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# A 12-month survey of recreational fishing in the Pilbara region of Western Australia during 1999-2000

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Government of Western Australia

Fish for the future

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The Fisheries Research Division of the Department of Fisheries is based at the Western Australian Fisheries and Marine Research Laboratories, PO Box 20, North Beach (Perth), Western Australia, 6920. The Fisheries and Marine Research Laboratories serve as the centre for fisheries research in the State of Western Australia.

Research programs conducted by the Fisheries Research Division and laboratories investigate basic fish biology, stock identity and levels, population dynamics, environmental factors, and other factors related to commercial fisheries, recreational fisheries and aquaculture. The Fisheries Research Division also maintains the State data base of catch and effort fisheries statistics.

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 Pilbara region of Western Australia during 1999-2000

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## Abstract

*A 12-month creel survey of recreational boat-based and shore-based fishing in the Pilbara region (Onslow to Broome inclusive) of Western Australia was conducted between December 1999 and November 2000. During the survey 3,085 boat crews were interviewed at public boat ramps when they returned from their fishing trips. Patrols conducted along the coastline interviewed 73 groups of boat-based fishers and 569 groups of shore-based fishers at fishing locations and camp sites.*

*The total annual recreational fishing effort for the Pilbara region was estimated to be 201,000 fisher days (95%CI: 193,000 – 210,000). This comprised 109,000 fisher days by boats launched from public ramps, 26,000 fisher days by boats launched from beaches and 67,000 days by shore-based fishers.*

*The total recreational catch of all finfish species for the region was estimated at 383 tonnes (95%CI: 331 – 435). This was approximately one sixth of the commercial catch of 2,442 tonnes taken in the region during 2000. The most common species kept by recreational fishers in the Pilbara region were (in order of estimated weight kept) spangled emperor (31 tonnes), narrow-barred Spanish mackerel (28 tonnes), golden trevally (26 tonnes), blue-lined emperor (23 tonnes), blue swimmer crabs (22 tonnes), blackspot tuskfish (22 tonnes), threadfin salmon (18 tonnes), green mud crabs (17 tonnes), mullet species (13 tonnes), estuary cod (13 tonnes), black-tip reef shark (12 tonnes), Queensland and Australian spotted mackerel (11 tonnes) and stripey seaperch (11 tonnes). These catches do not include charter boats and therefore understate the total recreational catch for the region.*

*Anglers have adopted modern technology to increase the efficiency of recreational fishing with 71 percent of boats launched from public boat ramps fitted with an echo-sounder and 40 percent using a global positioning system. There was a very high level of compliance with the fishing regulations. Only five percent of boats launched from public ramps, three percent of boats launched from the beaches and one percent of shore-based fishers interviewed kept undersize fish. Very few fishers exceeded the bag limits. Most fishers had a reasonable knowledge of the fishing regulations and knew the bag (67%) and size (67%) limits for the species they were targeting or the predominant species they had caught.*

# 1.0 Introduction

The Recreational Fisheries Program of the Department of Fisheries has a strategic plan to conduct creel surveys of recreational fishing in each of the four bioregions within the state on a rotating bioregion-by-bioregion basis (Penn *et al*., 2003). The bioregions include the South Coast, West Coast, Gascoyne Coast and North Coast (Figure 1). To record and monitor changes in recreational catch and fishing effort, an integrated approach where all bioregions are to be surveyed on a regular basis (about once every five to six years) was proposed.

Information on the recreational catch and fishing effort for each bioregion of Western Australia is required to develop management strategies to ensure the sustainability of fishing activities, and for the conservation of fish stocks and fish habitat. These data will be used in the assessment of the status of stocks for the prime recreational species and provide fishing quality indicators such as catch rates, size composition, and variety of species caught. This information will also be used in the development of a management plan for each bioregion and will form the basis for future management decisions to improve or maintain the quality and diversity of recreational fishing experiences, and to achieve equity between different users of this resource.

Recreational fishing is one of the most popular leisure activities in Western Australia. A survey (Baharthah, 2004) estimated that 533,000 persons participated in recreational fishing at least once a year. According to this survey, the Pilbara region of the North Coast bioregion was utilised by 27,000 (five percent) recreational fishers each year.

Due to logistical constraints imposed by cost efficiencies and the size of the North Coast bioregion only the western half (Pilbara) was surveyed. This survey incorporated the area between 4nm south of the Ashburton River (114°50′E) up to and including Broome, and included approximately 1,200 kilometres of coastline. In the Pilbara most recreational fishing occurs in the ocean, whereas, in the eastern half (Kimberly) fishing is predominantly in rivers and estuaries. The surveyed region includes many of the prime recreational fishing locations in Australia. There is excellent recreational boat-based and shore-based fishing along the coastline. The region offers a range of fishing experiences including angling and fishing for crabs in the ocean and tidal creeks. The region is a popular tourist destination between April and October when residents of the south of the state travel north to escape the winter weather. Visitors from the eastern states and overseas also participate in fishing activities. Local residents participate in recreational fishing throughout the year.

The purpose of this report is to provide an estimate of the recreational catch and fishing effort for the Pilbara region (including Broome) of Western Australia, using creel survey techniques. The estimated catch for major species recorded is presented together with information on species targeted, fisher's place of residence, compliance with the regulations and attitudes of recreational fishers.

# 2.0 Methods

## 2.1 Survey design

There are many access sites for boats (including boat ramps and places where boats may be launched from the beach) and potentially unlimited access for shore-based fishers on most of the Western Australian coastline. This is true for the Pilbara region, which includes many locations on the coast that are accessible to recreational fishers. Many of these locations are remote and only accessible by four-wheel drive vehicle. Nonetheless, many recreational fishers visit the region and camp at these locations for extended periods. For this reason, creel surveys must cover a large geographical area, creating logistical difficulties for conducting field work. Furthermore, survey methods for boat-based fishers must be suitable for regions with many boat ramps and large distances between ramps (Figure 2).

Two separate creel survey methods were used to estimate the recreational catch of all species for boat-based and shore-based fishers in the region. The bus route method (Robson and Jones 1989, Jones *et al*. 1990), where a survey interviewer visits all boat ramps in a district on the one day, was used for trailered boats launched from public boat ramps. Roving creel surveys were used to estimate the catch and fishing effort for shore-based fishers and fishers launching small boats from beaches.

The recreational catch and fishing effort from tourists on Thevenard Island (Figure 2) was estimated by surveying groups staying on the island. The Island Manager conducted the survey on a random sample of days at the end of each days fishing activities. The survey continued while the island was open to tourists from March 1 to October 15, 2000.

Staff working on Barrow Island, Varanus Island and Thevenard Island (Figure 2) were asked to complete a questionnaire before leaving the islands. This component of the recreational catch and effort for the region was estimated from the sample data collected from the survey together with information on the number of trips to these islands during the 12-month survey.

Catch and fishing effort information for recreational fishers was recorded at a resolution of 5×5 nautical miles. These blocks fit within the statistical blocks used for recording the commercial catch in Western Australia (60×60 nautical mile) and offer a finer resolution for reporting the recreational catch.

The catch and fishing effort from charter boats was not included in the study since a compulsory returns system for tour operators was undergoing development at the time. This information will be reported elsewhere.

Estimates of recreational catch and effort have been reported for the whole of the Pilbara region. Similar information has been reported for the Dampier Archipelago separately since this area was subject to a marine park proposal at the time.

## 2.2 Spatial and temporal stratification

The 12-month survey commenced in December 1999 and concluded at the end of November 2000.

### Bus route method - boats launched at public boat ramps

The region was divided into a number of districts so that an interviewer could visit all the boat ramps within a district in a day. Seven geographic districts were defined, their boundaries were chosen to minimise travel time and hence costs of using the bus route method. Routes with prolonged stops at all public marine boat ramps were set up for each district (Figure 2). The districts and the number of boat ramps surveyed (in parentheses) were as follows: Onslow (1), Dampier (3), Karratha (1), Wickham (3), Port Hedland (3), Cape Keraudren (1) and Broome (3).

The survey of public boat ramps was stratified by district, season (wet or dry) and day type (weekday or non-weekday). Separate total catch and fishing effort estimates were made for each of the 28 strata (seven districts × two seasons × two for weekdays and non-weekdays). These estimates were then aggregated to obtain the total recreational boat-based catch and effort for the region.

### *Roving creel survey – shore-based fishing and boats launched from beaches*

The roving creel survey of shore-based fishers and boats launched from beaches was stratified by season and area. The areas were Onslow to Dampier and Dampier to Broome. The two areas were combined to obtain the catch and fishing effort for the entire region. The survey included but was not limited to the following locations:

1) Onslow to Dampier

Secret Creek, Hooley Creek, Ashburton River, Old Onslow, Four-Mile Creek, Sunset Beach, Sunrise Beach, Onslow, Beadon Creek, Mary Anne Creek, Yardie River, Cane River, Fortescue River, Fourty-Mile Camp (Devil's Creek), Yanyare and Maitland River.

2) Dampier to Broome

Dampier, Cleaverville, Cossack, Point Sampson, Sam's Creek, Pope's Nose Creek, Walcott, Balla Balla, Yule River, Port Hedland, Finucane Island, Spoil Bank, Cemetery Beach, Cooke Point, Pretty Pool, Four-Mile Creek, Six-Mile Creek, De Grey River, De Grey Bridge Picnic Area, Tichalar, Condon, Pardoo Station, Keraudren, Eighty Mile Beach Caravan Park, Port Smith, Barn Hill, Broome Jetty, Entrance Point, Gantheaume Point, Cable Beach, Town Beach, Riddell Beach and Crab Creek.

## 2.3 Sampling strategy

### *Bus route method - boats launched at public boat ramps*

The bus route method (Robson and Jones 1989, Jones *et al*. 1990) was used for trailered boats launched from public boat ramps.

The survey of boat ramps (questionnaire shown as Appendices A and B) was restricted to eight hours during the day, from 10:00 am to 6:00 pm, which included most of the period when fishing activity occurred. Periods of lower fishing activity, such as at night, could not be covered with the available resources. Prior information suggested that, although night fishing occurred in some districts at certain times of the year, it comprised only a small portion of the total recreational fishing effort. Almost all recreational boats return to the boat ramps by 6:00 pm to avoid having to navigate the return trip in darkness. The safety of interviewers at night was also a concern.

A separate morning bus route survey was conducted at Dampier (Figure 2) from 6:00 am to 10:00 am to estimate the number of boats returning to the ramp before 10:00 am. This was intended to pick up boats returning from the islands in the Dampier Archipelago following an overnight stay.

### *Roving creel survey – shore-based fishing and boats launched from beaches*

A roving creel survey (questionnaire shown as Appendix C) was used to collect catch and effort information from shore-based fishers and boat-based fishers that launched small boats from beaches. The interviewers visited most fishing locations in the region where these activities occurred. This included locations only accessible by four-wheel drive vehicle. Instantaneous counts of the number of shore-based fishers and boats fishing, estimated by counting boat trailers and vehicles with roof racks, were made on arrival at each fishing location visited. The time spent fishing, catch and other relevant information was recorded from shore-based fishers and boat crews when they returned from their fishing trip. In addition, groups of people were interviewed at camping sites to collect additional catch rate information.

The duration of these patrols was also limited to daylight hours due to concerns for the safety of staff and budgetary constraints.

### Other methods – offshore islands

The recreational catch and fishing effort from Thevenard Island was estimated by surveying groups staying on the island. The Island Manager conducted the door-to-door survey at the end of the days fishing activities using the same questionnaire as the roving creel survey (Appendix C). The survey continued while the island was open from March 1, to October 15, 2000.

Staff working on Barrow Island, Varanus Island and Thevenard Island were asked to complete a questionnaire (Appendix D) before leaving the islands. This component of the recreational catch and effort for the region was estimated from sample data collected from the survey together with information on the number of trips to these islands during the 12-month survey.

## 2.4 Estimation of total catch and effort

### Boats launched at public boat ramps – bus route method

The fishing effort for the day was estimated from counts of the number of trailers at the boat ramps and recorded launch and retrieval times. Fishing effort by boats that were launched before the start of shift (10.00am) and returned after the start of the shift was also taken into account. The ratio of effort occurring prior to the start of a shift to that occurring after the start of a shift was estimated and a correction factor (*f*) applied to the effort estimate for each season (Appendix E). Boats that returned to the ramp before 10:00am or fishing effort occurring after 6:00pm could not be included.

The measure of fishing effort for each season was adjusted to correct for the number of boats not involved in fishing activities. The correction was made by multiplying trailer counts by the proportion of boats interviewed that were participating in recreational fishing.

Catch rates were estimated from information on the time spent fishing and catch obtained by interviewing fishers 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 (Appendix E). The number of hooked fish eaten by sharks and the number of hooked fish where lines were broken off were estimated by multiplying the loss rate by fishing hours.

The total number of fish both kept and released for all species was estimated. The standard error associated with the estimate of the number of fish kept $SE(\hat{c})$ was calculated for each species. Assuming a student $t$ distribution, the (1-$\alpha$) percent confidence interval for the number kept $(\hat{c})$ was calculated from the standard error as follows:

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

where $\alpha = 0.05$ for the 95% confidence interval and $n$ is the number of boats surveyed (sample size). The estimates reported in the results (Section 3.0) have been rounded to reflect the level of precision.

### Boats launched from beaches – roving creel survey

Fishing effort (boat-hours) was calculated by multiplying the instantaneous counts by the number of hours surveyed in the fishing day (9). Catch rates were estimated from information on the time spent fishing and catch obtained by interviewing boat-based fishers when they returned to the beach at the completion of the fishing trip. The total catch was estimated by multiplying the catch rate by the estimate of total fishing effort in boat hours (Appendix F).

### Shore-based fishing – roving creel survey

Fishing effort (fisher-hours) was calculated by multiplying the instantaneous counts by the number of surveyed hours in the fishing day (9). Catch rates were estimated from information on the time spent fishing and catch obtained by interviewing anglers and netters while they were still fishing. The total catch was estimated by multiplying the catch rate by the estimate of total fishing effort in fisher hours (Appendix G).

### Estimation of effort in fisher-days

For boat-based fishing, the effort estimates in fisher-hours was converted to fisher-days by dividing by the mean time spent fishing and multiplying by the mean number of fishers on the boat. For shore-based fishing the effort estimates in fisher-hours was converted to fisher-days by dividing by the mean time spent fishing.

### Weight estimation

For all three survey methods, the whole weight of the catch, in tonnes, was estimated from existing length to weight relationships for each species. The weight of fish kept has been reported for the predominant species only.

# 3.0 Results

## 3.1 Interviews

### Boats launched from public boat ramps

During the 12-month survey, 3,085 boat crews were interviewed at public boat ramps when they returned from their fishing trip. Of these 2,276 boat crews had been angling, 732 were targeting crabs (of which 387 were both angling and crabbing), 44 had been diving using compressed air, 31 were snorkelling, two were collecting species like rock lobsters and mud crabs by hand and 387 were not involved in fishing activities.

### Boats launched from beaches

Mobile patrols conducted along the coastline interviewed 72 groups of fishers that launched small boats from the beaches. Of these groups, six were returning from fishing at the time of the interview, 33 had already finished fishing for the day, 27 were not planning on fishing that day and six were planning a trip for later that day.

### Shore-based fishing

Mobile patrols also interviewed 569 groups of shore-based fishers at fishing locations and campsites. Of these groups, 391 were shore-based fishing at the time of the interview, 110 had already finished fishing for the day, 45 had not fished by the time they were interviewed and 23 were planning on fishing later that day.

### Place of residence for recreational fishers

The largest proportion of recreational fishers launching boats from public ramps were residents of the Pilbara region itself (Figure 3). Residents from other regional areas of the state, the Perth metropolitan area and other states also fished in the region. No overseas residents were interviewed.

## 3.2 Species targeted

The species targeted by fishers launching boats at public ramps was related to the range of species frequently caught at the time of year. However, often anglers were not targeting a specific species. When this response occurred, the interviewer recorded whether they were fishing on the surface, bottom or both (i.e. surface fishing, bottom fishing or general fishing) since this determines the range of species that are likely to be caught.

The target species varied with the district and fishing platform (boat or shore). For example, many anglers that launched boats from public ramps from all districts except Karratha could not name a specific species that they were targeting so general bottom fish was recorded (Figures 4). Fishers from Karratha largely targeted blue swimmer crabs. Fishers who launched boats over beaches targeted a variety of species including mangrove jack and blackspot tuskfish (Figure 5). Many shore-based fishers also targeted bottom fish (Figure 6).

Some recreational fishers caught the species being targeted (Tables 1, 2 and 3). For crabs the gear used was specific to these species. Anglers were also successful at targeting specific fish species. Many anglers fishing from boats launched at public ramps targeting mackerel, emperors, mangrove jack, threadfin salmon and tuskfish, caught that species. Anglers were less successful at targeting barramundi and coral trout. However, it was common for anglers to catch species other than those targeted.

## 3.3 Recreational fishing effort

The recreational fishing effort for boats launched from public ramps, boats launched from the beaches and shore-based fishers were estimated separately due to the different creel survey methods used. Overall, recreational fishers in the region spent more days boat-based fishing than shore-based fishing (Figure 7).

### 3.3.1 Boats launched from public ramps

The estimated total annual recreational fishing effort by boats launched from public ramps was 109,000 fisher days (95%CI: 105,000 – 113,000). The recreational boat-based fishing effort was greatest in Dampier (Hampton Harbour Boat and Sailing Club, Public Ramp and Whitnell Bay) followed closely by Broome (Gantheaume Point, Mangrove Point and Entrance Point) (Figure 8). The dry season (April through to October) was by far the most popular season for fishing in all districts.

Results indicate that most fishing occurred during the period of the day surveyed (10:00am to 6:00pm). However, fishing also occurred both before and after the survey period, as indicated by the boat launch and retrieval times. The ratio of fishing effort occurring prior to the start of the morning shift to that occurring after the start of the morning shift was estimated and a correction factor ($f$) applied to the effort estimate for each season (Table 4 and Appendix E).

Most boats had returned to the ramp before the end of the shift (6:00pm). The number of boats returning after this time of the day, based on the number of trailers remaining, was relatively small (1.8 boats per ramp on average).

### 3.3.2 Boats launched from beaches

The estimated total annual recreational boat-based angling effort for boats launched from beaches in the Pilbara region was 26,000 fisher days (95%CI: 22,000– 29,000) (Figure 9). This included 23,000 fisher days from the mainland and 3,000 days from Thevenard, Barrow and Varanus Islands. The dry season was again the most popular season for fishing.

### 3.3.3 Shore-based fishers

The estimated total annual recreational shore-based angling effort for the Pilbara region was 67,000 fisher days (95%CI: 60,000 – 73,000) (Figure 10). This included 58,000 fisher days from the mainland and 9,000 days from Thevenard, Barrow and Varanus Islands. The dry season was also the most popular season for fishing.

### 3.3.4 Total fishing effort

The estimated total annual recreational fishing effort for the Pilbara region was 201,000 fisher days (95%CI: 193,000 – 210,000). The fishing effort was highest in the more accessible areas such as Dampier, Karratha, Port Hedland, Broome and Onslow (Appendix H).

## 3.4 Recreational fishing catch

The recreational catches for boats launched from public ramps, boats launched from the beaches and shore-based fishers were estimated separately due to the different creel survey methods used. Where the catch for a species was small and could not be accurately estimated the results were not reported separately.

### 3.4.1 Boats launched from public ramps

The most common species kept by recreational fishers that launched a boat from a public ramp in the Pilbara region were (in order of estimated number kept rounded to nearest 100) blue swimmer crabs (65,100), stripey seaperch (17,700), blue-lined emperor (14,800), green mud crabs (13,400), Queensland school and Australian spotted mackerel (8,700), spangled emperor (7,000), squid (northern calamari) (5,600), golden trevally (4,700), threadfin salmons (4,600) and mangrove jack (3,900) (Appendix I).

### 3.4.2 Boats launched from beaches

The most common species kept by recreational fishers that launched a boat from the beaches in the Pilbara region were (in order of estimated number caught rounded to nearest 100) blue swimmer crabs (6,500), green mud crabs (4,500), blue-lined emperor (3,600) and blackspot tuskfish (3,000) (Appendix J).

### 3.4.3 Shore-based catch

The most common species kept by recreational shore-based anglers and netters in the Pilbara region were (in order of estimated number caught rounded to nearest 100) mullet species (19,000), threadfin salmon species (8,100), yellowtail trumpeter (7,000), western yellowfin bream (6,400), northern whiting (3,800) and yellow-finned whiting (3,200) (Appendix K).

### 3.4.4 Total catch

#### Number kept

The most common species kept by all recreational fishers in the Pilbara region were (in order of estimated number kept rounded to nearest 100) blue swimmer crabs (71,600), mullet species (21,500), stripey seaperch (21,300), green mud crabs (19,200), blue-lined emperor (18,700), spangled emperor (16,400), threadfin salmon species (15,600), Queensland school and Australian spotted mackerel (8,900), western yellowfin bream (8,700), blackspot tuskfish (8,400) and golden trevally (8,300) (Appendix L). The range of species caught was dependent upon the fishing platform (boat or shore) and abundancy of species in each district and the time of the year. For instance, many boat-based fishers in Karratha and Point Samson caught blue swimmer crabs (Figures 11 and 12). However, boat-based fishers elsewhere and shore-based fishers caught other species such as stripey seaperch, trevallies and emperor species (Figures 11, 12 and 13).

#### Weight kept

The total recreational catch of all species was estimated at 383 tonnes. The total weight of fish kept was calculated from size composition data (Figures 14 to 21) for species for which a length to weight relationship was available (Table 5). The total weight of the most common fish kept in the region was (in order of weight kept rounded to nearest tonne): spangled emperor (31 tonnes), narrow-barred Spanish mackerel (28 tonnes), golden trevally (26 tonnes), blue-lined emperor (23 tonnes), blue swimmer crabs (22 tonnes), blackspot tuskfish (22 tonnes), threadfin salmons (18 tonnes), green mud crabs (17 tonnes), mullet species (13 tonnes), estuary cod (13 tonnes), black-tip reef shark (12 tonnes), Queensland school and Australian spotted mackerel (11 tonnes) and stripey seaperch (11 tonnes).

### 3.4.5 Catch of individual species

#### Spangled emperor

Spangled emperor (*Lethrinus nebulosus*) is an important species for recreational and commercial fishers in this region. The estimated recreational catch for the region was 16,500 fish kept (31 tonnes). A further 700 fish were estimated to have been eaten by sharks. The commercial catch from the region for the same period was 18 tonnes (Penn, 2001). All spangled emperor were caught by boat-based fishers. Many fish kept (14%) were below the minimum size limit at the time of 410 mm.

#### Narrow-barred Spanish mackerel and other mackerel species

In the Pilbara region, all narrow-barred Spanish mackerel (*Scomberomorus commerson*) were caught by boat-based fishers. The estimated recreational catch for the region included 4,000 fish that were kept (28 tonnes), a further 1,500 fish were estimated to have been eaten by sharks and 1,500 fish were released. The commercial catch for the Pilbara region (not including Broome) during 2000 was 105 tonnes (Penn, 2001). A stock assessment of the fishery has recently been completed (Mackie *et al*., 2005).

Recreational fishers kept approximately 10,000 (16 tonnes) of other mackerel species. This included 9,000 (11 tonnes) of both Queensland school mackerel (*Scomberomorus queenslandicus*) and Australian spotted mackerel (*Scomberomorus munroi*). These species could not be separated due to problems with identification, however, the catch was predominantly Queensland school mackerel in all areas other than Broome where it was predominantly Australian spotted mackerel. The catch also included 1,000 (5 tonnes) broad-barred Spanish mackerel (*Scomberomorus semifasciatus*) and 200 Shark Mackerel (*Grammatorcynus bicarinatus*). The commercial catch of other mackerel species for the same period in this region was 27 tonnes (Penn, 2001).

### Trevally species

Trevally species (Family Carangidae) are predominantly recreationally caught. The estimated total recreational catch of trevally for the region was 16,500 fish kept (45 tonnes). When assessed by weight the combined catch of all trevally species was the largest kept by recreational fishers in the Pilbara region.

Golden trevally (*Gnathanodon speciosus*) was the most common trevally species caught for the region with an estimated 8,500 fish kept (26 tonnes), 7,000 released and a further 200 fish were estimated to have been eaten by sharks. Golden trevally were predominantly (62%) caught by boat-based fishers. There was no minimum size for northern trevally species at the time of the survey.

The estimated recreational catch of giant trevally (*Caranx ignobilis*) for the region was 1,500 fish kept (7 tonnes) with 5,500 released. All giant trevally were caught by boat-based fishers.

The estimated recreational catch of gold-spotted trevally (*Carangoides fulvoguttatus*) for the region was 1,500 fish kept (3 tonnes) with 2,500 released. All gold-spotted trevally were caught by boat-based fishers.

The estimated recreational catch of big-eye trevally (*Caranx sexfasciatus*) for the region was 2,000 fish kept (2 tonnes) with 1,000 released. All big-eye trevally were caught by boat-based fishers.

The estimated recreational catch of gold-spotted trevally (*Carangoides fulvoguttatus*) for the region was 1,500 fish kept (3 tonnes) with 2,500 released. All gold-spotted trevally were caught by boat-based fishers.

The estimated recreational catch of bludger trevally (*Carangoides gymnostethus*) was 1,000 fish kept (2 tonnes) with 5,000 released. All bludger trevally were caught by boat-based fishers.

Small quantities of black trevally (*Caranx lugubris*), brassy trevally (Caranx papuensis) and other trevally species were also kept by recreational fishers in the region.

In addition to the catch of trevally reported above, 2,500 trevally were kept (approximately 5 tonnes) and 4,500 released that could not be allocated to a particular species due to identification problems.

### Blue-lined emperor

Blue-lined emperor (*Lethrinus laticaudis*) is predominantly a recreationally caught species. The estimated recreational catch for the region was 18,500 fish kept (23 tonnes) and 37,500 released. A further 500 fish were estimated to have been eaten by sharks. All blue-lined emperor were caught by boat-based fishers.

### Blue Swimmer Crab

Blue swimmer crabs (*Portunus pelagicus*) were mostly a recreational caught species in the Pilbara region at the time of the survey with 71,500 (22 tonnes) kept and 32,500 released. Most of the catch (19 tonnes) was taken from Nickol Bay. Almost all blue swimmer crabs were caught by boat based fishers.

### Mud Crabs

The estimated total recreational mud crab catch in the Pilbara was 25,500 (21 tonnes) kept and 24,000 released.

The majority of the catch were green mud crabs (*Scylla serrata*) of which recreational fishers in the region kept 19,000 (17 tonnes) and released 13,500. Green mud crabs were predominantly (93%) taken by boat based fishers.

Recreational fishers also kept 6,500 (4 tonnes) brown mud crabs (*Scylla olivacea*) and released 10,500. Almost all brown mud crabs (99%) were taken by boat-based fishers.

### Tuskfish

The estimated recreational catch of blackspot tuskfish (*Choerodon schoenleinii*) for the region was 7,500 fish kept (21 tonnes) and 17,000 released. Blackspot tuskfish were predominantly (81%) caught by boat-based fishers.

There was also a small catch of blue tuskfish (*Choerodon cyanodus*), purple tuskfish (*Choerodon cephalotes*) and bluespotted tuskfish (*Choerodon cauteroma*).

### Threadfin salmon species

The estimated recreational catch of threadfin salmon species for the region was 15,500 fish kept (18 tonnes) and 10,500 released. The recreational catch predominantly comprised blue threadfin salmon (*Eleutheronema tetradactylum*) and giant threadfin salmon (*Polydactylus macrochir*). There was also a small catch of northern threadfin salmon (*Polydactylus plebius*), black-finned threadfin (*Polydactylus nigripinnis*) and Gunther's threadfin (*Polydactylus multiradiatus*). Approximately half (53%) threadfin salmon species were caught by shore-based fishers.

### Mullet species

The estimated recreational catch of mullet species (Muglidae) for the region was 21,500 fish kept (13 tonnes) and 18,500 released. All mullet were caught by shore-based fishers.

### Estuary cod / Malabar Groper

The estimated recreational catch of estuary cod (*Epinephelus coioides*) and Malabar Groper (*Epinephelus malabaricus*) for the region was 5,500 fish kept (13 tonnes) and 14,000 released. Estuary cod were predominantly (86%) caught by boat-based fishers.

### Shark species

Black-tip reef shark (*Carcharhinus melanopterus*) was the most common shark species for the region with an estimated 2,000 fish kept (12 tonnes) and 5,000 released. Black-tip reef shark was caught by both shore and boat-based fishers.

The estimated recreational catch of bronze whaler (*Carcharhinus spp.*) for the region was 500 fish kept (10 tonnes) and 2,500 released. Bronze whaler were predominantly (84%) caught by boat-based fishers.

### Stripey seaperch (Spanish flag)

Stripey seaperch (*Lutjanus carponotatus*) is an important recreational species with 21,500 fish kept (11 tonnes). A further 500 were estimated to have been eaten by sharks. Although at the time of the survey there was no size limit, and a bag limit of 40 applied to this species, 49,000 were released. Almost all (99%) stripey seaperch were caught by boat-based fishers.

### Coral trout

The estimated recreational catch of and bar-cheeked coral trout (*Plectropomus maculatus*) and coral trout (*Plectropomus leopardus*) for the region was 3,000 fish kept (8 tonnes) and 4,000 released. A further 300 fish were estimated to have been eaten by sharks. Coral trout were predominantly (96%) caught by boat-based fishers. Most of the catch (59%) was taken from the Dampier Archipelago.

### Chinaman fish

The estimated recreational catch of Chinaman fish (*Symphorus nematophorus*) for the region was 1,500 fish kept (8 tonnes) and 1,000 released. Chinaman fish were only caught by boat-based fishers.

### Cobia

The estimated recreational catch of cobia (*Rachycentron canadus*) for the region was 1,500 fish kept (8 tonnes) and 1,000 released. Cobia were only caught by boat-based fishers.

### Red Emperor

Red emperor (*Lutjanus sebae*) is an important species for recreational and commercial fishers. The estimated recreational catch for the region was 1,500 fish kept (6 tonnes) and 3,000 released. The commercial catch from the region for the same period was 115 tonnes (Penn, 2001). All red emperor were caught by boat-based fishers.

### Northern Calamari

The estimated recreational catch of northern calamari (*Sepioteuthis lessoniana*) for the region was 5,500 kept (6 tonnes) and 500 released. All northern calamari were caught by boat-based fishers.

### Sweetlip emperor

The estimated recreational catch of sweetlip emperor (*Lethrinus miniatus*) for the region was 4,000 kept (6 tonnes) and 12,000 released. Sweetlip emperor were caught by both shore and boat-based fishers.

### Mangrove jack

The estimated recreational catch of mangrove jack (*Lutjanus argentimaculatus*) for the region was 8,000 fish kept (5 tonnes) and 13,000 released. Mangrove jack were predominantly (92%) caught by boat-based fishers.

### Western yellow-fin bream

The estimated recreational catch of Western yellow-fin bream (*Acanthopagrus latus*) for the region was 8,500 fish kept (4 tonnes) and 12,000 released. Western yellow-fin bream were predominantly (71%) caught by shore-based fishers.

### Spotted javelinfish

The estimated recreational catch of spotted javelinfish (*Pomadasys kaakan*) for the region was 3,500 fish kept (4 tonnes) and 4,500 released. Spotted javelinfish were predominantly (56%) caught by boat-based fishers.

### Moses perch

The estimated recreational catch of moses perch (*Lutjanus russelli*) for the region was 3,500 fish kept (3 tonnes) and 4,000 released. Moses perch were predominantly (87%) caught by boat-based fishers.

### Tropical lobsters

The estimated recreational catch of green (painted) lobster (*Panulirus versicolor*) is 2,500 (2 tonnes) kept and 1,000 released. Most (90%) green lobsters were taken from the Dampier Archepeligo. A small number of ornate lobsters (*Panulirus ornatus*) were also kept. All lobsters were taken by boat-based fishers.

## 3.5 Dampier Archipelago

The total annual recreational fishing effort within the proposed Dampier Archipelago Marine Park was 50,000 fisher days from boats launched at the Hampton Harbour Boat and Sailing Club, Dampier public ramp, Whitnell Bay & Karratha boat ramp.

The most common species kept by all recreational fishers from the proposed Dampier Archipelago Marine Park were (in order of weight kept) blue swimmer crab (19 tonnes), narrow-barred spanish mackerel (14 tonnes), Queensland school and Australian spotted mackerel (7 tonnes), coral trout (6 tonnes), golden trevally (6 tonnes), northern calamari (6 tonnes), green mud crab (6 tonnes) and blackspot tuskfish (5 tonnes) (see Table 6).

The most common species kept by all recreational fishers from the proposed Dampier Archipelago Marine Park were (in order of estimated number kept) blue swimmer crab (61,000), green mud crab (6,000), Queensland school and Australian spotted mackerel (6,000), northern calamari (5,500), blue-lined emperor (3,500), stripey seaperch (3,500), coral trout (2,500), and painted rock lobster (2,500) (Appendix M).

## 3.6 Equipment used by fishers

Anglers have adopted modern technology to increase the efficiency of recreational fishing with 71% percent of boats launched at public boat ramps fitted with an echo-sounder (88% black and white, 12% colour) and 40% using a global positioning system to find fishing locations.

The global positioning systems and echo sounders should enable boat crews to more easily locate fishing grounds and return to the same ground on future trips. This increases the efficiency of recreational fishers by enabling anglers to effectively target a range of species and should, therefore, increase the catch rates for these species.

## 3.7 Compliance with fishing regulations

The survey data indicated that there was a high level of compliance with the fishing regulations. Undersize fish were only retained by 164 (5%) of the 3,085 boat crews interviewed at boat ramps, five (3%) crews fishing from small boats launched from the beach and five (1%) shore-based fishers. Very few fishers exceeded the bag limits.

Most of the undersize fish kept by recreational fishers were spangled emperor, which had a larger minimum size than the other emperors. For this species the number of boats not complying with the regulations was higher in Point Sampson (9%) and Onslow (8%) and less than 2% at all other districts. It is likely that this is due to incorrect fish identification or lower community awareness of the regulations in these districts and could be dealt with by improved communication. The level of non-compliance was low (less than 2%) for all other species in all districts.

Most fishers were able to demonstrate a reasonable knowledge of the fishing regulations. That is, the majority of fishers knew the bag (67%) and size (67%) limits for the species they were targeting or the predominant species they had caught.

## 3.8 Attitudinal responses

The attitudinal responses show that fishers had an appreciation of the impact of recreational fishing on fish stocks and the importance of keeping within bag and size limits (Table 7). Almost all fishers believed they knew the rules (87%) and that information on fishing rules was easy to obtain (81%). Almost all fishers also reported that they had enjoyed their trip and this was not related to the quantity of fish caught, or the cost of the trip (94%). Once they have caught enough fish for a couple of meals most fishers said that they stop fishing (72%). Almost all fishers enjoy fishing even if they don't catch anything (95%).

# 4.0 Discussion

## 4.1 General

This study provides the first comprehensive assessment of the recreational catch within the Pilbara region. It has highlighted the important recreational species in the region and therefore which ones will require ongoing attention.

Historically, annual stock assessments for most species important to recreational fishers have had to be based solely on the available commercial catch data. These assessments have used age-structured models, yield per recruit or eggs per recruit analysis to help determine management targets and in some cases limit reference points. A time series of recreational catch data should improve the reliability of stock assessments for species with a relatively high level of recreational catch. However, due to the costs involved, it is not practical to conduct creel surveys to obtain this information in all bioregions of the state on an annual basis. For this reason, comprehensive creel surveys are planned for each bioregion at regular intervals. Other sources of information such as recreational fisher log books and surveys conducted by Fisheries Officers and Volunteer Fisheries Liaison Officers are expected to provide information on variations in recreational catch rates for the years between surveys.

Charter boats were not included in this study since a compulsory returns system for tour operators was undergoing development at the time. This system commenced in September 2001. By the end of 2003, the North Coast bioregion (Onslow to NT border) had 97 licensed fishing tour operators plus an additional 13 licensed restricted fishing tour operators or eco tour licences.

## 4.2 Size limits and bag limits

Based on the survey, size limits do have an effect on the individual fish retained because anglers reported releasing substantial numbers of undersize fish. However, the release of undersize fish to meet the regulations does not necessarily ensure their survival, particularly in deep waters. Most anglers were able to demonstrate a good knowledge of the fishing regulations for species that they were targeting. This was supported by a high level of compliance in this region of the state.

The survey indicated that very few fishers achieved the daily bag limits specified under the state-wide recreational fishing regulations that applied at the time. For this reason, the bag limits for some species that were in place at the time were too large to provide a significant restriction in total catch levels. However, bag limits were effective in limiting occasional large catches.

## 4.3 Sampling issues

The bus route method was used to estimate the catch and effort from public boat ramps. The hours that the boat ramps were surveyed (10:00am to 6:00pm) covered the times that most recreational boats were returning to the boat ramps. There were few trailers if any left at the ramps after 6:00pm. The morning survey (6:00am – 10:00am) conducted at Dampier confirmed that the number of boats returning to this ramp before 10:00am was negligible.

The catch of many species could not be reported individually due to poor identification by the interviewers. The catch for the family was reported rather than for the individual species where correct identification was an issue. This was an issue for some mackerel species, threadfin salmon species and a lesser number of trevally. For future surveys, fish identification could be improved by placing more emphasis on the training and supervision of survey interviewers.

A roving creel survey was used to estimate the catch and fishing effort for shore-based fishers. For this method the length of the fishing day was estimated as nine hours (9:00am to 6:00pm). Shore-based fishing activity outside this time at many locations, particularly Eighty Mile Beach, was not picked up by the survey. It was not practical to record fishing activities after 6:00pm due to concerns for the safety of staff travelling on rough bush tracks in four wheel drive vehicles at night. For this reason, little catch and fishing effort information was collected beyond 6:00pm or before 9:00am. The catch and effort for shore-based fishers has, therefore, been underestimated by this survey, however, this activity was considerably less important than the catch and fishing effort from the public boat ramps.

The roving creel survey was suitable for estimating the fishing effort from boats launched from across the beaches from counts of boat trailers. However, the roving creel survey was not well suited to estimating the catch rates and hence total catch. The best time to collect catch information was when the survey interviewers were at a location when these fishers returned from their fishing trip. Unfortunately, this seldom occurred due to the length of coastline and large number of places boats could be launched from across the beach. For this reason, this information was supplemented by interviewing groups at campsites that had been fishing earlier that day. Despite this, the errors for this component of the recreational catch for the region were still relatively large due to the limited catch data collected. There was no easy way to collect this information and alternative survey methods will have their own difficulties.

# 5.0 Conclusions

The total recreational catch of all finfish species for the region was estimated to be 383 tonnes. The recreational catch was one sixth of the commercial catch of 2,442 tonnes at the time. Spangled emperor, red emperor, barramundi, threadfin salmon species and mackerel species were taken by both the recreational and commercial sectors. The results indicate the importance of recreational fishing in the Pilbara region, particularly in the proposed Dampier Archipelago Marine Park. The Pilbara region offers excellent opportunities for boat-based and shore-based recreational fishers who catch an extensive variety of prime angling species.

The actual recreational catch for the Pilbara region is likely to exceed the estimates provided by this survey. The catch from shore-based fishers and boats launched from the beaches was under-estimated since night fishing was not covered and some of the locations where these activities occurred were missed on occasions. Charter boats, that operate in the region, catch a range of species including spangled emperor, red emperor, narrow barred Spanish mackerel and chinaman fish that have not been included.

The information from this survey has been and will be used in the development of regional recreational fisheries management arrangements and will provide a basis for future management decisions to improve or maintain the quality and diversity of recreational fishing experiences in the Pilbara region. The information collected will also be used in the assessment of the sustainability of fishing activities in the Pilbara region and will provide one of the inputs for future catch allocation decision processes. Furthermore, these data provide indicators of fishing quality such as size composition, and variety of species caught.

Further creel surveys are planned on a regular basis to assess changes in the recreational catch for this and other bioregions of the state, with less comprehensive survey data being used to indicate trends during the intervening years.

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# 8.0 Tables and figures

**Table 1.** Comparison of the primary target species and the predominant species kept by boats launched from public ramps in Pilbara region.

| | Species Targeted | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bottom fish | General fish | Blue swimmer crab | Mackerels/Tunas | Green mud crab | Barramundi | Coral trout | Emperor general | Surface fish | Mangrove Jack | Threadfin salmon | Tuskfish general |
| Proportion of boats | 0.33 | 0.11 | 0.09 | 0.09 | 0.08 | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.02 | 0.02 |
| **Predominant Species Kept (Proportion of boats*)** | | | | | | | | | | | | |
| Stripey seaperch | 0.22 | 0.13 | | 0.09 | | | 0.14 | 0.20 | | | | 0.09 |
| Blue-lined emperor | 0.15 | 0.14 | | 0.07 | | | 0.15 | 0.23 | | | | 0.05 |
| Spangled emperor | 0.09 | | | | | | | 0.23 | | | | 0.05 |
| Golden trevally | 0.08 | 0.11 | | 0.08 | | | | 0.08 | 0.08 | | | |
| Estuary cod | 0.07 | | | | 0.03 | 0.05 | | | | 0.2 | | |
| Australian spotted mackerel | | 0.11 | 0.01 | 0.23 | | | | | 0.09 | | | |
| Narrow-barred spanish mackerel | | 0.11 | | 0.23 | | | | 0.08 | 0.09 | | | |
| Blue swimmer crab | | | 0.96 | | 0.18 | | | | | | | |
| Green mud crab | | | 0.13 | | 0.79 | 0.09 | | | | 0.19 | 0.25 | |
| Coral crab | | | 0.04 | | | | | | | | | |
| Threadfin salmon | | | 0.03 | | 0.05 | 0.12 | | | | 0.11 | 0.40 | |
| Brown mud crab | | | | | 0.11 | | | | | | | |
| Queensland school mackerel | | | | | | | | | 0.05 | | | |
| Barramundi | | | | | | 0.15 | | | | | | |
| Mangrove jack | | | | | | 0.11 | | | | 0.36 | 0.14 | 0.07 |
| Coral trout | | | | | | | 0.24 | | | | | |
| Bar-cheeked coral trout | | | | | | | 0.18 | | | | | |
| Blackspot tuskfish | | | | | | | 0.13 | | | | | 0.59 |
| Mackerel tuna | | | | | | | | | 0.09 | | | |
| Northwest black bream | | | | | | | | | | 0.14 | | |
| Spotted javelinfish | | | | | | | | | | | 0.07 | |
| Giant threadfin salmon | | | | | | | | | | | 0.05 | |
| Nil species kept | 0.27 | 0.26 | 0.04 | 0.23 | 0.15 | 0.50 | 0.15 | 0.16 | 0.45 | 0.31 | 0.21 | 0.21 |

**Since more than one species was often kept by boat crews, the sum of proportion of species kept may exceed 1.*

**Table 2.** Comparison of the primary target species and the predominant species kept by boats launched from beaches in the Pilbara region.

**Species Targeted**

| | | Bottom fish | Surface fish | Tuskfish general | Emperor general | General fish | Mangrove jack | Mackerels/Tunas | Green mud crab |
|---|---|---|---|---|---|---|---|---|---|
| | Proportion of shore fishers | 0.34 | 0.15 | 0.13 | 0.09 | 0.07 | 0.05 | 0.05 | 0.04 |
| | | | | | | | | | |
| Predominant Species Kept (Proportion of boats*) | Spangled emperor | 0.36 | | | 0.54 | | | | |
| | Saddle-tailed seaperch | 0.16 | | | | | | | |
| | Chinaman cod | 0.16 | | | 0.15 | | | | |
| | Estuary cod | 0.16 | | | | 0.18 | 0.25 | | |
| | Stripey seaperch | 0.14 | 0.18 | 0.32 | | 0.27 | | | |
| | Narrow-barred spanish mackerel | | 0.41 | | | | | 0.25 | |
| | Golden trevally | | 0.14 | | | 0.18 | | | |
| | Queenfish | | 0.14 | | | | | | |
| | Rankin rockcod | | 0.09 | | | | | | |
| | Mangrove jack | | | | | 0.18 | 0.50 | | 0.33 |
| | Coral trout | | | | | 0.18 | | | |
| | Green mud crab | | | | | | 0.25 | | 0.83 |
| | Brown mud crab | | | | | | | | 0.33 |
| | Blue-lined emperor | | | | 0.23 | | | | |
| | Blackspot tuskfish | | | 0.47 | | | | | |
| | Painted sweetlips | | | 0.26 | | | | | |
| | Queensland school mackerel | | | 0.11 | | | | | |
| | Nil species kept | 0.16 | 0.18 | 0.11 | 0.15 | 0.23 | 0.38 | 0.25 | 0 |

** Since more than one species was often kept by boat based fishers, the sum of proportion of species kept may exceed 1.*

**Table 3.** Comparison of the primary target species and the predominant species kept by shore-based fishers in Pilbara region.

| | | Species Targeted | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bottom fish | Threadfin salmon | Whiting | Bream general | Surface fish | General fish | Mangrove jack | Green mud crab | Golden trevally | Tuskfish general |
| | Proportion of shore fishers | 0.39 | 0.18 | 0.09 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 |
| | | | | | | | | | | | |
| Predominant Species Kept (Prop. of shore fishers*) | Western yellowfin bream | 0.08 | 0.03 | 0.12 | 0.24 | | | 0.11 | | | |
| | Golden trevally | 0.05 | | | | 0.12 | 0.09 | | | 0.40 | |
| | Threadfin salmon | 0.04 | 0.23 | | | | | | | | |
| | Estuary cod | 0.03 | | | | | | 0.22 | | | |
| | Spotted javelinfish | 0.02 | | | | | | | | | |
| | Smaller salmon catfish | | 0.05 | | 0.07 | | | | | | |
| | Black-tip reef shark | | 0.02 | | | | | | | | |
| | Yellow-finned whiting | | | 0.24 | | | | | | | |
| | Northern whiting | | | 0.12 | | | | | | | |
| | Garfish | | | 0.04 | | | | | | | |
| | Mangrove jack | | | | | | | 0.22 | | | |
| | Green mud crab | | | | | | | | 0.21 | | |
| | Yellowtail trumpeter | | | | 0.17 | | | | | | |
| | Northwest black bream | | | | 0.10 | | | | | | |
| | Blackspot tuskfish | | | | | | | | | | 0.40 |
| | Nil species kept | 0.76 | 0.75 | 0.50 | 0.62 | 0.42 | 0.59 | 0.50 | 0.71 | 0.40 | 0.40 |

** Since more than one species was often kept by shore based fishers, the sum of proportion of species kept may exceed 1.*

**Table 4.** Correction factors for fishing effort occurring before the start of the daily survey period.

| District | Season | Ratio of effort prior to start to after start | Correction factor (f) |
|---|---|---|---|
| Broome | Wet | 0.390 | 1.390 |
| Broome | Dry | 0.219 | 1.219 |
| Cape Keraudren | Wet | 0.839 | 1.839 |
| Cape Keraudren | Dry | 0.233 | 1.233 |
| Dampier | Wet | 0.680 | 1.680 |
| Dampier | Dry | 0.511 | 1.511 |
| Karratha | Wet | 0.494 | 1.494 |
| Karratha | Dry | 0.314 | 1.314 |
| Onlsow | Wet | 0.317 | 1.317 |
| Onslow | Dry | 0.166 | 1.166 |
| Pt Samson | Wet | 0.357 | 1.357 |
| Pt Samson | Dry | 0.351 | 1.351 |
| Port Hedland | Wet | 0.420 | 1.420 |
| Port Hedland | Dry | 0.315 | 1.315 |

**Table 5.** Estimated total recreational catch by weight for major species caught in Pilbara region.

| Common Name | Length-weight relationship | Source for length-weight relationship | Total weight (tonnes) | Standard error |
|---|---|---|---|---|
| Spangled emperor | $W=1.73x10^{-2}(L/10)^{3.01}$ | Carpenter & Allen 1989 | 31 | 9 |
| Narrow-barred Spanish mackerel | $W(kg)=3.34x10^{-9}FL^{3.12}$<br>$L=42.74+1.06FL$ | Mackie *et al*. 2005 | 28 | 4 |
| Golden trevally | $W=1.94x10^{-2}(FL/10)^{3.01}$<br>$FL=0.86L$ | Letourneur *et al*. 1998 | 26 | 4 |
| Blue-lined emperor | $W=9.15x10^{-6}L^{3.09}$ | Ayvazian *et al*. 2004 | 23 | 6 |
| Blue swimmer crab (male)<br>(female) | $W=2.56x10^{-5}CW^{3.26}$<br>$W=5.97x10^{-5}CW^{3.06}$ | Potter *et al*. 1983 | 22 | 3 |
| Blackspot tuskfish | $W=2.86x10^{-5}L^{2.94}$ | Fairclough *et al*. 2003 | 22 | 12 |
| Threadfin salmon species | $W=7.92x10^{-6}L^{2.98}$ | Pember pers. com. | 18 | 6 |
| Green mud crab (male)<br>(female) | $W=2.29x10^{-4}CW^{3.00}$<br>$W=1.58x10^{-4}CW^{3.00}$ | Knuckey 1999 | 17 | 4 |
| Mullet species | $W=9.4x10^{-3}(L/10)^{3.02}$ | Torres 1991 | 13 | 11 |
| Estuary cod | $W=1.05x10^{-2}(L/10)^{3.08}$ | Letourneur *et al*. 1998 | 13 | 10 |
| Black-tip reef shark | $W=7.14x10^{-2}L^{3.01}$ | Torres 1991 | 12 | 2 |
| Queensland school & Australian spotted mackerel[1] | $W=exp(3.775+0.006xFL)$<br>$L=1.06FL+35.36$ | Cameron & Begg 2002 | 11 | 1 |
| Stripey seaperch[2] | $W=7.72x10^{-6}FL^{3.14}$ | Newman *et al*. 2000 | 11 | 2 |
| Bronze whaler | $W(kg)=1.04x10^{-6}(L/10)^{2.9}$ | Torres F. 1991 | 10 | 2 |
| Coral trout | $W=1.56x10^{-2}L^{3.0}$ | Moran *et al*. 1988 | 8 | 1 |
| Chinaman fish | $W=3.03x10^{-2}L^{2.87}$ | Letourneur *et al*. 1998 | 8 | 1 |
| Cobia | $W=5.62x10^{-6}FL^{3.16}$<br>$FL=0.92L$ | Torres 1991 | 8 | 2 |
| Giant trevally | $W=2.03x10^{-2}(FL/10)^{3.0}$<br>$FL=0.86L$ | Pauly *et al*. 1996 | 7 | 3 |
| Red emperor | $W=2.05x10^{-5}FL^{3.16}$<br>$L=1.0654FL+3.5947$ | Newman & Dunk 2002 | 6 | 1 |
| Sweetlip emperor[3] | $W=9.15x10^{-6}L^{3.09}$ | Ayvazian *et al*. 2004 | 6 | 3 |
| Northern calamari[4] | $W=8.9x10^{-2}(L/10)^{2.7}$ | Smith 1983 | 6 | 2 |
| Giant salmon catfish | $W=9.7x10^{-3}(L/10)^{3.04}$ | Pauly *et al*. 1996 | 5 | 1 |

| Common Name | Length-weight relationship | Source for length-weight relationship | Total weight (tonnes) | Standard error |
|---|---|---|---|---|
| Broad barred spanish mackerel[5] | W(kg)=$3.34 \times 10^{-9} FL^{3.12}$<br>L=42.74+1.06FL | Mackie *et al*. 2005 | 5 | 2 |
| Mangrove jack | W(kg)=$7.1 \times 10^{-6}(L/10)^{3.18}$ | Torres 1991 | 5 | 3 |
| Western yellow-fin bream | W=$1.76 \times 10^{-5} L^{2.99}$ | Hesp 2003 | 4 | 1 |
| Spotted javelinfish | W=$6.57 \times 10^{-2}(L/10)^{2.71}$ | Van der Elst 1991 | 4 | 1 |
| Black jewfish | W=$1.28 \times 10^{-2}(L/10)^{2.94}$ | Venkata Subba Rao 1966 | 4 | 1 |
| Mackerel tuna[6] | W=$7.63 \times 10^{-6} L^{3.09}$ | Ward pers. com. | 4 | 1 |
| Brown mud crab[7] (male)<br>(female) | W=$2.29 \times 10^{-4} CW^{3.00}$<br>W=$1.58 \times 10^{-4} CW^{3.00}$ | Knuckey 1999 | 4 | 3 |
| Moses perch | W=$1.87 \times 10^{-5} FL^{2.97}$<br>L=1.0675FL+3.3597 | Newman 2002 | 3 | 1 |
| Talang queenfish | W=$2.95 \times 10^{-2}(FL/10)^{2.81}$<br>FL=L/1.146 | Kulbicki *et al*. 1993 | 3 | 1 |
| Gold-spotted trevally | W=$4.61 \times 10^{-2}(FL/10)^{2.71}$<br>FL=L/1.104 | Letourneur *et al*. 1998 | 3 | 1 |
| Barramundi | W(kg)=$1.07 \times 10^{-2}(L/10)^{3.03}$ | Volvich & Appelbaum 2001 | 2 | 0.2 |
| Tropical lobsters[8] (male)<br>(female) | W=$1.61 \times 10^{-3} L^{2.87}$<br>W=$2.51 \times 10^{-3} L^{2.78}$ | Morgan 1977 | 2 | 0.3 |
| Painted sweetlips | W=$7.7 \times 10^{-3}(L/10)^{3.13}$ | Pauly *et al*. 1996 | 2 | 0.5 |
| Big eye trevally | W=$2.62 \times 10^{-2}(FL/10)^{3.01}$<br>FL=0.87L | Harrison 2001 | 2 | 1 |
| Bludger trevally | W=$4.68 \times 10^{-2}(FL/10)^{2.74}$<br>FL=0.91L | Letourneur *et al*. 1998 | 2 | 1 |
| Blue-spotted emperor[9] | W=$9.15 \times 10^{-6} L^{3.09}$ | Ayvazian *et al*. 2004 | 1 | 0.3 |

Note: W is weight in g; L is total length in mm; FL is fork length in mm; CW is carapace width in mm

1 Using relationship for Queensland school mackerel
2 Weight is cleaned weight rather than whole weight
3 Using relationship for blue lined emperor
4 Using relationship for southern calamari
5 Using relationship for narrow barred Spanish mackerel
6 Using relationship for oriental bonito
7 Using relationship for green mud crab
8 Using relationship for western rock lobster
9 Using relationship for blue-lined emperor

**Table 6.** Estimated total recreational catch by weight for major species caught in Dampier Archipelago.

| Common Name | Total weight (tonnes) | Standard error |
|---|---|---|
| Blue swimmer crab | 19 | 2.5 |
| Narrow-barred Spanish mackerel | 14 | 2 |
| Queensland school & Australian spotted mackerel | 7 | 1 |
| Golden trevally | 6 | 1.5 |
| Northern calamari | 6 | 2.5 |
| Coral trout | 6 | 0.5 |
| Green mud crab | 6 | 1 |
| Blackspot tuskfish | 5 | 1 |
| Blue-lined emperor | 4 | 1 |
| Spangled emperor | 4 | 1.5 |
| Red Emperor | 3 | 1 |
| Chinaman fish | 3 | 0.5 |
| Estuary cod | 3 | 0.5 |
| Stripey seaperch | 2 | 0.5 |
| Painted rock lobster | 2 | 0.5 |
| Giant trevally | 2 | 0.5 |
| Gold spotted trevally | 2 | 0.5 |

**Table 7.** Response to statements about recreational fishing in WA.

| Statement | Disagree | Not Sure | Agree |
|---|---|---|---|
| There are so many fish off the West Coast that we can catch as many as we like. | 663 (97%) | 15 (2%) | 7 (1%) |
| The recreational fishing catch is too small to affect fish stocks. | 466 (68%) | 101 (15%) | 117 (17%) |
| Individual fishers can help protect fish stocks by keeping within bag and size limits. | 5 (1%) | 2 (0%) | 676 (99%) |
| I know the current rules for the fish I catch and try to keep up to date. | 15 (2%) | 71 (11%) | 596 (87%) |
| Information of fishing rules is hard to get. | 552 (81%) | 50 (7%) | 78 (12%) |
| If I don’t catch enough fish to justify the cost I don’t really enjoy the trip. | 644 (94%) | 7 (1%) | 32 (5%) |
| Once I have caught enough for a couple of meals I usually stop fishing. | 150 (22%) | 42 (6%) | 492 (72%) |
| I usually try to catch as many fish as the bag limit allows. | 505 (74%) | 30 (4%) | 147 (22%) |
| I enjoy fishing even if I don’t catch anything. | 24 (3%) | 12 (2%) | 650 (95%) |

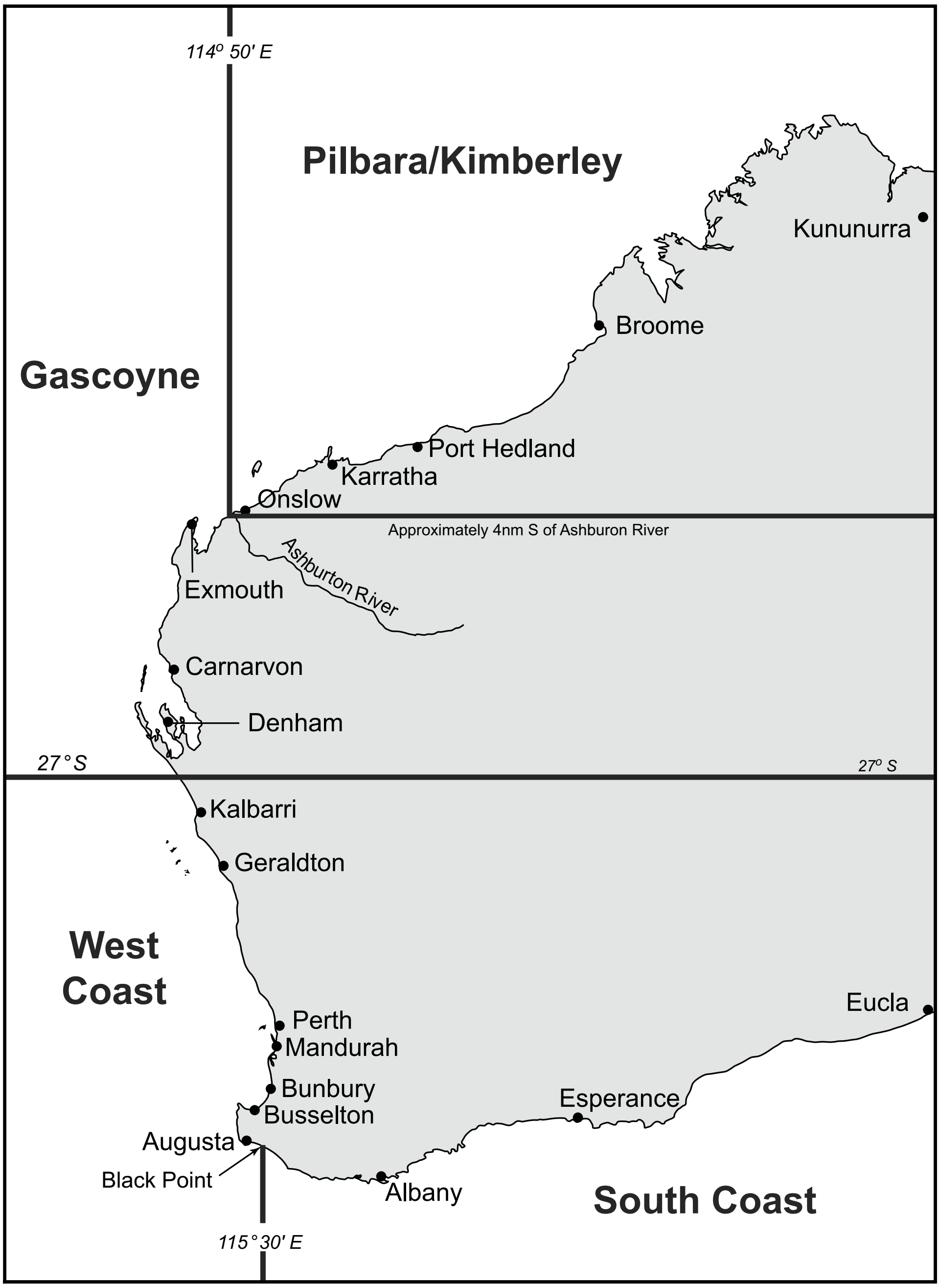



**Figure 1.** Map of Western Australia showing the boundaries of the marine Bioregions used for management of the state's fisheries.

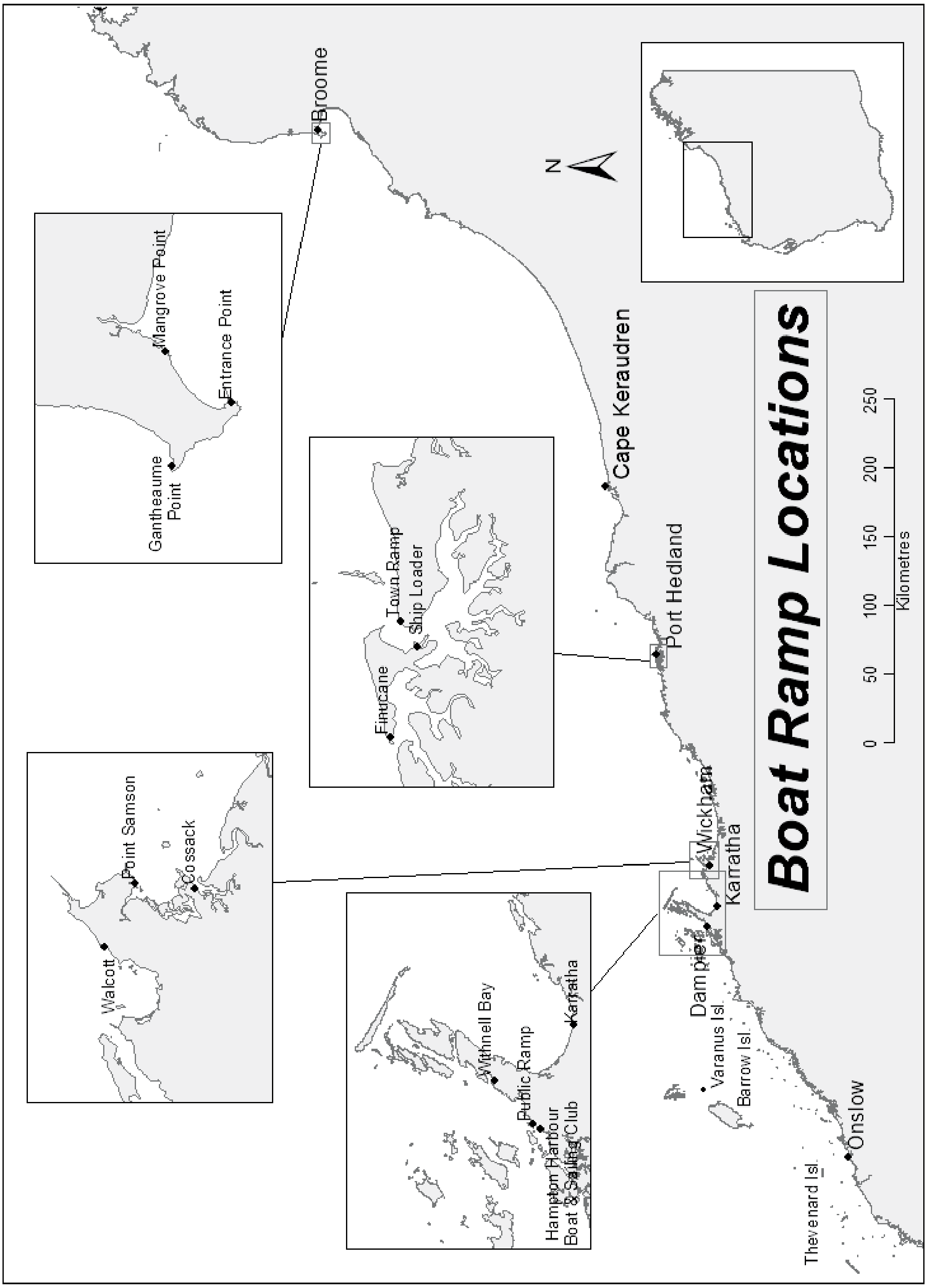



**Figure 2.** Map of Pilbara region showing boat ramps surveyed to record recreational fishing catch and effort 1999-2000.


**Figure 3**. Place of residence for recreational fishers interviewed during the survey of recreational fishing in the Pilbara region 1999-2000.

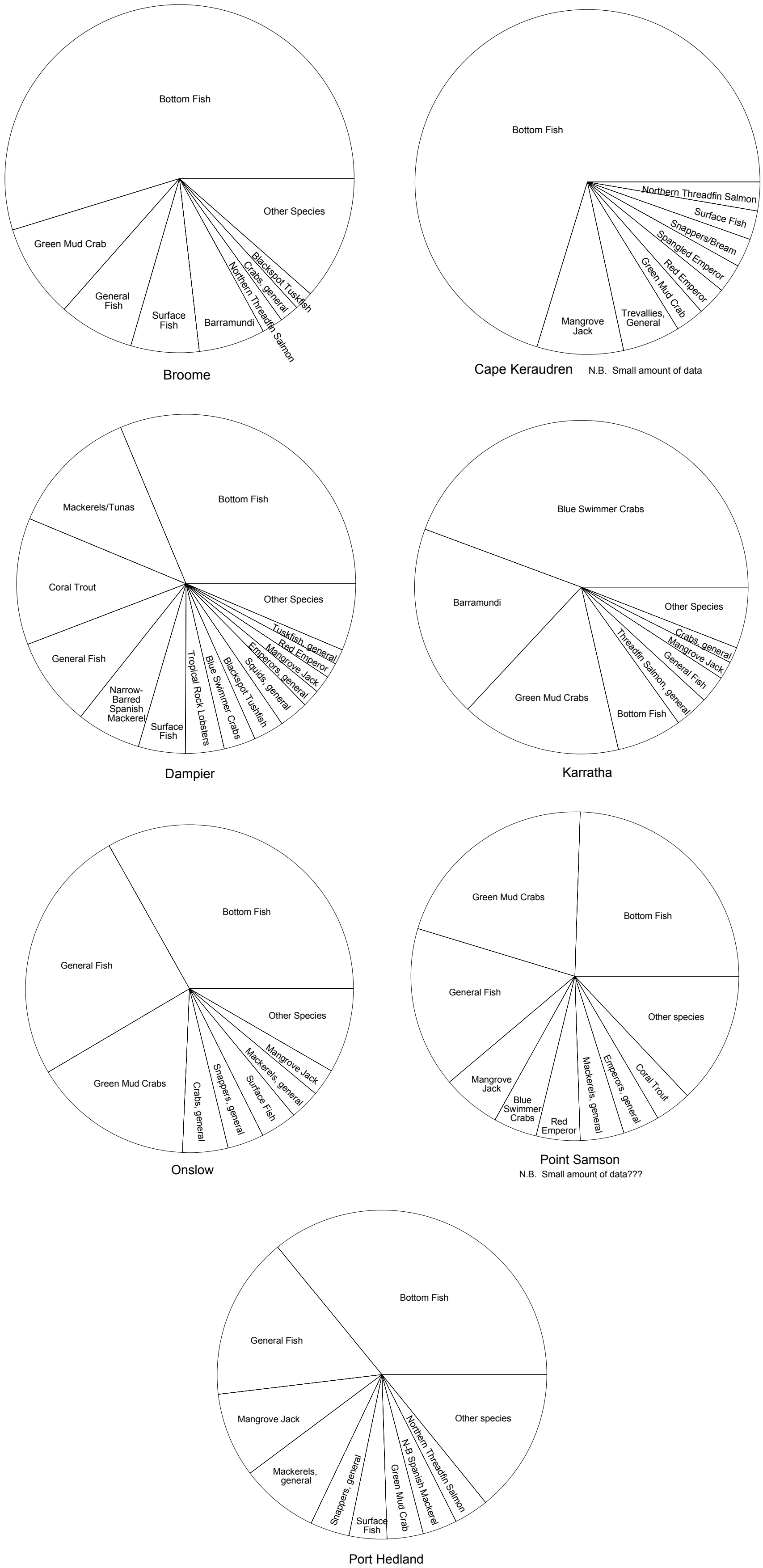



**Figure 4.** Species targeted by boats launched from public ramps during the survey of recreational fishing in the Pilbara region 1999-2000.

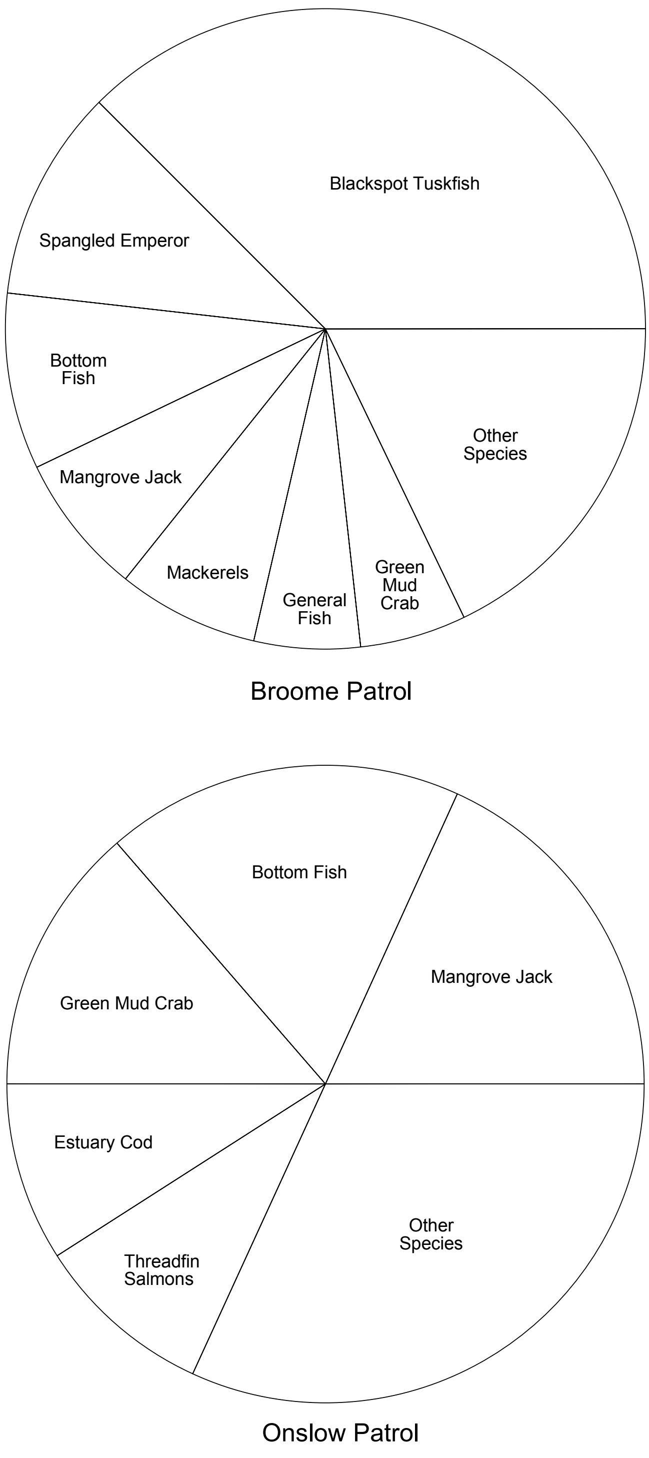
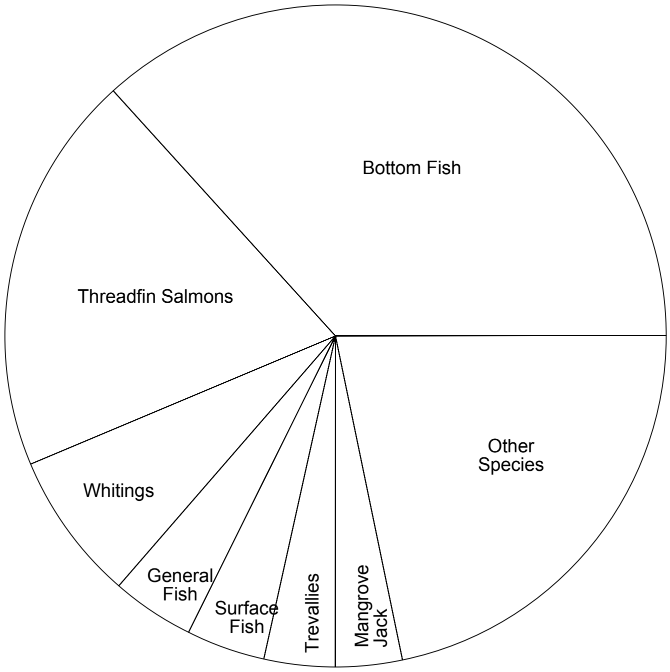
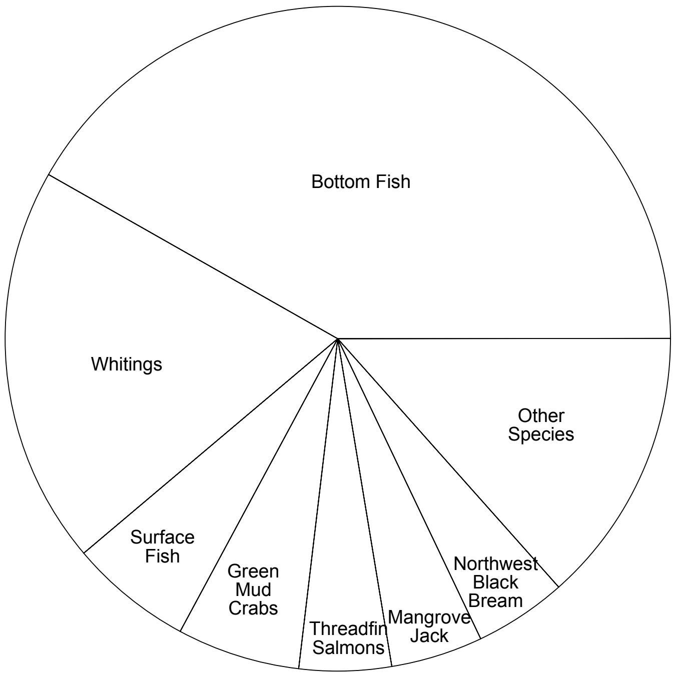



**Figure 5.** Species targeted by boats launched from beaches during the survey of recreational fishing in the Pilbara region 1999-2000.




Broome Patrol




Onslow Patrol

**Figure 6.** Species targeted by shore-based fishers during the survey of recreational fishing in the Pilbara region 1999-2000.

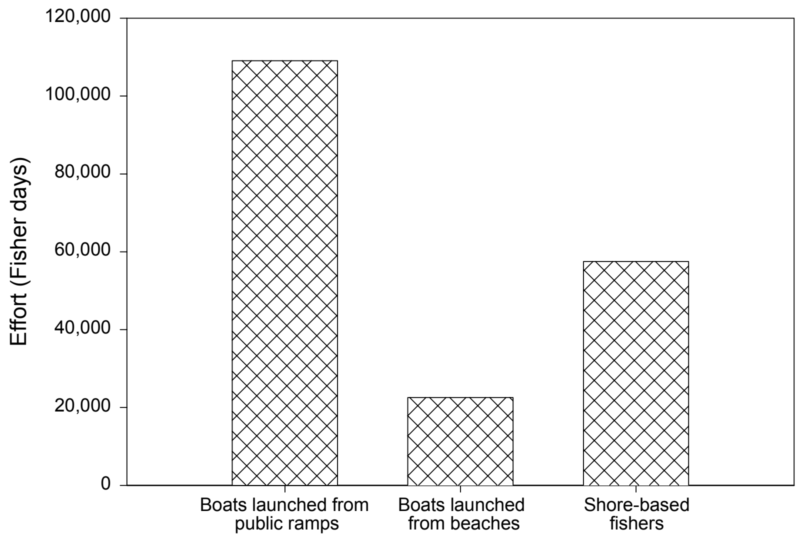



**Figure 7.** Estimated recreational fishing effort in Pilbara region.

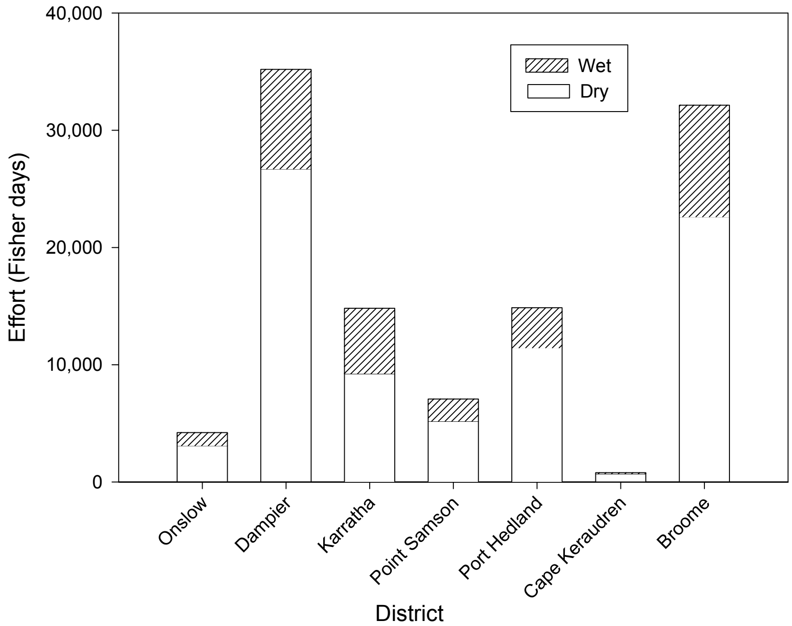



**Figure 8.** Estimated seasonal fishing effort for boats launched from public ramps in Pilbara region.

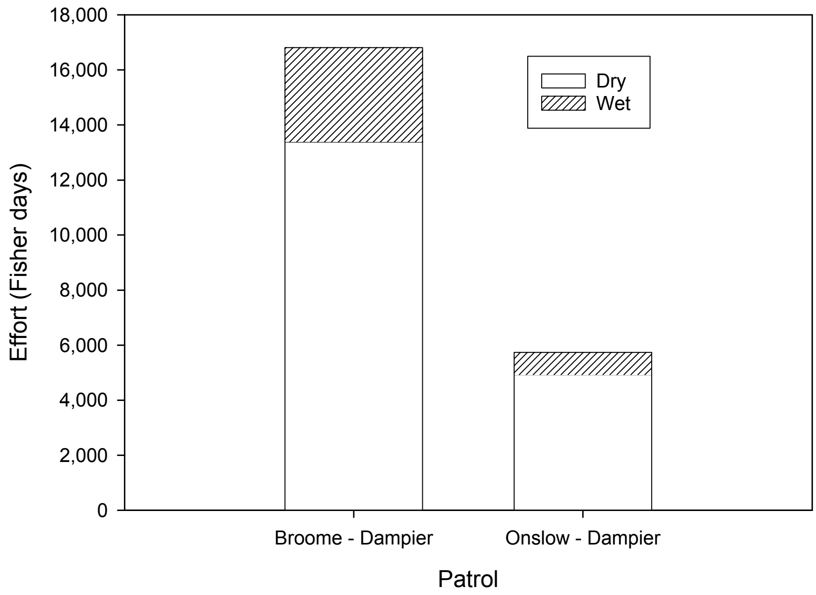



**Figure 9.** Seasonal fishing effort for boats launched from beaches in the Pilbara region.

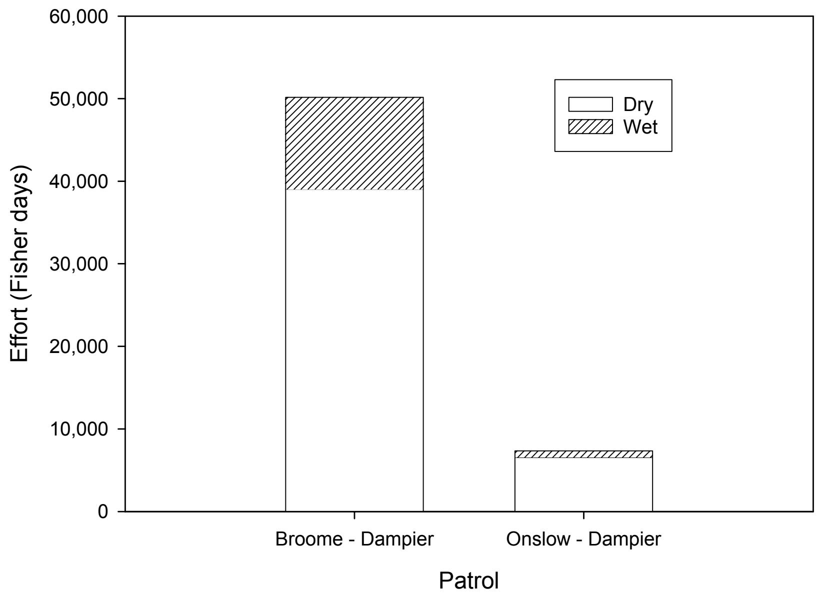



**Figure 10.** Seasonal fishing effort for shore-based fishers in the Pilbara region.

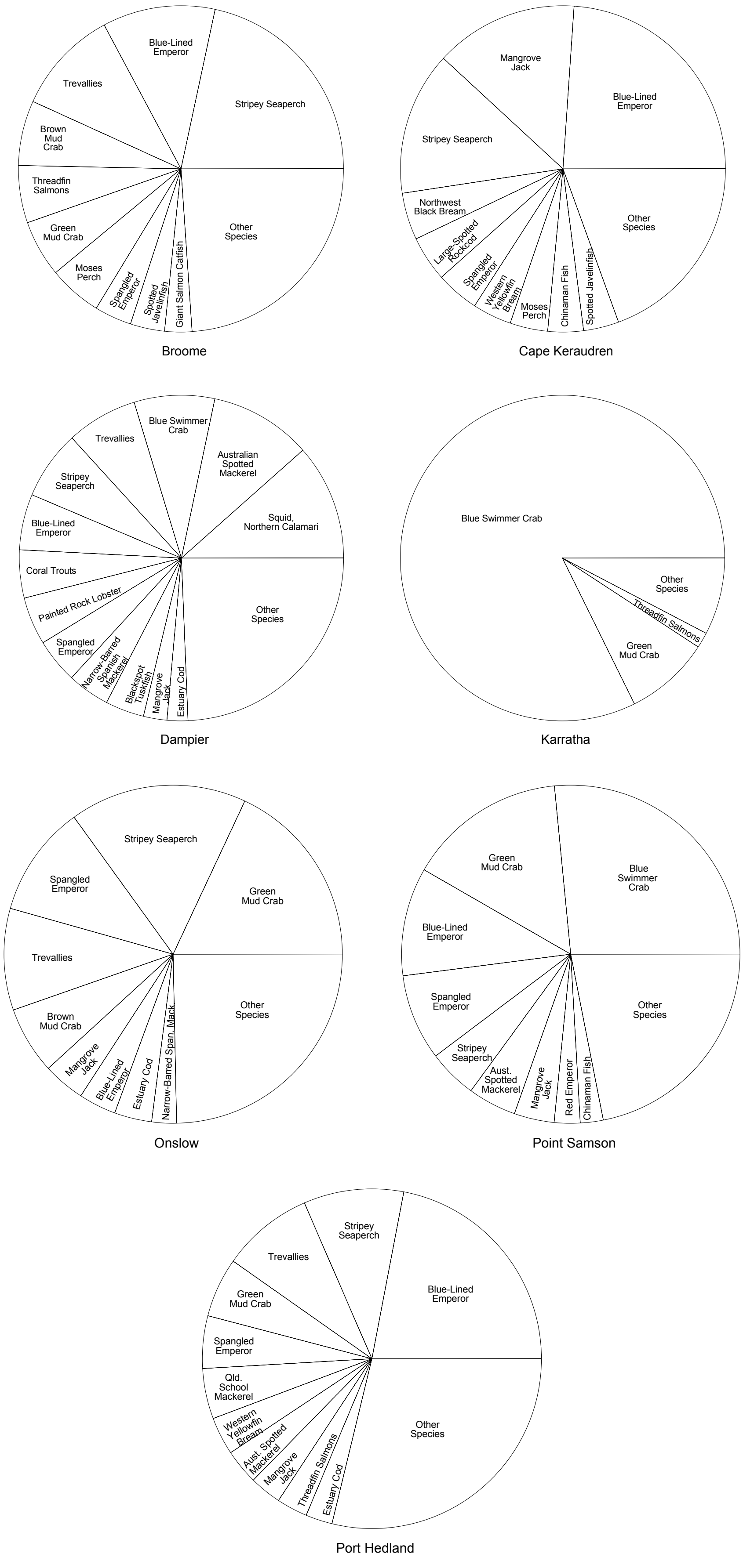
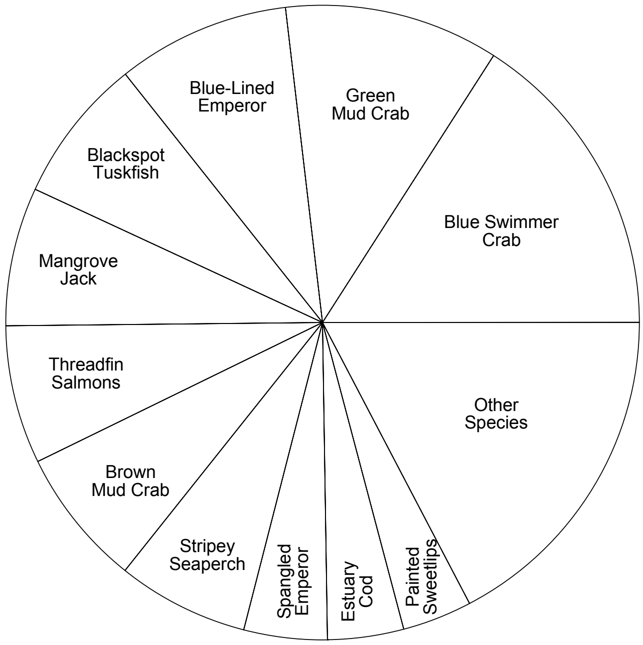
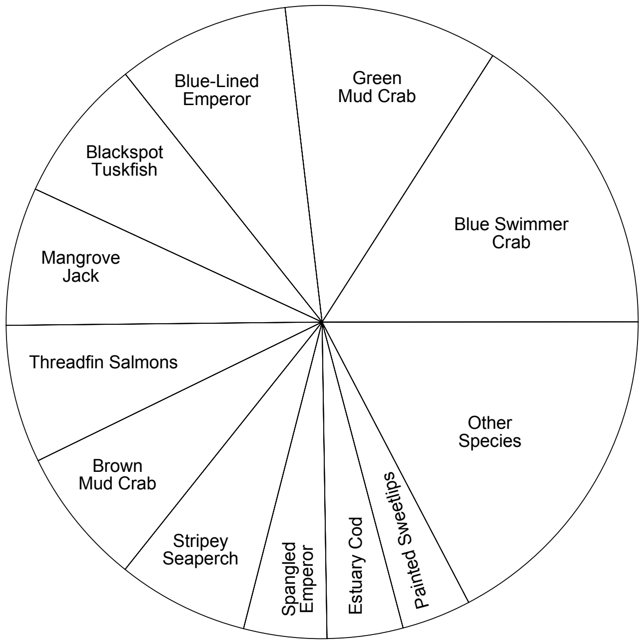



**Figure 11.** Species composition (by number of fish) of recreational catch for boats launched from public ramps in Pilbara region.

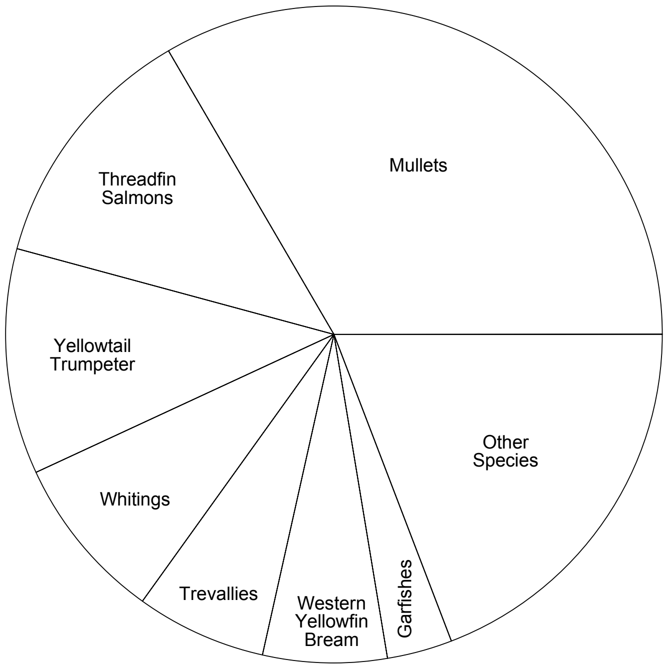



Broome Patrol

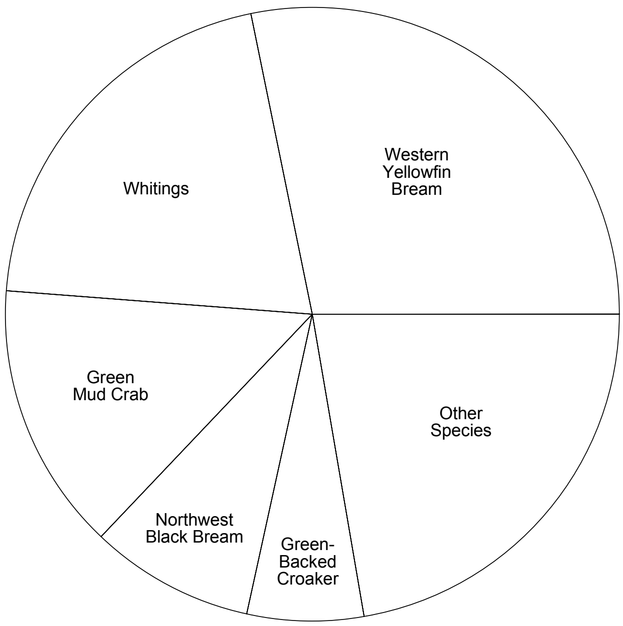



Onslow Patrol

**Figure 12.** Species composition (by number of fish) of recreational catch for boats launched from beaches in Pilbara region.




Broome Patrol




Onslow Patrol

**Figure 13.** Species composition (by number of fish) of recreational catch for shore-based fishers in Pilbara region.

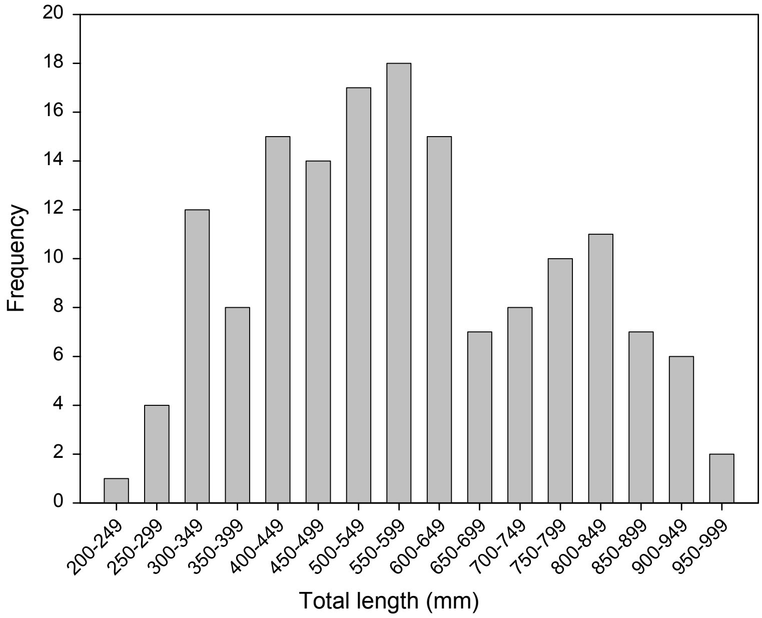



**Figure 14**. Size composition for golden trevally kept by recreational anglers.

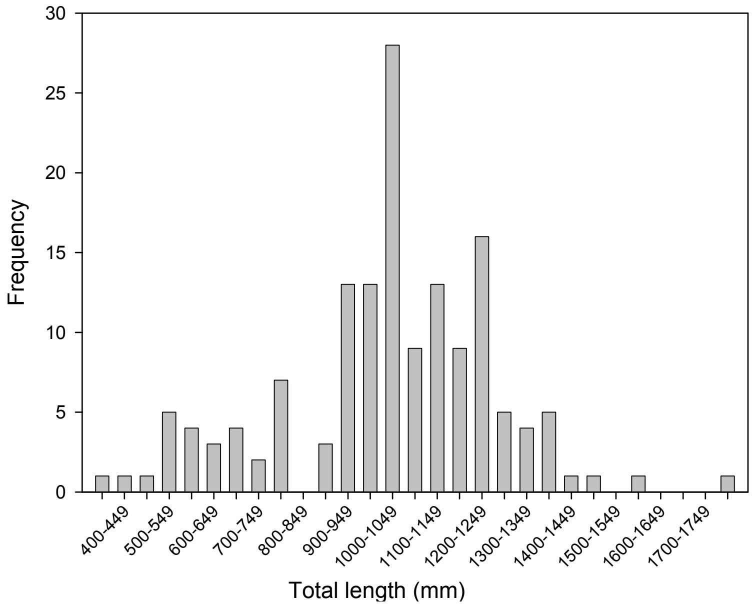



**Figure 15**. Size composition for narrow-barred spanish mackerel (minimum length 900mm) kept by recreational anglers

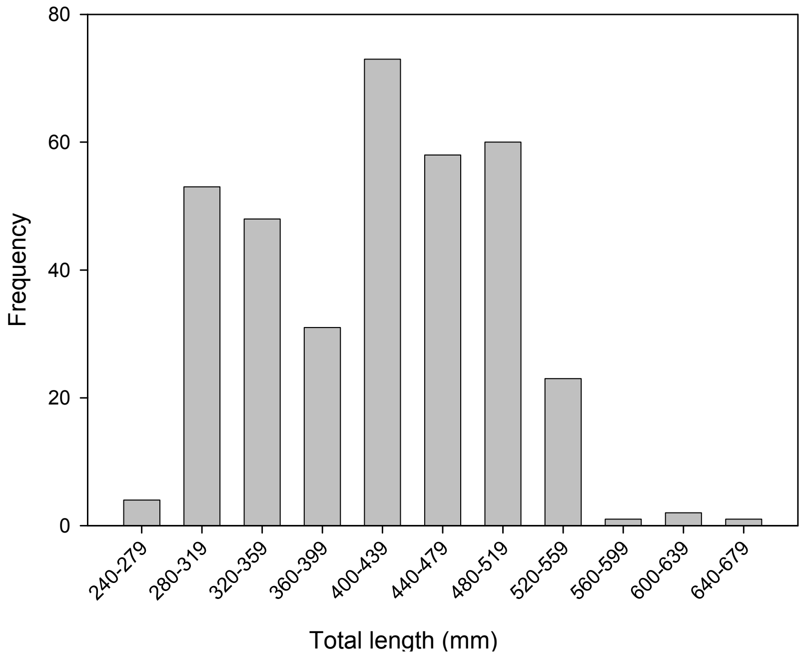



**Figure 16**. Size composition for blue-lined emperor (minimum length 320mm) kept by recreational anglers.

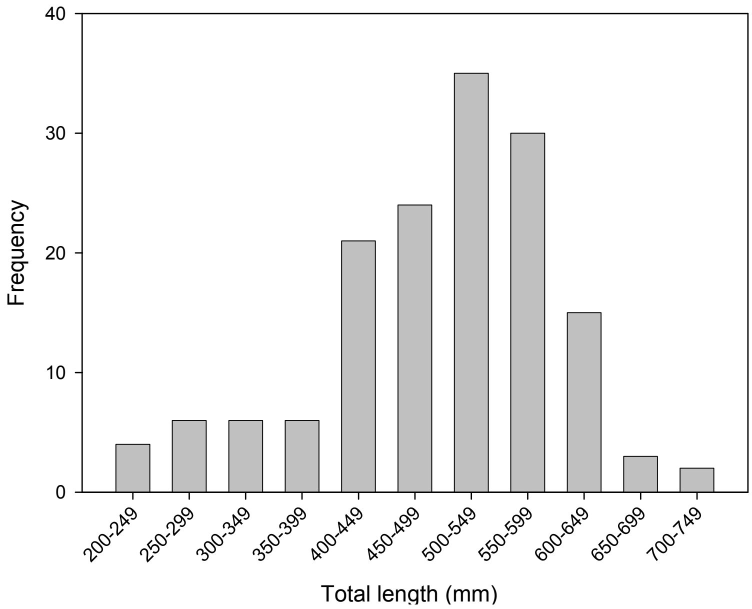



**Figure 17**. Size composition for blackspot tuskfish (minimum length 400mm) kept by recreational anglers.

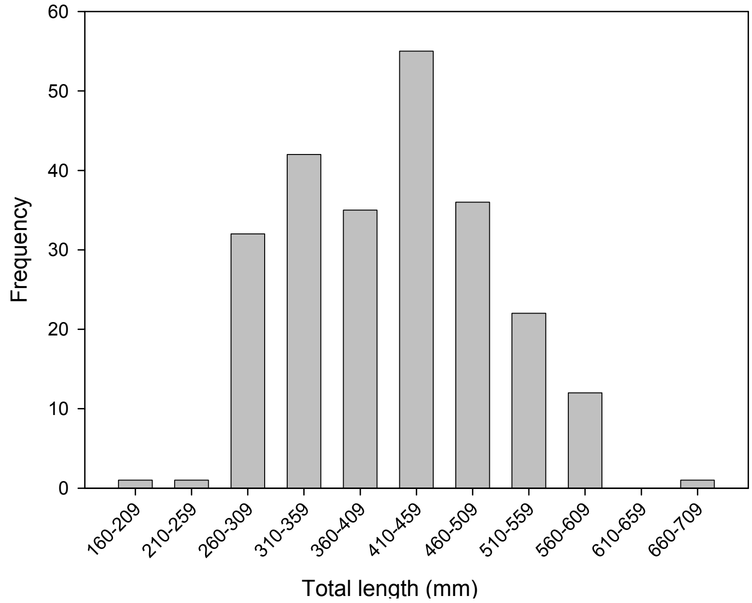



**Figure 18**. Size composition for spangled emperor (minimum length 410mm) kept by recreational anglers

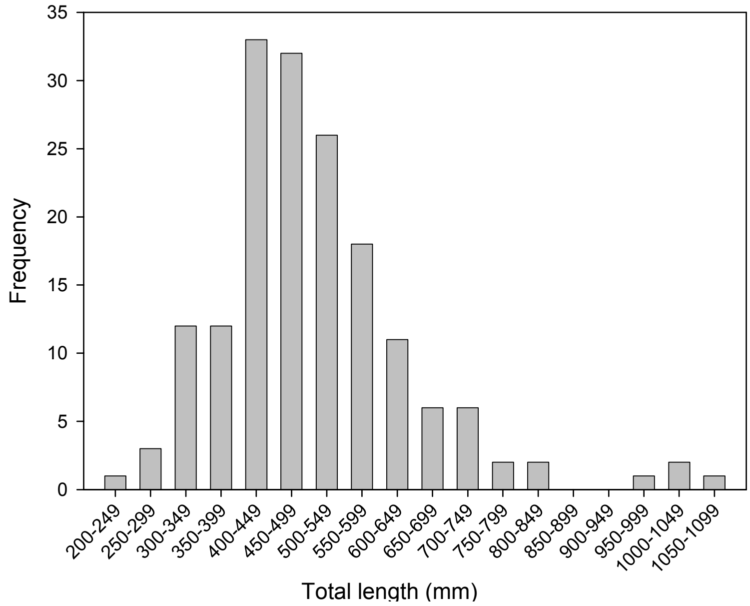



**Figure 19**. Size composition for estuary cod kept by recreational anglers.

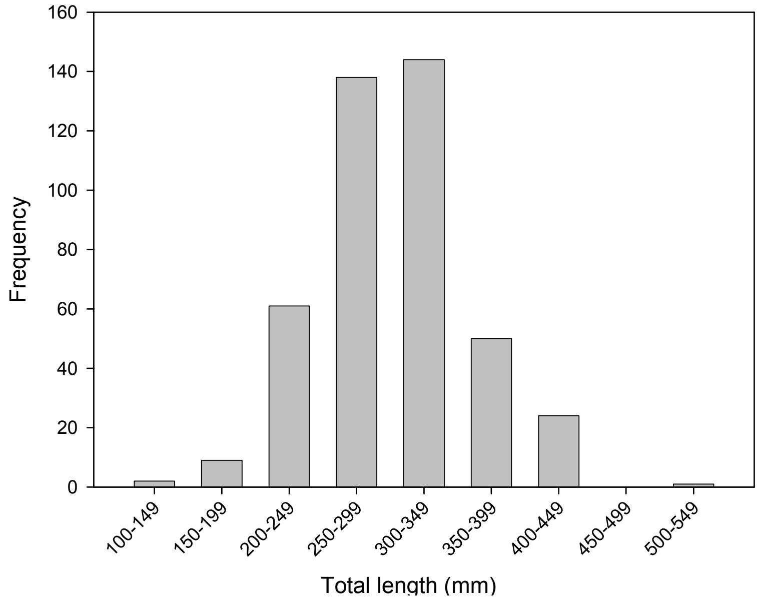



**Figure 20**. Size composition for stripey seaperch kept by recreational anglers.

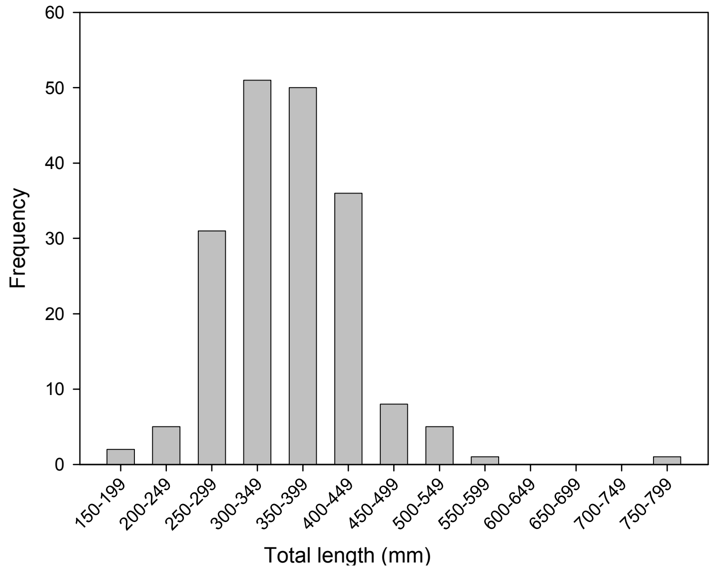



**Figure 21.** Size composition for mangrove jack (minimum length 300mm) kept by recreational anglers.

# 9.0 Appendices

## Appendix A – Boat ramp trailer count form

**Interviewer's Name:** ______________________________

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

**District:** ____________________ **Boat Ramp:** ____________________

**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 | | | |
|---|---|---|---|---|---|---|---|
| Time | Type | Time | Type | Time | Type | Time | Type |
| | | | | | | | |
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| Total Number of Trailers | |
|---|---|
| At Start | At Finish |
| | |

Boat Types
P: Power boat
Y: Yacht
O: Other

# Appendix B – Boat ramp interview questionnaire form

**Date:** _________ **Boat Ramp:** __________________ **Boat Reg. No.:** __________________

| Interview Time | Boat (Power/Yacht/Other) | Boat Departure Time | Fish/Dive/Snorkel/Collecting/Other | Number in Boat | Number of Females in Boat | Age Group of Interviewee | Home Postcode of Interviewee | Length of Boat (ft/m) | Member Angling Club (Yes/No) | Time Spent Fishing (decimal hrs) | Block Number | Number of Lines Used | Number and type of nets - Crab,Set, Haul,Throw,Pots | Number of Times Interviewed Before |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |
| | | | | FISHERS ONLY | | | | | | | | | | |

| Species (Also record sex for lobsters) | Number Kept | Number Released | Taken by Sharks | Number break-offs | Under/Over size Kept | Species Targeted________________________ Measurements (mm) |
|---|---|---|---|---|---|---|
| blue-lined emperor | | | | | | |
| spangled emperor | | | | | | |
| stripey seaperch | | | | | | |
| northern threadfin salmon | | | | | | |
| giant salmon catfish | | | | | | |
| smaller salmon catfish | | | | | | |
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## Appendix B – Interview questionnaire form (continued)

1. Does your boat have any of the following equipment:

| | |
|---|---|
| Echo sounder (**C**olour/**B**lack & White/**N**o) | |
| Global Positioning System(**Y**es/**N**o) | |

| | |
|---|---|
| Marine Band Radio(**Y**es/**N**o) | |
| Number of Snapper winches | |

2. What is the size limit for _______________*targeted/predominant species from catch*?

| Correct | Incorrect | Don't Know |
|---|---|---|

3. What is the bag limit for ________________*targeted/predominant species from catch*?

| Correct | Incorrect | Don't Know |
|---|---|---|

4. To what extent do you agree or disagree with the following statements about fishing in W.A.:

| | Disagree | Not Sure | Agree |
|---|---|---|---|
| There are so many fish off the West Coast that we can catch as many as we like | 1 | 2 | 3 |
| The recreational fishing catch is too small to affect fish stocks | 1 | 2 | 3 |
| Individual fishers can help protect fish stocks by keeping within bag and size limits | 1 | 2 | 3 |
| I know the current rules for the fish I catch and try to keep up to date | 1 | 2 | 3 |
| Information on fishing rules is hard to get | 1 | 2 | 3 |
| If I don't catch enough fish to justify the costs I don't really enjoy the trip | 1 | 2 | 3 |
| Once I've caught enough for a couple of meals I usually stop fishing | 1 | 2 | 3 |
| I usually try to catch as many fish as the bag limit allows | 1 | 2 | 3 |
| I enjoy fishing even if I don't catch anything | 1 | 2 | 3 |

5. How many times have you seen a Fisheries Officer or Fisheries Patrol in this region in the last 10 years?_______

## Appendix C - Shore patrol interview questionnaire form

FISHERIES WESTERN AUSTRALIA

District: ____________________

Location: ____________________

Officer's names: ____________________

____________________

Date: ____/____/____

Time (24hr): ____________________

Number groups camped: __________

Number boats not fishing: __________

Number boats fishing: __________

Number shore fishers: __________

**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 & RAINFALL**

| Cloud % | Nil 1 | Light 2 | Moderate 3 | Heavy 4 |
|---|---|---|---|---|
| | | | | |

**LENGTHS OF RANDOM SAMPLE (mm)**

Species: ____________________

Lengths: ____________________

Species: ____________________

Lengths: ____________________

Species: ____________________

Lengths: ____________________

**Fishing Today**

C: Completed fishing
N: Not fishing today
F: Fishing currently
L: Will fish later

**Gear Types**

DR: Drop net (crab or marron)
SE: Set (or 'gill') net
HA: Haul (or 'drag') net
CA: Cast (or 'throw') net
PO: Pot (rock lobster)
SC: Scoop (crab, prawn or marron)
SN: Snare (rock lobster or marron)
HO: Hook (rock lobster or crab)
SP: Spear

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### Pilbara Region Shore Survey 1999/2000

| Fisher Number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Home postcode | | | | |
| Number in group | | | | |
| Times interviewed before | | | | |
| Fishing today (C/N/F/L) | | | | |
| Fishing yesterday (Y/N/E) | | | | |
| Boat/Shore/Dive/sNorkel | | | | |
| Number persons fishing | | | | |
| Time spent fishing (decimal hours) | | | | |
| Number of lines used | | | | |
| Gear (Number & Type) | | | | |
| Species Targeted | | | | |
| **Species 1** | | | | |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Number break-offs | | | | |
| Under/Over size kept | | | | |
| **Species 2** | | | | |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Number break-offs | | | | |
| Under/Over size kept | | | | |
| **Species 3** | | | | |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Number break-offs | | | | |
| Under/Over size kept | | | | |
| **Species 4** | | | | |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Number break-offs | | | | |
| Under/Over size kept | | | | |
| **Species 5** | | | | |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Number break-offs | | | | |
| Under/Over size kept | | | | |

## Appendix D – Recreational Fishing Questionnaire form for Barrow, Varanus and Thevenard Islands

FISHERIES
WESTERN AUSTRALIA

# *Pilbara Recreational Fishing Survey*

This questionnaire will take less than 5 minutes of your time.

**(Please complete and return even if you did not go fishing.)**

| | | | |
|---|---|---|---|
| **What Island were you on ?** | Thevenard ☐ | Barrow ☐ | Other (Please Specify) ☐ |
| **Did you go fishing?** | | | Yes / No (Please Circle ) |
| Date arrived on island | | | ____ / ____ / ____ |
| Date leaving island | | | ____ / ____ / ____ |
| **How many days did you go fishing?** | | | |
| From a boat | days. | Average time spent fishing per day from boat. | hours. |
| From the shore | days. | Average time spent fishing per day from shore. | hours. |
| Where did you fish most of the time? | | | |

| Species caught | Number kept | Number Released | Lost to sharks | Break-offs |
|---|---|---|---|---|
| Narrow Barred Spanish Mackerel | | | | |
| Broad Barred Spanish Mackerel | | | | |
| Red Emperor | | | | |
| Spangled Emperor | | | | |
| Unknown Species | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Thank you for participating in this important survey on recreational fishing.

# Appendix E - Catch and effort calculations for boats launched from public boat ramps

**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 $T$=8 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 $\ell_j$ 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

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

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

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

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) since the probability of sampling a boat is independent of trip length

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

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

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

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

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

The variance of $\hat{C}$ is estimated as

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

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

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

## Appendix F - Catch and effort calculations for boats launched from beaches

**Estimation of total effort**

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

$$e = IT \qquad (1)$$

where $I$ is the count of boats and $T$=9 is the length of the shift. The estimated variance within stratum $k$ is (Pollock *et al.*, 1994)

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

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

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

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

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

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

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

The standard error is calculated by the usual method

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

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

$$\hat{E} = \sum_{k=1}^{n}\hat{E}_k \qquad (7)$$

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

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

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 (Crone and Malvestuto, 1991) since the probability of sampling a boat is independent of trip length

$$\hat{R}_k = \frac{\overline{c}_k}{\overline{L}_k} = \frac{\sum_{j=1}^{n_k} c_{kj} / n_k}{\sum_{j=1}^{n_k} L_{kj} / n_k} \tag{10}$$

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 (2) and (3) without the finite population correction factor). The variance for $\hat{R}_k$ can be estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{R}_k) \approx \hat{R}_k^2 \left( \frac{Var(\overline{c}_k)}{\overline{c}_k^2} + \frac{Var(\overline{L}_k)}{\overline{L}_k^2} - \frac{2Cov(\overline{c}_k, \overline{L}_k)}{\overline{c}_k \overline{L}_k} \right) \tag{11}$$

The covariance term was assumed to be zero. The total catch for stratum *k* is estimated as

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

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

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

The variance of $\hat{C}$ is estimated as

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

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

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

# Appendix G - Catch and effort calculations for shore-based fishers

**Estimation of total effort**

The fishing effort (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 $T$=9 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

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

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

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

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) since the probability of sampling an angler is dependent on trip length

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

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

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

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

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

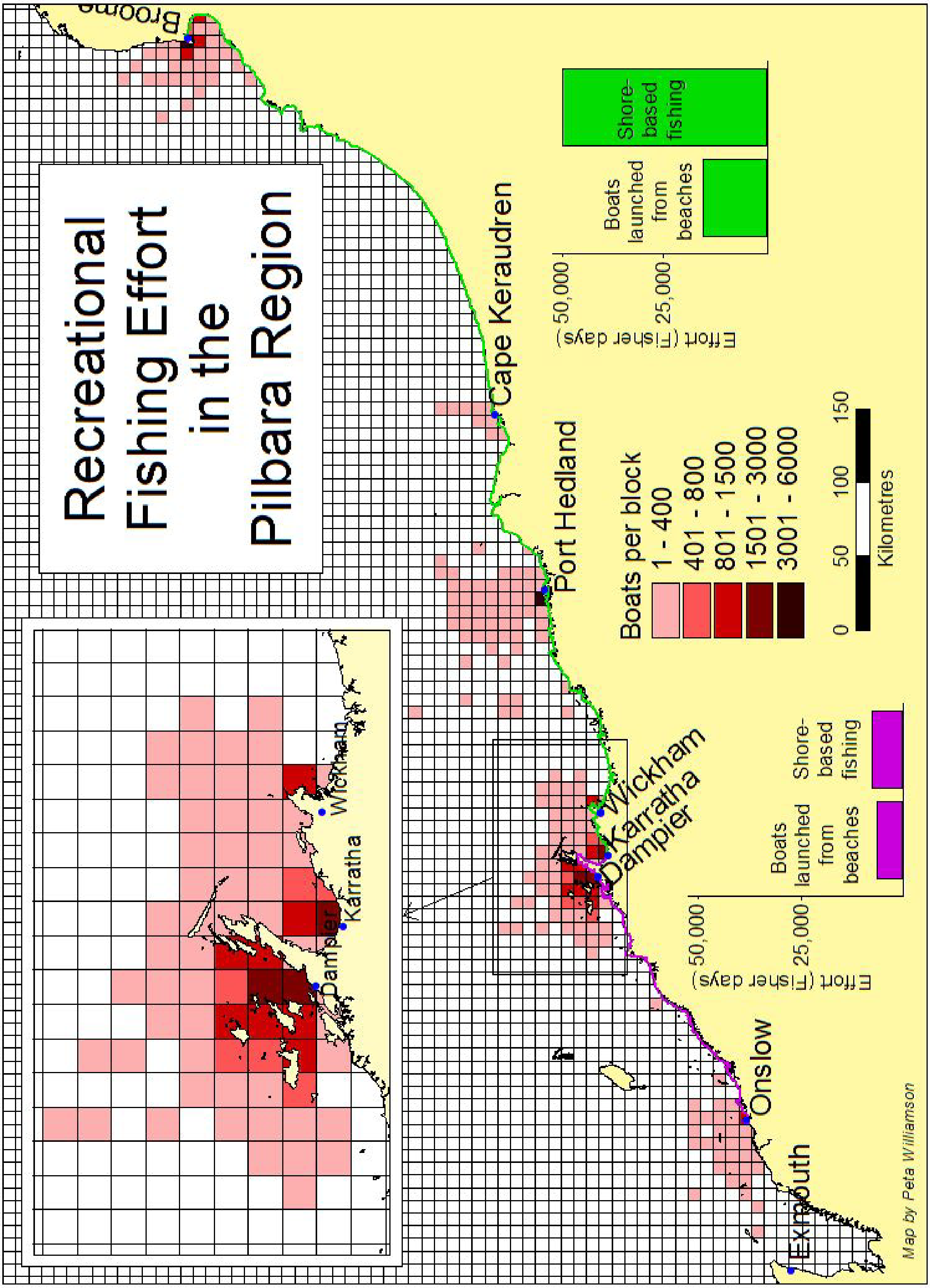
The variance of $\hat{C}$ is estimated as

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

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

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

## *Appendix H – Spatial distribution of recreational fishing effort in the Pilbara bioregion*



# Appendix I – Estimated recreational catch (by species) for boats launched from public ramps in the Pilbara region

| Common name | Scientific name | No. kept | SE kept | No. released | No. eaten by sharks | No. break-offs |
|---|---|---|---|---|---|---|
| Crab, blue swimmer | *Portunus pelagicus* | 65,096 | 8,682 | 32,284 | 204 | 82 |
| Seaperch, stripey | *Lutjanus carponotatus* | 17,739 | 1,838 | 42,558 | 471 | 304 |
| Emperor, blue-lined | *Lethrinus laticaudis* | 14,816 | 1,459 | 25,154 | 342 | 300 |
| Crab, mud green | *Scylla serrata* | 13,398 | 1,247 | 8,434 | 7 | 167 |
| Mackerel, Qld school & Australian spotted | *Scomberomorus queenslandicus/ S. munroi* | 8,657 | 823 | 6,573 | 73 | 1,064 |
| Emperor, spangled | *Lethrinus nebulosus* | 6,958 | 978 | 14,870 | 307 | 527 |
| Squid, northern calamari | *Sepioteuthis lessoniana Photololigo* spp. | 5,568 | 2,175 | 541 | 0 | 183 |
| Trevally, golden | *Gnathanodon speciosus* | 4,731 | 575 | 5,438 | 221 | 970 |
| Threadfin salmon | Family - Polynemidae | 4,600 | 660 | 4,807 | 43 | 609 |
| Mangrove Jack | *Lutjanus argentimaculatus* | 3,867 | 598 | 6,880 | 0 | 246 |
| Tuskfish, blackspot | *Choerodon schoenleinii* | 3,845 | 421 | 18,322 | 294 | 213 |
| Crab, mud brown | *Scylla olivacea* | 3,721 | 773 | 3,582 | 0 | 0 |
| Mackerel, narrow-barred Spanish | *Scomberomorus commerson* | 3,342 | 381 | 1,602 | 612 | 1942 |
| Perch, moses | *Lutjanus russelli* | 3,329 | 624 | 3,986 | 28 | 7 |
| Cod, estuary (slimy) | *Epinephelus coioides/ E. malabaricus* | 2,971 | 317 | 9,546 | 53 | 281 |
| Trout, coral | *Plectropomus* spp. | 2,877 | 301 | 3,737 | 332 | 115 |
| Rock lobster, painted | *Panulirus versicolor* | 2,415 | 435 | 1,079 | 0 | 0 |
| Bream, western yellowfin | *Acanthopagrus latus* | 2,072 | 327 | 5,512 | 8 | 33 |
| Emperor, sweetlip | *Lethrinus miniatus* | 1,960 | 418 | 1,771 | 24 | 171 |
| Javelinfish, spotted | *Pomadasys kaakan* | 1,908 | 421 | 2,852 | 0 | 0 |
| Trevally, big-eye | *Caranx sexfasciatus* | 1,904 | 777 | 947 | 0 | 25 |
| Trevally, giant | *Caranx ignobilis* | 1,598 | 582 | 5,488 | 10 | 422 |
| Trevally, general | Family - Carangidae | 1,572 | 362 | 3,911 | 180 | 78 |
| Emperor, red | *Lutjanus sebae* | 1,542 | 274 | 2,994 | 28 | 139 |
| Chinaman fish | *Symphorus nematophorus* | 1,533 | 246 | 866 | 21 | 44 |
| Catfish, giant salmon | *Arius thalassinus* | 1,513 | 309 | 8,459 | 0 | 143 |
| Trevally, gold-spotted | *Carangoides fulvoguttatus* | 1,382 | 298 | 2,261 | 152 | 374 |
| Bream, northwest black | *Acanthopagrus palmaris* | 1,264 | 266 | 4,033 | 0 | 0 |
| Emperor, blue-spotted | *Lethrinus sp.* | 1,138 | 360 | 1,436 | 0 | 5 |
| Sweetlips, painted | *Diagramma labiosum* | 1,086 | 226 | 967 | 0 | 27 |
| Shark, black-tip reef | *Carcharhinus melanopterus* | 884 | 218 | 3,962 | 0 | 586 |
| Jewfish, black | *Protonibea diacanthus* | 862 | 175 | 1,658 | 10 | 0 |
| Trevally, bludger | *Carangoides gymnostethus* | 806 | 232 | 4,828 | 15 | 0 |
| Queenfish, talang | *Scomberoides commersonnianus* | 779 | 167 | 1,346 | 56 | 0 |
| Tuna, mackerel | *Euthynnus affinis* | 772 | 167 | 934 | 79 | 0 |
| Cobia | *Rachycentron canadus* | 761 | 180 | 141 | 0 | 0 |
| Barramundi | *Lates calcarifer* | 694 | 162 | 2,330 | 0 | 25 |
| Garfish | *Hyporhamphus spp* | 677 | 309 | 454 | 0 | 0 |
| Shark, bronze whaler | *Carcharhinus spp* | 558 | 131 | 2,358 | 0 | 474 |
| Other species | | 12,701 | | 74,804 | 1920 | 11,669 |

# Appendix J – Estimated recreational catch (by species) for boats launched from beaches in the Pilbara region

| Common Name | Scientific name | No. kept | SE kept | No. released | No. eaten by sharks |
|---|---|---|---|---|---|
| Crab, blue swimmer | *Portunus pelagicus* | 6,461 | 4,439 | 431 | 0 |
| Crab, mud green | *Scylla serrata* | 4,451 | 4,445 | 3,733 | 0 |
| Emperor, blue-lined | *Lethrinus laticaudis* | 3,589 | 4,459 | 11,916 | 0 |
| Tuskfish, blackspot | *Choerodon schoenleinii* | 3,015 | 4,472 | 4,163 | 0 |
| Crab, mud brown | *Scylla olivacea* | 2,871 | 4,476 | 6,604 | 0 |
| Threadfin salmon | Family - Polynemidae | 2,871 | 4,476 | 2,871 | 0 |
| Mangrove jack | *Lutjanus argentimaculatus* | 2,871 | 4,476 | 5,025 | 0 |
| Seaperch, stripey | *Lutjanus carponotatus* | 2,728 | 4,480 | 4,738 | 0 |
| Emperor, spangled | *Lethrinus nebulosus* | 1,723 | 4,514 | 4,881 | 0 |
| Cod, estuary (slimy) | *Epinephelus coioides/ E. malabaricus* | 1,579 | 4,519 | 3,159 | 0 |

# Appendix K – Estimated recreational catch (by species) for shore-based fishing in the Pilbara region

| Common Name | Scientific name | No. kept | SE kept | No. released | Eaten by sharks |
|---|---|---|---|---|---|
| Mullet, general | Family - Mugilidae | 19,049 | 18,689 | 0 | 0 |
| Threadfin salmon | Family - Polynemidae | 8,111 | 1,691 | 2,897 | 0 |
| Trumpeter, yellowtail | *Amniataba caudovittatus* | 7,014 | 2,027 | 2,024 | 0 |
| Bream, western yellowfin | *Acanthopagrus latus* | 6,398 | 1,800 | 6,461 | 0 |
| Whiting, northern | *Sillago sihama* | 3,792 | 1,171 | 819 | 45 |
| Whiting, yellow-finned | *Sillago schomburgkii* | 3,239 | 930 | 1,022 | 0 |
| Trevally, golden | *Gnathanodon speciosus* | 3,119 | 949 | 1,284 | 0 |
| Mullet, sea | *Mugil cephalus* | 2,049 | 972 | 0 | 0 |
| Garfish, general | Family - Hemiramphidae | 2,026 | 928 | 231 | 0 |
| Emperor, sweetlip | *Lethrinus miniatus* | 1,847 | 1,867 | 9,236 | 0 |
| Catfish, smaller salmon | *Arius graefei* | 1,654 | 569 | 4,955 | 0 |
| Javelinfish, spotted | *Pomadasys kaakan* | 1,501 | 715 | 1,501 | 0 |
| Tuskfish, blackspot | *Choerodon schoenleinii* | 1,473 | 639 | 2,630 | 0 |
| Crab, mud green | *Scylla serrata* | 1,319 | 590 | 1,321 | 0 |
| Bream, northwest black | *Acanthopagrus palmaris* | 1,039 | 453 | 592 | 0 |
| Cod, estuary (slimy) | *Epinephelus coioides/ E. malabaricus* | 721 | 186 | 936 | 0 |

# Appendix L – Estimated total recreational catch (by species) from the Pilbara region

| Common Name | Scientific name | No. kept | SE kept | No. released | Eaten by sharks |
|---|---|---|---|---|---|
| Crab, blue swimmer | *Portunus pelagicus* | 71,615 | 9,751 | 32,715 | 204 |
| Mullet, general | Family - Mugilidae | 21,466 | 18,714 | 0 | 0 |
| Seaperch, stripey | *Lutjanus carponotatus* | 21,299 | 4,850 | 48,863 | 471 |
| Crab, mud green | *Scylla serrata* | 19,168 | 4,654 | 13,488 | 7 |
| Emperor, blue-lined | *Lethrinus laticaudis* | 18,703 | 4,693 | 37,323 | 458 |
| Emperor, spangled | *Lethrinus nebulosus* | 16,400 | 4,647 | 28,257 | 686 |
| Threadfin salmon | Family - Polynemidae | 15,582 | 4,830 | 10,575 | 43 |
| Mackerel, Qld school & Australian spotted | *Scomberomorus queenslandicus/ S. munroi* | 8,868 | 826 | 6,611 | 80 |
| Bream, western yellowfin | *Acanthopagrus latus* | 8,656 | 1,831 | 12,105 | 8 |
| Tuskfish, blackspot | *Choerodon schoenleinii* | 8,407 | 4,538 | 18,322 | 294 |
| Trevally, golden | *Gnathanodon speciosus* | 8,281 | 1,128 | 6,920 | 228 |
| Mangrove Jack | *Lutjanus argentimaculatus* | 7,720 | 4,521 | 13,055 | 0 |
| Trumpeter, yellowtail | *Amniataba caudovittatus* | 7,094 | 2,028 | 2,282 | 0 |
| Crab, mud brown | *Scylla olivacea* | 6,650 | 4,542 | 10,391 | 0 |
| Cod, estuary (slimy) | *Epinephelus coioides/ E. malabaricus* | 5,687 | 4,535 | 13,842 | 53 |
| Squid, northern calamari | *Sepioteuthis lessoniana* | 5,663 | 2,176 | 541 | 0 |
| Whiting, northern | *Sillago sihama* | 4,224 | 1,177 | 860 | 45 |
| Mackerel, narrow-barred Spanish | *Scomberomorus commerson* | 4,074 | 575 | 1,653 | 766 |
| Emperor, sweetlip | *Lethrinus miniatus* | 3,978 | 1,915 | 11,885 | 46 |
| Perch, moses | *Lutjanus russelli* | 3,519 | 630 | 4,025 | 28 |
| Javelinfish, spotted | *Pomadasys kaakan* | 3,409 | 830 | 4,353 | 0 |
| Whiting, yellow-finned | *Sillago schomburgkii* | 3,318 | 931 | 1,053 | 0 |
| Trout, coral | *Plectropomus* spp. | 3,185 | 310 | 3,893 | 332 |
| Garfish, general | Family - Hemiramphidae | 2,703 | 978 | 685 | 0 |
| Rock lobster, painted | *Panulirus versicolor* | 2,521 | 439 | 1,216 | 0 |
| Trevally, general | Family - Carangidae | 2,500 | 522 | 4,684 | 180 |
| Bream, northwest black | *Acanthopagrus palmaris* | 2,303 | 525 | 4,625 | 0 |
| Catfish, smaller salmon | *Arius graefei* | 2,198 | 624 | 27,305 | 70 |
| Trevally, big-eye | *Caranx sexfasciatus* | 1,904 | 777 | 947 | 0 |
| Shark, black-tip reef | *Carcharhinus melanopterus* | 1,770 | 231 | 5,044 | 0 |
| Chinaman fish | *Symphorus nematophorus* | 1,744 | 252 | 866 | 36 |
| Trevally, giant | *Caranx ignobilis* | 1,728 | 585 | 5,507 | 10 |
| Emperor, red | *Lutjanus sebae* | 1,727 | 287 | 3,181 | 78 |
| Catfish, giant salmon | *Arius thalassinus* | 1,652 | 339 | 8,728 | 0 |
| Trevally, gold-spotted | *Carangoides fulvoguttatus* | 1,497 | 309 | 2,261 | 152 |
| Queenfish, talang | *Scomberoides commersonnianus* | 1,285 | 251 | 1,428 | 56 |
| Emperor, blue-spotted | *Lethrinus sp.* | 1,138 | 360 | 1,436 | 0 |
| Sweetlips, painted | *Diagramma labiosum* | 1,125 | 227 | 967 | 0 |
| Jewfish, black | *Protonibea diacanthus* | 900 | 176 | 1,658 | 10 |
| Tuna, Mackerel | *Euthynnus affinis* | 845 | 170 | 941 | 79 |
| Trevally, bludger | *Carangoides gymnostethus* | 806 | 232 | 4,828 | 15 |
| Cobia | *Rachycentron canadus* | 761 | 180 | 141 | 0 |
| Barramundi | *Lates calcarifer* | 694 | 162 | 2,330 | 0 |
| Shark, bronze whaler | *Carcharhinus spp* | 662 | 140 | 2,671 | 0 |

# Appendix M – Estimated total recreational catch (by species) from Dampier Archipelago

| Common Name | Scientific name | No. kept | SE kept | No. released |
|---|---|---|---|---|
| Crab, blue swimmer | *Portunus pelagicus* | 61,166 | 8,579 | 31,102 |
| Crab, mud green | *Scylla serrata* | 6,101 | 929 | 3,121 |
| Mackerel, Queensland school & Aust. spotted | *Scomberomorus queenslandicus/ S. munroi* | 6,067 | 713 | 5,031 |
| Squid, northern calamari | *Sepioteuthis lessoniana* | 5,568 | 2,175 | 541 |
| Emperor, blue-lined | *Lethrinus laticaudis* | 3,617 | 741 | 4,728 |
| Seaperch, stripey | *Lutjanus carponotatus* | 3,396 | 473 | 19,215 |
| Trout, coral | *Plectropomus* spp. | 2,374 | 286 | 2,936 |
| Rock lobster, painted | *Panulirus versicolor* | 2,289 | 427 | 1,072 |
| Emperor, spangled | *Lethrinus nebulosus* | 2,223 | 766 | 3,910 |
| Trevally, golden | *Gnathanodon speciosus* | 2,043 | 445 | 2,541 |
| Mackerel, narrow barred Spanish | *Scomberomorus commerson* | 2,038 | 323 | 960 |
| Mangrove jack | *Lutjanus argentimaculatus* | 1,954 | 342 | 3,807 |
| Tuskfish, blackspot | *Choerodon schoenleinii* | 1,953 | 295 | 6,143 |
| Cod, estuary (slimy) | *Epinephelus coioides/ E. malabaricus* | 1,419 | 226 | 5,395 |
| Threadfin salmon | Family - Polynemidae | 1,158 | 287 | 1,495 |
| Emperor, blue-spotted | *Lethrinus punctulatus* | 1,026 | 356 | 1,296 |
| Emperor, sweetlip | *Lethrinus miniatus* | 915 | 257 | 1,294 |
| Bream, western yellowfin | *Acanthopagrus latus* | 874 | 210 | 2,471 |
| Garfish, general | Family - Hemirampidae | 866 | 517 | 341 |
| Emperor, red | *Lutjanus sebae* | 854 | 222 | 1,213 |
| Trevally, gold-spotted | *Carangoides fulvoguttatus* | 741 | 209 | 1,084 |
| Chinaman fish | *Symphorus nematophorus* | 703 | 170 | 335 |
| Bream, northwest black | *Acanthopagrus palmaris* | 691 | 206 | 2,130 |
| Queenfish, talang | *Scomberoides commersonnianus* | 571 | 159 | 954 |
| Perch, moses | *Lutjanus russelli* | 430 | 116 | 1,560 |
| Seaperch, striped | *Lutjanus vitta* | 393 | 163 | 1,403 |
| Trevally, giant | *Caranx ignobilis* | 379 | 133 | 1,993 |

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