace width (CW) range for crabs kept by both boat and shore-based crabbers.

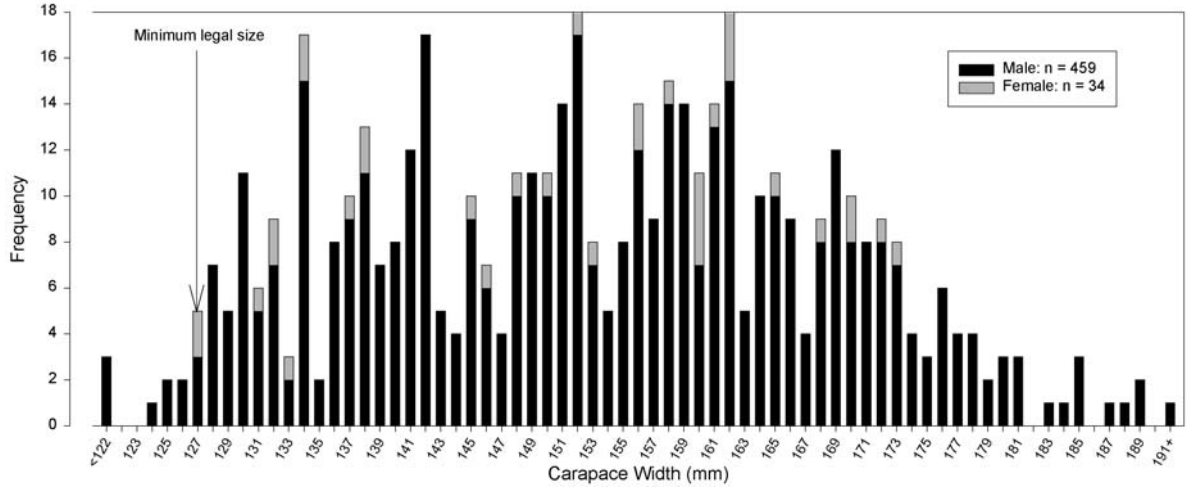

Figure 7 Size frequency for blue swimmer crabs kept

There was a relatively even distribution of crabs from the legal size of 127mm up to 173mm. Crabs as small as 120mm CW and as big as 194mm CW were kept by recreational crabbers. No female crabs bigger than 173mm were recorded (Figure 7).

3.2.2 Boat-based catch

Of the crabs kept for which sex was recorded, 745 (95%) were males and 40 (5%) females. The sex of crabs released was also recorded where possible; of these 265 (70%) were males and 112 (30%) females.

	Total	Standard error
Number kept	20,176	1,674
Number released	9,952	1,296
Weight kept (tonnes)	7.1	565
Catch rate (crabs/boat/hour)	1.36	0.19
Catch rate (crabs/net/trip)	0.68	0.08
Catch rate (crabs/boat/trip)	5.86	0.71

Table 4 Estimated recreational boat-based catch of blue swimmer crabs

An estimated 20,176 crabs were kept (1,028 females and 19,148 males) and 9,952 released (2,957 females and 6,995 males) by boat-based crabbers during 1998-99 (Table 4). The error associated with the estimate of the number of crabs kept was calculated; the standard error for the estimated number kept $SE(\hat{c})$ was 1,674. If we assume a student t distribution, the (1-α) percent confidence interval for the number kept ($\hat{c}$) can be calculated from the standard error

$$\hat{c} \pm t(1-\alpha/2\,;n-1)\,SE(\hat{c})$$
$$\hat{c} \pm t\,1.96\;SE(\hat{c}) \qquad (1)$$

where $\alpha = 0.05$ for the 95% confidence interval and n is the number of boats surveyed (sample size).

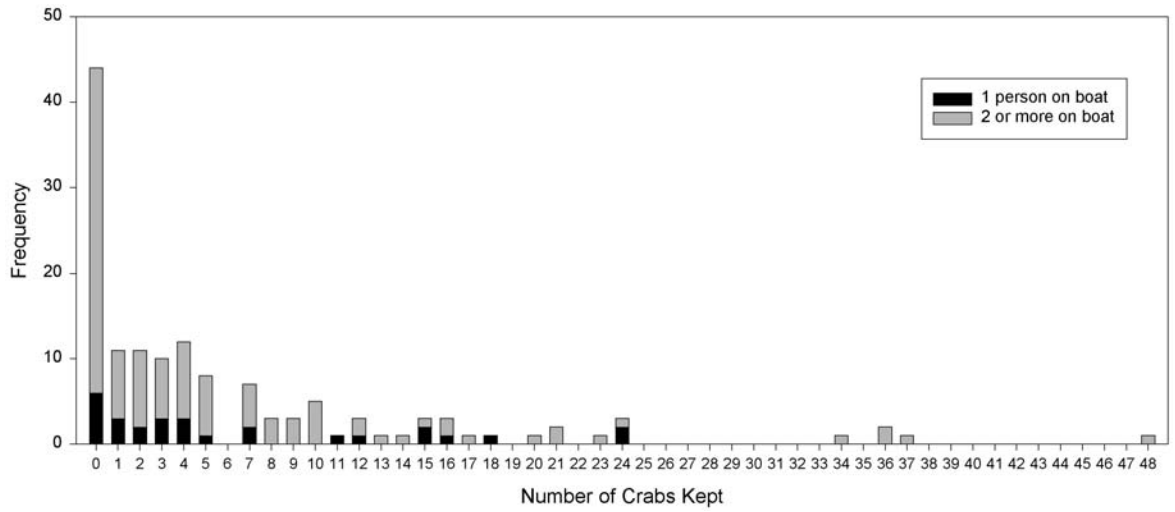

Figure 8 Frequency of crabs kept per boat

Only one of the 112 boats interviewed with two or more on board achieved the boat limit of 48 crabs. However, two of the 28 boats with only one person on board achieved the daily bag limit of 24 crabs. The majority of boats targeting crabs (69%) caught five or less crabs, with 31% of boats not keeping any crabs at all (Figure 8).

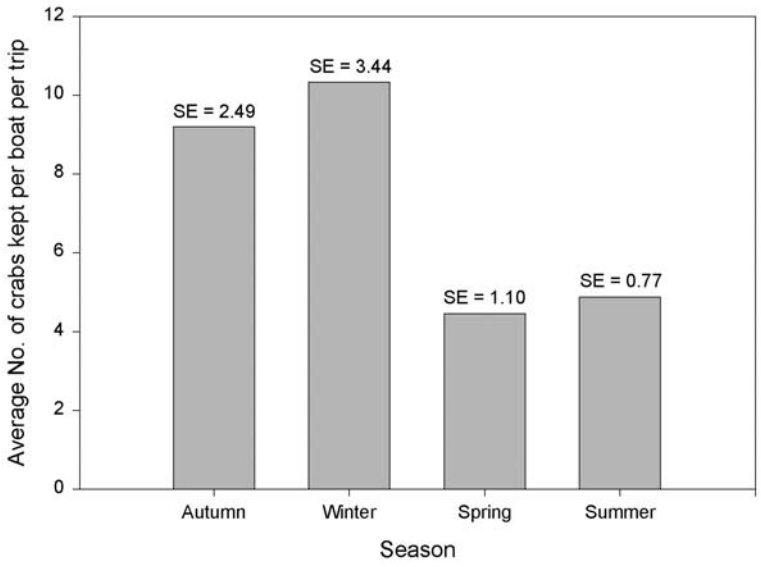

Figure 9 Crab catch rates per season for boat-based fishers

Catch rates peaked at 10.3 crabs per boat per trip during winter. During summer when the majority of effort occurred, the catch rate was only 4.9 crabs per boat per trip (Figure 9).

Most (44%) of the recreational crab catch made by boat-based fishers was made in the summer months, 31 per cent was caught during autumn, 13 per cent in winter and 12 per cent during spring (Figure 10).

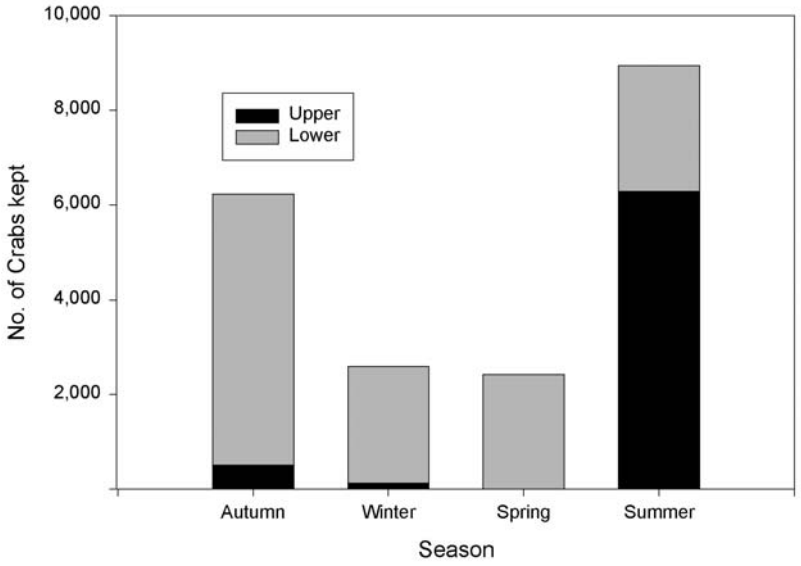

Figure 10 Estimated number of crabs kept per area per season

The majority of crabs kept were from boats launched from the boat ramps in the lower reaches of the Swan River. Almost all crabs were landed from the lower boat ramps during autumn, winter and spring. However, in accordance with the effort most crabs were landed at the upper ramps during summer (Figure 10).

Female crabs comprised 26 per cent of the crabs kept during winter but less than 10 per cent of the crabs kept during summer, autumn and spring. However, of the crabs released, 55 per cent were females during winter and around 30 per cent were females during summer, autumn and spring (Figure 11).

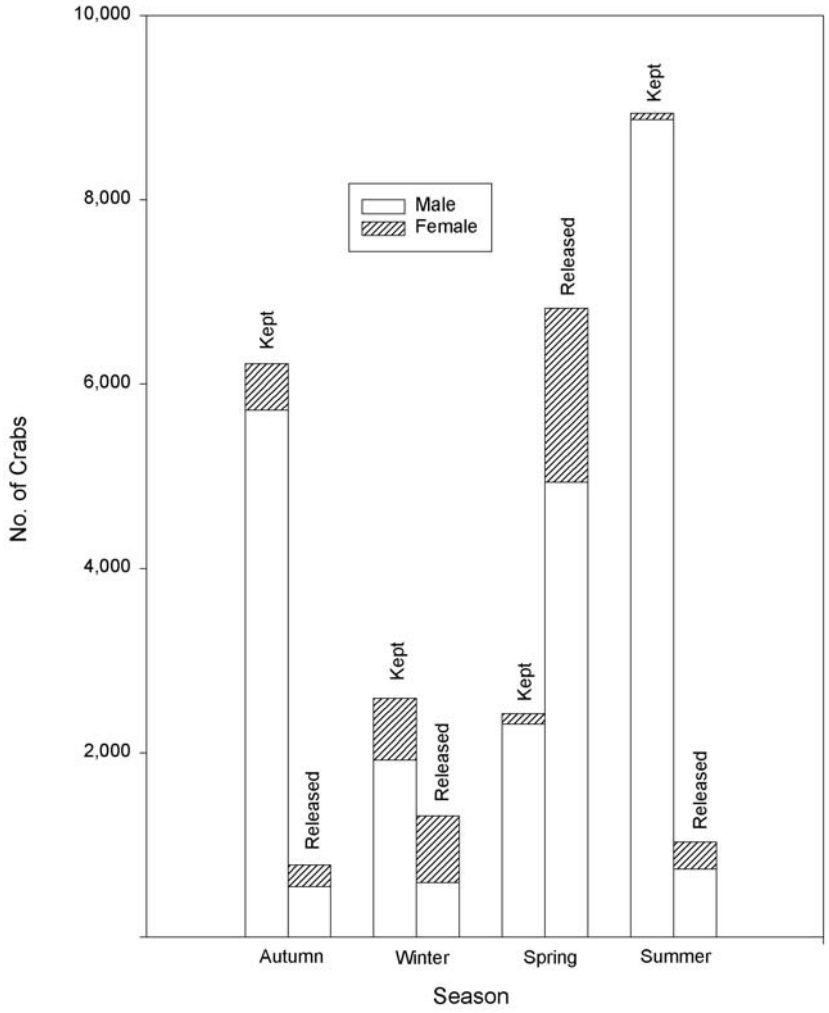

Figure 11 Estimated number of crabs kept and released per season by boat-based crabbers

During autumn and summer for every crab released by recreational boat-based crabbers there were eight crabs kept. However, during spring there were almost three crabs released for each one kept (Figure 11).

The total annual weight of crabs kept by recreational boat-based crabbers in the Swan-Canning Estuary Basin was estimated to be 7.1 tonnes (6.8 tonnes of males and 0.3 tonnes of females) (Table 4).

3.2.3 Shore-based catch

Of the crabs kept for which sex was recorded, 20 (65%) were males and 11 (35%) females. The sex of crabs released was also recorded where possible; of these 21 (46%) were males and 25 (54%) females.

	Total	Standard error
Number kept	699	166
Number released	651	111
Weight kept (tonnes)	0.19	0.04
Catch rate (crabs/person/trip)	0.57	0.19
Catch rate (crabs/person/hour)	0.27	0.10
Catch rate (crabs/party/trip)	1.57	0.51

Table 5 Estimated recreational shore-based catch of blue swimmer crabs

An estimated 699 crabs were kept and 651 released by shore-based crabbers (Table 5).

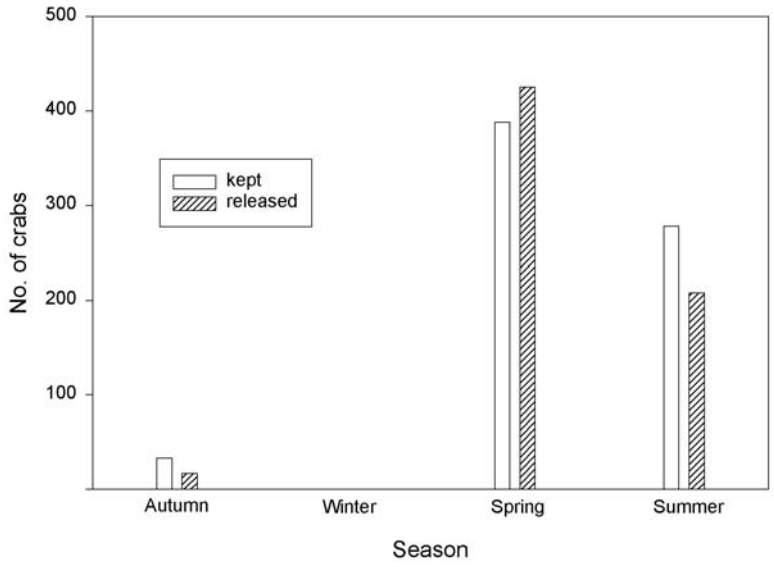

Figure 12 Estimated number of crabs kept and released per season by shore-based crabbers

Most (56%) of the crabs kept by shore-based crabbers were caught in spring (Figure 12). A further 40 per cent of the catch was made in summer. During both spring and summer there were similar numbers of crabs kept and released. Very few crabs were caught in autumn and no crabs were recorded during winter (Figure 12).

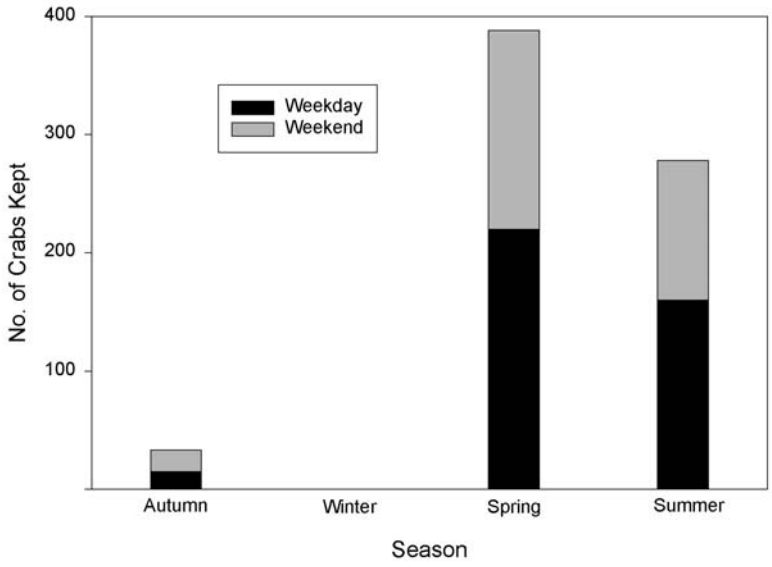

Figure 13 Estimated number of crabs kept per season per weekday/weekend by shore-based fishers

A similar proportion of the crabs kept by shore-based fishers were caught on weekdays and weekends (Figure 13).

The total annual weight of crabs kept by recreational shore-based crabbers in the Swan-Canning Estuary Basin was estimated to be 0.19 tonnes (0.13 tonnes of males and 0.06 tonnes of females) (Table 5).

3.2.4 Total catch of blue swimmer crabs

The total recreational harvest of blue swimmer crabs from the Swan-Canning Estuary Basin during 1998-99 is estimated to have been 20,875 crabs (or 7.3 tonnes). It is also estimated that 10,603 crabs were released by recreational fishers during the 12 month period (Table 6).

	Boat	Shore	Total	Standard error
Number kept	20,176	699	20,875	1,682
Number released	9,952	651	10,603	1,301
Weight kept (tonnes)	7.1	0.2	7.3	0.6

Table 6 Estimated total recreational catch of blue swimmer crabs

3.3 Recreational catch of fish

A total of 18 species of fish were kept by recreational anglers in the Swan-Canning Estuary Basin (Appendix G). Of these, only 12 species were caught in sufficient numbers for the annual catch to be estimated. The species composition of fish caught by boat and shore-based anglers is shown in Figures 14 and 15.

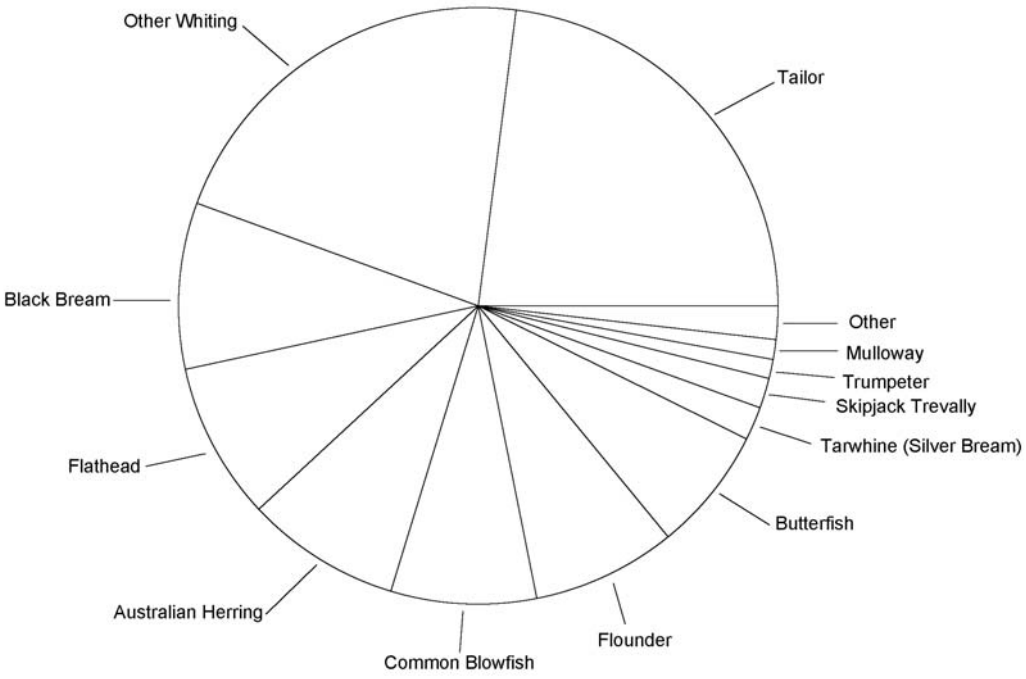

Figure 14 Species composition of recreational boat-based fish catch

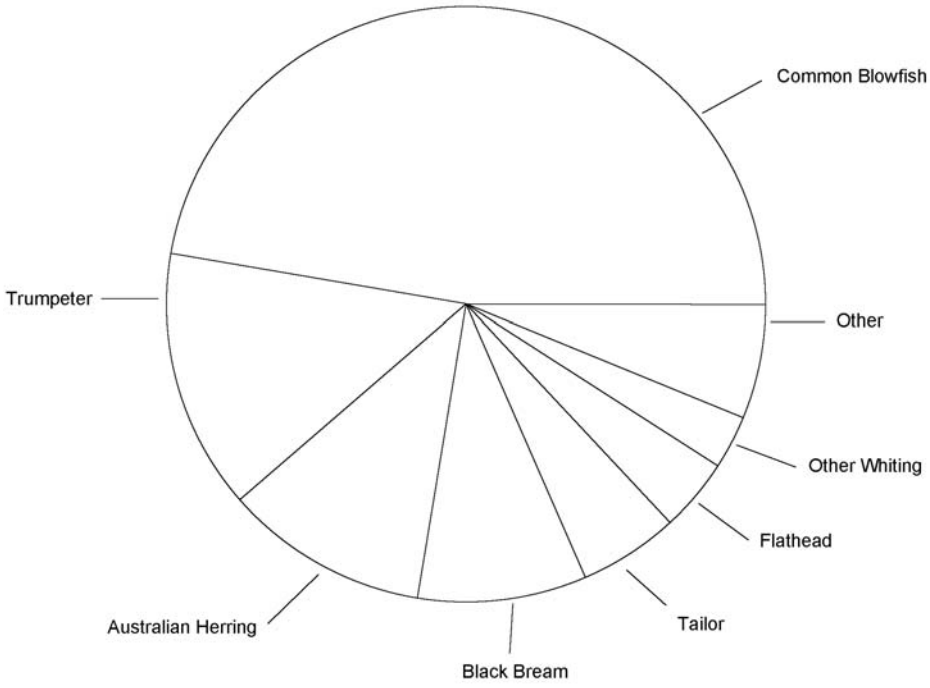

Figure 15 Species composition of recreational shore-based fish catch

3.3.1 Boat-based catch

Tailor were the most commonly kept fish by boat-based anglers in the estuary basin with an estimated annual catch of 2,306 fish (Table 7). Whiting other than King George (*Sillago* spp.) were the next most common fish kept with an estimated annual catch of 2,153 fish. Other important species were black bream with an estimated annual catch of 900 fish kept, flathead with an annual estimate of 849 fish kept and Australian herring with an annual estimate of 843 fish kept. Common blowfish were the most commonly caught species with an estimated 793 fish kept and 14,086 released.

Common name	Scientific name	Number kept	SE kept	Number released	SE released
Tailor	*Pomatomus saltatrix*	2,306	256	271	53
Other Whiting	*Sillago* spp.	2,153	714	900	286
Black Bream	*Acanthopagrus butcheri*	900	227	1,449	242
Flathead	*Platycephalus* spp.	849	115	1,233	169
Australian Herring	*Arripis georgianus*	843	152	105	26
Common Blowfish	*Torguigener pleurogramma*	793	189	14,086	928
Flounder	*Pseudorhombus* spp.	775	136	765	123
Western Australian Butterfish	*Pentapodus vitta*	681	238	327	114
Silver Bream (Tarwhine)	*Rhabdosargus sarba*	181	34	903	126
Skipjack Trevally	*Pseudocaranx spp.*	160	27	73	21
Trumpeters	*Teraponidae family*	107	37	400	60
Mulloway	*Argyrosomus hololepidotus*	107	37	0	0

Table 7 Estimated recreational boat-based fish catch

Small quantities of wrasse (*Labridae* family), red gurnard (*Chelidonichthys kuma*), yellow-eye mullet (*Aldrichetta forsteri*) and Ogilby's hardyhead (*Pranesus ogilbyi*) were also kept by recreational boat-based anglers.

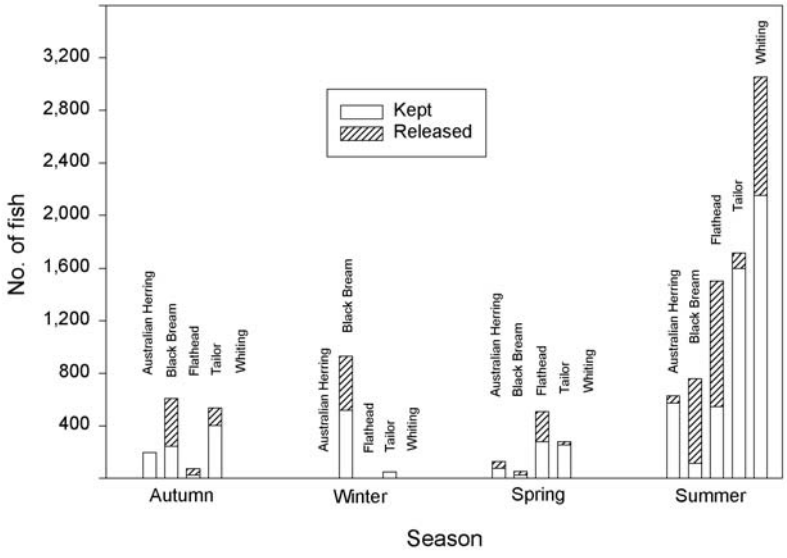

Figure 16 Estimated catch of predominant fish species per season

The fish species that dominated the catch depended on the season. Black bream were the most commonly caught fish species in autumn, although as more than half of these fish were released, tailor were the most commonly kept fish. Black bream were clearly the dominant species caught in winter while flathead was the most common species in spring. During summer whiting other than King

George, which were not caught at any other time of year, were the most common species caught. Good numbers of tailor were also kept during summer (Figure 16).

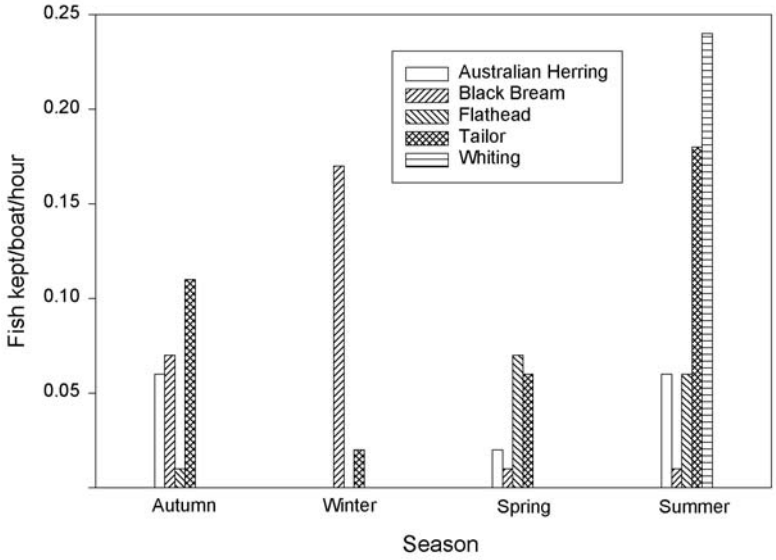

Figure 17 Angling catch rates per season (fish kept/boat/hour)

The best catch rate for a single fish species of just under 0.25 fish kept/boat/hour was found for whiting other than King George during summer. The next best catch rate of around 0.17 fish kept/boat/hour was found for both black bream during winter and tailor during summer (Figure 17).

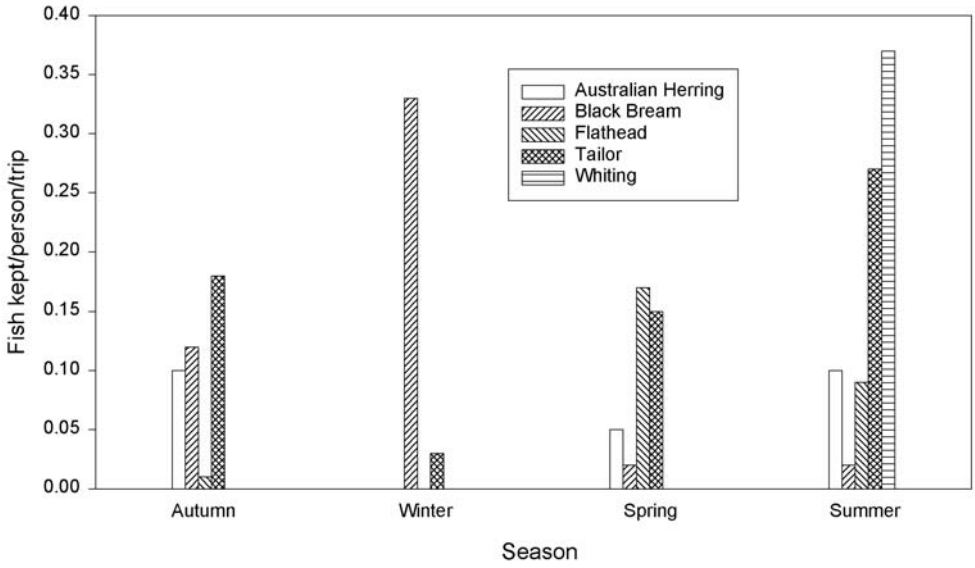

Figure 18 Angling catch rates per season (fish kept/person/trip)

Catch rates in fish kept/person/trip (Figure 18) follow a similar trend to fish kept/boat/hour, with the exception of the black bream catch rate during winter which is almost as high as the whiting other than King George catch rate in summer.

The total weight of tailor kept by boat-based fishers in the estuary basin was estimated at 0.73 tonnes, followed by 0.50 tonnes of black bream, 0.25 tonnes of flathead, 0.20 tonnes of whiting other than King George, and 0.12 tonnes of Australian herring.

3.3.2 Shore-based catch

Common blowfish were the most commonly caught fish by shore-based anglers in the estuary basin with an estimated annual catch of 3,544 fish kept. Trumpeters were the next most common species with an estimated annual catch of 1,049 fish kept. It is also estimated that 831 Australian herring and 699 black bream were kept (Table 8).

Common name	Scientific name	Number kept	SE kept	Number released	SE released
Common Blowfish	*Torguigener pleurogramma*	3,544	777	24,801	2,792
Trumpeters	*Teraponidae family*	1,049	207	1,887	316
Australian Herring	*Arripis georgianus*	831	288	41	9
Black Bream	*Acanthopagrus butcheri*	699	182	927	158
Tailor	*Pomatomus saltatrix*	406	113	336	107
Flathead	*Platycephalus* spp.	302	93	370	95
Other Whiting	*Sillago* spp.	182	53	75	19

Table 8 Estimated recreational shore-based fish catch

Small quantities of silver bream (*Rhabdosargus sarba*), mullet (*Mugilidae* family), gobbleguts (*Apogon rueppellii*), flounder (*Pseudorhombus* spp.), skipjack trevally (*Pseudocaranx* spp.), Western Australian butterfish (*Pentapodus vitta*) and yellowtail scad (*Trachurus novaezelandiae*) were also kept by recreational shore-based anglers.

The total weight of black bream kept in the estuary basin was estimated to be 0.31 tonnes, followed by 0.12 tonnes of Australian herring, 0.12 tonnes of flathead and 0.09 tonnes of tailor.

The overall combined boat-based and shore-based catch of the five key species (tailor, whiting other than King George, Australian herring, black bream and flathead) was estimated to be less than three tonnes. However, since the primary focus of the study was blue swimmer crabs rather than fish, the black bream catch has been greatly underestimated since much of the recreational catch of black bream occurs upstream of the estuary basin.

3.4 Commercial catch and effort for blue swimmer crabs

During 1998-99 the commercial blue swimmer crab catch of 24.0 tonnes was more than three times the recreational catch. The commercial crabbing effort was 557 boat days during this period.

The annual commercial crab catch between 1991-92 and 1998-99 ranged from 8.6 tonnes in 1991-92 to a high of 30.6 tonnes in 1997-98 (Figure 19). The mean annual crab catch for these years was 18.8 tonnes. The annual crabbing effort in boat days per year ranged from 492 days in 1993-94 to 825 days in 1997-98 (Figure 19).

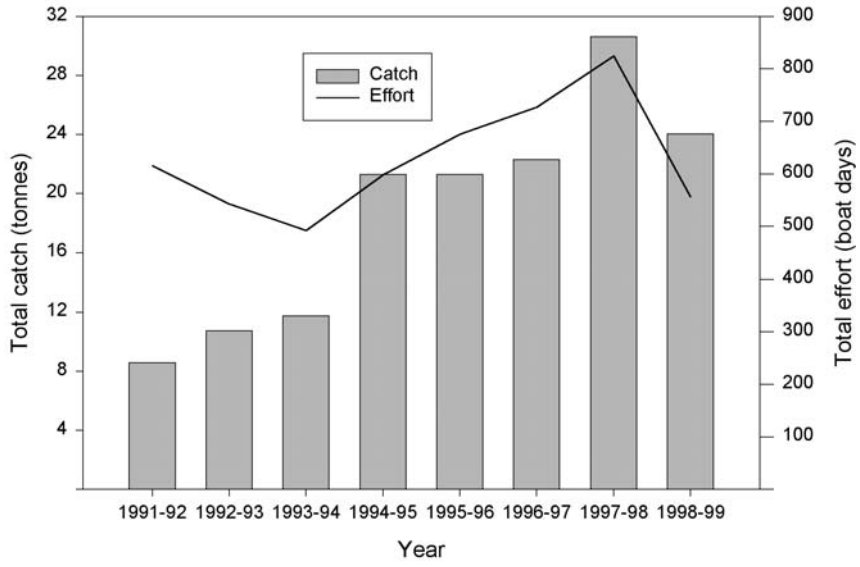

Figure 19 Annual commercial catch and effort for blue swimmer crabs in the Swan-Canning Estuary Basin (1991-92 to 1998-99)

3.5 Commercial catch and effort for fish

During 1998-99 the commercial fish catch in the Swan-Canning Estuary Basin was 43.0 tonnes. This consisted of 18 species categories, 13 of which are single species (Appendix H). The catch was predominantly sea mullet (17.4 tonnes) and Perth herring (16.1 tonnes). The next biggest catch was of yellow-eye mullet (3.0 tonnes). The fishing effort was 736 boat days.

The annual commercial fish catches in the Swan-Canning Estuary Basin between 1989-90 and 1998-99 ranged from 43.0 tonnes in 1998-99 to 115.0 tonnes in 1991-92 (Figure 20) with a mean annual catch of 69.7 tonnes. The annual commercial effort in days spent fishing per year ranged from 1,431 days in 1991-92 to 736 days in 1998-99 (Figure 20).

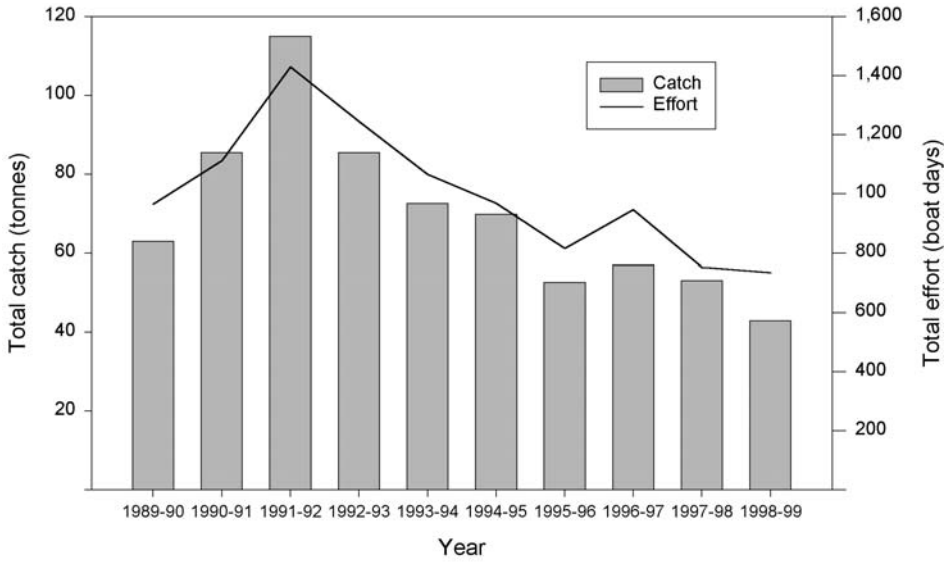

Figure 20 Annual commercial catch and effort for all fish species in the Swan-Canning Estuary Basin (1989-90 to 1998-99)

3.6 Fishing regulations

Only one of the 112 boats interviewed (0.9%), with more than one person on board, that had been crabbing achieved the boat limit of 48 crabs specified under current statewide recreational fishing regulations. However, two of the 28 boats interviewed (7.1%), with only one person on board, achieved the bag limit of 24 crabs per person.

No anglers interviewed achieved their daily bag limit of any fish species and no crabbers interviewed exceeded their bag or boat limit of crabs.

There was a very high level of compliance with the size limits amongst boat-based fishers. Only three (2.2%) of the 139 boats crabbing had kept undersize crabs while only 1.3 per cent of boats angling had kept undersize fish.

Compliance rates were lower amongst shore-based crabbers with two (5.4%) of the 37 shore-based crabbing parties interviewed having kept undersize crabs. A further 10 (2.6%) of the 378 shore-based angling parties interviewed were found to have kept undersize fish.

4.0 DISCUSSION OF RESULTS

The bus route method estimates fishing effort from the amount of time boat trailers are present at boat ramps. The effort includes the elapsed time between the boat launch and boat retrieval rather than the time spent fishing. Furthermore, the effort for the bus route method includes travelling time between the boat ramp and the fishing destination. In an estuary where the travelling time is small there will be close agreement between the effort estimated from the bus route method and the actual fishing time.

The bus route method, with adaptations, proved to be a suitable approach for estimating the recreational catch and effort for the Swan-Canning Estuary Basin. The survey method proved to be robust and was readily adapted to the area surveyed. The roving creel survey conducted while the interviewer was travelling from one boat ramp to the next worked well. Combining the two methods resulted in a significant saving of data collection costs.

The collection of effort information on shore-based fishers while the interviewer was driving between ramps had two advantages over using separate surveys for boat-based and shore-based fishing. Firstly, effort information on shore-based fishing could be collected while the interviewer drove from one ramp to the next during the bus route method reducing the data collection cost. Secondly, the schedule and checkpoints reduced bias normally associated with 'count-while-interviewing' methods. Without checkpoints, the movement of the interviewer slows down during busy times and speeds up when few fishers are encountered. This approach produces an under count of anglers since, while a fisher is being interviewed, the interviewer is unable to count or interview another angler elsewhere (Wade *et al*., 1991).

The results may slightly understate the recreational boat-based catch since the survey could not include any boats fishing after 7:00 pm (6:00 pm in April, May, September and October and 5:00 pm in June, July and August), and boats that had finished fishing and returned to the boat ramp before 7:00 am (8:00 am in winter). It is likely that most of the boats remaining at the end of an afternoon shift would return to the ramp before nightfall although this could vary depending on the time of the year. It was not, however, possible to account for boats that returned to the ramp after the end of an afternoon shift since no catch and effort information was collected beyond this time.

Similarly, the shore-based catch will also be slightly underestimated since any shore-based fishing, which was completed prior to the start of a morning shift or commenced after the completion of an afternoon shift, could not be accounted for. The jetties/bridges on the lower bus route were only surveyed on completion of an afternoon shift to take into account fishing that often occurred at that time of the day. The survey of shore-based fishing covered most, but not, all fishing locations in the estuary basin (Figure 1). The incidental night time catch by divers was also not included since it did not warrant special attention.

4.1 Blue swimmer crabs

The level of sampling (number of days worked by interviewers) gave estimates of the total recreational catch of blue swimmer crabs with an acceptable level of precision. The standard error was only 8 per cent of the estimated catch for boat-based crabbers and 24 per cent for shore-based crabbers.

Seasonal fluctuations in crabbing effort and catch for recreational boat-based crabbers were clearly evident, particularly between the upper and lower survey areas. This can be explained by the biology of blue swimmer crabs. Potter and de Lestang (in press) found that crab numbers in the Leschenault Estuary reach maximum levels from late spring through summer and into early autumn when salinities and water temperatures are at their highest. Crab numbers then decline from late autumn when the majority of crabs move out of the estuary as the salinity and water temperature drops. In the Swan-Canning Estuary Basin crab catches peaked in summer with most of the catch coming from the upper areas. This would have coincided with the peak in water temperature and salinity in this upper area. Crab catches then declined in autumn as the water temperature and salinity in the upper areas began to drop.

The crabs caught (both kept and released) during summer were predominantly males, indicating that the females, which were more common during the previous spring, may have either stayed in the more saline lower reaches or moved out to sea. This may be linked to spawning which generally occurs in the Peel-Harvey and Leschenault Estuaries during summer (Potter *et al*, 1983, 1998, Potter and de Lestang (in press)).

Catch rates were high for the few people who targeted crabs in the lower reaches during autumn and winter, indicating that many crabs had not left the estuary but settled in the deeper semi-marine waters in the lower reaches of the estuary.

The large difference in the proportion of male to female crabs caught is supported by the results of research conducted in the Leschenault and Peel-Harvey Estuaries. The overall sex ratio of females to males for crabs caught (both kept and released) by recreational boat-based crabbers using drop nets was 1:3.5 in the Leschenault Estuary (Malseed *et al*., 2000) and slightly higher at 1:5.1 in the Peel-Harvey Estuary (Malseed and Sumner, 2001). In the Swan-Canning Estuary Basin the overall sex ratio of females to males was slightly higher again at 1:6.6.

Blue swimmer crabs are a key species for recreational boat-based fishers in the Swan-Canning Estuary Basin with 44 per cent of boat-based fishing effort targeting crabs. The estimated recreational catch for 1998-99 of 7.3 tonnes is significant and makes up almost a quarter of the combined recreational and commercial catch of 31.3 tonnes.

4.2 Fish

The estimates of recreational catch were less precise for fish species since they were caught in much smaller quantities than crabs. The standard error relative to the estimated catch for the key species caught by boat-based anglers were tailor 11 per cent, whiting other than King George 33 per cent, black bream 25 per cent, flathead 14 per cent and Australian herring 18 per cent.

The recreational fish catch from the Swan-Canning Estuary Basin during 1998-99 was smaller than the recreational crab catch. The overall combined catch of the five key species (tailor, whiting other than King George, Australian herring, black bream and flathead) was estimated to be less than three tonnes. However, since the primary focus of the study was blue swimmer crabs rather than fish, recreational shore-based fish catches have been underestimated as the shoreline between Claremont Jetty and Qantas boat ramp and between Point Walter and Canning Bridge was not surveyed (Figure 1) and jetties were not surveyed around dusk at upstream sites. Furthermore, the estimate of the recreational catch of black bream is not representative of the larger Swan-Canning river systems since most of the catch of black bream occurs upstream of the estuary basin.

The commercial catch during 1998-99 was much greater, around 43 tonnes, but was predominantly made up of mullets (sea and yellow-eye) and Perth herring which were not often caught by recreational anglers.

The commercial and recreational catch of tailor, Australian herring, flathead and whiting other than King George were of similar magnitude, however, the commercial data is not available for publication and direct comparison as fewer than five operators landed these species.

5.0 CONCLUSIONS

The study has provided information on the extent and distribution of recreational fishing effort. In the Swan-Canning Estuary Basin, recreational boat-based fishing effort is relatively evenly split between crabbing and angling with most effort occurring during the summer months.

The results show the importance of recreational fishing in the Swan-Canning Estuary Basin. It is suggested that further creel surveys are required on a regular basis, about every five years, to monitor the recreational catch for both the Swan-Canning Estuary Basin and all other estuaries throughout the state and to study long term trends in catch and catch rates.

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APPENDIX A: Boat ramp form

SWAN-CANNING RECREATIONAL FISHING SURVEY
BOAT RAMP FORM

Interviewer's Name: _____

Date: _____ **Start Time (24hr):** _____ **Finish Time (24hr):** _____

Boat Ramp Location: _____

ENVIRONMENTAL DATA

Wind:	**Calm 1**	**Light 2**	**Mod 3**	**Strong 4**	**Gale 5**	**Direction**
Water:	**Calm 1**	**Light 2**	**Mod 3**	**Strong 4**	**Gale 5**	

Cloud Cover:	**Cloud %**	**Rainfall:**	**Nil 1**	**Light 2**	**Mod 3**	**Heavy 4**

Boat Launches				**Boat Retrievals**				**Total Number of Trailers**	
Time	**Type**	**Time**	**Type**	**Time**	**Type**	**Time**	**Type**	**At Start**	**At Finish**
								Shore Fishers Sighted Between Last Ramp & This Ramp	

Boat Types

P: Power boat
Y: Yacht
O: Other

APPENDIX B: Interview form

SWAN-CANNING RECREATIONAL FISHING SURVEY
INTERVIEW QUESTIONNAIRE

Date: _____ **Location:** _____ **Boat Reg. No.:**_____

Interview Time	Boat (Pwr/Yacht/Other), Shore	Start Time	Fish/Dive/Snorkel/Other	Number in Party	Number of Females in Boat	Age of Interviewee	Home Postcode of Interviewee	Length of Boat (ft/m)	Member Angling Club (Yes/No)	Time Spent Fishing (decimal hrs)	Block Number or Estuary	Number of Lines Used	Number and type of nets – Crab, Gill, Scoop, Pots	Number of Times Interviewed Before
				FISHERS ONLY										

Species	Number Kept	Number Released	Undersize Kept	Species Targeted _____ Measurements (mm)
Blue Swimmer Crab (Male)				
Blue Swimmer Crab (Female)				
Blue Swimmer Crab (Sex Unknown)				

APPENDIX C: Bridge/jetty interview form

FISHERIES
WESTERN AUSTRALIA

Swan-Canning Shore Survey 1998/99

Officer's Name: _____

Location: _____

Date: ____/____/____

Time (24hr): _____

Number shore fishers: _____

WIND	Direction:			
Calm 1	Light 2	Mod 3	Strong 4	Gale 5

WATER				
Calm 1	Slight 2	Mod 3	Rough 4	V. Rough 5

CLOUD COVER & RAINFALL				
Cloud %	Nil 1	Light 2	Moderate 3	Heavy 4

RANDOM SAMPLE LENGTHS (mm)
Blue Swimmer Crabs

Length	Male		Female	
(mm)	No.	Total	No.	Total
126				
127				
128				
129				
130				
131				
132				
133				
134				
135				
136				
137				
138				
139				
140				
141				
142				

Other Species

Species: .....
Lengths: .....
Species: .....
Lengths: .....
Species: .....
Lengths: .....

Fisher Number	1	2	3	4
Home postcode				
Number in group				
Times interviewed before				
Boat/**S**hore/**D**iver/s**N**orkel				
Number persons fishing				
Time spent fishing (decimal hours)				
Number of lines used				
Nets (**C**rab, **G**ill, **S**coop), **P**ots				
Species Targeted				
Male Crabs	Blue swimmer crab - male	Blue swimmer crab - male	Blue swimmer crab - male	Blue swimmer crab - male
Total number kept				
Number released				
Under size kept				
Female Crabs	Blue swimmer crab - female	Blue swimmer crab - female	Blue swimmer crab - female	Blue swimmer crab - female
Total number kept				
Number released				
Under size kept				
Berried females kept				
Crabs (Sex unknown)	Blue swimmer crab	Blue swimmer crab	Blue swimmer crab	Blue swimmer crab
Total number kept				
Number released				
Under size kept				
Species 2				
Total number kept				
Number released				
Under size kept				
Species 3				
Total number kept				
Number released				
Under size kept				
Species 4				
Total number kept				
Number released				
Under size kept				
Species 5				
Total number kept				
Number released				
Under size kept				

APPENDIX D: Catch and effort calculations for boat-based fishers

Estimation of total effort

The fishing effort for a day (hours) was estimated by the method of Jones and Robson (1991) as follows:

$$e = fT\sum_i \left[\left(\frac{1}{w_i}\right)\sum_j X_{ij}\right] \quad (1)$$

where T is the time taken to complete the bus route, wi is the interviewer wait time at site i and X_{ij} is the time trailer j spends at site i. A correction factor $f \geq 1$ was used to adjust the effort for fishing that occurred before the morning shift commenced at time t.

$$f = \frac{\sum_j (r_j - l_j)}{\sum_j b_j} \quad (2)$$

where

$$b_j = \begin{cases} r_j - t, & l_j < t \\ r_j - l_j, & l_j \geq t \end{cases}$$

r_j is the retrieval time for boat j and l is the launch time for boat j. The fishing effort was estimated for a random sample of days in each stratum (see Section 2.1). The estimated variance within stratum k is (Pollock *et al*., 1994)

$$s_k^2 = \frac{1}{n_k - 1}\sum_{m=1}^{n_k} (e_{km} - \overline{e}_k)^2 \quad (3)$$

where n_k is the sample size (days) for stratum k, e_{km} the effort for stratum k on day m and $\overline{e}_k$ the mean daily fishing effort for stratum k. The variance associated with the estimate of the mean, with finite population correction (Neter *et al*., 1988), is calculated as

$$Var(\overline{e}_k) = \frac{s_k^2}{n_k}\left[\frac{N_k - n_k}{N_k}\right] \quad (4)$$

where N_k is the total number of days in stratum k. The total effort for stratum k is estimated as

$$\hat{E}_k = \frac{N_k}{n_k}\sum_{m=1}^{n_k} e_{km} \quad (5)$$

The variance associated with is estimated by

$$Var(\hat{E}_k) = N_k^2\, Var(\overline{e}_k) \quad (6)$$

and the standard error is calculated by the usual method

$$SE(\hat{E}_k) = \sqrt{Var(\overline{e}_k)} \tag{7}$$

The total effort is estimated by summing the effort for the strata as follows

$$\hat{E} = \sum_{k=1}^{n} \hat{E}_k \tag{8}$$

where n is the number of strata. Similarly the variance of $\hat{E}$ is estimated from the independent variances for the strata

$$Var(\hat{E}) = \sum_{k=1}^{n} Var(\hat{E}_k) \tag{9}$$

and the standard error of $\hat{E}$ is calculated by the usual method

$$SE(\hat{E}) = \sqrt{Var(\hat{E})} \tag{10}$$

Estimation of total catch

The catch rate for each stratum k is estimated by (Crone and Malvestuto, 1991)

$$\hat{R}_k = \frac{\overline{c}_k}{\overline{L}_k} = \frac{\sum_{j=1}^{n_k} c_{kj} / n_k}{\sum_{j=1}^{n_k} L_{kj} / n_k} \tag{11}$$

where n_k is the number of boats where the catch was recorded, the catch for boat j and L_{kj} the effort, in hours, for boat j. The variances for $\overline{c}_k$ and $\overline{L}_k$can be calculated by the usual method (see (3) and (4) without the finite population correction factor). The variance for $\hat{R}_k$ can be estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{R}_k) \approx \hat{R}_k^2 \left[\frac{Var(\overline{c}_k)}{\overline{c}_k^2} + \frac{Var(\overline{L}_k)}{\overline{L}_k^2} - \frac{2Cov(\overline{c}_k, \overline{L}_k)}{\overline{c}_k \overline{L}_k} \right] \tag{12}$$

The covariance term was assumed to be zero.

The total catch for stratum k is estimated as

$$\hat{C}_k = \hat{E}_k \hat{R}_k \tag{13}$$

and the variance was estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{C}_k) \approx \hat{C}_k^2 \left[\frac{Var(\hat{E}_k)}{\hat{E}_k^2} + \frac{Var(\hat{R}_k)}{\hat{R}_k^2} - \frac{2Cov(\hat{E}_k, \hat{R}_k)}{\hat{E}_k \hat{R}_k} \right] \tag{14}$$

where the covariance term was assumed to be zero. The total catch is estimated by summing the catch for each strata as follows

$$\hat{C} = \sum_{k=1}^{n} \hat{C}_k \tag{15}$$

and the variance of $\hat{C}$ is estimated as

$$Var(\hat{C}) = \sum_{k=1}^{n} Var(\hat{C}_k) \tag{16}$$

and the standard error of $\hat{C}$ is calculated by the usual method

$$SE(\hat{C}) = \sqrt{Var(\hat{C})} \tag{17}$$

APPENDIX E: Length-weight relationships used to estimate weights for various species

Species	Length-weight	Source
Blue swimmer crab (male) (*Portunus pelagicus*)	$W(g) = 2.56 \times 10^{-5}\ CW(mm)^{3.260}$ ($r^2 = 0.99$, n = 694)	Potter *et al*., 1983
Blue swimmer crab (female) (*Portunus pelagicus*)	$W(g) = 5.97 \times 10^{-5}\ CW(mm)^{3.056}$ ($r^2 = 0.99$, n = 1076)	Potter *et al*., 1983
Tailor (*Pomatomus saltatrix*)	$W(g) = 5.15 \times 10^{-5}\ L(mm)^{2.714}$	R. Steckis, unpubl. data
Australian Herring (*Arripis georgianus*)	$W(g) = 1.022 \times 10^{-5}\ L(mm)^{3.015}$	Fairclough, 1998
Black Bream[1] (*Acanthopagrus butcheri*)	$W(g) = 8.13 \times 10^{-6}\ L(mm)^{3.14}$ ($r^2 = 0.99$, n = 865)	G. Sarre, unpubl. data
Flathead[2] (*Platycephalus* spp.)	$W(g) = 8.1 \times 10^{-3}\ L(cm)^{2.92}$ ($r^2 = 0.98$, n = 58)	Steffe *et al*., 1996
Whiting other than King George[3] (*Sillago* spp.)	$W(g) = 8.32 \times 10^{-6}\ L(mm)^{2.98}$	G. Hynes, unpubl. data

[1] Using relationship for females
[2] Using relationship for marbled flathead (*Platycephalus marmoratus*)
[3] Using realtionship for yellow-fin whiting (*Silago schomburgkii*)

APPENDIX F: Catch and effort calculations for shore-based fishers

Estimation of total effort

The fishing effort for a half day shift (hours) was estimated by the roving creel survey method (Pollock *et al*., 1994) as follows:

$$e = IT \tag{1}$$

where I is the count of anglers and T is the length of the shift. The estimated variance within stratum k is (Pollock *et al*., 1994)

$$s_k^2 = \frac{1}{n_k - 1} \sum_{m=1}^{n_k} (e_{km} - \overline{e}_k)^2 \tag{2}$$

where n_k is the sample size (days) for stratum k, e_{km} the effort for stratum k on day m and $\overline{e}_k$ the mean daily fishing effort for stratum k. The variance associated with the estimate of the mean, with finite population correction (Neter *et al*., 1988), is calculated as

$$Var(\overline{e}_k) = \frac{s_k^2}{n_k}\left[\frac{N_k - n_k}{N_k}\right] \tag{3}$$

where N_k is the total number of days in stratum k. The total effort for stratum k is estimated as

$$\hat{E}_k = \frac{N_k}{n_k} \sum_{m=1}^{n_k} e_{km} \tag{4}$$

The variance associated with $\hat{E}_k$ is estimated by

$$Var(\hat{E}_k) = N_k^2 \, Var(\overline{e}_k) \tag{5}$$

and the standard error is calculated by the usual method

$$SE(\hat{E}_k) = \sqrt{Var(\overline{e}_k)} \tag{6}$$

The total effort is estimated by summing the effort for each strata as follows

$$\hat{E} = \sum_{k=1}^{n} \hat{E}_k \tag{7}$$

where n is the number of strata. Similarly the variance of $\hat{E}$ is estimated as

$$Var(\hat{E}) = \sum_{k=1}^{n} Var(\hat{E}_k) \tag{8}$$

and the standard error of $\hat{E}$ is calculated by the usual method

$$SE(\hat{E}) = \sqrt{Var(\hat{E})} \tag{9}$$

Estimation of total catch

The catch rate for each stratum k is estimated by (Pollock *et al*., 1994)

$$\hat{R}_k = \frac{\sum_{j=1}^{n_k} \frac{w_{kj} c_{kj}}{L_{kj}}}{\sum_{j=1}^{n_k} w_{kj}} \tag{10}$$

where c_{kj} is the total catch and L_{kj} the total effort, in person hours, for party j with w_{kj} fishers, n_k is the number of shore-based parties where the catch was recorded. The variance for $\hat{R}_k$ can be estimated using the formulae

$$Var(\hat{R}_k) \approx \frac{1}{\sum_{j=1}^{n_k} w_{kj} \left[\sum_{j=1}^{n_k} w_{kj} - 1 \right]} \sum_{j=1}^{n_k} w_{kj} \left[\frac{c_{kj}}{L_{kj}} - \hat{R}_k \right]^2 \tag{11}$$

The total catch for stratum k is estimated as

$$\hat{C}_k = \hat{E}_k \hat{R}_k \tag{12}$$

and the variance was estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{C}_k) \approx \hat{C}_k^2 \left[\frac{Var(\hat{E}_k)}{\hat{E}_k^2} + \frac{Var(\hat{R}_k)}{\hat{R}_k^2} - \frac{2Cov(\hat{E}_k, \hat{R}_k)}{\hat{E}_k \hat{R}_k} \right] \tag{13}$$

where the covariance term was assumed to be zero. The total catch is estimated by summing the catch for each strata as follows

$$\hat{C} = \sum_{k=1}^{n} \hat{C}_k \tag{14}$$

and the variance of $\hat{C}$ is estimated as

$$Var(\hat{C}) = \sum_{k=1}^{n} Var(\hat{C}_k) \tag{15}$$

and the standard error of $\hat{C}$ is calculated by the usual method

$$SE(\hat{C}) = \sqrt{Var(\hat{C})} \tag{16}$$

APPENDIX G: Fish species kept by recreational anglers in the Swan-Canning Estuary Basin during 1998-99

Common name	Scientific name	Kept by boat-based anglers	Kept by shore-based anglers
Tailor	*Pomatomus saltatrix*	Yes	Yes
Whiting other than King George	*Sillago* spp.	Yes	Yes
Black Bream	*Acanthopagrus butcheri*	Yes	Yes
Flathead	*Platycephalus* spp.	Yes	Yes
Australian Herring	*Arripis georgianus*	Yes	Yes
Common Blowfish	*Torguigener pleurogramma*	Yes	Yes
Flounder	*Pseudorhombus* spp.	Yes	Yes
Western Australian Butterfish	*Pentapodus vitta*	Yes	Yes
Silver Bream (Tarwhine)	*Rhabdosargus sarba*	Yes	Yes
Skipjack Trevally	*Pseudocaranx* spp.	Yes	Yes
Trumpeters	*Teraponidae* family	Yes	Yes
Mulloway	*Argyrosomus hololepidotus*	Yes	No
Wrasse	*Labridae* family	Yes	No
Yellow-eye Mullet	*Aldrichetta forsteri*	Yes	Yes
Ogilby's Hardyhead	*Pranesus ogilbyi*	Yes	No
Yellowtail Scad	*Trachurus novaezelandiae*	No	Yes
Red Gurnard	*Chelidonichthys kuma*	Yes	No
Gobbleguts	*Apogon rueppellii*	No	Yes

APPENDIX H: Fish species kept by commercial fishers in the Swan-Canning Estuary during 1998-99

Common name	Scientific name
Sea Mullet	*Mugil cephalus*
Perth Herring	*Nematalosa vlaminghi*
Yellow-eye Mullet	*Aldrichetta forsteri*
Black Bream	*Acanthopagrus butcheri*
Tailor	*Pomatomus saltatrix*
Yellowtail Scad	*Trachurus novaezelandiae*
Flathead	*Platycephalus* spp.
Flounder	*Pseudorhombus* spp.
Mulloway	*Argyrosomus hololepidotus*
Cobbler	*Cnidoglanis macrocephalus*
Other Whiting	*Sillago* spp.
Rays and Skates	*Rhinobatidae, Dasyatididae, Urolophidae, Myliobatididae* and *Rajidae* families
Australian Herring	*Arripis georgianus*
Yellowtail Trumpeter	*Amniataba caudavittatus*
Other Shark	*Carcharhinidae* family
Bull Shark	*Carcharhinus leucas*
Skipjack Trevally	*Pseudocaranx* spp.
Other Species	