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Catch susceptibility and life history of barred javelin (*Pomadasys kaakan)* in north eastern Queensland, Australia

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ABSTRACT

The recreational fishery in Australia is an important part of the country's economy and culture. However, broad spatial and temporal monitoring schemes that are currently used to estimate effort and catch of the recreational fishing sector are insufficient for sustainable management. Often species-specific information is unavailable due to identification problems, as well as area and time specific fisheries (pulse fisheries) which are not identified. This dissertation aims to evaluate current monitoring and management schemes for the fishing industry by (1) developing a profile of a community experiencing seasonal fluctuations in fishing effort, (2) identifying the harvest and life history characteristics of a primary target species, the barred javelin (*Pomadasys kaakan*) as they apply to the commercial and recreational fishing sectors, and (3) use this information in a Biological Reference Point model to predict the productivity of *P. kaakan* and assess the effectiveness of recent management changes.

Currently, communities which experience fluctuations in fishing effort due to the seasonal movements of anglers are unrecorded. Lucinda, a community in northeast Queensland, experiences fluctuations of tourist visitation which coincides with changes in fishing catch and effort within the local region. The demographic characteristics and motivations of the tourists visiting Lucinda, as well as a harvest description of the recreational sector, are described in this dissertation. This will demonstrate the importance of identifying communities affected by fishing pressures and the possible impact anglers are having on coastal ecosystems.

A biological description of catch characteristics for the commercial and recreational sector is also required for key species. Updated life history characteristics, including growth parameters and reproductive behaviours, are necessary for use in management plans which keep the collective industry sustainable. For this dissertation, key life history characteristics were defined for *Pomadasys kaakan.* These data were used in the Spawning Potential Ratio model, with catch characteristics for each sector, to evaluate historical and current minimum size limit laws, as well as the gear selectivity influences of both fishing sectors.

Demographic and motivational profile data was collected using on-site, access point surveys at the main boat ramp in Lucinda and face-to-face surveys of tourists in the local caravan park – Wanderer's Holiday Village. This data were also used to create a harvest description for recreational anglers in Lucinda. Biological samples of *P. kaakan* were collected from fishery dependent sources, including recreational and commercial

fishers. These samples were used to define age and growth parameters, as well as reproductive characteristics.

A definable, seasonal recreational fishery was identified in Lucinda with a 500% increase in fishing effort during the winter months. This fishery was driven by the movement of grey nomads, i.e. senior citizens who travel for prolonged lengths of time in a specific area. The social motivation of travel linked to fishing indicates declines in fishery stock and changes in management may have no effect on return visits to Lucinda and continued participation in fishing. In addition, a high level of targeting behavior was focused on *Pomadasys spp*. This exemplifies the need for regionally specific monitoring and management plans which sustain the industry and the community.

A comparison of the harvest of P*. kaakan* for the commercial and recreational sector indicated a higher impact by the recreational sector for this species. The recreational sector has higher harvest rates, targets fish over a broad length range and has a high female sex bias. However, the combined impacts of the commercial and recreational sector, as indicated by the SPR model, had the largest impact on the future productivity of the species. The high female bias in the harvest of *P. kaakan* in Lucinda also suggests sexual segregation may occur in the Hinchinbrook Channel. This may make the population more susceptible to overexploitation.

As a result of these findings, management may need alternative methods to achieve sustainability goals. Controls on total effort, not individual angler impacts, need to be implemented for effective management. In addition, continued monitoring coupled with a dynamic approach to regulating changes in effort is needed to maintain the status of regional populations. Further research regarding post-release mortality and identification of spawning aggregations are suggested in this dissertation to further assist management with development of future plans.

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LIST OF ABBREVIATIONS

BRP	Biological Reference Point
CapReef	Capricorn Reef Monitoring Program
CPUE	Catch per unit effort
DEEDI	Department of Employment, Economic Development and Innovation, Queensland
DPIF	Department of Primary Industries and Fisheries, Queensland
ECIFF	East Coast Inshore Fin Fishery
FFRC	Fishing and Fisheries Research Centre
FRDC	Fisheries Research and Development Corporation
FWS	Fish and Wildlife Service
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
MRFSS	Marine Recreational Fisheries Statistic Survey
MLS	Minimum legal size
MTSRF	Marine and Tropical Sciences Research Facility
NOAA	National Oceanic and Atmospheric Administration
NMFS	NOAA National Marine Fisheries Service
QDAFF	Queensland Department of Agriculture, Fisheries and Forestry
RRRC	Reef and Rainforest Research Centre
SPR	Spawning potential ratio
TL	Total length

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Chapter 1 Introduction

In Australia, recreational fishing is a popular pastime that is enjoyed by approximate 3.5 million people per year (Henry and Lyle, 2003). Recreational fishing is ingrained in the Australian culture due to the multiple social values placed on the sport, including camaraderie and relaxation (Pitcher and Hollingworth, 2008). In addition, a billion dollar economy is supported by the recreational fishing industry's expenditure on angling related travel, services and equipment (Henry and Lyle, 2003). However, the negative impacts of recreational fishing on the environment may also be significant. These impacts could, in turn, lead to loss of social and economic benefits. Therefore, monitoring and management of the recreational fishery is essential to maintain a sustainable industry and, in turn, the cultural value of the sport.

Understanding the level of catch and effort in recreational fisheries is important for sustainable management (McPhee, 2008). Effective monitoring programs should identify potentially impacted species including the level of impact sustained, as well as trends in catch rates. This information could help identify changes in the status of a population and as such, indicate a need for changes in management. Continued monitoring of a fishery and target species will allow managers to adopt dynamic management plans which maintain the sustainability of the industry.

In Queensland, catch and effort are monitored at a large spatial scale and infrequent temporal scale. As such, changes in fishing pressures on small regional and temporal scales are not recognised. For example, coastal communities which are experiencing seasonal, intense fishing pressures, or "pulse fishing", are currently unidentified by recreational fishery monitoring. As a result little is known about these small fisheries, including the level of impact they may be having and which species are affected. Currently, management is unable to create custom plans to account for these trends.

One fishery that is omitted by statewide catch and effort monitoring occurs in the Hinchinbrook channel near the community of Lucinda, in north Queensland. Preliminary research by the Centre for Sustainable Tropical Fisheries and Aquaculture, James Cook University revealed a seasonal (winter) increase in population of the township driven by interstate tourists coinciding with an increased activity on the main boat ramp in Lucinda (Tobin et al., 2010b). In addition, anecdotal evidence indicates this increase in effort may be driven by a strong targeting behavior for a single species – barred javelin (*Pomadasys kaakan). P. kaakan* is known to form predictable spawning aggregations; a phenomenon which is highly susceptible to overfishing

(Pears and Russell, 2007). As such, locations experiencing high levels of effort targeted at this species need to be monitored. Currently, apart from anecdote this seasonal fishery is unidentified and characteristics including level of fishing effort and target species are unknown.

This study aims to complete a regional-level snap shot of fishing effort in Lucinda in north Queensland, Australia. A tourist demographic and motivational profile, as well as a harvest description of anglers in Lucinda, will be developed to establish links between fluctuations in fishing effort and tourist presence. This thesis will also include a biological report of *P. kaakan.* This data can then be used to amend and improve current management plans, as well as develop future monitoring plans to help protect fishing communities, target species, and the industry. The remainder of this chapter reviews the literature on impacts of the recreational fishing industry, species-specific impacts, and monitoring schemes which are currently in place for the recreational fishery. This will include an overview of the grey nomads, a demographic with a known influence on the environment and coastal communities.

Potential Impacts of the Recreational Fishing Industry

Declines in fish populations are commonly attributed to harvest by the commercial sector without due consideration of the role of recreational fisheries (Hilborn, 1992; Botsford et al., 1997; Smith, 2002; Christensen et al., 2003; Hilborn et al., 2003; Pauly et al., 2003). Globally, recreational harvest is rarely questioned in regards to maintaining a sustainable fishery (Post et al., 2002). Thus, fishery monitoring and management protocols are often geared toward commercial fishery activities. Recreational fisheries may have subtle, though serious impacts on fish populations making over-fishing and fisheries collapses difficult to detect (Post et al., 2002; Pereira and Hansen, 2003); consequently, inclusion of this sector in monitoring schemes is essential.

In the past, some managers have assumed that different sectors fishing the same stock will impact the stock identically and evenly, thus negating any need to monitor more than one sector (Policansky, 2001). While this is one method to ensure inclusion of multiple fishing sectors when information for a given sector is lacking, it does not identify sector specific differences in targeting gears and/or methods which impact different life history stages of a population. For example, recreational anglers frequently harvest smaller individuals (McPhee et al., 2002; Cooke and Cowx, 2004). If there is extensive removal of small individuals from a population there is a possibility that future productivity will not be high enough to replenish the population, and there is a risk of collapse. The selectivity of the nets used by the inshore commercial fishers, on the other hand, allows them to target larger fish, and therefore different life stages of the species than the recreational fishery (Hamley, 1975; Halliday et al., 2001; Tobin and Mapleston, 2004). This difference in characteristics between the commercial and recreational fisheries may exacerbate overexploitation, and management methods should reflect those concerns (Beal et al., 1998; Cooke and Cowx, 2006). Without acknowledgement of these differences in targeting behaviour, (i.e. different components of the same resource are being harvested), the combined efforts of the commercial and recreational sector may increase the potential for overexploitation of the population.

Recreational anglers and commercial fishers also have direct access to inshore waters that are critical habitats for multiple life stages of many species, including immature individuals (Jackson et al., 2001). A relatively high rate of catch-and-release is practised by recreational anglers compared to commercial fishers, due in part to the size-selectivity of the gear used. If post-release mortality levels are low for a given species, this high level of catch-and-release may reduce the impact to the stock. However, if post-release mortality is high for a given species, immature individuals may not be protected by minimum legal size (MLS) limits. The unknown and variable post-mortality rates for specific species (examples include de Lestang et al., 2004; Phelan et al., 2008) further complicate the determination of sustainable levels of catch and effort. For example, post-release mortality varies from as low as 2% for the common snook to as high as 66% for striped bass (Bettoli and Osborne, 1998; Taylor et al., 2001). Despite the fact that commercial and recreational sectors may fish in the same locations, given their tendency to target different life history stages (Tobin et al., 2010a) there is a need for independent harvest assessments.

Further, the recreational harvest for some inshore species often surpasses that of the commercial harvest. For example, in Queensland the recreational harvest of *P. kaakan* and blue threadfin (*Eleutheronema tetradactylum*) far exceeds that of the commercial fishery (Greiner and Gregg, 2010). The importance of monitoring the recreational fishing industry can be seen in the collapse of two species in California: Barred sand bass (*Paralabrax nebulifer*) and kelp bass *(Paralabrax clathratus)* are two important marine recreational fisheries of southern California. From 2000 until 2008, catch per unit effort (CPUE) declined by 70%, and eventually the stocks collapsed. Due to insufficient monitoring of the recreational effort, the decline went unnoticed, meaning required management protocols were not implemented and the fishery was no longer sustainable (Erisman et al., 2011). Because many recreationally important species are not as heavily harvested by the commercial sector, the fishery and populations are not monitored, effectively precluding sustainable management.

Recreational Fishing Monitoring

Management plans and impact assessments that take into consideration the recreational sector of the fishery are essential to maintain the integrity of the ecosystem. Recently, the high level of participation in the recreational sector has led to some attempts to include the recreational harvest in status reports and to direct management plans (McPhee et al., 2002; Post et al., 2002; Schroeder and Love, 2002; Coleman et al., 2004). Fisheries managers around the world have used various methods to monitor the status of recreational fisheries: for example telephone surveys (McInnes, 2008), angler diaries (Kleiven, 2010), and species-specific fishing licenses (Taylor et al., 2001). Despite the development of multiple methods of monitoring the recreational sector, implementation of strategies is expensive and problematic due to the diffuse nature of the recreational fishery. Monitoring schemes need to be consistent and detailed to identify small, independent fisheries (Post et al., 2002).

Internationally, monitoring of the recreational fishing sector has met with challenges. The United States is an example of a country that devotes a lot of resources to monitoring recreational fishing catch and effort. Every five years the Fish and Wildlife Service (FWS) conducts the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. The surveys began in 1955 and have changed methodology periodically up until 1991. The latest report was completed in 2006 and covered information including number of anglers, level of participation for each angler and fishing related expenditure. While the surveys are able to identify target species on a national level, they are unable to establish specific fishing trends such as temporal and seasonal fluctuations in effort and species-specific targeting (U.S. Department of the Interior, Fish and Wildlife Service et al. 2006).

The original and currently active National Oceanic and Atmospheric Administration (NOAA) Marine Recreational Fisheries Statistic Survey (MRFSS) is a phone and access point survey also utilised in a majority of the U.S. which works independently of the FWS survey. The MRFSS began in 1979 and covers individual anglers and charter boat agencies. The validity of the survey has in recent times been called into question due to the broad spatial scale of the surveys (they are conducted on large regional levels) and lack of cooperation with all states and territories (the Pacific Coast, Alaska, Texas and a few U.S. territories conduct their own surveys with their own methodologies and do not participate in the NOAA survey), (Essig and Holiday 1991;

U.S. Department of the Interior, Fish and Wildlife Service et al. 2006). In order to identify variations in fishing catch and effort at small spatial scales, surveys need to be standardised throughout the country for comparison of the regions. In additon, efficient montioring of the recreational sector needs to be able to identify small communities which are experiencing strong pulses of effort.

Monitoring Recreational Fishing in Australia

Australia's recreational fishery harvest data is collected at both a national and state or territory level. The National Recreational and Indigenous Fishing Survey (NRIFS), completed in May 2001, is the only survey to obtain the initial statistics for nation-wide catch and effort for recreational fishers. NRIFS had a standardized protocol to develop a national description of the recreational fishing sector. A combination of telephone and diary surveys were used to gather data on attitudinal and fishing behaviours as well as create a basic harvest description that could be coalesced into one profile for the nation or could be compared between regions. The Fisheries Research and Development Corporation (FRDC) funded this project (Henry and Lyle, 2003), but it has not, at the time of submission, been continued. The discontinuity of this survey prevents interpretation of the status of the fishery and changes in angling effort by the recreational sector. This survey could also not be used to determine detailed region or species specific management plans due to the broad coverage.

The first state-based recreational fishery surveys began in New South Wales in the late 1970s (Tilzey, 1977a; Tilzey, 1977b). Monitoring at the national level did not occur until the 1980s when a demographic and economic behaviour study was completed to understand the extent of utilisation of Australia's marine resources (PA Management Consultants, 1984). Since then methodologies have changed substantially to provide more accurate estimates of the level of participation in recreational fishing and create a demographic profile of anglers, from off-site methods such as telephone and/or angler diaries to on-site methods such as access point (boat ramp) interviews. Changes in methodology, however, have not included ways to monitor fishing effort at a regional scale. In recognition of this issue, preliminary access point surveys to obtain fine-scale regional data have recently been conducted in southeast Queensland; however, there is still a need to collect representative samples of fishing activity following a structured methodology that is consistent through time (Webley et al., 2009a).

Most states or territories in Australia conduct their own monitoring of their recreational fisheries; however the diversity in methodologies has prevented effective utilisation of the data at the national level. One element of these methodologies that is particularly distinct is the sampling frame used for the telephone surveys. Currently, many states conduct random telephone surveys based on the state of residence to identify anglers. Victoria is currently the only state which has utilised the recreational license database to help identify anglers and collect catch and effort information. New South Wales and Western Australia have license databases but have not conducted a state-wide survey since the introduction of fishing licenses. Random residential telephone surveys risk under-coverage by missing anglers who have private numbers, but also those who travel interstate (Pollock et al., 1994; Tuckel and O'Neill, 2002).Telephone surveys are affected as a whole by other detriments, including recall and prestige bias, which are important factors to consider when monitoring catch and effort. Recall bias arises because of a respondent's inaccurate recollection of events, whereas prestige bias involves exaggeration of data if not outright falsification (Sudman and Bradburn, 1974; Chu et al., 1992; Pollock et al., 1994). Additionally, for most states, these telephone surveys have not been repeated since 2001. Consequently, given the large time lag between implementation, they are not able to observe temporal changes in recreational catch and effort data.

Monitoring Recreational fishing in Queensland

State-wide recreational fishing monitoring in Queensland is conducted via the Queensland Department of Agriculture, Fisheries and Forestry (QDAFF)[1] Recreational Fisheries Information System (RFISH). Monitoring was initiated in 1995 to estimate catch and effort within the Queensland recreational fishery and to inform and contribute to sustainability goals of management policies. The system was designed to run biannually, but funding ceased temporarily after 2004. The program recommenced in 2010 and results are currently being finalised. RFISH is a two-phase contact system with a telephone survey as the initial contact through random-digit dialing covering large, regional statistical areas, followed by a voluntary fishing diary phase. Telephone surveys are used to obtain demographic and fishing effort information about anglers, and to identify anglers in each region to participate in a 12-month diary program which catalogues their fishing activities (Department of Employment Economic Development and Innovation, 2008; McInnes, 2008; Queensland Department of Employment, Economics Development and Innovation, 2010).

[1] The Queensland Department of Agriculture, Fisheries and Forestry (QDAFF) was formerly known as the Department of Employment, Economic Development and Innovation (DEEDI), Queensland Primary Industries and Fisheries (QPIF) and Queensland Department of Primary Industries and Fisheries (QDPI&F). Fisheries Queensland is the fisheries management agency within QDAFF.

RFISH has been successful in providing estimates of recreational fishing harvest and behaviour, and has been repeated over time to allow broad comparisons temporally; however, it does not provide a comprehensive profile of all anglers fishing in the state nor is it specific enough to identify regional, species-specific, or regional temporal fluctuations in recreational catch and effort. The telephone surveys were conducted based on residential telephone numbers within Queensland. Due to the low diary participation rate – in 2004, of the approximately 730,000 recreational anglers in Queensland (McInnes, 2006) less than 970 (0.1%) participated in the diary program – the data collected were also unable to create an amalgamated angler profile or definite regional harvest description. While the diary program was able to identify catch statistics for individual anglers it could not identify areas in Queensland which experience relatively high levels of effort and hence likely catch.

The information collected by programs such as RFISH does not capture the fishing effort and catch data of out-of-state, tourist anglers. The absence of information about visiting anglers is a major concern when attempting to assess resource sustainability. A case study in Karumba in the Southern Gulf of Carpentaria, Queensland, exemplifies this problem – Interstate anglers in Karumba target javelin (*P. kaakan* and *P. argenteus,* in this case) which are important by-catch species for commercial fishers and an important target species for recreational anglers. In Karumba alone, interstate anglers harvested nearly 15 tons of javelin in 2004 (Hart and Perna, 2008), which is over half of the harvested commercial catch for the entire state for the same year. Prior to the independent 2004 survey by Hart and Perna, data concerning this fishery was not measured or included in any assessment of fishery sustainability. Clearly, overlooking interstate anglers in monitoring plans excludes a major component of the recreational catch and effort and consequently, current monitoring does not describe the industry as a whole.

One particular demographic of tourists may be helping drive the seasonal increase in fishing effort. The northern seasonal migration undertaken during winter months by older Australians colloquially referred to as “grey nomads”, represent a significant number of unmonitored travelers (Pearce, 1999). Onyx and Leonard (2005) defined grey nomads as “people aged over 50 years, who adopt an extended period of travel (at least 3 months) independently within their own country”. While motivations between individual travelers vary, the bulk of grey nomads consider fishing to be a significant draw to certain areas and they are prone to residing for longer periods of time in locations associated with fishing and boating (Onyx and Leonard, 2005).

The actions of the grey nomads while visiting coastal communities have already been identified as having a negative influence on some coastal ecosystems (Cridland, 2008). Various cases across Australia have demonstrated the need for species-specific or site-specific fisheries monitoring and management for areas that experience seasonal fishing pressures, such as those created by grey nomads. For example, increased fishing effort by the grey nomads in Karumba (mentioned above) on popular recreational species have led to recommendations of management changes to curtail potential over-exploitation (Hart and Perna, 2008). Other communities and regions, such as Lucinda, which are influenced by tourism, are currently unidentified formally, and as such the level of impact tourist groups, including grey nomads, may be having on regional ecosystems cannot be determined.

Despite the grey nomads' negative influence on regional ecosystems, they are coupled with positive influences on coastal communities. Identifying the characteristics and trends in recreational catch and effort inclusive of tourist anglers, particularly grey nomads, will assist in creating management plans that not only maintain a sustainable fishery but also assist small communities with sustaining a stable economy (Ditton et al., 2002). Senior citizens, including grey nomads, spent $895 million on domestic travel in Australia. This figure is expected to increase to over $2 billion by 2050 with the rising elderly population (Golik et al., 1999). The extended amount of time the grey nomad population spends in a given community lends to the idea that a large proportion of their spending will be within the local region. Importantly, however, a social case study examined the sustainability of the grey nomad phenomenon in relation to the fishing pressures experienced in Karumba: It was determined that the industry was only sustainable for the local economy if the fish populations were also maintained (Stoeckl et al., 2006). In other words, the sustainability of the fish populations directly influences the sustainability of the local culture and community. Current fishery management plans which do not include adequate estimates of local and tourist recreational harvest may not provide a stable industry that has become an important social and economic asset to coastal communities, the state, and the nation.

Regional, Species-specific Fishing Pressures

Research has been conducted in specific areas within Queensland which identifies common target species and seasonal fluctuations in fishing effort. Research in areas such as the Capricorn Coast (via CapReef, or Capricorn Reef Monitoring Program, a community based monitoring program (CapReef, 2012)) and Karumba, have used on-site, access point surveys to establish not only catch and effort information for inshore species, but also, in the Karumba case, preliminary investigations into angler residential origin and distance travelled. Given that monitoring of the recreational fishery in Queensland is only conducted with residential anglers, the identification of the origin in these alternative surveys highlights the level of effort excluded on specific species by state-wide reports. These projects have provided a prelude for the data that is needed to establish state-wide harvest estimates that take into consideration not only the fishery as a whole, but the details required to maintain a sustainable fishery.

Seasonal fishing pressures that target specific species need to be identified and monitored. Research needs to identify highly targeted species and measure the intensity of that harvest. Increases in effort on a species which may already be experiencing pressure from local anglers need to be taken into consideration. This information regarding targeting behaviour, coupled with knowledge of the life history characteristics of the species, will help managers create management plans based on a species' resilience to various levels of fishing pressure. Identification of locations where species that are susceptible to over-exploitation due to high fishing pressure, coupled with biological information, is essential for fully protecting a species from overfishing.

Predictable reproductive behaviour which may influence the rate of exploitation of a targeted species is one important biological characteristic that is especially important to identify. Species that aggregate to spawn, for example, are known to more susceptible to exploitation if such aggregations are targeted by fishers. An example of overfishing spawning aggregations by recreational and subsistence anglers in northern Australia is on the black jewfish (*Protonibea diacanthus)*. Anecdotal evidence suggested increased angler effort on jewfish due to the ease of harvest of fish aggregating to spawn (Bowtell, 1995; Bowtell, 1998). Up until 1995, large adult fish made up a bulk of the harvested fish caught. The harvested black jewfish decreased in individual mean size until 1999 and 2000, at which point the fishery was based entirely on immature size classes. A two year prohibition on black jewfish harvest was implemented in 2001 and 2002; however, during this time the fish population was monitored and only modest gains in mean fish size were made (Phelan, 2002a; Phelan, 2002b; Phelan, 2005; Phelan et al., 2008). While recovery rates differ between species, this example exemplifies the speed in which fish populations may be depleted relative to potential recovery due to lack of appropriate monitoring and subsequent management of spawning aggregations.

Special management arrangements have been developed for regional, species-specific fishing pressure around the world. For example, in Florida, pompano *(Trachinotus carolinus)* are a popular trophy fish for recreational anglers. In 2002 the recreational harvest exceeded the commercial harvest of Florida pompano depicting the increasing importance of pompano to the recreational sector (Muller et al., 2003). A distinct recreational fishery was identified in the Florida Keys in association with spawning aggregation behaviours of the pompano. In 2011, the Florida Fish and Wildlife Conservation Commission amended protection protocols for all pompano and permit species by increasing size limits and changing bag limits from "per boat" to "per harvester" in order to protect spawning individuals and maintain the recreational fishery in the Florida Keys (Florida Fish and Wildlife Conservation Commission, 2011). A similar regional change in Australia was implemented in the Northern Territory to create a sustainable industry for local communities. The Mary and Daly rivers have lowered possession limits in response to increasing pressures on local barramundi (*Lates calcarifer)* populations by recreational anglers (Coleman, 2004). Regional populations of highly targeted fish species can only benefit from management plans that identify and address issues at the local scale.

The Seasonal Fishery for P. kaakan in Lucinda, Queensland

A community experiencing influxes of fishing pressure which may be overlooked by current monitoring and management schemes is Lucinda. The port of Lucinda is a small township located in north-eastern Queensland, 100km north of Townsville and 50km south of Cardwell on the Hinchinbrook Channel (Figure 1-1). The inshore area includes mangrove-lined estuaries and salt marsh flats which support an important recreational fishery (McPhee et al., 2002). The close proximity to Hinchinbrook Island shelters the surrounding waterways allowing safe access for small vessels. The combination of these factors has made Lucinda a destination for tourists from around the globe (Beets and Friedlander, 1992). The Hinchinbrook Channel itself offers a diverse array of habitats and multiple channels that provide access to many locations for locals and tourists alike to fish for multiple species. This location is part of the Great Barrier Reef region, a recognised World Heritage Site (Le Quesne and Jennings, 2012).

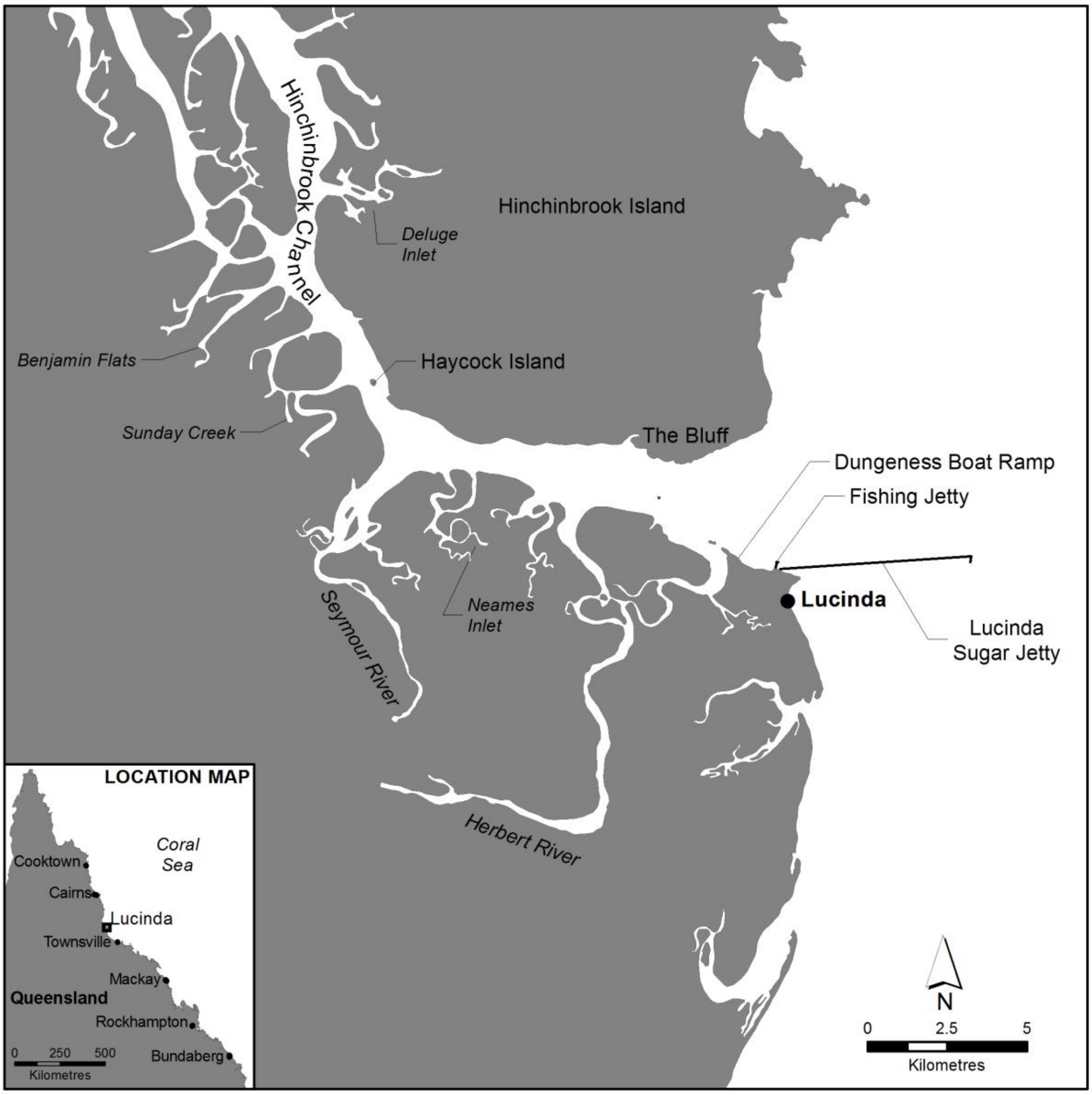


Figure 1-1 Map outlining the study area within Queensland, Australia.

Aims of thesis

Recreational catch and effort data as well as species-specific biological indices need to be complete and accurate if management plans are to be effective. The current methodologies used to monitor catch and effort do little to ensure sustainable management due to deficiencies on a temporal, spatial and species-specific scale. Lucinda, QLD is a community with seasonal fluctuations in fishing pressure which is not identified in current recreational fishing monitoring schemes. Consequently, effective management plans may not be in place to keep the fishery and key targeted species sustainable. This thesis will define the recreational fishing industry in Lucinda, including details about the demographics of the anglers and tourists, as well as the level of fishing effort imparted on the area and specific species, such as *P. kaakan,* by recreational anglers. This will help determine what is missed by current state-wide monitoring plans and assist in providing suggestions for future management.

Another aim of this thesis is to re-evaluate and define the biological factors and a harvest description of a known target species in the Lucinda winter fishery, *P. kaakan.* The harvest description will be completed for the recreational and commercial fishing sectors to determine the level of impact the industries are having independently and as a whole on *P. kaakan.* A Spawning Potential Ratio model based on the reproductive characteristics of *P. kaakan* and fishing trends of the Lucinda community will be used to analyse possible outcomes and subsequently, specific management plans which ensure a sustainable industry.

Thus the specific aims of this thesis are –

1. Develop a recreational fishing profile of Lucinda, QLD. This profile is to include:
    a. A demographic and motivational profile of visiting tourists;
    b. Trends in fishing behaviour, including identification of target species and seasonal fluctuations in effort;
2. Define life-history and fishery catch characteristics for *P. kaakan* for input into Biological Reference Point modeling;
3. Identify critical areas in need of improvement in current monitoring and management of recreational fishing in Queensland;

Chapter 2 Snapshot of the fishing culture in a Hinchinbrook Channel township

Introduction

The culture and economy of many coastal communities in Australia are built around tourism. However the impacts of some tourists may be detrimental to regional ecosystems, in particular the impacts of travelling anglers to local fish stocks (Stoeckl et al., 2006). Lucinda, the study site for this thesis, is one community on the east coast of north Queensland which may be experiencing fluctuations in tourist visitation resulting in “pulse events” of recreational fishing effort and catch. This chapter will illustrate the importance of monitoring fishing effort in communities similar to Lucinda including the identification of target species and motivations of visiting anglers. Understanding these factors will help fisheries managers ensure the future of fish stocks and the culture of the fishing community.

One group of tourists in Australia which may support coastal fishing-tourism communities are the grey nomads. The Bureau of Tourism Research estimated in 2000 approximately 200,000 caravan trips of more than six weeks are taken by grey nomads every year, contributing to a substantial portion of the tourism industry (Carter, 2002). The specific movement of grey nomads is not well researched, however there is some evidence of the annual movement of many grey nomads to the north from the cooler southern states during the winter months along coastal routes (Pearce, 1999). If, as the Bureau’s data suggests, grey nomads are travelling to north Queensland in large numbers, the impact on coastal ecosystems could be significant. In addition, given the likely importance of grey nomads and fishing to these small communities, management plans that are tailored to creating a sustainable industry are important to ensure not only the protection of the ecosystems, but also the culture and potentially the economy in these small towns.

Pulse, localised fishing in tourist driven communities may threaten sustainability because it can result in large volumes of fish being removed from a location in very short time periods. This type of fishing behaviour can lead to localised depletion, as outlined by Phelan (2002a; 2008) who found localised pulse fishing for black jewfish in north Queensland led to overexploitation of local populations. Monitoring and understanding the potential impacts of pulse fishing events is also problematic because timing of sampling events is critical to ensure the dynamics of the event are captured within ongoing monitoring. Further, understanding the motivations of the anglers driving these pulse fishing events may help managers plan for future changes in effort. In turn, appropriate protocols can be developed to manage a changing fishery.

Culture of a Recreational Fishing Community

Lucinda is a popular fishing destination attracting seasonal interstate tourist visitation (Tobin et al., 2010b). During the winter months, an increase in the population of the township which is driven by the grey nomads coincides with an increased activity on the Dungeness Boat Ramp, the main boat ramp in Lucinda (Tobin et al., 2010b). In other words, increased fishing effort within the Hinchinbrook Channel may be directly influenced by the grey nomads. Importantly, there is no monitoring of the magnitude of these seasonal fluctuations of grey nomads or of their potential impacts on local fish populations.

Preliminary research shows a similar situation in Lucinda to a case study in Karumba. Situated in the Gulf of Carpentaria in remote north Queensland, Karumba is a community in which experiences strong seasonal fishing pressure generated by interstate tourists taking up temporary residence for the purposes of fishing (Hart and Perna, 2008). Identification of the tourist driven fishery in Karumba allowed Hart and Perna to make management suggestions which addressed the increased level of fishing effort within the community. If the impacts of grey nomads are occurring in other communities in Australia, fine-scale management plans such as this is needed to monitor and manage impacted fish populations.

Determining the grey nomads' motivations for visiting coastal communities will help fisheries managers incorporate the needs of the community while ensuring the sustainability of the fishery. Fishing may direct travel of the grey nomads; however other factors which contribute to the community need to be considered. For example, place attachment may also influence the movements of grey nomads. Place attachment is a result of the emotional bond formed by an individual through interactions associated with the site (Milligan, 1998). Further, the relationships between grey nomads may create a tourist community which has social and emotional value. In other words, while a combination of multiple travel motivations may currently keep the tourist industry in these small communities working, individually each motive may not fully sustain the needs of the grey nomads. Identifying social drivers as well as specific fishing trends may help managers predict likely changes in effort, and in turn, customize management plans for specific species and communities.

Species Monitoring

Barred javelin (*Pomadasys kaakan)* is a prime target species for recreational anglers and an important by-product for commercial fishers in Queensland. The Queensland recreational sector harvests over 100 t annually, with a further 350 t of *P. kaakan* captured and released (Zeller, 2007). In comparison, QDAFF fishery status reports stated that 22 t of annual commercial inshore finfish catch consists of javelin (*Pomadasys spp.)* (Department of Employment Economic Development and Innovation, 2011*)*. Clearly, *P. kaakan* are experiencing high levels of fishing effort by the recreational sector state-wide. However, monitoring of species-specific effort needs to identify not only state-wide impacts, but also regional pulses of effort by the recreational sector.

Regional monitoring has been used to obtain preliminary harvest information of *P. kaakan* for some small communities. In Rockhampton, Queensland, 'CapReef' (a regional community-based organisation) determined 13.9% of the recreational catch was composed of *P. kaakan* making it the second most landed species in the region (Sawnyok, 2008). High regional fishing pressure has also been demonstrated between Cardwell and Ayr, north Queensland, by preliminary evidence from voluntary catch logbooks which show that *P. kaakan* is the second most landed species by recreational anglers in this region (R. Tobin, 2003, unpublished data). Further identification of other communities which experience high levels of effort is needed.

This chapter addresses the first aim of this thesis: to develop a recreational fishing profile of Lucinda, QLD. This will include a demographic and motivational profile of visiting tourists, as well as identify trends in fishing behaviour, including identification of target species and seasonal fluctuations in effort.

Objectives

1. Identify the seasonal demographic and motivational profile of the tourist anglers that visit Lucinda, QLD;
2. Identify the catch characteristics of the tourist anglers, including species preferences and spatial and temporal patterns of effort; and
3. Compare methods of collecting harvest data at a regional scale.

Methods

Two different types of data were collected to create a profile of the fishing community in Lucinda: 1) tourist demographics (i.e. age and origin) and motivations; and 2) harvest description for the local and tourist recreational fishery. The demographic and motivation data were collected mainly via face-to-face surveys of tourists staying at Wanderer's Holiday Village (from here referred to as the "Caravan Park Survey", Appendix 1). A small component of demographic information (origin) was also collected via access point, intercept surveys of anglers at Dungeness Boat Ramp – a five lane boat ramp which allows access to inshore creeks, the Hinchinbrook Channel and offshore areas within the Great Barrier Reef World Heritage Area (GBRWHA), (from here referred to as the "Boat Ramp Survey", Appendix 2).

The harvest description was collected via the Boat Ramp Survey, as well as via volunteer angler logbooks and single trip catch cards (Appendix 5). These methods collected angler fishing trip information, i.e. catch composition and time spent fishing (effort), and assisted in examining different strategies to obtain catch and effort information from anglers utilising the Hinchinbrook region.

Survey Development

Initial drafts of the survey questions for both the Caravan Park and Boat Ramp Surveys were developed based on the study objectives and preliminary catch and effort data collected previously in Lucinda by the Centre for Sustainable Tropical Fisheries and Aquaculture, James Cook University (JCU) to ensure compatibility of data for analysis. A draft was evaluated by JCU research staff members and volunteer anglers to estimate the completion time and complexity of the questions. The edited draft of the Boat Ramp Survey was pilot tested with approximately 20 anglers at Dungeness Boat Ramp in Lucinda to assure practicality and ease of interpretation, before being finalised.

Tourist Demographics and Motivations

The Caravan Park survey was semi-structured, composed of a series of closed-ended questions to ensure quantitative results were available to allow comparison, as well as some open-ended questions to allow room for detail where required. Demographic questions collected information including age, length of stay, origin and motivations for travel to Lucinda. "Origin" was described based on the location of respondents' permanent residence, and grouped as 'Local' (within 100km of Lucinda), 'Non-local QLD' (>100km from Lucinda but still within Queensland), and 'Interstate' (i.e. anywhere outside of Queensland). No international anglers were encountered during the course of this study.

Motivational questions investigated the importance of fishing, both generally and for specific species, to anglers visiting Lucinda during the peak fishing season. Questions were developed to create profiles of tourist families or couples and explore travel motivations including why they chose Lucinda. Tourists travelling to Lucinda to fish were then asked a series of questions to determine if they were targeting a specific species and the course of action they would take if that species were no longer available (e.g., if management changes prevented catch or if populations declined).

Catch Characteristics

Fishing trip data were collected including start and finish times to establish effort, plus target species and actual catch. Anglers could list more than one target species with each response counted in equal proportion. Some of the catch results from this survey, including length frequency and sex of *P. kaakan*, are addressed in Chapter 3.

A zoned map was created to include in the Boat Ramp Survey to understand the distribution of fishing effort and to improve the accuracy of identification of locations fished for each trip (Figure 2-1). The map was developed in consultation with anglers residing at Wanderer’s Holiday Village to ensure familiarity to the respondents, ease of reference by including and naming all major estuaries and land marks, and appropriateness of size of the zones. Each zone was coded with a letter to assign the location in the channel and subsequent distance from the mouth of the channel (with A and B being closest to the Dungeness Boat Ramp and E being the farthest away), and a number to identify those fishing in the main channel (#1) as opposed to those fishing in adjacent creeks and rivers fishing (#2) (Figure 2-1).

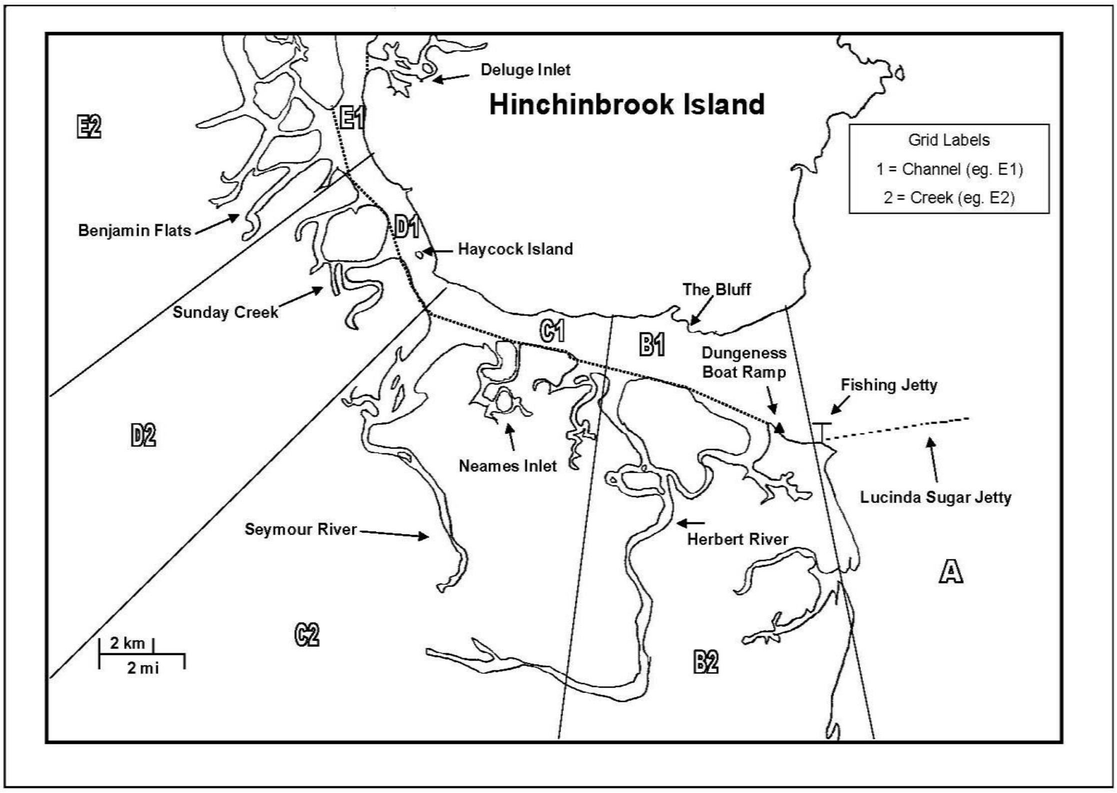


Figure 2-1 Map of Hinchinbrook Channel with designated zones

The final Boat Ramp Survey was then adapted into two different formats to test different methods of data collection: face-to-face on-site surveys, and catch cards. Face-to-face surveys were conducted on-site at the Dungeness Boat Ramp. Given that this is the main ramp in the area, surveys on-site were likely to sample a high proportion of the anglers accessing the southern Hinchinbrook region.

Individual catch cards collected information about a single fishing trip. These were also available as voluntary logbooks, which consisted of multiple catch cards in one book, allowing individual anglers to collect information for multiple trips. Logbooks were kept by individual anglers who volunteered to record daily fishing activities during their entire holiday period at Lucinda. The logbooks were provided in a folder which also contained a description of the project, a zoned map to chart locations fished, researcher contact information and detailed instructions. Contact information was collected from participating anglers to allow for periodic updates and reminders.

All catch cards and logbooks were formatted to be easy to follow and complete, and were printed on waterproof paper to encourage use on the boat as opposed to at the end of the trip, to reduce recall bias. Catch cards and logbooks were also identified with a unique identification number rather than angler name to ensure angler anonymity, which aimed to encourage anglers to provide more honest answers.

Distribution Methods

Caravan Park Surveys

Caravan Park Surveys were conducted during the 2010 high tourist season from June to September at the Wanderer's Holiday Village. These surveys, in agreement with the managers of the caravan park, were face-to-face interviews with the visitors of the caravan park. Surveys were conducted after 2 pm to increase the probability of anglers being present at their caravan site. Each caravan site that was occupied was visited and occupants were given the opportunity to respond to the interview. Each survey took an average of 10 minutes to complete.

Boat Ramp Surveys

Boat Ramp Surveys were conducted bimonthly (at a minimum) for one year (June 2009 - December 2009) with additional surveys at times of high seasonal angler activity (primarily June-August). Preliminary data collected from September 2007-April 2009 were also used in this study, and was collected by the Centre for Sustainable Tropical Fisheries and Aquaculture, JCU. Sampling days were chosen randomly but included weekend and week days to ensure adequate coverage of diverse day types, where public holidays were categorised as a weekend day, as defined by Pollock (1994). The length of time spent surveying at the ramp was based on the amount of traffic accessing the Dungeness Boat Ramp on any given survey day. Surveys were conducted at Dungeness Boat Ramp for a minimum of four hours, from 10 am to 2 pm, when anglers were more likely to be encountered returning from fishing.

Catch Cards and Logbooks

Catch cards and logbooks, including the zoned maps, were formally presented to the recreational anglers occupying Wanderer's Holiday Village at a barbeque held at the beginning of the 2009 fishing season. This gave the anglers an opportunity to openly provide feedback on the survey questions and logbook formats, as well as provide exposure of the project itself to the public.

Catch Cards were made available at the Wanderer's Holiday Village and visitors were encouraged to examine them upon check-in. Additional cards were also made available at the boat ramp when the researcher was present. Anglers returned completed catch cards to the Wanderer's Holiday Village receptionist, from whom the cards were collected monthly by the researcher.

Logbooks were also provided to willing volunteer anglers in Wanderer's Holiday Village and at the Dungeness Boat Ramp. Supplemental logbook pages were available upon request. Anglers returned completed pages and logbooks upon trip end to Wanderer's Holiday Village or directly to the researcher. On request, anglers could obtain a record of catches for the entire trip via mail at the end of their trip.

Analysis methods

Data resulting from the surveys were subjected to basic descriptive analysis within Microsoft Excel. Responses to demographic and motivational, as well as catch characteristic questions were analysed using chi-square tests (using SPSS) to determine any significant differences between origin categories.

Specific species within the harvest descriptions were combined to create "species groups" due to the nature of the responses given by the anglers: Many respondents did not identify individual fish to a species, particularly when discussing target species, and only gave the common name (e.g. javelin or bream) which can include more than one species (e.g. "Javelin" includes *Pomadasys argenteus and P. kaakan*). The species were categorised by the researcher into 14 species groups with those that were listed by less than ten people placed into the "Other" category (See Appendix 5 for species in each category).

Catch Per Unit Effort (CPUE) was calculated by dividing the number of landed fish by the number of anglers on each trip, and by the number of hours fished. This was then multiplied by the average length of a standard trip (for Lucinda, the average fishing trip was five hours) to standardise the unit of effort. Trends of CPUE were compared and analysed using Analysis of Variance (ANOVA) using Statistica.

Results

A total of 59 face-to-face Caravan Park Surveys were completed at Wanderer's Holiday Village over a single weekend during the peak tourist season in 2009. The park had reached capacity at the time and approximately 50% of the tourists at the park were surveyed. Families or couples staying at the same site in the park were counted as one respondent. Only two of the occupants approached refused questioning, giving a response rate of 96.7%.

A total of 386 access point Boat Ramp Surveys were completed between September 2007 and December 2009. Data collected before April 2009 is additional data collected by the Centre for Sustainable Tropical Fisheries and Aquaculture, JCU. These additional data did not include the place of residence (i.e. ’origin’) of the anglers; therefore the origin of 41% of the total respondents is not known.

Seasonality and Demographics

Activity on the boat ramp and the origin of the angler varied seasonally. The high tourist season is demonstrated by the percentage of full capacity of Wanderer’s Holiday Village from August to December. Data regarding park capacity was not available prior to August of 2009. This coincides with an increase in activity on the boat ramp (Figure 2-2) and a pronounced increase in Interstate anglers (Figure 2-3). The level of activity on Dungeness Boat Ramp differed significantly throughout the year (chi-squared= 36.256, df= 12, p= .000). It should be noted that the utilisation of the boat ramp also decreased during summer months.

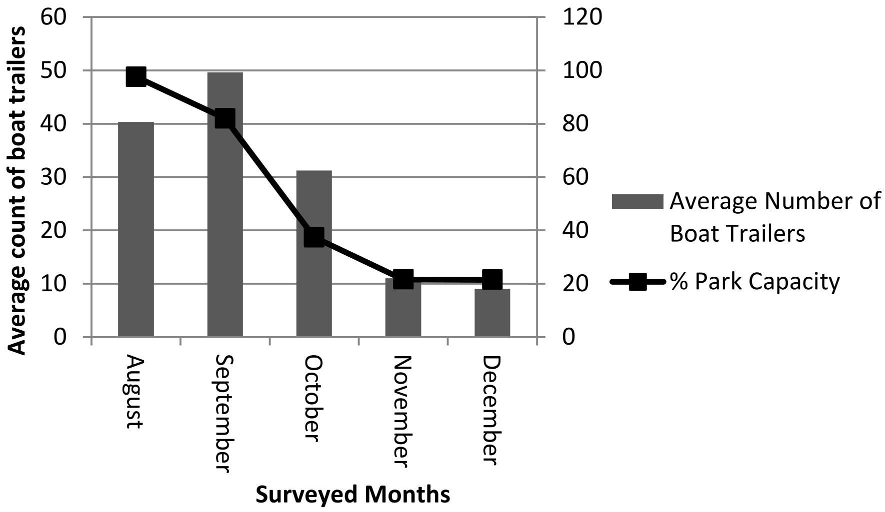


Figure 2-2 Average number boat trailers in the Dungeness Boat Ramp parking lot during surveyed months in 2009 and the percentage of capacity of Wanderer's Holiday Village

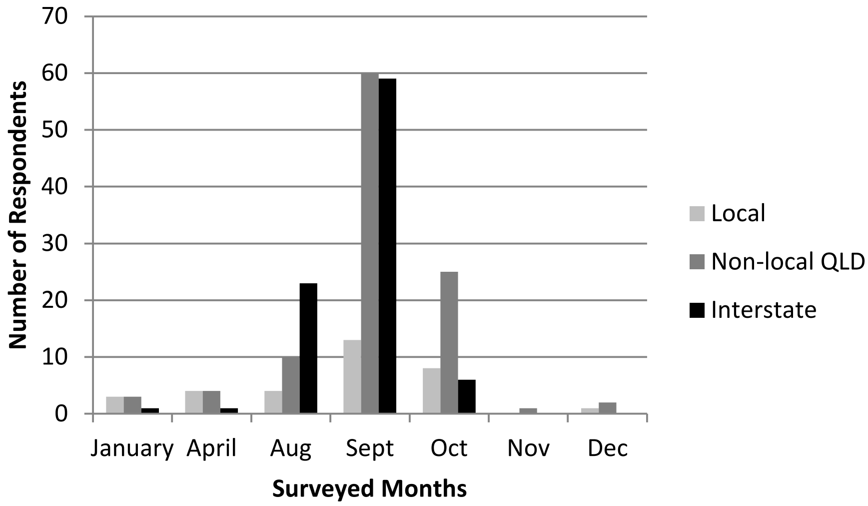


Figure 2-3 Seasonal fluctuations of utilisation of Dungeness Boat Ramp by recreational anglers from around Australia

For the anglers surveyed at the boat ramp, chi-squared analysis indicated angler origin was dominated by Non-local QLD (46%) and Interstate (39%) anglers with few Local anglers encountered (14%) (Figure 2-4) (chi-square=36.587, df=2, p=.000). The observed fishing effort was dominated by tourists, with this group recording nearly six times as much effort as local anglers during the high tourist season.

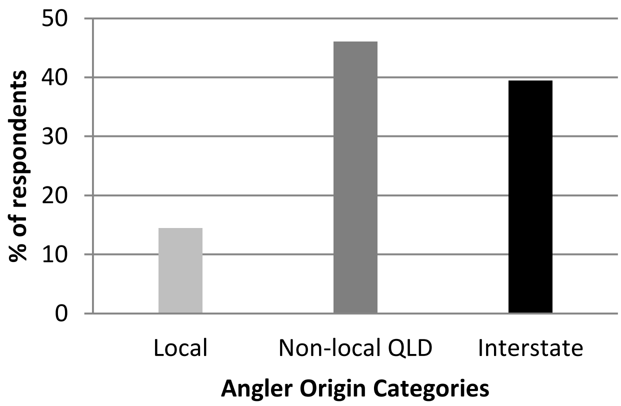


Figure 2-4 Recreational anglers' origin category based on boat ramp surveys from April-December 2009

For those surveyed at the caravan park, respondents predominantly resided permanently outside QLD (Interstate= 74%; Non-local QLD= 26%) (Figure 2-5). All of the respondents were over the age of 50 years old, with 84% over 60 years of age.

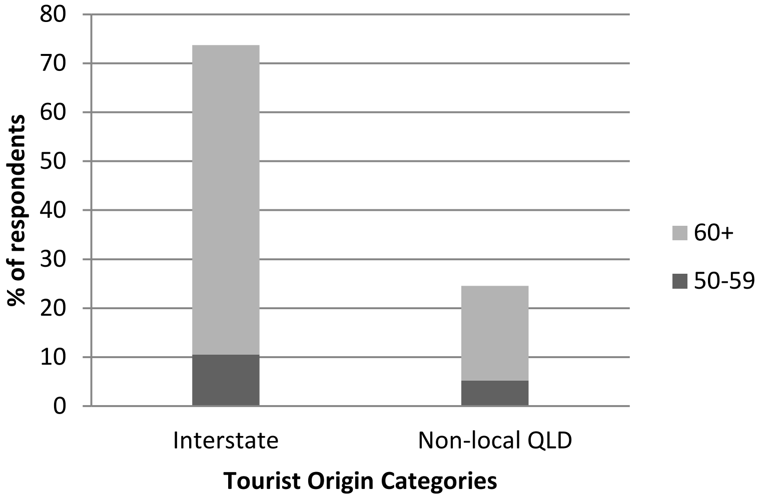


Figure 2-5 Tourist origin category and age demographic for Wanderer's Holiday Village

The avidity of surveyed anglers varied significantly with origin (chi-squared= 42.222 df=8, p=.000). Although Local anglers represented all avidity classes relatively evenly, Non-local and Interstate anglers were more likely to be highly avid anglers (Figure 2-6). This was particularly apparent for the Interstate anglers.

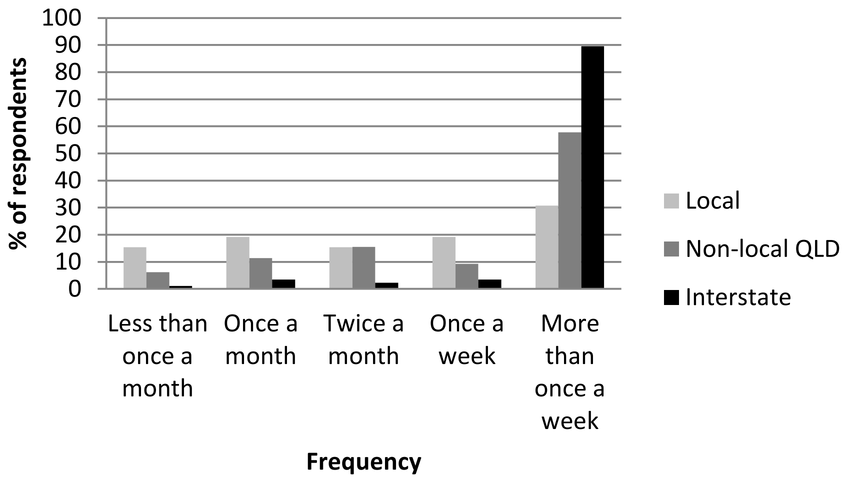


Figure 2-6 Avidity and origin categories of recreational anglers

Motivations and Holiday Characteristics

Total holiday time (i.e. time spent away from their permanent residence) for each respondent in the caravan park averaged between 5 and 6 months. Tourists spent from 2 days to 7 months, with an average of 2.5 months in Lucinda specifically. On average, the Interstate tourists stayed an additional 3 weeks longer than the Non-local QLD tourists. Interstate tourists spent all or over half of their holiday time in Lucinda (59%) while Non-local QLD tourists spent just under half (48%) of their holiday time in Lucinda

(Figure 2-7). It should be noted, however, that of the Non-local QLD tourists, 50% stayed in Lucinda for less than 25% of the time (Figure 2-8). Interstate tourists, on average, also returned to Lucinda for more years (Average 6.6 years) than the Non-local QLD group (Average 3.6 years). The repeated visits and extended length of time spent in Lucinda indicates a strong attachment to area by the tourists.

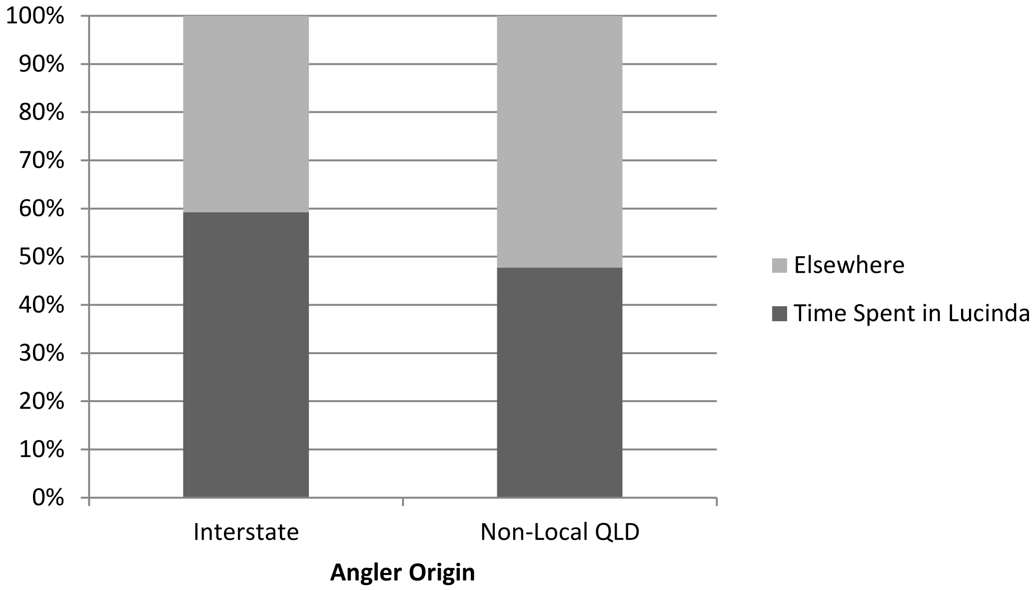


Figure 2-7 Comparison of the percentage of Interstate and Non-local QLD visitors' entire holiday spent away from their permanent residence, and relative time spent in Lucinda

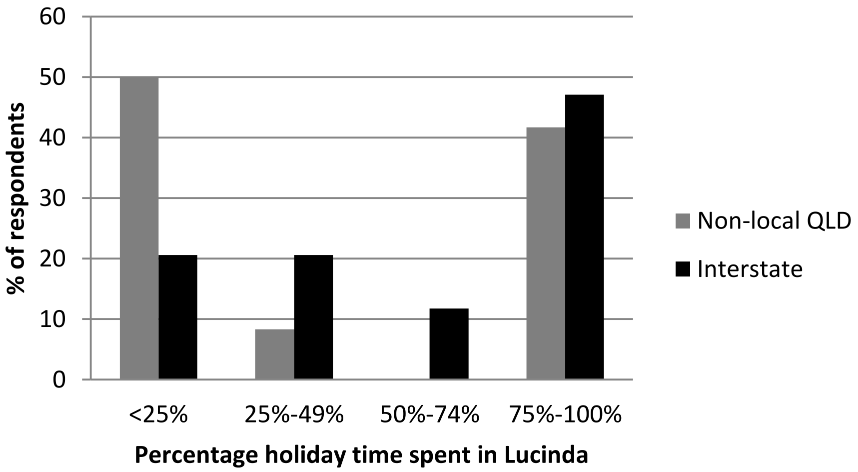


Figure 2-8 Percentage time respondents spent in Lucinda relative to the amount of time of their entire holiday

When asked an open-ended question regarding their reasons for travelling to Lucinda, 10 different reasons were listed by respondents. However, the largest group of respondents said that the main reason for travelling to Lucinda was for fishing (44%) followed by socialising (20%) (Figure 2-9). Many of the respondents who returned to the caravan park every year came to Lucinda to see friends they do not see any other time of the year. This pattern remained consistent when divided into tourist origin categories. Respondents also named multiple secondary reasons for visiting Lucinda. Importantly, fishing was mentioned by 80% of the respondents, either as a main or secondary reason. Reasons listed by <5% of respondents in both visiting demographics were grouped within the “Other” category. These activities included golf, rest and the beach.

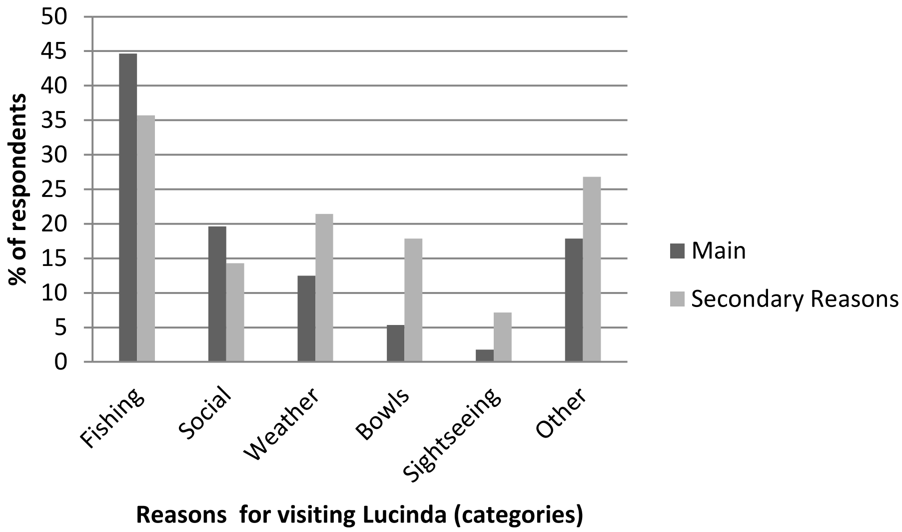


Figure 2-9 Reasons and motivation of respondents for choosing Lucinda as a holiday destination

Respondents who had stated that fishing was one of the reasons for choosing Lucinda were then asked if they came to this area to target a specific species. A majority of these tourists (81%), regardless of origin, said that they were fishing “for anything, more for the activity” but some of these respondents (19%) further stated they target some specific species, such as javelin, just “not very intensely and are happy with anything” (Figure 2-10).

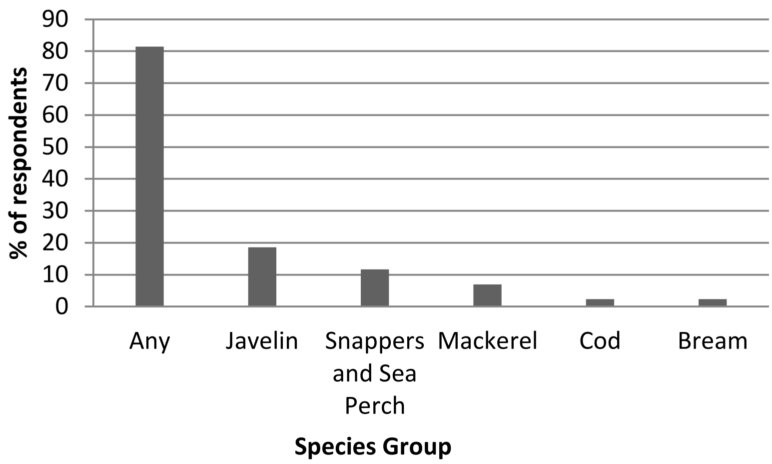


Figure 2-10 Fishing target species for fishing-motivated tourists at Wanderer's Caravan Park

Fishing-motivated tourists were then asked if their target species, may it be a specific species or "All" fish (i.e. they just wanted to catch any fish), were not available what their course of action would be. Over half of these tourists said they would "stay in Lucinda and still fish" (55%). Some anglers would not continue to fish in Lucinda: 17% stated they would "stay in Lucinda but do something else entirely", and 14% stated they would "choose another location and target a different species". It should be noted that many of the tourists stated that the fishing was an "added bonus" that contributed to a total reason for coming to Lucinda. Many said they noticed a diminished quality of fishing over the past few years or pointed out the particularly wet winter season in 2009 that prevented them from going on fishing trips; however they still planned on coming back the following year because there were other reasons to be there. These statements were offered voluntarily rather than in response to a specific question, and hence are not quantifiable.

Target Species

Target species were evaluated from the information collected via the Boat Ramp Survey. This survey included anglers staying at Wanderer's Holiday Village as well as locals and day trip anglers. Twenty different species of fish were listed by the respondents as preferred target species. Most anglers targeted "all species" (49%). Of those that were targeting something specifically (51% of all anglers that listed a specific target), javelin was the most commonly favoured target species (22% of all anglers; 44% of those that listed a specific target). The other categories were listed by fewer anglers (<10% of all anglers) There was a significant difference between the number of anglers targeting each species (chi-square= 397.875, df= 6, p= .000). The results were not significant when the target species were further categorised by the origin of the angler (chi-square= 13.121, df= 12, p=.360) (Figure 2-11). The Local anglers responded with a fewer number of species; however, this may be impacted by the low number of Local respondents (n=34).

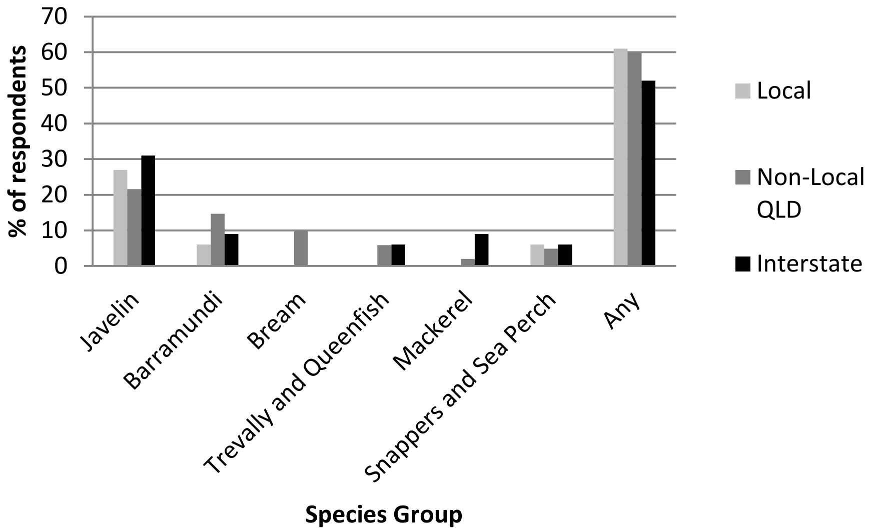


Figure 2-11 Boat Ramp Survey-Target species by angler origin. Anglers were allowed to name multiple species without indicating level of preference

Looking more closely at javelin species specifically, a higher percentage of the Local angler respondents (29%) were targeting javelin as opposed to the Interstate and Non-local QLD groups (18% and 8%, respectively), (Figure 2-12), (chi-square= 12.299, df= 2, p= .002).

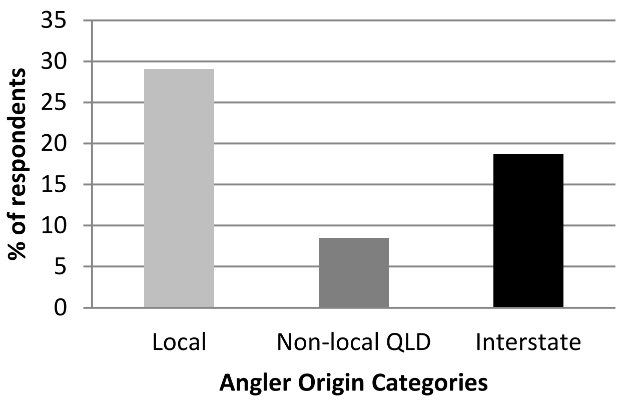


Figure 2-12 Percentage of anglers from each origin category that were targeting javelin

Fishing Locations

A significant number of respondents (49%) fished either around the Lucinda Fishing Jetty (Figure 1, Zone A) or in the zone closest to the boat ramp (37%) (Figure 1, Zone B). The proportion of surveyed anglers fishing in each zone decreased with increasing distance from the boat ramp. When the origin of the anglers was compared to the zones that were fished, the locals were the only demographic that strayed from this pattern as they stayed nearer the boat ramp (Zone B) as opposed to moving towards the jetty (Zone A). Locals were also more likely to travel the farthest away from the boat ramp (Figure 2-13) (chi-square= 17.104, df= 8, p= .029).

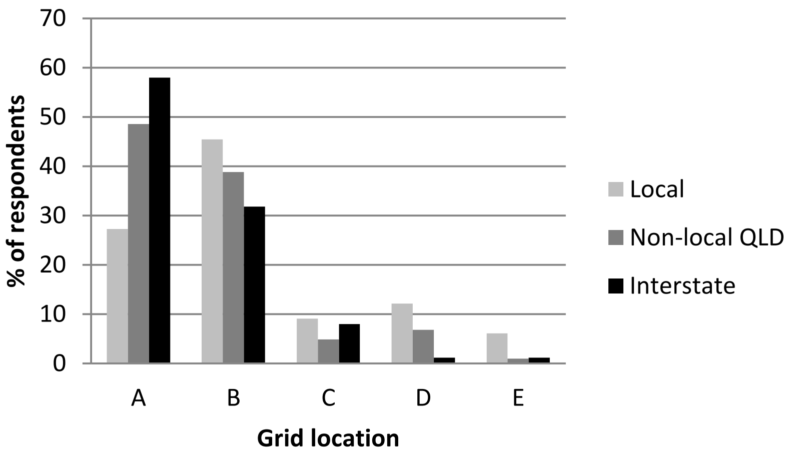


Figure 2-13 Fishing locations utilised by anglers within and around the Hinchinbrook Channel

Fishing locations were also identified as “channel” fishing or “creek” fishing. Channel fishing (i.e. between the mainland and Hinchinbrook Island) was significantly more preferred (67%) (chi-square= 12.578, df= 1, p=.000), regardless of the origin of the angler (chi-square= .505, df= 2, p= .777), (Figure 2-14). Only Zones B-E were used for this category.

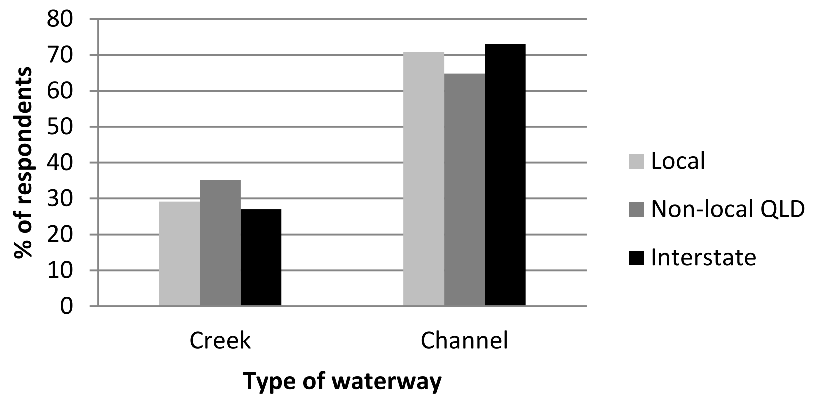


Figure 2-14 Percentage of anglers utilising different waterways within the Hinchinbrook Channel

Catch Composition

Catch composition was evaluated from the information collected via the Boat Ramp Survey. Total catch was more species diverse than the target composition, with 93 different species recorded. A majority of the catch consisted of species within the Bream (22%) and Javelin (15%) species groups. The remaining species groups individually accounted for less than 15% of the catch.

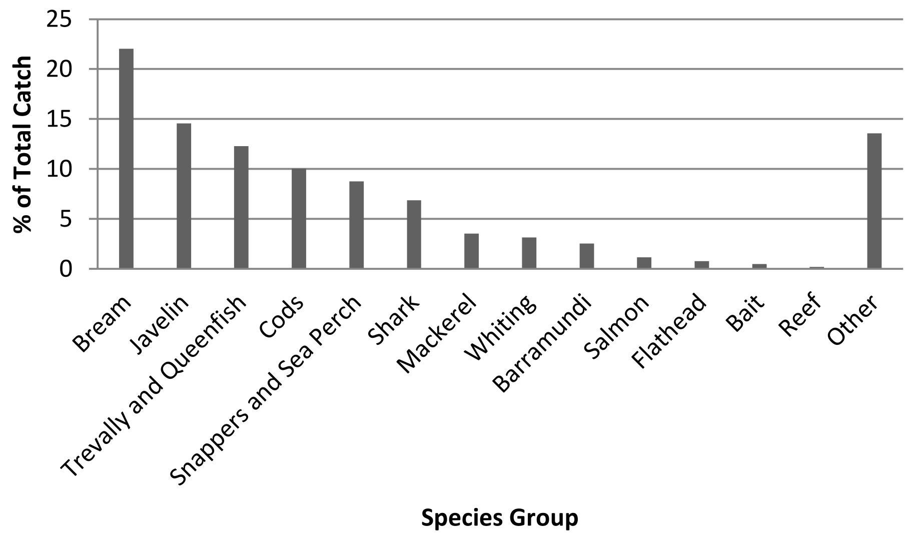


Figure 2-15 Boat ramp Surveys-Actual catch by species groups for each angler for a single trip

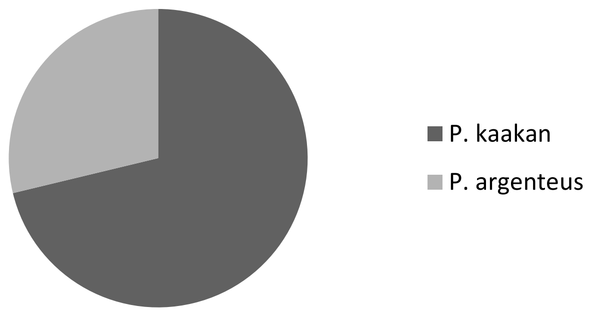


Figure 2-16 Boat Ramp Surveys – Actual retained catch of Pomadasys species for each angler for a single trip

Catch composition varied significantly among the angler origin categories (Chi-square= 263.306, df= 36, p= .000). For the Interstate anglers, the most commonly caught groups were the Trevally and Queenfish (23%), Other (21%), and Javelin (19%) species groups. For the Non-local QLD group, the Bream (36%), Javelin (18%), and Trevally and Queenfish (9%) species groups were high on the list, while the Local anglers caught Javelin (35%), Other (18%), and Cod (11%) species groups. It should be noted that the javelin species fell into the top three highest catch groups for all angler origins. Catch composition of Javelin varied significantly among the two observed species, *P. kaakan* and *P. argenteus* (Chi-square= 13.164, df= 72, p= .000).

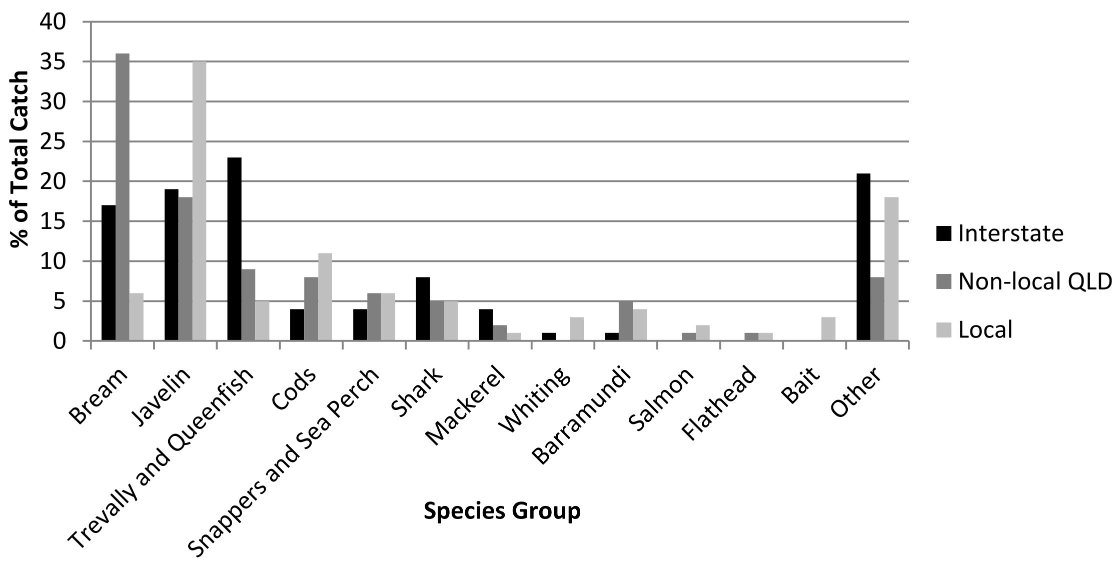


Figure 2-17 Actual catch species groups for each angler for each trip distinguished by angler origin

Catch per Unit Effort (CPUE)

Comparison of CPUE trends from April 2008 to December 2009 showed an increase in catch rate, for both kept ($F_{1,7}$= 5.50, p <0.05) and released ($F_{1,7}$= 7.76, p <0.05) fish, for all species during the summer months of 2008/09 and the high tourism winter months in 2008 (See Figure 2-18). There was also a spike in catch rate in October of 2009.

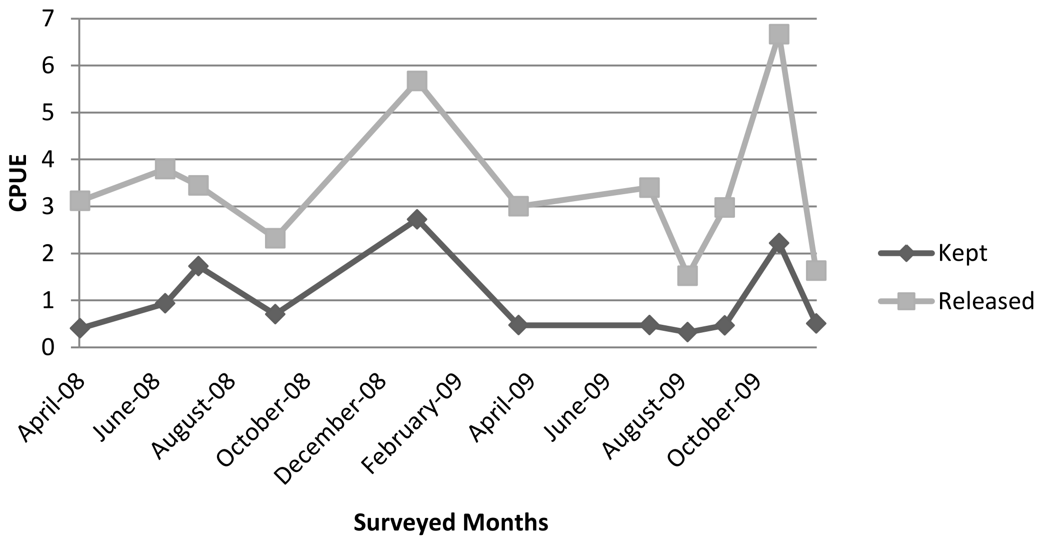


Figure 2-18 CPUE rates for all species of fish between April 2008 and December 2009

When the data were separated to explore CPUE for javelin specifically, the trends were not immediately apparent. There was a significant peak in the CPUE for released javelin during October of 2009 and another smaller peak in August 2009, but no seasonal trends (Figure 2-19). Further inspection of raw data revealed 2 anglers who reported over 20 released javelin in October. These data points were removed to determine if the outliers were affecting the ability to identify trends, however still no trends were identified.

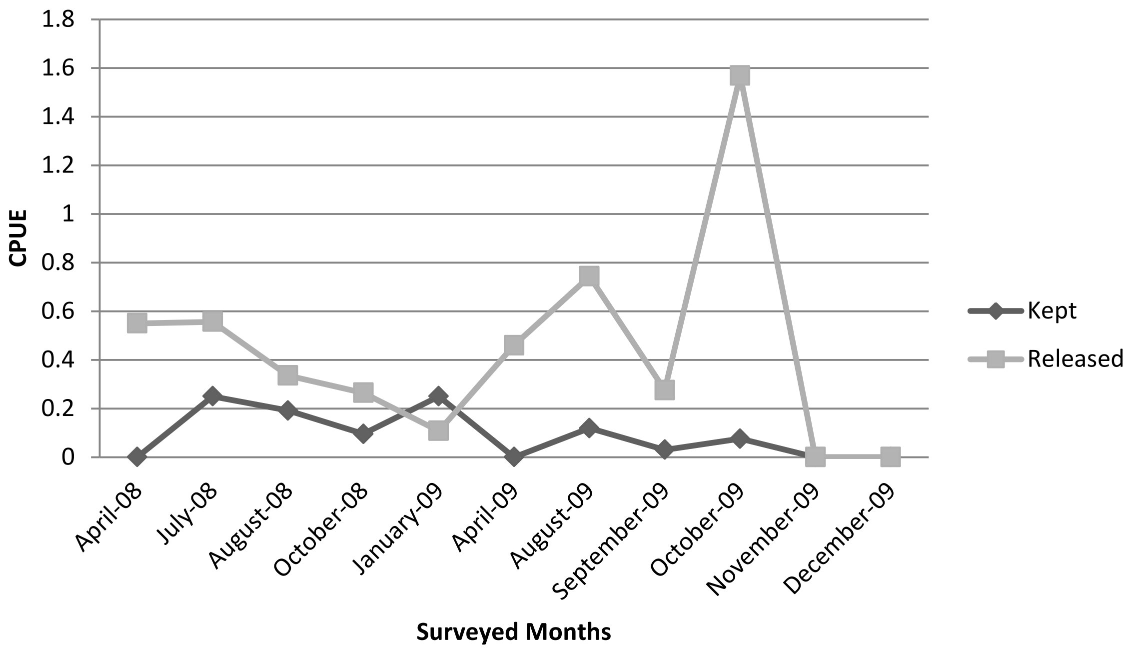


Figure 2-19 CPUE rate for javelin between April 2008 and December 2009

Logbooks and Catch Cards

Fifteen logbooks were distributed over the course of the study. Of these, four books were returned in person at the boat ramp during the Boat Ramp Surveys. Only one book had completed trip data representing six days of fishing. Seven catch cards were taken by anglers from either Wanderer's Holiday Village or from the researcher on the boat ramp, with five cards returned. Resulting data were insufficient to include in analysis.

Discussion

The relationship between the high amount of activity on the Dungeness Boat Ramp during winter, the corresponding high percentage capacity at Wanderer's Holiday Village and the demographic profile of tourists within Wanderer's Holiday Village demonstrates the presence of seasonal grey nomad-driven fishing pressure in Lucinda. These findings have important implications for both the local fish populations and the local community of Lucinda, as discussed here.

Grey Nomads and Their Travel Motivations

Of the 96 individuals interviewed at Wanderer's Holiday Village, all but two fit the definition of grey nomad defined by Brayley and Obst (2010): i.e. they were 50 years of age or older and tour within Australia for a minimum of three months by caravan.

Discussion of grey nomads from here includes Non-Local QLD and Interstate anglers. Interestingly, the grey nomads visiting Lucinda travelled for a longer time period than the stated definition, highlighting both the importance of the region as a travel destination for grey nomads, as well as the potential impact this demographic may have on the surrounding environment. This potential impact depends in part on the motivations of grey nomads for coming to the region.

Most of the grey nomads taking temporary residence in Wanderer's Holiday Village chose Lucinda for both the fishing in the region and the social aspects of staying in the park. It is the combination of these factors which draws these tourists to the area, however, not one factor independently. The social networks developed by the grey nomads year after year hold a strong bearing on their attachment to place and lead to return visits in the future (Hwang et al., 2005; Gross and Brown, 2008). Fishing is an activity that may provide the key way to interact and strengthen social cohesiveness through shared experiences with other members of the caravan community (Kearney, 2002). The constant repeat visitation of the grey nomads in Lucinda is fostered by not only the strong bond with the destination itself, but also with other grey nomads with similar mobility and interests – a common trend with this demographic (Trauer and Ryan, 2005).

This combination of motivations likely relates to stated reactions of grey nomads given a hypothetical decrease in fishing quality. If the quality of fishing and fish populations, regardless of species, were to decrease or if managers were to increase management restrictions many of the grey nomads said they would still come back to Lucinda the following year but what they would do with their holiday differed between individuals. Over half said they would still fish regardless of the quality of fishing, while a small percentage suggested they would focus on other social based activities substituted for fishing. While ongoing visitation is beneficial for the Lucinda community, the potential transfer of fishing pressure from one species to another if fish populations decline or access to a given species is restricted could affect the sustainability of the entire ecosystem (Post et al., 2002; Sutton and Ditton, 2005). Given that the fishing motivations in Lucinda for this demographic are mostly fuelled by shared experiences and not the quality of fishing, the amount of effort will likely not see a decrease in the coming years.

Interestingly, this positive social sentiment was absent when the anglers were surveyed at the boat ramp. The attitude on the boat ramp was one of frustration when the targeted species, or any desirable species, was not caught. When asked about the success of the fishing trip, if no fish were caught, many stated that “there are no more fish; we will not be back next year”. These statements were offered voluntarily and hence were not quantifiable, but nevertheless are important to consider. The presence of these statements at the boat ramp but absence during the face-to-face surveys in the caravan park may be a result of the timing of the initial questionnaire which was administered immediately after the fishing trip. The lack of strong reaction of the grey nomads in the caravan park may be related to the recall bias that occurs between the fishing trip and the interaction with the surveyor. During this period the memory of frustrations from the trip are dulled and the social aspect of the visit has been refreshed (Berntsen and Rubin, 2002). More evidence of this is provided in the supplemental responses given by the grey nomads in the caravan park including the “overall quality of fishing here has gone down the past few years but we still go out and try. Gives you something to talk about”. The positive memories of the experience support the idea that even if the quality of fishing were to decrease, the overall memory of the visit is positive thus a return visit would be more likely.

In addition, a majority of respondents stated they were happy to “get a bite, maybe something for dinner” but were not necessarily targeting a specific species. The indifference of actual species caught, indicates that grey nomads would not necessarily be directly affected by further controls on specific species. Motivations for fishing for a specific species were suggested but not strongly, and thus stringent management plans for potentially impacted species would not deter the tourist population from the activity. Despite this, consultation with stakeholders should be implemented given the social importance of the sport to the grey nomad community.

One of the changes in management made during the course of the study was an increase in the minimum legal size (MLS) and bag limits for *P. kaakan*. In March 2009 the minimum size limit was raised from 300 mm to 400 mm and a bag limit of 10 was imposed where there previously was no limit (Queensland Department of Agriculture Fisheries and Forestry, 2012). It was possible that this change in size and bag limit may impact the CPUE of legal sized fish. However, the CPUE data for the entire study period, which included time before and after the management changes, did not show any change in pattern. Anglers did not mention the 2009 size limit change specifically; however, some anglers informally stated that the current size limit needed to be higher. This suggests that the grey nomads would likely return to the area despite further harvest controls.

A previous study completed in Karumba to examine the link between the status of the environment and tourist demographics determined that a decrease in the quality of fishing would deter many grey nomads from returning to the site. Short-term success of the tourism industry in Karumba was dependent on the attainment of a sustainable fishery through effective fishery management plans. Research highlighted the importance of a diversification of tourists who do not fish, thus relieving pressure on regional fish populations while still maintaining the economic benefits of tourism to the local community (Stoeckl et al., 2006). Specific characteristics of Karumba create a more volatile tourist industry than that in Lucinda. For example, the isolated nature of Karumba means the attraction to visit must be great in order for tourists to make the trip (Prideaux, 2002). Given Lucinda's location on the east coast and relative proximity to the major townships of Ingham and Townsville, Lucinda is comparatively non-remote. When one respondent was asked if he would choose another location to fish if the quality was to decrease in Lucinda, he said "Where? Like Karumba? That's an even further way to go to catch nothing!" The lack of activity diversity for the older generation in Karumba was also a factor. Very few of Karumba's grey nomads left the caravan park unless it was to fish (Stoeckl et al., 2006). Lucinda's grey nomad population, on the other hand, often takes advantage of sightseeing opportunities and lawn bowl facilities. The diversity in activities Lucinda has to offer suggests grey nomads are likely to return regardless of fishing quality or changes in access. This difference in motives and opportunities is important to consider when investigating tourist-based fishing communities.

Fine-scale Impacts and Target Species

Lucinda likely forms a representative snapshot of what similar small communities along the Queensland coast are experiencing, such as what has been shown in Karumba (Hart and Perna, 2008). Discrete fisheries that exist in small tourist-centric towns such as Lucinda are unrecorded, meaning management plans do not account for the seasonal fluctuations in effort and catch of specific species. Identifying the target species impacted by these fluctuations is important to ensure monitoring and management are including all the components of the fishery.

Certain characteristics of grey nomads potentially add to the impact this demographic may have on local fisheries. Grey nomads form socially cohesive groups, spending significant social time together sharing information, which may create a learning community that encourages angler skill development for a specific area. Adding their high avidity and extended length of stay in Lucinda to their social cohesiveness (Cridland, 2008), grey nomads have substantial capacity to develop a high level of knowledge of local fishing locations and techniques. This heightened level of fishing knowledge for a small area such as Lucinda could potentially create an influential demographic that is efficient at harvesting large quantities of fish within a relatively small amount of time. This is a particular issue if they are targeting key or vulnerable species.

This study has confirmed a high proportion of the pulse, tourist effort is focused on targeting javelin including *P. kaakan.* A substantial proportion of the grey nomads said they targeted javelin, and javelin were the subject of a much discussion when the topic was raised. Weekly competitions occur at Wanderer's Holiday Village for popular target species including javelin, further highlighting the social importance of the species. Given the importance of javelin to the grey nomad community, research needs to be conducted on how the species copes with high levels of fishing pressure. This information will help managers develop an appropriate level of management while still incorporating the value of the species to the grey nomad community.

Actual catch of javelin was also high, as a kept and released species. Without data to monitor these catch rates over time, including records of CPUE, impacts to the regional population of javelin in Lucinda may be subtle and are currently undetectable. Given the high proportion of the catch that is released, further information is also needed to establish the post-release mortality rates for javelin. *S*imilar communities in Queensland and around the nation that experience selective pressures on important recreational fisheries are not identified, and thus may be under the threat of localised overexploitation.

In addition, areas of high fishing effort on *P. kaakan* may be targeting spawning aggregations. Specific locations in the Hinchinbrook Channel were identified as preferred fishing spots by tourist anglers thus increasing the concentration of fishing pressure to select, fine scale areas. Tourist anglers repeatedly chose to stay close to the boat ramp around the Lucinda Sugar Jetty or across the channel to an area known as "the Bluff". The effects this may have on local fish populations needs to be explored. Based on trends of overexploitation of aggregating species that occur in very select and predictable areas such in Lucinda, the potential for overfishing is high (Garrett, 1997; Turnbull, 1997; Johannes and Conservancy, 1999; Claydon, 2004; Sadovy, 2008). Identification of spawning aggregations is particularly important in areas such as the Hinchinbrook channel which experience high levels of spatially concentrated fishing pressure.

Further research needs to be conducted to determine the movements and genetic structure of *P. kaakan* along the Queensland coast. Garrett (1997) and Keenan (1997) conducted preliminary studies to describe the distribution of estuarine fish species, including *P. kaakan,* in the Gulf of Carpentaria. Results suggested *P. kaakan* have localised restricted distributions. As a result, Garrett suggested that Gulf-wide management regimes would not be appropriate to manage the population. If the same situation is occurring in the Hinchinbrook Channel then the spatial selectivity of grey nomads fishing habits may require management tailored to the region.

Further research accounting for the variability in targeting behaviour in relatively small areas needs to be conducted. A Fisheries Queensland study completed in 2008 conducted a series of bus route, access point intercept surveys in the Brisbane surrounding area. This survey was used to fine tune the four previous RFISH surveys and provide detailed estimates of localised fishing activity. Within the designated route, target species between the boat ramps differed significantly. While snapper (*Pagrus auratus*) was targeted at one location, it was not targeted or landed at another boat ramp less than 10 kilometres away due to changes in angler targeting behaviour (Webley et al., 2009b). For the large area of the Hinchinbrook Channel, the potential for highly diverse angler targeting behaviour is noteworthy. If there is a high concentration in effort on different target species within a relative small region, various species and the surrounding ecosystem may be at risk.

Survey Method Review and Management Practicality

Recreational fishing research and monitoring is confronted with multiple challenges, including challenges in access to anglers and expense of monitoring (Committee on the Review of Recreational Fisheries Survey Methods, 2006). While not the sole focus, this study explored multiple methods of increasing contact with anglers within Lucinda. This in turn provided useful insight into effective monitoring methodologies that would reduce recall bias, increase response rates and improve the accuracy of collected data.

Boat ramp surveys were successful in capturing a high proportion of the recreational anglers in the area and provided useful data in this study. The value of using boat ramp surveys for determining catch and effort for the recreational fishery was recently noted in a study by Zischke et. al. (2012) in south-eastern Queensland. Zischke used access point surveys to monitor the catch of the spatially and temporally variable sport fishery. Estimates from the study were able to identify catch for yellowtail kingfish (*Seriola lalandi)*, Spanish mackerel (*Scomberomorus commerson)* and wahoo (*Acanthocybium solandri)* were significantly higher than that of commercial fishery, but had not been previously monitored. While boat ramp surveys are an expensive method for monitoring, they are effective at collecting a substantial portion of the catch and effort of the recreational fishery at a local scale.

The voluntary logbooks had a very low response rate in this study and were not able to be used for data analysis. Constant contact with diarists is needed in order to for this method to be successful and the magnitude of this contact was unattainable given other obligations of the overall study. RFISH was able to maintain contact with diarists via quarterly newsletters and telephone follow up (McInnes, 2008). To complete a logbook program on a state-wide level would require significant amounts of labour in order to maintain contact with recreational anglers and large financial foundation for printing and mailing costs. Projects which utilise logbooks are expensive (Pollock et al., 1994; Department of Employment Economic Development and Innovation, 2008), however, these costs are low compared to costs that would be required for a Queensland coast-wide boat ramp survey. A second problem encountered with the logbook program was the general feeling of unimportance to the anglers. Despite encouragement that no catch was still data, all four respondents felt that the logbooks were not worth filling out because “it was not like they were catching anything”. Education and ongoing contact with participants regarding importance of data collection would be needed.

Although QDAFF’s RFISH program records catch and effort information for Local and Non-Local QLD anglers, at the time of this study the diary coverage was not substantial enough to determine the fluctuations in effort at a regional level, thus neglecting the fishing pressures anglers impart on specific areas, such as Lucinda. Improvements to the current survey methods are needed to increase sample size and coverage, as well as understand where the effort is being placed and by whom. Alternative methods, such as those outlined by Griffiths et. al. (2010), include relatively inexpensive online diaries or time-location sampling (i.e. conducting surveys in areas other than boat ramps where recreational anglers may frequent, such as a tackle shop). These methods also present monitoring challenges such as lack of participation by anglers and under coverage due to increased online purchasing of fishing equipment respectively; however this could be the first step in creating a system that encompasses all the spatial and temporal requirements of a complete harvest description.

The collective amount of effort and fish harvest Queensland residents expend on state coastal waters complete only a portion of the needed information to conserve commonly targeted species and their habitats. Strategies for managing the effort and catch of local anglers are unlikely to be directly transferable to non-local anglers. The availability of a complete sampling frame, such as a list of anglers through a recreational fishing license database, would help increase the effectiveness of monitoring schemes by including all anglers regardless of origin. This method, however, still risks under coverage due to non-response issues (Tuckel and O'Neill, 2002).

Conclusion

In summary, pulses of high fishing pressure occur in Lucinda with predictable seasonality. This fishing pressure is driven by the movement of the grey nomads – a group currently unmonitored and hence not considered in fishery assessments in Queensland. The specific nature of this fishery in terms of the relatively high level of effort in a concentrated fishing area needs to be taken into account when devising monitoring priorities. The cohesive social networks developed by grey nomads, including the associated potential for increased local knowledge and likelihood of continued fishing despite declines in fishing quality, further implicates the grey nomads' potential impact on the region. In addition, intense targeting behaviour on *P. kaakan,* a species known to form spawning aggregations, increases the potential for negative impact. Overall, the potential high impact of these unrecorded fishing pulse communities has the potential to have an irreversible negative effect on regional fish populations, in particular for *P. kaakan* in this case.

The current management plans are based on an underestimate of harvest data and are too broad to identify fine-scale management issues including concentrated seasonal fishing pressures. Future management plans throughout Australia need to implement monitoring schemes which include interstate travelers and identify communities similar to Lucinda. This will enable the development of regional strategies which maintain the specific needs of a regional ecosystem and the industry.

Chapter 3 Biological Characteristics of *Pomadasys kaakan*

Introduction

Documenting and understanding the life history characteristics of important fishery species is critical for effective management. Particular life history characteristics, including reproductive capacity, growth and longevity, influence a species susceptibility and/or resilience to exploitation. Characteristics such as the relative life span of heavily targeted species, rate of off-spring production and age at which maturity occurs can indicate where species fall on the r- and K- selected spectrum which reflects how a species will cope with impacts including fishing pressures (Pianka, 1970; Department of Environment and Resource Management, 2012).

The previous chapter confirmed that *P. kaakan* is an important target species that is significantly harvested in the winter pulse fishery in Lucinda. Chapter 2 also indicated if the fishery is exploiting a spawning aggregation, the population may risk overexploitation. This chapter redefines the life history characteristics, including growth parameters and reproductive traits, of *P. kaakan.* Chapter 3 also investigates the catch characteristics of *P. kaakan* for the recreational and commercial sector, as well as modeling the productivity of the species with varied levels of fishing effort and management controls.

The life history characters of *P. kaakan* have been previously defined for a population in the Townsville region (Bade, 1989) as well as the southern Gulf of Carpentaria (Garrett, 1997). *P. kaakan* was depicted as K-selected (in this case, a slow rate of maturation and high vulnerability to impacts such as fishing pressures) species by both studies; however, Garrett's results identified a slower growth rate than Bade (1989). Updated age and growth data is needed to ensure appropriate and accurate information is available. Bade's (1989) method of using scales as opposed to otoliths to age individuals is considered to under-estimate age (Nedreaas, 1990; McBride et al., 2005; Gunn et al., 2008; Horká et al., 2010). Changes in growth have also been attributed to variations in fishing pressure (Moore et al., 2011) exemplifying the need for identification of spatial variations in growth and fishing pressure. A comparison of the results given by Garrett (1997) would help identify any changes in growth that may occur for *P. kaakan* based on these impacts.

Most coastal fisheries species are harvested by two co-occurring fisheries sectors – the commercial and the recreational sector. A description of catch characteristics for each sector is needed for appropriate management (Tobin and Mapleston, 2004), yet there is no information to identify if each sector harvests similar or different components of the population. Updated and complete harvest reports for the recreational fishery, along with current commercial reports, will help managers determine the efficiency of current management and assist in development of future plans. This will also help in ensuring a viable industry by modeling the effects biology and catch characteristics play on a species' productivity, and hence a species' vulnerability to exploitation.

In addition, it is thought that *P. kaakan* forms seasonal spawning aggregations (Pears and Russell, 2007), a phenomenon known to increase the vulnerability of fish populations to overexploitation (Russ, 1991; Colin, 1996; Turnbull, 1997; Johannes and Conservancy, 1999; Phelan, 2002a; Claydon, 2004). Fishing which targets spawning aggregations may lead to overfishing and in extreme cases, localised extinction (Sala et al., 2001; Aguilar-Perera, 2006; Phelan et al., 2008). Local anecdote in northern Queensland suggest transient spawning aggregations of *P. kaakan* do occur, are deliberately targeted by anglers and larger catches are made at this time. A section of Bowling Green Bay, located in north-eastern Queensland, was declared a green zone in 2004 due to the high level of fishing pressure imparted on a known grunter spawning aggregation (Joyce, 2006). GBRMPA has identified *P. kaakan* as a high priority research species for the identification and monitoring of spawning aggregations in order to manage fishing impacts (Pears and Russell, 2007).

Inshore species are under constant threat of overexploitation by anglers who have easy access to near shore coastal waters (Stuart-Smith et al., 2008). Management plans are needed that are based on accurate biological characteristics and contemporary data on fishing effort and catch. The biological information for a targeted species needs to be up-to-date in order for fisheries managers to properly monitor and manage for sustainable exploitation. This information coupled with harvest characteristics of both the recreational and commercial fisheries sector will create a comprehensive, detailed report that can be used to make efficient management plans. The data currently available for *P. kaakan* does not meet these criteria, nor has any analysis into the sustainability of the fishing industry been conducted. Current management plans are based on incomplete and out-dated information. There is a critical need to re-evaluate core life history traits to better inform management planning.

Spawning Potential Ratio (SPR)

SPR is a type of Biological Reference Point (BRP), a management tool used to inform the setting of management strategies (Williams and Shertzer, 2003). Different types of BRPs use different proxies, such as biomass levels or natural mortality rate, to estimate a reference point to which exploitation may be limited. Spawning Potential Ratio (SPR) is one type of BRP that incorporates data on life-history traits of a species, as well as combining fishing mortality with natural mortality to determine the optimal harvest levels which maintain sustainability (Goodyear, 1989; Goodyear, 1993). To do this, the SPR model estimates the reproductive potential of a recruit throughout its lifetime and compares the annual egg production in the presence and absence of fishing (i.e. an unfished population). Recently, many papers evaluating life history characteristics of fishery important species have included SPR in their assessments of sustainable use (Kawai et al., 2002; Pember et al., 2002; Slipke et al., 2002; Sun et al., 2002; Vaughan and Carmichael, 2002; Liu et al., 2006). SPR can be used to inform where bag and size limits are set with a goal of long-term sustainability.

For example, Pember et al., (2002) defined the life history parameters for five commercially and recreationally important species of the Pilbara and Kimberly coasts of north-western Australia, with the goal of using this information in an SPR model to determine the efficacy of current management for maintaining sustainability. The results showed that of the five fish species surveyed, the king threadfin (*Polydactylus macrochir)* was considered overexploited, the blue threadfin (*Eleutheronema tetradactylum)* was at the point of overexploitation, while the other three species were apparently sustainable at current fishing levels. The study was able to address the fishing pressure placed on the two threadfin species, and also made suggestions towards precautionary management due to the rapidly increasing targeting and harvesting of mangrove jack (*Lutjanus argentimaculatus)*. Management suggestions included increases to Minimum Legal Size (MLS) and regulations on fishing gear used by the commercial sector. Additional reports emphasising the status of the threadfin species has led to management agencies in Western Australia naming threadfin research a priority (Pember et al., 2005; Welch et al., 2010).

The SPR model is a helpful management tool to evaluate how a species will cope with various levels of fishing pressure based upon the potential productivity of the population, however, up-to-date biological parameters in the SPR model are important to ensure a correct estimation of productivity is calculated. The use of inaccurate reproductive and growth data may lead to inappropriate management (Tsai et al., 2011). In addition to effecting the outcomes of the model, the biological parameters help establish where the point of overexploitation is likely to occur. In a more conservative approach an SPR of less than 0.5 is suggested to reduce recruitment rates to the point of collapse (Walters and Kitchell, 2001; Walters and Martell, 2004). Some species more susceptible to fishing, such as large bodied elasmobranches, including spotted rays (*Raja montagui*) as well as long-lived groundfish, such as monk fish (*Lophius piscatorius*) species, have been conservatively analysed using a low SPR of 0.1 (Le Quesne and Jennings, 2012). The U.S. Fisheries, on the other hand, commonly uses an SPR of 1 or slightly less to identify when a species is considered overfished (National Oceanic and Atmospheric Administration, 2012). In other words, depending on the life-history characteristics of a target species their susceptibility to fishing pressure is variable and needs to be taken into account when using the outcomes of SPR models.

The revisiting of Bade's (1989) life history parameters will determine whether updates are needed for the current biological profile for *P. kaakan.* Further, a biological catch profile for each fishery sector will establish any differences in the catch characteristics of landed individuals. The combination of these two objectives will then be used in the SPR model to determine the level of fishing effort the species will be able to sustain before it is at risk of overexploitation. In addition, in a response to growing recreational fishery effort and catch, the MLS of *P. kaakan* was increased from 30 to 40cm TL in 2008. The outcomes of this management change have not been tested, as such, it is unknown if this change in MLS is effective at sustaining this population. These results will examine the effectiveness of historical and contemporary management.

The previous chapter demonstrated the level of fishing pressure impacting *P. kaakan* in a relatively small area. The resilience of the population to high levels of fishing pressure is directly linked to the life-history characteristics of the species, as well as the catch characteristics of the fishery. This chapter addresses the second aim of this thesis: to define life-history and fishery catch characteristics for *P. kaakan* for input into SPR modeling.

Objectives

1. Re-define the critical life history parameters of *P. kaakan;*
2. Define the contemporary characteristics of *P. kaakan* harvested by all fishery sectors data including length structure; and
3. Model the SPR of current minimum size limits for the recreational and commercial fisheries, including an assessment of the recent increase in MLS from 30 to 40cm using updated biological parameters.

Methods

Collection and Processing

All samples were collected from within the broader Hinchinbrook and Townsville region and were fished from a diversity of inshore habitats including sand shores, inshore shoals and estuarine waters. Commercial and recreational fishers fish the same habitats so analyses of gear effects are not confounded by habitat. Samples of *P. kaakan* were collected primarily from fisheries dependent sources, including both recreational and commercial fishers. Recreational samples were collected from volunteer anglers and from the Wanderer's Holiday Village in Lucinda, Queensland. Recreational anglers occupying Wanderer's Holiday Village utilised a filleting shed and a freezer for disposal of fish frames and gonads. These frozen frames were collected bi-weekly during the peak fishing season, May-August, and monthly during the down season from May 2008- June 2010. Commercial samples were collected by frame donations from volunteer anglers and also from fisheries observers from the Centre for Sustainable Tropical Fisheries and Aquaculture. Observers travelled on-board commercial vessels and collected samples to be processed either on board or taken ashore.

For each sample, recorded data included total (TL) and fork length, total weight, macroscopic sex and development stage, and whole gonad weight. Sagittal otoliths were dissected, cleaned and stored for later aging. Macroscopic staging of the gonads utilised developmental stages identified by West (1990) and Laevastu (1965) (Table 3-1).

Table 3-1 Macroscopic staging of male and female gonads of P. kaakan

Female Stage	Macroscopic Characteristics
Resting	Small and transparent. Yellowish orange in colour. Oocytes no visible through ovarian wall.
Developing	Slightly larger than above. Oocytes visible through ovarian wall.
Maturing	Larger than stage above, occupying half the body cavity. Creamy orange in colour. Large oocytes visible through ovarian wall.
Spawning	Large, occupying half to 2/3 of the body cavity. Extensive capillaries visible in ovarian wall. Hydrated oocytes sometimes visible through ovarian wall.

Male Stage	Macroscopic Characteristics
Resting	Testes small and ribbon like-flat
Developing	Testes white and occupy approximately half the length of the body cavity.
Maturing	No milt appears when pressure is applied to the gonad. Occupies more than half the body cavity.
Spawning	Milt exuded with firm pressure to the testes. Gonads fill 1/3 or more of the body cavity.

Ageing

Age estimates from whole otoliths were compared with estimates from sectioned otoliths to determine the more cost effective and accurate method for ageing *P. kaakan.* Age estimates for 100 fish were utilised to determine the better ageing method. Random samples were chosen over a wide size range to ensure accuracy both in young and old fish. Whole otoliths were immersed in baby oil and read on a blackened background. For sectioning, otoliths were mounted in clear epoxy resin using rubber moulds. A low speed circular diamond saw was used to cut thin transverse sections (.50-.70 mm) through the otolith nucleus which were then mounted on microscope slides with resin and cover slips. Both sectioned and whole otoliths were read under a dissecting microscope using reflected lighting. Otolith annuli were counted to determine the age of the individual. Two readers independently aged the whole and sectioned otoliths to assess the precision of the measurements and maintain objectivity. The whole and sectioned otoliths were read twice and when counts did not agree, discrepant otoliths were read for a third time. If agreement still was not achieved the otoliths were omitted from the data set. Comparison of whole and sectioned otoliths revealed the whole otolith ageing method consistently underestimated the age of the individuals. As a result, 167 sectioned otoliths were used for all age based analysis.

Data Analysis

Basic Life History Analysis

The von Bertalanaffy growth equation was fitted using a least squares regression of TL on age with the following equation:

$$L_t = L_\infty\,(1\text{-}e^{-K\ (t-t0)})$$

where L_t is the total length at age t, L_∞ is the mean asymptotic length, K is the growth coefficient or rate at which L_∞ are approached, t is the age of the fish and t_0 is the age at which the fish have a theoretical length of zero.

Hoenig's (1983) equation for natural mortality (M) was used in SPR analysis to estimate the given parameter:

$$Log_e\ M = 1.46\text{-}1.01\ log_e\ t_{\max}$$

where t_{max} is the longevity in years.

Reproductive characteristics were determined using only mature fish. This included length frequencies categorized by sex. The Gonadosomatic Index (GSI) was estimated for mature females to identify spawning season.) The Gonadosomatic Index (GSI) is calculated by expressing gonad mass as a percentage of body mass:

$$GSI = \frac{Gonad\ Mass}{Whole\ Body\ Mass}$$

SPR model

Productivity estimates were generated using the SPR model developed by Goodyear (1989). Goodyear's model uses age categories to group the proportion of mature females in a population and the mean weight of the females. However, to work with the data available, TL categories were used in increments of 40mm beginning at 70mm (i.e. 70mm-110mm was used in place of age class -0) (Ault et al., 2008). The standardized model first estimates Spawning Stock Biomass according to the equation:

$$SSB/R = \sum_{t=t_m}^{t_{\max}} \left(fr_t \times W_t \times e^{-\sum_{i=0}^{t-1}\left(M+\left(F_t \times V_t\right)\right)} \right)$$

where fr_t is the proportion of females mature for length class t, W_t the mean weight of females at length class t, M is the natural mortality rate, F_t is the fishing mortality rate at length class t and V_t is the vulnerability at length class t. The spawning potential ratio was then estimated as:

$$SPR = \frac{SSB/R}{SSB/R_{F=0}}$$

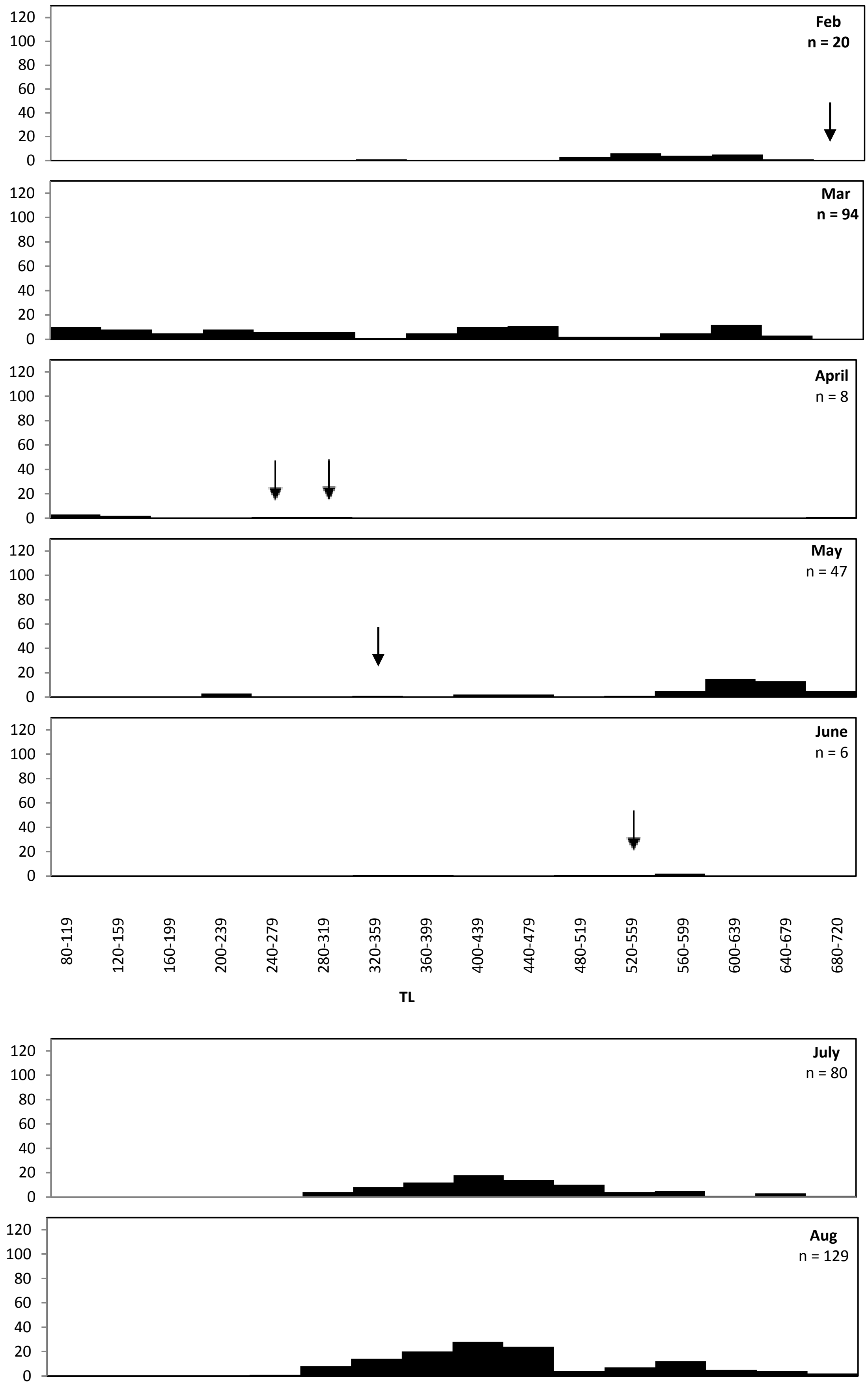
SPR for each fishing sector and MLS scenario was estimated under different levels of fishing pressure (F = 0 to F = 1.5, in increments of 0.1). Different levels of fishing pressure levels were used for each length class dependent on gear selectivity (F_{GEAR}) or management regulations (F_{REG}) From this, three different levels of SPR were calculated and compared: SPR_{ALL} where fishing pressure applied to all length classes equally; SPR_{GEAR} where V_t was determined from length class frequency distributions of each of the fishing sector's catches (the modal length class was used as the length of full selection to the fishery and for each length class below this modal age, a proportion of vulnerability was calculated); and SPR_{REG} where V_t was determined from minimum size limits applied to the fishery pre- and post-May 2009.

Results

A total of 1161 *P. kaakan* were sampled between July 2007 and November 2009. Of these, 733 were obtained from recreational sources while 368 were obtained from the commercial fishery. The remaining 59 fish were collected using fishery independent methods.

Length characteristics

The lengths of *P. kaakan* in the sample ranged from 85 to 715 mm TL (Figure 3-1). The smallest fish were captured in March and April. The largest fish were caught in May and October.


Feb
n = 20
Mar
n = 94
April
n = 8
May
n = 47
June
n = 6
July
n = 80
Aug
n = 129
0
20
40
60
80
100
120
80-119
120-159
160-199
200-239
240-279
280-319
320-359
360-399
400-439
440-479
480-519
520-559
560-599
600-639
640-679
680-720
TL

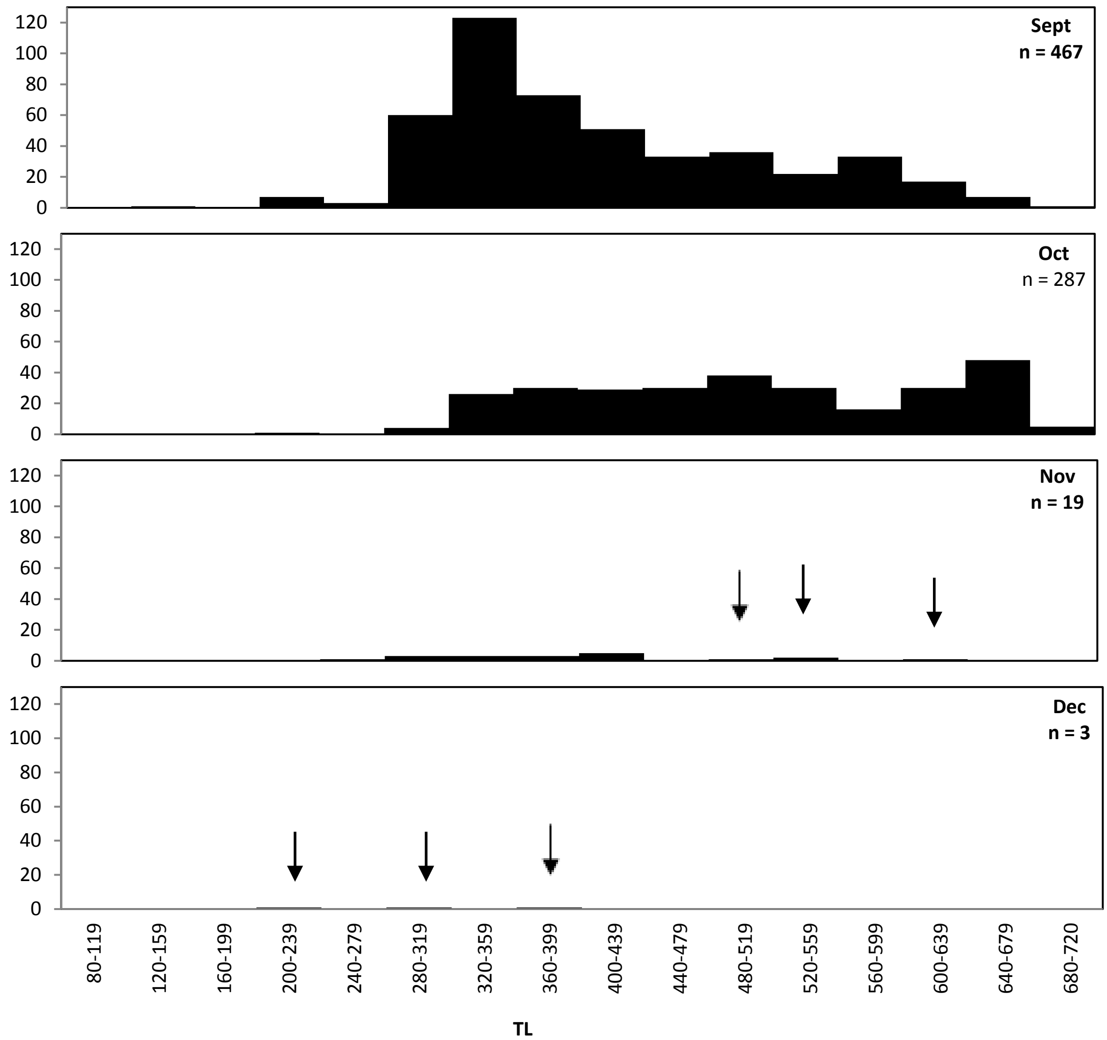


Figure 3-1 Length frequency of P. kaakan categorised by month. Arrows highlight small samples.

Female and male fish were represented across similar size ranges of 198 to 617 mm and 232 to 633 mm fork lengths respectively. However, female fish had a much smaller modal length of TL 320-439 mm, while the male mode was much larger to 600-679 mm (Figure 3-2). Despite this the mean lengths of male and females were not significantly different ($F = 1.07$, $df = 1, 1101$; $p = 0.302$). Similarly, while both the recreational and commercial sectors accessed fish across similar length ranges (198 to 617 mm and 232 to 633 mm respectively), the commercial sector commonly caught large fish (modal length range 600- 679 mm) while the recreational sector more commonly caught smaller fish (320- 439 mm) (Figure 3-3). However, the mean length of commercially harvested fish (534 mm +/- 5.3 mm SE) was significantly larger than the mean length of recreationally harvested fish (417 mm; +/- 3.8 mm SE) ($F = 260.4$, $df = 1, 1101$; $p <0.05$).

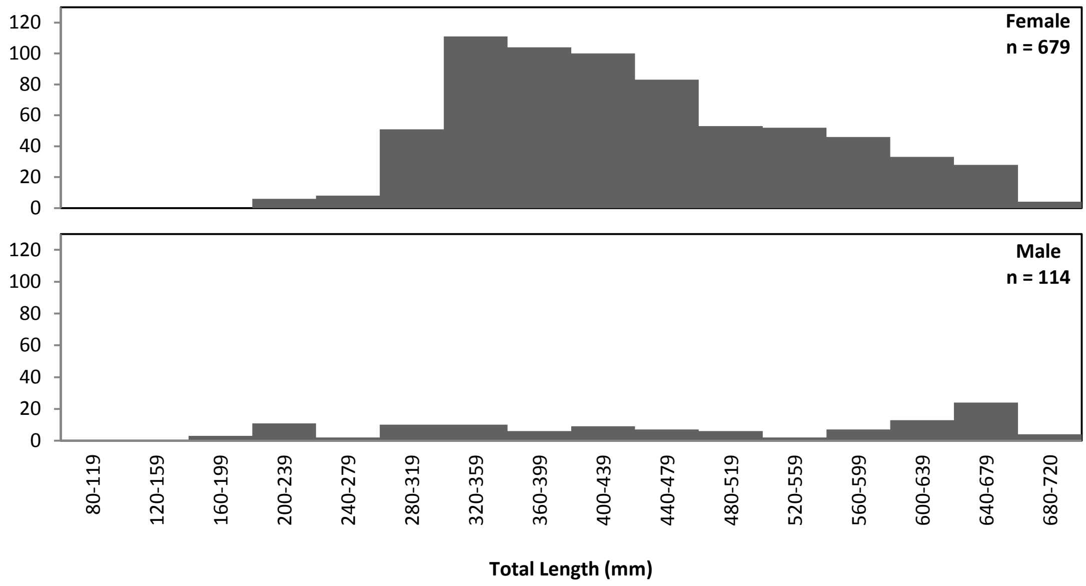


Figure 3-2 Length frequency of P. kaakan categorised by sex

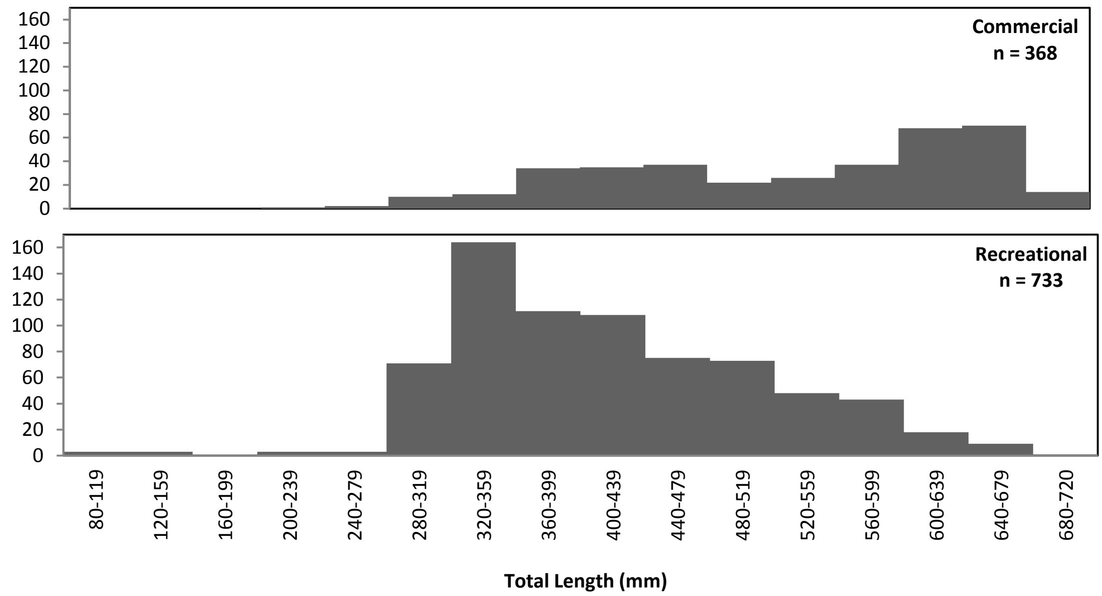


Figure 3-3 Length frequency for P. kaakan categorised by fishery sector

Age and Growth

von Bertalanffy Growth Functions

A von Bertalanffy growth curve (VBGR) was modeled for *P. kaakan* from the length-at-age data derived from aging sectioned otoliths. Growth parameters calculated from the VBGR were K = 0.177 year^{-1}, $L_{\infty} =$ 745.21 mm and t_0 = 0.78832. The growth described via sectioned otoliths varied from that reported by Bade (1989) who utilised scales as an aging method (Figure 3-4). The sectioned otoliths model suggested a slightly lower maximum length and slower growth rate. The equations are as follows:

$$L_t = 746.21 * (1 - e^{-0.177695*(t-0.78832)})$$

Szczecinski

$$L_t = 756 * (1 - e^{-0.243*(t-0.041)})$$

Bade

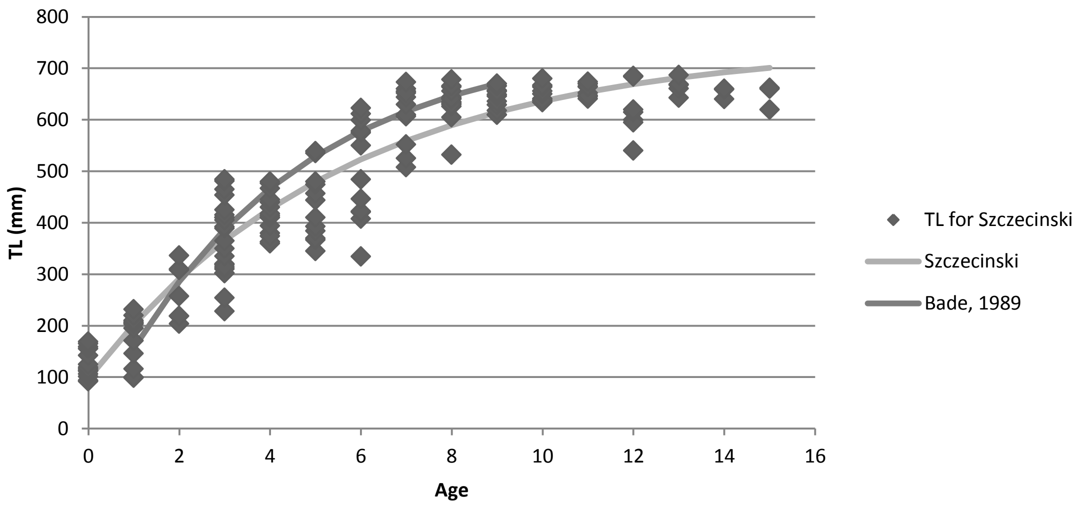


Figure 3-4 von Bertalanffy growth curve for P. kaakan from data for Szczecinski and Bade (1989)

Reproductive characteristics

The sex ratio was significantly skewed towards females in both recreational (chi = 265.1, df = 1, $p < 0.00001$) and commercial catches (chi = 17.2, df = 1, $p < 0.001$). In excess of 15 females were landed for each male in recreational catches, while commercial fishers landed more than 2 females for each male. The sex bias towards females was also consistent across all length classes captured by both sectors (Table 3-2).

Table 3-2 Percentage of males and females of P. kaakan categorised by TL (mm) and fishing sector

	201-300	301-400	401-500	501-600	601-700	Total
Commercial						
n	2	24	64	35	79	204
% Male	0	16.7	15.6	34.3	48.1	31.4
% Female	100	83.3	84.4	65.7	51.9	68.6
Recreational						
n	12	263	163	97	24	559
%Male	16.7	7.6	4.9	3.1	4.2	6.1
%Female	83.3	92.4	95.1	96.9	95.8	93.9

Macroscopic sexing and staging demonstrated that over 50% of the fish sampled were maturing or mature by 280-319 mm (Figure 3-5). Most of the females caught were maturing or spawning, while the males were more likely to be developing. In the case of the male fish, males over 600mm were likely to be mature and running milt (Figure 3-6).

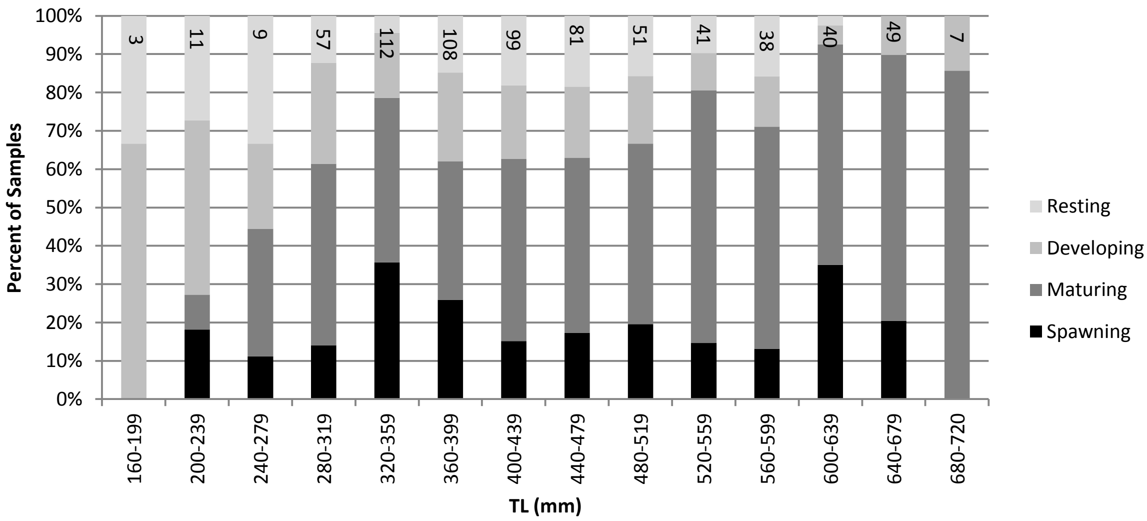


Figure 3-5 Gonad macro staging for P. kaakan for each length group

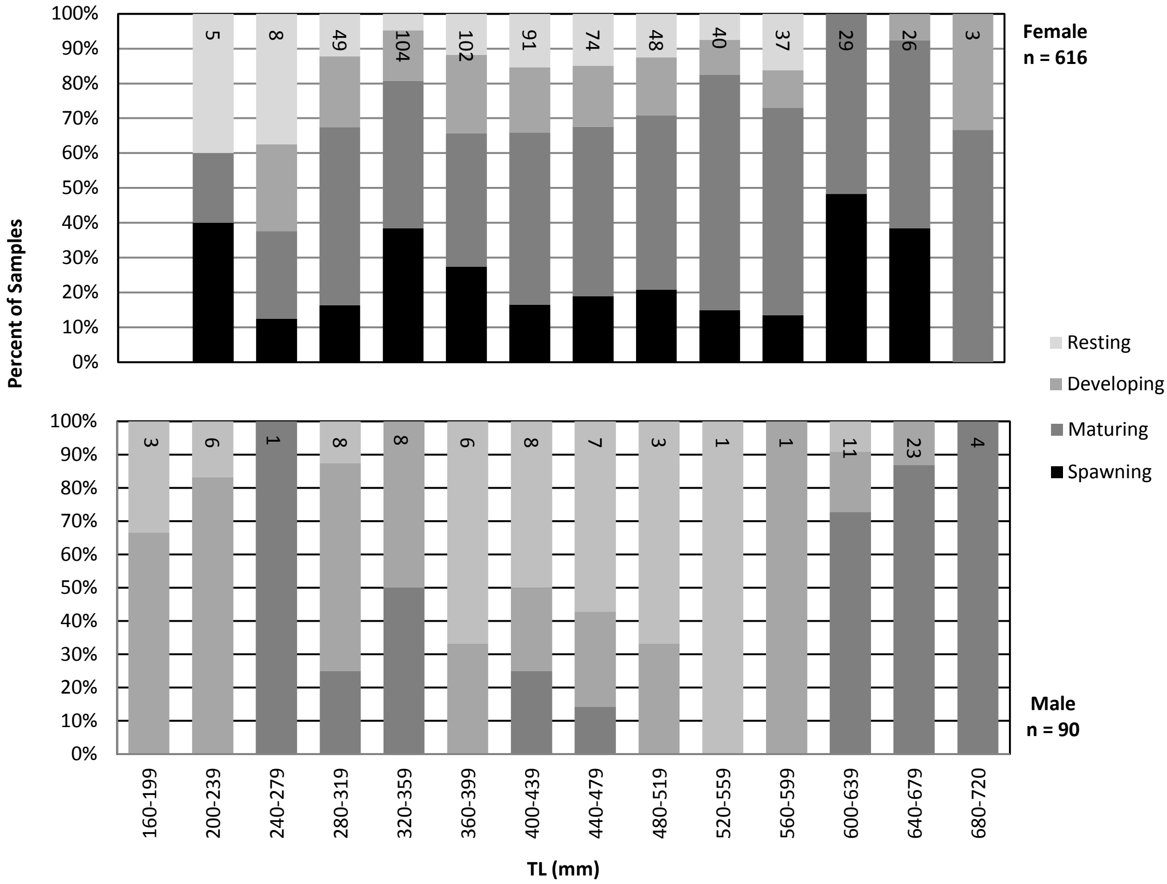


Figure 3-6 Gonad macroscopic staging for P. kaakan for males and females in each length group

Spawning Season

Mature or spawning female *P. kaakan* dominated numerically from August to November. Based on macroscopic gonad staging, over 50% of the females sampled between August and February were classified as having either maturing or spawning gonad stages (Figure 3-7). The female gonadosomatic index (GSI) showed a similar seasonality increasing in July, peaking in September and declining until April. The spawning period for *P. kaakan* appeared to occur from August-March, with a peak in September - October. Too few males were collected for GSI data to be useful for determining seasonal trends in testis maturity.

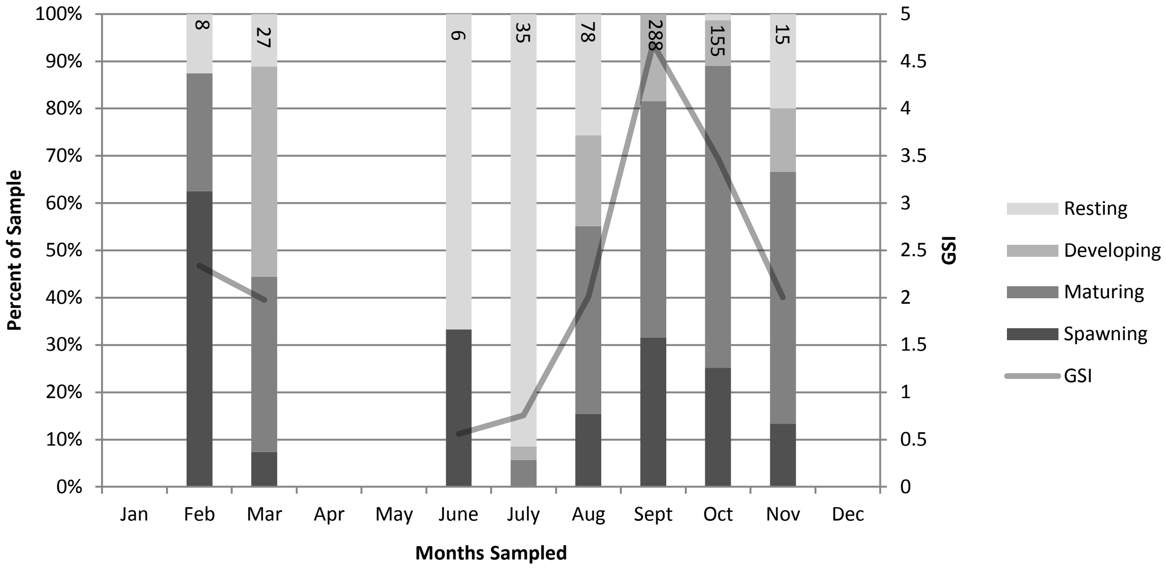


Figure 3-7 Average Gonadosomatic Index (GSI) and macro staging of monthly samples of female P. kaakan

Spawning Potential Ratio (SPR)

The SPR outputs predict that *P. kaakan*'s productivity is influenced by both the selectivity characteristics of each fishing sector, as well as changes in MLS (Table 3-3). The theoretical productivity of a fished population of *P. kaakan* was very low if fishing pressure is applied equally over all available length classes; this scenario replicates a fishery without gear selectivity or size limits (see dashed line in Figure 3-8 and Figure 3-9).

Table 3-3 Spawning Potential Ratio (SPR) values for P. kaakan. Items in dark grey are of low productivity (high vulnerability), light grey are moderate vulnerability, and white are of high productivity (low vulnerability). The symbol * indicates values that were calculated at SPR40.

	SPR_{ALL}	**SPR_{GEAR}**	**SPR_{REG}**
All Fisheries	0.170	0.246	N/A
Commercial	0.172	0.934*	N/A
Recreational	0.163	0.295	N/A
MLS set 300 mm	0.160	N/A	0.516
MLS set 400mm	0.171	N/A	1.11*

When the selectivity of the fishing gears used by each sector was incorporated in the SPR model, the combined effort of recreational and commercial sectors had most impact depressing productivity of *P. kaakan* (Figure 3-8). Considering sector-specific influences, the commercial sector had the least impacts on the productivity of the fished population (i.e. did not reach minimum SPR 20). At the more conservative SPR of 40, F_{Gear} = 0.934. Conversely, the recreational fishery when considered in isolation had an obvious impact on the theoretical productivity of the fished population with an F_{Gear} = 0.295.

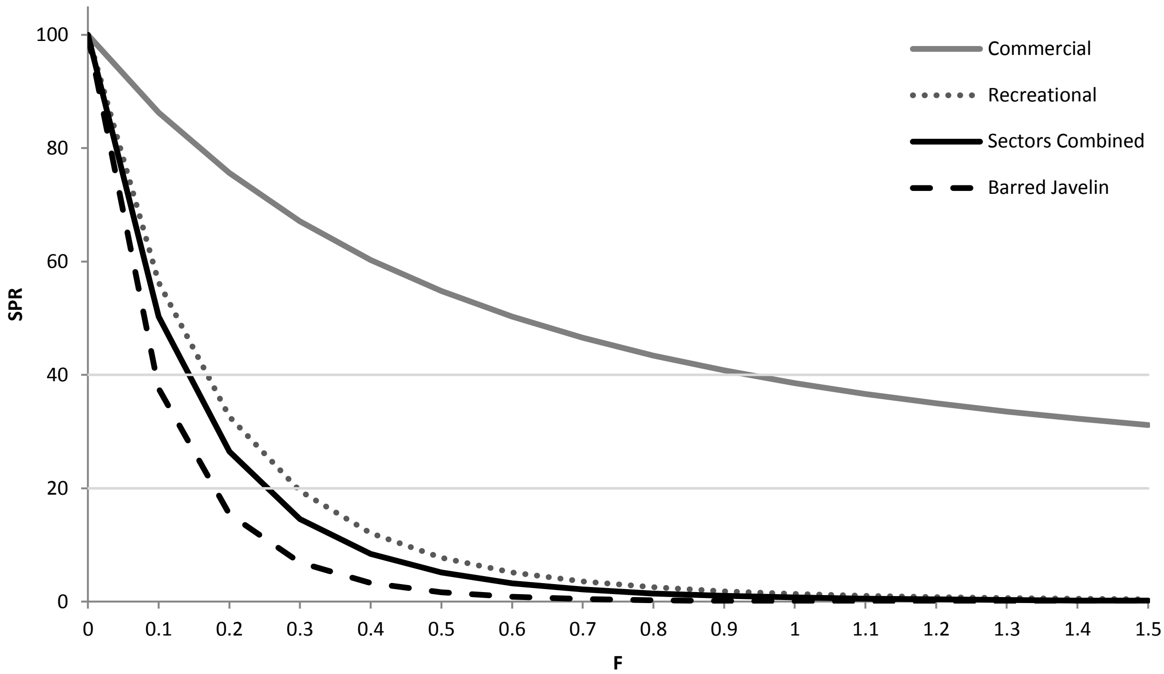


Figure 3-8 Spawning Potential Ratio (SPR) values of the commercial and recreational sectors. Restraints on effects of fishing pressure (F) are implemented due to gear selectivity only. Productivity of P. kaakan with no restrictions on the effects of fishing pressure is also given. Values less than 0.2 were taken to indicate low productivity (high vulnerability), values greater than 0.2 and less than 0.4 indicated moderate productivity (moderate vulnerability), and values over 0.4 indicated high productivity (low vulnerability). These are indicated by the grey, straight lines.

Minimum legal size limits increased productivity of *P. kaakan* hence lowering the vulnerability of the species to overexploitation. The MLS of 300 mm provided enough limitations to fishing pressures that the species may be able to withstand higher levels of effort. A MLS of 400mm further limited catch and hence increased productivity. The modeled SPR indicates the more conservative 400mm MLS increased the theoretical productivity at least two-fold, and possible up to three-fold under the more intense fishing effort scenarios (i.e. F > 1.0).

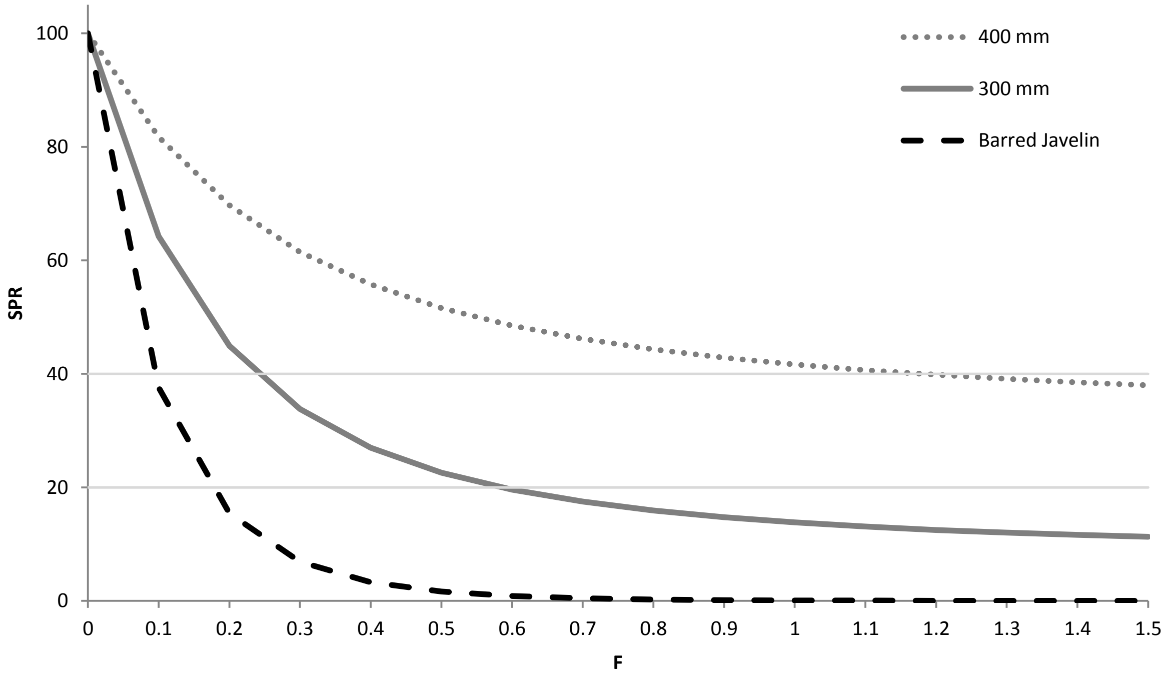


Figure 3-9 The theoretical modeling by the Spawning Potential Ratio (SPR) method, demonstrates the productivity of the fished population of P. kaakan with different Minimum Legal Size (MLS) measures - A no MLS limit scenario (dashed line); B the recently amended MLS of 300mm; and C the current more precautionary MLS of 400mm introduced in May 2009.

Discussion

The impact of recreational fishing on target species such as *P. kaakan* needs to be closely monitored and managed to ensure sustainability. The Spawning Potential Ratio (SPR) model has identified that the less size-selective and female biased harvest of the recreational fishing sector poses a greater risk to populations of *P. kaakan* than the more size-selective less female biased harvest taken by the commercial sector. Given these differences between sector harvests, managing the *P. kaakan* fishery based on the harvest characteristics of the commercial sector alone is unlikely to achieve sustainability goals. Current management plans need to consider the combined effects of both sectors in order to protect populations from overexploitation. Current management, such as bag limits, may be ineffective controls of total harvest and only temporarily control effort (Cox et al., 2002). Monitoring the catch and effort of the recreational sector is mandatory to create management plans that control the harvest to sustainable levels.

Fishing Sector Harvest Assessment

Although the SPR model indicates the spawning potential of the fished population is likely to be most impacted by the recreational fishing sector, the current minimum legal size (MLS) limit of 400 mm resulted in improved the potential reproductive output as compared with the previous 300 mm MLS. This management action is a start in controlling the level of impact on *P. kaakan;* however, the level of fishing effort impacting *P. kaakan* needs to be taken into account. MLS regulations are only temporarily effective at sustaining a species if fishing effort is high (Cox et al., 2002). Determining the current status of the population is a research priority, as well as developing management strategies that will control recreational fishing effort levels.

The level of fishing mortality and total harvest is also currently unknown for both fishery sectors. It is possible that fishing mortality is currently low enough that there are no sustainability concerns for *P. kaakan*. However, given there is a high level of discarding that occurs in the recreational fishery (up to 64% as determined by this study), identifying post-release mortality rates should be considered a research priority. Considerable research has focused on the issue of post-release mortality, and for some species these mortality rates can be as high as 25% (Hall et al., 2012). In any fishery where there are large numbers of fish captured and released due to management regulations (legal size limits) or cultural reasons (catch-and-release fishing) defining the rates of post-release mortality and inclusion of these data into estimations of total fishing mortality is imperative for sustainable management.

Further, given the SPR assumes equal susceptibility to fishing pressure through all length classes, the SPR only approximates the impact of fishing on reproductive potential of the population. Varying levels of fishing mortality has a direct effect on the production and future recovery of a given population (de Lestang et al., 2004; Shelton et al., 2006) and needs to be defined for *P. kaakan*. The results of the SPR model demonstrated the different levels of impact regulations for the recreational sector can have on one species and management choices need to be assessed to ensure they are effective for any given situation.

The female selective harvest by the recreational sector may also negatively impact the ability of a fished population of *P. kaakan* to regenerate itself. Myers and Barrowman (1996) examined the relationship between spawner abundance and recruitment levels for the Clupidae and Salmonidae. They found mean recruitment is higher if the spawner abundance is maintained above the median levels. Changes in the sex ratio affect the potential for future productivity and population size. The recreational catch for

P. kaakan shows a pronounced female bias (15:1). Under intense fishing effort significant changes to the Operational Sex Ratio would be likely, and negatively affect production levels as the probability of individuals encountering mates is reduced, thus reducing fertilisation success and recruitment (Myers and Barrowman, 1996; Rowe and Hutchings, 2003). Sex-selective harvesting has previously resulted in reductions in production of other fish species. Overfishing of the male bluegill (*Lepomis macrochirus)* in the Midwestern United States removed large males from the reproductive cycle. Small males which only produced low levels of sperm were left to propagate the population (Beard et al., 1997; Ehlinger, 1997) and stunted populations resulted due to poor size structure. Management suggestions due to this incident included reductions of anglers to limit effort, as well as spawning season closures as opposed to minimum size limits. Reduction of minimum size limits would not have reduced the total level of fishing effort on the population, and as such, would have been ineffective. The effects the selective removal of females from a population of *P. kaakan* needs to be explored.

The high number of females caught by the recreational sector suggests sexual segregation of *P. kaakan* may occur in the Hinchinbrook Channel. The presence of sexual segregation of teleost fish has been documented in multiple species such as the American eel (*Anguilla rostrata)* and Atlantic salmon (*Salmo salar*), (Wearmouth and Sims, 2008). Differences in feeding behaviour and habitat choice by male and female fish can affect the spatial distribution of a species (Magurran and Garcia, 2000; Robichaud and Rose, 2003; Mucientes et al., 2009; Knip et al., 2012). More research needs to be conducted to determine possible reasons for the high female bias of *P. kaakan* in Lucinda. If spatial segregation of the sexes of *P. kaakan* occurs and sex specific locations can be identified, spatial management may be appropriate for managing the impacts of fishing.

Given the known susceptibility of some fish aggregations to fishing (Turnbull, 1997; Johannes and Conservancy, 1999; Claydon, 2004; Sadovy, 2008), as well as examples where recreational fisheries in particular have been responsible for depleting aggregating fishes (Bolden, 2000; Phelan, 2002a; Aguilar-Perera, 2006), the seasonal pulse fishing of *P. kaakan* should be managed conservatively. It is possible *P. kaakan* aggregate seasonally for the purposes of spawning, and that these aggregations are targeted by fishing. A recent fishery stakeholder workshop identified that *P. kaakan* aggregations are a likely future concern within the GBRMPA, and that these aggregations are known and exploited by fishing (Pears and Russell, 2007). The spatiotemporal characters of such aggregations, if they in fact exist, need to be defined in order for management to protect the population from overfishing and depletion that can occur if fishing continues unabated (Phelan et al., 2008).

Monitoring and Management

Updated biological parameters of *P. kaakan* are imperative to ensure the sustainable management of the species. Previously, only out-dated biological data for *P. kaakan* were available to managers. The importance of ensuring accurate data are used in management plans and productivity assessments can be demonstrated in the comparison of *P. kaakan* growth parameters modeled by Bade (1989) and those presented here. Bade modeled a faster growth rate after deriving length-at-age data from scales as compared with the growth rate modeled from length-at-age data determined by otolith aging by this study. If the SPR model had used the growth defined by Bade, the model would have estimated a less conservative higher productivity and lower vulnerability to fishing for the sectors regardless of gear selectivity or management. Given that scale age readings commonly underestimate the age of individuals (Nedreaas, 1990; McBride et al., 2005; Horká et al., 2010), the update to ageing *P. kaakan* was imperative to obtaining accurate results. With the updated data, more robust management suggestions are able to be developed.

Inefficient management protocols have failed to prevent overexploitation by the recreational sector in species such as barred sand bass (*Paralabrax nebulifer*) and kelp bass (*Paralabrax clathratus*) in California (Erisman et al., 2011). Fishing on spawning aggregations of *Paralabrax spp.* combined with persistent targeting produced a hyper stable relationship between CPUE and stock abundance. This situation masked the collapse of both species, but demonstrated the difficulties with monitoring a species which aggregate to spawn. Research has identified *P. kaakan* also participate in spawning aggregations (Pears and Russell, 2007). If appropriate monitoring protocols are not adapted with *P. kaakan,* population levels may be lower than previously expected and the level of fishing effort may not be sustainable. Management which is not solely dependent on fishery-dependent CPUE data (Erisman et al., 2011), and that takes into account the timing and locations of spawning aggregations needs to be implemented in order to sustainably manage fisheries that target aggregating fishes.

Concern over excessive effort and catch of *P. kaakan* have already been shown in Karumba (Hart and Perna, 2008; Greiner and Gregg, 2010), with suggestions for additional management including reductions in bag and increases in size limits. However, due to the inability of BLs and MLS to control overall harvest (Cox et al., 2002), management measures that control total effort and/or catch may need to be introduced in locations such as Lucinda. Anecdote suggests that there are many other coastal communities like Lucinda that experience seasonal pulses of fishing effort. These others communities should be identified as a priority. Input controls that would be effective for controlling such pulse fishing include seasonal closures during peak fishing periods. Direct effort control, in the form of limited licenses or seasonal closures, are more effective at limiting extractive harvest as these measures control the fishing community as a whole as opposed to regulating individual anglers (McPhee, 2008).

The occurrence of high fishing effort by travelling anglers on specific fish populations requires custom monitoring programs which frequently assess participation and exploitation rates. If the recreational anglers are fishing aggregations, standard methods of monitoring fishery sustainability such as CPUE may not be effective because hyper stable catch rates may mask population declines (Erisman et al., 2011). Implementation of an age structure monitoring program needs to be developed if sustainable fishing practices are to be used (Patterson et al., 2001). These types of programs will be better at maintaining a population that allows for maintaining productivity and harvesting opportunities for all sectors.

Conclusion

The recreational fishing sector is having a significant and potentially detrimental impact on *P. kaakan* populations in the Hinchinbrook area. Management strategies that are based on commercial fishery statistics alone may not be sufficient to maintain a sustainable population. Given the catch characteristics of the recreational fishery differ from the commercial sector, such as differences in amount of catch and fish size, monitoring of both is imperative to ensure sustainability. Overexploitation is heavily influenced by the recreational industry’s harvest characteristics, such as female catch bias, as well as reproductive behaviours of *P. kaakan,* including the presence of spawning aggregations. Management plans and monitoring of regional centres needs to be up-to-date and continuous to prevent the overfishing of the species and potential regional extinction.

Chapter 4 <u>The Recreational Fishing Industry and Community Impacts</u>

A distinct seasonal fishery has been identified in the southern Hinchinbrook Channel near Lucinda, a regional area of Queensland, Australia. Seasonal trends in the recreational fishery in Lucinda are driven by the grey nomads, a traveling group of tourists which is not currently monitored. In addition, this fishery heavily targets one species — *Pomadasys kaakan.* Given the identified differences in catch characteristics of the commercial and recreational fisheries, the industry could have a significant impact on the productivity of the stock. Consequently, continued fine-scale monitoring and customised management plans are needed into order to maintain the sustainability of the industry. This chapter discusses the results of this study and will suggest further research as well as monitoring and management strategies for the recreational fishery.

Previous to this study, recreational catch and effort data for Queensland waters was only available across broad spatial scales and infrequently collected through time. For example, recreational catch and effort data are only available for the years 1996, 1998, 2001 and 2004 and northern Queensland catch is grouped together over 100s of kilometres of coastline. The infrequent sampling and low spatial resolution does not permit the identification of areas and/or times of pulse fishing events (McInnes, 2008) that may require special management. Multiple species are grouped at the family level. Current recreational catch reporting includes, for example, four Sillaginids grouped as whiting, three Platycephalids as flathead and two Pomadasids as javelin. In the absence of robust catch and effort data for the recreational fishery, management plans and strategies may be based on the characteristics of co-occurring commercial fisheries. However, commercial fisheries may interact with different components of a population. For example, Tobin and Mapleston (2012) found recreational anglers consistently targeted and landed smaller and younger Spanish mackerel than the commercial sector. Thus applying the well-known catch characteristics of the commercial sector to the recreational sector would be inappropriate, particularly when the cumulative catch from the fishery targets all components of life history.

This study confirmed anecdote about the seasonal targeting of the barred javelin (*P. kaakan*) in Lucinda, Queensland. This thesis has described catch characteristics and seasonal changes in fishing effort (Chapter 2) that have not been captured by previous recreational fishing surveys in Queensland. Current monitoring of the recreational sector does not identify key target species, such as *P. kaakan*, as all Pomadasid species are reported cumulatively. In addition, the recreational sector lands larger volumes of Pomadasid species than the commercial sector (Zeller, 2007; Department of Employment Economic Development and Innovation, 2011). Given this, current management may be ineffective in achieving sustainable management goals for *P. kaakan* and the fishing sectors the species supports.

This study also showed the potential effects of using inaccurate growth data in productivity models, such as the Spawning Potential Ratio (SPR) (Chapter 3). Failure to take into account the sensitivity of SPR to changes in growth could lead to inappropriate management. Tsai et. al. (2011) demonstrated how inaccurate biological parameters may lead to inaccurate estimates of productivity which can result in serious management consequences. Continuous research which monitors changes in population structure and updates in life history characteristics were suggested to improve the accuracy of management models.

Furthermore, this project identified a group of recreational anglers accessing fisheries resources in Queensland which are currently unmonitored. Although the grey nomad community consider social interaction as the most important activity of their travels, fishing is also an important activity, and in communities such as Lucinda, the fishing effort (and probably catch) of grey nomads likely exceeds that of local anglers. Given the propensity of grey nomads to coastal routes and communities (Pearce, 1999) and their association with fishing and boating (Onyx and Leonard, 2005), coupled with the aging population of Australia (Golik et al., 1999), further increases in fishing effort in communities like Lucinda should be expected. In addition, it has been identified that fishing is supplemental to the social value of visiting these coastal communities. This is an important finding because as a result, return visits and continued fishing effort may be likely despite a reduction in fishing quality.

Regional catch characteristics

Chapter 1 outlined the inadequacies of recreational fishing monitoring in Australia and around the world; particularly the lack of detailed monitoring identifying fluctuations in fishing effort and target species at appropriate regional and temporal scales. Communities which may be affected by the seasonal movement of tourists are currently unidentified. Previous studies, including the case study in Karumba in the Gulf of Carpentaria (Hart and Perna, 2008), have identified grey nomad-driven communities are largely unrecognised and hence unmonitored. This study described a similar unmonitored, discrete but identifiable, grey nomad based fishery in Lucinda, Queensland (Chapter 2).

Since 2000, trips by grey nomads have risen by 90% (Tourism Research Australia, 2012). According to the Australian Bureau of Statistics, population ageing had been increasing steadily since the early 1970s, continuing through to 2011 due to an increase in life expectancies (ABS, 2008). With a growing elderly population of Australia (Rowland, 2003) it is predicted that there will be a marked increase in domestic travel by senior citizens (Golik et al., 1999), which includes grey nomads. Hence, it is probable there will also be an increase in the number of trips, and hence potential level of environmental impact by the grey nomads. Concern about the environmental impacts of grey nomads was raised by Cridland (2008). Field observations by Cridland (2008) showed inappropriate disposal methods of human waste and grey water in campsites frequented by grey nomads. As a result of these environmental impacts, local councils and national parks have appointed caretakers to maintain the environment in effected camping areas.

Environmental impacts can extend to impact on local fisheries where grey nomads are motivated by fishing. This project has identified that the fishing effort in some areas such as Lucinda can fluctuate significantly through time due to the seasonal influx and participation in fishing by grey nomads. The continued fishing on a population of a given species in localised areas, coupled with the likely increasing population of grey nomads, exemplifies the need for appropriate monitoring. Monitoring must include interstate anglers in order to create a complete profile of the fishery otherwise management is unable to account for the fishing effort and catch of grey nomads. Continued monitoring of fishing effort will allow managers to develop a dynamic approach to regulating fishing effort as well as to any changes in the status of regional fish populations (McPhee et al., 2002).

Adaptive management may be needed to manage the impacts of pulse fishing events that are created by grey nomads. For example, a significant decline in the harvest rates of a sea urchin fishery in Southern California motivated a co-management approach to managing the fishery. Local anglers were proactive in introducing a MLS and the fishery has recovered. This strategy allowed management in a small region that was adaptable to changing circumstances (Barcott, 2011; Gutierrez et al., 2011). While the specifics of this method may not work in all situations, this example demonstrates that adaptive management can be effective. It is important management strategies be adaptable for inevitable fluctuations that are associated with not only the tourist fishery, but the recreational fishery as a whole (Walters, 1986; Hilborn et al., 1995; Runge, 2011).

Recreational fisheries management is not only about managing the sustainability of the species targeted but also the maintenance of the social and economic values that are supported or generated by the activity of fishing (Hickley and Tompkins, 1998; Stoeckl et al., 2006). Recreational fishing provides enjoyment at an important social level and increases the quality of life for many participants (Toth and Brown, 1997). The grey nomad fishing community is built around social ties, some of which can be attributed to fishing (Chapter 2). The social significance of fishing is an important factor in the quality of life to a group such as the grey nomads and needs to be taken into consideration when discussing management options.

Current Biological Parameters and Management Models

Successful management of a fisheries exploited species is more likely when the harvest and biological characteristics of the species are well known. Factors such as sex selective harvest and growth rates influence the productive capacity of a population and hence how various levels of fishing pressure are likely to impact a population. If the catch characteristics and/or biology are unknown, management plans risk being ineffective (Tsai et al., 2011). The sex selective catch that occurs in the recreational sector at Lucinda is particularly noteworthy. Theory suggests the reproductive potential of a fish population in some species may be limited by egg production capacity of the female long before it is limited by the sperm production of males (Myers and Barrowman, 1996). Recognising this, sex selective harvest of females could be a significant concern for maintaining a viable population. A sex ratio of 15 : 1 of harvested fish is quite unique, and may be explained by the presence of spawning aggregations. However, the exact reason for the bias could be attributed to many different factors, including sex-specific habitat preference (e.g. Knip et al., 2012) or schooling behaviours (Magurran and Garcia, 2000). Removal of a large amount of females from the population may restrict reproductive capacity leading to population declines such as has occurred with the black jewfish (*Protonibea diacanthus*) in Cape York, Australia (Phelan et al., 2008) and the Nassau grouper (*Epinephelus striatus)* in Mexico (Aguilar-Perera, 2006). Once a fishery species has reached this state, the fishery would almost certainly be closed in an attempt to recover the population (Phelan et al., 2008).

The biological traits of fish species can also influence their ability to sustain fishing pressure. A range of Biological Reference Points (BRPs) can be estimated for a species, and based on the species' life history, can be useful guides for managers to assess the likely successes of various management strategies such as at what length to set minimum legal size limits. The outcomes of productivity models, such as the SPR model used in this study (Chapter 3), need to consider the accuracy of the input biological parameters when basing management on the results. In addition, given fishing effort is likely to increase over time and with these increases changes to population structure and hence the biological characteristics of the catch may be likely, the SPR model should be updated so that responsive management can occur when and if needed.

The SPR model provides predictions based on age or length at maturity and relative levels of fishing effort, but does not take into account factors such as post-release mortality figures, actual levels of fishing effort and actual harvest rates. Management should use SPR models as an initial look at the sensitivity of a species to fishing pressure but not as final report on the status of the fish population. For example, given 60% of landed fish are discarded, it is possible a species may be more heavily impacted by fishing than is initially described in catch statistics (Bartholomew and Bohnsack, 2005; Cooke and Wilde, 2007; Department of Employment Economic Development and Innovation, 2011). The post-release mortality levels vary among species. For example, tailor (*Pomatomus saltatrix*) have been demonstrated to have very high post-capture survival rates (~97%) (Ayvazian et al., 2002), while conversely snapper (*Pagrus auratus*) post-capture survival is much lower at 67% (Broadhurst et al., 2005). However, post-release mortality has not been measured for *P. kaakan* and hence is not included in the calculations of the model. Given most captured *P. kaakan* are released, even a moderate post-release mortality rate could significantly alter fishery related mortality rates. Thus post-release mortality of line caught *P. kaakan* should be investigated as soon as possible.

These findings demonstrate a complex situation within the recreational fishery. A previously undefined fishery has been identified but the direct effect the seasonal influx of Grey Nomad anglers may be having on the population of *P. kaakan* requires further attention. More research examining the current status of the population and impacts of the recreational fishery including fishing mortality rates is needed before conclusions can be made about the sustainability of current levels of fishing effort and catch. A conservative approach to management of the recreational fishery may be needed until these needs are met. In such a situation Cox et. al. (2002) suggest the most effective measure in managing recreational fishing pressure is through reduction of access. For Lucinda (and similar locations), successful management strategies may include temporal or spatial closures, or limited entry.

Recreational Fisheries Management

The recreational fishery, despite the economic benefit to the economy, is difficult to monitor and manage due to the high numbers of participants, diversity of motivations and fishing behaviours. Recreational anglers disperse over large landscapes, on often variable spatial and temporal scales (Post et al., 2002). Because of this, managers of recreational fisheries rarely have the funding to monitor or manage such a diffuse group. Despite the challenges faced by managers, however, alternative methods of management need to be considered and implemented to control total level of impact this activity places on the ecosystem.

A common issue in natural resource management is how to control the total impact on the ecosystem. One method is to limit access to the resource / ecosystem. For example, big game hunters in the midwestern United States participate in a lottery system to obtain an area specific license for the hunting season (Colorado Parks and Wildlife, 2012). This is an extreme example of where the anthropogenic impact has exceeded the biological capacity of the exploited resource to a point where the numbers of animals removed needs to be managed with precision. In Australia, popular hikes in World Heritage Areas such as the Overland Track in Tasmania and the Thorsborne Trail on Hinchinbrook Island in north Queensland, only allow a certain number of hikers on the trail (Department of Environment and Resource Management, 2012; Parks and Wildlife Service Tasmania, 2012) in order to minimise the cumulative impacts. Despite being vastly different activities, the management policies used to maintain the integrity of these natural resources are based upon managing cumulative impact. In other words, instead of managing the individual participant, the cumulative footprint is limited.

Requiring recreational anglers to obtain fishing licenses is one management strategy that will allow managers to at least monitor the number of participants (McPhee, 2008). Licenses should include all demographic groups, including as senior citizens (i.e. grey nomads). Licenses will not only help in determining total fishing effort, but also provide contact information obtained by the license applications that can also be used as a contact source for future monitoring surveys. This will give managers a database that includes resident as well as out-of-state anglers, and as a result, will provide a complete profile for catch and effort statistics. Future research should include understanding the perceptions of Queensland anglers towards recreational fishing licenses. Understanding the costs and benefits of a recreational fishing license can help management create a program that works for the community as well as is effective for management needs. Any negative feedback regarding license programs may highlight the need for further research to help change the perceptions of these programs have amongst recreational anglers.

The recreational fishing sector may need a similar system of management to reduce the total impact on fish populations. Management protocols that are currently used for maintaining fish populations, such as MLS and bag limits, control the impacts of individual anglers but are ineffective at managing the total harvest given these types of management fail at regulating the total level of effort (Cox et al., 2002). Large scale management which controls the level of effort of the collective number of anglers may be necessary to appropriately manage the fishery. Long-term prevention of over-exploitation may only be attainable if total effort is reduced, especially in cases such as those described in this study where research of the impacts of the fishery are in preliminary stages.

Conclusion

The results of this study illustrate the need for detailed monitoring of the entire fishing industry, as well as updated information about the life-history traits of key target species. The current methodology of monitoring and managing the recreational fishing sector is insufficient for maintaining a sustainable industry. Fishing communities in Australia which are experiencing intense localised pressures are not currently identified and as such, target species may be overfished. A dynamic management plan needs to be developed which acknowledges the mark left by the industry as a whole, as opposed to current management that does not include any mechanism to control total harvest.

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APPENDIX 1: CARAVAN PARK SURVEY

JAMES COOK UNIVERSITY AUSTRALIA		**Recreational Fisheries** **Caravan Surveys**				F&F
Date:				**Location:**		
Site Number:				Origin:		
# in party:				Length of Stay:		
Length of Holiday:				Years Visited Lucinda:		
Age:	<20	20-29	30-39	40-49	50-59	60+
Reason for choosing Lucinda: Fishing Water Sports (Such as:________________) Sightseeing Other:						
If fishing: Are they targeting something in particular?						
If that species were not available, would they: Stay in Lucinda and target another species? Stay in Lucinda for a shorter trip and target different species? Choose another location but target the same species? Choose another location and target a different species? Other:						
Comments						

INSHORE PROJECT: RECREATIONAL FISHING BOAT RAMP SURVEY

p of

Location (Ramp): **Surveyor:**

Date: **Entered:**

Trip #	# Fishers	Target Species	Fishing Method*	Avidity	Time spent fishing			Fishing locations		Home Town
					Depart	Return	Time	Grid #	Locations	

Trip #	RETAINED CATCH			RELEASED		Notes (e.g. details on fisher, catch, fish, loc'n, fisher comment)	
	Species	Lgth (mm)	#	Species	#		
						Weather Conditions:	Start time:
							End time:
							# Trailers:

*Fishing method categories: L = Lure, F = Fly, DB = Dead Bait, LB = Live Bait

Please return: *Natasha Szczecinski, Fishing & Fisheries Research Centre, James Cook University, Townsville, 4811, ph:04 04102564*

APPENDIX 3: CATCH CARD AND LOGBOOK INSTRUCTIONS

Instructions

Please fill out one catch card for every trip fished. If you do not catch any fish on a trip, while it may be disappointing, I still need to know about it! Make sure to still fill out a card and write “No Catch”.

Location does not need to be specific, secret fishing spots are best kept under lock and key! Grid number and general location (e.g. B1-The Bluff) will be sufficient.

Average Number of Days Spent Fishing a Year will be used to find out the level of effort you put into fishing each year. ‘<12’ = less than once a month, ‘12’ = once a month, ‘24’ = twice a month, and ‘52’ = once a week, etc.

Actual Time Spent Fishing should be the estimated time that the lines were actually in the water and does not include the time travelling between the boat ramp and your secret fishing spot.

Target Species can be a specific species, such as Spanish mackerel, but if you are just aiming for something to catch and are not targeting anything in particular, please put “All”.

For Catch Composition please be as specific about the fish as possible (e.g. barred javelin (also known as barred grunter) instead of Javelin).

Total lengths, from the snout to the end of the tail, should be measured in centimetres and as accurately as possible. Even if you estimate, write it down! (I.e. Est. 400 cm)

When you have completed an entire logbook, or you’re leaving Lucinda, please mail to the address below in one of the reply paid envelopes provided. And if you had fun with the project, let me know and I will send more catch cards your way! Anyone returning catch cards is automatically in the bi-monthly draw for a free hat and cap.

Please do not hesitate to contact me with any questions you may have. Thanks for your help! And good luck!

c/o Natasha Szczecinski
Fishing and Fisheries Research Centre
James Cook University
Douglas, QLD 4811

APPENDIX 4: WELCOME LETTER

Dear (Name),

Thank you for your participation with the inshore recreational fishing project. Any information you are able to provide will be greatly appreciated.

Inside this folder you will find a logbook with multiple **'catch cards'**, a **map** with grids to help you identify your fishing location without giving away too much, instructions for the catch cards and a **pencil**.

The catch cards have been printed on waterproof paper which means you can **fill out the catch cards while you are fishing**. So please take catch cards with you on the boat to help reduce any mistakes which happen when trying to remember the size of a fish later on. The waterproof paper works well with pencil but not with ink (pen). Please read the instructions carefully before filling out the catch cards – they're not hard, but we need to make sure we get the right information from everyone.

Your valuable fishing data will contribute to a project aimed at answering questions about the social and biological dynamics of recreational fishing in Lucinda. This information will in turn aim to help maintain the quality of fishing in the Hinchinbrook Channel. In order for this information to be defensible and useful, I need you to answer the questions as truthfully and accurately as possible. So please **include any trips where you don't catch anything** (it happens to all of us!) plus anything you **released-**including unwanted fish, like pesky catfish, or fish that are under the legal size limit.

You may notice an identification (ID) number at the top of the catch cards. This number should be the same on all of your cards and is linked to a profile which contains your name, experience fishing and contact information. It saves us collecting this multiple times, and helps us keep fisher records confidential. I do need it however, so I can contact you if you win the prize in the bi-monthly draw!

If the catch cards are unclear please feel free to contact me with any questions. The catch cards are meant to be fairly easy and not time consuming, so suggestions to make them more efficient are always welcome. You can reach me at the number or e-mail below with any question you may have about the cards, or the overall project.

If you want to continue with the project after the catch cards in this logbook are complete, please let me know and I will send you fresh catch cards. All the catch data will be linked to your ID number and is strictly confidential.

Thank you again for your help with the project. I look forward to hearing from you!

Kind regards,

Natasha Szczecinski

APPENDIX 5: CATCH CARDS AND LOGBOOK PAGES

JAMES COOK UNIVERSITY AUSTRALIA	**Recreational Fisheries Catch Cards**	F&F

Personal Profile

Name or ID #	Average Number of Days Spent Fishing a Year (circle) <12 12 24 52 >52
Address	How many years experience fishing do you have?
Preferred Phone Number	

Trip Information

Date:	Time Start Fishing:
# of anglers:	Time Finish Fishing:
Location:	Actual time spent fishing:

Species Targeted (circle): Anything Barramundi Mangrove Jack Fingermark Javelin/Grunter Mackerel Other:________

Gear Used (circle): Lure Fly Dead Bait Live Bait

Catch Composition

Grid Number	Species	Length (mm TL)	Fate (Kept/Rel)

APPENDIX 6: SPECIES LIST

Bait
Mugilidae spp.
Mugil cephalus
Prawn

Barramundi
Lates calcarifer

Bream
Acanthopagrus australis
Acanthopagrus berda

Carangidae
Carangoides fulvoguttatus
Caranx ignobilis
Gnathanodon speciosus
Scomberoides commersonianus
Scomberoides lysan

Cods
Cromileptes altivelis
Epinephelus coioides
Epinephelus fuscoguttatus
Epinephelus malabaricus

Grunter
Pomadasys argenteus
Pomadasys kaakan

Mackerel
Scomberomorus commerson
Scomberomorus munroi
Scomberomorus queenslandicus

Salmon
Eleutheronema tetradactylum

Snappers and Sea Perch
Lutjanus argentimaculatus
Lutjanus carponotatus
Lutjanus erythropterus
Lutjanus johnii
Lutjanus russelli

Whiting
Sillago analis
Sillago sihama

Flathead
Platycephalus endrachtensis
Platycephalus fuscus

Shark
Carcharhinus melanopterus
Carcharhinus amblyrhynchos
Carcharhinus dussumieri
Rhinobatos typus
Sphyrnidae spp.
Unknown ray species
Unknown shark species

Other
Ambassis spp.
Arius spp.
Arothron hispidus
Arothron spp.
Balistidae spp.
Choerodon venustus
Diagramma spp.
Drepane punctata
Echeneis naucrates
Gerres spp.
Katsuwonus pelamis
Lethrinus laticaudis
Megalops cyprinoides
Nibea soldado
Platax spp.
Psammoperca waigiensis
Rachycentron canadum
Scatophagus spp.
Scombridae spp.
Scorpaenidae spp.
Soleidae spp
Sphyraena barracuda
Synodus spp.
Trachinotus spp.
Unknown eel species
Unknown sea snake species