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Quantifying recreational fishing catch and effort: a pilot study of shore-based fishers in the Perth Metropolitan area

C. B. Smallwood, K. H. Pollock, B.S. Wise, N.G. Hall and D.J. Gaughan

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Government of **Western Australia**
Department of **Fisheries**

Fisheries Research Division
Western Australian Fisheries and Marine Research Laboratories
PO Box 20 NORTH BEACH, Western Australia 6920

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Enquiries:

WA Fisheries and Marine Research Laboratories, PO Box 20, North Beach, WA 6920
Tel: +61 8 9203 0111
Email: library@fish.wa.gov.au
Website: www.fish.wa.gov.au
ABN: 55 689 794 771

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1.0 Executive summary

Recreational fishing is a popular activity throughout Western Australia, including adjacent to the populous Perth Metropolitan area. Understanding the level of catch and effort associated with this activity is essential for the sustainable management of fish stocks. Whilst the focus of recent surveys in the Perth Metropolitan area has been on boat-based fishers targeting demersal species, shore-based fishing has not been measured for many years. Recent changes to management controls for these demersal species, including the implementation of a fishing boat licence, may increase existing pressures on nearshore stocks by displacing fishing effort onto these resources. Therefore, a need exists for the collection of information on the behaviour and catch of recreational shore-based fishers to support management measures.

Surveying recreational shore-based fishing can be complex because it can occur over diffuse spatial and temporal scales, which is challenging for designing a robust survey. Given these difficulties, a pilot study was conducted from April – June 2010 to examine the relative benefits of different survey techniques for measuring shore-based recreational fishing in the Perth Metropolitan area. Video cameras at four groynes revealed a peak in shore-based fishing activity from 2 – 6 pm, but with significantly greater numbers of fishers on weekends/public holidays. Aerial surveys identified a heterogeneous spatial distribution of shore-based fishers along the coastline, with the highest numbers observed on groynes and jetties. Roving creel surveys yielded 1,194 interviews with parties actively undertaking shore-based fishing, during which Australian herring (*Arripis georgianus*) was the most frequently retained species. Comparing instantaneous counts of recreational shore-based fishers between techniques found the strongest relationship between aerial and roving creel surveys, while a restricted field of view at some cameras reduced the effectiveness of this method.

Total shore-based fishing effort for the Perth Metropolitan area during the pilot study was estimated to be 196,430 fisher hours (SE± 8,662). The total retained catch for all species was 327,414 fish (SE± 33,107), of which Australian herring was the dominant species. An additional 70,412 fish (SE± 13,771) had been released by shore-based fishers.

Each survey technique had different costs, benefits and limitations. Cameras have great potential as a tool for ascertaining within-day variability of fishing activity, including night fishing, which is rarely considered in surveys of recreational fishing. Such potential was highlighted in this study, but the high costs of data analysis and assumptions required to apply these data to calculate total fishing effort were also revealed. Aerial surveys were effective at rapidly collecting data on the spatial distribution of shore-based fishers, used to calculate fishing effort, whilst also providing valuable information for allocating sampling effort in future surveys. Roving creel surveys were the only method from which data on trip length and the catch of shore-based fishers could be obtained, enabling calculation of catch rate. Although this was the most expensive technique due to high fieldwork costs, this information cannot be collected cost-effectively using other methods, such as phone/diary surveys, without a known sampling frame. The findings from this study provided benchmark data from which changes in patterns of shore-based recreational fishing activity can be detected and used to generate a much better understanding of the potential exploitation levels of nearshore fish stocks.

2.0 Introduction

Recreational fishing from boats and the shore is a popular activity undertaken by an estimated 11.5% of the global population (Cooke and Cowx, 2004) and a growing availability of leisure time and disposable income is facilitating greater participation, and efficiency, in many countries (Cooke and Schramm, 2007; McPhee *et al.*, 2002). Such efficiency may result in the exploitation of many species in freshwater, estuarine and nearshore marine ecosystems, which are easily accessible to recreational fishers (Arlinghaus and Cooke, 2005; Coleman *et al.*, 2004; Jackson *et al.*, 2001). Understanding the level of recreational fishing catch and effort, and how this changes through time and space, is therefore critical to the sustainable management of fish stocks (Griffiths *et al.*, 2010; Steffe *et al.*, 2008).

In Western Australia, it is estimated that 600,000 people participate in recreational fishing (DoF, 2002). These fishers are drawn from a total population of 2.3 million; which is the fastest growing of all states in Australia (ABS, 2009). Such growth has implications for participation in recreational fishing, as effort is largely unrestricted, and may continue to increase in line with population size (Wise *et al.*, 2007). Bag and size limits are the primary management controls used by the Western Australian Department of Fisheries to constrain recreational catches. However, pressure on nearshore fish stocks from shore-based recreational fishers may be exacerbated by displacement of fishing effort onto these resources following the implementation of new management arrangements for demersal species (Metcalf *et al.*, 2010). These measures include a statewide boat fishing licence and reduced bag limits in the West Coast bioregion, which encompasses the Perth Metropolitan area (Fletcher and Santoro, 2009) (Fig. 1).

Whilst the catch of demersal species from boats has been measured using surveys at boat ramps throughout the West Coast Bioregion (Sumner and Williamson, 1999; Sumner *et al.*, 2008), shore-based fishing has not been recently investigated. The earliest study of recreational shore-based fishing in the Perth Metropolitan area and on Rottnest Island was completed from April – June 1973, corresponding to the peak time of year for Australian herring (*Arripis georgianus*) (Lenanton and Hall, 1976). Total catch and catch rates of Australian herring and Western Australian salmon (*Arripis truttaceus*) along parts of the Perth Metropolitan area were calculated from February 1994 – December 1995 as part of a larger study encompassing the entire southern coast of Western Australia (Ayvazian *et al.*, 1997). Most recently, a survey on Rottnest Island was completed in 2003 that calculated catch rate and total catch for species retained and released by shore-based fishers, for which Australian herring was the dominant species (Smallwood *et al.*, 2006). These studies were all implemented using roving creel surveys, whereby an interviewer travels a set route through the fishery intercepting shore-based recreational fishers for interview (Pollock *et al.*, 1994).

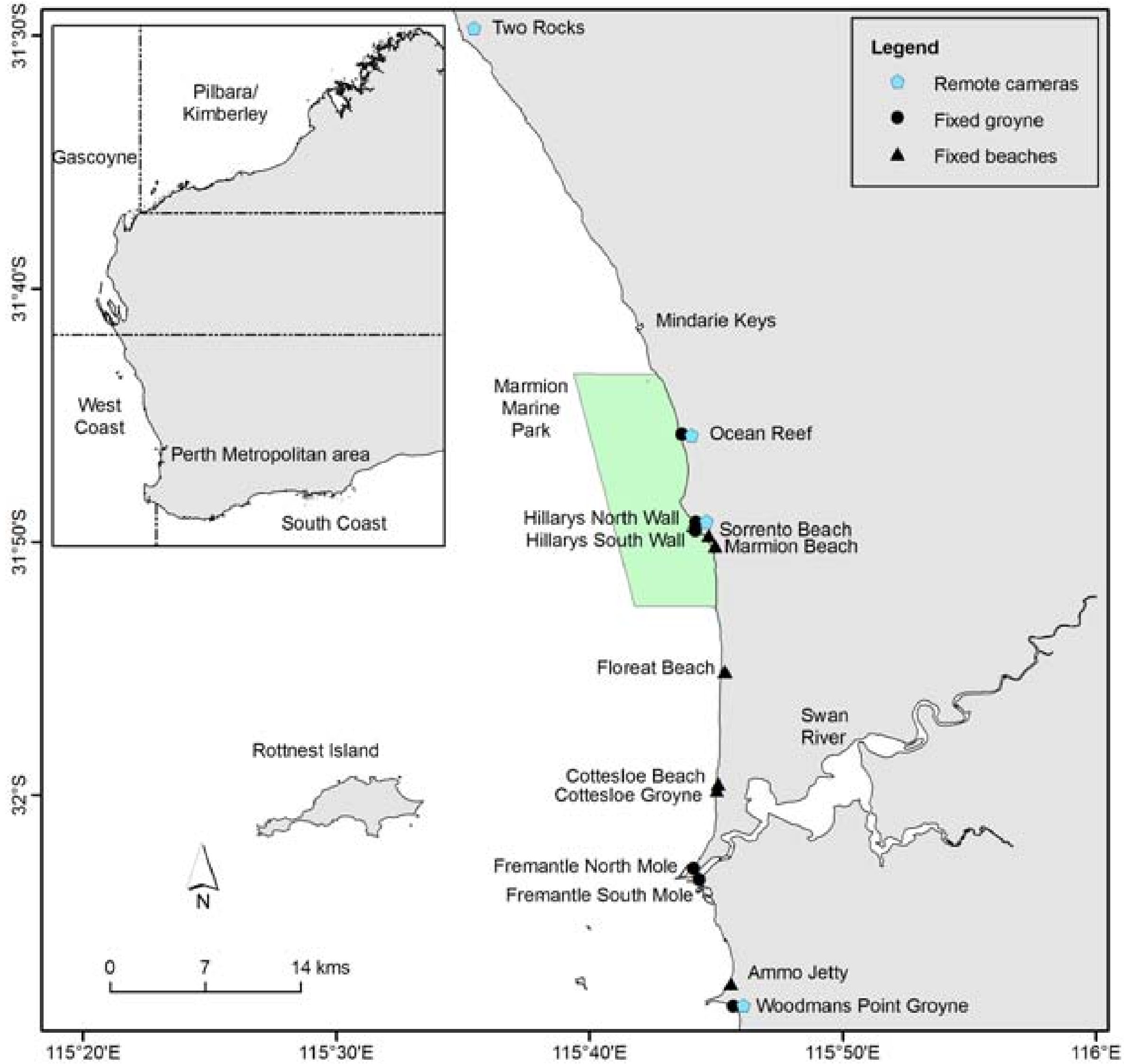

Fig. 1 Perth Metropolitan area, from Two Rocks Marina to Woodmans Point Groyne, along with location of remote cameras, fixed groynes and fixed beaches incorporated into the study of shore-based recreational fishers.

Comprehensive reviews of the various methods available for sampling recreational fishers have been published by Guthrie *et al.* (1991), Pollock *et al.* (1994) and NRC (2006). Such methods include roving creel surveys, access point (or bus route) surveys, aerial surveys, logbook and phone/diary surveys as well as combinations of these techniques, known as complementary surveys. Selection of a survey technique depends on a number of factors including; the size of the study area, nature of the recreational fishery, budgetary constraints, available staff resources and management objectives with respect to spatial and temporal scales of estimates. Achieving a balance between all these aspects is difficult, and inadequate survey design may lead to large sampling errors and high uncertainty of results (Griffiths *et al.*, 2010; NRC, 2006). Challenges also arise from the diffuse nature of fishing activity as well as the wide diversity of characteristics exhibited by recreational fishers in terms of age, occupation, origin and frequency of participation.

Roving creel surveys and access point surveys are both intercept techniques suited for collecting in-depth information on catch, effort and other fisher characteristics (Pollock *et al.*, 1994).

Although fishing from boats and the shore can be widely distributed throughout a study area, the number of boat ramps is often limited and most boat-based fishers return to these locations at the completion of their fishing trip, where they can be intercepted to obtain complete trip information. However, shore-based fishing can occur from a multitude of fishing platforms such as jetties, groynes and beaches for which there may be numerous access points, and this generally results in the collection of incomplete trip information using a roving survey. The time it takes to traverse a study area is often limiting. Such studies are often conducted within smaller, confined study areas, e.g. lakes (Lockwood *et al.*, 2001), reservoirs (Soupir *et al.*, 2006) or islands (Smallwood *et al.*, 2006). Although aerial surveys are only able to obtain estimates of fishing effort, the rapid speed of travel enables a large study area to be surveyed within a short timeframe (Brouwer *et al.*, 1997; Parker *et al.*, 2006).

Phone/logbook surveys are where participants are recruited and provided with a logbook to record all fishing details; each is then contacted monthly via phone. Such an approach circumvents the high fieldwork costs associated with some other techniques. However, for such surveys to be cost-effective, a known sampling frame is required (i.e. a database of recreational fishing licence holders) from which to draw information. Such surveys have been implemented in the United Kingdom (Aprahamian *et al.*, 2010), North America (Ashford *et al.*, 2009; Sutton *et al.*, 2001; Whitehead *et al.*, 2002) and also in Western Australia for people who hold licences for western rock lobster and abalone (DoF, 2006; 2007). The recently implemented Western Australian recreational boat fishing licence will allow a sampling framework to be developed for surveying boat-based fishing using off-site techniques. However, no such sampling frame exists for recreational shore-based line fishing. Volunteer logbook programs are another option for unlicensed recreational fisheries, although previous studies found they should be used to support, rather than replace, other assessment options (Bray and Schramm, 2001).

Complementary survey designs are a powerful tool as they can combine various survey techniques to increase the accuracy and precision of fisheries estimates (Steffe *et al.*, 2008). Boat-based fishing has been the focus of many complementary survey designs (Hartill *et al.*, in prep; Steffe *et al.*, 2008; Volstad *et al.*, 2006). However, recent studies have begun to explore such designs for shore-based fishing using aerial-roving (Veiga *et al.*, 2010) and aerial-access designs (Volstad *et al.*, 2006). Recent advances also include the use of time-lapse photography to capture information on patterns of recreational fishing (Parnell *et al.*, 2010) as well as video monitoring of commercial vessels (Ames and Schlindler, 2009).

Given the challenges of surveying shore-based recreational fishing, a three month period, from April – June 2010, was selected for a pilot study examining the relative benefits of different survey techniques for measuring this activity throughout the Perth Metropolitan area. This timeframe coincided with the peak recreational catches of Australian herring, a recreationally and commercially important nearshore pelagic species which occurs in high abundances along the southern half of the Western Australian coastline (Ayvazian *et al.*, 2004). Aerial surveys were scheduled at expected times of maximum fishing activity to provide information on fishing effort, as well as to determine the spatial variability of shore-based recreational fishing activity. Roving creel surveys obtained data on catch, fishing time, number of fishers that were applied to calculations of catch rate, total catch and fishing effort. The pilot study also utilised remote camera technology to provide information on the within-day variability of shore-based fishing activity.

3.0 Objectives

The overarching aim of the study was to ascertain the suitability of various survey methods for estimating catch and effort for shore-based recreational fishers targeting nearshore fish stocks in the Perth Metropolitan area, with particular focus on the Australian herring (*Arripis georgianus*).

Specific objectives were;

1. to determine the temporal (within-day) variability of shore-based recreational fishing across a 24-hr day,
2. ascertain the spatial variability and density of shore-based recreational fishers,
3. calculate catch rate and derive estimates of total catch and fishing effort for main species retained and released by shore-based fishers,
4. describe the costs, benefits and limitations of each survey technique and,
5. make recommendations for future surveys of recreational shore-based fishing.

4.0 Methods

4.1 Study area

The coastline adjacent to the Perth Metropolitan area extends between Two Rocks Marina in the north and Woodmans Point Groyne in the south (Fig. 1). This area corresponds to access points used in previous surveys of boat-based recreational fishing (Sumner and Williamson, 1999; Sumner *et al.*, 2008) and fits within the 'Metropolitan Zone' of the West Coast Demersal Scalefish fishery, a multi-species fishery operating throughout the West Coast bioregion (Wise *et al.*, 2007). Numerous platforms for shore-based recreational line fishing exist along the Perth Metropolitan coastline, including man-made groynes, natural rocky outcrops, intertidal reef platforms, jetties and sandy beaches.

The Perth Metropolitan coastline was split into 56 survey locations (Appendix 1). Boundaries of each location were defined using specific features identified by GPS co-ordinates, and were classified into four types of fishing platforms; beach (n=43), large groynes (n=11), small groynes (n=1) and jetties (n=1). Large groynes were defined as those constructed for the purpose of creating sheltered waters for marina or boat ramp facilities, as opposed to a small groyne (spur) created to prevent alongshore movement of sand on beaches (Fig. 2a-d). Beaches were classified as such because they were dominated by sand or rock substrate, but it should be noted that some of these comprised a mix of platforms, i.e. a sandy beach may have several small groynes distributed along its extent.

Fig. 2 Images of each type of fishing platform included in the survey of shore-based fishing in the Perth Metropolitan area, namely, (a) large groynes, (b) small groynes, (c) sand or rock dominated beaches and (d) jetties.

Background information on fishing activity occurring at each of these locations was obtained from previous surveys (Ayvazian *et al.*, 1997; Blackweir and Beckley, 2004; Lenanton and Hall, 1976). Anecdotal evidence was also acquired from research scientists, fisheries management officers and volunteer fisheries liaison officers who have intimate knowledge of shore-based fishing along the Perth Metropolitan coast. This information assisted with classifying each survey location on a scale of fishing activity from low to very high (Appendix 1), which was then used to proportion sampling effort during roving creel surveys.

4.2 Survey design

The complexity and diversity of recreational shore-based fishing activity creates challenges for obtaining reliable catch and effort estimates. To this end, a complementary survey approach was employed to ascertain the spatial and temporal patterns in recreational shore-based fishing, as well as estimate catch and effort, in the Perth Metropolitan area. Fieldwork was conducted throughout the Perth Metropolitan area for three months (April – June 2010), and combined remote cameras, roving creel surveys (including incomplete interviews with shore-based fishes) and aerial surveys. These months were selected as they matched the annual migration of Australian herring along the south-western coast of Australia (Ayvazian *et al.*, 2004) as well as corresponded to the timeframe of a previous roving creel survey of Australian herring in the Perth Metropolitan area undertaken in 1973 (Lenanton and Hall, 1976).

4.2.1 Remote cameras

Cameras were placed at four large groynes in the Perth Metropolitan area; Two Rocks Marina, Ocean Reef, Hillarys North Wall and Woodmans Point Groyne (Fig. 1). These groynes were selected as they had existing infrastructure (i.e. power supply) from which to mount and operate the equipment. Installation of cameras was prohibited at Fremantle North and South Moles, due to the security issues associated with a working port. Cameras were not installed at beaches due to a lack of infrastructure and concerns over perceived potential for invasion of privacy.

Two Rocks Marina, Ocean Reef and Woodmans Point Groyne were fitted with cameras with a day/night lens while a camera with a 180-degree field of view and anti-vandalism kit was installed at Hillarys North Wall, as the camera was easily accessible by the public. All cameras provided high resolution images and had pan, tilt and zoom capabilities that allowed fine-tuning of the desired field of view as well as lenses that were optimized for low light conditions, enabling viewing of night fishing activity. Cameras were attached to a computer which handled image capture, streaming and file upload.

Electronic data collection has the advantage of allowing a complete census of shore fishing activity occurring at these groynes throughout the study period (i.e. 91 days) (Table 1). Camera coverage at each site was focused on a ‘choke’ point (i.e. a single entry/exit through which people accessed the groyne) or, at Hillarys North Wall, a standard field of view in which all people within the frame could be counted (Fig. 3). Date, time and site of capture metadata were embedded in the recorded footage and images were time-lapsed to record frames at 8 – 45 second time increments, depending on the location.

Camera footage was viewed as soon as possible after the date they were recorded. Each time an individual or group of people arrived or departed the groyne, an event was recorded on a datasheet (Appendix 2) and then entered into an Access database with the following attributes;

- time (to the nearest second),
- if the individual or group was arriving or departing,

- an activity type for each individual or group (fishing, not fishing or unknown), and
- number of people in the group.

Participation in fishing activity was ascertained by the presence of equipment such as rods, tackle box or catch bucket. If one person within a larger group was in possession of such equipment, then the entire group was classified as a fishing party. For any events where it was difficult to ascertain group size, especially after dark, this field was left as a null value.

Fig. 3 Location of the remote cameras at each of the four groynes, their field of view and, if relevant, the choke point at which people were counted.

There were periods of time for which footage was not obtained as a result of technical faults or reduced visibility due to environmental conditions (i.e. heavy rainfall). The start and finish times of such time periods, along with its cause, was also recorded in the database.

Table 1. Comparison of methods and sampling design for each survey technique used to obtain estimates of shore-based fishing catch and effort in the Perth Metropolitan area.

	Remote camera	Roving creel survey	Aerial survey
Sampling frame			
Survey period	April – June 2010	April – June 2010	April – June 2010
Number of surveyed days	91	36	36
Length of fishing day	24-hr	14-hr (6 am – 8 pm)	9.5-hr (8 am – 5.30 pm)
Stratification			
Month	Complete census	Yes – 12 days per month	Yes – 12 days per month
Day type	Complete census	Yes – equal allocation of weekdays and weekends/ public holidays	Yes – equal allocation of weekdays and weekends/ public holidays
Time of day	Complete census	Yes – equal allocation of morning and afternoon shifts	Yes – equal allocation of morning and afternoon shifts
Randomisation			
Starting location	NA	Randomly selected	Mirror roving creel survey
Travel direction	NA	Randomly selected	Mirror roving creel survey
Data collection techniques			
Survey length	24-hr	7-hr	1.5-hr
Shift times	Complete census	Morning (6 am – 1 pm); Afternoon (1 pm – 8 pm)	Morning (8 am – 9.30 am) Afternoon (4 pm – 5.30 pm)
Number of locations per survey	4	16 - 19	55
Fishing platform	Large groynes	Small and large groynes, beaches and jetties	Small and large groynes, beaches and jetties
Counts of shore fishers	Complete census	Yes – instantaneous	Yes – instantaneous
Interviews with shore fishers	No	Yes – incomplete trip	No
Calculation of fishing estimates			
Fishing effort	Yes	Yes	Yes
Catch rate	No	Yes	No
Total catch	No	Yes	No

4.2.2 Roving creel surveys

Roving creel surveys were undertaken by two staff travelling in a vehicle to nominated survey locations between Ocean Reef and Woodmans Point Groyne to complete instantaneous counts from vantage points as well as incomplete interviews with people actively fishing from the shore. The northern stretch of coast (from Two Rocks Marina to Ocean Reef) was not included in the roving survey due to the constraints of travel time. Furthermore, there were few vantage points from which instantaneous counts could be obtained, and some areas were only accessible by 4WD. Such factors combined to further increase the time required to survey this northern section, which could not be achieved with available staff resources.

Roving surveys were completed 12-days per month on an equal number of weekdays and weekends/public holidays (Appendix 2; Table 1). Saturdays, Sundays and public holidays were classified as weekend days, and Monday through Friday as weekdays, in accordance to previous surveys of recreational fishing activity (Steffe *et al.*, 2008). Survey days were randomly selected without replacement in each of the three months. Two extra roving surveys were completed in May due to re-scheduling of concurrent aerial surveys (see Section 4.2.3) and these were selected from the reduced number of days available within that month.

A fishing day was defined as extending from 6 am – 8 pm to encompass all twilight and daylight hours, and was divided into two seven-hr shifts comprising morning (6 am – 1 pm) and afternoon (1 pm – 8 pm). These survey shifts were randomly allocated in equal proportions to survey days within each month. Maximum day length was based on knowledge that Australian herring, the main species of interest in this study, are predominantly targeted by fishers from first light through to the early morning and also in the early evenings. Although other species are caught outside these times, especially tailor (*Pomatomus saltatrix*), it was expected that fishers targeting these species could still be intercepted for interviews prior to departure in the early morning or after arrival in the early evenings.

The coast from Ocean Reef to Woodmans Point Groyne extends linearly for 60 km and contained 42 survey locations. Thus the number of survey locations that could be visited during a seven-hr shift was limited by travel time. As a consequence, a subset of 16 - 19 survey locations was randomly selected for each survey day to ensure representative coverage of all shore-based fishing in the Perth Metropolitan area. When selecting the locations to be used for the roving creel survey, six (out of the total nine) large groynes were visited on every survey day to obtain instantaneous counts on arrival and departure as well as incomplete interviews with people actively shore-based fishing (Fig. 1). These locations were termed 'fixed groynes' and were selected as they corresponded to locations with three remote cameras, thereby calibrating count information between methods, while also comprising locations identified from anecdotal evidence as highly popular with shore fishers.

An additional six locations were selected from the remaining survey locations (excluding the six fixed groynes) at which instantaneous counts were conducted on every survey day; Sorrento Beach, Marmion Beach, Floreat Beach, Cottesloe Beach, Cottesloe Groyne and Ammo Jetty (Fig. 1). These locations were termed 'fixed beaches' and were selected at random using non-uniform probability of sampling. Probabilities for each survey location were allocated based upon anecdotal evidence of levels of shore-based fishing (Appendix 1).

Up to seven 'random beaches' were also selected at which instantaneous counts on arrival and departure as well as incomplete interviews with people actively shore fishing were completed. Fixed beaches were also included in this selection process, as it was important to obtain catch data, in addition to instantaneous counts, from these locations. Random beaches were selected for each survey day, using non-uniform probability of sampling, based on anecdotal evidence of greater shore fishing activity, similar to Volstad *et al.* (2006). Coogee Marina North Wall was added to the list of survey locations in the final month of June, as it was closed for construction in the previous months.

Once all locations for a specific survey day had been chosen, a schedule was created using a randomly selected starting location and a random travel direction (i.e. north or south). Travel times between two locations were incorporated into the schedule wait times, which were reflective of the tasks to be completed, the extent of the survey location and its popularity with shore fishers. Fixed beaches (where only a single instantaneous count was performed) were allocated between 5 – 10 minutes while random beaches and fixed groyne locations were allocated up to 30 minutes to allow staff enough time to conduct two instantaneous counts plus interviews. Once the northern (Ocean Reef) or southern (Woodmans Point Groyne) extent of the survey area was reached, staff travelled directly to the opposite end to survey the remaining sites for that particular shift in the same direction as they had been previously travelling.

On arrival at a survey location, an instantaneous count of people actively shore fishing was completed. People actively shore fishing were defined as those with rods or handlines in the water targeting finfish species at the time of observation or, who were re-baiting or handling a caught fish. The presence of a catch bucket was also useful for distinguishing between fishers and non-fishers. To validate data obtained from remote cameras and aerial surveys, counts of non-fishers were also made at all fixed groynes.

The number of interviews completed depended on the time that had been allocated to each specific survey location; in some cases all fishing parties were not interviewed. When people were fishing in groups, one individual was randomly selected to answer questions relating to the current fishing trip on behalf of the entire group. Information collected during interviews included; number of shore fishers in the group, fishing gear (type and number), time spent fishing and number of times fished in the last month (i.e. four weeks) (Appendix 4). The common name, and number, of all species retained or released by the entire group was documented. If time permitted, total lengths of a random sample of the retained catch were obtained, along with the number of undersized fish. Time of interview and fishing platform (i.e. beach, jetty or groyne) were also recorded by the interviewer. At completion of these interviews, and just prior to departure from a survey location, a second instantaneous count of shore fishers (and non-fishers at fixed groynes) was completed.

4.2.3 Aerial surveys

Aerial surveys were completed by a single observer in a Cessna 172 fixed (high) wing aircraft on the same 12-days per month, and time of day, as the roving creel survey. The primary aim of these surveys was to determine the spatial variability of shore fishing effort at all locations between Two Rocks Marina and Woodmans Point Groyne (Appendix 1; Fig. 1). Surveys were conducted at a cruising speed of 100 knots, although this could be slowed to 65 knots if a survey location was crowded with people. The pilot positioned the plane over the water ~100 m out from the shoreline so the observer, sitting in the rear of the plane, could have a clear view of any shore-based fishers. Flying over water also allowed the pilot to fly at an altitude of 500 ft, rather than the higher minimum of 1,000 ft legally required when passing over built-up residential or commercial areas. This height (500 ft) provided good views along the ocean-side of a large groyne but it could be difficult to identify fishers on the 'inside' of a large groyne, especially if it curves parallel to the coastline. Therefore, observers were provided with maps to ensure that the same areas of each large groyne were counted for shore-based fishers. Flight time was ~1.5-hrs depending on weather conditions and the survey start location.

Data from the aerial surveys were required to 'scale-up' estimates of fishing effort obtained from other survey methods and, as such, timing of aerial surveys was crucial. Based on anecdotal evidence of shore-based fisher behaviour, the selected survey times aimed to correspond to periods of maximum fishing activity (i.e. early morning and early evening). However, aerial surveys cannot be conducted in the dark and the sun needs to be at an angle that will not affect the likelihood of observing fishers due to glare off the water surface (i.e. at sunrise or sunset). Start times were initially set to 8 am for morning flights and 4 pm for afternoon flights in April, the first month of sampling, and were adjusted 30 minutes later and 30 minutes earlier in May and June for morning and afternoon flights, respectively.

Direction of travel and start location of aerial surveys mirrored that assigned to the roving creel surveys, although duplicate counts were completed on the 'return' flight between the furthest survey extents. Each time people were sighted actively fishing from the shore, a time of observation was recorded, along with the number of people. A digital camera was used to obtain a permanent record of the majority of shore-based fishing activity, and was particularly useful for locations where it was difficult to directly identify fishers from the plane, such as in large numbers on groynes. If more time was required for making observations, the pilot was asked to slow the speed of the plane or perform a circuit.

The geo-referenced location of all people observed actively shore-based fishing was obtained by matching the time of observation to information recorded on a data logger, with an inbuilt-GPS, which ran throughout each flight. Date, altitude, speed and direction of travel were also recorded every second of the flight. At the completion of each flight, these data were processed using Aerial Survey Assistant (OVER, 2010), which created a shapefile that was imported into a ArcGIS 9.3 project. The time stamp associated with any digital photographs taken throughout the flight was also used to identify them with a particular data point, so they could be easily retrieved for viewing. During processing, each data point was identified to a specific survey location by overlaying them with a polygon shapefile marking the extent of all locations in the study area. Polygons extended 250 m each side of the mean high water mark, while the northern and southern boundaries of each location matched those used in the concurrent roving surveys. Once displayed in an AcrGIS 9.3 project, the number of people associated with each data point was manually added to the shapefile from information recorded by the observer during the flight, and from viewing digital photos. Watches and cameras were synchronized to a GPS prior to every flight to ensure that the time of observation and photographic records matched.

The rapid speed of travel by air resulted in an instantaneous count of shore-based fishers for each location. As there could be more than one geo-referenced point within a location, the number of fishers associated with these data points were aggregated on each survey day to provide a total number of fishers. Any non-fishers associated with the fishing party were excluded if they could be identified either at the time of observation, or during post processing of digital photos. As with roving creel surveys, people actively fishing from the shore were defined as those with rods or handlines in the water at the time of observation or, who were re-baiting or handling a caught fish. In congested areas it was not possible to discriminate between fishing parties, and more than one party may have been attributed to a single data point. Therefore, analysis of these aerial data was based on individual shore-based fishers, rather than the fishing party.

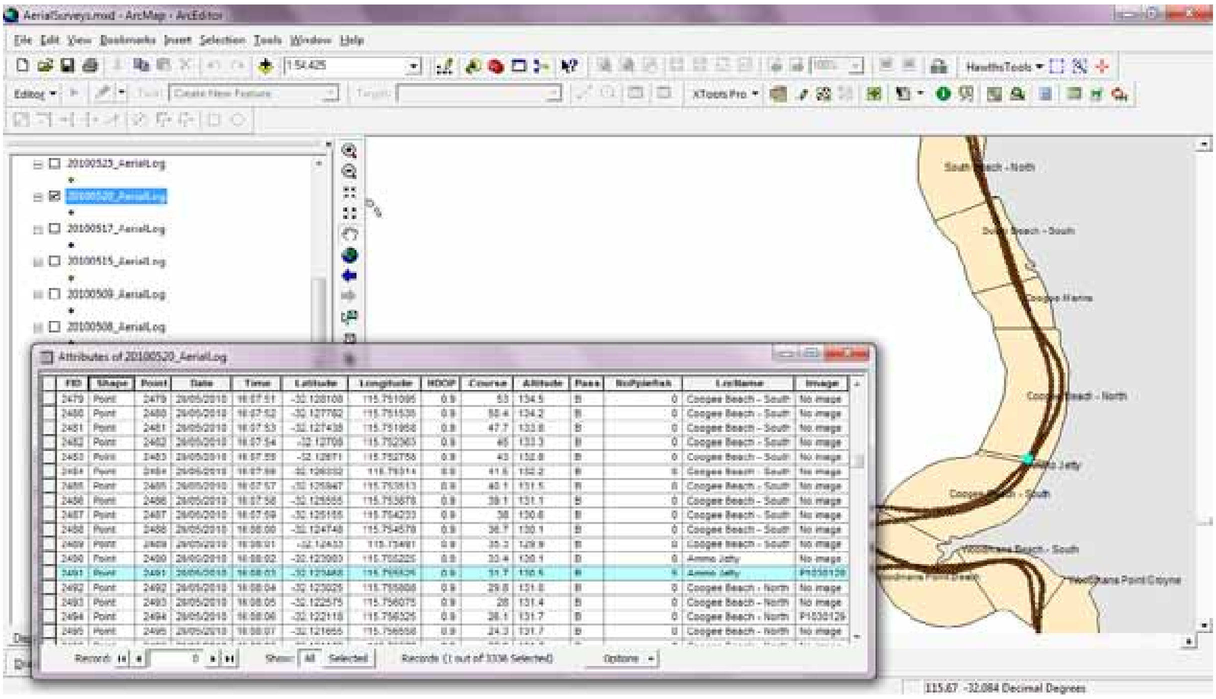

Fig. 4 Screen view of ArcGIS 9.3 project displaying shapefile and attribute table used for storage and analysis of data collected during each aerial flight, along with polygon shapefile of location extents. Note: attribute table extracted from data logger using Aerial Survey Assistant (OVER, 2010).

4.3 Data analysis

Output from the cameras was used to ascertain the proportion of recreational shore-based fishing activity occurring across a 24-hr day, while aerial surveys were used to determine its spatial variability. Roving creel surveys, including incomplete trip interviews, enabled catch rate to be calculated. Information from all techniques was combined to estimate total catch and fishing effort of shore-based recreational fishers in the Perth Metropolitan area from April – June 2010. Details of this analysis are explained in Sections 4.3.1 - 4.3.3.

4.3.1 Temporal variability

Analysis of camera footage was completed within an MS Access database and using the statistical package R. Data from each of the four groynes was summarized as the mean number of events occurring on different day types to provide an indicator of total activity occurring on each groyne for each surveyed month. Events (defined as any time at which an individual or group of people arrived or departed the groyne) were used, rather than number of people, as there were difficulties in ascertaining group size for a small number of observations, especially at night. However, mean group size was calculated for each groyne and day type using the events for which this information was available, so that values could be assigned to these missing data points and used in subsequent analysis. An activity type (not fishing, unknown and fishing) was also assigned to each event and allowed calculation of the proportion of people undertaking each activity on different day types. Only people arriving at a groyne were selected for this specific analysis, as it was assumed that people were assigned the same activity type when they departed.

The cumulative total count of people (TC) on each groyne at time t, across a 24-hr day, was calculated as

$$TC_{pt} = \sum_{t=1} [(Z_{ptk_1}) - (Z_{ptk_2})]$$

where

Z = the sum of people at that discrete sample time interval,

t = the sample time interval, commencing at midnight (00:00)

k = a specific event, with k_1 representing people arriving at a groyne and k_2 representing people departing from a groyne.

Calculating the total number people at each time interval revealed some negative counts (where the number of people leaving a groyne exceeding the number arriving). In this situation, the total was re-set to zero for that sample time. Analysis of video footage also revealed there was very little activity between 22:00 and 04:00. Therefore, midnight (00:00) was used as a calibration point, i.e. the groyne was assumed to be empty of people at this time.

Total counts of people present on a groyne were calculated for each 2-hr time interval of every surveyed day, and then averaged by day type. However, non-fishers still needed to be excluded and the mean number of people assigned to each activity type was used to adjust these total counts. This was completed using two approaches to provide;

- a lower limit of fishing activity (by using only people assigned to fishing) and,
- an upper limit of fishing activity (by using people assigned to fishing and unknown activity types).

Incorporating people assigned to an unknown activity was important as they may be about to, or have been, involved in shore-based fishing.

Although there were differences in the number of shore fishers obtained from each camera, similar trends were evident, and patterns were assumed to be consistent across the entire study area. Data were then combined across all cameras to calculate the proportion of fishing activity occurring within each 2-hr time interval, on different day types. These proportions were central to calculating estimates of total fishing effort as they were used to extrapolate counts of shore-based fishers from the aerial surveys. Time intervals of this length were selected as 75% of aerial surveys fell entirely within 8 am – 10 am and 4 pm – 6 pm intervals. Of the remaining aerial flights, more than half of each survey was completed within these time intervals.

Video monitoring of groynes should provide a full census of activity occurring within a field of view during the three months of the pilot study. However, there were several periods of time where no camera footage was collected, due to technical faults or inclement weather, which were documented during processing. As these periods of lost data may affect the calculation of the total number of people on a groyne, if there was not a complete record of activity from across an entire day, it was excluded from analysis.

4.3.2 Spatial variability

Analysis of data collected during aerial surveys of the Perth Metropolitan area was completed using ArcGIS 9.3, an Access database and the statistical package R. Although each observation of people shore-based fishing was geo-referenced, they were aggregated to the same locations used in the roving creel surveys. The mean number of shore-based fishers for each combination of day type (weekends/public holidays, weekdays) and time of day (morning, afternoon) strata were calculated for each of the 55 locations within the study area. Standard errors were also calculated for each of these strata to highlight the variability in these findings. These data were displayed spatially to compare differences in densities of fishing activity between locations.

The total number of people observed shore-based fishing during aerial surveys was compared against data from the remote cameras. Counts were matched to the nearest minute and displayed using scatterplots. A positive 1:1 linear relationship would be expected between these counts and a regression was performed to test the strength of this relationship.

4.3.3 Calculation of total effort, catch rate and total catch

Shore-based fishing effort (e_{sd}), in fisher hours, for each strata s on day d was calculated as

$$e_{sd} = \frac{I_s}{\hat{P}_s} \overline{m_s}$$

where

I_s = instantaneous counts of shore-based fishers from each aerial survey

$\hat{P}_s$ = proportion of total fishing activity occurring within a 2-hr time interval t, derived from remote camera data

$\overline{m}_s$ = mean total trip length of shore-based fishers. Incomplete trip length was obtained from interviews and doubled to obtain an estimate of total trip length.

The total effort $(\hat{E}_s)$, in fisher hours, for strata s was calculated as

$$\hat{E}_s = \frac{\sum_{d=1}^{n} e_{sd}}{n/N}$$

where

n = number of surveyed days in strata s

N = total number of days in strata s.

Variance of total effort $(\hat{E}_s)$ was calculated using the standard variance of a product, as

$$V\hat{a}r\left(\hat{E}_s\right) = V\hat{a}r(I_s)\left(\frac{\overline{m}_s}{\hat{P}_s}\right)^2 + V\hat{a}r\left(\frac{\overline{m}_s}{\hat{P}_s}\right){I_s}^2 - \left(V\hat{a}r(I_s)\right)\left(V\hat{a}r\left(\frac{\overline{m}_s}{\hat{P}_s}\right)\right)$$

The variance of instantaneous aerial counts (I_s) was calculated using the standard variance of a total while the variance of mean trip length ($\overline{m}_s$) was calculated using the standard variance of a mean. The variance associated with the proportion of people fishing $(\hat{P}_s)$ was calculated using a binomial variance.

Additionally, $V\hat{a}r\left(\frac{\overline{m}_s}{\hat{P}_s}\right)$ was calculated using the variance of a quotient, represented as

$$V\hat{a}r\left(\frac{\overline{m}_s}{\hat{P}_s}\right) = \left[\frac{\overline{m}_s}{\hat{P}_s}\right]^2 \left[\frac{V\hat{a}r(\overline{m}_s)}{(\overline{m}_s)^2} + \frac{V\hat{a}r(\hat{P}_s)}{(\hat{P}_s)^2}\right]$$

Total effort ($\hat{E}$) was calculated using the sum of individual estimates for each strata s

$$\hat{E} = \sum_{s=1} \hat{E}_s$$

Variance of the total effort ($\hat{E}$) was calculated using the sum of individual variance estimates for each strata s

$$V\hat{a}r(\hat{E}) = \sum_{s=1} V\hat{a}r(\hat{E}_s)$$

Standard error of the total effort was calculated by

$$SE(\hat{E}) = \sqrt{V\hat{a}r(\hat{E})}$$

The mean of ratios estimator was used to calculate catch rate (R_p) for each day d using incomplete trip information from fishing parties, as follows

$$r_d = \frac{\sum_{i=1}^{k_d}\left(\frac{c_{di}}{m_{di}}\right)}{k_d}$$

where,

c = total catch of a particular species by fishing party *i,*

m = total trip length, in decimal hours, for a fishing party *i,*

k = total number of fishing parties interviewed on day d,

Total catch rates for the pilot study ($\hat{R}_d$), in fish per angler hour, were calculated as

$$\hat{R}_d = \frac{\sum_{d=1}^{d} r_d}{n}$$

Short incomplete trips were omitted from analysis, similar to previous studies using this survey technique (Hoenig *et al.*, 1997; Pollock *et al.*, 1997). An assumption was also made that trip length was the same for each gear type, so that if multiple types (i.e. rods and handlines) were used within a fishing party the total hours fished could still be calculated by multiplying the number of people fishing by trip length.

The variance of the catch rate ($\hat{R}_d$) was estimated using

$$V\hat{a}r(\hat{R}_d) = \frac{\frac{\sum(r_d - \hat{R}_d)^2}{n-1}}{n}$$

Random sub-sampling of survey locations provided catch rates that were representative of people shore-based fishing between Ocean Reef – Woodmans Point Groyne on a given day during the pilot study. However, a practical limitation was that roving creel surveys could not be completed in the northern extent of the study area (Two Rocks – Ocean Reef) due to constraints of travel time. Calculation of total catch therefore assumed that catch rates were consistent across the entire Perth Metropolitan area.

The total estimated catch ($\hat{C}$) was calculated as

$$\hat{C} = \hat{E}\hat{R}$$

Variance of total catch was estimated as

$$V\hat{a}r(\hat{C}) = \hat{E}^2 V\hat{a}r(\hat{R}) + \hat{R}^2\, V\hat{a}r(\hat{E}) - V\hat{a}r(\hat{E}) V\hat{a}r(\hat{R})$$

Standard error of the total catch was calculated by

$$SE(\hat{C}) = \sqrt{V\hat{a}r(\hat{C})}$$

5.0 Results

5.1 Remote cameras

Remote cameras that work effectively and are well maintained should provide a complete census of recreational shore-based fishing. However, outages did occasionally occur. Footage from Two Rocks Marina and Woodmans Point Groyne provided >90% coverage of shore-based fishing for each surveyed month while Ocean Reef and Hillarys North Wall had less data available within each month (0% – 80%) (Table 2).

Table 2 Percentage of time within each month of the pilot study that cameras were operational at each survey location.

Survey location	April	May	June
Two Rocks Marina	100%	100%	90%
Ocean Reef	47%	30%	0%
Hillarys North Wall	80%	74%	33%
Woodmans Point Groyne	100%	100%	100%

A total of 14,298 events were recorded across all four cameras during the three-month pilot study. There was no clear differentiation in the numbers of events recorded for each month (Fig. 5), and these were non-significant when compared across all cameras ($F_{(1,258)}$=0.10, ρ>0.05). Weekends/public holidays had significantly more events than weekdays across all four locations ($F_{(1,258)}$=110.10, ρ<0.05). Two Rocks Marina and Woodmans Point Groyne had a mean of >100 events on weekends/public holidays while this was much lower at Ocean Reef and Hillarys, most likely due to the limited field of view capturing only a small portion of people arriving or departing. The mean number of events occurring on surveyed days (i.e. those with roving and aerial surveys) was similar to non-surveyed days, as would be expected with random selection of survey days within each month.

The number of people associated with each event provided some indication of group size for those arriving or departing groynes and between 1.2 – 2.3 people across all months and cameras (Table 3). Weekends/public holidays had equal or greater mean group size than weekdays at each location, except Ocean Reef in May. However, group size was missing for 3.4% of events. Mean group size (for a specific survey location and day type) was therefore used to assign a number of people to those events for which it could not be determined from the camera footage.

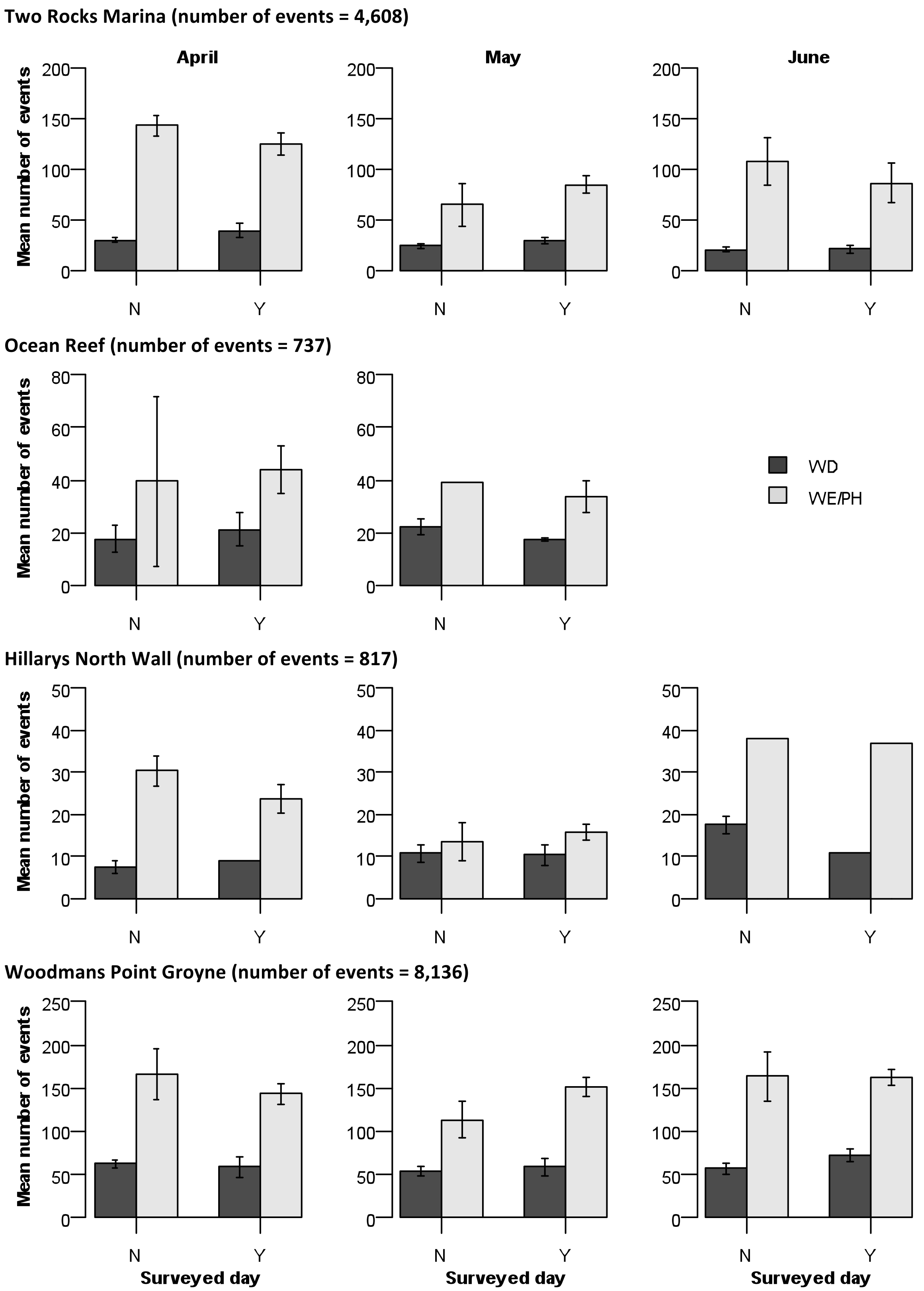

Fig. 5 Mean number of events occurring on groynes with remote cameras (±SE) for different day types (weekdays, weekends/public holidays) and surveyed days (N = no roving or aerial surveys, Y = roving and aerial surveys completed).

Table 3 Mean number of people per event (±SE) on each day type and groyne with remote cameras installed during the pilot study. Note: NA= no footage available for analysis.

Survey location	April		May		June	
	WD	WE/PH	WD	WE/PH	WD	WE/PH
Two Rocks Marina	1.9 (0.0)	2.3 (0.0)	1.8 (0.0)	2.1 (0.0)	1.7 (0.0)	2.2 (0.0)
Ocean Reef	1.6 (0.1)	1.7 (0.1)	2.1 (0.3)	1.5 (0.1)	NA	NA
Hillarys North Wall	1.8 (0.1)	1.8 (0.1)	1.3 (0.0)	1.8 (0.1)	1.2 (0.5)	1.2 (0.4)
Woodmans Point Groyne	1.5 (0.0)	1.9 (0.0)	1.3 (0.0)	1.7 (0.0)	1.4 (0.0)	1.7 (0.0)

Based on these findings, a number of assumptions were made regarding the strata used for determining the proportion of shore-based fishers across a 24-hr day, used to calculate total effort, including that;

- day types (weekends/public holidays and weekdays) exhibited significantly different levels of activity and were incorporated in further analysis, and
- all three surveyed months displayed the same patterns of activity and data were therefore aggregated across the entire pilot study.

The proportion of people assigned each activity type were different for each groyne, with nearly 100% of people arriving at Hillarys North Wall deemed to be fishing in April and May (Fig. 6). Ocean Reef and Woodmans Point Groyne had the highest percentage of unknown activities, with >10% and >50%, respectively. Such high percentages of unknown activities were due to several factors, such as the camera being positioned too far from a choke point to determine activity, or people arriving at night.

It should be noted that only information on people arriving was utilized for this analysis, as it was assumed that people were assigned the same activity type when departing. However, there were differences of up to 10% between the total number of people arriving or departing a groyne on any given day.

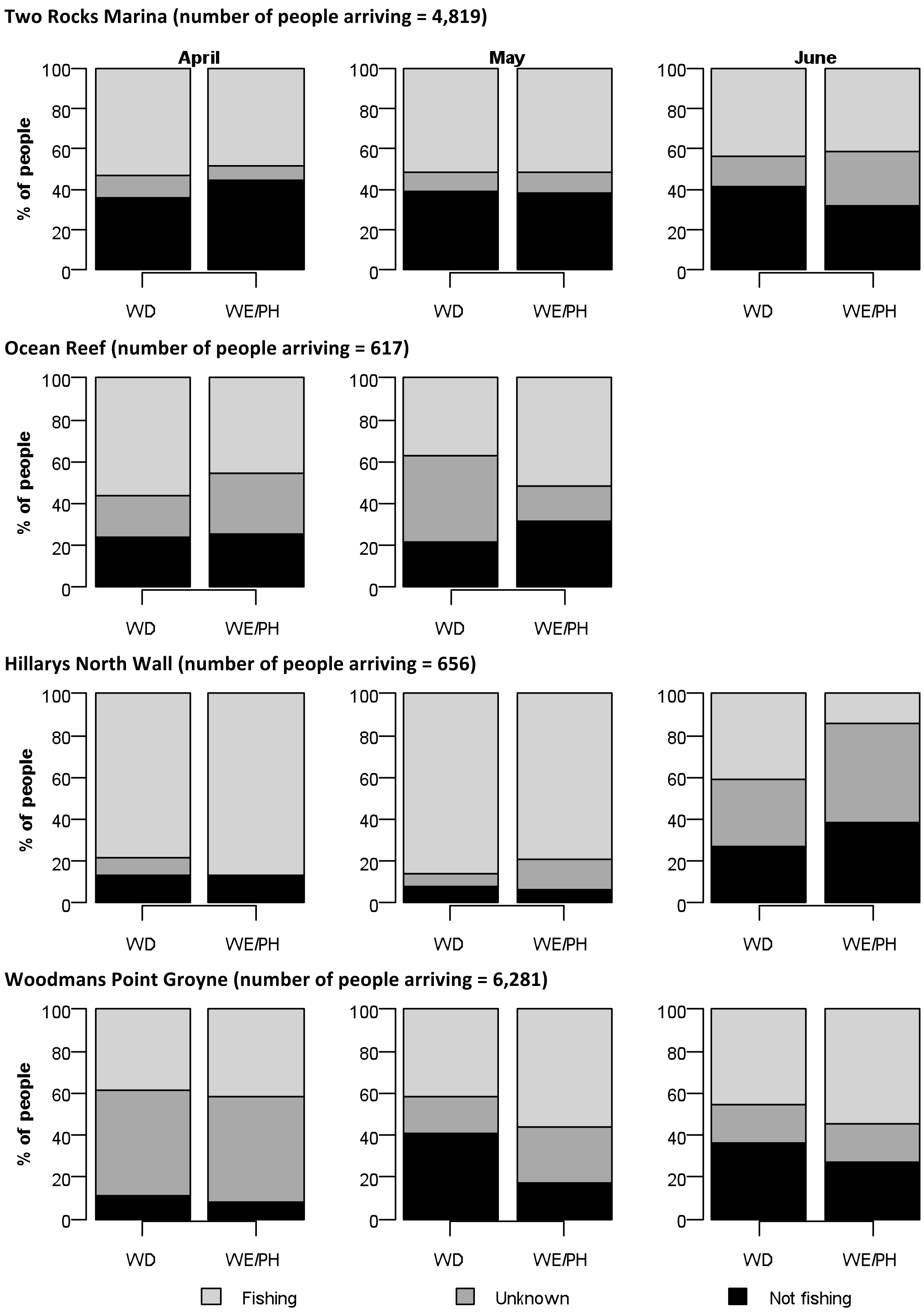

Fig. 6 Percentage of each activity type associated with people arriving at survey locations with remote cameras on different day types.

The lower (fishing only) and upper (fishing and unknown) numbers of shore-based fishers present on each groyne across a 24-hr day was calculated, revealing that the number of people assigned to an unknown activity was not consistent across the day (Fig. 7). Two Rocks Marina and Woodmans Point Groynes had the greatest number of people assigned to an unknown activity type, especially on weekends/public holidays. This difference was greatest from 6 pm – midnight, indicating that it was difficult to identify activity type at night. Hillarys North Wall had very few people assigned to an unknown activity type; therefore the upper and lower limits of fishing activity were almost identical. The total number of people observed on groynes at night was 23.4%, across all sites, of which over half were designated as an unknown activity.

Weekdays had lower levels of fishing activity than weekends/public holidays at all camera locations (Fig. 7). However, activity on weekends/public holidays was also more widely distributed across the day, especially at Two Rocks Marina. All four groynes had a maximum peak in fishing activity occurring between 2 pm – 6 pm on both day types, although this was less marked at Hillarys North Wall and Woodmans Point Groyne on weekdays, when compared to other locations. A smaller peak in fishing activity was also seen on weekdays around 8 am at Ocean Reef.

Although there were differences in the mean number of shore-based fishers between camera locations, the general patterns were similar. Therefore, data were combined across cameras to calculate the mean proportion of fishing activity occurring within each 2-hr time interval across a 24-hr day for both day types (Table 4). Only the lower limit of fishing activity was used in this analysis.

The maximum proportion of fishing activity on weekdays occurred within the same time intervals during which both the morning (8 am – 10 am) and afternoon (4 pm - 6 pm) aerial flights were completed. This was also true of afternoon flights on weekends/public holidays, but the maximum proportion of fishing activity in the mornings on this day type occurred between 10 am – 12 noon, after the aerial flights had been completed. Although only based on data from cameras at four locations, these proportions were assumed to be representative of the entire Perth Metropolitan area.

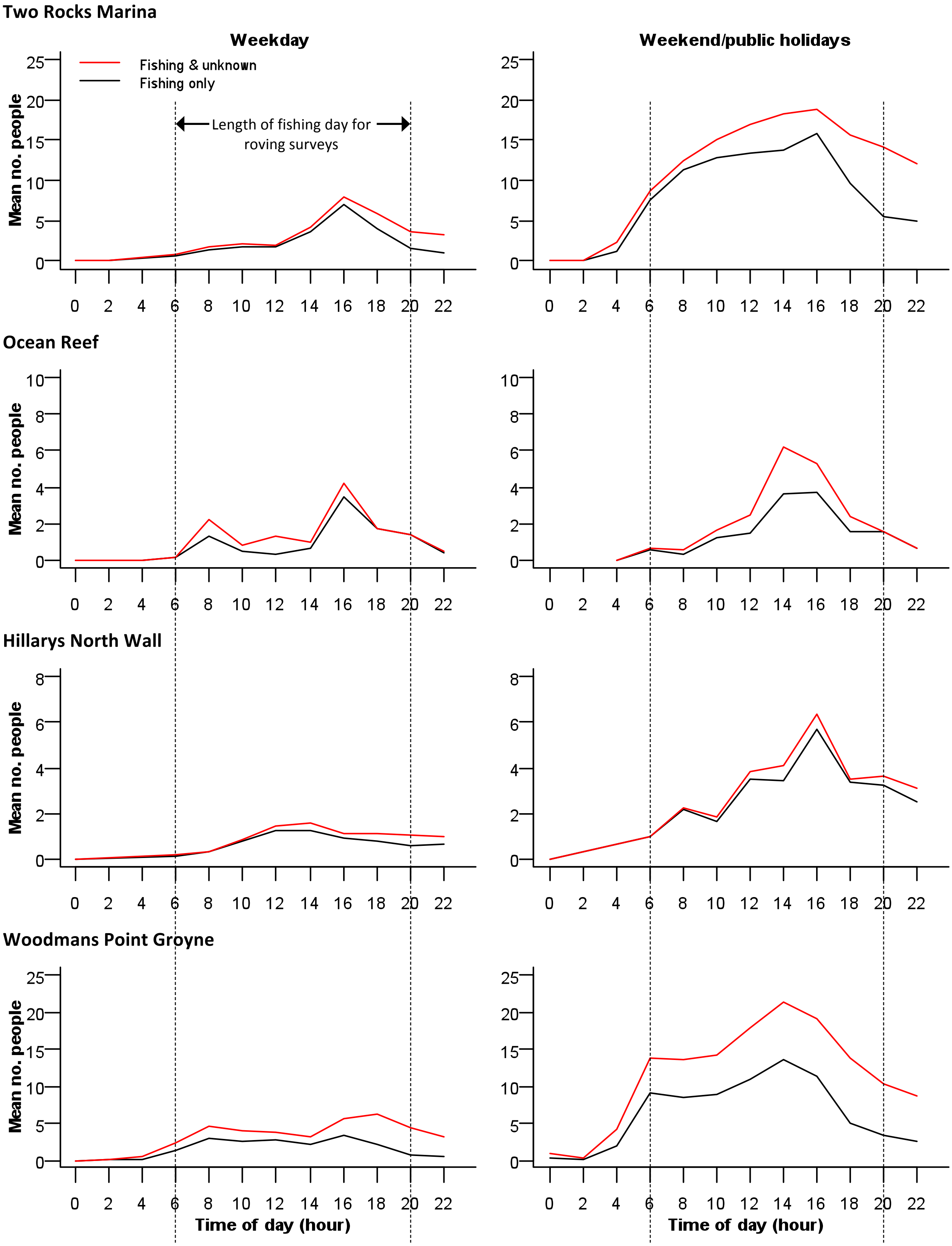

Fig. 7 Estimated mean number of people fishing only (lower limit) and, mean number of people fishing and conducting unknown activity types (upper limit) on each groyne for each day type (weekends/public holidays and weekdays) from April - June 2010.

Table 4 Proportion of shore-based fishing activity each 2-hr time interval across a 24-hr day, on different day types. Note: proportion calculated using morning and afternoons as separate strata.

Morning		
Time interval	**WD**	**WE/PH**
00:00 – 02:00	0.00	0.00
02:00 – 04:00	0.01	0.00
04:00 – 06:00	0.02	0.07
06:00 – 08:00	0.20	0.28
08:00 – 10:00*	0.41	0.30
10:00 – 12:00	0.36	0.35

Afternoon		
Time interval	**WD**	**WE/PH**
12:00 – 14:00	0.14	0.22
14:00 – 16:00	0.18	0.24
16:00 – 18:00*	0.31	0.25
18:00 – 20:00	0.21	0.14
20:00 – 22:00	0.10	0.08
22:00 – 24:00	0.06	0.07

Note: * indicates timing of aerial flights

5.2 Aerial surveys

A total of 4,985 shore-based fishers were observed in the Perth Metropolitan area during the segments of the 36 flights which mirrored the roving surveys. Duplicate counts conducted on the 'return' flight between the survey northern and southern extents recorded 4,963 shore-based fishers. Unless indicated, duplicate counts of recreational shore-based fishers were excluded from the remainder of analysis.

Public holiday weekends in April and June had the highest counts for individual aerial flights, with 582 fishers and 597 fishers, respectively. The lowest counts were obtained on weekdays in April (<60 fishers). The overall mean number of shore-based fishers observed on weekends/public holidays was significantly higher than on weekdays ($F_{(1,34)}$=66.64, ρ<0.05). This pattern was consistent across all types of fishing platforms (Table 5; Appendix 1). However, when standardised by number of survey locations, large groynes and jetties had higher numbers of shore-based fishers.

Table 5 Mean number of shore-based fishers (±SE) observed on different day types during aerial flights on each type of fishing platform from April – June 2010. Note: n = number of survey locations between Two Rocks Marina and Woodmans Point Groyne.

Fishing platform	WD	WE/PH
Large groyne (n=11)	41.7 (4.0)	95.6 (7.4)
Small groyne (n=1)	1.4 (0.6)	3.6 (0.6)
Jetty (n=1)	8.7 (1.5)	26.3 (3.5)
Beach (n=43)	26.6 (3.5)	71.8 (3.5)

There was no significant difference between the total number of shore-based fishers observed in each month of the pilot study ($F_{(2,33)}$=0.19, ρ>0.05). Therefore, each month was assumed to be the same and data were aggregated across the entire study period and stratified by day type (weekends/public holiday, weekdays) and time of day (morning, afternoon) (Fig. 8). Weekends/public holidays had the highest densities of shore-based fishers, especially during afternoon flights. Afternoon flights on weekdays also had higher mean densities than the morning, although neither achieved the same densities found on weekends/public holidays. A two-way ANOVA revealed the interactive effect between day type and time of day was not significant ($F_{(1,35)}$=2.38, ρ>0.05) while the main effect of day type was significant ($F_{(1,35)}$=74.33, ρ<0.05).

The Ammo Jetty recorded the highest densities of all survey locations (Fig. 8). Mindarie Keys, Hillarys South Wall and Fremantle North Mole had the highest densities of shore-based fishers of the large groynes within the study area, whilst Floreat and Woodmans Point Beach were the most popular beaches. On weekends/public holidays the northern beaches between Mindarie Keys and Two Rocks Marina, such as Yanchep Beach – South, were also popular with shore-based fishers who are able to access the beach using 4WD vehicles.

Only three survey locations had no shore-based fishing recorded throughout the three-month pilot study; South Trigg Beach, Port Beach – North and Bathers Beach. Standard errors were calculated for each of the strata and demonstrated that the greatest variability was at survey locations with the highest mean number of people, such as Ammo Jetty, North Mole and Hillarys (Fig. 9).

The Marmion Marine Park extends along the coastline within the northern region of the Perth Metropolitan area, and includes the large groynes at Ocean Reef and Hillarys. These two locations were the most popular with recreational shore-based fishers within the Marine Park, followed by Whitfords Beach. A total of 977 shore-based fishers were observed in the Marmion Marine Park during the segments of the 36 flights during the study.

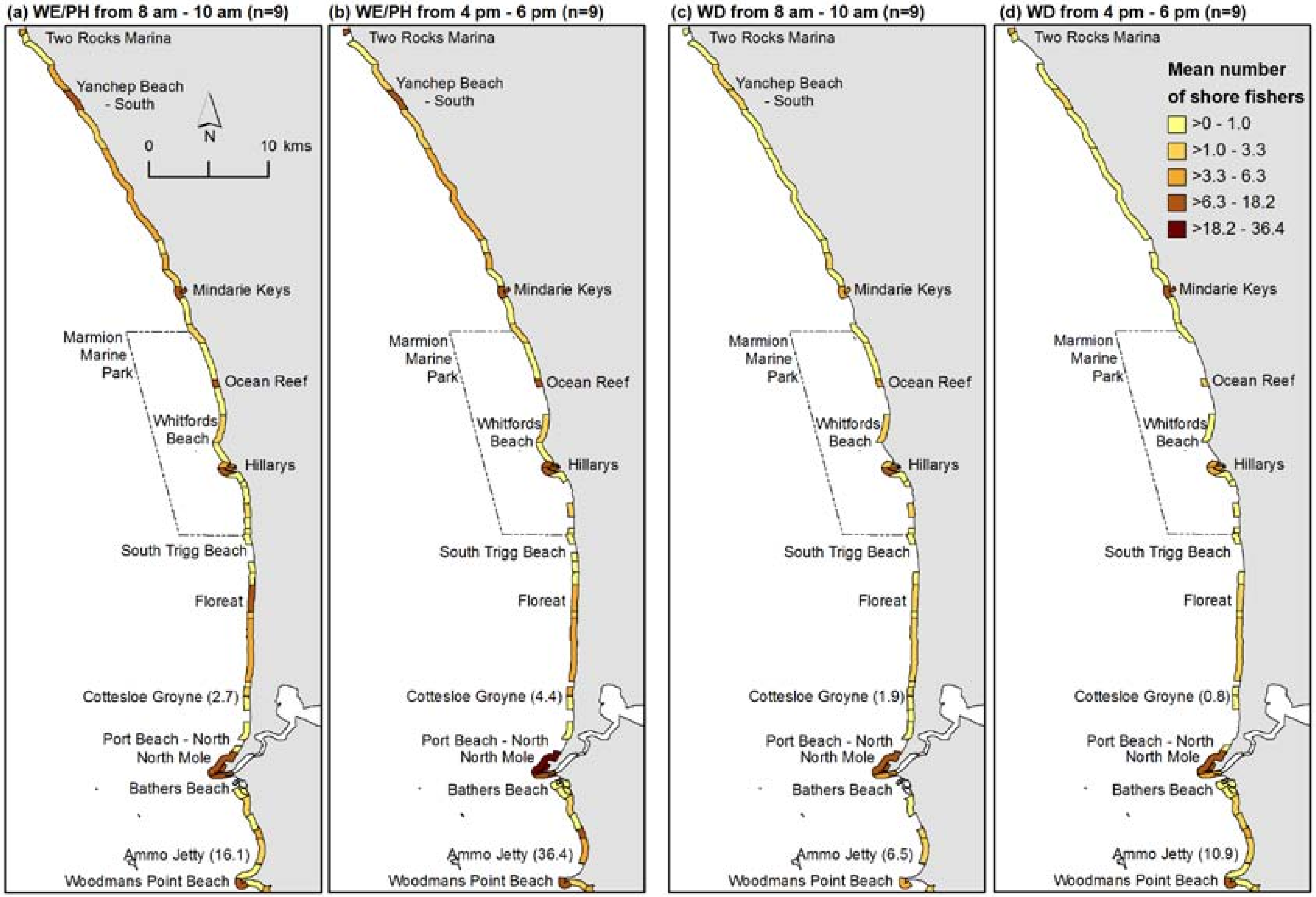

Fig. 8 Mean number of shore-based fishers per beach in the Perth Metropolitan area within each stratum during aerial flights from April – June 2010 (where n = number of flights).

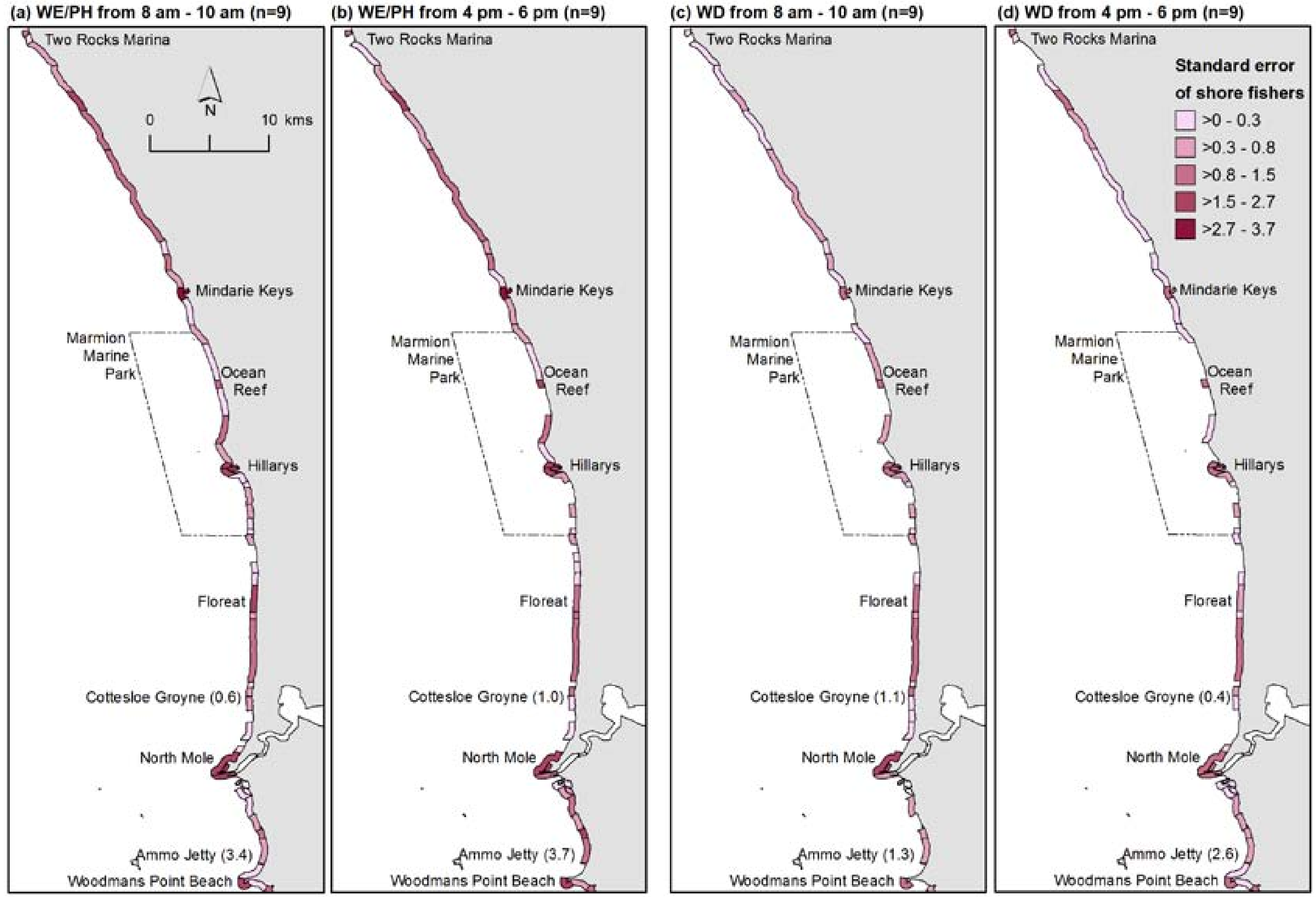

Fig. 9 Standard error for shore-based fishers per beach in the Perth Metropolitan area within each stratum during aerial flights from April – June 2010 (where n = number of flights).

5.3 Roving creel surveys

Roving creel surveys on 38 days yielded 1,194 interviews with parties actively engaged in shore-based fishing in the Perth Metropolitan area. Instantaneous counts of shore-based fishers on arrival at each survey location resulted in 3,449 individual shore-based fishers being recorded; with the highest numbers occurring on weekend survey days in April and May (191 – 243 fishers). However, as instantaneous counts were only made at selected survey locations, they were unsuitable for providing an independent estimate of fishing effort across the study area.

As with the other survey techniques, there were significantly more shore-based fishers counted on weekends/public holidays than weekdays ($F_{(1,36)}$=27.67, ρ<0.05), while between month variation was non-significant ($F_{(1,36)}$=0.882, ρ>0.05). Fishers were also counted on departure from a survey location if interviews had been completed. Although the maximum difference in number of shore-based fishers on arrival and departure was 23, there was a significant positive relationship between these counts (R^2=0.947, ρ>0.05).

5.3.1 Characteristics of shore-based fishers

For the roving creel survey, conducted from Ocean Reef to Woodmans Point Groyne, interviews were obtained at large groynes and beaches (Table 6). Interviewed shore-based fishers resided predominately within the Perth Metropolitan area and were located across all fishing platforms. Fishers who resided overseas were the next most popular group, and were recorded in highest numbers on large groynes.

As the species of interest for this study was Australian herring, only shore-based fishers using rods and handlines were selected for interview. Rods were the dominant gear type, used by >89% of shore-based fishing parties on all fishing platforms (Table 6). Multiple gear types (i.e. both rods and handlines) were used by only 1.0% of fishing parties. The mean number of shore-based fishers within an interviewed group was lower than the total number of people, indicating that there were often non-fishers in the group. A large majority of fishing parties had the same number of gear 'units' as fishers (indicating that most only had one line in the water per person).

Mean fishing time (in hours) varied between each fishing platform, with the longest incomplete trip length recorded by fishing parties on large and small groynes, comprising 1.4 hours and 1.3 hours, respectively (Table 6). When compared by strata, the longest incomplete trips were fishing parties intercepted on weekends/public holidays (mean=1.4 hours; ±SE=0.1), as opposed to weekdays (mean=1.3 hours; ±SE=0.1).

Table 6 Characteristics of interviewed shore-based fishers by different fishing platforms within the Perth Metropolitan area from April - June 2010. Note: n = number of survey locations between Ocean Reef and Woodmans Point Groyne, which is lower than the aerial surveys due to the reduced survey extent.

Variable	Large groyne (n = 8)	Small groyne (n = 1)	Jetty (n = 1)	Beach (n = 32)
Survey information				
Total number of visits for interviews	239	16	16	219
Total number of interviews	944	41	89	120
Place of residence of fishers (% of interviews)				
Perth Metropolitan area	97.1%	87.8%	100%	96.7%
Regional Western Australia	1.0%	0.0%	0.0%	2.5%
Interstate	1.3%	0.0%	0.0%	0.0%
Overseas	0.6%	12.2%	0.0%	0.8%
Gear type used by fishers (% of interviews)				
Rods	98.0%	100%	89.3%	98.3%
Handlines	2.0%	0%	10.6%	1.7%
Mean number of people and units of gear per fishing party (±SE)				
Total number people	1.8 (0.0)	1.8 (0.2)	2.1 (0.1)	1.8 (0.2)
Number of fishers	1.6 (0.0)	1.4 (0.1)	1.9 (0.1)	1.5 (0.1)
Number of gear units	1.7 (0.0)	1.4 (0.0)	1.9 (0.0)	1.6 (0.0)
Mean hours spent fishing (±SE)	1.4 (0.0)	1.3 (0.2)	1.2 (0.1)	1.2 (0.2)

*measured as mean number of times fished in the last month (i.e. four week period).

Beaches were classified as such because they were dominated a sandy or rocky substrate. However, there were a number of small groynes (spurs) and jetties located within these broader extents. Interviewers documented the specific fishing platform on which each fishing party was located, revealing that 44.2% of fishing on beaches actually occurred on small groynes and jetties nested within these other sand or rock substrates. The remaining 55.8% of interviewed fishing parties were located on sand or rocky substrate.

Avidity of shore-based fishers was measured as the number of times an interviewee had fished in the previous month (~4 week period). The majority had fished 1 – 4 times in the previous month (mean=4.2; ±SE=0.1) with a small number (1.2%) not fishing on any previous occasion during this time period (Fig. 10). Similarly, 1.2% of interviewees had fished on >21 occasions in the previous month.

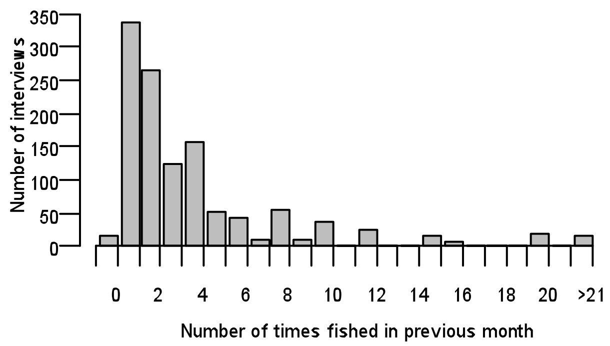

Fig. 10 Number of shore-based fishing trips undertaken by interviewees in the previous month (i.e. four week period) (number of interviews = 1,194).

5.3.2 Catch of nearshore fish species

There were 23 species and 15 families, or general categories, of aquatic organisms kept or released by shore-based recreational fishers interviewed during the pilot study (Table 1). The most frequently kept species were Australian herring, various whiting species (*Sillago* spp.), southern sea garfish (*Hyporhamphus melanochir*) and yellowtail scad (*Trachurus novaezelandiae*). Australian herring, common blowfish (*Torquigener pleurogramma*), skipjack trevally (*Pseudocaranx georgianus*) and southern sea garfish were the most frequently released species.

At the time of interview, 46.1% of fishing parties had not retained or released any species. Conversely, five fishing parties had achieved their bag limit of low risk species (combined maximum of 30 fish) at the time of interview. Low risk species include Australian herring, blue mackerel (*Scomber australasicus*) and southern sea garfish. An additional 12 fishing parties were within five fish of achieving their combined bag limit of low risk species at the time of interview.

Medium risk species have a combined bag limit of 12 fish, and include species such as flathead (Family Platycephalidae), tailor (*Pomatomus saltatrix*), Australian salmon and King George whiting (*Sillaginodes punctata*). No fishing parties had achieved their combined bag limit of these species at the time of interview. However, one shore-based fishing party had exceeded the single species limit for Australian salmon (of 4 fish).

Table 7 Total number of retained and released species recorded during interviews with shore-based fishers from April – June 2010.

Common species name	Scientific name	Retained	Released
Herring, Australian	*Arripis georgianus*	2,484	311
Garfish, southern sea	*Hyporhamphus melanochir*	661	40
Whiting, combined species*	*Sillago* spp.	182	43
Scad, yellowtail	*Trachurus novaezelandiae*	124	13
Trevally, skipjack/silver	*Pseudocaranx georgianus*	85	125
Mullet, yellow eye (pilch)	*Aldrichetta forsteri*	66	2
Squids, general		58	0
Mackerel, blue	*Scomber australasicus*	38	5
Garfishes	Family Hemiramphidae	34	1
Mackerel, scaly	*Sardinella lemuru*	30	0
Tailor	*Pomatomus saltatrix*	21	6
Salmon, Australian	*Arripis truttaceus*	16	0
Wrasse/gropers, general	Family Labridae	9	7
Wirrah, western	*Acanthistius serratus*	7	0
Buffalo bream, common (silver drummer)	*Kyphosus sydneyanus*	6	0
Bream, silver (tarwhine)	*Rhabdosargus sarba*	6	9
Leatherjackets, general	Family Monocanthidae	5	0
Trumpeter, six lined (striped trumpeter)	*Pelates sexlineatus*	5	2
Octopus, general		4	0
Snapper, pink	*Pagrus auratus*	4	7
Cobbler	*Cnidoglanis macrocephalus*	4	0
Whiting, King George	*Sillaginodes punctata*	3	1
Flatheads, general	Family Platycephalidae	3	7
Blowfish, common	*Torquigener pleurogramma*	3	214
Pomfret, Woodward's	*Schuetta woodwardi*	3	0
Wrasse, brown-spotted	*Pseudolabrus parilus*	3	2
Goatfish, blue-spotted	*Upenichthys vlamingii*	3	0
Cuttlefish		1	0
Flounders, general		1	0
Snook	*Sphyraena novaehollandiae*	1	0
Sweep, sea	*Scorpis aequipinnis*	1	2
Parrotfish, general	Family Scaridae	0	1
Rays, general	Family Rhinobatidae	0	4
Shark, general		0	1
Shark, Port Jackson	*Heterodontus portusjacksoni*	0	6
Stingrays, general		0	2
Trumpeters/grunters, General	Family Teraponidae	0	4
Unknown species		2	10
Total		3 875	825

* exclude King George Whiting (*Sillaginodes punctata)*

No species classed as pelagic in the current fishing regulations for the West Coast bioregion were caught from the shore and pink snapper (*Pagrus auratus*) was the only high risk species retained by shore-based fishers during the pilot study. One person had achieved their bag limit of this species (2 fish) at the time of interview.

5.3.3 Catch rates of nearshore fish species

Catch rates for the main species retained and released by recreational shore-based anglers were calculated as fish per angler hour. Excluding interviews with an incomplete trip length <=15 mins resulted in 261 (21.9%) being removed from analysis. Catch rates for retained fish were highest for Australian herring, southern sea garfish and whiting (combined species) (Table 8). Catch rates for Australian herring, common blowfish and skipjack trevally were highest for released fish.

Catch rates were assumed to be consistent throughout the day, and on different day types, due to the small sample size for many species. People fishing at night were also assumed to have a catch rate consistent with those recorded during daylight hours, as interviews were not completed between the hours of 8 pm – 6 am.

Table 8 Catch rate, in fish per angler hour, of main species retained and released by recreational shore-based fishers in the Perth Metropolitan area from April – June 2010, where n = number of interviews in which that species was recorded.

Common species name	Scientific name	n	Catch rate (fish per angler hour)	
			Retained	Released
Herring, Australian	*Arripis georgianus*	359	1.08	0.13
Garfish, southern sea	*Hyporhamphus melanochir*	123	0.27	0.02
Whiting, combined species	*Sillago* spp.	53	0.10	0.03
Scad, yellowtail	*Trachurus novaezelandiae*	47	0.04	0.00
Mullet, yellow eye (pilch)	*Aldrichetta forsteri*	13	0.03	NA
Trevally, skipjack/silver	*Pseudocaranx georgianus*	88	0.03	0.04
Garfishes	Family Hemiramphidae	13	0.02	0.00
Blue mackerel	*Scomber australasicus*	5	0.01	0.00
Scaly mackerel	*Sardinella lemuru*	7	0.01	NA
Blowfish, common	*Torquigener pleurogramma*	30	0.01	0.11
Australian salmon	*Arripis truttaceus*	7	0.01	NA
Tailor	*Pomatomus saltatrix*	14	0.01	0.00

5.3.4 Length-frequency of main species

Australian herring and southern sea garfish were the only two species for which there was a sufficient sample of total lengths (mm) from which to create length-frequency graphs (Fig. 11 a,b). Australian herring had a normal distribution with a median length of 230 mm whilst southern sea garfish displayed a slightly skewed distribution with a median length of 320 mm.

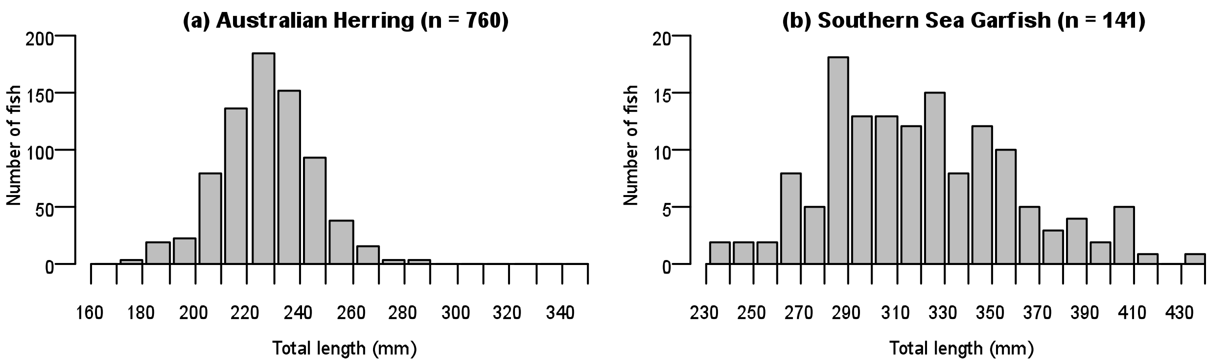

Fig. 11 Total length (mm) frequency graphs of a random selection of (a) Australian herring and (b) southern sea garfish retained by recreational shore-based fishers within the Perth Metropolitan area from April – June 2010.

Undersized fish comprised 0.5% of all retained fish recorded during the roving creel surveys. Undersized species retained by fishers included skipjack trevally (minimum size 250 mm), pink snapper (minimum size 410 mm), tailor (minimum size 300 mm), leatherjackets (Family Monocanthidae)(minimum size 250 mm), silver bream (minimum size 250 mm) and Australian salmon (minimum size 300 mm).

5.4 Comparison of counting methods

Roving creel surveys and data from remote cameras also recorded information on the number of non-fishers, allowing the proportion of people fishing at a particular location to be ascertained. Roving creel surveys found slightly higher percentages of shore-based fishers when compared to the upper limit (incorporating people both fishing and unknown) of remote cameras, except for weekends/public holidays at Hillarys North Wall (Table 9). This finding justifies incorporating people assigned to an unknown activity type as shore-based fishers. Aerial surveys did not count non-fishers at these survey locations, so comparisons of the proportion of people fishing could not be made with other methods.

Table 9 Percentage of shore-based fishers observed on groynes during roving creel surveys (instantaneous counts on arrival) and using remote camera data (lower - upper limits) from April – June 2010 on different day types.

Survey location	Roving		Remote	
	WD	WE/PH	WD	WE/PH
Ocean Reef	82.6%	84.4%	50.5 – 77.5%	48.0 – 72.5%
Hillarys North Wall	89.9%	75.4%	70.0 – 84.7%	77.3 – 86.4%
Woodmans Point Groyne	93.6%	82.8%	41.8 – 69.5%	48.5 – 81.2%

Comparing instantaneous counts on arrival from roving creel surveys with those from remote cameras revealed a strong positive relationship at Woodmans Point Groyne (R^2 = 0.518 – 0.524), and very weak relationships for Ocean Reef and Hillarys North Wall (R^2 = 0.024 – 0.029) (Table 10). Counts of shore-based fishers from the roving creel survey were consistently higher than those from the remote camera at Ocean Reef and Hillarys North Wall due to the field of view not capturing all shore-based fishing activity. The roving survey did not extend as far north as Two Rocks Marina so no comparison could be made at this location.

Table 10 Regression components for each groyne using lower and upper limits of shore-based fishing obtained from remote camera data when compared to instantaneous counts collected during roving surveys (on arrival).

Survey location	Lower limit	Upper limit
Ocean Reef	R^2=0.029, $F_{(1,11)}$=0.33, ρ>0.05	R^2=0.027, $F_{(1,11)}$=0.31, ρ>0.05
Hillarys North Wall	R^2=0.027, $F_{(1,13)}$=0.36, ρ>0.05	R^2=0.024, $F_{(1,13)}$=0.33, ρ>0.05
Woodmans Point Groyne	R^2=0.518, $F_{(1,25)}$=26.9, ρ<0.05	R^2=0.524, $F_{(1,25)}$=27.56, ρ<0.05

Counts of shore-based fishers from each aerial survey were compared to remote cameras at the same time of day (to the nearest minute). Two Rocks Marina and Woodmans Point Groyne had the strongest relationship, with R^2 values between 0.282–0.336 (ρ<0.05) (Table 11). As with the previous comparison, aerial counts at Ocean Reef and Hillarys North Wall were higher than those from the remote camera.

Table 11 Regression components for each groyne using lower and upper limits of shore-based fishing obtained from remote camera data when compared to counts collected during aerial flights. Note: including duplicate counts.

Survey location	Lower limit	Upper limit
Two Rocks Marina	R^2=0.282, $F_{(1,56)}$=21.98, ρ<0.05	R^2=0.281, $F_{(1,56)}$=21.89, ρ<0.05
Ocean Reef	R^2=0.288, $F_{(1,21)}$=8.51, ρ<0.05	R^2=0.287, $F_{(1,21)}$=8.47, ρ<0.05
Hillarys North Wall	R^2=0.085, $F_{(1,24)}$=2.25, ρ>0.05	R^2=0.083, $F_{(1,24)}$=2.18, ρ>0.05
Woodmans Point Groyne	R^2=0.335, $F_{(1,48)}$=24.23, ρ<0.05	R^2=0.336, $F_{(1,48)}$=24.29, ρ<0.05

Aerial surveys were scheduled concurrently to the roving surveys to provide a direct relationship between information collected using each method. However, a direct time match between counts of shore-based fishers obtained from each of these methods (to the nearest minute) provided only one point of comparison (Table 12). As expected, increasing the rounding of time intervals provided more points for comparison. Rounding times to 1-hr intervals provided a strong positive relationship. Interestingly, a time interval of 7-hrs (i.e. equivalent of an entire roving creel shift) to compare counts of shore-based fishers at survey locations on a particular day still resulted in a strong relationship between methods.

Table 12 Regression components for instantaneous counts of shore-based fishers (on arrival) obtained from roving surveys with those from aerial surveys using specified time intervals where n = number of matching data points.

Rounded time interval	Linear regression
1-min (n = 1)	insufficient data points
15-min (n = 37)	R^2=0.598, $F_{(1,35)}$=52.15, ρ<0.05
30-min (n = 82)	R^2=0.663, $F_{(1,80)}$=157.20, ρ<0.05
1-hr (n = 148)	R^2=0.682, $F_{(1,146)}$=312.80, ρ<0.05
7-hrs (n = 1,199)*	R^2=0.649, $F_{(1,1197)}$=2,209, ρ<0.05

* entire roving survey shift

5.5 Estimates of fishing effort and total catch

Although the proportion of people shore-based fishing within each 2-hr interval were based on information collected from the four remote cameras placed at large groynes, a lack of equivalent data from beaches and other fishing platforms resulted in the assumption that all locations within the study area exhibited the sample activity patterns across a 24-hr day.

Total fishing effort for recreational shore-based fishing occurring in the Perth Metropolitan area from April – June 2010 was estimated at 196,430 fisher hours (SE± 8,662), of which 65.0% occurred on weekends/public holidays. The mean length of completed fishing trips applied in this calculation of shore-based fishing effort varied between 2.4 – 3.0 hours, depending on day type and time of day. This mean length was assumed to be consistent for the entire study area, even through interviews were not completed in the northernmost extent of the study area.

The total catch of all species retained by recreational shore-based fishers in the Perth Metropolitan area from April – June 2010 was 327,414 fish (SE±33,107). An additional 70,412 (SE±13,771) fish were released during this same time period. The total catch of main species are shown in Table 13, revealing that the largest estimated catches were obtained for Australian herring, southern sea garfish and whiting (combined species).

Table 13 Total catch, in numbers of fish, of main species retained and released by recreational shore-based fishers in the Perth Metropolitan area from April – June 2010.

Common species name	Scientific name	Total number of fish	
		Retained	Released
Herring, Australian	*Arripis georgianus*	211,447	25,858
Garfish, southern sea	*Hyporhamphus melanochir*	52,441	3,406
Whiting, combined species	*Sillago* spp.	19,879	6,209
Scad, yellowtail	*Trachurus novaezelandiae*	8,591	645
Mullet, yellow eye (pilch)	*Aldrichetta forsteri*	5,772	NA
Trevally, skipjack/silver	*Pseudocaranx georgianus*	5,430	8,390
Garfishes	Family Hemiramphidae	4,048	16
Blue mackerel	*Scomber australasicus*	1,975	34
Scaly mackerel	*Sardinella lemuru*	1,831	NA
Blowfish, common	*Torquigener pleurogramma*	1,256	20,682
Australian salmon	*Arripis truttaceus*	1,173	NA
Tailor	*Pomatomus saltatrix*	1,075	185

5.6 Relative survey costs

The total cost of the three-month pilot study was $172,900, with the roving creel survey comprising the largest component ($69,106) (Table 14-16). Although the costs attributed to all survey techniques were accrued predominantly during data collection and data entry phases, they belonged to different expense categories. Expenditure for the remote cameras was dominated by initial outlay for the hardware (i.e. cameras, cables, data storage) as well as data entry, which comprised viewing of the camera footage and entry into a database. However, some of the costs were reduced in this pilot by drawing on existing equipment setup for project surveying boat ramps using similar remote technology.

Transport was the greatest cost for the aerial surveys (with plane hire @ $325 per hour) while roving creel surveys had high transport and staff costs. All three methods had similar costs in terms of planning (i.e. survey design and implementation) and analysis, which also incorporated reporting. It should also be considered that the roving creel survey was designed using a reduced study area, due to travel time constraints. If this technique was to be expanded to cover the same area as the aerial surveys, then fieldwork and transport costs would be expected to double.

Expanding the pilot study out to 12-months to capture seasonal variations in fishing activity within the Perth Metropolitan area would increase the total survey costs to approximately $565,000, based on 12 surveys per month. These are not a direct expansion of costs, as equipment only needs to be acquired in the initial planning and implementation phase of the project. Enlarging the spatial extent beyond the Perth Metropolitan area (~100 km of coastline) would also have a substantial impact on the costs, and practicalities, of implementing such a complementary survey approach, especially for roving creel surveys where the number of staff required may be prohibitive.

Table 14 Summary of costs associated with operating four remote cameras from April-June 2010.

	Planning	Data collection	Data entry	Analysis	Total ($)
Equipment					
Hardware	–	$14,000	–	–	–
Software	–	$500	–	–	–
Stationary	–	–	$100	–	–
Misc (incl. uniforms)	–	–	–	–	–
Fieldwork costs					
Staff	–	–	–	–	–
Transport	–	–	–	–	–
Allowances	–	–	–	–	–
Additional staff costs					
Data entry	–	–	$17,760	–	–
Technical support	$4,680	$3,120	–	–	–
Analysis	–	–	–	$10,920	–
Management	$1,560	$1,560	$3,120	–	–
Total ($)	*$5,555*	*$19,180*	*$20,980*	*$10,920*	*$56,635*

Table 15 Summary of costs associated with 36 aerial surveys.

	Planning	Data collection	Data entry	Analysis	Total ($)
Equipment					
Hardware	–	$2,000	–	–	–
Software	–	$500	–	–	–
Stationary	–	$200	–	–	–
Misc (incl. uniforms)	–	–	–	–	–
Fieldwork costs					
Staff	–	$5,328	–	–	–
Transport	–	$20,738	–	–	–
Allowances	–	–	–	–	–
Additional staff costs					
Data entry	–	–	$4,263	–	–
Technical support	–	–	–	–	–
Analysis	$1,560	–	–	$9,360	–
Management	$1,560	$1,560	–	–	–
Total ($)	*$3,210*	*$30,326*	*$4,263*	*$9,360*	*$47,159*

Table 16 Summary of costs associated with 38 roving creel surveys.

	Planning	Data collection	Data entry	Analysis	Total ($)
Equipment					
Hardware	–	–	–	–	–
Software	–	–	–	–	–
Stationary	$1,000	$200	–	–	–
Misc (incl. uniforms)	$2,000	–	–	–	–
Fieldwork costs					
Staff	–	$26,782	–	–	–
Transport	–	$13,034	–	–	–
Allowances	–	$2,290	–	–	–
Additional staff costs					
Data entry	–	–	$2,520	–	–
Technical support	–	–	–	–	–
Analysis	–	–	$1,560	$9,360	–
Management	$3,120	$6,240	–	–	–
Total ($)	*$6,120*	*$49,546*	*$4,080*	*$9,360*	*$69,106*

6.0 Discussion

6.1 Temporal and spatial variability of shore-based fishing

The spatial distribution and temporal variability of recreational shore-based fishing in the Perth Metropolitan area was ascertained using remote cameras, aerial surveys and roving creel surveys. Investigation of temporal factors considered within-day, day type and monthly variablility. Seasonal variability was exluded due to short longitudinal timeframe of the study, from April – June 2010. However, these months were selected as they provide the peak recreational catches of Australian herring (Ayvazian *et al.*, 2004; Lenanton and Hall, 1976), which was the species of interest. Between-month variation in shore-based fishing activity was non-significant for all survey techniques, leading to the aggregation of data across the entire three-month study period.

Higher shore-based fishing activity was recorded on weekends/public holidays than on weekdays, for all survey techniques. This difference in levels of fishing activity has been documented in previous studies of recreational fishing (Ayvazian *et al.*, 1997; Smallwood *et al.*, 2006) and beach use (Blackweir and Beckley, 2004; Houghton *et al.*, 2003) in Western Australia. Such trends support the incorporation of stratification by day type into the sampling design, similar to other recreational fishing surveys conducted in Australia (Lynch *et al.*, 2004) and overseas (Veiga *et al.*, 2010; Volstad *et al.*, 2006).

The application of remote camera technology provided the opportunity to identify the variability of shore-based fishing activity across a 24-hr day, revealing a peak in fishing activity between 2 pm – 6 pm at all four locations surveyed. A smaller peak was also evident in the mornings at around 8 am. Time of day strata (i.e. morning/afternoons) are often incorporated into the sampling designs of recreational fishing surveys (Ayvazian *et al.*, 1997; Lynch *et al.*, 2004; Veiga *et al.*, 2010) but obtaining data on fishing activity occurring at night is rarely possible due to safety issues and high sampling costs.

Aerial flights were scheduled to coincide with peak shore-based fishing activity, in accordance with the maximum count method. Initial scheduling was based on anecdotal evidence, within the constraint of aerial flights only being possible during daylight hours. Results from remote cameras confirmed the scheduling of flights to be correct, with highest proportion of fishing occurring in the 8 am – 10 am and 4 pm – 6 pm time intervals. However, the highest proportion of fishing on weekend/public holiday mornings did occur slightly later (10 am – 12 noon) and some additional midday flights should be considered in future work to validate this finding.

Variation in daily weather conditions (i.e. wind speed and direction rainfall) would also be expected to have an effect on the number of recreational fishers present on a given day in the Perth Metropolitan area, based on previous research conducted worldwide (Provencher and Bishop, 2004; Sidman and Fik, 2005). Tidal phases have also been found to influence patterns of fishing activity (Gartside *et al.*, 1999; Reid and Montgomery, 2005). However, such analysis was outside the scope of this pilot study but should be considered in the future.

Spatial variability in shore-based recreational fishing activity was clearly shown in this study. Locations with the highest mean number of shore-based fishers observed were large groynes. It should also be noted that 44.2% of fishers interviewed on beaches were actually fishing from small groynes or jetties nested within these other substrates. Northern beaches, situated between Two Rocks Marina and Mindarie Keys, were also popular locations for shore-based recreational fishing on weekends/public holidays. A previous aerial survey in the Perth Metropolitan area also identified beaches in this area to be popular with shore-based fishers (Blackweir and Beckley, 2004). Based on these findings, it is important to consider roving creel surveys along this stretch of coast in future surveys to provide information on catch rate, as in this study it was assumed to be the same as the more southern beaches.

The level of fishing activity at each surveyed location was largely representative of anecdotal evidence collected prior to the study (Appendix 1). However, the identification of high and low use shore-based fishing sites can be used to improve the allocation of sampling effort of future surveys, thereby providing more robust estimates of fishing effort and catch. Analysis of aerial data was based on locations defined by natural breaks or features within the study area, and were therefore of unequal length. However, the spatially explicit nature of data collection would enable calculation of fisher density per km, similar to Mann *et al.* (2003), if it were deemed more appropriate for management requirements.

6.2 Estimates of fishing effort and total catch of nearshore fish species

Using information from all survey techniques, estimates of shore-based fishing effort and total catch of nearshore fish species were calculated for the Perth Metropolitan area from April – June 2010. Total shore-based fishing effort was estimated to be 196,430 fisher hours for the three-month study. Based on the seasonal distribution of similar estimates from previous studies in this region of Western Australia (Ayvazian *et al.*, 1997; Smallwood *et al.*, 2006), the months sampled in this study are likely to encompass one of the highest periods of fishing effort.

The validity of assumptions made during the analysis process will have a range of effects on catch and effort estimates, especially data obtained from the camera footage. The current estimate of shore fishing effort provided in this study is likely to be an underestimate, as only those people clearly identified as fishing were used to calculate the proportion of fishing activity occurring in each 2-hr interval. Additionally, while the issue of negative counts of people on groynes (i.e. when the number of departures exceeds arrivals) was addressed by reassigning these values to zero, there was no systematic method for dealing with excessive positive counts (i.e. when number of arrivals exceeded departures). This is likely to further underestimate fishing effort by biasing the proportion of people fishing towards those hours closest to midnight.

Many of these assumptions applied could be addressed by re-evaluating the placement of cameras at these sites to provide a clearer view of activity types. However, the non-random placement of cameras may also introduce bias into this dataset, with the temporal variability of fishing activity (and therefore the proportion used in calculating of fishing effort) assumed to be the same along the entire coastline of the study area, even though data was only available at groynes. Understanding such bias is especially pertinent for species such as tailor, which are often caught from beaches (Cusack and Roennfeldt, 2003).

Catch rate was assumed to be consistent across all hours of the roving creel survey (6 am – 8 pm), and on different day types, due to a small sample size for some species retained or released by anglers. This assumption also extended to include those hours outside the roving creel survey (8 pm – 6 am), which may not be an accurate representation of shore-based catch rates, as more avid fishers are more likely to be fishing at night, especially if targeting species such as tailor. Obtaining catch rate data at night is often difficult due to logistical constraints, high staffing costs and safety concerns (Sumner and Williamson, 1999; Veiga *et al.*, 2010), although roving surveys have been applied at night to recreational fisheries that use artificial light (i.e. to target prawns) (Reid and Montgomery, 2005). An alternative option is to conduct phone/logbook survey, which are not exposed to such limitations. However, the 6 am – 8 pm timeframe established for the roving creel surveys encompassed the periods for which Australian herring, the target species for this study, were most likely to be caught.

Catch composition of species caught by shore-based recreational fishers in the Perth Metropolitan area from this pilot study reflected that obtained in previous research, where Australian Herring, southern sea garfish, various whiting species and skipjack trevally the most frequently recorded (Ayvazian *et al.*, 1997; Smallwood *et al.*, 2006). Australian salmon and tailor are other iconic species targeted by shore-based recreational fishers, but were not recorded in high numbers during this study.

The total retained catch for all species from April – June 2010 was 327,414 fish, of which Australian herring was the dominant species, with 211,447 retained by shore-based fishers. Several broad assumptions associated with the calculation of catch and effort may affect the quality of these estimates, and this should be considered in any application of these data. In their study undertaken from April - June 1973, Lenanton and Hall (1976) estimated a total catch of 548,000 Australian herring within an area extending between Two Rocks and Mandurah (including Rottnest Island). Although the authors indicate the use of some broad assumptions to obtain this estimate, it may indicate a decline in catch of Australian herring within the Perth Metropolitan area within the last 30 years. Ayvazian *et al.* (1997) recorded lower numbers of Australian herring retained by shore-based fishers during their 1994 - 1995 study, with less than 200,000 retained in autumn and winter in each of these surveyed years. However, their definition of the Perth Metropolitan area was smaller than that applied in this current study. An additional 70,412 fish was estimated to have been released by shore-based fishers from April – June 2010. Estimated numbers of released fish are likely to be less reliable due to measurement errors (Pollock *et al.*, 1994).

6.3 Costs, benefits and limitations of survey techniques

6.3.1 Remote cameras

Remote cameras had several benefits including the ability to obtain a complete census of activity occurring across a 24-hr day, whereas other survey methods are only able to provide snapshots of data on recreational shore-based fishing. Additionally, the camera footage provided a permanent record of activity that can re-visited at a later date or reanalysed using different techniques, if necessary. This technique also captures information on night fishing, which is rarely undertaken in recreational fishing surveys.

The initial outlay for camera equipment and installation was high compared to other survey methods but, once operational, the costs were low. However, the cost of analysing camera footage was very high in terms of the length of time required by staff to extract information for each day (mean = 0.9 hour; max = 3.3 hours). Similar time constraints were identified by Parnell *et al.* (2010) in their use of time-lapse photography to ascertain patterns of boat-based recreational fishing in California. However, although analysis may be time consuming, the use of such digital technology has been identified as cost-effective when compared to on-site surveys (Ames and Schlindler, 2009).

Limitations of remote camera technology stemmed predominately from camera placement, as it may require more than one unit to capture all activity occurring on a groyne, i.e. Hillarys North

Wall and Ocean Reef cameras provided only partial views. Addressing these factors would reduce the assumptions needed for calculating total fishing effort (i.e. assigning a mean group size or treating unknown activity types as fishing). The use of a 'choke' point at Two Rocks Marina and Woodmans Point Groyne captured all people entering or exiting these locations and provided a better understanding of the temporal variability of recreational shore-based fishers. Data from these locations also matched more closely with counts completed during roving and/or aerial surveys. Furthermore, it is important to capture images at small time intervals (<30 seconds) to provide multiple photos of people accessing a groyne, otherwise it is difficult to ascertain attributes such as activity type, direction of travel and number of people. Good placement of cameras is also essential as it allows clear examination of attributes, especially at night or in heavy rain.

Cameras on beaches may be considered an invasion of privacy so activity levels at these locations must be determined using other methods. Regular checks of camera footage are also necessary so that any technical issues (i.e. malfunctions, incorrect zoom distance) are picked up promptly, and rectified, otherwise there can be substantial missing data within each month.

6.3.2 Roving creel surveys

Costs of roving creel surveys were highest during fieldwork, especially staffing and vehicle costs, as each survey required ~250 km of travel. The time required to travel this distance in a metropolitan setting was very constrictive, especially during peak hour and this had to be considered during scheduling. For safety reasons two staff were required for each survey, while weekends/public holidays had associated overtime payments.

Roving creel surveys were beneficial as they were the only technique during the pilot study which enabled interviews with recreational shore-based fishers to collect catch and trip information which was essential for calculating catch rates and estimating total catch. Although techniques such as phone/diary surveys may also be used to obtain such information, they are more likely to be exposed to recall bias or rounding bias, and species identification cannot be validated by researchers (Pollock *et al.*, 1994).

Instantaneous counts of shore-based recreational fishers were also undertaken during roving creel surveys. As the researchers were on-site, moving at slow speed, these were the most accurate counting method employed in the pilot study during daylight hours. However, it was difficult to obtain instantaneous counts of recreational shore-based fishers in the dark at some locations without traversing the entire beach on foot, which could be time consuming. Although fishers do use torches and lamps, these are often only activated when re-baiting or using the catch bucket. Staff also had to be cognisant of duplicate counts at some locations (i.e. at large groynes which could take >5 minutes to travel along) and were made aware of these issues at training prior to the commencement of fieldwork.

Another factor that may hinder instantaneous counts of recreational shore-based fishers is the difficulty of observing people along convoluted parts of the coastline. More vantage points where chosen at these locations to ensure the entire coast could be seen. Vehicle access to the coast was also limited in some areas (i.e. Eglington and Jindalee Beaches) and, although roving creel surveys were not conducted along this northern part of the coast, it should be incorporated into future studies, as aerial surveys did identify fishing activity at these locations.

6.3.3 Aerial surveys

The cost of hiring aircraft is expensive on a per hour basis, but they facilitate rapid coverage of recreational shore-based fishing occurring along a 100 km stretch of coastline and, unlike roving creel surveys, only required one staff member. Post-processing of data, which includes identifying the number of shore-based fishers from digital, can take up to 4-hrs per flight. However, the use of software, such as Aerial Survey Assistant, does significantly reduce the time it takes to extract information from the GPS/data logger unit and create shapefiles ready for import into a GIS project.

Light aircraft, such as the Cessna 172, have the capacity to fly further than the 100 km coastline (~200 km return) selected for this pilot study and it is therefore possible to expand on the current survey boundaries if required. Rottnest Island is a popular shore-based fishing location situated adjacent to the Perth Metropolitan area (Smallwood *et al.*, 2006) and should be considered for incorporation into future surveys. Flights could also be extended further north or south of the Perth Metropolitan area (i.e. from Two Rocks to Rockingham, Mandurah or Bunbury) without a need for re-fuelling. However, it should be noted that surveying greater lengths of coastline introduce difficulties with randomising starting locations (Mann *et al.*, 2003; Smallwood, 2010).

Visibility bias can affect the quality of results obtained from aerial flights (Pollock and Kendall, 1987), and may be caused by objects which obscure fishers from sight (i.e. trees, buildings), unfavourable weather (i.e. rain, smoke) and sun reflecting off the water, especially in the early morning. Fishers may also be difficult to spot when located on dark backgrounds such as rock platforms or groynes (especially if dressed in dark clothing). Digital camera settings therefore need to be chosen carefully to improve the quality of photos in various light conditions, and also in turbulence (using image stabilization). The wing may also obstruct the observers view when the plane is turning and this can be minimized through communication with the pilot to ensure that this does not occur at inconvenient times.

Once spotted by the observers, it may also be difficult to ascertain if people along the shoreline are fishing, especially if using handlines. However, <10% of shore-based fishers interviewed during roving creel surveys were using handlines, indicating that this type of misidentification should be relatively small. Numbers of shore-based fishers obtained using aerial and roving surveys also provided the strongest relationship when compared to the remote cameras.

6.3.4 Other methods

Other survey methods and technologies were considered during the design phase of the project, or were tested during the pilot study to ascertain any benefits they could provide towards understanding shore-based recreational fishing in the Perth Metropolitan area. Many of these methods were not practical, or were limited by cost, but technology is constantly evolving, they should be reviewed periodically.

Satellite or other remotely collected imagery (i.e. airborne photographic survey) were explored as a method for ascertaining the spatial variability of shore-based fishing. The high cost of acquiring these images was limiting, as was the availability of hardware at different times of day (i.e. satellites usually pass overhead within a standard time window) and the low frequency of passes. It is also unfeasible to expect the identification of individual shore-based fishers from the low resolution of some products. A low flying, fixed wing aircraft was more suited for surveying shore-based recreational fishers in terms of cost, flight scheduling and accuracy of observations.

Within the aerial surveys, a number of different options were trialled for recording information on recreational shore-based fishers, including digital cameras with in-built GPS and video cameras. It is important that any equipment used to collect a permanent record of shore-based fishing activity has high resolution, but are also of a size and weight that can be easily manoeuvred within the confines of a small aircraft. Currently, GPS systems built into digital cameras do not allow for rapid updating of positional information which is required to accurately record data from a fast moving platform. Until this technology is developed, an external GPS should be used to provide such data.

Video cameras have been widely used in aerial surveys and collect similar information to digital cameras so would be suitable for application in future studies. As with digital cameras it is important to obtain high resolution footage so that the observer can zoom into specific locations during post-processing. Software also needs to be available which has zooming and screen capture capabilities, as many packages only allow viewing of footage (rather than these more specific functions). The only remaining issue which needs to be considered when using video cameras is whether the equipment should be attached to the plane via a fix mount or hand-held by the operator, as it is imperative that the shoreline remain within the field of view.

Helicopters were investigated as an alternative to a fixed wing aircraft for the aerial surveys as they can hover at locations with high levels of activity to provide observers with a longer period of time to identify and count shore-based fishers. However, the flaps may be lowered on a fixed wing aircraft to slow the speed of travel and achieve a similar effect. Therefore, although helicopters do offer an alternative in terms of the practicalities of conducting a survey, their costs are more prohibitive (~$900 per hour) when compared to a fixed wing aircraft.

6.4 Implications for management of nearshore fish stocks

Findings from this study will enhance the provision of advice to managers when considering alternative management arrangements, such as changes to bag and size limits, for nearshore fish stocks in the Perth Metropolitan area. This is especially pertinent given recent changes to the management arrangements of demersal species, including a boat fishing licence and reduced bag limits, which may displace fishing effort onto these nearshore resources through either a shift of focus within the boat-based fishery, or a shift of fishing effort from the boat-based to shore-based fishery. Lack of previous research into shore-based fishing activity along the Perth Metropolitan coastline does hinder the identification of any displacement of fishing effort from these changes. However, comparison of the estimated catch from the current study with one completed during the same months in 1973 (Lenanton and Hall, 1976) does indicate a decline in the number of Australian herring caught by recreational shore-based fishers. The data collected in this study therefore provides a benchmark from which future changes in shore-based fishing pressure can be identified.

Recent boat-based surveys throughout the West Coast bioregion found that the catch of some species, such as Australian herring, skipjack/silver trevally and whiting species was concentrated adjacent to the Perth Metropolitan coastline (Sumner *et al.*, 2008). These species, especially Australian herring, were also retained in high numbers by shore-based fishers, indicating that it is important to consider all fishing platforms (i.e. shore and boat) when considering sustainable management of fish stocks.

Even through incomplete trip information was obtained from shore-based fishers during the roving creel surveys, a small number of parties had achieved their bag limit for some species or had retained undersized fish. Identifying survey locations with high and low densities of shore-based recreational fishers may assist with such non-compliance by fishers as this information can be used to target education and compliance activities, or alternatively, validate existing activities undertaken within the Perth Metropolitan area. Such knowledge of the spatial distribution of fishers will also contribute to the design of future surveys, in terms of assisting with the allocation of sampling effort.

6.5 Recommendations

The pilot study provided an opportunity to make recommendations for future surveys of shore-based recreational fishing in Western Australia, which are provided below.

1. Aerial surveys provided valuable information on the spatial distribution of shore-based fishers that was applied to calculation of total effort and can be used to guide the design of future on-site surveys, particularly in terms of allocation of sampling effort.
2. Light aircraft have the potential to cover a much larger area than surveyed in this pilot study. The extent of the survey boundaries should be considered in future studies and adjusted in accordance with management requirements.
3. Interviews with shore-based fishers during roving creel surveys provided data on trip length and number of retained and released species for each party, which was essential for the calculation of total effort, catch rate and total catch. Ideally, the extent of the study area for roving creel surveys should match that for aerial surveys to eliminate some assumptions relating to catch rate.
4. Remote cameras have great potential for understanding within-day variability in fishing activity at discrete locations, particularly during night-time hours, but there were high costs for analysis and limitations on where they can be installed. A reduced sampling schedule should be designed to reduce analysis costs but still identify changes in temporal patterns of fishing activity.
5. Placement of cameras needs to be carefully considered to provide the best field of view for counting recreational fishers. Such improved data collection should eliminate the need for assumptions relating to people assigned to an unknown activity type, and number of people associated with each event. Alternatively, this could be validated by obtaining on-site counts on a random number of nights which can be cross-validated with remote camera footage.
6. Advancements in camera technology will continue to offer more options and improve the quality of data collected using this method and should be monitored.

7.0 Conclusions

The complementary survey design revealed that recreational shore-based fishing in the Perth Metropolitan area had a heterogeneous spatial distribution, with the highest numbers of fishers observed on large groynes and jetties. Fishing activity also varied temporally, with greater numbers occurring on weekends/public holidays when compared to weekdays. Within-day variations were also evident, with peaks in shore-based fishing activity occurring during the afternoon. Australian herring was the most frequently caught species, and comparison of total catch estimates with previous research indicated a possible decline in the recreational catch of this species. Each survey technique had different benefits and limitations and, while a number of assumptions were instigated during analysis to address some aspects of data collection, the complementary approach was successful in achieving the project objectives. However, the cost of fieldwork and staff resourcing required to operate these techniques need to be carefully considered if implemented at larger spatial scales. The findings from this pilot study provided benchmark data from which future changes in patterns of shore-based recreational fishing activity could be determined and used to support the implementation of alternative management restrictions for nearshore fish stocks.

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Appendix 1 Name extent and level of fishing activity for all fishing locations in the Perth Metropolitan area as well as locations of coastal vantage point used for instantaneous counts during roving surveys.

(LG=large groynes, SG=small groynes, B= beach, J=jetty)

Location Name	Fishing platform	Fishing activity	Boundaries	Latitude	Longitude	Vantage points	Latitude	Longitude
Two Rocks Marina	LG	V High	Entire Marina			1. Walk along groyne	-31.4970	115.582
Two Rocks Beach - North	B	Mod	N - Base of Two Rocks Marina S - Wreck Point	-31.4970 -31.5032	115.5820 115.5841	1. Base of Two Rocks Marina	-31.4970	115.582
Two Rocks Beach - South	B	Mod	N - Wreck Point S - The Spot	-31.5032 -31.5215	115.5841 115.6040	1. Leemans Landing 2. The Spot	-31.5020 -31.5215	115.5862 115.6040
Yanchep Beach - North	B	Mod	N - The Spot S - Club Capricorn Groyne	-31.5215 -31.5407	115.6040 115.6158	1. The Spot 2. Club Capricorn north carpark	-31.5215 -31.5391	115.6040 115.6172
Yanchep Beach - South	B	High	N - Club Capricorn Groyne S - South end of Yanchep Lagoon platform	-31.5407 -31.5552	115.6158 115.6261	1. Club Capricorn south carpark 2. Yanchep Lagoon carpark	-31.5407 -31.5497	115.6173 115.6246
Eglington Beach	B	Mod	N - South end of Yanchep Lagoon platform S - Pipidinny Road	-31.5552 -31.5847	115.6261 115.6457	1. Compass Circle 2. Pipidinny Road (4WD access)	-31.5592 -31.5847	115.6314 115.6457
Jindalee Beach - North	B	Mod	N - Pipidinny Road S - Jindalee Blvd carpark	-31.5847 -31.6517	115.6457 115.6862	1. Pipidinny Road (4WD access) 2. Jindalee Blvd carpark	-31.5847 -31.6517	115.6457 115.6862
Jindalee Beach - South	B	Mod	N - Jindalee Blvd carpark S - Groyne north of Mary St carpark	-31.6517 -31.6637	115.6862 115.6892	1. Jindalee Blvd carpark 2. Mary Street carpark	-31.6517 -31.6663	115.6862 115.6905
Quinns Rocks - North	B	Mod	N - Groyne north of Mary St carpark S - Quinns Rocks	-31.6637 -31.6758	115.6892 115.6912	1. Mary Street carpark	-31.6663	115.6905
Quinns Rocks - South	B	Mod	N - Quinns Rocks S - Mindarie North Groyne	-31.6758 -31.6895	115.6912 115.6997	1. Corner Quinns Rd and Ocean Drive 2. Mindarie Keys north groyne	-31.6783 -31.6895	115.6954 115.6997
Mindarie Keys	LG	V High	Entire Marina			1. Mindarie Keys north groyne 2. Drive/walk along south groyne	-31.6895	115.6997
Mindarie Beach	B	Mod	N - Base of Mindarie Keys S - Burns Beach North Point	-31.6946 -31.7170	115.7027 115.7084	1. Claytons Beach carpark	-31.6946	115.7027
Burns Beach - North	B	High	N - Burns Beach North Point S - Burns Beach Rocks	-31.7170 -31.7312	115.7084 115.7191	1. Ocean Parade carpark	-31.7305	115.7191
Burns Beach - South	B	Low	N - Burns Beach Rocks S - Ocean Reef North Wall	-31.7312 -31.7590	115.7191 115.7285	1. Ocean Reef groyne	-31.7608	115.7269
Ocean Reef	LG	V High	Entire Marina			1. Ocean Reef Sea Sports Club 2. Walk along groyne	-31.7590	115.7285
Mullaloo Beach	B	Low	N - Base of Ocean Reef Groyne S - Mullaloo SLSC	-31.7640 -31.7856	115.7280 115.7338	1. Base of Ocean Reef Groyne 2. Mullaloo SLSC	-31.7640 -31.7856	115.7280 115.7338
Whitfords Beach	B	High	N - Mullaloo SLSC S - Pinaroo Point	-31.7856 -31.8057	115.7338 115.7279	1. Mullaloo SLSC 2. John Wilkie carpark	-31.7856 -31.8045	115.7338 115.7302

Location Name	Fishing platform	Fishing activity	Boundaries	Latitude	Longitude	Vantage points	Latitude	Longitude
Hillarys Beach	B	High	N - Pinaroo Point S - Hillarys North Wall	-31.8057 -31.8208	115.7279 115.7367	1. John Wilkie carpark 2. Hillarys North Wall	-31.8045 -31.8207	115.7302 115.7367
Hillarys North Wall	LG	V High	Entire North Wall			1. Drive or walk along groyne		
Hillarys South Wall	LG	V High	Entire South Wall			1. Drive/walk along groyne		
Sorrento Beach	B	Mod	N - South end of Hillarys Wall S - Third groyne south of Hillarys	-31.8269 -31.8333	115.7402 115.7472	1. Base of Hillarys South Wall 2. Ross Avenue lookout	-31.8265 -31.8349	115.7364 115.7489
Marmion Beach	B	Mod	N - Third groyne south of Hillarys S - Rocky outcrop south of MAAC	-31.8333 -31.8394	115.7472 115.7503	1. Ross Avenue lookout	-31.8349	115.7489
Watermans Beach	B	Low	N - Rocky outcrop south of MAAC S - WA Marine Research Labs	-31.8394 -31.8523	115.7503 115.7517	1. Troy Ave lookout 2. Ada St carpark	-31.8432 -31.8507	115.7511 115.7511
North Beach	B	High	N - WA Marine Research Labs S - Hamersley Pool	-31.8523 -31.8628	115.7517 115.7522	1. North Beach carpark	-31.8593	115.7523
Mettams Pool	B	Low	N - Hamersley Pool S - Bennion Beach carpark	-31.8628 -31.8710	115.7522 115.7524	1. Saunders Street carpark 2. Bennion Beach carpark	-31.8651 -31.8710	115.7523 115.7524
Bennion Beach	B	Low	N - Bennion Beach carpark S - Trigg Island carpark	-31.8710 -31.8756	115.7524 115.7519	1. Bennion Beach carpark	-31.8710	115.7524
Trigg Beach	B	High	N - Trigg Island carpark S - South end of Trigg Beach carparks	-31.8756 -31.8832	115.7519 115.7531	1. Trigg Island carpark 2. Trigg South carpark	-31.8756 -31.8791	115.7519 115.7530
South Trigg Beach	B	Low	N - South end of Trigg Beach carparks S - Scarborough Beach North End	-31.8832 -31.8899	115.7531 115.7550	1. Trigg South carpark	-31.8791	115.7530
Scarborough Beach	B	Low	N - Scarborough Beach North End S - Scarborough Beach South End	-31.8899 -31.8963	115.7550 115.7554	1. North end of Reserve Street carpark 2. Brighton Road carpark	-31.8810 -31.8979	115.7558 115.7563
Brighton Beach	B	Mod	N - Scarborough Beach South End S - Ventnor Street	-31.8963 -31.9042	115.7554 115.7577	1. Brighton Road carpark	-31.8979	115.7563
Peasholm Beach	B	Mod	N - Ventnor Street S - Hale Road	-31.9042 -31.9138	115.7577 115.7577	1. Peasholm Street carpark	-31.9074	115.7580
Floreat Beach	B	Mod	N - Hale Road S - City Beach North Groyne	-31.9138 -31.9345	115.7577 115.7545	1. Floreat SLSC 2. Floreat Drain (Access 12)	-31.9295 -31.9248	115.7556 115.7563
City Beach	B	High	N - City Beach North Groyne S - City Beach South Groyne	-31.9345 -31.9388	115.7545 115.7539	1. City Beach North carpark 2. City Beach South carpark	-31.9343 -31.9397	115.7559 115.7557
Swanbourne	B	Mod	N - City Beach South Groyne S - Grant Street	-31.9388 -31.9866	115.7539 115.7533	1. City Beach South carpark 2. Swanbourne SLSC	-31.9397 -31.9790	115.7557 115.7549
North Cottesloe Beach	B	Low	N - Grant Street S - Eileen Street (at OBH)	-31.9866 -31.9908	115.7533 115.7523	1. Blue Duck Cafe	-31.9893	115.7525
Cottesloe Beach	B	High	N - Eileen Street (at OBH) S - North side of Cottesloe Groyne	-31.9908 -31.9973	115.7523 115.7505	1. Cottesloe lookout	-31.9935	115.7516
Cottesloe Groyne	SG	High	Entire Cottesloe Groyne			1. Cottesloe lookout	-31.9935	115.7516

Location Name	Fishing platform	Fishing activity	Boundaries	Latitude	Longitude	Vantage points	Latitude	Longitude
South Cottesloe Beach	B	Low	N - Cottesloe Groyne S - Beach Street Groyne	-31.9973 -32.0074	115.7505 115.7513	1. Cottesloe Groyne lookout 2. Beach Street Groyne	-31.9983 -32.0074	115.7513 115.7513
Mosman Beach	B	Low	N - Beach Street Groyne S - Curtin Ave Carpark	-32.0074 -32.0170	115.7513 115.7518	1. Beach Street Groyne	-32.0074	115.7513
Leighton Beach	B	Low	N - Curtin Ave Carpark S - North End of Fuel Tanks (at point)	-32.0170 -32.0305	115.7518 115.7473	1. Curtin Ave carpark 2. Fremantle SLSC	-32.0170 -32.0289	115.7518 115.7490
Port Beach - North	B	Low	N - North End of Fuel Tanks (at point) S - Surf Club Cafe	-32.0305 -32.0349	115.7473 115.7456	1. Surf Club Cafe	-32.0349	115.7456
Port Beach - South	B	Low	N - Surf Club Cafe S - Base of Fremantle North Mole	-32.0349 -32.0406	115.7456 115.7409	1. Surf Club Cafe 2. Base of North Mole	-32.0349 -32.0406	115.7456 115.7409
Fremantle North Mole	LG	V High	Entire Fremantle North Mole			1. North Mole lighthouse 2. Carnegie Energy carpark	-32.0539 -32.0463	115.7246 115.7318
Fremantle South Mole	LG	V High	Entire Fremantle South Mole			1. Drive along groyne		
Bathers Beach	B	Low	N - Base of Fremantle South Mole S - Base of RPYC Annex Wall	-32.0567 -32.0597	115.7401 115.7409	1. Base of Fremantle South Mole	-32.0567	115.7401
RPYC Annex	LG	Mod	Entire RPYC Annex			1. Base of Fremantle South Mole 2. Walk from base of annex	-32.0567 -32.0594	115.7401 115.7417
FSC Marina South Wall	LG	Mod	Entire FSC Marina South Wall			1. Walk from base of marina		
South Beach - North	B	Low	N - FSC Marina South Wall S - Catherine Point	-32.0713 -32.0844	115.7503 115.7526	1. Base of FSC Marina South Wall 2. South Beach kiosk and cafe	-32.0705 -32.0776	115.7496 115.7516
South Beach - South	B	Low	N - Catherine Point S - Coogee Marina North Wall	-32.0844 -32.0970	115.7526 115.7584	1. Robb Road carpark	-32.0912	115.7576
Coogee Marina North Wall	LG	Mod	Entire Coogee Marina North Wall			1. Drive along base of marina		
Coogee Marina South Wall	LG	NA	Entire Coogee Marina South Wall			Closed to public at time of survey		
Coogee Beach - North	B	Low	N - Coogee Marina South Wall S - Ammo Jetty	-32.1048 -32.1244	115.7613 115.7595	1. Powell Road (with cafe) 2. Ammo Jetty	-32.1114 -32.1244	115.7640 115.7595
Ammo Jetty	J	High	Entire Ammo Jetty			1. Walk from base of jetty	-32.1244	115.7595
Coogee Beach - South	B	Mod	N - Ammo Jetty S - Woodmans Point Beach - Endpoint	-32.1244 -32.1346	115.7595 115.7406	1. Base of Ammo Jetty 2. Pumping Station carpark	-32.1244 -32.1341	115.7595 115.7477
Woodmans Point Beach	B	Mod	N - Woodmans Point Beach - Endpoint S - Groyne at end of Woodmans Point	-32.1346 -32.1353	115.7406 115.7468	1. Woodmans Point carpark	-32.1365	115.7453
Woodmans Beach - South	B	Mod	N - Groyne at end of Woodmans Point S - Base of Woodmans Point Groyne	-32.1353 -32.1396	115.7468 115.7611	1. Woodmans Point carpark 2. Base of Woodmans Point Groyne	-32.1365 -32.1377	115.7453 115.7617
Woodmans Point Groyne	LG	V High	Entire Woodmans Point Groyne			1. Walk from base of groyne		

Appendix 2 Form for documenting information from remote cameras.

Site: ______________________ **Date:** ______________

Time	Direction	Fishing	No. people
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	
: :	A / D	Y / N / U	

Direction

A	Arrive
D	Depart

Fishing

Y	Yes
N	No
U	Unknown

Pg ___ of ___

Outage events

Start time	End time	Outage reason/comment

Appendix 3 Sampling schedule for roving and aerial surveys of shore-based recreational fishing in the Perth Metropolitan area.

April

1	
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23	
24	
25	
26	
27	
28	
29	
30	

May

1	
2	
3	
4	
5	
6	No aerial flight
7	
8	
9	
10	
11	
12	No aerial flight
13	
14	
15	
16	
17	Reschedule (from 6/05)
18	
19	
20	Reschedule (from 12/05)
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	

June

1	
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Legend

- Weekend/public holiday
- Morning survey
- Afternoon survey

Appendix 4 Interview form for shore-based fishers in the Perth Metropolitan area using rods or handlines.

Government of **Western Australia**
Department of **Fisheries**

Perth Metropolitan Area - Shore Survey 2010

Name: ______________________ **Date:** ________________ **Location:** ________________

Beach Type	Fixed groyne ☐	Fixed beach ☐	Random beach ☐
At Arrival			
Time (24 hr)			
Number shore fishers			
Number non-fishers			
Interview	*Y*	*N*	*Y*
At Departure			
Time (24 hr)			
Number shore fishers			
Number non-fishers			

Wind				
Calm 1	Light 2	Moderate 3	Strong 4	Gale 5
Direction:				

Water				
Calm 1	Slight 2	Moderate 3	Rough 4	Very Rough 5

Cloud Cover & Rainfall				
Cloud %	Nil 1	Light 2	Moderate 3	Heavy 4

Total Lengths of Random Sample (mm)

Species: ______________________
Lengths: ______________________
Species: ______________________
Lengths: ______________________
Species: ______________________
Lengths: ______________________
Species: ______________________
Lengths: ______________________
Species: ______________________
Lengths: ______________________

Interview Number	**1**	**2**	**3**
Fishing platform (B/J/G)			
Time of interview			
Home postcode			
Number in group			
Number persons fishing			
Gear (number & type) R = Rod / H = Handline			
Time spent fishing (decimal hours)			
How many times have you fished in the last month?			
Target species			
Australian Herring			
Total number kept			
Total number released			
Total number over/under kept			
Species 1			
Total number kept			
Total number released			
Total number over/under kept			
Species 2			
Total number kept			
Total number released			
Total number over/under kept			
Species 3			
Total number kept			
Total number released			
Total number over/under kept			