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A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99

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Cover photograph: Tim Leary

Department of Fisheries
Government of Western Australia

Fish for the future

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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 Peel-Harvey Estuary of Western Australia during 1998-99

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Abstract

A survey of recreational boat-based and shore-based fishing in the Peel-Harvey Estuary was conducted between August 1998 and July 1999. During the survey 1,996 interviews were conducted at boat ramps. Of these, 1,136 boats had been crabbing and 136 angling in the estuary (43 were both crabbing and angling). In addition to the interviews at boat ramps, 909 shore-based fishing parties were interviewed.

The survey estimated the total annual boat-based recreational fishing effort as 126,000 fisher days, with 88% of this effort targeting blue swimmer crabs. The total annual shore-based recreational fishing effort was estimated to be 191,000 fisher days, with 83% of this effort targeting blue swimmer crabs.

The recreational blue swimmer crab catch from the Peel-Harvey Estuary is substantial and exceeds the reported commercial catch. The estimated total recreational catch of blue swimmer crabs was 1,360,000 crabs (range: 1,237,000 – 1,483,000) or 289 tonnes (range: 269 - 309 tonnes). This consisted of a boat-based catch of 832,000 crabs (range: 768,000 – 896,000) and a shore-based catch of 528,000 crabs (range: 423,000 – 633,000). Most crabs (86%) kept by recreational fishers were male.

The recreational catch of fish from the Peel-Harvey Estuary is relatively small compared to the recreational crab catch. The most common fish species kept by anglers are (in order of number kept) Australian herring, whiting other than King George (Sillago spp.), tailor, skipjack trevally, trumpeters, King George whiting, silver bream (tarwhine) and black bream.

There was a high level of compliance with the size limits amongst boat-based fishers. Only 5.8% of boat crews angling had kept undersize fish while 105 (9.2%) of the 1,136 boat crews crabbing had kept undersize crabs. However, 13% of shore-based crabbing parties interviewed were found to have kept undersize crabs.

Few boats with two or more people on board (7%) achieve the daily boat limit of 48 crabs specified under present statewide recreational fishing regulations. However, a greater proportion of boats with only one person on board (30%) achieve their daily bag limit of 24 crabs.

Summary

A survey of recreational boat-based and shore-based fishing in the Peel-Harvey Estuary was conducted between August 1998 and July 1999. During the survey 1,996 interviews were conducted at boat ramps. Of these, 1,136 boats had been crabbing and 136 angling in the estuary (43 were both crabbing and angling). In addition to the interviews at boat ramps, 909 shore-based fishing parties were interviewed.

The main species kept by recreational fishers in the Peel-Harvey Estuary during 1998-99 are (in order of number kept) blue swimmer crabs (93%), Australian herring, whiting other than King George (*Sillago* spp.), tailor, skipjack trevally, trumpeters, King George whiting, silver bream (tarwhine) and black bream.

The recreational catch for blue swimmer crabs is substantial. The estimated recreational catch from August 1998 to July 1999 of 289 tonnes (range: 269 - 309 tonnes) is more than 5 times the mean annual commercial catch since 1991/92.

The survey indicated that few boats with two or more people on board (7%) achieved the daily boat limit of 48 crabs specified under current statewide recreational fishing regulations. However, a greater proportion of boats with only one person on board (30%) achieved their daily bag limit of 24 crabs.

The size limits are an effective catch control measure as substantial numbers of undersize blue swimmer crabs caught were subsequently released.

The summer months are the most popular time for both recreational crabbing and angling in the Peel-Harvey Estuary.

There was generally a high level of compliance with fishing regulations amongst all anglers and boat-based crabbers. However, 13% of shore-based crabbing parties were found to have kept undersize crabs. Very few fishers exceeded the bag limits.

The recreational catch is the dominant component of the total blue swimmer crab catch in the Peel-Harvey Estuary. Further monitoring is therefore recommended since any assessment of the stock will require an understanding of the recreational catch and fishing effort.

1.0 Introduction

The Peel-Harvey Estuary, due to its size and location immediately south of the city of Mandurah approximately 70 kilometres south of Perth, is the most popular estuary for recreational fishing in the south-west of Western Australia. The blue swimmer crab (*Portunus pelagicus*) is the most common species targeted by recreational fishers in the estuary which provides much of the state's focus for recreational crabbing. Boat-based fishers use drop nets while shore-based fishers either wade through shallow water using wire scoop nets or use drop nets from bridges and jetties to catch crabs.

Commercial crab catches in the Peel-Harvey Estuary have increased over the past eight years (Fisheries WA, 1999). Recreational crabbing is recognised as being an extremely popular activity, although the recreational catch and fishing effort is not known. 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 crabs and fish and fishing effort for the Peel-Harvey Estuary.

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 Peel-Harvey Estuary. 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.

The estuary, which has a surface area of approximately 136 km^2 (Potter *et al*., 1998), contains the circular Peel Inlet and the elongate Harvey Estuary. It has a 5 km long natural entrance channel in the north-west corner of the Peel Inlet and a man-made 2 km long entrance channel (Dawesville Channel) at the northern end of the Harvey Estuary (Figure 1). There are 16 major public boat ramps within the estuary, eight referred to as eastern ramps and eight referred to as western ramps, three popular crab scooping areas and four bridges/jetties in the Mandurah entrance channel which are commonly used by recreational crabbers (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 monthly returns provided by these fishers.

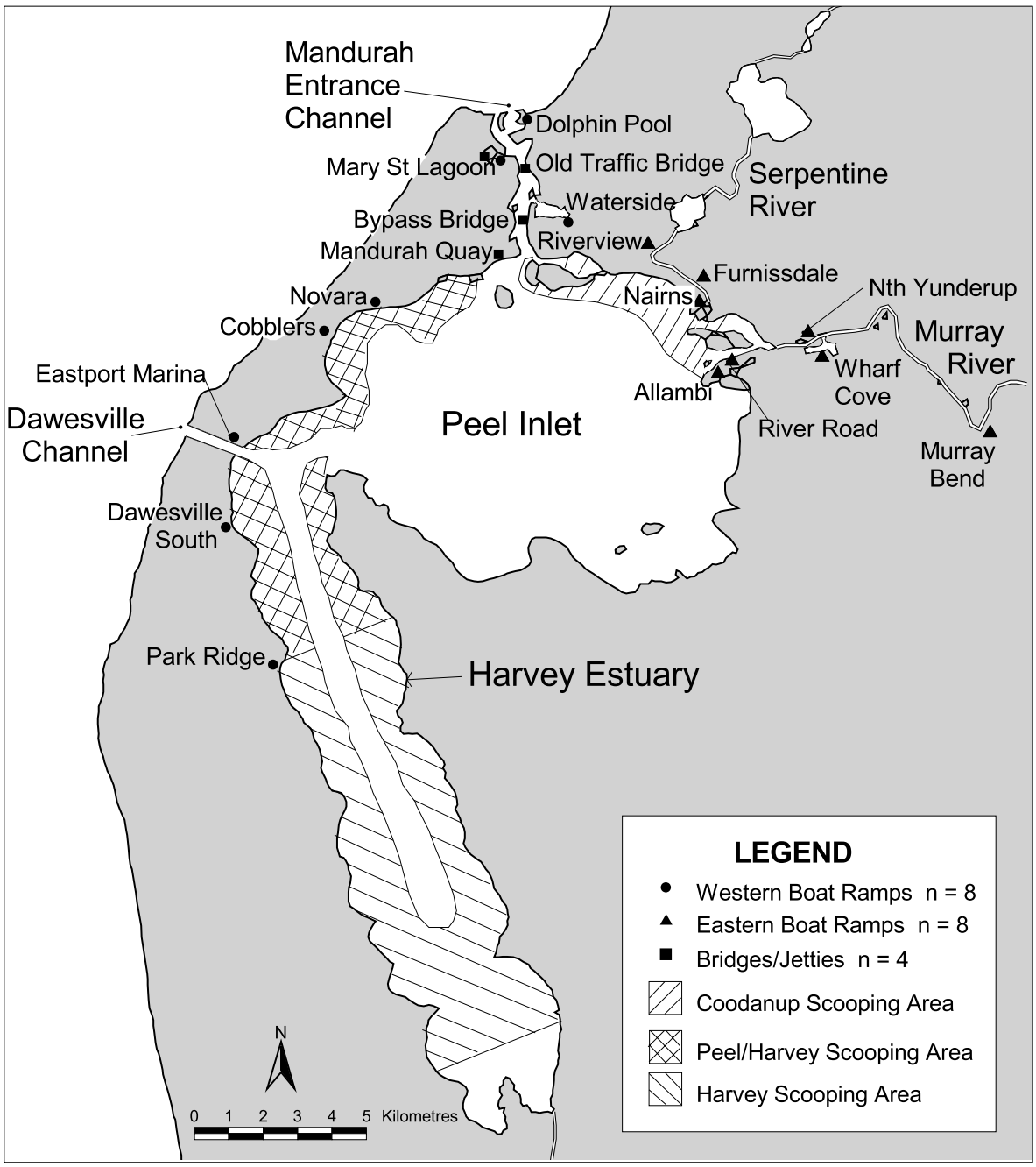

Figure 1. The Peel-Harvey Estuary showing sampling locations mentioned in the text.

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 Peel-Harvey Estuary.

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 with instantaneous counts was used to estimate the catch and fishing effort from shore-based fishers using wire scoop nets to catch crabs from the Coodanup, Peel/Harvey and Harvey areas (Figure 1). Similar information from shore-based crabbers and anglers fishing from or in the near vicinity of the bridges and jetties in the Mandurah entrance channel was also obtained from a roving creel survey with instantaneous counts.

In conjunction with the creel survey, houseboat and small power boat hire operators conducted a census to determine the catch and fishing effort of their clients.

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 of boat-based fishers was stratified by season (spring, summer, autumn or winter), time of day (morning or afternoon), weekdays or weekends (including public holidays) and area (eastern or western ramps). Each area was further stratified by ramp (eight in each) to account for the varying proportion of boats at each ramp which were crabbing or angling within the estuary, fishing outside the estuary or not fishing at all. Separate total catch estimates were made for each of these 256 strata (four seasons $\times$ 2 for mornings and afternoons $\times$ 2 for weekends and weekdays $\times$ 2 for area $\times$ 8 for each ramp). These estimates were then combined to obtain the total recreational boat-based catch and effort for the estuary.

Shore-based scoopers were surveyed during the crabbing season between December 1998 and April 1999. This is the time of year when legal size crabs are most abundant in the estuary (Potter *et al*., 1983; 1998) and therefore available for scooping in shallow water. The survey of fishers from the bridges and jetties along the Mandurah entrance channel was conducted during the fishing season between November and April. There was very little activity observed from these locations throughout the rest of the year.

Periods of low fishing activity, such as during the night, could not be covered with the available resources. 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 at night was also a concern. The interviewers commenced work before fishers started returning to the boat ramp. Almost all recreational boats return to the boat ramps before dusk when the interviewer finished work at the ramp.

Interviewers worked one boat ramp shift (morning or afternoon) on each of their 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.

The roving creel survey of shore-based crabbers using wire scoop nets was conducted by the two survey interviewers from a small boat. The day was divided into 4.5 hour morning and afternoon shifts. Morning shifts were conducted randomly between 7am and 12:30pm while afternoon shifts were conducted randomly between 12:30pm and 6pm.

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 "eastern" and "western") with eight boat ramps on each (Figure 1). This allowed the survey interviewer to visit all boat ramps in the designated area each shift. 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 the boat ramps on the "western" bus route were more popular than those on the "eastern" bus route. More shifts were therefore allocated to the "western" ramps. 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 12 to 32, which is effectively six to 16 full days (Table 1.)

Table 1. Monthly allocation of survey shifts.

Month	Number of shifts		Total shifts
	East	West	
January	12	20	32
February	8	16	24
March	8	16	24
April	8	16	24
May	8	12	20
June	4	8	12
July	4	8	12
August	4	8	12
September	8	12	20
October	8	12	20
November	8	12	20
December	8	16	24

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).

Table 2. Allocation of time to survey ramps.

Area	Ramp	Prop. of time	Area	Ramp	Prop. of time
East	Nairns	0.2	West	Waterside	0.13
East	Riverview	0.13	West	Dolphin Pool	0.07
East	Fernisdale	0.25	West	Mary St Lagoon	0.08
East	North Yunderup	0.12	West	Novara	0.14
East	Murray Bend	0.04	West	Cobblers	0.01
East	Wharf Cove	0.12	West	East Port Marina	0.18
East	River Road	0.08	West	Dawesville South	0.29
East	Allambi	0.06	West	Park Ridge	0.10

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. The 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) from spine point to point 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.

A simplified interview form was used to record the time spent fishing, catch and gear used by hire boats (Appendix C).

Shore-based fishing - roving creel survey

A roving creel survey was used for the survey of shore-based fishers. These included crabbers wading through shallow water with scoop nets or using drop nets from the bridges and jetties in the Mandurah entrance channel. Anglers found fishing from the bridges and jetties in the Mandurah entrance channel were also interviewed.

A small dinghy complete with outboard motor was used to count and interview crabbers wading with scoop nets to collect information on the time spent fishing and catch. The Coodanup, Peel-Harvey and Harvey areas were surveyed using the dinghy (Figure 1). Since the primary focus was on the catch of blue swimmer crabs, shore-based angling in the Dawesville Channel was not included. A separate interview form was used for shore-based fishers (Appendix D).

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 E).

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 or fishing outside the estuary. The trailer counts were multiplied by the proportion of boats interviewed that were targeting fish or crabs in the estuary to estimate the recreational fishing effort for these species.

Fishing effort by fishers from boats that were launched before the start of a morning shift (7:00am or 8:00am 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 E).

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

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 instantaneous 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 G).

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

3.0 Results

During the survey 1,996 interviews were conducted at boat ramps. Of these, 1,136 boats had been crabbing and 136 angling in the estuary (43 were both crabbing and angling). A further 400 were fishing or diving in the ocean and 360 were not involved in any fishing activity.

The majority of the boat-based crabbers (57%) were residents from the greater Perth metropolitan region living within a 50 km radius of the city centre. However, more than a third of boat based fishers (36%) were local Mandurah residents living within a 20km radius of the Peel-Harvey Estuary (Figure 2).

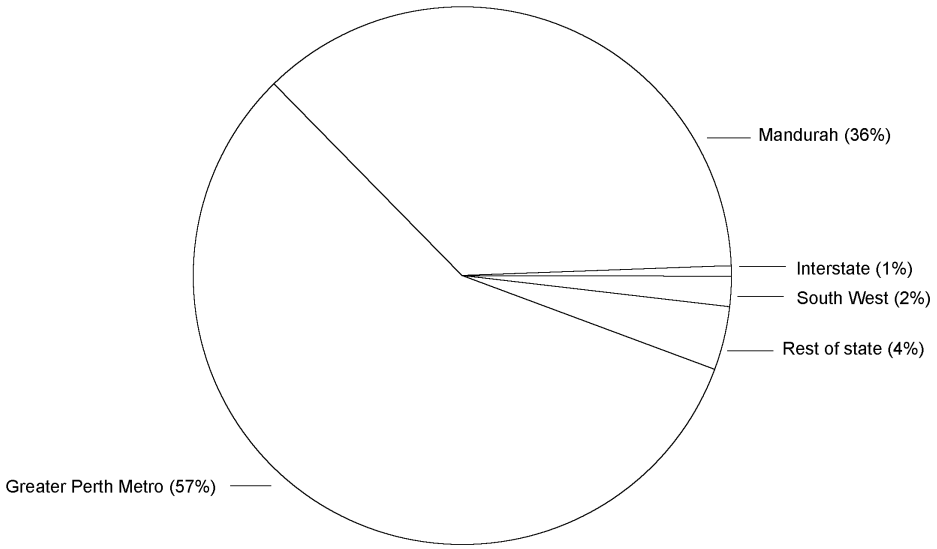

Figure 2. Boat-based crabbers' places of residence.

Blue swimmer crabs were the target species for 92% of recreational boat-based fishers interviewed in the Peel-Harvey Estuary. The remaining 8% of boat-based fishers targeted fish such as Australian herring, tailor and King George whiting.

In addition to the interviews at boat ramps, 595 shore-based fishing parties were interviewed at or in the near vicinity of the four major jetties/bridges along the main entrance to the Peel-Harvey Estuary. Of these groups, 397 were crabbing and 296 were angling (101 were both crabbing and angling).

A further 314 shore-based fishing parties targeting blue swimmer crabs with wire scoop nets in other areas were also interviewed.

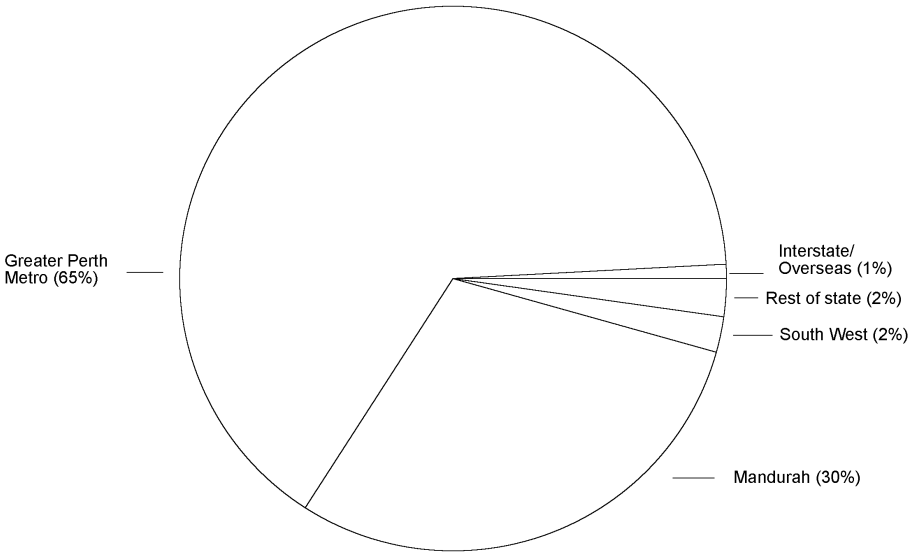

Figure 3. Shore-based crabbers' places of residence.

The majority of shore-based crabbers (65%) were also residents of the greater Perth metropolitan area (Figure 3).

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 (7:00am in spring, summer and autumn or 8:00am in winter) and returned after the start of a morning shift was 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 (Table 3 and Appendix E).

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

Season	ratio of effort prior to start to after start	correction factor *(f)*
Summer	0.087	1.087
Autumn	0.044	1.044
Winter	0.078	1.078
Spring	0.026	1.026

Most boats had returned to the ramp before the end of an afternoon shift (7:00pm during January, February, March, November and December, 6:00pm during April, May, September and October and 5:00pm 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 two per ramp on average between November and March) (Figure 4).

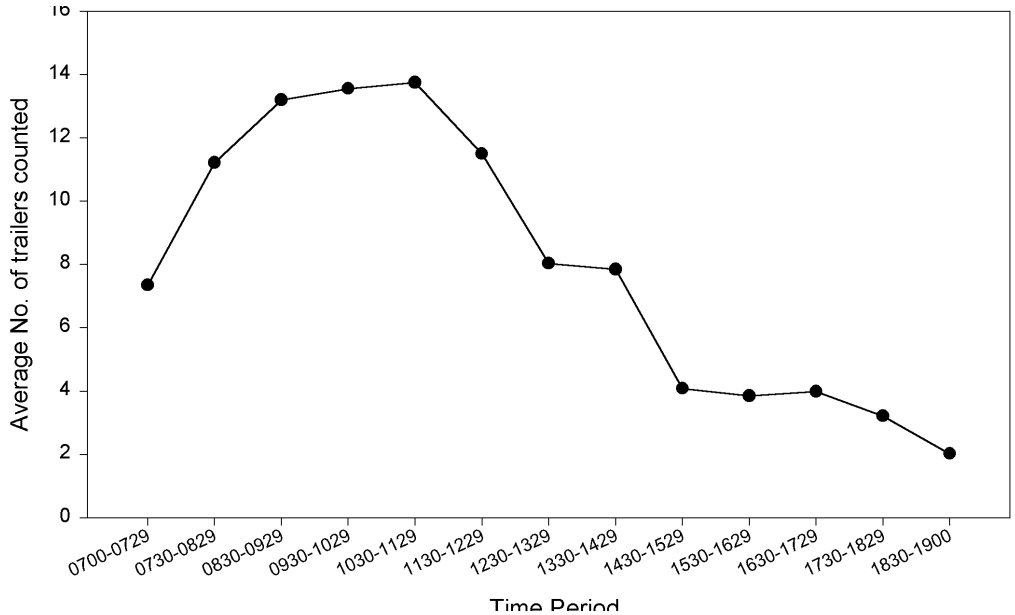

Figure 4. Average number of trailers counted on arrival/departure at all ramps (November to March).

Boat-based crabbing effort

Most boat-based crabbers used drop nets to catch crabs, although a small number used scoop nets.

The recreational boat-based crabbing effort was greatest in summer with 72% 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 5). The majority of boat-based crabbing took place from the western boat ramps (Figure 5).

The recreational crabbing effort varied from 3,214 fisher days during winter to 80,961 fisher days for summer (Figure 5).

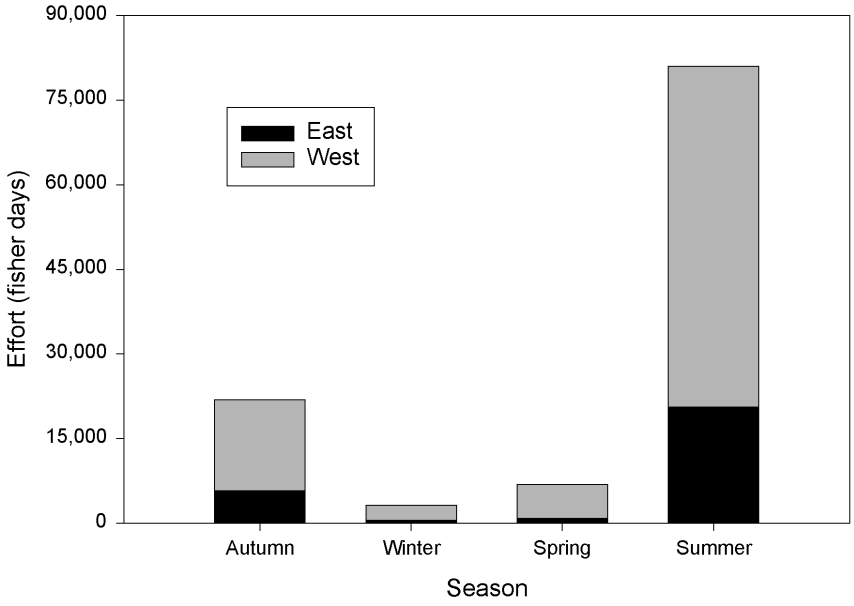

Figure 5. Recreational boat-based crabbing effort.

The estimated total annual recreational boat-based crabbing effort for the Peel-Harvey Estuary was 112,936 fisher days (123,383 boat hours). This effort does not include that expended by hire boats that contributed a further 2,087 boat hours of recreational crabbing effort over the 12 month survey period.

Boat-based angling effort

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

Spring is the most popular season for angling in the Peel-Harvey Estuary. The effort is only slightly less during summer, while winter is less popular (Figure 6).

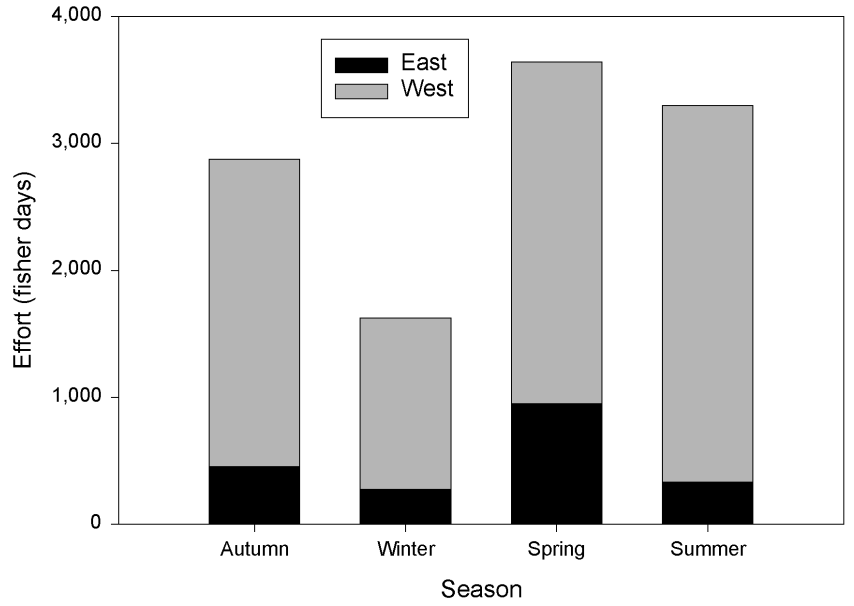

Figure 6. Recreational boat-based angling effort.

The western boat ramps were the most popular for estuary anglers. The eastern ramps were less popular but were also used by estuary anglers (Figure 6).

The estimated annual recreational boat-based angling effort for the Peel-Harvey Estuary was 11,441 fisher days (16,188 boat hours). Recreational angling effort from hire boats was negligible.

3.1.2 Shore-based effort

Shore-based scooper crabbing effort

Shore-based scoopers were defined as those fishing from the shore wading through shallow water using wire scoop nets.

The effort was relatively similar for all three areas where shore-based crab scoopers were surveyed. The Peel-Harvey area had the most effort followed by the Coodanup and Harvey areas (Figure 7).

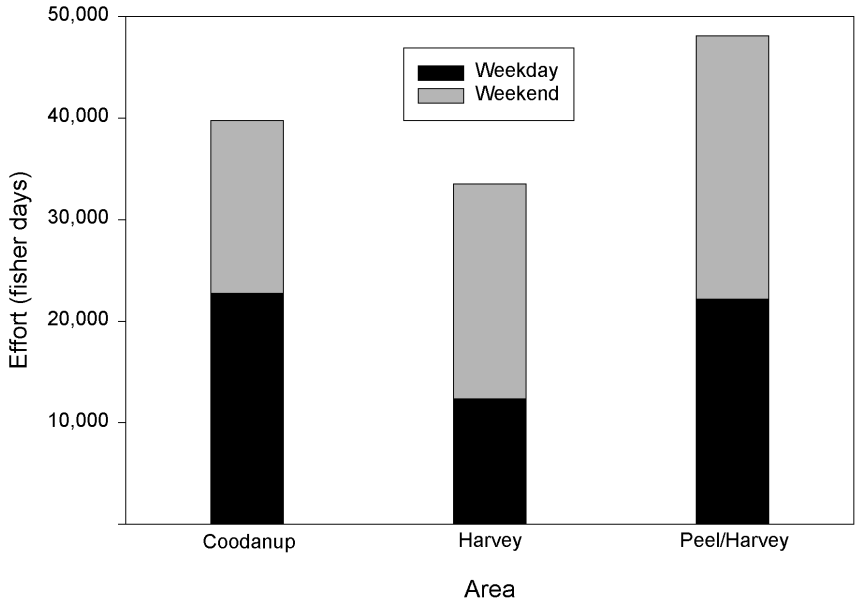

Figure 7. Recreational shore-based scooper crabbing effort.

The total fishing effort was similar for both weekdays and weekends despite the greater number of weekdays (Figure 7).

The estimated total annual recreational shore-based crab scooping effort for the Peel-Harvey Estuary was 121,323 fisher days (225,797 fisher hours).

Shore-based bridge/jetty crabbing effort

Shore-based crabbers using either drop nets or scoop nets on or in the near vicinity of bridges and jetties in the Mandurah entrance channel were included.

Mandurah Quay was the most popular bridge/jetty location for shore-based crabbers with an estimated annual fishing effort of 15,130 fisher days. The old traffic bridge and bypass bridge were also popular locations. The Mary Street area was the least popular with 2,635 fisher days (Figure 8).

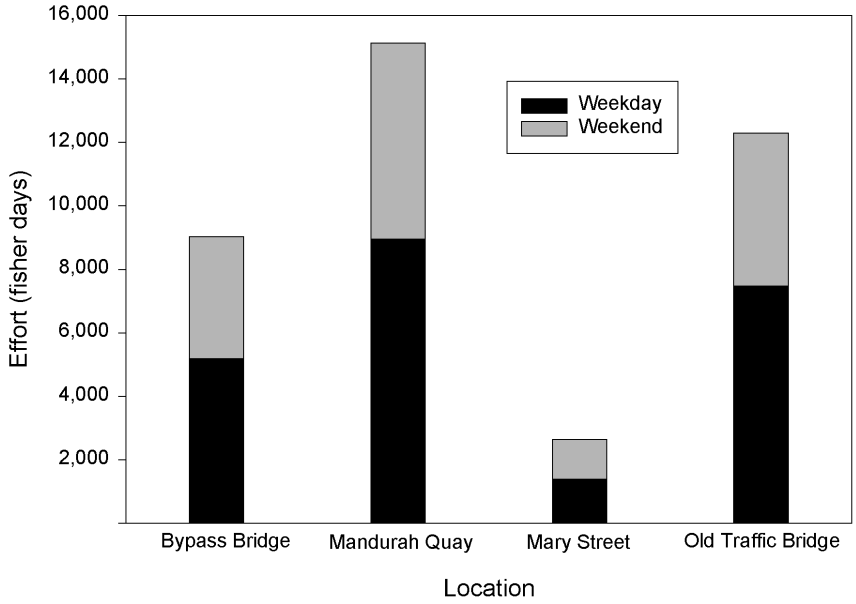

Figure 8. Recreational shore-based bridge/jetty crabbing effort.

Weekdays had a higher total fishing effort from shore-based crabbers on or in the near vicinity of bridges/jetties than weekends due to the greater number of weekdays (Figure 8).

It is estimated that the total annual recreational shore-based crabbing effort on and in the near vicinity of the major jetties and bridges in the Peel-Harvey Estuary was 39,072 fisher days (90,058 fisher hours).

Shore-based angling effort

The majority of shore based angling effort in the Mandurah entrance channel occurred from the old traffic bridge, with a total of 18,769 fisher days (60%). Annual effort was less than 5,000 fisher days for the bypass bridge, Mandurah Quay and Mary Street (Figure 9).

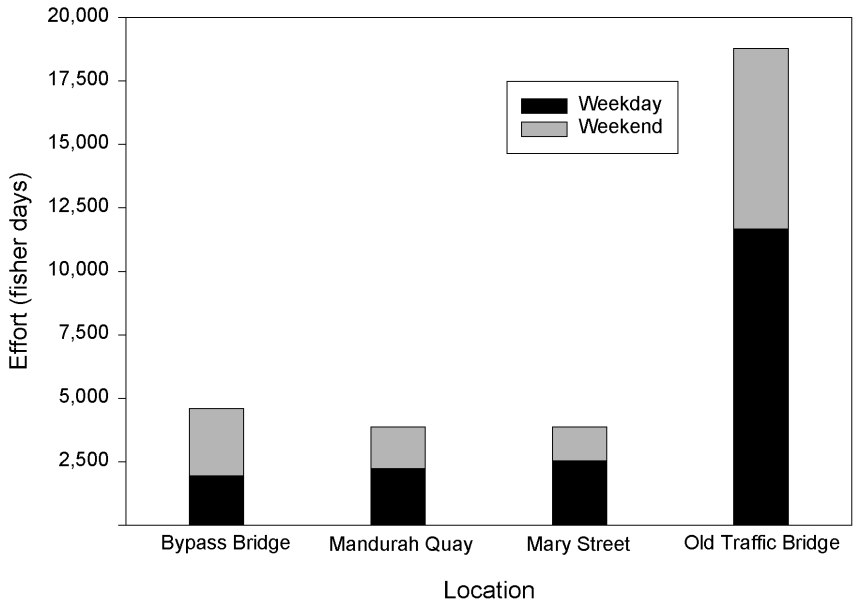

Figure 9. Recreational shore-based angling effort.

Weekdays had a higher total fishing effort from shore-based anglers than weekends due to the greater number of weekdays (Figure 9).

The estimated annual recreational shore-based angling effort for the Mandurah entrance channel was 31,104 fisher days (66,648 fisher hours).

3.2 Recreational catch of blue swimmer crabs

3.2.1 Size frequency

The size frequency for blue swimmer crabs displayed in Figures 10 and 11 shows the carapace width (CW) range for crabs kept by boat and shore-based crabbers respectively.

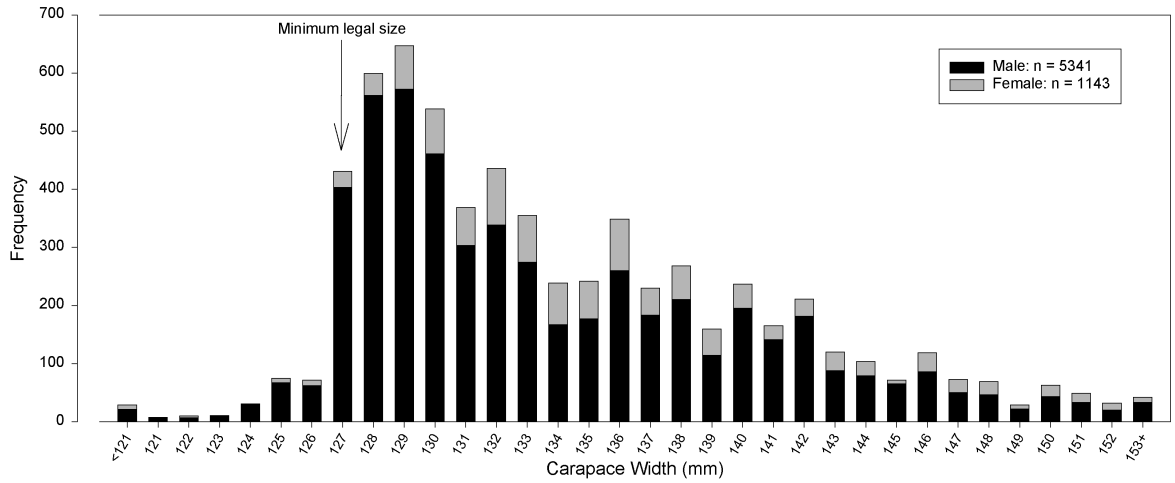

Figure 10. Size frequency for blue swimmer crabs kept by boat-based fishers.

Approximately 50% of crabs kept by boat-based fishers have a CW between 127mm (minimum legal size) and 133mm. However, crabs as small as 98mm CW and as big as 172mm CW were kept by recreational boat-based crabbers. The distribution was similar for both male and female crabs (Figure 10), although the catch was predominantly males.

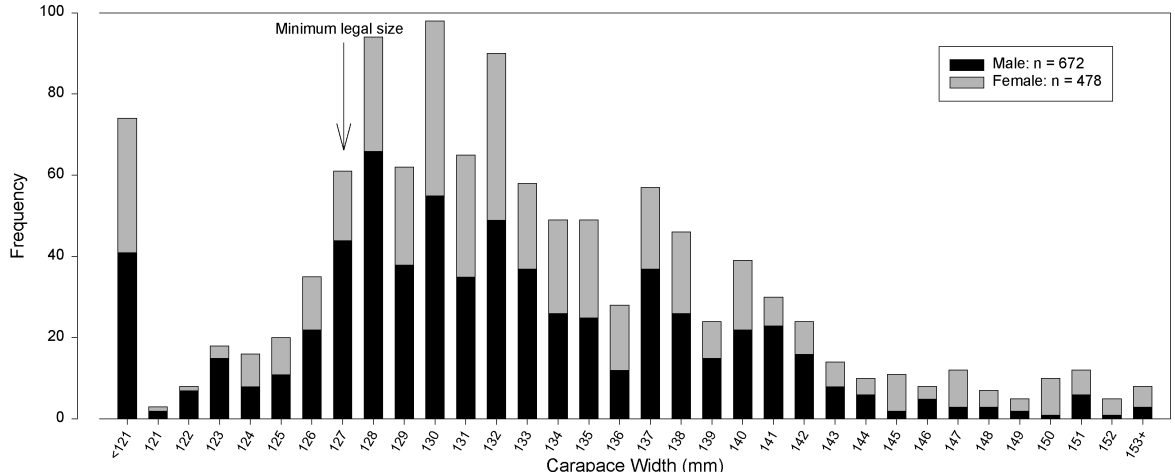

Figure 11. Size frequency for blue swimmer crabs kept by shore-based fishers.

Approximately 50% of crabs kept by shore-based fishers have a CW between 127mm (minimum legal size) and 134mm. However, crabs as small as 93mm CW and as big as 154mm CW were kept by recreational shore-based crabbers. The distribution was similar for both male and female crabs (Figure 11).

3.2.2 Boat-based catch

Of the crabs kept for which sex was recorded, 19,922 (90%) were males and 2,293 (10%) females. The sex of crabs released was also recorded where possible; of these 19,582 (78%) were males and 5,380 (22%) females.

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

	Trailer boat	Standard error	Hire boat	Total
Number kept	823,742	32,582	8,222	831,964
Number released	956,406	34,146	10,492	966,898
Weight kept (tonnes)	179.9	6.5	1.8	181.7
Catch rate (crabs/boat/hour)	5.93	0.19	3.94	
Catch rate (crabs/net/trip)	2.22	0.05		
Catch rate (crabs/boat/trip)	19.54	0.40		

An estimated 823,742 crabs were kept (85,025 females and 738,717 males) and 956,406 released (206,132 females and 750,274 males) by trailer boat-based crabbers (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 32,582. If we assume a student t distribution, the (1-α) percent confidence interval for the number kept $(\hat{c})$ was calculated from the standard error

$$\hat{c} \pm t(1-\alpha/2;\nu-1)\,SE(\hat{c})$$
$$\hat{c} \pm t1.96\,SE(\hat{c})$$

where α=0.05 for the 95% confidence interval and n is the number of boats surveyed (sample size). The range is given as the 95% confidence interval around the catch and fishing effort estimates.

Records from the four hire boat companies operating in the estuary showed that 8,222 crabs were kept and 10,492 released by fishers from hire boats (Table 4).

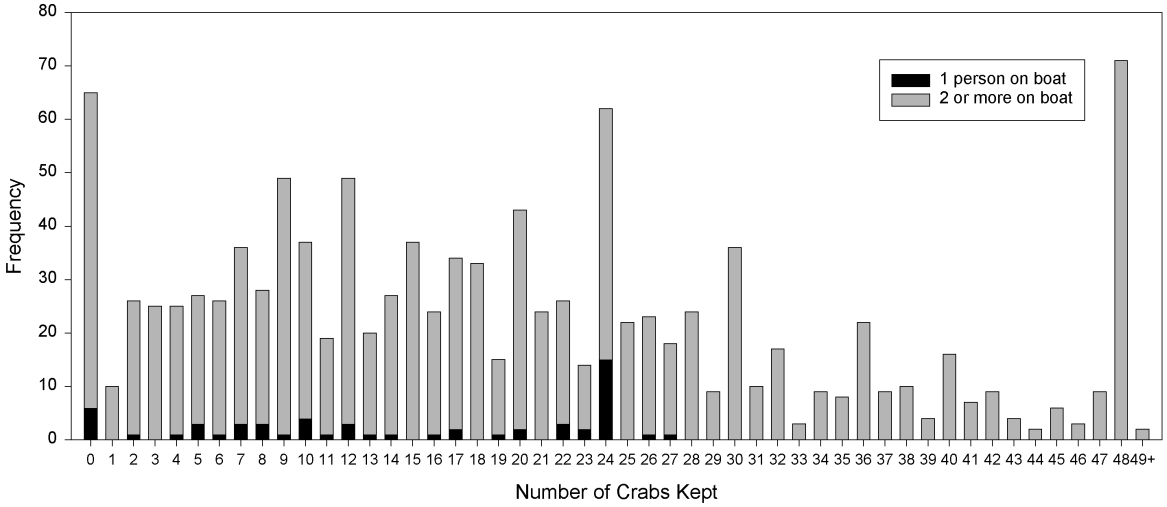

Figure 12. Frequency of crabs kept per boat.

Only 7% of trailer boats with two or more on board achieved or exceeded the boat limit of 48 crabs. However, 30% of boats with only one person on board achieved or exceeded the bag limit of 24 crabs. 6% of boats targeting crabs did not keep any crabs at all (Figure 12).

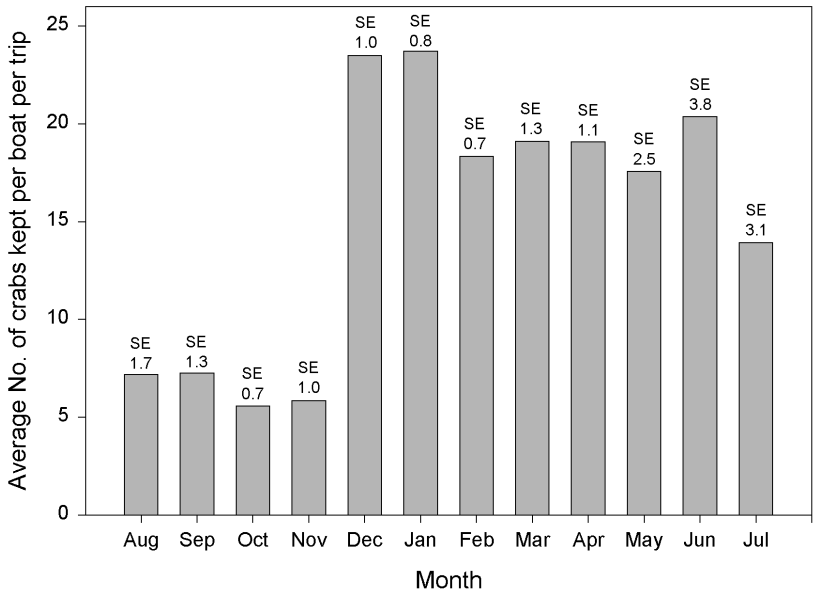

Figure 13. Crab catch rates per month for boat-based fishers.

Catch rates peaked at just over 23 crabs per boat per trip during December and January. Catch rates were slightly lower but steady at between 17 and 20 crabs per boat per trip from February to June. Catch rates then fell away to less than six crabs per boat per trip during October and November before peaking in December (Figure 13).

Most (75%) of the recreational crab catch taken by boat-based fishers occurred in the summer months, 19% was caught during autumn and only 6% of the catch was taken during winter and spring (Figure 14).

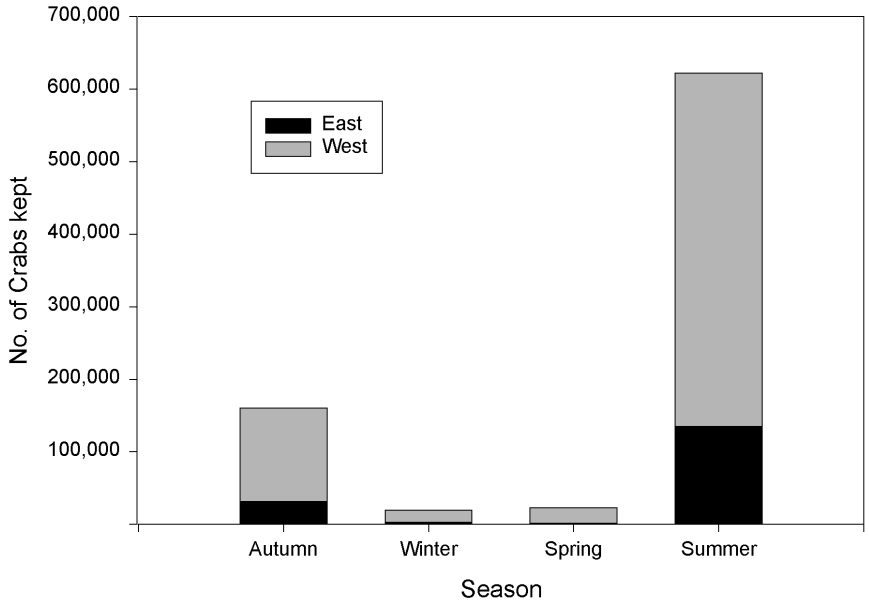

Figure 14. Estimated number of crabs kept per season.

The majority of crabs kept were from boats launched from the western boat ramps (Figure 14).

Female crabs comprised 26% of the crabs kept during autumn but only 5% of the crabs kept during summer. However, of the crabs released, a similar proportion were females during both summer (23%) and autumn (19%) (Figure 15).

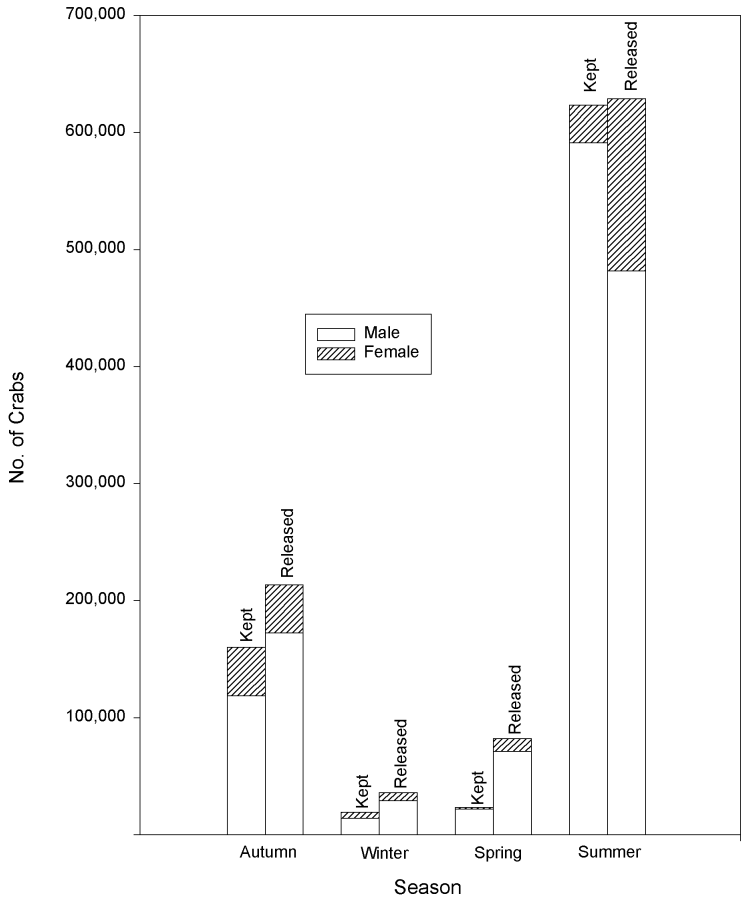

Figure 15. Estimated number of crabs kept and released per season by boat-based crabbers.

During autumn for every crab kept by recreational boat-based crabbers there were 1.3 crabs released. However, during summer there was an equal proportion of crabs kept and released (Figure 15).

The total annual weight of crabs kept by recreational trailer boat and hire boat-based crabbers in the Peel-Harvey Estuary was estimated to be 181.7 tonnes (164.7 tonnes of males and 17 tonnes of females) (Table 4).

3.2.3 Shore-based scooper catch

Of the crabs kept for which sex was recorded, 1,190 (60%) were males and 796 (40%) females. The sex of crabs released was also recorded where possible; of these 739 (61%) were males and 479 (39%) females.

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

	Total	Standard error
Number kept	445,291	53,045
Number released	302,508	39,834
Weight kept (tonnes)	89.9	7.8
Catch rate (crabs/person/trip)	3.95	0.35
Catch rate (crabs/person/hour)	1.93	0.21
Catch rate (crabs/party/trip)	13.00	1.03

An estimated 445,291 crabs were kept and 302,508 released by shore-based scoopers (Table 5).

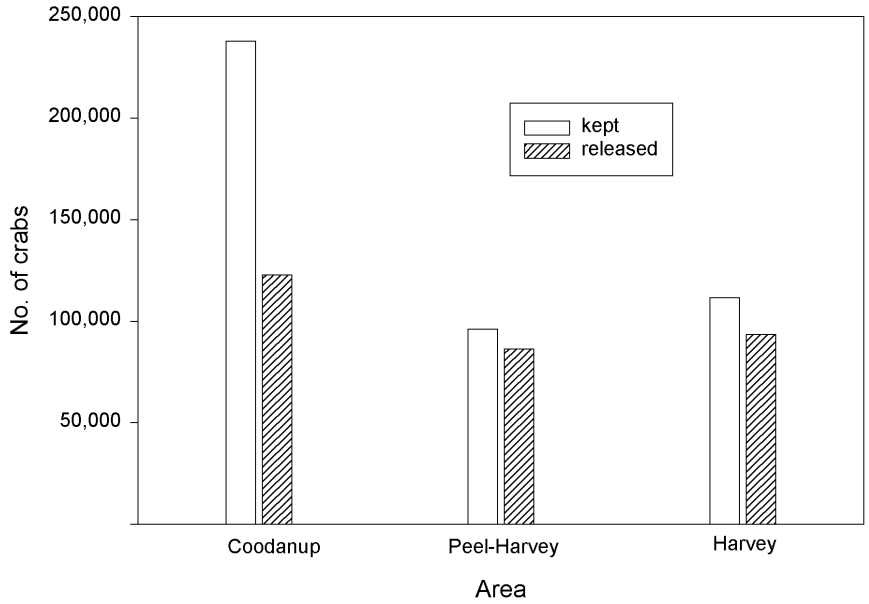

Figure 16. Estimated number of crabs kept and released per area by shore-based scoopers.

Over half (53%) of the crabs kept by shore-based scoopers were caught at Coodanup (Figure 16). At Coodanup there were 0.52 crabs released for every one kept. In the other areas there were similar numbers of crabs both kept and released (Figure 16).

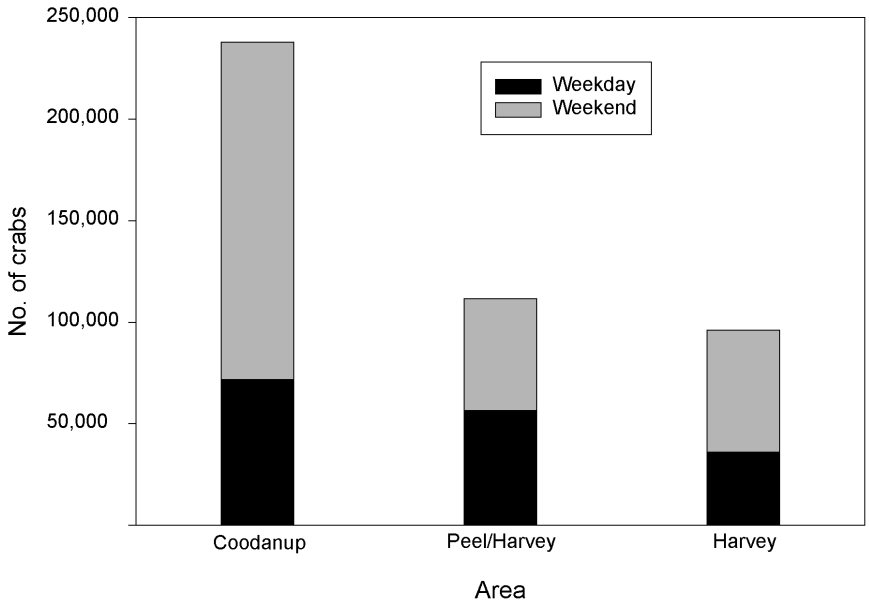

Figure 17. Estimated number of crabs kept by shore-based scoopers per area on weekday/weekend.

Despite the greater number of weekdays, 70% of crabs kept at Coodanup were caught on weekends. There were also more crabs caught on weekends (62%) in the bottom of the Harvey. A similar number of crabs were caught on weekdays and weekends in the Peel-Harvey area (Figure 17).

The total annual weight of crabs kept by recreational shore-based scoopers in the Peel-Harvey Estuary was estimated to be 89.9 tonnes (56.4 tonnes of males and 33.5 tonnes of females) (Table 5).

3.2.4 Shore-based bridge/jetty catch

Of the crabs kept for which sex was recorded, 885 (65%) were males and 484 (35%) females. The sex of crabs released was also recorded where possible; of these 867 (57%) were males and 642 (43%) females.

Table 6. Estimated recreational shore-based bridge/jetty catch of blue swimmer crabs.

	Total	Standard error
Number kept	82,994	8,005
Number released	96,967	10,801
Weight kept (tonnes)	17.0	1.2
Catch rate (crabs/person/trip)	1.60	0.14
Catch rate (crabs/person/hour)	0.57	0.06
Catch rate (crabs/party/trip)	6.75	0.49

An estimated 82,994 crabs were kept and 96,967 released by shore-based crabbers from bridges and jetties (Table 6).

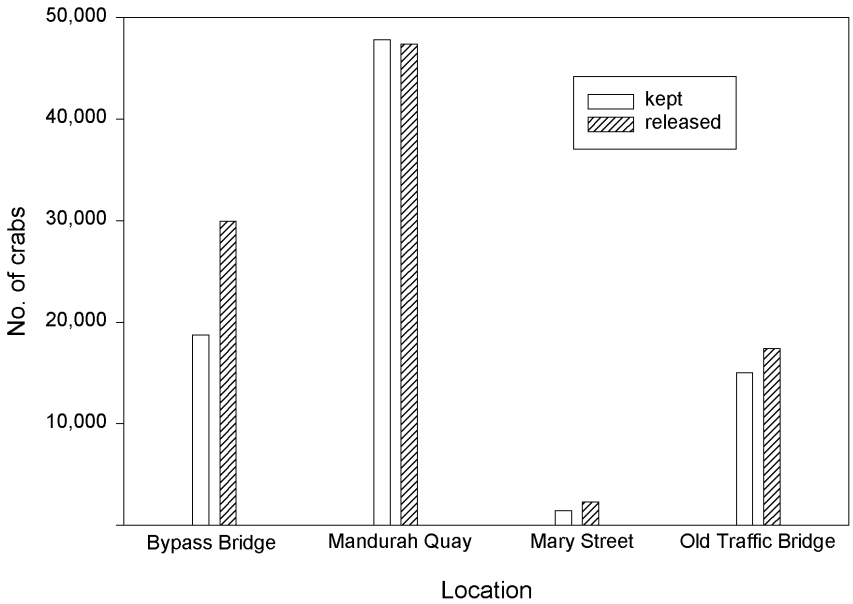

Figure 18. Estimated number of crabs kept and released per season by shore-based crabbers.

Over half (58%) of the crabs kept by shore-based crabbers from and in the close vicinity of the major bridges and jetties were caught at Mandurah Quay (Figure 18). Similar numbers of crabs were kept and released from all locations except for the bypass bridge where there were 1.6 crabs released for each one kept (Figure 18).

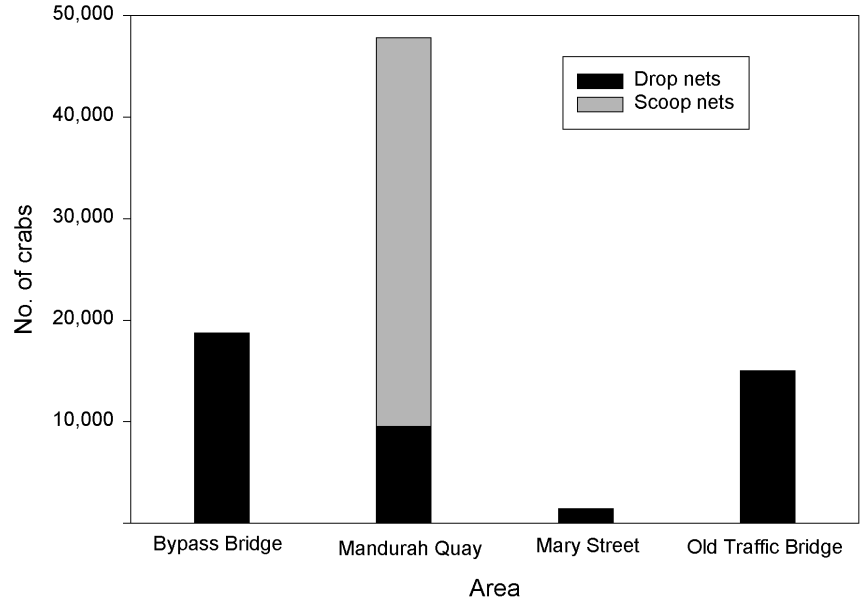

Figure 19. Estimated number of crabs kept per area by drop nets and scoop nets.

The majority of the Mandurah Quay catch was made by people scooping in the near vicinity of the quay. In all other areas the catch by scoopers was negligible (Figure 19).

The total annual weight of crabs kept by recreational shore-based crabbers from bridges and jetties in the Peel-Harvey Estuary was estimated to be 17.0 tonnes (11.6 tonnes of males and 5.4 tonnes of females) (Table 6).

3.2.5 Total catch of blue swimmer crabs

The total recreational harvest of blue swimmer crabs from the Peel-Harvey Estuary between August 1998 and July 1999 is estimated to have been 1,360,249 crabs (or 288.6 tonnes). It is also estimated that 1,366,373 crabs were released by recreational fishers over this same period (Table 7).

Table 7. Estimated total recreational catch of blue swimmer crabs.

	Boat	Scoopers	Jetties	Total	Standard error
Number kept	831,964	445,291	82,994	1,360,249	62,765
Number released	966,898	302,508	96,967	1,366,373	53,566
Weight Kept (tonnes)	181.7	89.9	17.0	288.6	10.2

3.3 Recreational catch of fish

A total of 21 species of fish were kept by recreational anglers in the Peel-Harvey Estuary (Appendix H). Of these, only 14 species were caught in sufficient numbers for the annual catch to be estimated. The species composition, by number of fish caught, for boat and shore-based anglers is shown in Figures 20 and 21.

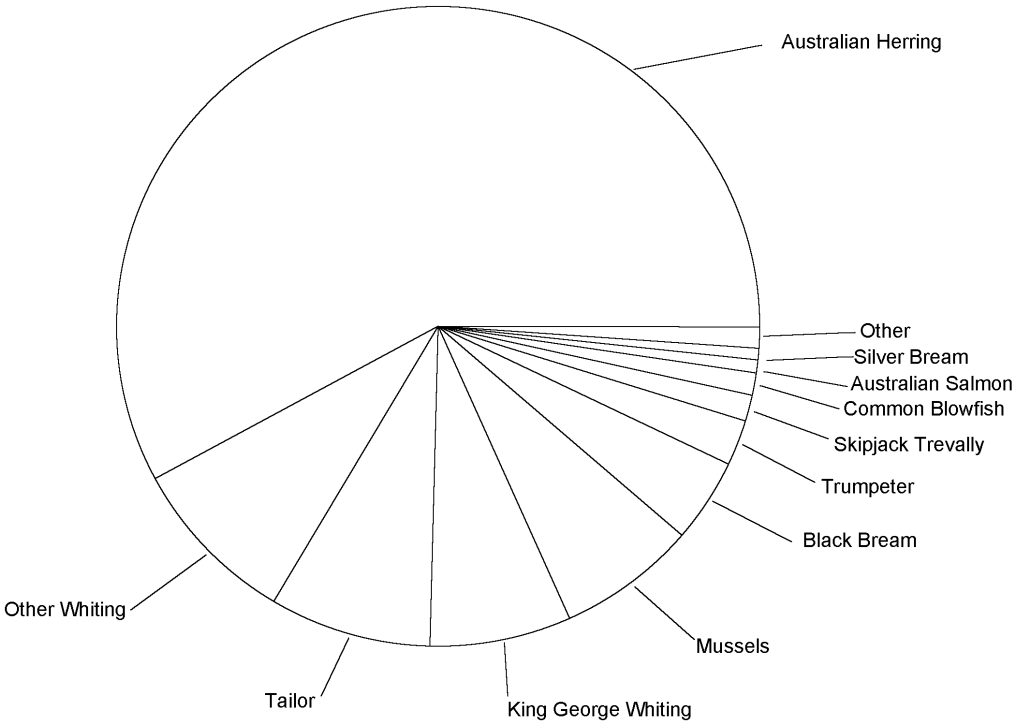

Figure 20. Species composition (by number) of recreational boat-based fish catch.

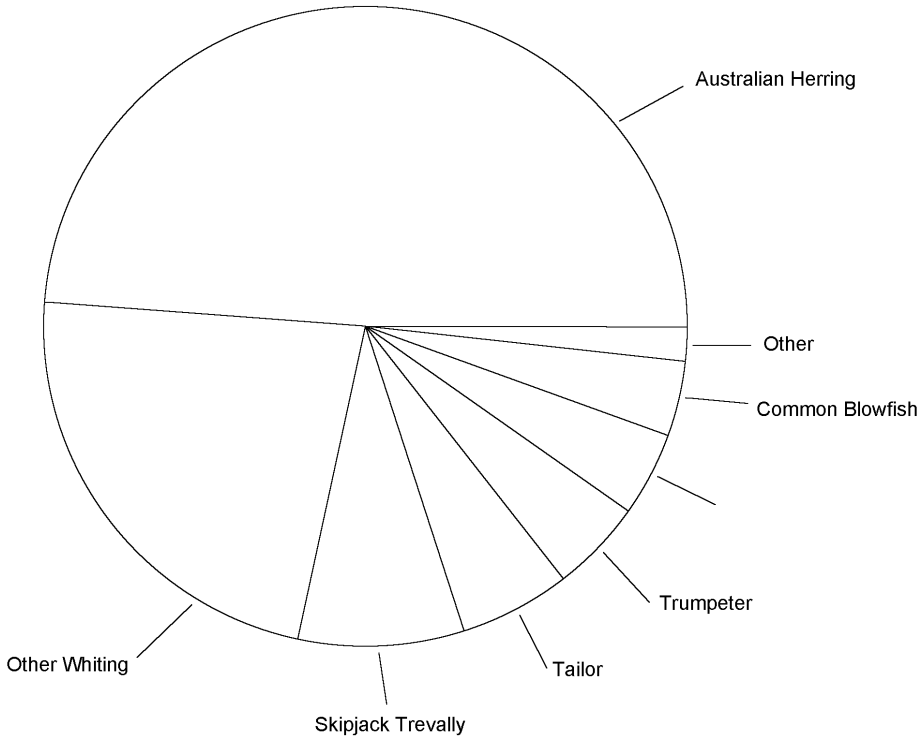

Figure 21. Species composition (by number) of recreational shore-based fish catch.

3.3.1 Boat-based catch

Australian herring were the most commonly kept fish by boat-based anglers with an estimated annual catch of 21,551 fish (Table 8). Whiting other than King George (*Sillago* spp.) were the next most common fish kept with an estimated annual catch of 3,210 fish. Other important species were tailor with an estimated annual catch of 3,051 fish kept, King George whiting with 2,659 fish kept and black bream with 1,556 fish kept. It was also estimated that 2,630 litres of mussels were kept by boat based fishers (Table 8).

Table 8. Estimated recreational boat-based fish catch.

Common name	Scientific name	No. kept	SE kept	No. released	SE released
Australian Herring	*Arripis georgianus*	21,551	1,550	1,060	160
Other Whiting	*Sillago spp.*	3,210	427	1,076	160
Tailor	*Pomatomus saltatrix*	3,051	336	2,960	418
King George Whiting	*Sillaginodes punctata*	2,659	792	602	287
Mussels	*Mytilus edulis*	2,630*	388	0	0
Black Bream	*Acanthopagrus butcheri*	1,556	405	2,440	1117
Trumpeters	*Teraponidae family*	855	137	738	168
Skipjack Trevally	*Pseudocaranx spp.*	495	113	166	36
Common Blowfish	*Torguigener pleurogramma*	421	139	3,064	471
Australian Salmon	*Arripis truttaceus*	237	80	309	65
Silver Bream (Tarwhine)	*Rhabdosargus sarba*	219	63	2,387	487
Flounder	*Pseudorhombus spp.*	86	17	0	0
Mulloway	*Argyrosomus hololepidotus*	42	16	335	148
Pink Snapper	*Pagrus auratus*	0	0	293	58

* The number of mussels kept is in litres.

Small quantities of garfish (*Hyporhamphus* spp.), wrasse (*Labridae* family), octopus *(Octopus* spp.) and cobbler (*Cnidoglanis macrocephalus*) were also kept by recreational boat-based anglers.

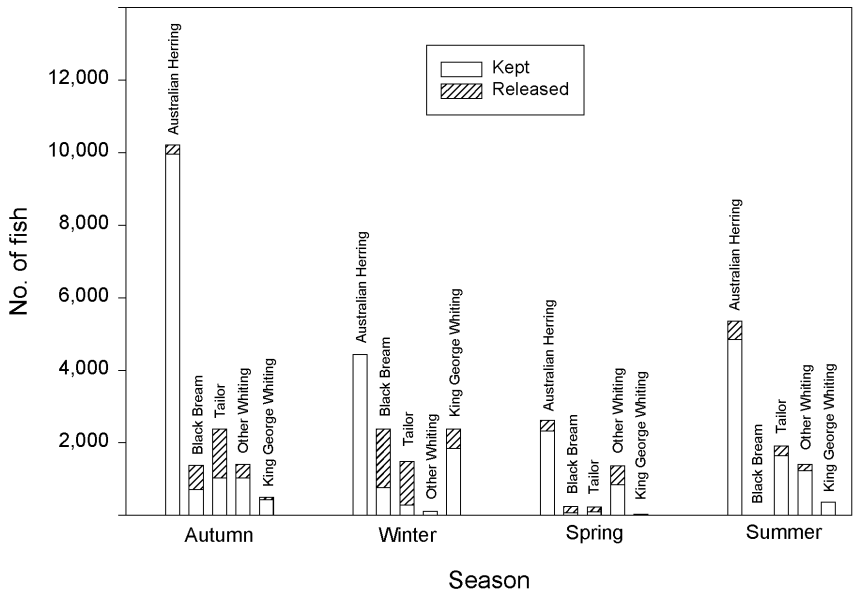

Figure 22. Estimated catch of predominant fish species per season.

Australian herring were the most commonly caught fish species during all seasons with the highest catch occurring during autumn (Figure 22).

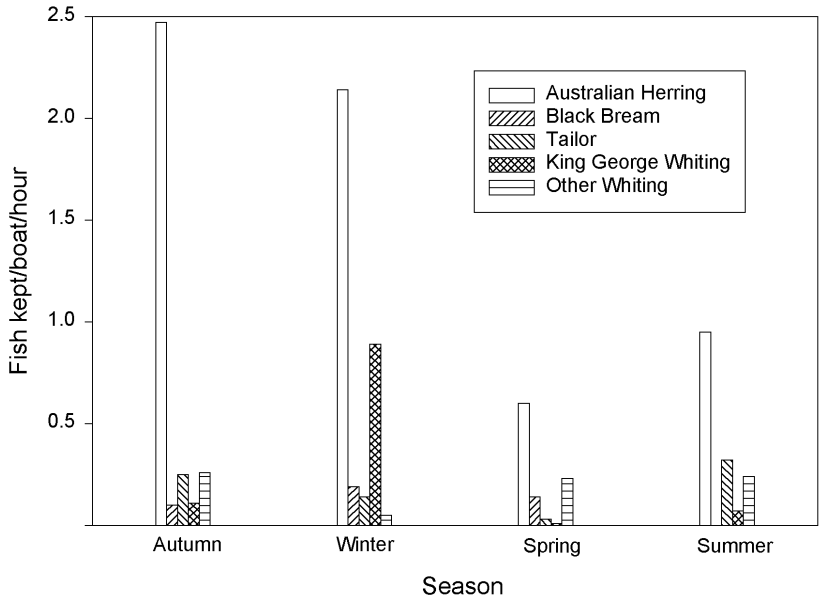

Figure 23. Angling catch rates per season (fish kept/boat/hour).

The best catch rate for a single fish species of almost 2.5 fish kept/boat/hour was found for Australian herring during autumn. The catch rate for Australian herring was also high in winter at just over two fish kept/boat/hour. The next highest catch rate of around one fish kept/boat/hour was found for both King George whiting during winter and Australian herring during summer (Figure 23).

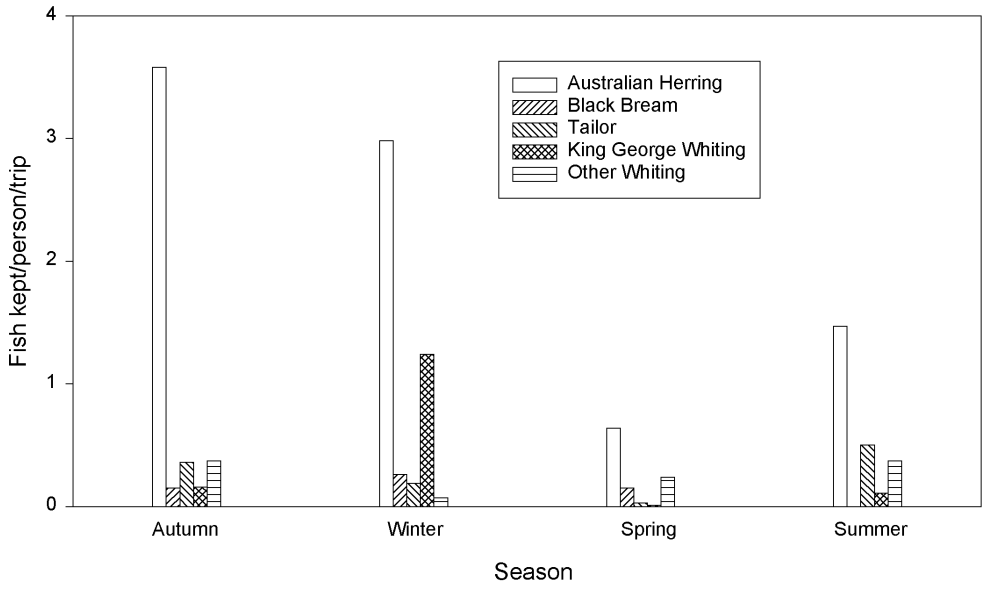

Figure 24. Angling catch rates per season (fish kept/person/trip).

Catch rates in fish kept/person/trip (Figure 24) follow the same trend as fish kept/boat/hour.

The total weight of Australian herring kept by boat-based anglers was estimated at 2.34 tonnes, followed by 0.19 tonnes of whiting other than King George, 0.88 tonnes of tailor, 0.30 tonnes of King George whiting, 0.53 tonnes of black bream and 0.06 tonnes of skipjack trevally.

3.3.2 Shore-based catch

In the Mandurah entrance channel Australian herring were the most commonly kept fish by shore-based anglers with an estimated catch of 25,989 fish. Whiting other than King George (*Sillago* spp.) were the next most common species with an estimated catch of 12,194 fish kept followed by skipjack trevally with 4,513 fish kept (Table 9). The shore-based estimates are for the bridges/jetties surveyed in the Mandurah entrance channel (see Section 3.1.5) between November and April and do not include the Dawesville Channel.

Table 9. Estimated recreational shore-based fish catch from the Mandurah entrance channel.

Common name	Scientific name	No. kept	SE kept	No. released	SE released
Australian Herring	*Arripis georgianus*	25,989	5,066	549	177
Other Whiting	*Sillago spp.*	12,194	1,709	1,767	450
Skipjack Trevally	*Pseudocaranx spp.*	4,513	1,053	898	293
Tailor	*Pomatomus saltatrix*	2,937	634	6,676	1,663
Trumpeters	*Teraponidae family*	2,517	614	3,321	1,141
Silver Bream (Tarwhine)	*Rhabdosargus sarba*	2,264	503	10,142	2,028
Common Blowfish	*Torguigener pleurogramma*	2,025	1,146	18,410	2,326
Pink Snapper	*Pagrus auratus*	314	139	1,590	360

Small quantities of yellowtail scad (*Trachurus novaezelandiae*), mussels (*Mytilus edulis*), King George whiting (*Sillaginodes punctata*) and flounder (*Pseudorhombus* spp.) were also kept by recreational shore-based fishers.

The total weight of Australian herring kept by shore-based anglers in the Mandurah entrance channel was estimated to be 1.99 tonnes, followed by 0.69 tonnes of whiting other than King George, 0.60 tonnes of skipjack trevally, 0.62 tonnes of tailor and 0.24 tonnes of silver bream.

3.4 Commercial catch and effort for blue swimmer crabs

During 1998-99 the commercial blue swimmer crab catch of 65.5 tonnes was 23% of the recreational catch and 19% of the overall catch. The commercial crabbing effort was 1,577 boat days during this period.

The annual commercial crab catch between 1991-92 and 1998-99 ranged from 11.2 tonnes in 1992-93 to a high of 83.2 tonnes in 1996-97 (Figure 25). The mean annual crab catch for these years was 46.2 tonnes. The annual crabbing effort in boat days per year ranged from 714 days in 1991-92 to 1,702 days in 1997-98 (Figure 25).

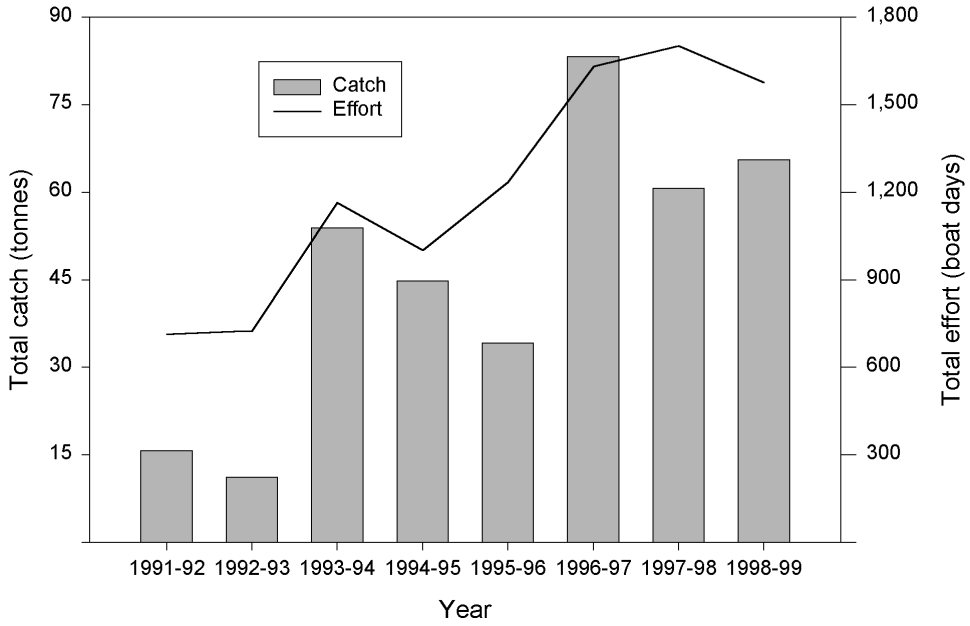

Figure 25. Annual commercial catch and effort for blue swimmer crabs in the Peel-Harvey Estuary (1991-92 to1998-99).

3.5 Commercial catch and effort for fish

During 1998-99 the commercial fish catch in the Peel-Harvey Estuary was 218,799 kg. This consisted of 15 species (Appendix I). The catch was predominantly sea mullet (109,441 kg) and yellow-eye mullet (61,416 kg). The next biggest catch was of King George whiting (16,491 kg). The fishing effort was 1,599 boat days.

The annual commercial fish catches in the Peel-Harvey Estuary between 1989-90 and 1998-99 ranged from 209,701 kg in 1991-92 to 336,748 kg in 1994-95 (Figure 26) with a mean annual catch of 260,193 kg. The annual commercial effort in days spent fishing per year ranged from 1,599 days in 1998-99 to 2,688 days in 1994-95 (Figure 26).

Figure 26. Annual commercial catch and effort for all fish species in the Peel-Harvey Estuary (1988 to 1998)

3.6 Fishing regulations

Only 7% of the 1,077 boats interviewed, with more than one person on board, that had been crabbing achieved or exceeded the boat limit of 48 crabs. However, 17 of the 57 boats interviewed (30%), with only one person on board, achieved or exceeded the bag limit of 24 crabs per person. Six boats (4%) caught their daily bag limit of a particular fish species (including mussels) while no anglers caught their daily bag limit of any fish species from the shore.

Two (3.5%) of the 57 boats with only one person on board exceeded the daily bag limit of 24 crabs. A further two (0.2%) of the 1,077 boats with two or more on board exceeded the daily boat limit of 48 crabs.

There was a high level of compliance with the size limits amongst boat-based fishers. Only 5.8% of boat crews angling had kept undersize fish while 105 (9.2%) of the 1,136 boat crews crabbing had kept undersize crabs.

Of the 105 boat crews which had kept undersize crabs, 69 (66%) were residents from the greater Perth metropolitan region living within a 50 km radius of the city centre and 30 (29%) were local Mandurah residents living within a 20 km radius of the Peel-Harvey Estuary.

Compliance rates were lower amongst shore-based crabbers with 92 (13%) of the 711 shore-based crabbing parties interviewed having kept undersize crabs. Sixteen (5.4%) of the 296 shore-based angling parties interviewed were found to have kept undersize fish.

Of the 92 shore-based crabbing parties which kept undersize crabs, 71 (77%) were residents from the greater Perth metropolitan region living within a 50 km radius of the city centre and 15 (16%) were local Mandurah residents living within a 20 km radius of the Peel-Harvey Estuary.

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 boat-based catch and effort for the Peel-Harvey Estuary. The survey method proved to be robust and was readily adapted to the area surveyed. The roving creel survey provided catch and fishing estimates for the shore-based crab catch in the Peel-Harvey Estuary with an acceptable level of precision. The roving creel survey also provided acceptable catch estimates of the key species caught by anglers in the Mandurah entrance channel.

The results may slightly understate the recreational boat-based catch since the survey could not include any boats fishing after 7:00pm (6:00pm in April, May, September and October and 5:00pm in June, July and August), and boats that had finished fishing and returned to the boat ramp before 7:00am (8:00am 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 as 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 taken into account.

Both the boat-based and shore-based catch and fishing effort will also be underestimated as it was not feasible to include the catch and fishing effort for boats kept in canals or for residents fishing from their properties in the canal developments

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 4% of the estimated catch for boat-based crabbers, 12% for shore-based scoopers and 10% for shore based crabbers fishing from bridges and jetties.

The seasonal fluctuations in crabbing effort and catch rates for recreational boat and shore-based crabbers are explained by the biology of blue swimmer crabs in the Peel-Harvey Estuary. Potter *et al*. (1983) and Potter *et al*. (1998) found that crab numbers in the 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. Recreational catch rates peaked during summer due to the increasing abundance of crabs over the minimum legal size limit (CW = 127mm) at this time of year (Potter *et al*., 1983).

The large difference in the proportion of male to female crabs caught by boat-based crabbers is supported by the results of research conducted in the Leschenault Estuary. The overall sex ratio of females to males for crabs caught (both kept and released) by recreational boat-based crabbers using drop nets in the Leschenault Estuary was 1:3.5 (Malseed *et al*., 2000), while Potter and de Lestang (in press) found the sex ratio of females to males for crabs caught in pots in the Leschenault Estuary to be 1:3.8. In the Peel-Harvey Estuary the overall sex ratio was slightly higher at 1:5.1.

Female crabs made up a much greater proportion of the shore-based catch. The sex ratio of females to males for crabs caught by shore-based crabbers was 1:1.5. Shore-based crabbers (particularly scoopers) target crabs in shallow water. This finding therefore supports the results of Potter *et al*. (1987), who found that female blue swimmer crabs are more abundant in shallow areas.

Blue swimmer crabs are the key species for recreational fishers in the Peel-Harvey Estuary with 88% of boat based fishing effort and 83% of shore based fishing effort targeting crabs. The estimated recreational catch for 1998-99 of 288.6 tonnes is substantial and more than four times the 1998-99 commercial catch in the estuary of 65.5 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 Australian herring 7%, whiting other than King George 13%, tailor 11%, King George whiting 30% and black bream 26%.

The recreational fish catch from the Peel-Harvey Estuary during 1998-99 was relatively small compared to the recreational crab catch. The shore based catch was, however, underestimated since the Dawesville Channel was not included in the survey and the bridges and jetties in the Mandurah entrance channel were only surveyed during the peak season from November to April. The catch from recreational netting in the estuary was also not included. The overall combined catch of the six key species (Australian herring, whiting other than King George, tailor, skipjack trevally, King George whiting and black bream) was estimated to be less than 10 tonnes (Appendix J).

The commercial catch during 1998-99 was much greater, around 219 tonnes, but was predominantly made up of mullets (sea and yellow-eye) which were not prevalent in the catch of recreational anglers. They would, however, have been taken by recreational netters who are permitted to fish on Wednesday nights from the 1 November to 31 July.

The commercial and recreational catch of Australian herring were of similar magnitude. However, the commercial catch of whiting, both King George and whiting other than King George was significantly larger than the recreational catch (Appendix J).

5.0 Conclusions

The study has provided information on the extent and distribution of recreational fishing effort. In the Peel-Harvey Estuary, recreational fishing effort is directed towards blue swimmer crabs with most effort occurring during the summer months.

The results clearly show the importance of recreational "crabbing" in the Peel-Harvey Estuary. 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 Peel-Harvey Estuary and all other estuaries throughout the state and to study long term trends in catch and catch rates.

6.0 Acknowledgments

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8.0 Appendices

APPENDIX A: Boat ramp form

PEEL/HARVEY RECREATIONAL BOAT 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**	**Slight 2**	**Mod 3**	**Rough 4**	**V. Rough 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**

Boat Types

P: Power boat

Y: Yacht

O: Other

APPENDIX B: Boat ramp interview form

PEEL / HARVEY RECREATIONAL BOAT SURVEY
INTERVIEW QUESTIONNAIRE

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

Interview Time	Boat (Pwr/Yacht/Other)	Start Time	Fish/Dive/Snorkel/Other	Number in Boat	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)				

MANDURAH HIRE BOAT SURVEY

Company Name:_____

Date	Hire Time (Hours)	Time Spent Fishing (Hours)	Number of Crab Nets Used	Number of Crabs Kept	Number of Crabs Released	Number of Lines Used	Number and Type of Fish Kept

APPENDIX D: Shore fisher interview form

PEEL/HARVEY SHORE SURVEY 1998/99

Officers' Names: _____

_____

Location: _____

Date: ____/____/____

Time (24hr): _____

Number boats fishing: _____

Number shore fishers: _____

WIND Direction: _____

Calm	Light	Mod	Strong	Gale
1	2	3	4	5

WATER

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

CLOUD COVER & RAINFALL

Cloud %	Nil	Light	Moderate	Heavy
	1	2	3	4

LENGTHS OF RANDOM SAMPLE (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: .....

Fisher Number	1	2	3	4
Home postcode				
Number in group				
Times interviewed before				
Boat/Shore/Dive/sNorkel				
Number persons fishing				
Time spent fishing (decimal hours)				
Number of lines used				
Nets (Crab, Gill, Scoop), Pots				
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 E: 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:

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

where T is the time taken to complete the bus route, w_i 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.

$$f = \frac{\sum_j (r_j - \ell_j)}{\sum_j b_j} \qquad (2)$$

where

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

r_j is the retrieval time for boat j and ℓ_j is the launch time for boat j. The fishing effort was estimated for a random sample of days in each stratum (see Section 2.2). The estimated variance within stratum k is (Pollock *et al*., 1994)

$$s_k^2 = \frac{1}{n_k - 1} \sum_{m=1}^{n_k} \left(e_{km} - \bar{e}_k \right)^2 \qquad (3)$$

where n_k is the sample size (days) for stratum k, e_{km} the effort for stratum k on day m and $\bar{e}_k$ 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

$$Var(\bar{e}_k) = \frac{s_k^2}{n_k} \left(\frac{N_k - n_k}{N_k} \right) \qquad (4)$$

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

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

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

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

and the standard error is calculated by the usual method

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

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, c_{kj} 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)

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

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

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

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

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

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

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

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

Species	Length-weight[1]	Source
Blue swimmer crab (male) *(Portunus pelagicus)*	$W = 2.56\times10^{-5}$ CW $^{3.260}$ (r^2= 0.99, n=694)	Potter *et al.*, 1983
Blue swimmer crab (female) *(Portunus pelagicus)*	$W = 5.97\times10^{-5}$ CW $^{3.056}$ (r^2= 0.99, n=1076)	Potter *et al.*, 1983
Tailor *(Pomatomus saltatrix)*	$W = 5.15\times10^{-5}$ L $^{2.714}$	R. Steckis, unpubl. data
Australian Herring *(Arripis georgianus)*	$W = 1.022\times10^{-5}$ L $^{3.015}$	Fairclough, 1998
King George Whiting *(Sillaginodes punctata)*	$W = 1.99\times10^{-6}$ L $^{3.19}$	McGlennon and Kinloch, 1997
Black Bream[2] *(Acanthopagrus butcheri)*	$W = 8.13\times10^{-6}$ L $^{3.14}$ (r^2= 0.99, n=865)	G. Sarre, unpubl. data
Silver Bream (Tarwhine) *(Rhabdosargus sarba)*	$W = 2.56\times10^{-5}$ L $^{2.9206}$	B. Malseed, unpubl. data
Skipjack Trevally *(Pseudocaranx dentex)*	$W = 1.4978\times10^{-5}$ L $^{2.9683}$ (r^2= 0.99, n=303)	B. Malseed, unpubl. data
Whiting other than King George[3] (Sillago spp.)	$W = 8.32\times10^{-6}$ L $^{2.98}$	G. Hynes, unpubl. data

[1] Total Length *(L)* or Carapace Width *(CW)* in millimetres and Weight *(W)* in grams
[2] Using relationship for females
[3] Using relationship for yellow-fin whiting *(Sillago schomburgkii)*

APPENDIX G: 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)

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

where n_k is the sample size (days) for stratum k, e_{km} the effort for stratum k on day m and $\bar{e}_k$ 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

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

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

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

and the standard error is calculated by the usual method

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

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 H: Fish species kept by recreational fishers in the Peel-Harvey Estuary during 1998-99

Common name	Scientific name	Kept by boat-based anglers	Kept by shore-based anglers
Australian Herring	*Arripis georgianus*	Yes	Yes
Tailor	*Pomatomus saltatrix*	Yes	Yes
King George Whiting	*Sillaginodes punctata*	Yes	No
Western School Whiting	*Sillago vittata*	Yes	Yes
Black Bream	*Acanthopagrus butcheri*	Yes	No
Trumpeters	*Teraponidae family*	Yes	Yes
Mussels	*Mytilus edulis*	Yes	No
Skipjack Trevally	*Pseudocaranx spp.*	Yes	Yes
Unspecified Whiting	*Sillago spp.*	Yes	Yes
Common Blowfish	*Torguigener pleurogramma*	Yes	Yes
Australian Salmon	*Arripis truttaceus*	Yes	No
Silver Bream (Tarwhine)	*Rhabdosargus sarba*	Yes	Yes
Yellow-finned Whiting	*Sillago schomburgkii*	Yes	Yes
Yellowtail Trumpeter	*Amniataba caudavittatus*	Yes	No
Flounder	*Pseudorhombus spp.*	Yes	No
Southern School Whiting	*Sillago bassensis*	Yes	No
Mulloway	*Argyrosomus hololepidotus*	Yes	No
Southern Sea Garfish	*Hyporhamphus melanochir*	Yes	No
Wrasse	*Labridae family*	Yes	No
Octopus	*Octopus spp.*	Yes	No
Cobbler	*Cnidoglanis macrocephalus*	Yes	No
Pink Snapper	*Chrysophrys auratus*	No	Yes

APPENDIX I: Fish species kept by commercial fishers in the Peel-Harvey Estuary during 1998-99

Common name	Scientific name
Sea Mullet	*Mugil cephalus*
Yellow-eye Mullet	*Aldrichetta forsteri*
King George Whiting	*Sillaginodes punctata*
Other Whiting	*Sillago spp.*
Australian Herring	*Arripis georgianus*
Perth Herring	*Nematalosa vlaminghi*
Tailor	*Pomatomus saltatrix*
Cobbler	*Cnidoglanis macrocephalus*
Southern Sea Garfish	*Hyporhamphus melanochir*
Roach	*Gerres subfasciatus*
Skipjack Trevally	*Pseudocaranx spp.*
Mulloway	*Argyrosomus hololepidotus*
Flounder	*Pseudorhombus spp.*
Samson Fish	*Seriola hippos*

APPENDIX J: Comparison of recreational and commercial catch of key recreational fish species in the Peel-Harvey Estuary during 1998-99

Common name	Scientific name	Recreational catch (tonnes)*	Commercial catch (tonnes)
Australian Herring	*Arripis georgianus*	4.33	5.8
Tailor	*Pomatomus saltatrix*	1.5	5.3
King George Whiting	*Sillaginodes punctata*	0.31	16.5
Other Whiting	*Sillago spp.*	0.88	11.1
Black Bream	*Acanthopagrus butcheri*	0.53	0
Skipjack Trevally	*Pseudocaranx spp.*	0.66	0.15
	Total	**8.21**	**38.85**

* Recreational shore-based catch from the Dawesville Channel has not been included.