The Effectiveness of Recreational Only Fishing Areas in north Queensland estuaries for reducing conflict and improving recreational catches.

Thesis submitted by

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I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

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STATEMENT ON THE CONTRIBUTION OF OTHERS

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ABSTRACT

Allocation of fisheries resources to recreational fishers via Recreational Only Fishing Areas (ROFAs) is becoming increasingly common in all developed countries, particularly in coastal areas. ROFAs are often introduced with the expectation that such action will segregate competing recreational and commercial fishers (by excluding commercial fishers) and thus resolve apparent conflict over previously shared fisheries resources. ROFAs also have the expected benefit of improving recreational catch quality for previously shared species. Whether these benefits are realised, however, is unknown because little monitoring of outcomes occurs post-ROFA implementation.

Using questionnaires of recreational and commercial fishers and collection of fishery-dependent and fishery-independent recreational catch data, this study investigated the outcomes of ROFAs in north Queensland estuaries. Specifically, the study examined: the nature and source of conflict between recreational and commercial fishers competing for shared barramundi stocks; whether current estuarine ROFAs are successful in segregating and reducing conflict between these sectors; and whether ROFAs result in improved recreational catches of barramundi.

Results from the questionnaires show that while recreational fishers (anglers) have high expectations of ROFAs and would like more implemented, most anglers are unaware of locations of current ROFAs, and do not deliberately choose to use them. Consequently, current ROFAs are not increasing segregation of recreational and commercial fishers. Moreover, contact between the recreational and commercial sectors appears to already be limited due to time segregation (commercial netting is not allowed in estuaries on weekends) and the finding that most commercial fishers avoid areas heavily occupied by recreational fishers. Thus the conflict between these sectors does not appear to be due to high levels of direct contact.

Investigations of the perceptions of fishers from both sectors via the questionnaire program revealed that the underlying conflict between commercial and recreational fishers in north Queensland appears to be based on mutual misperceptions of the competing sector's operations and impacts, particularly from anglers. Such misperceptions lead to blame (i.e. anglers blame commercial fishers) for negative outcomes such as (real or perceived) catch declines. ROFAs do not address this problem of mutual misperceptions of fishers and are therefore unlikely to resolve this conflict in the long-term. Increased communication between sectors and education from fisheries managers and researchers and stakeholder representatives regarding each sector's operations and impacts on the resource is more likely to reduce conflict.

Such actions should reduce misperceptions, adjusting attitudes of fishers to be more positive towards the competing sector, and hence reducing conflict.

Despite anecdotal claims and expectations of improved recreational catches of barramundi in ROFAs compared to open estuaries in north Queensland, fishery-dependent (from charter fishing records, voluntary recreational catch logbooks, and personal fisher time series records) and fishery-independent (in the form of structured fishing surveys) recreational catch data collected though this study did not reveal improvements in catch per unit effort or success rates for barramundi in ROFAs. Results did show that the average size of barramundi caught in ROFAs was larger than those caught in the open estuaries, though the reason for this difference in size structure is unknown. Further investigation into why recreational catch benefits are not being realised and what this may mean for barramundi populations is required. Results imply natural variation may be more influential on barramundi populations than fishing, or that recreational fishing is highly variable and not a good indicator of stock structure and abundance.

Overall, results of this project suggest current estuarine ROFAs in north Queensland are not resulting in the expected benefits: i.e. they are not reducing conflict between recreational and commercial fishers or resulting in improved recreational catches of barramundi. This study highlights the importance of determining the source of conflict, and collecting quality time-series recreational catch data before and after ROFA implementation. Future studies should aim to examine both the costs and expected benefits of ROFAs to determine whether benefits outweigh the costs involved. Costs and benefits should be examined from a multi-disciplinary approach, including social, ecological and economic aspects.

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LIST OF ABBREVIATIONS:

AFANT	Amateur Fisherman's Association of the Northern Territory
ANSA	Australian National Sportsfishing Association
CHRIS	Coastal Habitat Resources Information System
CPUE	Catch per unit effort
CRC Reef	CRC Reef Research Centre
DPA	Dugong Protection Area
ECIFF	East Coast Inshore Finfish Fishery
EoNF Project	Effects of Net Fishing Project
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
NSW	New South Wales
NRIFS	National Recreational and Indigenous Fishing Survey
QDPI	Queensland Department of Primary Industries
QDPI&F	Queensland Department of Primary Industries and Fisheries
QBFP	Queensland Boating and Fisheries Patrol
QSIA	Queensland Seafood Industry Association
RAP	Representative Areas Program
RFISH	QDPI&F Recreational Fisher Monitoring Program
ROFA	Recreational Only Fishing Area
WA	Western Australia

CHAPTER 1: GENERAL INTRODUCTION

1.1 Introduction

Competition and conflict between commercial and recreational fishers over shared fish stocks is a historic and current reality, and has been documented in all developed and some developing countries (Ruello and Henry 1977; Gartside 1986; Aas and Skurdal 1996; Sumaila 1999; Kearney 2002a, b; Pitcher and Hollingworth 2002; Sumaila 2002; McPhee and Hundloe 2004; Arlinghaus 2005). Although recreational and commercial fishing sectors are often in competition to the point of conflict with other users (including within their own sector), apparent conflict between recreational and commercial fishers is currently one of the most significant issues for fisheries management in Australia and many other countries (West and Gordon 1994; Brayford 1995; van Buerren et al. 1997; McPhee and Hundloe 2004; Arlinghaus 2005). Conflicts may be severe and expensive of management resources, regardless of whether they are “real” or only perceived (i.e. based on fishers’ beliefs but not substantiated) by one or more of the involved fishing sectors (Jacob and Schreyer 1980; Aas and Skurdal 1996).

Many authors suggest conflict between recreational and commercial fishing sectors is increasing as contact between the sectors increases, particularly in coastal areas and close to population centres (Gartside 1986; Edwards 1991; Hannah and Smith 1993; Brayford 1995; Ramsay 1995; Scialabba 1998; O'Neill 2000; McPhee et al. 2002; Steffe et al. 2005b). Increasing contact between the sectors may be due to a number of factors including: increased population; increased recreational fishing participation; and improved accessibility to previously remote fishing areas (Smith 1980; Henry 1984; Edwards 1990; van der Elst 1992; Hannah and Smith 1993; Green 1994; West and Gordon 1994; Kearney 2001, 2002b; Williams 2002a; Sumner 2003; Steffe et al. 2005b). Although conflict can occur when commercial and recreational fishers target different species, the conflict situation is enhanced when the same species are targeted by both sectors (Arlinghaus 2005).

In an attempt to reduce contact between competing sectors and hence reduce conflict, sector-specific closures are introduced in previously shared areas (Samples 1989; Department of Primary Industries and Fisheries 2003). Recreational Only Fishing Areas (ROFAs) (i.e. areas where commercial fishing is banned, leaving exclusive access to recreational fishers (also termed ‘anglers’ when they are recreational line fishers)) are becoming increasingly common in Australia and other developed countries (Owen 1981; Rogers and Gould 1995; Kearney 2002b; McPhee et al. 2002; Walters

2003). All States and Territories in Australia have implemented ROFAs, particularly in coastal areas. For instance, in New South Wales (NSW) in May 2002, 30 areas along the coast became “Recreational Fishing Havens” (termed ROFAs here), where commercial fishing was either completely banned or significantly restricted. These ROFAs resulted in the closure of 24% of the State’s estuarine waters to commercial fishing (NSW Department of Primary Industries 2004; Steffe et al. 2005b). In the Northern Territory, the rise of the recreational fishing sector in the 1980s shifted the focus of barramundi management to the allocation of the resource between the competing sectors. This resulted in the exclusion of commercial fishing from some areas including all freshwater areas, plus Darwin Harbour, Kakadu National Park, and the Daly, Mary and Roper Rivers (Pender 1995; Griffin 2003). In Victoria, only 4 of 25 bays and inlets allow commercial finfish fishing, making the remaining areas effectively ROFAs for finfish (Murray MacDonald, Department of Primary Industries Victoria, pers. comm., 2006)

Commercial Only Fishing Areas (COFAs), on the other hand, appear extremely rare. There is one published example of COFAs available: in the north-western Mediterranean there are areas where small-scale restricted commercial net fishing is allowed but recreational line and spear fishing is banned. However the purpose of such restrictions was for conservation of fish species, rather than segregation to reduce conflict (Francour et al. 2001). In Western Australia, priority access (but not exclusive access) is given to commercial salmon fishers for a set period on southern beaches (Bartleet 1995).

Given this trend, ROFAs are the focus of the present study. In north Queensland, Australia, a number of estuaries have been closed to commercial netting (effectively making them ROFAs for finfish) to reduce conflict between recreational and commercial fishers competing for shared estuary fish, particularly barramundi (*Lates calcarifer*) (Mark Doohan, QDPI&F, pers. comm., 2005). Although some of these ROFAs have been in place since the 1970s there has been very little evaluation of their social and biological effects. In most cases, the extent to which ROFAs are successful in segregating competing sectors, and thus reducing conflict, has not been tested.

In addition to potentially segregating competing sectors, ROFAs also have additional potential benefits for the recreational sector. In particular, with the exclusion of commercial fishing, there is less competition for previously shared fish stocks in the area. Consequently, improved recreational catches are expected, producing potential flow-on effects of increased effort from this sector, which may lead to increased spending and potentially increased value to the community (Ruello and Henry 1977;

Kearney 2001; Dominion 2002; McPhee and Hundloe 2004). While significant anecdotal evidence suggests such benefits are being realised, there are few cases where actual catch trends and flow-on benefits are examined, and when they are the results are mixed.

The introduction of ROFAs also attracts various potential costs. Many of these costs will be borne by the excluded commercial sector; however there are also potential costs to the community and the fish stocks (Kearney 2003a; MacDonald 2003). In practice, ROFAs are permanent – i.e. there are no published cases of ROFAs being reverted back to shared-access where both sectors are targeting the same species (McPhee and Hundloe 2004). Thus, with increasing calls for ROFAs from recreational fishers, and more claims for compensation for loss of commercial livelihood as a result, it becomes important to look at the actual costs and benefits of implementing ROFAs (Dominion 2002).

This project examines whether the expected benefits of ROFAs – in terms of reduced conflict between recreational line fishers (anglers) and commercial gill net fishers, and improved recreational catches – exist within the north Queensland barramundi fishery. In addition to providing an understanding of the benefits of ROFAs within this fishery, results will be relevant to many situations where ROFAs are being proposed or have been introduced with the goal of reducing conflict and/or improving recreational catches.

1.2 Literature Review: The benefits and costs of Recreational Only Fishing Areas

Sector-specific fishing closures (where one sector is excluded from an area to provide exclusive use of the resource to the other sector), designed to separate competing user groups (sectors) date back to the early 20th century (Department of Fisheries Western Australia 2000). Traditionally, fisheries resources were accessible to all sectors, with fisheries resources generally considered common property: i.e. the resources are owned collectively by a group and not owned by anyone (Rogers and Gould 1995; van der Elst et al. 1997; Marshall and Moore 2000). However, traditional 'open access' to common property resources can lead to depletion of stocks, through Hardin's well-known "Tragedy of the Commons" situation, where each fisher will have the incentive to catch as much as possible before someone else does (Smith and Pollard 1995; van der Elst et al. 1997; Kearney 2001). To avoid this, most fisheries are managed via regulation by the government or state, which allocates both commercial and recreational rights (Charles 1992; Rogers and Gould 1995; Marshall and Moore 2000).

However, there is a lack of agreed processes for determining appropriate sharing/allocation targets for particular resources (Henry and Lyle 2003), and both the commercial and recreational sectors aim to maximise their share of limited and finite fisheries resources, often at the expense of the other sector (Ruello and Henry 1977; Henry 1984; Smith and Pollard 1995).

Central to the problem of increasing competition between sectors is this question of ownership of the resource (Charles 1992; Kearney 2003a). Commercial rights may be regarded as a form of private property right purchased in the form of a transferable licence that provides a degree of ownership over the resource (Marshall and Moore 2000). For some commercial fisheries catch shares for each licence are also well-defined (Craig 2000; Kearney 2001). For recreational fisheries, although most anglers consider fishing to be their birthright, collectively their rights have not been defined (Rogers and Gould 1995; McMurran 2000; Kearney 2001; McPhee et al. 2002; Kearney 2003a). With increasing pressures on, and competition for, limited fish stocks there are increasing demands from the recreational fishing sector for greater recognition and definition of their rights of access (McPhee et al. 2002). With the rise of the recreational fishery there has been an increased political push for exclusive access to some areas and species (Teirney 1995; Kearney 2001; McPhee and Hundloe 2004). Allocation decisions such as these are unique in that the best available scientific information is not central to the conflict resolution (Hannah and Smith 1993).

Many fisheries researchers advocate sector-exclusive access/closures to areas as a feasible way to reduce conflict by reducing contact between competing sectors (e.g. Hendee 1974; Brown 1977; Owen 1981; Samples 1989; Brayford 1995; Rogers and Gould 1995; Taylor-Moore 1997; van der Elst 1997). For example, van der Elst (1997), suggested ongoing competition for King George whiting (*Sillaginodes punctatus*) in South Australia and Victoria could be resolved through sector-specific zonation by restricting recreational anglers to areas close to urban centres and allocating commercial rights beyond.

Other authors believe sector-specific closures are detrimental or unpopular, and may themselves cause conflict (Beaumariage 1978; Hannah and Smith 1993; Bennett et al. 2001). Resource allocation is one of the most challenging issues for fisheries managers (Department of Primary Industries and Fisheries 2004) and requires the most conflict producing decisions within fisheries management as they “pit group against group” (Hannah and Smith 1993). The likelihood of allocations to produce conflict depends on whether allocations are shared equally, or whether one sector gains at the expense of the other (such as in the case of sector-specific closures) (Hannah and Smith 1993). Conflict caused by dissatisfaction regarding allocation decisions can cause problems for the involved fishing sectors as well as fisheries managers. Time and money spent on conflict resolution efforts (including via legal proceedings) can be costly (Daigle et al. 1996).

Regardless of these varied opinions, sector-specific closures are becoming increasingly common, and it is most common to exclude commercial fishing to the advantage of recreational fishers – i.e. to introduce ROFAs (Pender 1995; McPhee et al. 2002; Rogers and Curnow 2003).

There are various possible benefits and costs of providing exclusive access to recreational fishers through areas such as ROFAs: for recreational and commercial fishers, the community, and the fish stocks. Often such benefits and costs are hypothesised, but few cases examine whether these benefits are actually realised, and whether they outweigh associated costs. Where expected benefits and costs are examined, results are mixed.

Despite the extensive use of ROFAs, detailed literature searches revealed that few case studies outlining examples of ROFAs, both pre- and post-implementation, are published in peer-reviewed scientific journals. Available literature on this topic is dominated by internal fisheries reports, conference proceedings and other grey literature (perhaps because conflict resolution is often seen as a local issue (Brayford 1995; Rogers and Gould 1995)). Consequently, available information about the effectiveness of ROFAs is limited.

1.2.1 Benefits of ROFAs

a) <u>Reduction of conflict between recreational and commercial fishers</u>

Where there is an overlap of recreational and commercial fishing in terms of fished species and area, ROFAs are expected to reduce contact between competing groups thereby reducing or eliminating the need for direct conflict intervention (Samples 1989). If successful, this resolution of conflict will benefit both of the competing fishing sectors as well as fisheries managers.

There are many cases within Australia and other developed countries where ROFAs have been suggested and/or implemented in order to reduce competition and conflict between sectors (see Owen 1981; Gwynne 1995; Dominion 2002; Department of Primary Industries and Fisheries 2003). For example, in Western Australia (WA), Fisheries Adjustment Schemes were developed which aimed to reduce commercial effort in specific areas or fisheries where there was a high level of conflict or competition for the available catch, particularly between the commercial and recreational fishing sectors. WA's Department of Fisheries advocated spatial separation of groups, and in 1996 the WA government provided $8 million to directly fund the voluntary surrender of commercial fishing licences in areas where there was community demand for greater recreational fishing opportunities. The scheme successfully removed 46 licences by 1999 (at a cost of $3.2 million) from the smaller but often highly contentious commercial fisheries in estuaries and inshore areas (Department of Fisheries Western Australia 2000). There is no further published information available outlining whether this scheme has reduced conflict in the long-term.

The effectiveness of ROFAs in resolving conflict may depend on: 1) the cause of the conflict; and 2) how the ROFAs are implemented. Each of these points are discussed below.

i) Causes of conflict

In most situations the cause of conflict between recreational and commercial fishing sectors is the perception that stocks, or at least catches, are declining, which is generally attributed to the competing sector. Such conflict can come from either or both sectors (Henry 1984; Samples 1989; Dovers 1994; Kearney 2002a; Arlinghaus 2005). Apparent conflict in Australia's Sydney Estuary in the 1980s reflected this: Anglers claimed that commercial gill net fishers killed many small fish, resulting in depleted fish stocks and poor angler catches. Commercial fishers reciprocated by claiming anglers also killed many undersize fish, either by deliberately keeping them or through poor handling prior to release (Henry 1984). Unfortunately, in most cases there is an absence of adequate stock and catch data, particularly for the recreational fishery, making such claims unresolvable as it is unknown whether they are based on misperceptions or reality (Dovers 1994; Presser 1994; Department of Fisheries Western Australia 2000; Murray-Jones and Steffe 2000; Kearney 2002a).

It is most common for recreational fishers to blame commercial fishers for perceived catch declines (Ruello and Henry 1977; Quinn 1988; Macreadie 1992; Bartleet 1995; Gladwin 1995; Kearney 1995a; Griffiths and Lamberth 2002; Kearney 2002a, 2003b). If conflict is present due to recreational fishers' perception of a commercial fishing impact on stocks and catches, the removal of commercial fishing should reduce the animosity recreational fishers feel towards commercial fishers for that particular area. However, commercial fishers are likely to feel resentful unless there is compensation for the lost fishing area (Kearney 2002a; Olsen 2003). In some cases compensation is available to displaced commercial fishers. For example, fees from newly introduced recreational fishing licences were used to buy-out commercial licences in Victoria, Australia. Such fees removed 52% of commercial licences, and complete buy-outs were effective in some waters making these areas ROFAs. The buy-outs, which were voluntary and endorsed by the peak body for recreational fishing (Morison and McCormack 2003), may reduce conflict in the area that has been ongoing for many years (see Gladwin 1995; van der Elst 1997; Kearney 2002a). However the long-term effects of the buy-outs on both the commercial and recreational sectors still needs to be assessed (Morison and McCormack 2003).

The success of ROFAs in resolving conflict resulting from blame for catch declines may further depend on whether the impacts of the commercial sector on recreational catches are perceived or real. In many cases perceptions of recreational catch declines are not examined, and where there is a lack of data anecdotal claims take precedence (Smith and Pollard 1995; Griffin and Walters 1999). Where perceptions are examined, results are mixed. In some cases the impact of commercial fishing on recreational catches is found to be real, and intervention is required. For example, in 1997 an experimental tuna longline fishery was initiated off South Africa. Due to a number of factors, the 'bycatch' of swordfish (*Xiphias gladius*) made up 70% of the total landed catch up to January 1999. At the same time there was a dramatic decline in recreational catch of swordfish. This situation, not surprisingly, led to considerable conflict between the two sectors, and the recreational sector strongly pushed for a closure of the commercial longline fishery[1] (Griffiths and Lamberth 2002).

In many fisheries, however, catch declines are misperceived. For example, Sztramko et al. (1991) examined anglers' catch rates at Long Point Bay on Lake Erie, Canada. Anglers were concerned about the effects of incidental catches of small-mouth bass (*Micropterus dolomieu*) in commercial gill nets targeting yellow-perch (*Perca flavescens*) and were thus calling for tighter restrictions on gill netting in the area. Creel surveys from the area's own angling group, however, showed an increasing trend in angler success rates. Thus, further restriction or banning of gill netting was not warranted, and the conflict was diffused. In many cases conflict results from misperceptions, and thus many conflicts can be resolved through education of the

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[1] For interest, closure of the longline fishery based on unavoidable swordfish bycatch was unlikely to occur at the time of publication, as foreign vessels within the fish's migratory path also target the South African swordfish stock. There is no international limit on swordfish catch; however the South African longline fleet has been limited to a swordfish catch of 3500 tonnes (Griffiths and Lamberth 2002).

parties involved rather than via ROFAs (see Ruello and Henry 1977; Henry 1984; Kearney 1995b; McLeod 1995; Aas and Skurdal 1996; Griffiths and Lamberth 2002).

ii) Method of implementation:

Recreational Fishing Only Areas can be implemented in a number of ways including political lobbying, through a management agency decision, or via consultation and stakeholder involvement. Whether conflict is resolved by ROFAs appears to depend on how the ROFAs are implemented.

Many ROFAs are implemented via political lobbying. Some authors consider fisheries managers have dealt with allocation issues by minimising the "political whinge" between user groups: i.e. managers have dealt with public perception and made adjustment to rules as combined fishing and/or lobbying pressure has increased, taking the minimal action needed to satisfy the most vocal stakeholders in what are regarded mostly as local concerns (Brayford 1995; Rogers and Gould 1995; Walters and Cox 1999; Rogers and Curnow 2003).

Recreational fishers have significant power when it comes to influencing political decisions regarding allocation of fisheries resources (Owen 1981; Hushak et al. 1986; Charles 1992; Adams 1994; Kearney 2001; McPhee et al. 2002; Walters 2003). Australia's peak national body for recreational and sport fishing, Recfish, states that in many reallocation scenarios, scientific considerations will be over-ridden by political decisions as a result of vocal and skilful political lobbying. They further state that anglers' awareness of lobbying power is reflected in the common bumper-sticker "I fish and I vote" (Recfish 2001).

Apparently, calls for ROFAs are often made by only a small number of vocal recreational fishers. They are however, the people to whom the government is most responsive (Ruello and Henry 1977; Beaumariage 1978; Henry 1984; McPhee 2001). Even the perception of such a political situation may increase the conflict between the groups as commercial fishers see the government bowing to a select group of recreational fishers who may not actually be representative of the recreational sector (Sutton 2006).

The most well known international example of recreational fishing groups' political power is the Florida 'netban': In this case, anglers perceived inshore commercial net fishing as having a detrimental impact on fish stocks and mega-fauna, and they sought to introduce a ban on the use of entanglement nets. An active multi-million-dollar media campaign ensued, with recreational fishing and conservation lobby groups arguing the nets indiscriminately killed endangered species and depleted finfish stocks. Despite the fact that available scientific information did not support these perceptions, the controversial campaign was successful in encouraging voters to approve a constitutional amendment in 1994 that prohibited the use of commercial entanglement nets in State waters, as well as other nets larger than 500 square feet in nearshore and inshore waters (Renard 1995; Anderson 1999; Adams 2000; Smith et al. 2003).

While ROFAs introduced via political decisions may appear to resolve conflict issues in the short-term, long-term solutions need better future planning. The use and success of political lobbying can lead to a distrust of management, and tensions over shared access will likely intensify unless there is consistency in allocation decisions (Brayford 1995; Rogers and Gould 1995; Daigle et al. 1996; Nakaya 1998; Walters and Cox 1999; Recfish 2001), which is difficult where political, local scale decisions are involved.

Adjustment in resource access between groups has historically taken place through government intervention. However managers are beginning to realise that conflict over resource allocations is more likely to be resolved if the relevant stakeholders are involved in decision-making (Charles 1992; Gladwin 1995; Hancock 1995; Rogers and Gould 1995; Hutton and Pitcher 1998; Department of Fisheries Western Australia 2000; McMurran 2000; Recfish 2001; Kearney 2002a). For example, recurring tensions regarding commercial netting in coastal waters in Portland Bay, Victoria (Australia) were resolved in the 1990s through mediation meetings involving recreational and commercial fishing representatives. Anglers were calling for a ban on commercial netting based on a perception (that was not supported by science) that commercial netting was depleting fish stocks and/or affecting the quality of angling. The issues were highly emotive, but it was recognised that this was social problem, not a stock conservation problem. Together with a mediator, both sectors developed a Code of Practice which included a “net free zone” (i.e. ROFA) in one area for times when recreational fishing participation was highest (i.e. Christmas holidays, during recreational fishing competitions and on long weekends), and a net free zone in another area for the whole year. The code of practice was approved by all delegates (Gladwin 1995).

Regardless of how ROFAs are implemented, the question of whether they are successful in resolving conflict has yet to be answered – there are no published examples of ROFAs being examined post-implementation to test whether they were successful in reducing or resolving conflict. Conflict is often manifested via media articles and letters to fisheries departments (Ruello and Henry 1977; Henry 1984;

Anderson 1999; Kearney 2002b): if such media outlining the conflict cease, then it could be assumed that the conflict is resolved. In many cases, however the same issues are raised again some years after ROFAs are implemented (or called for but deemed unnecessary at the time), usually with demands for further ROFAs. For example, in Australia's Northern Territory there has been a progressive implementation of ROFAs since the 1960s (Reed 1992; Pender 1995; Griffin 2003). Initially, commercial gill netting was prohibited in freshwater as a specific resource conservation measure. In 1978 the Mary River was closed to commercial fishing at the river mouth in response to declining recreational catch rates and high commercial pressure. This closure was extended in 1989. From 1987 the Commonwealth began progressively closing the Alligator Rivers in Kakadu to commercial fishing. The Daly River in 1989, and the Roper River in 1991 were closed to commercial netting in response to recreational fishing requests and in recognition of the importance of recreational fishing to the Northern Territory's outdoor oriented lifestyle (Reed 1992). In 2002, the MacArthur River was closed to commercial fishing, apparently due to lobbying efforts of the Amateur Fisherman's Association of the Northern Territory (AFANT) (AFANT 2005).

Perhaps understandably, commercial fishers are concerned that there seems to be no "bottom line" when it comes to negotiations with anglers over resource allocation (Loveday 1995). Consequently, to reduce conflict in the long-term the implementation of ROFAs requires more future planning and consistency of implementation based on scientific knowledge, rather than via the current 'ad-hoc' manner (Brayford 1995; McLeod 1995; Rogers and Gould 1995). In many cases recreational fishers are unaware of previous changes that have been made in their favour, which highlights the need to make such information more readily available (Ruello and Henry 1977; The Recreational Fishing Consultative Committee 1994).

b) Improved recreational catches

Recreational fishers advocate the implementation of ROFAs on the presumption that such action will improve the quality of angling (in terms of numbers and size of certain species caught) (Ruello and Henry 1977; Kearney 2001; Cox et al. 2003). Such improvement in angling quality may increase the value current anglers place on fishing (Hendee 1974; Graefe and Fedler 1986). There is significant anecdotal evidence through fishing clubs and the media that ROFAs do result in improved catches for anglers (see Griffin 1995; Brown 2001; Anon 2002b; AFANT 2005). There is at least an expectation that anglers' catches will improve in ROFAs given the removal of commercial fishing effort (so that fish previously harvested by commercial fishers are now available to the recreational sector only) (Steffe et al. 2005b), however there is no scientific information to support claims of improved fishing quality in most cases, and therefore anecdotal claims can take precedence (Smith and Pollard 1995; Griffin and Walters 1999).

There are a few cases where recreational catches are examined in ROFAs following their implementation. For example, in Iceland, anglers found a 28-35% increase in their catch when they effectively closed the River Hvitá mainstream to commercial netting from 1991. Recreational catch rates in the 'closed' area (i.e. ROFA) from 1991-2000 were compared to catch rates 10 years prior to the closure for the same area. The post-closure catch rates were also compared to catches in two other rivers that remained open to commercial fishing. Results showed significant increases in rod catches in the ROFA post-closure, while in the 'open' rivers the catches declined. Note that in this fishery the number of rods allowed on each river is fixed: i.e. it is not open access for recreational fishing (Einarsson and Gudbergsson 2003).

More recently, Steffe et al. (2005a) examined recreational harvest in the Tuross Lake estuary in NSW, which was declared a ROFA in May 2002. They compared two separate daytime, boat-based, recreational fishing surveys, with the first annual survey prior to ROFA implementation (March 1999 – Feb 2000), and the second 1.5 – 2.5 years post-ROFA implementation (Dec 2003 – Nov 2004). They found significant increases in recreational fishing effort (about 25%) in the post-ROFA survey year, and significant increases in harvest of many recreationally important species such as dusky flathead and bream. Some species harvest decreased, meaning there was no difference by number between survey years in the total annual harvest, but there was a significant difference by weight (41.6%) in the annual harvest of fish, crabs and cephalopods. This was due to the increase in mean and median size of most species harvested post-ROFA implementation. Further, the proportional increases in recreational harvest were all much larger than the corresponding proportional change in fishing effort. The authors stated the changes detected may be in part attributable to the implementation of the ROFA and/or may be in part attributable to natural fluctuations in fish abundance and catchability (which can be large in an open estuary system). Nonetheless, the comparison between the two annual survey periods shows that real differences occurred in the recreational boat-based fishery in the Tuross Lake estuary since the implementation of the ROFA.

In many other fisheries, improvements in recreational catches are not evident. For example the Florida net ban was expected to result in improved recreational catches in terms of catch per unit effort (CPUE). This is not evident according to current publications, which some authors suggest is due to increases in recreational effort to the degree that total fishing mortality rates returned to previous levels (Anderson 1999; Adams 2000; Walters 2003). Ruello and Henry (1977) found no noticeable improvements in recreational catches in Australia's Port Hacking and Brisbane waters despite being closed to commercial netting since the 1930s. They further stated that Botany Bay, which was open to commercial fishing, was considered a better angling area than either of these two ROFAs, despite anecdotal claims to the contrary[2]. In the Pumicestone Passage in Queensland, O'Neill (2000) examined recreational catches before and after commercial fishing was banned in 1995. No improvements in recreational catch rates were found.

Unfortunately, most of the studies that do examine recreational catches in ROFAs lack scientific rigour, either through a lack of comparable catch data from before and after ROFA implementation, a lack of time series data following the ROFA, or a lack of replication in sites. For instance, Einarsson's (2003) study in Iceland, while examining before and after closure data, was unable to provide a replicate ROFA with which to compare catch rates. Thus the changes in catch rates may have been a characteristic of the particular area. Steffe et al.'s (2005a) study provides a good comparison of recreational harvest pre- and post-ROFA implementation, however they do state that changes may be due to natural fluctuations and they recommend continued monitoring at intervals of about 3-5 years. Ruello and Henry's (1977) observations for Port Hacking and Brisbane waters were based on anecdotal information from 'experienced' fishers. Finally, O'Neill (2000) recommended re-examining angler catches in the Pumicestone Passage in future years as he sampled probably too soon since the closure to notice any potential catch improvements. O'Neill also noted he needed to interview twice as many anglers to have about an 80% confidence in detecting a 15% difference in catch rates between the before- and after-closure periods.

A more scientifically rigorous study was successful in showing higher fish abundances in ROFAs compared with non-ROFAs, although they did not examine recreational catches: Halliday et al. (2001) used commercial gill net fishing techniques to compare estuarine catches in three ROFAs and three non-ROFAs in north Queensland bimonthly over two years. The study found higher abundances of large barramundi (over 800 mm total length) in ROFAs compared to non-ROFAs. These results suggest improved angler catches of large barramundi in ROFAs are possible.

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[2] Interestingly Botany Bay was declared a ROFA in 2002 (NSW Fisheries 2003) – 25 years after Ruello and Henry's publication.

However, many studies show that there is not a strong relationship between fish abundance and angler catch rates because angling success is highly variable (Ruello and Henry 1977; Johnson and Carpenter 1994; Anderson 1999; Pierce and Tomcko 2003). For example, in Lake Mendota, Wisconsin, examination of 7-year creel survey data for the walleye (S*tizostedion vitreum vitreum*) fishery revealed that catch per unit effort varied independently of fish abundance (Johnson and Carpenter 1994). Further, the closure of the Mary River in the Northern Territory to commercial gill net fishing resulted in expectations of improved angling success. However, despite a rise in the availability of barramundi (due to commercial exclusion as well as a good wet season and strong recruitment), angler success rate did not change, with only 50% of parties landing a barramundi (Griffin and Walters 1999; Griffin 2003). With any commercial or recreational fishery, there are factors that affect catch rates outside of the abundance of fish stocks, such as the composition of fishing fleet (including number and skill level of fishers), method of fishing, and where and when fishing occurs (Maunder and Punt 2004).

Another explanation for the lack of relationship between recreational catch or success rate and stock abundance may be that overall recreational fishing effort increases as stocks increase such that an individual angler's fishing quality doesn't improve because there is higher competition between more anglers (Cox and Walters 2002; Cox et al. 2002; Le Goffe and Salanié 2005).

Some authors suggest that recreational catches may improve in newly implemented ROFAs, but such benefits may only be realised by 10% of the recreational fishing population – i.e. by the more skilled anglers who catch 90% of the recreational harvest – rather than the average angler (Johnson and Carpenter 1994; Griffin and Walters 1999; McPhee and Hundloe 2004).

c) <u>Flow-on benefits for the community</u>

If improved recreational catches are expected or perceived, ROFAs may result in greater recreational fishing effort (Griffin and Walters 1999; Cox and Walters 2002; Cox et al. 2002; Pereira and Hansen 2003; Post et al. 2003; Denny and Babcock 2004). Such increased participation may in turn result in benefit to the community in terms of increased expenditure within the community (Hushak et al. 1986; Dominion 2002; Pereira and Hansen 2003) and potentially increased social well-being, such as health, social cohesion and quality of life, which result from participation in an outdoor recreational past-time such as fishing (Pretty et al. 2005; Cox 2006). The possibilities of increased effort and economic benefit are considered below. While social well-being is an important benefit, it is difficult to measure and few studies examine the well-being benefits of recreational fishing compared to other activities specifically.

i) Increased recreational fishing effort

In many situations where ROFAs are introduced, an increase in recreational effort is expected. In NSW, for example, a rise in angling demand is expected within the 30 ROFAs introduced in the year 2002 (Dominion 2002; NSW Fisheries 2003; McPhee and Hundloe 2004). This expectation was fulfilled at least in one of the ROFAs – in the Tuross Lake estuary – where angling effort (boat days) increased by about 25% approximately 1.5 to 2.5 years after ROFA implementation (Steffe et al. 2005a). For the walleye fishery in Lake Mendota, Wisconsin, angler expectations of increased catches due to stocking resulted in increased annual effort in the fishery (although the expectations were linked more to publicity than actual improvements in catch rates for the average angler) (Johnson and Carpenter 1994).

On the other hand, the relationship between angler effort and fish abundance is not known for most fisheries (Post et al. 2003), and some authors argue that even if angler catches improve, there is not a positive relationship between fish abundance (or catch rates) and the number of anglers (O'Neill 2000). For example, after commercial fishing was banned in the Northern Territory's Mary River an increase in recreational fishing activity in response to improved fish stocks was expected but did not occur. In contrast there was a decrease in angling activity despite increases in available barramundi stocks. The authors concluded that while abundance of fish is the basic factor that determines whether or not fishing activity will occur, it is not the only factor (Griffin 1995; Griffin and Walters 1999).

There is the growing notion that non-catch related reasons are the principal motivation for angling (Henry 1984; Holland and Ditton 1992; Fedler and Ditton 1994; Vigliano et al. 2000; McPhee and Hundloe 2004), and that a certain amount of angler behaviour is fixed, or at least unresponsive, to catch rate (Johnson and Carpenter 1994). There are conflicting views on the level of importance anglers place on catching fish (Schramm et al. 2003): some authors state that catching a fish remains a primary goal of angling, meaning there must be some probability of catching a fish before non-catch motivations gain more importance (Hendee 1974; Graefe and Fedler 1986; Arlinghaus 2005); while others argue that fishing quality contributes to satisfaction but for most anglers it is less important than other factors such as the physical setting of the fishing experience and social and leisure factors (Holland and Ditton 1992; Fedler and Ditton 1994; Vigliano et al. 2000; Ready et al. 2005). For example, Responsive

Management (2004) conducted a survey in Pennsylvania, USA, in 1993 and 1996 to examine why anglers who bought a recreational fishing licence the previous year decided not to buy a licence on the year of the survey. Most anglers cited a loss of interest, lack of free time, work and family obligations, etc. Only 10% of anglers stated the quality of fishing affected their decision of whether to fish (Responsive Management 2004; Ready et al. 2005).

Given the level of importance attributed to fishing quality may vary widely between individuals and individual situations, it is unknown whether an improvement in angling quality will result in increased recreational effort.

ii) Increased economic value

Regardless of these varied views and outcomes, if there is an increase in effort in a ROFA, it is theorised that expenditure of anglers in the area adjacent to the ROFA will increase (Hushak et al. 1986; Pereira and Hansen 2003). Expenditure of current anglers may also increase as anglers may place a higher value on a fishery with greater fishing quality (Dwyer and Bowes 1978; Cauvin 1980; Graefe and Fedler 1986). Some authors consider an increase in expenditure to be equivalent to an increase in economic ‘value’ (Nicholls and Young 2000; Young 2001; Murphy 2003), and this is a common argument used by anglers to promote further ROFA implementation (McPhee and Hundloe 2004).

In some cases increased economic input into the community is expected. For example, the recently appointed NSW ROFAs are expected to result in an increase in expenditure on fuel, bait, supplies, fishing gear, boats, etc, resulting in an expansion in employment in the recreational sector. Such economic gains are expected to exceed those lost from the commercial fishery[3] (Dominion 2002). Similarly, Mann et al. (2002) suggest the proposed introduction of commercial gill net fishing in a previously recreational only estuary in South Africa would probably not provide as much employment and economic gain as that generated by the recreational fishery.

While economic benefits are theorised, there are no published cases where such expectations of increased expenditure as a result of ROFA introduction in the adjacent community have been tested following ROFA implementation. For example Hushak et al. (1986) estimated the required increase in angling effort and expenditure to offset commercial losses following allocation of yellow perch (*Perca flavescens*) and

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[3] There are no current publications available outlining whether recreational expenditure has increased in areas adjacent to these NSW ROFAs as expected.

white bass (*Morone chrysops*) to the recreational fishery in Ohio's portion of Lake Erie. Whether this increase would occur, however, was unknown: the authors stated that further research is needed to confirm the response of anglers to reallocations. In some situations changes to recreational effort has been examined, but whether related expenditure has increased as well is not explored. Some authors suggest that angler success apparently does not strongly influence angler expenditure (McPhee and Hundloe 2004).

If, hypothetically, angler expenditure does increase in the region adjacent to the ROFA, it may merely be a transfer or re-distribution of spending from other areas (e.g. other nearby towns, or other leisure activities), so the overall net national benefits would be zero (Edwards 1990; Hundloe 2002; Kearney 2003b; McPhee and Hundloe 2004). This may certainly be the case in Queensland where the overall number of anglers is declining (Higgs 2003), as it is in other areas (e.g. America (Fedler and Ditton 2001)), and thus the likelihood is low that any increased expenditure comes from new anglers.

Importantly, there is also abundant literature available arguing that an increase in expenditure is not equivalent to an increase in 'value' to the community (see Gordon et al. 1973; Edwards 1990, 1991; Kearney 2001; Hundloe 2002; Pitcher and Hollingworth 2002; McPhee and Hundloe 2004). There are numerous papers debating the use of various economic methods for assessing economic value and allocating resources accordingly between recreational and commercial fishing sectors (see Edwards 1991; Nicholls and Young 2000; Hundloe 2002; McPhee and Hundloe 2004). Currently, however, there is no consistent or accepted method for evaluating recreational fisheries – a common problem against which Gordon et al. (1973) made a plea for consistency in the 1970s – much less for comparing recreational and commercial fishing values. Given numerous differences between these two sectors, values (social and/or economic) are difficult to compare (Beaumariage 1978; Coastal Engineering Research Center 1984; Winwood 1994; Gresswell and Liss 1995; van der Elst 1997; van der Elst et al. 1997; Kearney 2002b; Pitcher and Hollingworth 2002), and there is a lack of studies that examine the social and economic values of the recreational and commercial sectors at the same time and/or using the same methods (Holland et al. 1992; Hobson 1993; Peterson 1994; van der Elst 1997; The South Australian Centre for Economic Studies 1999; McPhee and Hundloe 2004). Furthermore, there are few data available for any method of economic evaluation or comparison, particularly for the recreational sector (Holland et al. 1992; McLeod 1995; Rogers and Gould 1995; Kearney 2001; Rogers and Curnow 2003).

With the inability to demonstrate comparable values, it is impossible to demonstrate comparable costs and benefits of different allocation strategies (van der Elst 1997), and there is a scarcity of studies examining the net economic impacts of reallocating resources from the commercial to the recreational sector (Berman et al. 1997; Sharma and Leung 2001). Therefore it is important the economic costs and benefits are monitored or assessed where allocation changes are made (McPhee and Hundloe 2004).

Regardless of whether economic values are available or correct, some authors argue that ROFAs may be "second best" in terms of economic efficiency (Edwards 1990; McPhee and Hundloe 2004), although they may have the advantage of political expediency (Samples 1989; Rogers and Gould 1995). Allocation based on economic value infers that stocks should be allocated to the sector which gains the greatest marginal value from using the resource, hence maximising benefits to the community (Edwards 1991; Presser 1994; van der Elst et al. 1997; Department of Fisheries Western Australia 2000; Kearney 2002b). McPhee & Hundloe (2004) argue that if the purpose of reallocation is to increase community benefits, resources should be allocated to the point where net marginal benefits for each sector are equal, rather than providing one sector with exclusive access such as via ROFAs.

d) Conservation of fish stocks

Some proponents of ROFAs believe ROFAs will be able to fulfil sustainability or conservation goals by removing the more efficient commercial effort; the catch from which may not be completely harvested by anglers (MacDonald 2003; Rogers and Curnow 2003; Denny and Babcock 2004). For instance in Iceland, following the closure of the River Hvitá to commercial fishing, while anglers' catches improved, they were only able to harvest 39-52% of the previous commercial catch (Einarsson and Gudbergsson 2003), which may be a positive outcome for the fish stocks. This outcome, however, may differ in open access recreational fisheries (in Iceland there is a limit on recreational rod number per day) because recreational effort may continue to increase to the point that the original total harvest is taken (Cox and Walters 2002; Cox et al. 2002; Rogers and Curnow 2003; Walters 2003). Unfortunately in most cases where ROFAs are introduced the total recreational harvest from the area prior to and following ROFA implementation is unknown.

On the other hand, many authors suggest resource allocation and conservation issues should be treated separately, as allocating a resource to one sector does not necessarily address conservation imperatives (Kearney 2003a; MacDonald 2003;

O'Regan 2003; Denny and Babcock 2004). In Western Australia, for example, there are calls by anglers to remove commercial fishing in an attempt to improve sustainability of the dhufish (*Glaucosoma hebraicum*) fishery. In the short-term fish stocks may benefit from the removal of commercial fishing and recreational catches would likely improve. However, current recreational bag limits are ineffective – the recreational bag limit is 4 fish per person per day, but catch surveys indicate the average catch is 0.4 dhufish per angler per trip. Hence there is room for angler catches to increase within current regulations, meaning long-term benefits to the stock of removing commercial harvest would likely be zero as recreational effort increases in response to improved CPUE (Rogers and Curnow 2003). In the Tuross Lake estuary in NSW, there were concerns that dusky flathead were growth overfished (where excessive fishing effort leads to the harvesting of many smaller fish such that they do not get a chance to reach their maximum growth) prior to ROFA implementation. Surveys of recreational fishing 1.5 to 2.5 years after ROFA implementation revealed only a small improvement in average size of dusky flathead, indicating that the increase in recreational fishing effort (25%) was sufficiently large to offset most of the potential gain made by removing commercial fishing effort (Steffe et al. 2005a).

In many fisheries, though estimates are not considered reliable, the total recreational catches are at least as high as those of the commercial sector, particularly in coastal areas close to population centres (Anon 1995; Hancock 1995; Rogers and Gould 1995; McPhee et al. 2002; Sumner 2003). For instance recreational harvest is similar to commercial harvest for King George whiting, snapper, garfish, blue crabs and squid in South Australia (Hall 1993), barramundi on Queensland's east coast (Williams 2002a), and snapper in New Zealand (Sullivan 1997). In some fisheries the recreational catch exceeds commercial take and is seen as a major threat to the resource (Cox et al. 2002; Schroeder and Love 2002; Cooke and Cowx 2004), such as within the tailor (*Pomatomus saltatrix*) fishery in southern Queensland (Pollock 1979; Pollock 1980; Williams 2002a); red drum (*Sciaenops ocellatus*) in the South Atlantic (where recreational harvest is 93% of total harvest); and red snapper (*Lutjanus campechanus*) in the Gulf of Mexico (where recreational harvest is 58% of total harvest) (Coleman et al. 2004). Thus removal of commercial effort in fisheries where recreational harvest is dominant is unlikely to result in conservation of fish stocks.

In situations where recreational harvest is significant (as a proportion of total harvest) or where effort and catches increase dramatically as a consequence of declaring ROFAs, ROFAs are unlikely to be effective in meeting conservation goals without management intervention to limit or reduce recreational effort (and harvest). Some authors advocate limiting recreational effort in ROFAs through catch quota, limited licensing, or even limited facilities at boat ramps (Cox and Walters 2002; Mann et al. 2002; Cox et al. 2003; Walters 2003). However, there is often reluctance by fisheries managers to limit recreational access in many fisheries (Pereira and Hansen 2003).

1.2.2 Costs of ROFAs

Costs of ROFAs are not often considered when ROFAs are proposed. Some studies outline hypothetical costs (e.g. Dominion 2002), but fail to detail actual costs. There are various potential costs, not just for the excluded commercial fishers, but also for recreational fishers, the community and the fish stocks. There are also potentially significant costs to fisheries agencies and the government of implementing ROFAs.

a) Costs to commercial fishers

For the commercial sector, ROFAs bear the obvious potential cost of reduced product and income, due to a decrease in area available for fishing (Hushak 2000). In some cases there is a complete loss of livelihood from fishing if the fisher's licence is bought back, such as via the ROFAs introduced recently in NSW (see Dominion 2002; NSW Fisheries 2003) and Victoria (see Morison and McCormack 2003). Increased pressures of reduced disposable income are likely to be felt both at the family and the broader community level (Bureau of Rural Sciences 2003).

Studies of Marine Protected Areas suggest costs can be significant for individual fishers (Bureau of Rural Sciences 2003; Cook and Heinen 2005). For example, the implementation of a 'no take' area within the Florida Keys National Marine Sanctuary was expected to impact 8% of shrimp catch, 14% of king mackerel catch, 12% of lobster catch and 20% of reef-fish catch. These catch reductions would result in a loss of almost $844,000 in harvest revenue and 49 jobs by commercial fishing operations (Cook and Heinen 2005). The Representative Areas Program (RAP) implemented in 2004 in the Great Barrier Reef Marine Park (GBRMP), Queensland, was estimated to result in a $10.5 million reduction per annum in the gross value of production of key commercial fisheries (otter-trawl, net, line and crab), which represents on average approximately 10% of production value (Bureau of Rural Sciences 2003; Hand 2003).

Factors which will influence the level of impact on individual fishers include the magnitude of the change (i.e. the extent to which ROFA will reduce access to resource fishers currently use), fishers' capacity to shift effort, change the nature of their fishing operations or take other mitigating action, fishers' level of dependence on the fishery, their individual resilience to managing change (which varies among individuals depending on socio-demographic factors such as age and family structure, income, housing type, employment, and education, plus how localised their fishing operation is), and the level of compensation available. There may be a range of responses from fishers, including changing their fishing location (which may increase travel and running costs), increasing effort to maintain production, or changing the nature of their operations (e.g. shifting operations to higher value outputs or to other target species). Some fishers may leave the fishing industries altogether (potentially with assistance from government buy-outs), although previous studies reveal fishers prefer to remain in the industry (Bureau of Rural Sciences 2003; Hand 2003; Cook and Heinen 2005).

In those areas where no, or insufficient, licences are bought-out from newly implemented ROFAs, the resulting effort shift can potentially put greater pressure on remaining areas and result in increased competition within the commercial sector and between recreational and commercial fishers in areas to which commercial effort is displaced (Department of Primary Industries and Fisheries 2004).

There are also potential social costs for affected commercial fishers and their families, such as those outlined following the Florida net ban. These costs included mental health impacts and emotional problems, higher use of drugs or alcohol, and higher divorce rates. These negative impacts lasted well after the net ban was implemented (Anderson 1999; Bureau of Rural Sciences 2003; Smith et al. 2003). In NSW, social impacts including declining coastal communities and effects on family cohesion were hypothesised but not measured (Dominion 2002). The ability of families within the industry to manage can be examined in terms of a family resilience measure which includes socio-demographic factors such as age and family structure, income, housing type, employment, and education. The strong self-identification of fishers with their industry highlights the potential for increased feelings of alienation if commercial fishing options are no longer available. Many fishers have difficulty transferring to other employment outside the fishing sector both due to lack of formal skills and education, and due to cultural resistance to shifting out of the fishing sector (Bureau of Rural Sciences 2003; Hand 2003; Cook and Heinen 2005). There are no published cases where such costs have been quantified to examine whether they are outweighed by benefits gained from ROFAs.

b) Costs to recreational fishers

For the recreational sector, some anglers claim that the benefits of exclusive access may be negated by a disproportionate increase in recreational effort. As catches improve (perceived or real), the number of anglers may increase, leading to increased pressure on the resource and increasingly crowded conditions, which would be detrimental to angling satisfaction (Anderson 1999; Hunt 2005; Le Goffe and Salanié 2005; Ready et al. 2005). Further, as more anglers enter the area, individual angling success may decrease as competition increases within the recreational fishing sector (Cox et al. 2003; Arlinghaus 2005). There may also be increased conflict between recreational and commercial fishers in areas adjacent to ROFAs if commercial effort is displaced to these areas (Hancock 1995; Bureau of Rural Sciences 2003; Department of Primary Industries and Fisheries 2004).

c) Costs to the community

There are various potential costs to the community, depending on how central commercial fishing is to the community as a whole. In some cases while costs may be significant for individual fishers, costs may be minor for the overall community, depending on the proportional contribution to the community from fisheries compared to other industries (Bureau of Rural Sciences 2003; Cook and Heinen 2005). For instance, the direct economic impacts of closing a reserve within the Florida Keys National Marine Sanctuary to commercial fishing was expected to have significant impacts on affected commercial fishers, but was projected to be unnoticeable on the Monroe County economy. As a proportion of the Monroe County total catch, only 1.16% of harvest revenue would be lost. Plus only 0.08% of total annual income and 0.08% of total employment, of Monroe County would be negatively impacted (Cook and Heinen 2005).

For other communities there may be significant impacts. The introduction of the RAP in the GBRMP was expected to have significant impact on 13 of 20 town resource clusters (TRCs) along Queensland's east coast which relied solely or heavily on the Marine Park for their fishing activities. Some regions will be more vulnerable than others as a consequence of their underlying socio-demographic characteristics such as dependency on the fishing industry, housing, age, labour force, occupation, weekly incomes, education, family structure and proportion of Indigenous persons (Bureau of Rural Sciences 2003). Other studies have found that fishing-related populations are older than average, have lower levels of education, and have been strongly associated with fishing employment for some time. Fishing dependent communities also generally have higher than average dependency ratios (ratios of young and aged people to those of working age). All of these factors affect a community's ability to cope with closure to commercial fishing (Bureau of Rural Sciences 2003).

Further, commercial fishing provides local employment directly, plus employment in upstream and downstream industries and businesses associated with it (Bureau of Rural Sciences 2003). Anderson (1999), highlighted the effects of the Florida net ban on industries related to commercial fishing: The affected industries included gasoline, diesel and oil suppliers; ice, bait and fishing gear suppliers; services associated with docking, registration and licences; and fish processing plants, warehouses and distributors. Fenton and Marshall (2000) outlined the flow-on effects of fisheries closures in Queensland resulting from reduced income of commercial fishers and predicted effects on neighbouring towns or regions where fishers would normally spend their income.

While there may be costs of economic loss to the community through a reduction in commercial product, some authors consider these may be offset by increases in recreational spending (Dominion 2002), Others dispute this theory, however (see *Flow-on benefits for the community* above). For example, in Lake Erie, stock increases of yellow trout were expected to result in increased recreational effort and expenditure; however, these expected increases did not eventuate (Hushak 2000).

There are also other costs to the community aside from direct economic loss from commercial product. For example, authors have listed positive reasons to keep commercial fishing in an area including local seafood and bait supply for residents and tourists, plus the importance to the national economy (e.g., via decreased dependence on imports) (Ruello and Henry 1977; Peterson 1994; Hushak 2000; Bureau of Rural Sciences 2003). Loss of local seafood for local and tourist consumers may also result in an increase in price of seafood, or forced substitution with lesser valued or imported species (Lampl 1989; Anderson 1999; Hushak 2000; Dominion 2002). Further, commercial fishing can have strong historical links in local communities, and for many is considered a defining industry in the livelihood and character of the region (Bureau of Rural Sciences 2003).

d) <u>Costs to fish stocks</u>

Costs to the fish stocks are also possible, though they are rarely considered or monitored when ROFAs are suggested or implemented. There are potential costs from unmonitored recreational fishing, costs to adjacent areas from displaced commercial effort, and potential costs for mobile species, as outlined below.

There is a perception that the exclusion of the commercial sector may result in a more sustainable use of the resource (see *Conservation of fish stocks* above). Some authors and anglers argue that anglers are more conservation conscious than commercial fishers (Arlinghaus 2005; Grimm 2005). This is not always supported by the limited available data, however. Individual recreational fishers may be conservation-minded, but they rarely take into account the high numbers of people participating, which together can have a significant impact on the resource (Brayford 1995; Francour et al. 2001; Kearney 2001; McPhee et al. 2002; Pitcher and Hollingworth 2002; Schroeder and Love 2002; Kearney 2003a; Walters 2003; Coleman et al. 2004; Hecht and Vince 2004). Whether the potential impacts of recreational fishers in ROFAs outweigh the combined impacts of commercial and recreational fishing in shared areas is unknown. However, the potential impacts of recreational fishing in ROFAs are outlined here.

Recreational fishing can have significant impacts on fish stocks within ROFAs. Westera et al. (2003), for example, compared fish abundance and size between 'sanctuaries' (where no fishing is allowed) and ROFAs in Ningaloo Marine Park, Western Australia. They examined three regions, each containing one sanctuary and one ROFA, and found higher abundances of legal-sized Lethrinids (the most targeted finfish family) in sanctuaries than in ROFAs, concluding that recreational fishing does have an impact on target species. Similarly, New Zealand snapper (*Pagrus auratus*) populations were compared between the Mimiwhangata Marine Park, which is open to some recreational fishing methods only (i.e. effectively a ROFA), to areas with no protection (i.e. open to all fishing) and areas with complete protection (i.e. no fishing allowed). The study found Mimiwhangata had fewer and smaller snapper than in any of the other areas, concluding that partial closures are ineffective as conservation tools. The authors further stated that there may be a perception that, in the absence of commercial fishing, fish are larger and more plentiful in the ROFA, which may result in higher recreational fishing effort (Denny and Babcock 2004).

Open-access recreational fisheries may respond to perceived or real fish abundance increases within ROFAs with strong effort responses that may negate any gains in quality of fishing for individual recreational fishers (Sullivan 1997; Department of Fisheries Western Australia 2000; Cox and Walters 2002; Cox et al. 2002; Pitcher and Hollingworth 2002; O'Regan 2003; Walters 2003; Arlinghaus 2005; Le Goffe and Salanié 2005), although some authors dispute whether this will occur (see *Flow-on benefits for the community* above). Some authors state there is potential for the recreational sector to fish stocks to a lower level than the commercial sector would as anglers derive their personal incomes independent of fish resources: this means their fishing operations are 'subsidised' in an economic sense, and subsidised fisheries often collapse (van der Elst 1992; Hall 1993; Department of Fisheries Western Australia 2000; Francour et al. 2001).

Conventional management methods, such as size and bag limits, aim to limit recreational harvest in many fisheries. However these measures are considered ineffective in many open access recreational fisheries (Cox et al. 2002; Post et al. 2003; Morales-Nin et al. 2005). These management measures assume that released fish survive, however post-release survival rates are variable between species and often unknown for many species (Post et al. 2003; Sumner 2003; Coleman et al. 2004; de Lestang et al. 2004; Thorstad et al. 2004; Bartholomew and Bohnsack 2005). In some high-effort recreational fisheries post-release mortality has been found to be high (Bohnsack 1993), such as in the walleye fisheries in Alberta, USA (Sullivan 2003 in Pereira and Hansen 2003), and the common snook (*Centropomus undecimalis*) in Florida (Muller et al. 2001 in Pereira and Hansen 2003). For the Atlantic striped bass (*Morone saxatilis*) catch-and-release mortality losses were estimated to be 1.2 million fish compared to the total recreational landings of 1.4 million fish in 1998. This level of mortality, when combined with total commercial fishery losses, led to an overfishing declaration for striped bass (NMFS 1999 in Cox et al. 2002). Research suggests that all recreational fishing results in some level of injury and stress to an individual fish, however, the severity of the injury, magnitude of stress, and potential for mortality varies in response to a variety of factors such as fishing gear (e.g., type of hook, bait or landing net) and angling practices (e.g., duration of fight and air exposure, fishing during extreme environmental conditions, fishing during the reproductive period) (Cooke and Sneddon 2007). Bartholomew and Bohnsack (2005) reviewed 53 release mortality studies, and found release mortality varied greatly between and within species. They listed various important factors that affected mortality, including anatomical hooking location (the most important mortality factor), type of bait, removing hooks from deeply hooked fish, hook type, depth of capture, warm water temperatures, and extended playing and handling times. There is also growing debate regarding the ethics of catch-and-release angling in terms of pain and suffering experienced by released fish (Cooke and Sneddon 2007).

Given these potential impacts, some fisheries departments are becoming increasingly concerned about the unmonitored impacts of recreational fishing in ROFAs. Unfortunately, when commercial fishers are excluded from an area, the time-series data provided by commercial catch logbooks is also lost (Hancock 1995; Cowx 1999; Cox et al. 2002; McPhee et al. 2002; Griffin 2003; Hall 2003; Cooke and Cowx 2004). Thus, some managers recommend monitoring of recreational catches, implementation of limited access within ROFAs, or even allocation of quotas for recreational fishers (Sullivan 1997; Cox and Walters 2002; Cox et al. 2002; Anon 2003; Sumner 2003; Walters 2003). Fisheries independent monitoring within ROFAs may be required, however, as recreational fishing alone may not provide the necessary data to accurately assess the status of fish stocks (Cowx 1999; Arlinghaus 2005).

Other environmental impacts of recreational fishing should also be considered. While there are no data available on the environmental impacts of recreational fishing, anecdotal evidence outlines problems such as discarded line, lead weights, litter, impacts on habitat through bait harvesting, direct impacts on sea-birds, marine mammals and reptiles, and potential trophic or ecosystem effects similar to commercial fisheries (Dominion 2002; McPhee et al. 2002; Sumner 2003; Coleman et al. 2004; Cooke and Cowx 2004).

Implementation of ROFAs may also affect adjacent areas or other species, by moving commercial interests from one area or stock to another (Hancock 1995; Bureau of Rural Sciences 2003). This was shown in the case of the Florida net ban, where commercial fishers previously targeting mullet moved to other species such as stone and blue crab which apparently now require increased regulations to protect these intensely targeted species. Such action will probably refocus or intensify commercial efforts on yet another species as commercial fishers' families strive to retain their way of life (Anderson 1999; Smith et al. 2003). In situations where commercial licences are bought-out to implement the ROFA, there is less likelihood of increased pressure on remaining areas or other species.

Size of ROFAs may also be important, particularly for mobile species, because closed areas are less effective for species that have larger home-ranges. Fish that settle in a ROFA can be exposed to the commercial fishery if relocations take them outside the ROFA boundaries (Kramer and Chapman 1999).

e) <u>Costs to the government:</u>

Authors such as McPhee and Hundloe (2004) suggest other costs of a new fisheries allocation plan to the community should also be considered: i.e. costs of management (e.g., legal proceedings and licence buy-backs), compliance, research and education. There are expected costs for changing legislation, but additional costs such as buying out commercial licences, or paying compensation, can be significant. For example, 114 commercial licences were initially bought-out as a result of the RAP in the GBRMP at a cost of over $31 million (QSIA 2004). Assistance to fishing and related businesses as a result of the RAP exceeded $87 million (Campbell 2006). In some instances costs of licence buy-outs and compensation for ROFA implementation may be funded by recreational fishing licences, such as in NSW, where the creation of 30 ROFAs required the purchase of 251 fishing businesses at cost in excess of $18.5 million (NSW Department of Primary Industries 2004; Steffe et al. 2005a).

Costs of negotiation and legal proceedings can also be significant. While there are no exact figures published, the Florida net ban for example was preceded and followed by numerous challenges taken to the Supreme Court by conservationists, recreational fishers and affected commercial fishers (Renard 1995; Smith et al. 2003). Sutinen and Johnston (2003) state that in the US, litigation costs have increased in such a way that resources are diverted from the basic tasks of fisheries management.

Other studies highlight the need for ongoing public education and stakeholder analysis over time, which incur costs but are necessary to ensure the public are aware of closures and to allow managers to better-understand any social impacts or benefits (Cook and Heinen 2005).

1.2.3 Conclusion

While many benefits and costs of ROFAs are possible, there are few cases where they are examined and quantified, much less compared, to determine whether the benefits outweigh the costs involved. Considering the mixed results for both benefits and costs outlined above, and with continued pressure from recreational fishing bodies to implement more ROFAs, potential benefits and costs of current ROFAs should be examined and monitored. There is a need for fisheries managers to develop clear management objectives for ROFAs, and for investigation into whether these objectives are achieved.

The present study focuses on whether benefits of current ROFAs for commercial and recreational fishing sectors are being realised within the Queensland east coast barramundi fishery. An investigation of costs of current and future ROFAs for this fishery is beyond the scope of this study. Information on potential costs provided here, however, highlight the importance of examining whether benefits of ROFAs are realised, as ROFAs are unlikely to come without costs.

1.3 ROFAs within Queensland east coast estuaries

Following concern for fish stocks, in 1976 all or part of 6 river systems on Queensland's east-coast were closed to commercial gill net fishing, effectively making them ROFAs for finfish (commercial crabbing is still allowed in these areas) (Healy 1995). Later, a further approximately 35 estuaries north of Fraser Island were closed or partly closed to commercial gill netting. All estuarine ROFAs are listed within Queensland's Fisheries

Regulations 1995 (see Appendix 1 for a list constructed from the Regulations), however information on the timing and reason for each closure is not readily available – a number of areas were permanently closed to commercial netting due to their role as nursery habitats where fish are in relatively high numbers and can be more susceptible to net capture (including inshore seagrass beds, upper reaches of estuaries within rivers, and whole estuaries of some smaller creeks) (Zeller and Snape 2005); and an unknown number of estuaries were closed to commercial netting in order to reduce conflict between competing recreational and commercial fishers (Mark Doohan, QDPI&F, pers. comm., 2005).

In January 1998, further closures and restrictions to commercial gill netting were introduced via the implementation of 17 Dugong Protection Areas (DPAs) on Queensland's east coast. While these areas were set aside specifically for dugong conservation, some of these DPAs effectively became ROFAs for finfish (particularly barramundi) because set gill netting was banned or restricted. The DPA regulations appear complicated when combined with other fisheries regulations. Of most interest to this project is the DPA encompassing the Hinchinbrook Channel – due to a combination of fisheries regulations and the DPAs, within the Hinchinbrook Channel there is a large area (from approximately the Herbert River to just south of Cardwell, see Figure 1.2), where no netting is allowed within the channel and adjoining estuaries. Adjoining areas allow restricted netting under 'N1' and 'N6' symbols, with which no barramundi are allowed to be kept (there are a number of netting symbols in the East Coast Inshore Finfish Fishery – see *The commercial fishery* below). Other DPAs allow restricted netting. The introduction of DPAs resulted in some commercial effort displacement from areas where DPA 'a' zones were declared to areas where lesser restrictive DPA 'b' zones were implemented, and to adjacent non-DPA areas (see Queensland Department of Primary Industries 1995; Williams 2002a; Zeller and Snape 2005; Great Barrier Reef Marine Park Authority unknown-a) for further information).

More recently (in July 2004) approximately 50 inshore 'Conservation Park (yellow) Zones' were implemented through the Great Barrier Reef Marine Park Authority's (GBRMPA) 'Representative Areas Program' (RAP) (Zeller and Snape 2005; Great Barrier Reef Marine Park Authority unknown-b). Many of these yellow zones were mirrored within the Great Barrier Reef Coast Marine Park for the low to high tidal waters, including part of some rivers (Environmental Protection Agency 2004). Yellow zones were implemented with the aim of protecting biodiversity and as such certain fishing methods are restricted. Within these zones, line fishing with one line and hook per person is allowed, but commercial netting (except baitnetting) is banned (Great Barrier Reef Marine Park Authority unknown-b). Hence for inshore areas these yellow zones are effectively ROFAs for barramundi at least, for which there is no commercial line fishing (Queensland Department of Primary Industries 1995; Department of Primary Industries and Fisheries 2004). There are very few estuaries closed to all fishing (i.e. both recreational and commercial fishing) in Queensland (Queensland Department of Primary Industries 1995; Halliday et al. 2001), however a number of bays (not including adjoining estuaries) were closed to all fishing within 'Marine National Park (green) Zones' in 2004 via the RAP (Great Barrier Reef Marine Park Authority unknown-b).

Recreational and commercial estuarine fishers are also separated through time segregation: No commercial gill netting is allowed in estuaries on weekends, allowing anglers exclusive access at a time when angler activity is highest (Healy 1995; Queensland Department of Primary Industries 1995).

Currently, there are calls for the introduction of further estuarine ROFAs on Queensland's east coast (see The Recreational Fishing Consultative Committee 1994; Eussen 2001; Knowles 2001; Sunfish 2001), in an attempt to: a) reduce apparent conflict between the commercial and recreational sectors; and b) improve angler catches of barramundi (primarily) and other fish species.

1.3.1 ROFAs for barramundi

While commercial and recreational estuarine fishers share access to most estuarine fish species, barramundi (*Lates calcarifer*), is the main target of commercial gill net fishers within the East Coast Inshore Finfish Fishery (ECIFF) in the Great Barrier Reef World Heritage Area (GBRWHA), and is one of the most important target fish for anglers in north Queensland (Healy 1995; Welch et al. 2002; CRC Reef Research Centre 2005a; Robinson and Cully unknown). Barramundi drive many of the calls for further ROFAs and claims of effects of commercial gill net fishing on angler catches (see Brayford 1995; Brown 2001). Consequently, barramundi has been selected as the focus species of this project.

1.3.2 Goals of ROFAs

a) <u>Reduction of conflict</u>

In Queensland, overall recreational fishing participation has declined in recent years (Higgs 2003). This decline may be due to a number of factors, however one suggestion is that declining recreational fishing participation is often attributed (by anglers) to declines in fish stocks and increasing competition with commercial fishers. Regardless of this decline in participation, increased access to fishing locations has apparently increased contact between the commercial and recreational fishing sectors, which may be increasing conflict (Higgs 2003).

Overlap in species taken by recreational and commercial fisheries within the Queensland ECIFF has created, and will continue to create, conflict over resource allocation (Department of Primary Industries and Fisheries 2004). Conflict between recreational anglers and commercial gill net fishers over barramundi has been reported in some areas since the 1960s (Griffin 1987a). Currently the presence of such conflict is apparent through various media articles, letters to fisheries departments and lobby groups, at public meetings and vandalism at boat ramps (see The Recreational Fishing Consultative Committee 1994; Eussen 2001; Hansford 2001; Knowles 2001; Sunfish 2001; Anon 2002a; Olsen 2002). It is unknown, however, whether the majority of the general fishing public experiences the conflict. Also, the causes of the conflict have not been investigated. Such questions are rarely asked in resource competition situations; however their answers will have important implications for possible solutions to conflict, including whether ROFAs would be successful in reducing apparent conflict.

b) <u>Improve recreational catches</u>

Anecdotal claims of improved recreational catches in current ROFAs also frequent media articles (see Brown 2001). Concerns over the impact of commercial fishing on recreational catch rates in shared areas encourage the push for more ROFAs. For example, during the 1993 Queensland Inquiry into recreational fishing, the committee was of the view that “prospects for recreational fishers were diminished as a consequence of commercial effort being applied to a number of specific areas”. This view was based on strong anecdotal evidence presented at public meetings and within a number of submissions (48% of 4085 submissions) that expressed concern about commercial gill netting in Queensland estuaries. The committee subsequently recommended the introduction of more estuarine ROFAs, particularly near population centres (The Recreational Fishing Consultative Committee 1994).

There is currently no scientific information, however, to support or refute claims of the effect of commercial fishing on angler catches and improved angler catches in Queensland estuarine ROFAs. Recreational catch data for barramundi are limited to state-wide surveys (see Higgs 1997; Higgs 2001; Henry and Lyle 2003), with insufficient detail at the small-scale to allow comparisons of catches between specific estuaries. Such lack of information is common where ROFAs have been introduced.

It is unknown whether opinions portrayed in the media and via submissions are representative of the general fishing public, although it is often assumed by fisheries managers that they are. These generally negative opinions, however, may be held only by a vocal minority group that apparently consist either of those peripherally engaged in fishing or those within organised fishing groups. Hence, the degree to which statements found in the media are representative is unclear. Because such opinions can influence management decisions, their representativeness should be investigated (Beaumariage 1978; Henry 1984; Pender 1995; Smith and Pollard 1995).

1.3.3 Available data for Queensland estuarine ROFAs

Halliday et al. (2001), using commercial gill net techniques, examined the abundance of barramundi and other species in north Queensland estuaries open and closed (i.e. ROFAs) to commercial gill net fishing through the Effects of Net Fishing (EoNF) Project. They found significantly fewer large (>800 mm total length (TL)) barramundi in estuaries open to commercial gill netting (‘open’ estuaries) than in the ROFAs. Barramundi ranging from 600-800 mm TL were commonly caught at all sites. Their study supported the notion that ROFAs could benefit the recreational fishery in terms of improving catches of large barramundi. They noted, however, that the lower abundances of large legal barramundi in open systems might also be due to unquantified recreational fishing pressure. For interest, the study also found no significant differences in the abundance of other species between estuaries open and closed to commercial gill netting.

While the EoNF Project did find higher abundances of larger barramundi in estuarine ROFAs than in open estuaries, suggesting this may translate into improved angler catches, it is unknown whether this will occur – some studies suggest it may not because angling success is often highly variable (see Ruello and Henry 1977; Johnson and Carpenter 1994; Anderson 1999; Griffin 2003).

1.4 Objectives of Project

The overall aim of the current project is to examine the effectiveness of north Queensland estuarine finfish ROFAs in: a) resolving apparent resource competition and conflict between recreational and commercial fishers in north Queensland estuaries, and b) improving recreational catch quality for barramundi in north Queensland estuaries. To achieve these aims, the specific objectives are:

1. To explore the nature and source of apparent competition and conflict between recreational line and commercial gill net fishers in north Queensland;
2. To examine whether fishers support the current and future use of estuarine finfish ROFAs to reduce conflict between the two sectors;
3. To determine if there is a difference in recreational line fishing quality between estuaries that are open and closed (ROFAs) to commercial gill net fishing.

The impartial data obtained will be provided to all Queensland fisheries stakeholders and managers, in an attempt to reduce or resolve potential resource competition and conflict regarding barramundi. Data from this case study may be relevant to other situations where resource competition and conflict is present.

1.5 Study Area

The study area, within north Queensland (see Figure 1.1 for the location of the study area within Australia) includes all estuaries between the Murray River (north of Cardwell), south to Cape Upstart (south of Ayr) (Figure 1.2). The residential area of interest is Cardwell south to Ayr. This area was chosen due to proximity to Townsville and was considered a manageable area to study for a PhD project. Approximately 11 estuaries within the study area have been partly or completely closed to commercial gill net fishing for many years prior to commencement of the study – the exact date specific closures were implemented is unknown but is between four (prior to DPA implementation) and 25 years. Information about timing of closures is available only in archives (to which I was unable to gain access) at QDPI&F, reflecting the ad hoc nature with which these closures were implemented. Regardless, the closure periods are considered long enough to notice potential improvements in recreational catches for barramundi which typically recruit to the commercial fishery at about 3 years of age (Williams 2002a). Further gill net closures are encompassed by the DPA of the Hinchinbrook Channel (including all adjoining estuaries) which was implemented in January 1998. Other DPAs within the study area restrict netting only in the encompassed bays, not including adjoining rivers. There are differences between each DPA zone: DPA ‘a’ zones have stricter netting controls than DPA ‘b’ zones. In DPAa zones, the use of offshore set, foreshore set and drift nets are prohibited, but river set nets are allowed with modifications except in the Hinchinbrook Channel. In DPAb zones, mesh netting practices are allowed to continue, but with more rigorous safeguards and restrictions than prior to DPA implementation (Zeller and Snape 2005; Great Barrier Reef Marine Park Authority unknown-a).

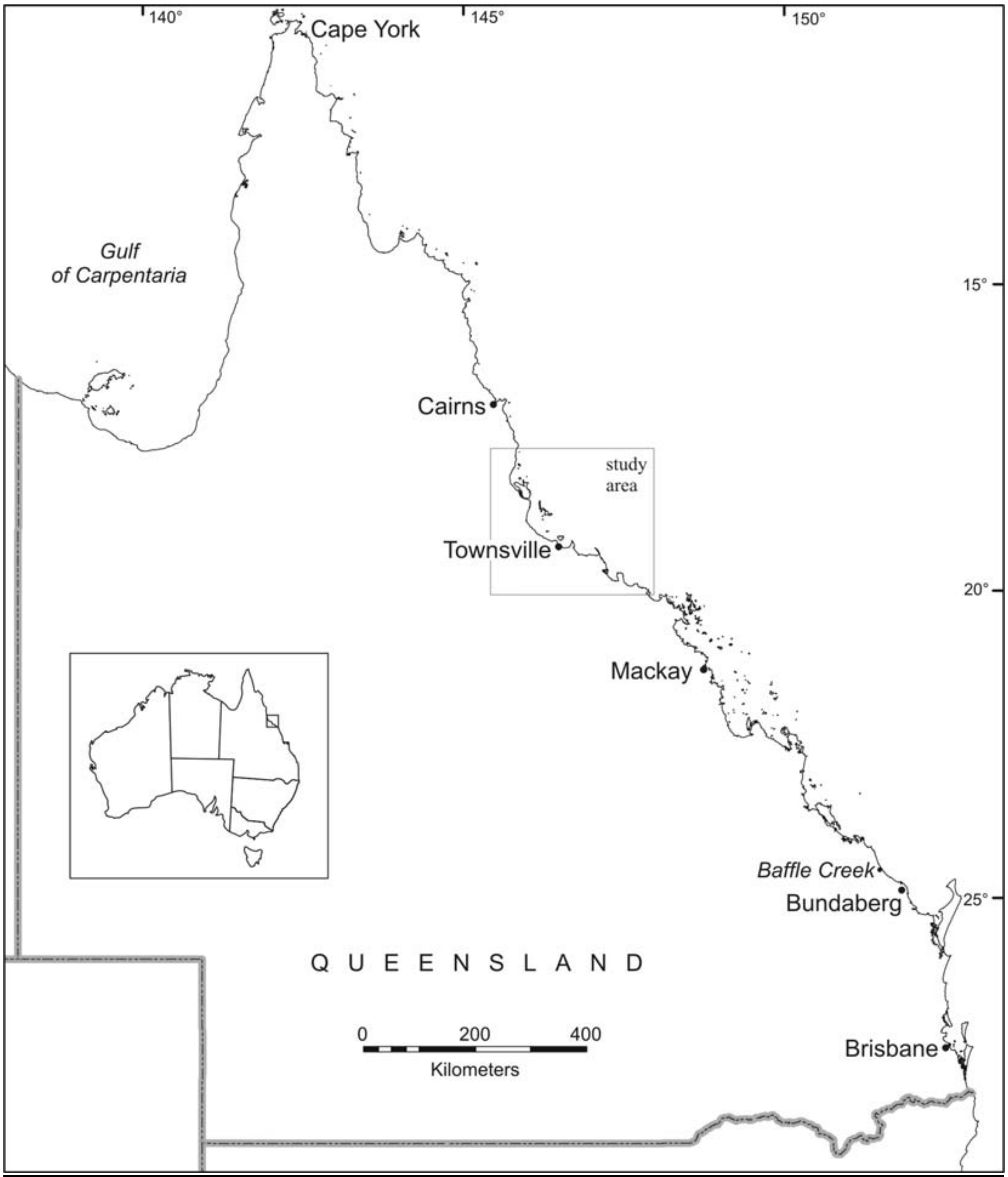


Figure 1.1 Map outlining the study area within Queensland, Australia**.**

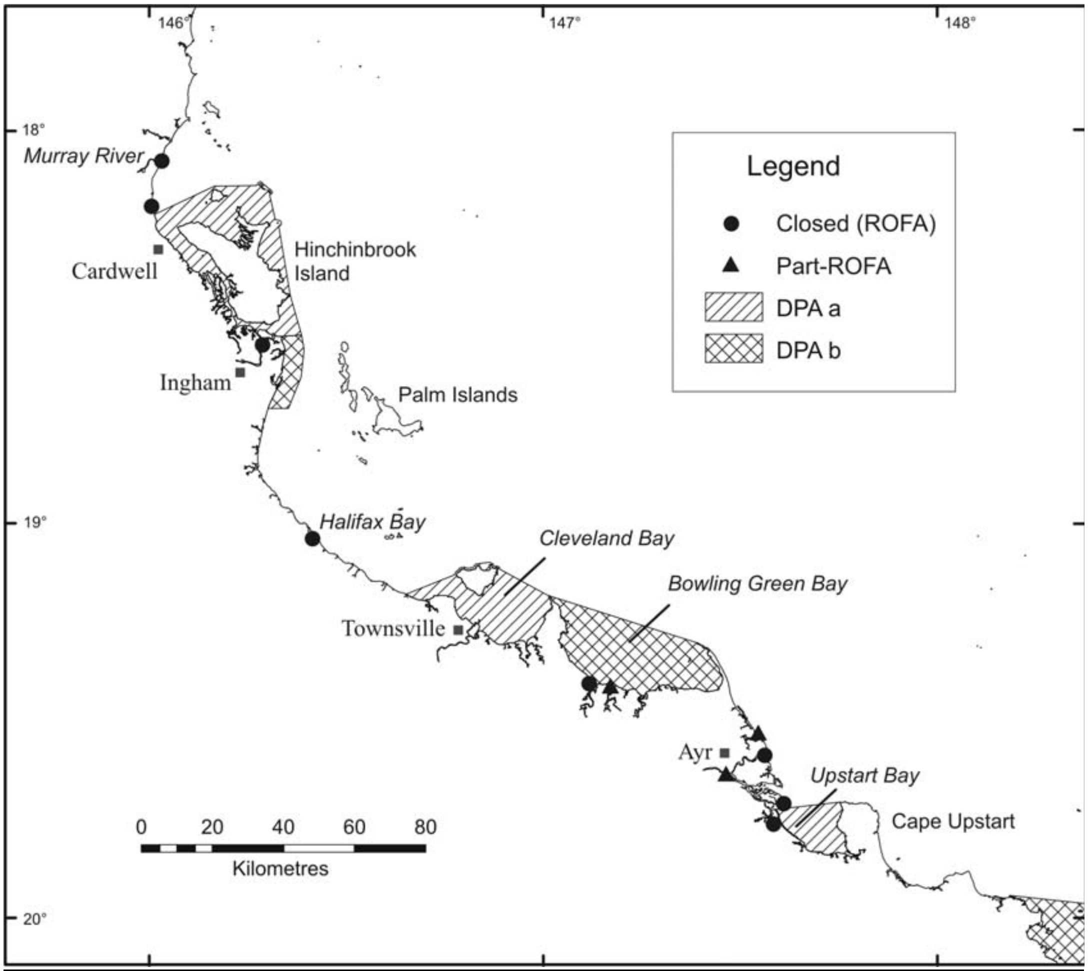


Figure 1.2 Map of study area in north Queensland outlining ROFA and part-ROFA estuaries and Dugong Protection Areas (DPAs).

1.6 The Barramundi fishery

1.6.1 Barramundi biology

The barramundi (*Lates calcarifer* (Bloch)) is a predatory centropomid perch, generally found in freshwater, estuarine and coastal habitats (Dunstan 1959; Russell and Garrett 1983; Davis and Kirkwood 1984; Russell and Garrett 1985; Garrett 1987; Russell and Garrett 1988; Welch et al. 2002). Recreational and commercial fishers compete for shared stocks of barramundi in bays and estuaries (i.e. tidal waters of coastal rivers (Coastal Engineering Research Center 1984)) – netting is not allowed in non-tidal waters (Queensland Department of Primary Industries 1995).

In Australia, barramundi are found from southern Queensland, north to the central coast of Western Australia (Dunstan 1959; Shaklee and Salini 1985). In

Queensland, this protandrous hermaphrodite matures as a male between 45 and 75 cm total length (TL) (4-5 years of age), then changes sex between 55 and 95 cm TL (usually 7-8 years of age). Female barramundi can live for more than 30 years and reach 1.5 m TL and 60 kg body weight. They recruit to the commercial fishery after approximately 3-5 years (typically 3 years on Queensland's east coast), sometimes still sexually immature (Dunstan 1959; Garrett 1987; Department of Primary Industries and Fisheries 2001; Welch et al. 2002; Williams 2002a).

Barramundi are highly fecund, and spawning aggregations occur just before the onset of the wet season at estuary mouths. Juveniles subsequently take advantage of the aquatic habitat that results from flooding (Dunstan 1959; Russell and Garrett 1983, 1985; Davis 1987; Russell and Garrett 1988; Griffin and Walters 1999; Halliday et al. 2001; Welch et al. 2002; Williams 2002a). In some localities the severity of the wet season determines the number of spawners available, and the amount and timing of rainfall affects the amount of freshwater habitat available for coastal wetland nursery areas (Dunstan 1959). Positive relationships have been found between the amount of freshwater flow and barramundi year-class strength (Staunton-Smith et al. 2004).

1.6.2 The Barramundi Fishery

Catches of barramundi by the commercial and recreational fishing sectors on Queensland's east coast have been comparable (Zeller and Snape 2005): In 1999, 204 commercial boats reported a harvest of 211 t in tidal waters, and Queensland's Department of Primary Industries and Fisheries (QDPI&F) bi-annual recreational fishing monitoring program (known as 'RFISH') reported a harvest of about 270 t of barramundi by Queensland anglers (non-Queensland anglers were not surveyed) in tidal and non-tidal waters (Williams 2002a). Both of these harvest estimates were reduced in 2002, particularly for the recreational sector: In 2002 172 commercial boats harvested 197 t of barramundi (Department of Primary Industries 2002)), while the recreational sector harvested 96 t (Higgs, QDPI&F, unpublished data) on Queensland's east coast.

QDPI&F's RFISH surveys estimated approximately 22 400 Queensland anglers targeted barramundi at least once a year in 2002, although the proportion of anglers targeting barramundi (33.5% of anglers) is higher in north Queensland than in other parts of the state (Higgs and McInnes 2003).

Indigenous fishers also capture barramundi, using lines, nets, spears and traps (Williams 2002a), however their barramundi catch is relatively small (5.7 t per annum in

Queensland in 2000/01 (Henry and Lyle 2003)), and potential competition with the indigenous sector is not considered within this project.

Size restrictions apply to both the recreational and commercial sectors, with a minimum legal size of 580 mm total length (TL) and a maximum legal size of 1200 mm TL (to protect large females). A closed season to protect spawning stock applies from the 1st of November to the 1st of February each year on the east-coast of Queensland (Healy 1995; 1995; Halliday et al. 2001; Welch et al. 2002; Williams 2002a).

a) <u>The commercial fishery</u>

Barramundi is targeted commercially in Queensland in the Gulf of Carpentaria and on the east-coast: there are separate management plans for these two areas (Williams 2002a). The East Coast Inshore Finfish Fishery (ECIFF), the focus of this project, operates along the length of Queensland's east coast, though barramundi are harvested northward from Baffle Creek (24^0 30'S) to Cape York (Zeller and Snape 2005), (see Figure 1.1). The ECIFF, mainly comprising small, owner operated family businesses (Fenton and Marshall 2001), is a multi-species fishery where operators target a range of finfish species using a variety of net methods under N1-N8 and K1-K8 symbols (Healy 1995; Welch et al. 2002; Zeller and Snape 2005). Barramundi fishers are licensed with an 'N2' symbol (East Coast Set Net Fishery), though many east coast net fishers are mixed gear fishers with a number of licence symbols which they use when inshore finfish catches or market demand are low (Zeller and Snape 2005). The N2 fishery operates in all Queensland tidal waters east of longitude 142º09' east, but does not include waterways flowing into the Gulf of Carpentaria west of longitude 142º09' east (Queensland Department of Primary Industries 1995). On the east coast, the mean number of days spent fishing for barramundi per boat per year is about 25 days (varying from 50 days in Far North Queensland, to around 8 days in the Fraser Island Region) (Williams 2002a).

Commercial gill net licences were restricted in 1981, and since 1986, 272 licences were authorised to operate in the N2 fishery (Healy 1995), of which about 250 reported catch each year to the year 2000 (Williams 2002a). From the entire ECIFF (i.e. not only N2 licences), 38 licences were bought out during the implementation of measures to protect the dugong in 1997, 56 were bought out with the RAP restructure in 2004, and the latent effort policy in 2004/5 reduced the remaining licences by 40%. Following these buy-outs, 189 N2 licences remain (Mark Doohan, QDPI&F, pers. comm., 2005; Zeller and Snape 2005).

A gill net is a wall of netting which entangles finfish by their gills and other hard structures such as spines and fins. A gill net is fixed at both ends, often with one end tied to the bank of a river, and the other anchored. Set gill nets fish “passively”: i.e. fish must swim past the gear to be caught. The top of the net has floats attached and the bottom, with weights attached, sinks to the substrate forming a wall of mesh (Anderson 1999; Millar and Fryer 1999). Gill netting is considered a highly selective method of fishing with the ability to capture mostly targeted species: not all finfish species are susceptible to set gill nets due to their size, shape or behaviour (Russell and Garrett 1985; Petrakis and Stergiou 1996; Millar and Fryer 1999; Halliday et al. 2001; Gray 2002). Gill nets are also size selective for barramundi – Halliday et al. (2001) found catches of undersize fish in 150 mm mesh size nets were low, with less than 9% of the barramundi catch being under legal size, and large barramundi are capable of forcing their way through nets using the razor-sharp edges of their operculum (Department of Primary Industries and Fisheries 2001). Gill net selectivity is also a dependent on water clarity, net colour and hanging ratio, habitat, water currents, etc (Petrakis and Stergiou 1996; Gray 2002). The east coast set net fishery is restricted in rivers and estuaries to a prescribed net type (monofilament), length (3 nets totalling no more than 360 m in length), and mesh size (between 150 and 215 mm). These net restrictions differ slightly in foreshore areas where species other than barramundi are also targeted. Fishing predominantly occurs at night, with soak times varying between 2 and 6 hours. Most fishing effort occurs close to regional population centres (Zeller and Snape 2005).

b) <u>The recreational fishery</u>

The recreational barramundi fishery represents a multi-million dollar tourist industry in Queensland, including a private and charter sector, although exact estimates of value are unknown (Welch et al. 2002; Robinson and Cully unknown). There was an increase in recreational effort in the 1970s, mostly attributable to improved mobility and greater access to fishing areas (Healy 1995). Barramundi are caught using hook and line, with anglers restricted to a bag limit of 5 barramundi per person. Historic information on recreational catch is limited; however QDPI&F's RFISH surveys have been collecting catch information biennially through an extensive recreational fisher diary program since 1997 (Higgs 1997, 2001; Williams 2002a). As stated above, RFISH estimated the recreational sector harvested approximately 96 t on Queensland’s east coast in 2002 (Higgs, QDPI&F, unpublished data). Approximately 22 400 Queensland anglers targeted barramundi at least once a year in 2002, although the proportion of anglers targeting barramundi (33.5% of anglers) is higher in north Queensland than in other parts of the state (Higgs and McInnes 2003).

1.6.3 Threats to the resource

CPUE trends for the commercial fishery, showing a steady increase from 1981 to 2001, suggest current effort levels are not threatening to the stock. There was a slight downturn in biomass estimates on the east coast from 1999-2001, however this may be due to management changes introduced in 1998-9 (i.e. DPA introductions and associated licence reductions) (Welch et al. 2002). Other papers suggest the recreational catch needs to be incorporated into future fishery assessments before conclusions are drawn regarding resource sustainability (Williams 2002a).

Another concern for barramundi stocks that has been listed is the loss of habitat, particularly for juvenile fish, through urban and rural development and other land uses (Garrett 1987; Russell 1987; Williams 2002a). Coastal wetland nursery habitats appear critical to the life cycle of barramundi (Moore 1982; Russell and Garrett 1983; Davis 1985) and their destruction could lead to a decline in barramundi stocks (Russell and Garrett 1985; Russell 1987).

1.7 Chapter Outline

The perceptions of a representative sample of recreational and commercial estuarine fishers within the study area were examined via a questionnaire program, outlined in Chapter 2. The questionnaire program examined whether competition and conflict between the two sectors is an issue for the general fishing public, and what the nature and source of the conflict might be. Respondents were asked: how they view their own and the competing sectors' impacts on estuarine fisheries resources (relating to blame theory); how they think apparent conflict might be resolved; their knowledge of current ROFAs and support of future ROFAs; and whether they think ROFAs result in improved angler catches for barramundi.

Chapter 3: "Fishery-dependent recreational catch data" provides a comparison of current recreational catch trends between estuaries open and closed (ROFA) to commercial gill net fishing. The fishery-dependent data sources are: 1) three years of charter fishing records from compulsory QDPI&F logbooks for the study area; 2) a 2-year voluntary recreational catch logbook program, which recorded anglers' catch information including estuary, time of day and time spent fishing, number of fishers, methods, target species and catch (including species, length and fate); and 3) time series recreational catch data for the Hinchinbrook region from a group of fishers from the Australian National Sportsfishing Association (ANSA).

The results from the fishery-dependent data sources, which provide variable data, were verified through a more statistically valid fishery-independent structured fishing survey program, outlined in Chapter 4. The structured surveys sampled six randomly chosen estuaries within the study area (3 ‘open’ and 3 ROFA estuaries); similar to the design used for the EoNF project outlined above. The surveys used recreational line fishing techniques to test whether the EoNF project results translate into improved line catches in estuarine finfish ROFAs.

Each of these chapters are tied together as a general discussion in Chapter 5, providing an overview of whether competition and conflict within estuaries is an issue within the north Queensland fishing community as a whole; from where such conflict might originate; and therefore whether further ROFAs are appropriate to resolve this conflict. Other potential solutions to conflict are discussed. The general discussion also includes whether improved recreational catch rates in finfish ROFAs are real or perceived and what this may mean for future ROFAs and research needs.

CHAPTER 2: QUESTIONNAIRE PROGRAM

2.1 Introduction

Competition and conflict between recreational and commercial fishers is currently one of the most significant issues for fisheries management in Australia and other developed countries (West and Gordon 1994; Brayford 1995; van Buerren et al. 1997; McPhee and Hundloe 2004). Conflict is thought to be increasing due to increasing contact between the sectors (Edwards 1991; Scialabba 1998; O'Neill 2000; McPhee et al. 2002). Hence, Recreational Only Fishing Areas (ROFAs) are commonly suggested to reduce or resolve conflict by segregating the commercial and recreational sectors and thus reducing contact. However, the extent to which ROFAs are successful in resolving conflict has not been tested.

In north Queensland, a number of estuaries have been closed to commercial fishing, effectively making them ROFAs for finfish. Some of these closures have been implemented with the aim of reducing conflict between recreational line fishers and commercial gill net fishers competing for shared estuary fish, particularly barramundi (*Lates calcarifer*) (Mark Doohan, QDPI&F, pers. comm., 2005). However whether these ROFAs are successful in segregating these sectors and/or reducing conflict is unknown. With further calls for the introduction of more ROFAs (see The Recreational Fishing Consultative Committee 1994), it becomes important to examine whether current and future ROFAs are appropriate to reduce conflict in this fishery. To determine this, the nature and source of conflict in north Queensland estuaries is examined in this chapter.

2.1.1 The nature and source of conflict

Before conflict can be resolved, conflict situations should be examined to determine the possible cause(s) (Aas and Skurdal 1996; Daigle et al. 1996; Scialabba 1998). Most research into resource conflict has been descriptive, with few researchers attempting to define the causes of conflict (Jacob and Schreyer 1980).

Resolution of resource allocation competition and conflict is increasingly being seen as a social process. Conflicts between recreational and commercial fishers are mostly driven by partisan observations by each sector. Consequently, many conflicts are based in perception or beliefs rather than substantive evidence. Unfortunately, substantive evidence in support of the beliefs and perceptions held by members of each sector is often difficult to obtain in the absence of reliable fishery data (Ruello and Henry 1977; Jacob and Schreyer 1980; Berkes 1984; Henry 1984; Quinn 1988;

Gladwin 1995; Department of Fisheries Western Australia 2000; Griffiths and Lamberth 2002; Kearney 2002a; Arlinghaus 2005).

In north Queensland, competition and conflict for barramundi between recreational line fishers (also called ‘anglers’) and commercial gill net fishers is apparent via complaint letters to fisheries departments and representative bodies, and letters and articles in the public media (see The Recreational Fishing Consultative Committee 1994; Eussen 2001; Knowles 2001). Such letters and articles, plus threats of physical violence and vandalism of equipment, are common to many resource sharing situations (Ruello and Henry 1977; Henry 1984; Anderson 1999; Kearney 2002b; Pike 2003).

Opinions expressed in such ways frequently influence decisions that allocate or distribute access to shared fisheries resources (Ruello and Henry 1977; Loveday 1995; Pender 1995; Smith and Pollard 1995; Sutton 2006). It is often assumed that these opinions represent those held by the majority of the fishing population; however, it has been argued that these generally negative opinions are often held only by a vocal minority group which may not represent the views of the majority. Hence, the degree to which statements found in the media are representative of the fishery as a whole is questionable (Beaumariage 1978; Henry 1984; Smith and Pollard 1995; Burger et al. 1999; Griffin and Walters 1999; Sutton 2006). For instance Burger et al. (1999) compared perceptions of recreational fishers with perceptions of public officials charged with making decisions about environmental issues in the New Jersey area. They found the officials thought environmental problems in the local area were more severe than did the fishers, and consequently suggested that officials may be hearing from some of the more vocal people about problems, rather than from typical fishers.

Given the above uncertainties and the strong perception basis of much resource conflict, it is important to examine the opinions of a representative sample of the fishing population to gauge the degree to which opinions are homogeneous for the group as a whole and whether opinions are consistent with those portrayed in the media (Burger et al. 1999). Furthermore, investigation of the opinions of fishers about resource competition and conflict, and how their own behaviours and perceptions of their competitors affect these opinions, may help determine the source of conflict (Jacob and Schreyer 1980). Surveys of a wider group of people may also help to outline possible solutions to apparent conflicts.

a) <u>Definition of fisheries conflict</u>

There are various definitions of conflict. FAO define fisheries conflict as when "the interest of two or more parties clash and at least one of the parties seeks to assert its interests at the expense of another party's interest" (Scialabba 1998). The push from anglers for the exclusion of commercial fishing via ROFAs fits this definition of conflict.

Whereas the FAO definition of conflict is useful for understanding the outcomes of conflict, it does not help us understand the factors underlying the conflict. Jacob and Schreyer (1980) provide an alternative definition of conflict that addresses these underlying factors. They define conflict as resulting from "goal interference attributed to another's behaviour". In other words, conflict occurs when members of one sector blame the competing sector for their inabilities to achieve the desired outcomes. For instance, if an angler's goal is to catch more or bigger barramundi and commercial fishing is perceived to be interfering with that goal (i.e. commercial fishing is blamed), conflict results.

Blame is common in resource conflict, where one group does not see itself as responsible for impacts on shared resources, and thus attributes any negative outcomes, such as catch declines in fisheries, to the competing sector (Jacob and Schreyer 1980; Garrell 1994; Morgan 1999; Stoll-Kleemann et al. 2001; Bickerstaff and Walker 2002; Kearney 2002b). Blame can come from both the recreational and commercial sectors, and may be a major cause of conflict between the sectors (Jacob and Schreyer 1980; Gartside 1986; Garrell 1994; Morgan 1999; Stoll-Kleemann et al. 2001; Bickerstaff and Walker 2002; Kearney 2002b). The likelihood of blame depends on how a group perceives their own impacts and the operations and impacts of their competitors (Jacob and Schreyer 1980; Holder 1992; Nakaya 1998). Such situations may occur with or without scarcity of resources (Jacob and Schreyer 1980).

Combining the definitions of conflict discussed above, fisheries conflict within this study is defined as:

> *When the goals of one sector are believed to be interfered with by the competing sector, and the affected sector seeks to assert its interests at the expense of their competitors.*

For the Queensland barramundi fishery, this definition of conflict is reflected in various media articles (e.g. Eussen 2001; Sunfish 2001; Olsen 2002), where anglers believe their catches are being affected by commercial fishing, and are thus seeking to assert their interests of catching fish at the expense of the commercial sector, by pushing for Recreational Only Fishing Areas (ROFAs) through the exclusion of commercial fishing.

Conflicts can be asymmetrical (one group dislikes the other but not vice versa) or symmetrical (mutual) (Jacob and Schreyer 1980). Therefore, the above definition of fisheries conflict can apply to either one or both of the involved sectors. Previous studies suggest that someone who is already unpopular within the community (which is usually the commercial fishers) is likely to be blamed for any negative outcomes such as catch declines (Bickerstaff and Walker 2002). In the public media, it appears conflict over shared barramundi stocks in Queensland is asymmetrical: i.e. anglers appear to be calling for ROFAs (see Eussen 2001; Knowles 2001; Sunfish 2001), but commercial fishers are seeking shared access (see Proebstl 1992; Loveday 1995).

2.1.2 Are ROFAs likely to resolve the conflict?

The success of ROFAs in resolving any apparent conflict between recreational and commercial fishers will depend on the nature and source of the conflict, and whether ROFAs are successful in reducing contact between these sectors. There are no published examples of ROFAs being examined post-implementation to test whether they were successful in reducing or resolving conflict. Some anglers in north Queensland are pushing for more ROFAs; however, it is unknown whether current ROFAs are being used by the general recreational fishing public. The use of current ROFAs should be investigated to determine whether future ROFAs are warranted.

2.2 Objectives

This chapter aims to address the first two project objectives:

1. To explore the nature and source of apparent competition and conflict between recreational line and commercial gill net fishers in north Queensland;
2. To examine whether fishers support the current and future use of estuarine finfish ROFAs to reduce conflict between the two sectors.

2.3 Methods

Semi-structured questionnaires were used to examine the opinions and perceptions of recreational estuarine line fishers and commercial gill net fishers fishing in the study area. The recreational and commercial sectors were sampled separately, but the questionnaires for each sector were similar to allow comparison.

2.3.1 Questionnaire development

A base questionnaire was developed first for the recreational fishery, which was then modified to suit the commercial sector. Questions were developed based on the above objectives, examining: fishers' perceptions about competition and conflict between the sectors; fishers' view and knowledge of their own and the competing sectors' operations and impacts (to examine the presence of blame); fishers' support of ROFAs; and any other suggested solutions to competition.

Most questions were closed (including 5-point likert scale) to ensure quantitative results were available to allow comparisons between the sectors. Open-ended questions were also included, for which the answers were later coded. Additional partially closed questions allowed a compromise between closed and open questions (Pollock et al. 1994). Repetitive questions tested for honesty, consistency, and whether questions were interpreted correctly (Neuman 1997). Questions were ordered in such a way as to avoid influencing other answers – i.e. to avoid respondents forming opinions while being interviewed (Essig and Holliday 1991; Green et al. 1991; Miranda and Frese 1991). Anonymity of respondents was guaranteed for all questionnaires to encourage more honest answers from respondents (Pollock et al. 1994).

A draft questionnaire was circulated for review from various research staff and fishers, who noted possible sources of misinterpretation, bias, or leading. The modified questionnaire was then further tested – for leading questions, misinterpretations, ease of implementation, and length of interview – via a pilot study incorporating more research staff, and fishers via e-mail and at boat ramps. The questionnaire was then refined further and finalised. The final base questionnaire (of opinion, attitude and knowledge questions) took approximately 8 minutes to complete. Additional questions were added to collect catch and effort information for the day of the interview, however these data were not analysed due to lack of confidence with their accuracy (being a lower priority compared to the opinion questions, extra time was not spent on each interview to verify catch and effort information).

The base questionnaire was adapted for commercial fishers where appropriate. For instance, questions examining anglers' opinions about the commercial sector in the base questionnaire were altered to examine commercial fishers' opinions about the recreational sector. Additional questions examined the fishing practices of the commercial fishers, which were compared with anglers' perceptions about commercial fishing practices.

The final questionnaires are listed in Appendix 2.

2.3.2 Distribution methods

On-site survey methods were used for both sectors, because on-site methods have a higher response rate than off-site methods such as mail or telephone surveys. On-site methods also reduce avidity bias common with off-site surveys – avid anglers or those with strong opinions are more motivated to complete off-site surveys than those with less interest in the fishery (Kokel et al. 1991; Pollock et al. 1994) – although some avidity bias is still likely to be present for the recreational fishery because on-site surveys more often encounter anglers that fish more frequently.

Ideally, a representative sample of fishers would be chosen from a complete list of available fishers. Lists of fishers were available for commercial fishers (although details are confidential), but not for anglers in Queensland. Therefore two different methods were used to gain a representative sample of each sector (below).

The local media (newspaper, radio and television news) was utilised to alert fishers from both sectors to the upcoming surveys.

a) <u>Recreational fisher questionnaires</u>

Access point surveys were considered the most efficient method to achieve a representative sample of anglers – because only one third of the Queensland population fishes recreationally (Roy Morgan Research 1999), random telephone and mail surveys would sample a high proportion of non-fishers (Pollock et al. 1994).

Anglers were sampled using access point (boat ramp) 'Bus-Route Surveys' (BRS), where each boat ramp is treated as a 'bus-stop' along a set route, similar to a bus timetable. Each ramp was visited for a set amount of time, which was pre-determined according to the number of people expected to use that ramp. The BRS method reduces under-coverage bias in situations where there are numerous access points and relatively low fishing effort (Robson and Jones 1989; Jones and Robson 1991), which was consistent with the study area.

A complete list of ramps that allow access to estuaries that are open ('open'), closed ('ROFA') and partly closed ('part-ROFA') to commercial gill net fishing within the study area was compiled. Information sources included *The Official Tide Tables and Boating Safety Guide* (Queensland Department of Transport 2002), local maps, and local experts including tackle-shop owners and fishing club members. The Queensland Boating and Fisheries Patrol (QBFP), and previous CRC Reef Research Centre (CRC Reef) surveys provided expected usage data for most ramps, against which each ramp was ranked. These ranks were further refined using expert opinion from tackle shop owners and some fishing club members. Such ranks acquired from people familiar with the general distribution of fishing effort (‘experts’) provide an inexpensive and time efficient substitute to pilot surveys (Stanovick and Nielsen 1991). At the completion of the surveys the ranks were re-assessed according to the average number of trailers counted on arrival at each ramp: the ranks were found to be accurate, with only 50% of the ramps changing one rank up or down post-survey (the other 50% remained in the same rank).

The study area was divided into 4 regions, or ‘routes’ (Table 2.1 & Figure 2.1), each with 5 or 6 randomly chosen ramps (22 ramps in total for the study area), including both high and low-use ramps. Ramps on each route were chosen in proportion to the expected level of fishing effort, increasing the precision in areas where effort was expected to be non-uniform (Hayne 1991; Malvestuto and Knight 1991; Stanovick and Nielsen 1991; Pollock 2003). The use data and expert ranks were combined to give an estimate of time to be spent at each ramp given the number of ramps on each route and the travel times between each ramp. Travel times were measured prior to starting the surveys (Robson and Jones 1989; Kinloch et al. 1997). Each ramp was visited for at least 15 minutes. Trailer numbers were counted at each ramp to gauge effort levels. See Table 2.2 for details of each route, and Appendix 3 detailing start points on each sampling day.

Table 2.1 Regions within study area for the recreational fisher access point Bus-Route Surveys, listed south-north**.**

Route #	**Region Name**	**Area Covered**
1	Burdekin	Molongle to Ocean Creek
2	Townsville to Ayr	Ross River to Barrattas River
3	Townsville to Ingham	Ross Creek to Balgal Beach
4	Hinchinbrook	Forrest Beach to Murray River

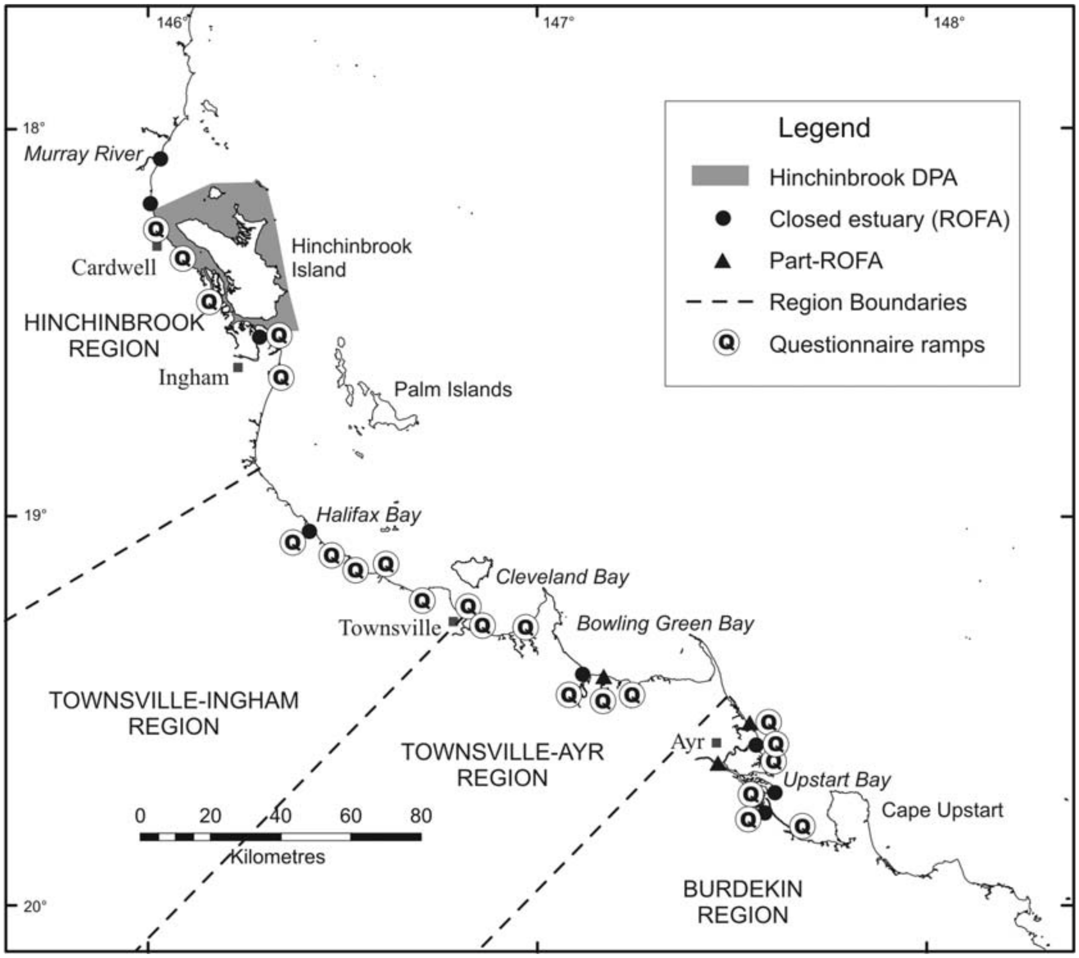


Figure 2.1 Map of regions within the study area for the recreational fisher access point (boat ramp) Bus Route Surveys.
Each region contains one bus-route. Sampled ramps are highlighted with a "Q" symbol.

Each bus-route was sampled for 6 days (3 weekdays and 3 weekend days) in March and April 2002. Public holidays were treated as weekend days (Hayne 1991; Malvestuto and Knight 1991). Sampling days were randomly chosen from a list of all available days in March and April, and assigned routes randomly to the chosen days. Start positions on each route and direction around the route were chosen first randomly, then sequentially, so that all access points were sampled throughout the different times of the day (Hayne 1991). Each route was sampled for 10 hours, from 8am to 6pm – when returning fishers were most likely to be encountered, and when interviewer safety was optimum (Steffe and Murphy 1995; Ditton and Hunt 2001).

Table 2.2 Sampling timetable for the recreational fisher access point Bus-Route Surveys**.**

Bus Route # (and region)	**Ramp Name**	**Usage rank**	**Management status**	**Minutes spent (% total route time)**	**Travel time to next ramp N-S (mins)**
1 (Burdekin region)	Ocean Creek	4	Open	75 (12.5%)	15
	Plantation Creek	4	Part-ROFA	75 (12.5 %)	30
	Phillips Landing	4	Part-ROFA	75 (12.5%)	45
	Groper Creek Settlement	4	ROFA	75 (12.5%)	30
	Yellowgin Creek	2	ROFA	38 (6.3%)	30
	Molongle Creek	3	Part-ROFA	57 (9.5%)	55
Total	**6 ramps**	**21**		**395 (65.8%)**	**205**
2 (Townsville – Ayr region)	National Park Ramp (Ross River)	5	Open	93 (15.5%)	50
	Cocoa Creek	2	Open	36 (6%)	45
	Cromarty Creek	5	ROFA	93 (15.5%)	30
	Barramundi Creek	3	Part-ROFA	55 (9%)	40
	Barrattas River	5	Open	93 (15.5%)	65
Total	**5 ramps**	**20**		**370 (61.6%)**	**230**
3 (Tsv – Ingham region)	Townsville City (Ross Creek)	5	Part-ROFA	118 (19.6%)	35
	Stoney Creek (Bohle River)	5	Open	118 (19.6%)	20
	Saunders Beach	2	Open	47 (7.8%)	25
	Bluewater Creek	1	Open	24 (4%)	30
	Toomulla	1	Open	24 (4%)	15
	Rollingstone Creek	4	ROFA	94 (15.6%)	50
Total	**6 ramps**	**18**		**425 (70.8%)**	**175**
4 (Hinchinbrook region	Cardwell (Sheridan St)	1	ROFA	25 (4.1%)	10
	Port Hinchinbrook	5	ROFA	125 (20.8%)	20
	Fishers Creek	3	ROFA	75 (12.5%)	30
	Dungeness Creek	5	ROFA	125 (20.8%)	20
	Taylors Beach (Victoria Creek)	5	Open	125 (20.8%)	45
Total	**5 ramps**	**19**		**475 (79.1%)**	**125**

NB: All ramps are ranked 1-5, from low-high use respectively according to usage data from CRC Reef and QBFP, and expert opinion. Regions are listed south-north. Ramps are listed north-south in each region.

Two people were present on each sampling day (the project leader and one trained volunteer). Successive fishing parties (1 angler from each fishing party) were interviewed at each ramp by alternate interviewers. At busy ramps every second returning fishing party was interviewed, and the number of missed fishing parties was noted (16%), (Hayne 1991). Only one angler per fishing party was subjected to the questionnaire – The respondent from each fishing party was selected as the first person to be approached, which varied between the boat owner and any passenger. No fishers were interviewed twice. Non-response due to refusal was recorded (8%).

In total, 377 anglers (320 of which actually lived within the residential area of interest) were interviewed, which is adequate to yield a 95% confidence interval with a margin of error not exceeding 5% for a population proportion (McNamara 1994). Based on a total population for the residential area of interest (from Cardwell to Ayr) of 190,200 (Australian Bureau of Statistics 2002), and RFISH statistics stating that 33% of the north Queensland population (over 5 years of age) fished at least in the 12 months prior to the RFISH surveys (Higgs and McInnes 2003), the total fishing population for the study area was estimated to be approximately 62 766 fishers. Sixty eight percent of these fishers were within the target age groups (over 19 years) (Higgs and McInnes 2003), giving an estimated target population of 42 680. It is unknown how many of these anglers fish in estuaries or specifically fish in the area, however, 33.5% of north Queensland anglers target barramundi at least once a year (in fresh water and estuarine habitats) (Higgs and McInnes 2003), giving an estimate of 14 298 barramundi fishers for the area. Approximately 85% of fishers fish in saltwater as opposed to freshwater (there is no further distinction by habitat available) (Higgs and McInnes 2003), reducing the estimates to 36 278 saltwater fishers and 12 153 saltwater barramundi fishers in the study area. Therefore, the actual target population lies between these last 2 estimates, meaning between 0.8 and 2.6% of the target population were sampled.

b) Commercial fisher questionnaires

Due to confidentiality of contact information at the time of sampling, it was not possible to contact commercial fishers directly. Therefore, the QDPI&F contacted commercial gill net fishers that had recorded barramundi catch in the study area in the previous 5 years. These fishers were asked to make contact with the researcher regarding participating in the questionnaire program.

One week after the mail-out of the letters, regional representatives from the commercial gill net fishery for the study area were contacted (with permission from the Queensland Seafood Industry Association, QSIA). Due to a low response, further contacts were found via word-of-mouth (following procedure used by Nakaya 1998).

A total of 28 commercial gill net fishers were interviewed face-to-face at a location and time convenient for the fisher. There was some difficulty estimating response and non-response, because some of the fishers contacted by QDPI&F were irrelevant to the project (e.g. people who had recently bought licences with gill netting history but no longer gill netted with that licence). QDPI&F's Coastal Habitat Resources Information System (CHRIS) website reported barramundi catch from 78 vessels for the year 2002 for the 'grids' within the study area, however each vessel may have reported catch more than once (up to 6 times corresponding with the number of grids in the study area) (Department of Primary Industries 2002)). Therefore the maximum possible number of commercial barramundi fishers for the study area for the year of the surveys was 78, meaning there was a response rate of at least 36%.

2.3.3 Data Analysis

Data resulting from the questionnaires were subjected to basic descriptive analysis within Microsoft Excel. Results for each question were graphed, and where error bars (i.e. 95% confidence intervals (CI) calculated according to population proportion sampled (McNamara 1994)) did not overlap a significant difference between answers was concluded. Note that all CI's are approximate given the uncertainties surrounding the population estimates. CI's will be conservative as the population estimates are likely overestimates.

Initially, the recreational fisher data were tested (via bar graphs with 95% CI's) to examine whether certain sub-groups held different opinions regarding whether competition is a personal issue: i.e. different demographic groups including age, gender, home region and avidity category (how often the angler fishes per year); anglers who target barramundi specifically vs. those who don't; fishing club members vs. non-members; and anglers fishing ROFAs vs. fishing open estuaries at the time of interview. As expected, more avid anglers positively responded that conflict was an issue for them personally (Schreyer et al. 1984); however the difference between the avidity category groups was not significant (error bars overlapped), probably due to low sample numbers in each category. No significant difference was found between the answers for any of the comparisons (the error bars broadly overlapped). Therefore all data from the recreational fisher questionnaires were grouped together.

2.4 Results

2.4.1 Objective 1: To explore the nature and source of apparent competition and conflict between recreational line and commercial gill net fishers in north Queensland.

a) Is conflict realised by a representative sample of the fishing population?

Overall, approximately half of all fishers (from both sectors) interviewed regard competition between recreational and commercial fishers in north Queensland estuaries as a problem at some level. The results are varied at a more detailed level: most respondents from both the recreational (49%) and commercial (48%) fishing sectors think competition between the sectors is a 'big' problem for their local area or community (Figure 2.2 a & b, respectively). When asked whether they regard competition as a problem that affects them personally, however, fishers from both sectors are split between 'yes' and 'no', although there are more fishers from the commercial sector who regard competition as a 'big' problem for them personally than from the recreational sector (40% vs. 28%, respectively).

b) Is blame present?

i) What do fishers attribute negative outcomes to?

All fishers were asked what they see as the biggest threat to local estuarine fish stocks, to gauge how they view each fishing sector in relation to other perceived threats to the resource. This question was open-ended and was asked before any other opinion questions, to avoid influencing respondents' answers. Anglers tend to list fishing in some form as the biggest threat to the resource: most (65%) listed "commercial fishing effort", followed by "overfishing (both/unspecified sectors)" (18%). "Recreational fishing" was listed by just 5% of anglers (Table 2.3). Commercial fishers listed non-fishing factors such as "environmental damage" (78.5%) and "weather" (14%) as the biggest threats. "Recreational fishing effort" was listed by 18% of commercial fishers, but there was no mention of commercial fishing.

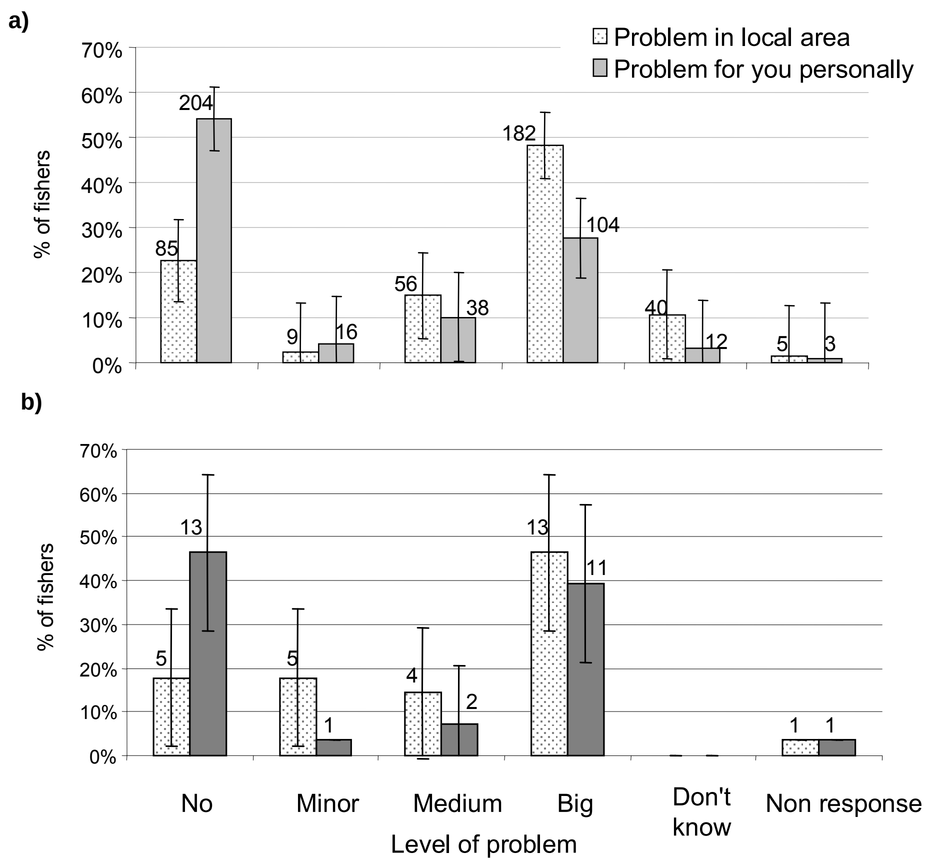


Figure 2.2 Percentage of a) recreational fishers, and b) commercial fishers in each answer category for the question: "Do you think competition/conflict between recreational and commercial fishers in estuaries is a significant problem in the local area; or for you personally? If yes, at what level?"

Number of respondents (n) is shown above each corresponding bar. Error bars are 95% confidence intervals (CIs) determined according to the population proportion sampled.

Table 2.3 Perceived threats to the resource listed by recreational and commercial fishers in response to the open-ended question: "What do you see as the biggest threat to local estuarine fish stocks?"
Ranks for each sector are listed in parentheses.

Threat	Percentage from each sector that listed the threat	
	Recreational fishers	Commercial fishers
Commercial fishing effort	65 (1)	0
Recreational fishing effort	5.5 (5)	18 (3)
Overfishing (both/unspecified)	18 (2)	3.5 (5)
Illegal fishing	6 (4)	25 (2)
Environmental damage	17.5 (3)	78.5 (1)
Over/undersize take	5 (6)	0
Restocking (lack of)	2.5 (7)	0
Weather (incl. lack of wet season)	1 (9)	14 (4)
Regulations (problems with)	1 (9)	3.5 (5)
Don't know	1.5 (8)	0
Non-response	0.002	0

Fishers were also asked whether they think the number of fish they catch has increased or decreased in recent years, and what they see as the cause of any changes. Figure 2.3 shows a significantly greater proportion of anglers think their catch has decreased in recent years than: a) those who think their catch has increased or not changed; and b) the proportion of commercial fishers who think their catch has decreased. There is no significant difference between the proportion of commercial fishers who think their catch has increased, not changed, or decreased.

For those anglers who think their catch has increased (n=58), the most common reason given is "commercial fishing absence" (31%) in the areas they fish (Table 2.4). Similarly, most anglers who think their catches have decreased (n=326) quote "commercial fishing presence or increase" (30%). Anglers' second most common answer is "recreational fishing" (17%), followed by "overfishing by all groups" (16%).

For commercial fishers, those that think their catches have increased (n=12) again quote non-fishing causes: most (33.5%) quote "weather (including wet season presence)" as a likely cause of increases in catches, as do those who think their catches have decreased (50% of n=10), although they refer to wet season "absence". "Recreational fishing" is listed as a cause of declines in catches by some commercial fishers (20%), but they do not mention commercial fishing (Table 2.4).

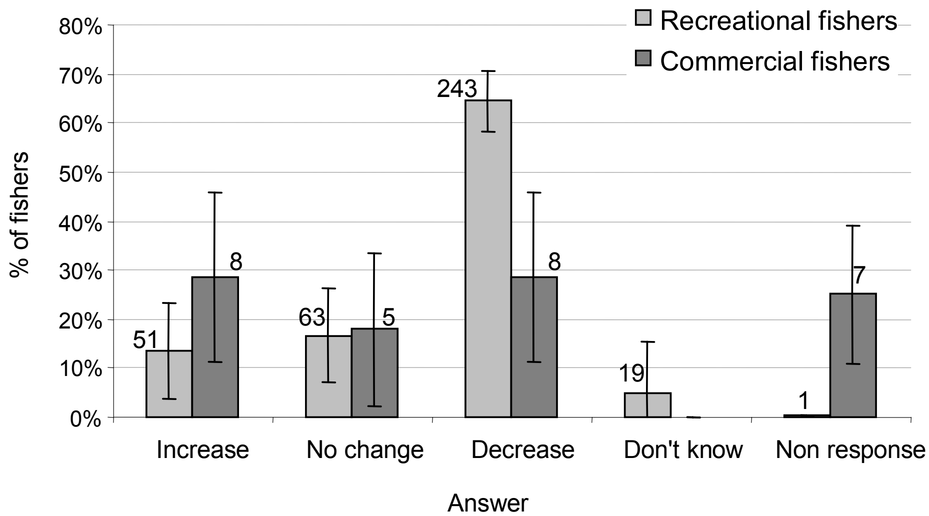


Figure 2.3 Percentage of respondents from the recreational and commercial sectors that think the number of fish they catch has increased, decreased or not changed in recent years.

n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

Table 2.4 Reasons listed by recreational and commercial fishers for why they think their catch has changed in recent years

Answers are separated according to whether fishers stated their catch had increased or decreased. Ranks for each sector are listed in parentheses.

Reason for catch change	**Percentage in each category in each sector that listed each reason**			
	Recreational fishers		**Commercial fishers**	
	Increase	**Decrease**	**Increase**	**Decrease**
Commercial fishing	31 (1)	30 (1)	0	0
Recreational fishing	4 (6)	17 (2)	0	20 (2)
Overfishing (both/unspecified)	0	16.5 (3)	0	0
Weather (incl. wet season)	3.5 (7)	2.5 (7)	33.5 (1)	50 (1)
Regulations & closed season	7 (4)	1 (9)	33.5 (1)	0
Restocking	22.5 (2)	1 (9)	0	0
Experience level	21 (3)	2 (8)	16.5 (2)	0
Increased policing	0	0	8.5 (3)	0
Technology	2 (8)	2 (8)	0	0
Trawling	2 (8)	5 (6)	0	0
Environmental damage	2 (8)	9 (4)	0	20 (2)
Illegal fishing (incl. u/s)	0	5 (6)	0	0
Don’t know	5 (5)	6 (5)	0	0
Non-response	0.002		0.1	

ii) Fishers' attitude toward the competing sector

Attitude toward the competing sector was measured by asking fishers whether they 'like' or 'dislike' the competing sector. Most anglers (55%) hold a negative attitude toward the commercial sector (Figure 2.4). There is no significant difference between the alternative attitudes for commercial fishers; however a lower proportion of commercial fishers (18%) than anglers hold a negative attitude towards their competing sector.

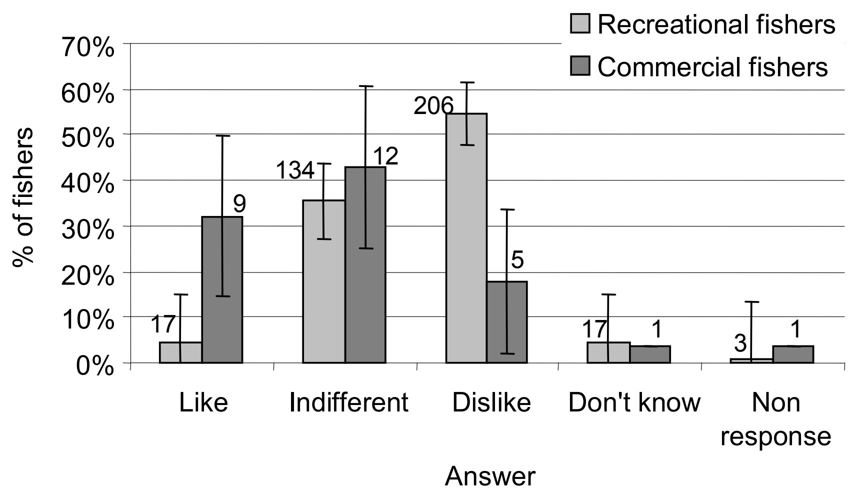


Figure 2.4 Percentage of recreational and commercial fishers who hold a positive ('like'), neutral ('indifferent') or negative ('dislike') attitude toward the competing sector. n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

For those anglers that have a positive attitude toward the commercial sector (n=17), the reasons most commonly quoted are "they are necessary" (including "they provide seafood") (30%), "I have personal contact/history with the fishery" (20%), and "they are making a livelihood" (20%). For those with a negative attitude (n=206), the most common reasons given are the commercial fishery "over-fishes" or is "unsustainable" (34%), "takes a lot of bycatch" (18%), and is "competing with recreational fishers [for fish]" (14%).

For those commercial fishers with a positive attitude toward the recreational sector (n=9), the reasons most commonly given are they had "no issue" with the recreational sector (22%) or they "also recreationally fish" (22%). The commercial fishers with a negative attitude (n=6) quote reasons such as anglers' "lack of knowledge of commercial operations or regulations" (50%), and that "anglers don't like us" (33%).

iii) Perceived impacts of each sector

Each sector was then asked more specifically about how they perceive each sector's impacts:

1) Perceptions towards the recreational fishing sector

Most fishers from both sectors believe recreational fishers, as a group, do have an impact on estuarine fish stocks at some level, although a significantly greater proportion of commercial fishers (96%) than anglers (71%) think this, particularly for the 'big' impact category (Figure 2.5).

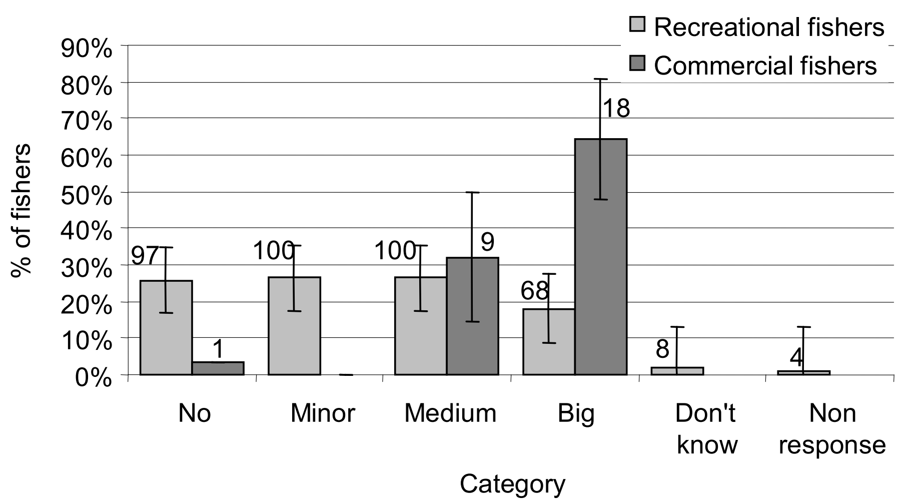


Figure 2.5 Percentage of recreational and commercial fishers in each answer category for the question: "Do you think recreational fishers as a group have an impact on estuarine fish stocks? If yes, to what extent?"
n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

Commercial fishers were also asked whether they think the recreational fishery is sustainable at current effort levels. Fifty four percent (+/- 17%) of commercial fishers believe the estuarine recreational fishery is sustainable, while 29% (+/- 17%) think it is not, although the confidence intervals for these answers overlap.

To examine views of specific impacts, commercial fishers were asked if they think anglers regularly keep undersize fish, large barramundi (over 1m), more than their bag limit, or fish to sell on the black market: these are commonly quoted as concerns of commercial fishers (Henry 1984; Gladwin 1995). Most commercial fishers answered ‘yes’ to all of these questions (Figure 2.6).

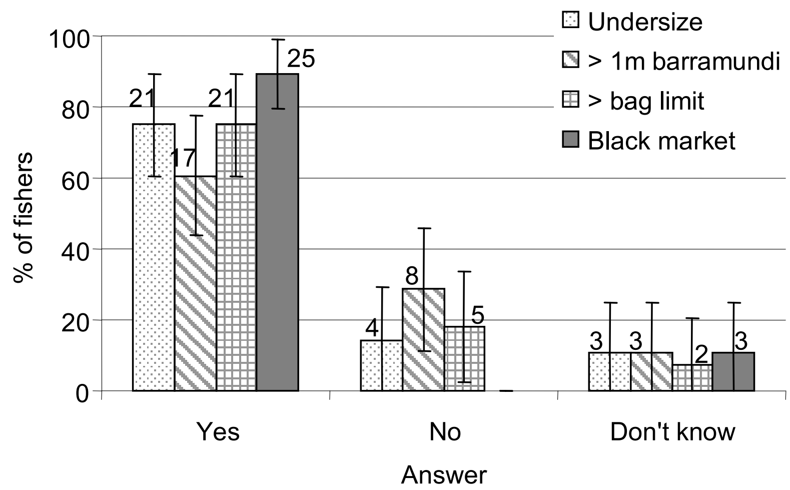


Figure 2.6 Percentage of commercial fishers who answered ‘yes’ or ‘no’ to the questions: “Do you think recreational fishers regularly keep undersize fish; barramundi over 1m; more than their bag limit; or fish to sell on the black market?”

n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

2) Perceptions towards the commercial gill net fishing sector

All respondents were asked whether they think the commercial gill net fishery is sustainable on Queensland’s east coast at current levels of effort. A significantly greater proportion of anglers believe the commercial gill net fishery is not sustainable (71%) than those who think it is sustainable (11%), which is also significantly different to the opinion of commercial fishers: 89% of commercial fishers believe their industry is sustainable (Figure 2.7).

Commercial fishers were asked whether they think their sector catches more or less barramundi per year than the recreational sector on Queensland’s east coast: most fishers (61%) think the commercial sector catches less or ‘a lot’ less barramundi than the recreational sector (Figure 2.8). Unfortunately the converse question was omitted from the recreational fisher questionnaire.

Anglers were asked whether they think the commercial gill net fishery takes a lot of undersize or large (over 1m) barramundi. These were concerns noted during fishing club meetings prior to the questionnaire program. More anglers answered ‘yes’ to both questions (40% and 60%, respectively) than for any other answer categories (Figure 2.9).

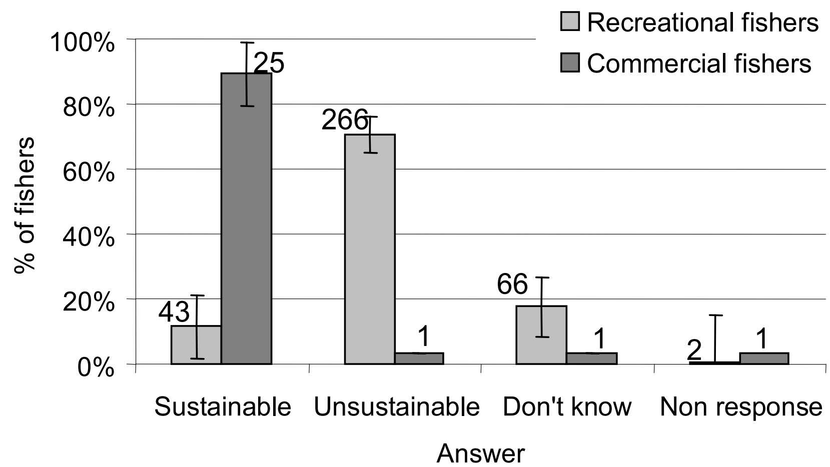


Figure 2.7 Percentage of recreational and commercial fishers that think the commercial gill net fishery is, or is not, sustainable at current effort levels on Queensland's east coast.

n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

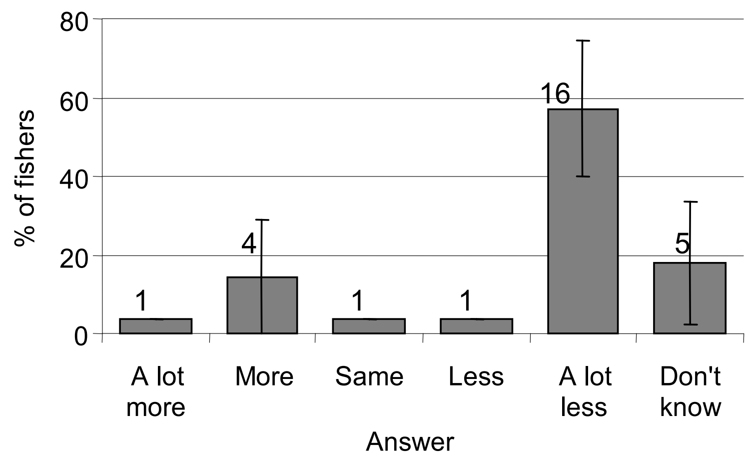


Figure 2.8 Percentage of commercial fishers in each answer category for the question: "Do you think the commercial gill net sector catches more or less barramundi per year than the recreational sector on Queensland's east coast?"

n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled. Non-response = zero.

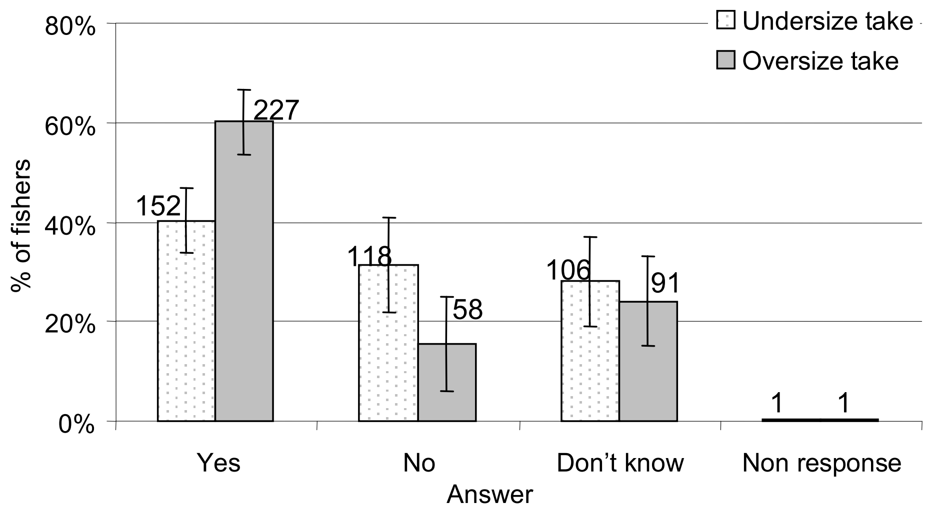


Figure 2.9 Percentage of recreational fishers that answered 'yes' or 'no' to the question: "Do you think commercial gill net fishers regularly keep undersize barramundi; or large female barramundi (over 1m)?"
n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

Anglers were questioned (via open-ended questions to reduce interviewers' influence) about their understanding of local commercial gill net fishers' target species and catch. Most anglers (60%) list barramundi as commercial gill net fishers' main target, which is listed significantly more times than any other species (Figure 2.10). This compares well with the main target listed by the commercial fishers interviewed. Other species listed by commercial fishers are not listed by many anglers. Thirty percent of anglers claim they do not know the target species – an answer which is significantly greater than the remaining species listed.

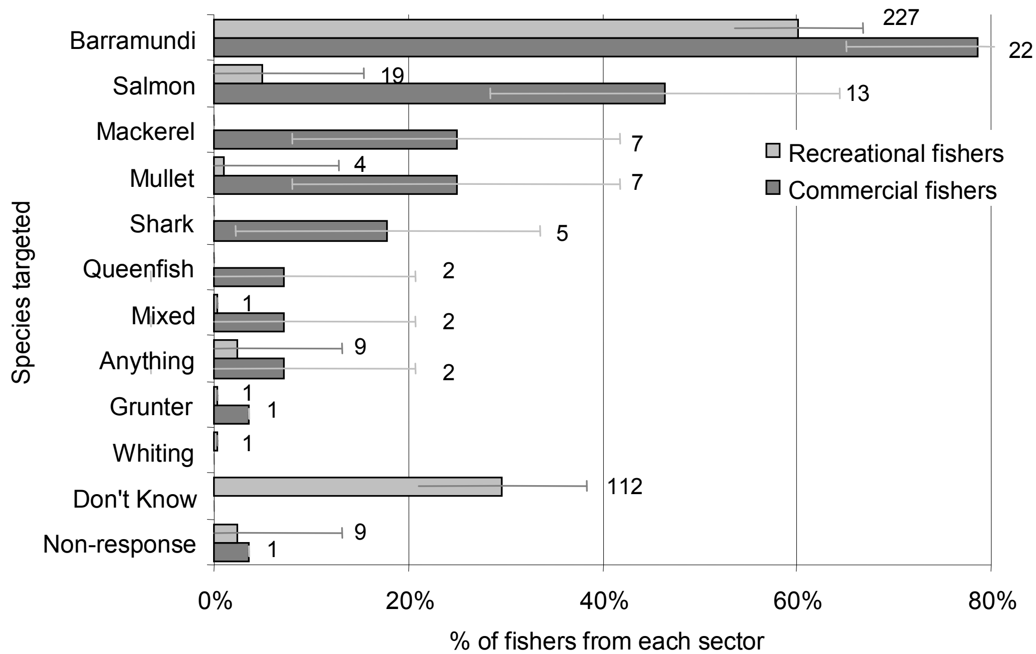


Figure 2.10 Species listed by recreational and commercial fishers when asked what the main target species is for the estuarine commercial gill net fishery on Queensland's east coast.
n (number of respondents) is shown beside each corresponding bar. Fishers were able to list more than 1 species. Error bars are 95% CIs determined according to the population proportion sampled.

When asked to list the species caught by commercial gill net fishers, anglers appear to have a good knowledge of the main species caught (Figure 2.11): most anglers (59% - significantly more than any other answer) list barramundi, followed by salmon (28%) and grunter (21%). Thirty two percent of anglers claim they don't know what species are caught, while 17% think they catch "anything" or "everything".

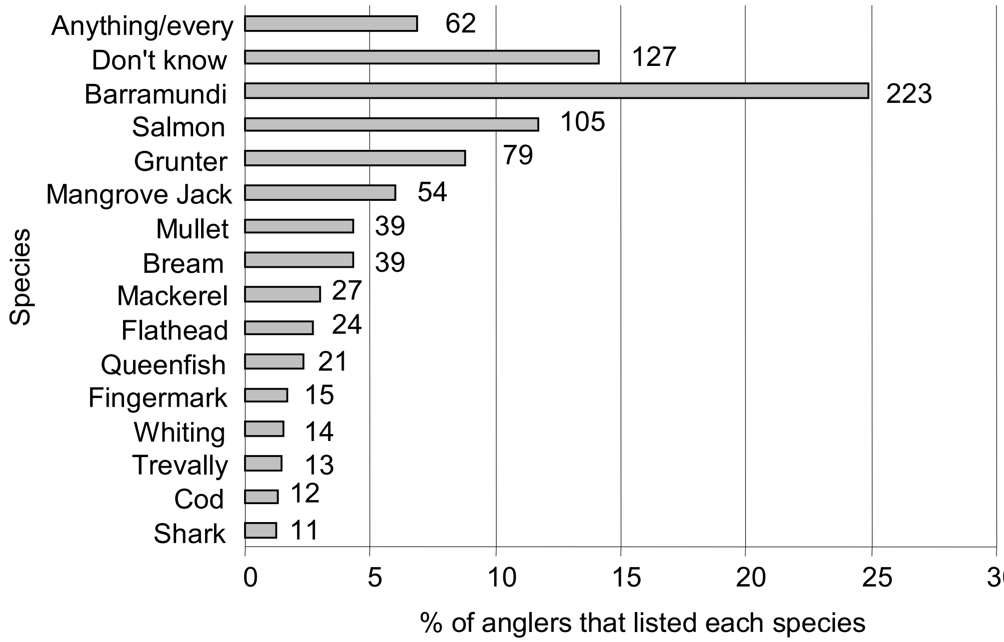


Figure 2.11 Species listed by recreational fishers when asked what they believe commercial estuarine gill nets catch on Queensland's east coast.
n (number of respondents) is shown beside each corresponding bar. Anglers were able to list more than 1 species. Error bars are 95% CIs determined according to the population proportion sampled.

2.4.2 Objective 2: To examine whether fishers support the current and future use of estuarine finfish ROFAs to reduce conflict between the two sectors.

Fishers were asked to list possible solutions to apparent conflict between the commercial and recreational estuarine fishing sectors: this was an open-ended question to avoid influencing respondents' answers, and more than one answer per respondent was possible. Fishers' suggestions are shown in Table 2.5. There is a significant difference between each sector for the most common suggestions: for example while 82% of commercial fishers suggest increasing "communication/ education" between and within sectors, only 10% of anglers list this solution. Likewise, 45% of anglers suggest "changes to commercial fishing" (such as effort reductions or regulation changes) – no commercial fishers list this suggestion. "Segregation" (e.g. via ROFAs) is listed by a greater proportion of anglers than commercial fishers (20.5% compared to 3.5%, respectively), however the "compensation/buy-out" category may be related to this: i.e. some commercial fishers (21.5%) suggest that if they are to be banned from an area they should be compensated.

Table 2.5 Solutions suggested by recreational and commercial fishers to resolve or reduce competition between the two sectors in local estuaries**.** Ranks for each sector are listed in parentheses.

Solution	Percentage of fishers in each sector that listed each solution	
	Recreational	**Commercial**
Changes to commercial fishing	44 (1)	0
Segregation (e.g. ROFAs)	20.5 (2)	3.5 (6)
Compensation/buy-out commercial	0	21.5 (3)
Closed areas (i.e. to all groups)	10.5 (4)	0
Share (i.e. share fairly between sectors)	0	11 (4)
Communicate/educate	9.5 (5)	82 (1)
Police/monitor	9 (6)	25 (2)
Reduce recreational effort	8 (7)	0
Aquaculture (i.e. increase in place of commercial fishing)	7 (8)	0
Restock	3.5 (9)	3.5 (6)
Use media – be proactive	0	3.5 (6)
Reduce effort shift	0	3.5(6)
Area specification - within commercial (e.g regional specific licences)	0	3.5 (6)
Rotate closures (all groups)	0	7 (5)
Don't know/ no solution	12.5 (3)	3.5 (6)
Non-response	0.2	0.1

The use and support of ROFAs specifically was then examined:

b) Perceived benefits of ROFAs

Most anglers and many commercial fishers believe anglers will catch more fish on an average day in an estuarine ROFA than an open estuary; however the proportion of respondents that gave this answer is significantly greater for anglers (76%) than commercial fishers (39%) (Figure 2.12).

As a further gauge of potential differences in catches in areas closed to commercial fishing, anglers were asked whether they fish in DPAs, and if so, whether they think their catches have changed since they were implemented. A significantly greater proportion of anglers (57%) think their catches have not changed in the DPAs than those that do (19%), which suggests potential catch improvements are not obvious to most anglers after over 4 years of closure to commercial gill net fishing.

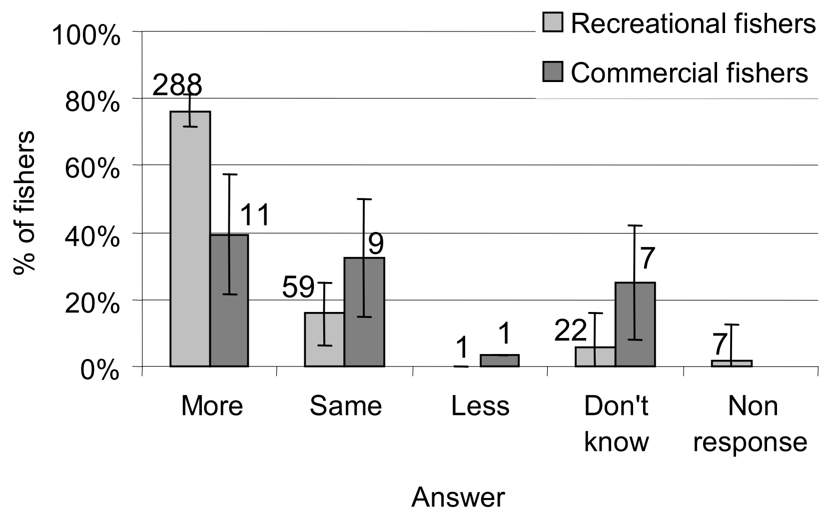


Figure 2.12 Percentage of recreational and commercial fishers that think anglers will catch more, less or the same number of fish on an average fishing day in an estuary that is closed to commercial fishing (ROFA) compared to one that is open.

n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

Fishers from both sectors were asked whether they think recreational fishing effort would increase in potential new ROFAs[4]. Significantly more fishers from both sectors believe that there would be a large increase in recreational effort in any newly introduced estuarine ROFA (Figure 2.13).

[4] Depending on your view an increase in recreational effort in a ROFA can be a benefit (e.g. for the community) or a cost (e.g. for fish stocks or for anglers due to crowding) of ROFAs, so the result to this question should be considered along with other potential costs listed below.

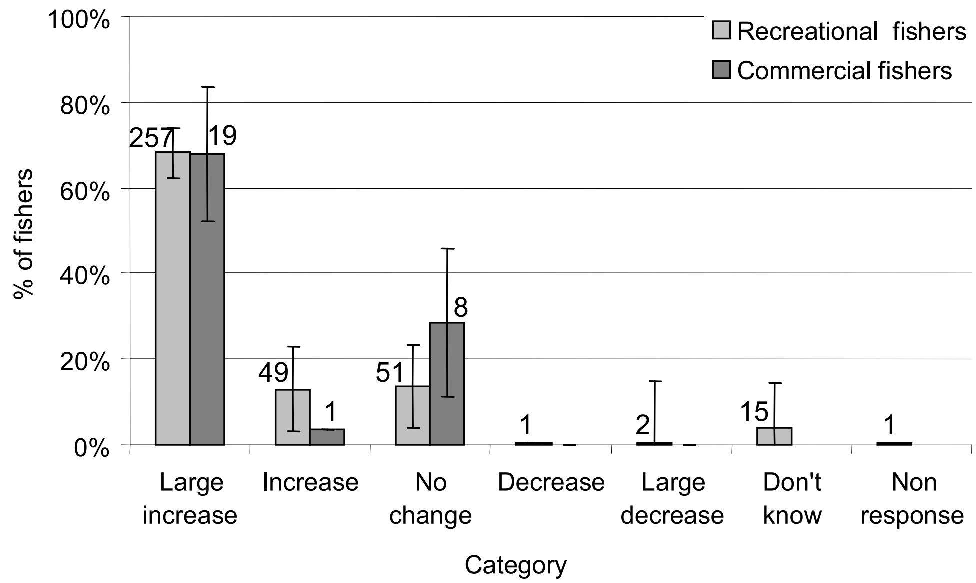


Figure 2.13 Percentage of recreational and commercial fishers in each answer category for the question: "If an estuary was closed to commercial gill net fishing, do you think recreational effort would increase as a result? If yes, at what level?"

n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

c) <u>Perceived costs of ROFAs</u>

Costs of ROFAs are most relevant to commercial fishers, so the effect of closing estuaries to commercial fishing was examined for the commercial sector only. Commercial fishers were asked whether the current estuarine ROFAs affected them: fishers are split almost equally between 'yes' (54%) and 'no' (46%). When asked how the ROFAs affected those that answered 'yes' (n=15), fishers state they "have less area to fish" (26%), "good fishing areas are closed" (20%) and there is "crowding in remaining open areas" (13%).

Commercial fishers were also asked about the effect of the more recently introduced DPAs. Ninety six percent of the commercial fishers interviewed state they used to fish in what are now DPAs. Of these fishers, 81% state the implementation of the DPAs does affect them, listing effects such as "reduced catch" (36%); "changed fishing practices" (36%) such as net size, target species, etc; having "less area to fish"(27%), "reduced income" (18%); being "more limited by or exposed to weather" in remaining areas (14%); have had to “move to another area” (14%) and concern over “effort concentration” in remaining areas (9%).

Finally, commercial fishers were asked whether the introduction of further estuarine ROFAs would affect them and how: 89% of fishers agree further ROFAs would affect them, stating effects such as “reduced income” (43%), “effort displacement/concentration” (21%) and having “less area to fish” (21%).

d) Current and future support of ROFAs

Fishers from both sectors were asked questions relating to whether they use or support the current estuarine ROFAs, and whether they would like to see further segregation of fishing sectors, such as via ROFAs, introduced.

i) Current estuarine ROFAs

A number of questions explored whether anglers are aware of, and use, the current estuarine ROFAs. Anglers were first asked what usually affects their choice of fishing location: Table 2.6 shows “commercial absence” as 7th on the list (5.5% of anglers) of factors that affect their choice. Anglers were then asked whether they avoid estuaries currently open to commercial gill net fishing: 68% of anglers answer ‘no’, which is significantly more than those that answer ‘yes’ (26%). Further, there is no significant difference between ramps providing access to open or ROFA estuaries for estuary fisher interview number per hour (Figure 2.14), or for trailer number.

Similar questions were posed for commercial fishers, to examine whether they support the current segregation of sectors. Like anglers, commercial fishers were first asked why they usually chose a particular estuary to fish, to examine whether the presence or absence of recreational fishing affects their choice. “Fewer recreational boats” is equal 2nd on the list (Table 2.6), indicating that they do avoid areas with high recreational fishing activity. To confirm this, commercial fishers were also asked if they actively avoid estuaries that are heavily fished by recreational anglers: most fishers (79%) answered ‘yes’.

Interestingly, proximity, accessibility and fishing quality are important factors for choosing an estuary to fish for both sectors. Presence or absence of the competing sector is only important for commercial operators.

Table 2.6 List of factors given by recreational and commercial fishers that usually affect their choice of fishing location**.**
Ranks for each sector are listed in parentheses.

What affects choice	Percentage of fishers in each sector that listed each factor	
	Recreational	Commercial
Proximity	**23** (1)	35.5 (2)
Fishing quality	22.5 (2)	**39** (1)
Weather	21.5 (3)	0
Accessibility	15.5 (4)	21.5 (4)
Tide	12 (5)	0
Fewer boats (recreational)	6.5 (6)	35.5 (2)
Commercial absence	5.5 (7)	0
Fewer boats (commercial)	0	10.5 (5)
Beauty	4 (8)	3.5 (6)
Familiarity	2.5 (9)	35 (3)
Habitat	1.5 (10)	0
Species target	1 (11)	0
Camping/Holiday	1 (11)	0
Water quality	1 (11)	0
Don't know	1 (11)	0
Non-response	0.01	0

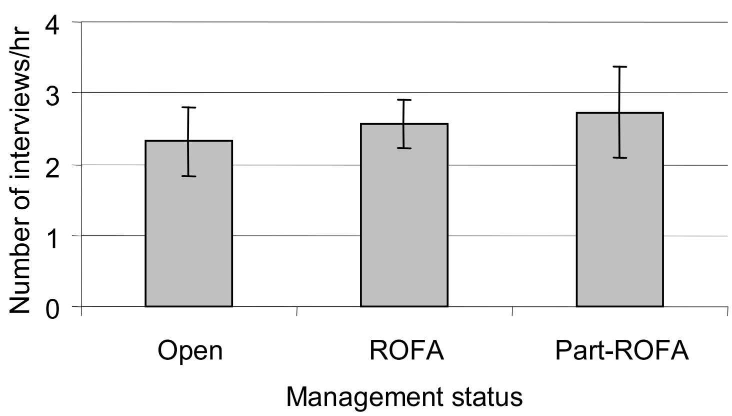


Figure 2.14 Number of interviews per hour from anglers fishing in open, ROFA and part-ROFA estuaries surveyed with the access point Bus Route Surveys. Error bars are 95% CIs determined according to the population proportion sampled.

Anglers' knowledge of current estuarine ROFAs was explored. Firstly anglers were asked whether they are familiar with the estuaries in their local area that are currently estuarine ROFAs: anglers' knowledge is split between 'yes' (47%) and 'no' (53%).

Anglers' knowledge was then tested by asking if they knew if the estuary they were fishing on the day of the interview was open or closed to commercial fishing: for those anglers that were fishing an estuarine ROFA, level of knowledge about the closure is relatively high, with 57% of anglers correctly stating the estuary they were fishing is a ROFA (Figure 2.15). For those anglers that claim they are familiar with the closures, the difference between the proportions of correct and incorrect answers is even greater for those anglers fishing in a ROFA on the day of the interview (Figure 2.16). Proportion of anglers with correct knowledge of the open estuaries is significantly lower, with no significant difference between the proportion of correct and incorrect answers for all anglers combined (Figure 2.15) and those anglers claiming knowledge of ROFAs (Figure 2.16).

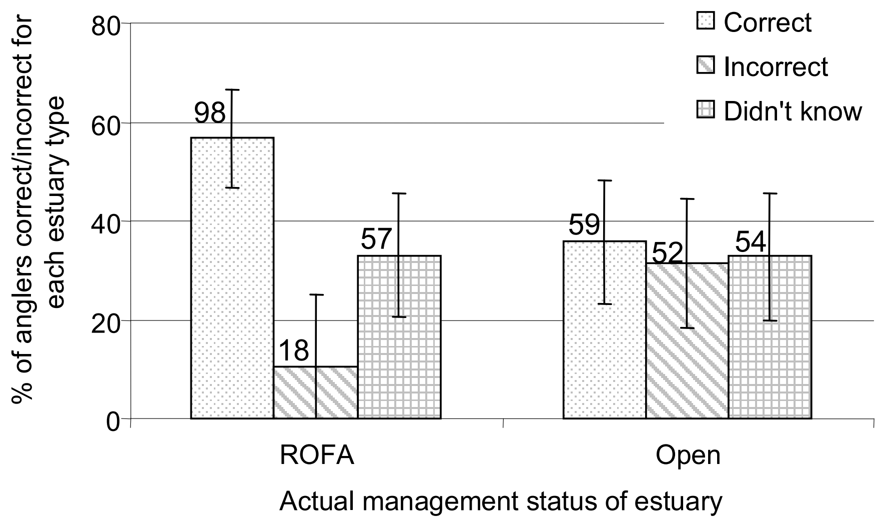


Figure 2.15 The percentage of anglers that correctly or incorrectly stated whether the estuary they were fishing on the day of the interview was open or closed (ROFA) to commercial gill net fishing.

n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled. Non-response = 28 anglers.

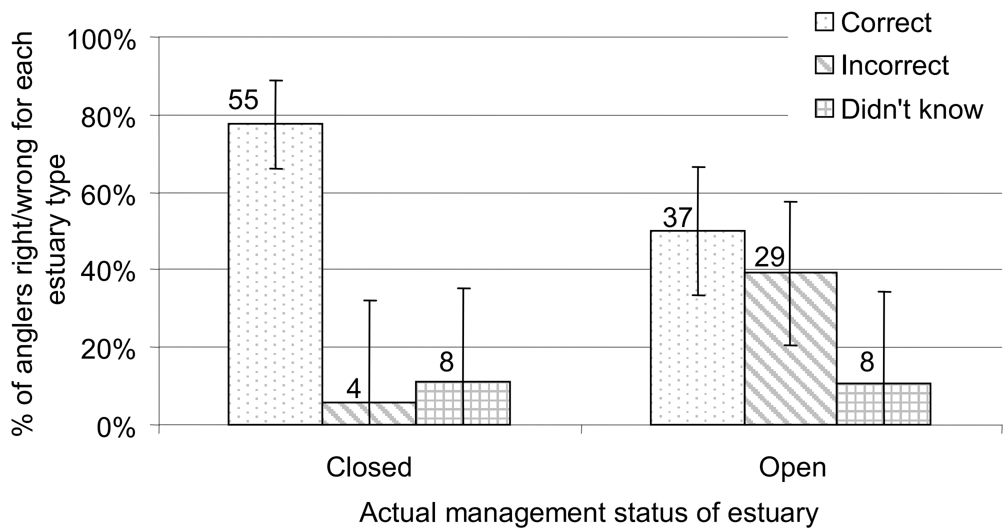


Figure 2.16 The percentage of anglers (from those that claimed knowledge of ROFAs) that correctly or incorrectly stated whether the estuary they were fishing on the day of the interview was open or closed (ROFA) to commercial gill net fishing. n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled. Non-response = 4 anglers.

ii) Future segregation

Both sectors were asked if it is necessary to implement more estuarine ROFAs in the local area. Answers for each sector are contrasting: for anglers, most (76%) answer ‘yes’ to more ROFAs, while for commercial fishers, most (86%) answer ‘no’ (Figure 2.17).

To gauge fishers’ opinions of segregation via sector-specific closures, each sector was asked if they viewed such closures as “fair”. Anglers’ views are divided between ‘fair’ (49%) and ‘unfair’ (41%), however most commercial fishers (93%) view sector-specific closures as ‘unfair’ (Figure 2.18). For further interest, commercial fishers were asked if they would consider Commercial Only Fishing Areas (COFAs) as a “trade-off” if more ROFAs were introduced: 82% answered ‘no’.

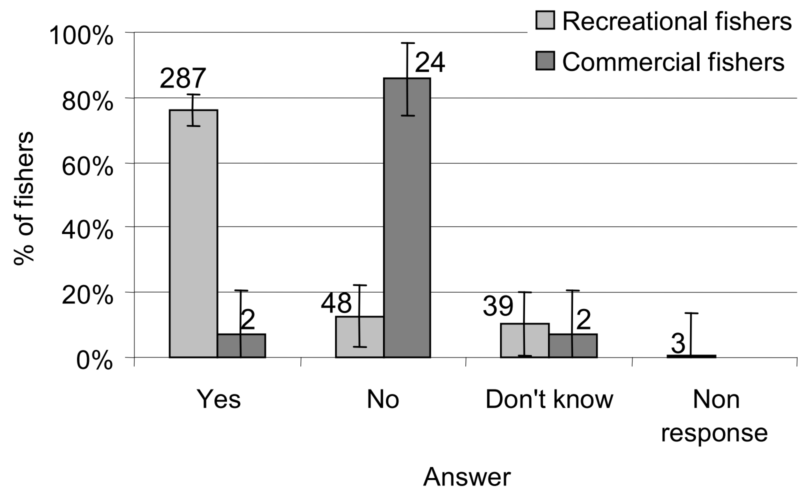


Figure 2.17 Percentage of recreational and commercial fishers who answered ‘yes’ or ‘no’ to the question: “Do you think it is necessary to close more estuaries in the local area to commercial gill net fishing?”
n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

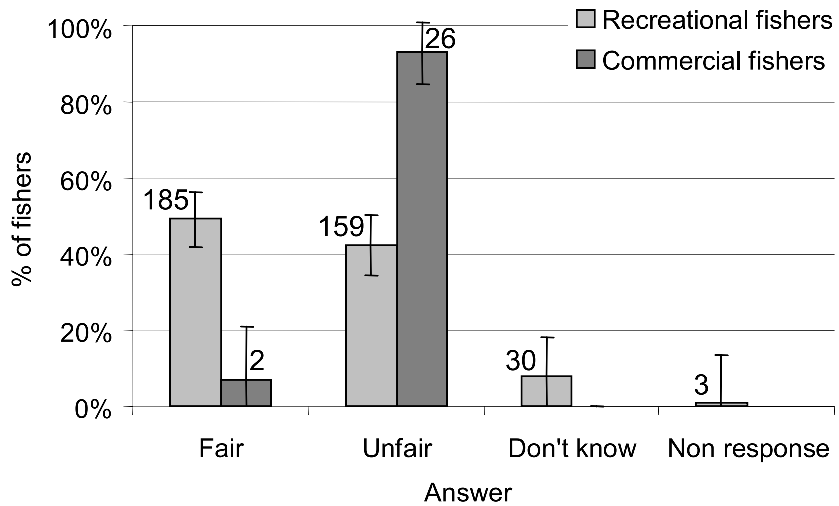


Figure 2.18 Percentage of recreational and commercial fishers who think closing an area to one sector for the benefit of the other (i.e. sector-specific closures) is ‘fair’ or ‘unfair’**.**
n (number of respondents) is shown above each corresponding bar. Error bars are 95% CIs determined according to the population proportion sampled.

2.5 Discussion

2.5.1 Is competition and conflict realised by the general fishing public?

Evidence that competition and conflict between recreational and commercial estuarine fishers in north Queensland is realised by recreational and commercial fishers is mixed. Results show that over half of the fishers from both sectors agree competition is a significant problem in the local community; however, while most commercial fishers also regard competition as a significant problem that affects them personally, most anglers do not.

When people are questioned about the presence of conflict, it is often not clear whether their perception is based on personal experience or on information from newspapers, gossip or other sources (Jacob and Schreyer 1980). This study found that anglers were significantly more likely to regard competition and conflict as a problem within their community rather than seeing conflict as a problem for them personally. This result suggests that anglers see the problem outlined in the local media, but probably don't often find themselves in direct conflict situations with commercial gill net fishers. This conclusion is supported by the recent National *Community Perceptions of Fishing* survey which found that very few people had direct experience with the commercial wild catch sector, and that much of the media coverage of the sector was negative (Aslin and Byron 2003). Several authors highlight the tendency of media articles to be derogatory towards the commercial sector, and that the attitudes each sector holds towards each other may be subject to media influence (Berkes 1984; Loveday 1995; Aslin and Byron 2003; Symes 2005).

In further support of this conclusion, one of the main factors that affected those commercial fishers who held a positive attitude towards anglers was that they recreationally fish themselves, and thus have significant contact with the sector, perhaps also explaining why they do find competition and conflict affecting them personally.

2.5.2 What is the nature and source of the conflict?

a) <u>Is blame present?</u>

The likelihood of blame occurring depends on how fishers perceive their own impacts, and the operations and impacts of their competitors (Jacob and Schreyer 1980; Holder 1992; Nakaya 1998). Results from this study show that each sector holds a more negative opinion of the competing sector than they do of their own (although this is more pronounced for the recreational fishing sector). Thus, it is expected that fishers, particularly anglers, blame the competing sector for adverse experiences (such as declining catches) regardless of whether they are perceived or real.

Expectations of blame from anglers were confirmed. Most anglers hold commercial fishing as responsible for declines in catches (and the absence of commercial fishing as most responsible for increases in catches), and most anglers consider commercial fishing as the greatest threat to the resource. Moreover, only 5.5% of anglers listed recreational fishing as a threat to fisheries resources (18% listed overfishing by both sectors). This finding was expected given previous studies which found that anglers are more likely to blame commercial operators for declines in catch (rather than themselves or any other sector). This blame is thought to be due to anglers' inability to see their individual catch as part of the overall recreational fishing harvest, and because catch is well documented for the commercial sector but not for anglers (Gartside 1986; Ballantine 1991; Dovers 1994; McMurran 2000; Kearney 2002b; Henry and Lyle 2003; McPhee and Hundloe 2004).

Opinions of commercial gill net fishers were varied regarding whether they hold a positive, neutral or negative view of the recreational sector. Commercial fishers do, however, regard their own sector more positively than the recreational sector. Regarding blame, recreational fishing was listed as a possible cause of declines in commercial catches and a threat to the resource; however it was listed by less than 20% of commercial fishers. Most commercial fishers listed non-fishing factors such as environmental damage and the weather for any changes in catches. Hence, blame from commercial fishers is not as pronounced as it is for anglers in north Queensland.

b) <u>Is blame justified?</u>

The results demonstrate that commercial and recreational fishers hold a number of negative perceptions of the competing sector, leading fishers to blame the competing sector for negative outcomes (e.g. catch declines). To determine whether these negative perceptions are substantiated, fishers' perceptions of each sectors' operations were compared to available scientific and fisheries data:

i) Angler's perceptions of the commercial gill net fishery

While anglers believe commercial gill netting results in capture of undersize and large barramundi, data available from the Effects of Net Fishing (EoNF) Project, which detailed catches of commercial gill nets over 2 years, show catches in a standard 6" mesh net of barramundi that were undersize and over 1m in length to be very low (9% & 0.06%, respectively) (Halliday et al. 2001). In addition, of the 63 inshore gill net fishers inspected by the Queensland Boating and Fisheries Patrol (QBFP) in the

2002/03 financial year within the study area, only 1.6% recorded a breach of any kind (QBFP, unpublished data), suggesting that commercial fishers do not regularly keep under- or over-sized fish.

A number of anglers also stated they believed commercial gill nets caught a lot of bycatch species. It is not clear whether anglers referred to ‘bycatch’ (non-marketed product) or ‘by-product’ (non-target but marketed catch). Regarding by-product, the EoNF project found, for barramundi fishers, 45% of the catch was non-target marketed product, mostly made up of blue threadfin salmon (*Eleutheronema tetradactylum*) and queenfish (*Scomberoides commersonnianus*). Regarding bycatch, however, the EoNF project found very low catches of bycatch species (6% of total catch) (Halliday et al. 2001). Further, the recent ecological assessment of the East Coast Inshore Finfish fishery stated that with Dugong Protection Areas and various other closures in place under either Fisheries or Marine Parks legislation together with existing “in attendance” rules for use of gill nets, management of bycatch is not considered a significant issue in this fishery (Zeller and Snape 2005). These findings are supported by studies on other estuarine gill net fisheries (Grant 1981; Quinn 1988; Petrakis and Stergiou 1996; Gray 2002). Gill net selectivity is a function not only of mesh size and fish shape, but also depends on such factors as fish behaviour, water clarity, net colour and hanging ratio, habitat, water currents, etc (Petrakis and Stergiou 1996; Gray 2002).

Anglers’ knowledge of fish species caught by commercial gill nets was compared to data on gill net catches from the EoNF project, and harvest information for 2002 from the Coastal Habitat Resources Information System (CHRIS) website. There are limitations with each of these data sets, however – for instance the EoNF data, while recording all catch (including released fish), sampled in estuaries only (not bays) and was limited to a maximum 6” mesh size, while the CHRIS data lists only kept species, and includes all inshore net fisheries for the Great Barrier Reef coast. Regardless, anglers’ perceptions of commercial catches were similar to the commercial data sources for most species. Exceptions were grunter, mangrove jack and bream which were listed as commercial catch by 21%, 14% and 10% of anglers, respectively, but which were very low in the commercial data sources (<4% for grunter, <1% for the others) (Halliday, QDPI&F, unpublished data; Department of Primary Industries 2002).

Most anglers also believe the commercial gill net fishery is unsustainable on Queensland’s east coast. However, catch per unit effort (CPUE) trends for the commercial fishery suggest current effort levels are not threatening to the stock (Welch et al. 2002; CRC Reef Research Centre 2005b).

ii) Commercial fishers' perceptions of the recreational estuarine fishery

The majority of commercial gill net fishers believe anglers regularly keep undersize fish, oversize barramundi, over their bag limit and fish to sell on the black market. These perceptions were compared to the best available data on actual practices. While there are no specific statistics available for exactly how many undersize and oversize barramundi are kept by anglers, the QBFP has some grouped statistics for illegal activities – for the 2002/03 financial year, the QBFP inspected approximately 6400 anglers within the study area. From these inspections, 0.7% were charged with any kind of offence (i.e. "breached"), and 0.08% were given a warning regarding keeping undersize fish (of any species) specifically (QBFP, unpublished data). Undersize catch for anglers is expected to be high, but anglers' rate for releasing fish (for any reason) is also high (> 70% for barramundi, 44% for all fish) (Higgs 2001; Department of Primary Industries 2002; Henry and Lyle 2003)). In addition, for the 3 years of catch diary data from QDPI&F's RFISH surveys, only 2% of anglers reported catching their bag limit of 5 legal sized barramundi, and only 2% of anglers reported catches over the barramundi bag limit (which they apparently shared amongst other boat passengers) (Higgs, QDPI&F, unpublished data). QBFP unpublished data for 2002/03 shows no anglers were warned regarding keeping over their bag limit of any fish within the study area. The same was found for warnings for illegal marketing by anglers (i.e. zero warnings) (although these offences may be included within "breaches").

Most commercial gill net fishers think the recreational sector has a 'big' impact on estuarine fish stocks, and that anglers catch more barramundi per year than the commercial sector on Queensland's east coast. Also, while 89% of commercial fishers believe their own sector is sustainable, only 54% believe the recreational fishery is sustainable. Documented catch data, however, show the catch of barramundi for both sectors on Queensland's east coast was very similar (270T recreational harvest (including freshwater habitats) and 211T commercial (no freshwater) harvest) in 1999 (Williams 2002a). More recent catch data show that the recreational catch has declined considerably in recent years to be much lower than commercial harvest (In 2002 172 commercial boats harvested 197 t of barramundi (Department of Primary Industries 2002), while the recreational sector harvested 96 t (Higgs, QDPI&F, unpublished data) on Queensland's east coast).

These results indicate that many of the apparent negative opinions held by fishers from both sectors are based on misinformation, which indicates that accurate information about fishing practices is not reaching the general fishing public. This suggests that conflict may be reduced through increased education of fishers about the fishing practices of each sector. Options for increasing education are discussion in Section *2.5.5.*

2.5.3 Do fishers support the use of ROFAs?

Anglers are more likely than commercial fishers to recommend ROFAs as a solution to conflict between the sectors. While commercial fishers did not list ROFAs specifically as a solution to conflict, it appears they would consider ROFAs if compensation for lost areas was made available to them. An overwhelming majority of commercial fishers do not think ROFAs are a "fair" allocation of the resource, whereas anglers are split on this issue. Likewise, most commercial fishers would not consider the use of 'commercial only fishing areas'.

These findings are logical in light of the benefits and costs expected by fishers. Most anglers expect to see benefits from ROFAs including improved catches and increased recreational fishing opportunities and effort. On the other hand, commercial gill net fishers expect to bear the costs such as reduced catch, decreased area to fish, and a consequential decline in income. Some fishers were also concerned about the concentration of commercial fishing effort in remaining areas, which would affect both sectors – hence explaining the commercial fishers' recommendation to buy-out licences if more ROFAs are introduced.

While anglers would like more ROFAs introduced, it appears most anglers are currently unaware of, and consequently do not specifically choose, the current estuarine ROFAs. It is not known whether anglers' choice of fishing location may alter if they were made aware of the presence and location of current ROFAs; however, anglers' awareness of alternative fishing sites (and attributes of those sites, such as commercial fishing absence) may influence site choice (Hunt 2005). At the time of interview, however, the presence or absence of commercial fishing was a low priority for anglers when determining where to fish. "Fishing quality", on the other hand, was a high priority for site selection for many anglers, suggesting that if ROFAs do result in improved fishing quality (or the perception of improved quality) then anglers may be more likely to utilise these areas if they are aware of them. For example, in South Africa the availability of grunter during what is known as the "grunter run" has been found to be positively correlated with angling effort (Mann et al. 2002). Many studies on fishing site choice by anglers, however, suggest fishing site selection is complex and dependent on more than one variable (Schramm et al. 2003). Anglers are often unwilling to change from their familiar fishing sites even when the attributes of these sites degrade (Hunt 2005). For instance, Pradervand et al. (2003) found most (up to 77%) estuarine anglers that they interviewed in South Africa fished exclusively in one of the studied estuaries throughout their entire fishing history, despite the perception of most anglers that fishing quality had deteriorated at their chosen site.

2.5.4 Are more ROFAs necessary?

Most anglers believe more ROFAs are necessary, whereas most commercial fishers do not. Given the finding that most estuarine anglers currently do not regard conflict between the sectors as a significant problem for them personally, and do not currently choose their fishing location according the absence of commercial fishing, it is questionable whether more ROFAs would have any further benefits. Anglers should first be informed about the location of current estuarine ROFAs before reassessing the need to introduce more.

Most anglers in north Queensland do not deliberately avoid estuaries fished by commercial gill netters, and do not choose their fishing locations according the absence of commercial fishing. The earlier conclusion that anglers currently have limited contact with the commercial fishery may relate to these findings – i.e. perhaps contact is already limited due to: 1) time segregation that is currently implemented (no commercial gill nets are allowed in estuaries on weekends (Queensland Department of Primary Industries 1995), when anglers are most active); and/or 2) the finding that commercial fishers currently avoid estuaries that are heavily fished by anglers. This latter explanation has two potential implications: 1) perhaps future ROFAs in areas with prior high angler activity may not have as big an impact on commercial fishers if they are already avoiding these areas; or 2) perhaps ROFAs are unnecessary because the sectors are already voluntarily segregating themselves to a certain degree. Unfortunately, current information is not sufficient to provide answers to these questions.

If further ROFAs are deemed necessary, results from this study suggest they should be positioned close to population centres because the most common factor affecting anglers' choice of fishing location is proximity to home – a common finding in other studies (see Post et al. 2002; Queensland Transport 2002). These areas should, therefore, coincide with areas of highest angler activity. Results also suggest commercial fishers currently avoid areas commonly fished by anglers. Consequently, areas close to population centres may also be areas of low commercial fishing activity and hence would provide a low cost option for implement of ROFAs. Further investigation of actual activity levels of both recreational and commercial fishers in specific areas are needed to confirm this. Current comparable information for both sectors is not available at an estuary-specific scale.

Regardless, ROFAs do not address the issue of mutual mis-perceptions of fishers regarding their competitors; thus ROFAs are likely to provide only a short-term solution because unless mis-perceptions are corrected, the same issues are likely to re-surface in future years.

2.5.5 Other potential solutions to conflict

Most commercial fishers recommend increasing education of, and communication between, the recreational and commercial fishing sectors as a method to resolve conflict. The findings of this study and others (see Ruello and Henry 1977; Henry 1984; Mitchell 1991; Hannah and Smith 1993; Loomis and Ditton 1993; Kearney 1995b; McLeod 1995; Aas and Skurdal 1996; Arlinghaus 2005) support this recommendation. It appears that much of the conflict between recreational and commercial fishers is resulting from misperceptions about each sector's operations and impacts on the resource, which results from a lack of communication between sectors and often fisheries managers. Numerous studies have found that anglers are generally uninformed about commercial fishing practices, and commercial fishers are equally mis-informed about recreational fishing practices (Ruello and Henry 1977; Henry 1984; Kearney 2002a; Aslin and Byron 2003). Some authors suggest conflicts should first be attempted to be resolved by providing information, education, communication and cooperation, rather than the current route of mitigation and mediation (Arlinghaus 2005; Bruckmeier 2005).

a) <u>Who is responsible for education?</u>

Numerous studies highlight the need for increased dissemination of information regarding the fishing practices of, and research about, commercial and recreational fisheries (Ruello and Henry 1977; Henry 1984; Mitchell 1991; Loomis and Ditton 1993; Kearney 1995b; McLeod 1995; Aas and Skurdal 1996; Arlinghaus 2005). However, few papers outline who should be responsible for education and how it should be done. Fisheries departments are commonly responsible for providing information on fishing rules and regulations (Aslin and Byron 2003), and government departments have undertaken specific education campaigns - For example, GBRMPA undertook an education campaign to minimise user impacts on the integrity of the marine park. They broadcast television community service announcements, for example asking boaters to reduce speeds in shallow waters throughout the World Heritage Area, distributed information kits and media releases, held reef user workshops and liaised with advisory committees and stakeholders (Anderson et al. 2005).

General information about fisheries, however, is rarely distributed to the general public by fisheries departments. Further, recreational fishers in particular rarely rely on fisheries departments, universities or research organisations for general information, and some suggest government departments are not trusted by anglers (Bateman 1995; Aslin and Byron 2003; Arlinghaus 2006). Recreational fishers tend to rely on knowledge of peers that are known and respected (Aslin and Byron 2003). With this in mind, perhaps specific fishing sector organisations or representative bodies should be more active in distributing information about their industry to their constituencies. Arlinghaus (2006), for example, suggests fisheries researchers should try to inform angler organisations and the angling media about all aspects of recreational fishing, including negative impacts of certain angling practices. These organisations and media should then objectively disseminate such information to their constituencies. This applies to commercial fishing organisations as well: QDPI&F's *Strategic Directions Document* outlined the need to "encourage industry initiatives that promote commercially net and line caught product as ecologically sustainable" (Department of Primary Industries and Fisheries 2004). Some studies suggest commercial fishing sectors should make use of the public media to promote themselves as a worthwhile, valuable community service to counter the adverse publicity released by some sections of the community (Henry 1984; Aslin and Byron 2003). However there are some concerns that the commercial industry has a vested interest, and thus may provide information that is not trusted by the recreational sector (and vice versa).

Managers and researchers could work together with fisheries organisations in developing methods and providing support to communicate information about each fishing sector. For example, researchers in Western Australia developed a *Community Communication Guide* to assist participants in the commercial fishing industry in developing community communication plans. The guide encourages commercial fishing organisations to communicate the industry's activities, social and economic contributions, and environmental commitment to community leaders and the broader community (Ham 2001).

Whether fisheries departments alone or stakeholder groups alone are most appropriate to provide general fisheries information is likely to be variable depending on the information to be disseminated. Perhaps a combination of these options is most appropriate – i.e. fisheries departments distribute information covering general aspects about both fishing sectors (e.g. comparable catch and effort statistics, compliance statistics, etc), and stakeholder groups can disseminate information to their own sectors about their own and/or the other sector. Regardless, managers, researchers and stakeholder groups should work in partnership.

For managers, researchers and stakeholders to be able to work together, it will be essential for fisheries managers and researchers to build relationships, communication and trust with fisheries organisations (Ham 2001; Bruckmeier 2005; Kyllonen et al. 2006; Taylor et al. 2007), to encourage stakeholders to objectively and effectively disseminate information about both fishing sectors. Considerable staff time would be needed to develop and maintain these relationships and fisheries departments may benefit from a dedicated education coordinator for such a role (Taylor et al. 2007). An education coordinator would need to have ongoing face-to-face communication with representatives from each fishing sector, because mutual respect and tact are more likely in face-to-face relations (Kyllonen et al. 2006; Taylor et al. 2007). Another way to build trust is to encourage stakeholder participation in research, or through focus group discussions or joint working groups in which information can be exchanged through open and confidential discussion (Schusler et al. 2003; Bruckmeier 2005; Kyllonen et al. 2006).

b) How to educate?

Investigation is needed to determine the most appropriate methods to disseminate information. Aslin and Byron (2003) found that most people source information about fisheries from public media sources such as television (quoted by 54% of respondents), and newspapers (45%). Unfortunately, some fishing magazines and newspapers publish material critical of specific sectors which often increases the friction and antagonism between fishing sectors (Ruello and Henry 1977; Henry 1984; Loveday 1995; Williams 2002b). Public media methods were utilised more positively by the *National Strategy for the Survival of Released Line Caught Fish* ('the strategy'), which ran a national television awareness campaign in 2003. The strategy is an initiative of the Fisheries Research and Development Corporation (FRDC) (a federal fisheries funding body) in conjunction with the Australian National Sportfishing Association (ANSA) and Recfish Australia (both recreational fishing organisations). The strategy aimed to improve the understanding of, and increase the survival rates of, released line caught fish. The television campaign involved a series of advertisements and was supported by a website, best practices pamphlet and best practices video. The website contained fact sheets detailing the best practices for releasing key fish species or groups of similar species. Surveys were carried out prior to and following the awareness campaign to gauge the results. A total of 59% of fishers recalled seeing the campaign, and 35% of anglers stated they had changed their practices as a result of the campaign (Sawynok and Pepperell, 2004, in Anderson et al. 2005).

The specific methods used within an education campaign will depend on available resources. Ongoing television advertising is likely very expensive in the long-term and for large areas (Ham 2001), though it may be required occasionally given the likely success of information distribution. Newspaper and magazine articles are more affordable, and are important sources of information for a large number of fishers (Aslin and Byron 2003), but care needs to be taken to ensure information is presented objectively. Other ideas include radio announcements, public interest workshops, seminars, presentations, displays and seafood festivals, seafood education for school children (children provide a way of getting messages through to adults, and ideas and perceptions formed by children often stay with them throughout life), brochures or fact sheets, seafood recipe books containing fisheries information, or a website for each sector (Ham 2001; Schusler et al. 2003; Taylor et al. 2007).

Some studies suggest education campaigns should include participatory processes (e.g., workshops, or festivals) rather than solely passive methods (e.g., posters) (Taylor et al. 2007). Participatory methods may include management advisory committees (MACs) already in place, where representatives from each fishing sector along with managers and researchers meet to discuss issues regarding their particular fishery. van der Elst and Schnetler (1999) outlined how successful the South African Marine Linefish Management Association (SAMLMA) (similar to MACs in Australia) was at reducing conflict between recreational and commercial fishers, by promoting wider user participation, providing forums to discuss linefishery problems, holding special workshops and information sessions, and creating greater public awareness of linefish matters. Such participatory methods may facilitate ‘social learning’, which occurs when people engage one another, sharing diverse perspectives and experiences to develop a common framework of understanding. Social learning can occur via discussion and communication, where stakeholders raise and collectively consider issues and increase understanding. When communication enables social learning, individuals and groups evolve their understanding of issues, relevant facts, problems and opportunities, areas of agreement and disagreement, and their own values and those of others (Schusler et al. 2003). The important aspect about participatory methods is that those who are involved in meetings share their knowledge objectively with their constituencies.

Obviously, there are numerous options for education methods. Some methods require ongoing commitment where others may be more short term or may address specific issues as they arise. The most appropriate methods may vary, and will likely depend on resources available. Importantly, education campaigns may need to be flexible depending on their effectiveness, which should be measured by surveying fisher perceptions before, during and after any education campaign (Anderson et al. 2005; Taylor et al. 2007). This could be done via focus groups (which include representatives from each stakeholder group) or random phone surveys, each measuring perceptions regarding key messages.

c) What are the key messages?

Determination of key messages is essential prior to any education campaign (Taylor et al. 2007). As such, it is essential to survey fishers (such as via phone surveys) prior to starting any education campaign to determine what misperceptions are present (Marshall et al. 2007; Taylor et al. 2007). The present study has revealed numerous misperceptions of recreational and commercial fishers, and the resulting key messages for future education campaigns to address these would include information about participation and harvest (including sustainability) levels of each fishing sector, regulations that apply to each sector, facts about fishing practices (e.g., selectivity of set gill nets, release rate within recreational fisheries, adherence to regulations of both sectors), location of ROFAs, potential impacts on the resource of each sector, common issues applying to each sector (e.g., importance of habitat), and benefits to the community from commercial and recreational fishing.

d) How long-term should a campaign be?

Any education campaign needs to be ongoing, particular given the long history associated with conflict between fishing sectors. Taylor et al. (2007), for instance, ran a low-cost eight month community education campaign in an attempt to change people's attitudes and behaviour regarding stormwater litter loads. They concluded significant human resources were needed to make the campaign ongoing, because 8 months after the campaign ended there was no change in public littering behaviour compared to prior to the campaign (there was a slight change in behaviour during the campaign). They suggested educators need organisational support and planning to ensure that resources are available to enable momentum to be maintained. Costs of ongoing education may be significant; however, the common method of conflict resolution via mediation, negotiation (Bruckmeier 2005) and likely legislation change is wasteful of time and money, particularly if such conflict is a result of misperceptions, as is the case here. If education (including via increased communication between sectors) can reduce unnecessary conflict between fishing sectors, economic and social costs of negotiation and resource allocation may be avoided.

2.6 Conclusion

Conflict between recreational and commercial fishers over shared barramundi stocks in north Queensland is consistent with the given definition of fisheries conflict for recreational fishers. Most anglers believe commercial gill net fishing is interfering with their goal of catching fish, and they seek to assert their interests at the expense of commercial fishers i.e. by excluding them from some areas via ROFAs. Whereas commercial fishers have a negative view of many recreational fishing practices, they are less likely to blame recreational fishing for any declines in catches, and do not seek to exclude recreational fishing (e.g. via COFAs).

Importantly, the apparent conflict between sectors appears not to be caused by direct contact between the recreational and commercial fishing sectors, but rather misperceptions fishers from each sector hold about the other. Consequently, conflict between these sectors may be reduced by increasing education of, and communication between, each fishing sector. Such education may not eliminate conflict completely, and some future segregation (e.g. via ROFAs) may be appropriate. However, the need for future ROFAs should be reassessed only after anglers are informed about the current estuarine ROFAs. In many fisheries anglers appear unaware of fisheries regulations that have been made for their benefit (Ruello and Henry 1977; The Recreational Fishing Consultative Committee 1994). This highlights the onus that lies with fisheries managers and scientists to communicate with stakeholders in order to reduce unnecessary conflict.

2.7 Future survey improvements

Future surveys of recreational fishers should aim to reduce any sources of error or bias. For instance, surveys require a pre-determined system for avoiding recaptures of survey respondents, although it is likely that fishers who had previously been interviewed for the current project would not consent to a second interview given the amount of time required to participate in an interview. During field work, a number of fishers were encountered who had been interviewed previously and were clearly not willing to be re-interviewed. Also required is a system for randomly selecting a respondent from each fishing party (e.g., the fisher with the next upcoming birthday). Local fishers and visitors to the area should also be treated separately, as their opinions may vary. Questions within this survey may have benefited from more thorough pilot testing to ensure wording of questions within and between recreational and commercial fisher surveys are consistent and therefore that answers are directly comparable.

The recreational fisher survey initially aimed to collect catch and effort information from fishers at boat ramps. However, accurate collection of such information requires significant time and effort. The opinion, attitude and knowledge questions within the current survey were considered of greater importance in this instance, meaning that the catch and effort information was not collected reliably. Given time limitations for individual surveys, future access-point surveys should aim to collect attitude and opinion information separately from catch and effort information.

CHAPTER 3: FISHERY-DEPENDENT RECREATIONAL CATCH DATA

3.1 Introduction

In fisheries with shared access, it is common for fishers to blame the competing sector for (perceived or real) declines in catches (Henry 1984; Samples 1989; Dovers 1994; Kearney 2002a). In particular, anglers regularly blame commercial fishers for perceived catch declines, probably because catch is well documented for the commercial sector but not for anglers (Gartside 1986; Ballantine 1991; Dovers 1994; McMurran 2000; Kearney 2002b; Henry and Lyle 2003; McPhee and Hundloe 2004). There are many cases, however, where it is unclear whether there is a real impact of commercial fishing on recreational catches. Unfortunately, anecdotal evidence usually takes precedence where data is lacking (Smith and Pollard 1995; Griffin and Walters 1999).

Anglers often advocate the exclusion of commercial fishing via Recreational Only Fishing Areas (ROFAs) when there is a perceived impact of commercial fishing on recreational catches or fisheries sustainability. The general expectation amongst anglers seems to be that exclusion of commercial fishing will decrease competition for fish stocks and thus improve recreational fishing quality (i.e. quantity and/or size of target fish species (Ruello and Henry 1977; Kearney 2001; Cox et al. 2003; Pereira and Hansen 2003). Data presented in Chapter 2 confirmed that such expectations are commonly held by anglers in north Queensland.

Significant anecdotal evidence suggests that recreational catch benefits of ROFAs are often realised (see Griffin 1995; Brown 2001; Anon 2002b; AFANT 2005). Consequently, there are increasing calls for the introduction of further ROFAs, including for inshore areas along Queensland's east coast (see The Recreational Fishing Consultative Committee 1994; Eussen 2001; Knowles 2001; Sunfish 2001). Unfortunately, there are few cases, however, where actual recreational catch trends in ROFAs are examined (Smith and Pollard 1995; Griffin and Walters 1999).

In situations where catch trends have been examined following ROFA implementation, findings are mixed. For example, when annual surveys from prior to and post-ROFA implementation were compared in the Tuross Lake estuary in NSW, recreational harvest and average size of harvested fish of most fish species were found to have increased (Steffe et al. 2005a). Similarly, In Iceland, anglers' catch rates were examined in the River Hvitá after recreational fishing groups leased commercial licences which effectively closed the mainstream to commercial netting in 1991. When catch rates from the 'closed' area (i.e. ROFA) from 1991-2000 were compared to catch rates 10 years prior to the closure for the same area, researchers found a 28-35%

increase in angling catch rates. The post-closure catch rates were also compared to catches in two other rivers open to commercial fishing. Results showed significant increases in rod catches in the ROFA post-closure, while in the 'open' rivers the catches declined. Interestingly, in this fishery the number of rods allowed on each river is fixed: i.e. it is not open access for recreational fishing (Einarsson and Gudbergsson 2003), which contrasts to most other recreational fisheries.

In other fisheries, improvements in recreational catches are not evident. For example, in the Pumicestone Passage in Queensland, O'Neill (2000) examined recreational catches before and after commercial fishing was banned and found no improvements in catch rates. Likewise, no significant differences of recreational King George whiting catch rates were found between areas in Franklin Harbour, South Australia, despite some areas being closed and others open to commercial fishing (Jones and Retallick 1990).

In the Northern Territory, investigations of recreational catches following progressive ROFA implementation in the Mary River from 1978-88 yielded mixed results. Surveys of catches from 1986-92 showed an improvement in angling in terms of size of fish (i.e. the proportion of barramundi caught being of memorable size increased steadily, with almost 10% of the catch in 1992 being greater than 90 cm in length) (Griffin 1995). However, data from creel surveys up to 1995 showed that while fish abundance increased in the Mary River ROFA (due to commercial exclusion as well as a good wet season and strong recruitment), angler success rate did not change (Griffin and Walters 1999; Griffin 2003). A weak improvement was found for guided anglers (Griffin and Walters 1999), which is consistent with other studies that suggest any improvements in catch rates are evident only to the more experienced anglers, or those anglers who spend more time fishing (Hilborn 1985; Johnson and Carpenter 1994; McPhee and Hundloe 2004).

Unfortunately, many of the studies that do examine recreational catches in ROFAs lack scientific rigour, either through a lack of comparable catch data from before and after the ROFA was implemented, a lack of time series data following the ROFA, or a lack of replication in sites. For instance, Steffe et al.'s (2005a) study in the Tuross Lake Estuary (NSW) provides a good comparison of recreational harvest pre- and post-ROFA implementation, however they have so far only surveyed once since ROFA implementation, and they recommend to continue monitoring this recreational fishery at intervals of about 3-5 years to ensure any changes are not solely due to natural variation. Einarsson's (2003) study in Iceland, while providing time series data from before and significantly (10 years) after ROFA implementation, was unable to provide a replicate ROFA with which to compare catch rates. Thus the changes in catch rates may have been a characteristic of that particular river. O’Neill (2000) recommended re-examining angler catches in the Pumicestone Passage in future years because he probably sampled too soon after the closure for any potential catch improvements to be detected. O’Neill also noted he needed to interview twice as many anglers to have about an 80% confidence in detecting a 15% difference in catch rates between the before- and after-closure periods.

A more rigorous study was successful in showing higher fish abundances in north Queensland ROFAs compared with open estuaries in the same area as the present study. Halliday et al. (2001) used commercial gill net fishing techniques to compare estuarine catches in three estuarine ROFAs and three open estuaries in north Queensland bimonthly over two years. Their study found higher abundances of large barramundi (over 800 mm total length) in ROFAs compared to open estuaries, and hence suggested improved recreational line fishing catches of large barramundi in north Queensland ROFAs are possible.

Some authors, however, suggest such increases in abundances may not translate into improved angling quality because angling success is highly variable and not always directly related to the size of the fish population (Ruello and Henry 1977; Johnson and Carpenter 1994; Anderson 1999; Griffin and Walters 1999). The Mary River (NT) example discussed above, for instance, found an increase in fish abundance but no increase in angler success (Griffin and Walters 1999; Griffin 2003). With any commercial or recreational fishery, there are factors that affect catch rates outside of the abundance of fish stocks (Maunder and Punt 2004).

As is the case for most recreational fisheries, there is limited recreational catch data available on the Queensland barramundi fishery to provide comparisons of recreational barramundi catches between specific estuaries open (‘open’) and closed (‘ROFA’) to commercial gill net fishing. Available recreational catch data are limited to large-scale regional and state-wide surveys through QDPI&F's RFISH surveys (see Higgs 1997; Higgs 2001) and the *National Recreational and Indigenous Fishing Survey* (see Henry and Lyle 2003).

A number of fishery-dependent data sources are available which allow the examination of recreational catch information on a smaller scale, though they are rarely examined for this purpose. These data sources include QDPI&F compulsory catch logbooks from the Commercial Charter Fishery, voluntary recreational catch logbooks, and anglers’ personal records. Each data source has its own advantages and limitations, but together they can provide an indication of recreational catch trends in open and ROFA estuaries, to determine whether improvements in abundance of large barramundi in estuarine ROFAs in north Queensland found via the EoNF project translate into improved recreational fishing quality.

3.1.1 Fishery-dependent data sources

a) Charter Fishery Logbooks

Charter fishers are required to complete compulsory catch logbooks, which provide relatively easy to access catch data down to the level of 6' grids (see Appendix 4 for an example logbook page). Detailed information about each fishing day is limited, however, with no information on the size of the fishing party, fishing methods used, species targeted, size of individual fish caught (weight is grouped for each species each day), duration of fishing, or exact location of fishing (Operators record the relevant 6' grid they fished in, usually not including the specific estuary. Often only small sections of the coast are located in the corners of each grid, therefore, grids were able to be classified as ROFA, part-ROFA or open grids depending on the estuaries contained within – see Appendix 4 for a map showing the locations of the grids). There are also a number of biases inherent with any logbooks, including recall bias (as logbooks are completed after the fishing trip), rounding bias (where weights are often rounded), misidentification of species, and intentional lies (Pollock et al. 1994).

b) Voluntary recreational catch logbooks

To gain more detailed information about recreational catch at a small (estuary level) scale, an extensive voluntary recreational catch logbook program was employed through the present study. These logbooks provide more detailed information about each fishing day, allowing a more accurate estimate of catch per unit effort available for specific estuaries than that available from charter records. The main advantage of logbooks is that they are very inexpensive and relatively simple to administer, and with continued contact and education of cooperative participants, logbooks can provide trustworthy information (Sztramko et al. 1991; Pollock et al. 1994). While voluntary recreational catch logbooks often suffer from a number of biases (e.g. prestige bias (where anglers exaggerate their catch rate and size of fish), rounding bias (where sizes are often rounded upwards), misidentification of species, intentional lies, and non-response bias (where respondents' characteristics differ from non-respondents)), logbooks are commonly used to compare catch rates, both temporally and spatially. Biases such as non-response bias are less of a problem in situations where logbooks are used to compare catches are between areas (as is the case in the present study), rather than to estimate overall catches for the fishery (Essig and Holliday 1991; Sztramko et al. 1991; Pollock et al. 1994).

c) ANSA time-series catch data

The recreational catch logbooks used in this study do not provide time series data, therefore making comparisons of catches prior to and following ROFA implementation impossible. Some recreational fishers keep good quality catch records over time. One particular group of anglers from the Australian National Sportsfishing Association (ANSA) regularly record all catch and effort information from their annual fishing trips in the Hinchinbrook region – an area in the study region which was recently (January 1998) closed to commercial fishing via the introduction of Dugong Protection Areas (DPAs). This group provided detailed catch and effort data annually from 1987 to 2001, allowing the comparison of catch trends from before- and after-DPA implementation within the DPA area and adjacent open estuaries.

3.2 Objectives

This chapter aims to address the following objective:
3. To determine if there is a difference in recreational line fishing quality between estuaries that are open and closed (ROFAs) to commercial gill net fishing.

3.3 Methods and Results

Due to the complexity of presenting data from three different data sources, methods and results are presented for each data source in turn.

3.3.1 Charter fishery catch data

Methods

Barramundi catch data were obtained via compulsory QDPI&F catch logbooks for all charter fishing trips from inshore habitats within the study area for the years 2000-2003. These logbooks include information on fishing location (to the level of 6' grids), and estimated total weight of each species caught on the fishing day. In some instances the weight of fish caught was divided into kept and released categories, however, it is unknown whether legal-sized fish were also released so only the overall catch data were analysed. No additional information such as time spent fishing, fishing method, number of anglers, or target species was recorded. Days when no barramundi were caught were not included in the analyses because the reason for the zero catch was unknown – those fishing days may have been days where barramundi was targeted but not caught, or days when other species were targeted.

The research question for these data is:

1. Do ROFA estuaries provide higher catch per unit effort (CPUE) for barramundi than open estuaries within the study area for chartered fishing trips?

CPUE (weight per day) of barramundi for successful charter fishing days were analysed via Classification and Regression Trees (CARTs) using TreesPlus 2000 software, to investigate any differences in CPUE between estuaries open ('open') and closed ('ROFA') to commercial gill net fishing in any of the bays within the north Queensland study area. The predictor variables were bay and management status (i.e., open and ROFA). CARTs have no implicit assumption that underlying relationships between the predictor variables and the dependent variable are linear, follow some non-linear link function, or that they are even monotonic (De'ath and Fabricius 2000). CARTs can often reveal simple relationships between just a few variables that could have gone unnoticed using other analytical techniques (De'ath and Fabricius 2000; StatSoft 2005).

Final CART models were selected by running 50 ten-fold cross-validations from which the most frequently occurring tree size was selected. This is standard practice as described by De'ath and Fabricius (2000). Initially the tree model selected was the most frequently occurring tree with cross-validation relative error within 1 standard error of the tree having the smallest cross-validation error (1-SE rule). This procedure is generally considered to produce the most parsimonious valid model (Breiman et al. 1984). The minimum cross-validation (CV) error rule (which generally leads to a larger, more complex tree) was also applied to allow further exploration of the data, although information from additional splits should be treated as indicative only (analogously to ambiguous p-levels in ANOVA). The model resulting from the min-CV error rule is shown only in instances where a larger tree (than that produced with the 1-SE rule) with results of interest (i.e. whether ROFAs provide higher CPUE than open estuaries) was produced.

Results

CARTs examining the effect of management status (i.e. open vs. ROFA) and bay reveal CPUE (weight caught per day) for barramundi for charter fishing trips is higher for Bowling Green and Upstart Bays. However, there is no difference in CPUE between open and ROFA estuaries (Figure 3.1). Application of the min-CV error rule does not reveal any further splits.

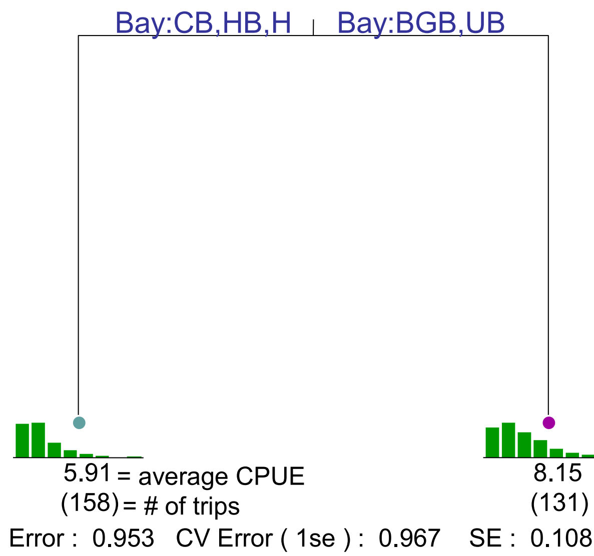


Figure 3.1 Classification and Regression Tree (CART) with the 1-SE rule examining the effect of fishing location (management status and bay) on catch per unit effort (CPUE, weight per day) of barramundi for the Commercial Charter Fishery**.**

"Error" refers to the amount of variability in the data unexplained by the model (95.3% in this case). The graphs for each node are frequency histograms of barramundi CPUE for each branch, with average CPUE (and number of trips) listed below.

Key: Bay – BGB = Bowling Green Bay, CB = Cleveland Bay, HB = Halifax Bay, H = Hinchinbrook, UB = Upstart Bay.

3.3.2 Voluntary recreational catch logbooks

Methods

a) <u>Logbook development</u>

Logbooks were developed to collect basic catch and effort data from anglers fishing in open and ROFA estuaries within the study area. Participants' details were kept confidential to encourage honesty, however general information about each participant was collected, including number of days usually spent fishing per year (i.e. avidity code, which was developed to match those used in QDPI&F's RFISH surveys to allow estimation of avidity bias), gender, and whether the participant was a fishing club member. See Appendix A5.1 for the logbook introductory page.

Information collected for each fishing day included date, estuary name, time the boat was launched and retrieved, amount of time spent fishing, tidal direction fished, angler number per vessel, average number of lines used per vessel, species target, fishing methods, and catch information including fish species, total length, method of capture and fate (kept or released). See Appendix A5.2 for the logbook data page.

The draft logbook was reviewed by other researchers and selected anglers from fishing clubs. Following review, the logbook was circulated to a group of volunteer anglers, who were asked to comment on whether the logbook was easy to complete, and whether they had any suggestions for improvement. Minor changes were made following this first round of distribution.

Logbooks were printed on waterproof paper to encourage participants to complete the logbooks while fishing, hence reducing recall bias common with catch logbooks in other studies (Pollock et al. 1994). To allow ease of interpretation, detailed instructions were included at the front of the logbook (see Appendix A5.1) and in a cover letter accompanying the initial logbook (see Appendix A5.3).

b) Logbook distribution

Anglers were alerted about the logbook program via media releases (TV news, radio, fishing magazines, and newspapers), brochures at local tackle shops within the study area, at the annual Fishing and Outdoor Expo held in Townsville in March, through fishing club meetings, and following interviews with the questionnaire program (Chapter 2). Anglers were asked to volunteer by directly contacting the researcher, most often immediately following presentations at fishing club meetings.

Regular contact with participants was essential to reduce intentional deception or question misinterpretation, and to encourage participants to continue to complete their logbooks, hence reducing non-response bias between successful and unsuccessful participants (Pollock et al. 1994). Logbook holders were contacted via occasional phone calls, e-mails and reminder letters; however regular contact was difficult due to time constraints.

Overall, 77 anglers completed 156 logbooks, totalling 1775 fishing trips (560 trips targeting barramundi; each ‘trip’ is usually within one day) over the 2 year collection period, from March 2001 to March 2003. Due to high variability among anglers, and the fact that barramundi are the main focus of this project, only the trips where anglers targeted barramundi (sometimes among other species) were included in analyses. A basic description of these fishers is presented in the results.

c) Data Analysis

All catch data from fishers targeting barramundi were divided into the following 'fish groups' : 1) all combined fish species ('all fish'); 2) all barramundi; 3) undersize barramundi; and 4) legal-sized barramundi.

Due to the high number of trips with zero catch, particularly for barramundi (51% for all barramundi, 74% for legal-sized barramundi), the catch data for each fish group were examined first for differences in success rate (i.e. percentage of trips where fish in the particular fish group were present in the catch vs. those where they were absent) between open and ROFA estuaries before the CPUE (number of fish per angler per hour) for successful trips were investigated. This is a standard method of analysing recreational catch data which is characterised by a high number of trips with no catch (Maunder and Punt 2004). Overall CPUE (i.e. including zero catch days) was examined initially, however results of interest (i.e. whether ROFAs provided a higher CPUE than open estuaries) did not differ from the successful trips CPUE results; therefore, the results from the overall catch data are not included here.

i) Effect of fishing trip factors

Prior to comparisons of catches between open and ROFA estuaries, the data were examined to determine the effect of other fishing factors – including time spent fishing, avidity of logbook holder, number of anglers in fishing party, number of lines per angler, fishing method, and fishing location (bay and management status) – on success rate and CPUE.

The influence of all fishing factors on success rate was examined via CARTs, as explained in Section 3.3.1, to determine whether fishing location or other fishing factors had the greatest influence on success. As with the charter fishery data, the model resulting from the min-CV error rule is shown only in instances where a larger tree with results of interest (i.e. whether fishing location had a greater effect on success rate than other fishing factors) was produced. All other models are listed in Appendix A6.1.

For CPUE, particular levels of the various fishing factors (angler avidity, number of anglers, lines per angler) provided a greater CPUE than other levels (CARTs are listed in Appendix A6.2). These factors were combined into a "fishing factor code" (i.e. Coded ### as: #1 = avidity code, #2 = number of anglers, and #3 = line number per angler . See Table 3.1 for a complete list of codes for each factor). The average CPUE for each fishing factor code for each fish group was examined via CARTs. Where the chosen model revealed a particular fishing factor code produced a higher average CPUE, the CPUEs for the remaining codes were standardised to be equivalent to the code that produced the highest CPUE; i.e. the CPUE for each code was divided by the average CPUE for that code and multiplied by the average CPUE for the 'optimum' code (i.e. the code that produced the highest CPUE for that fish group). This method was repeated for all fishing factor codes within each fish group, to produce standardised CPUEs so that only the effect of fishing location on CPUE was being examined in following analyses.

Table 3.1 Codes assigned to each fishing factor within the "fishing factor code"**.**

Factor	Code	Meaning
Avidity	1	<12 = less than once a month / <12 times per year
	2	12 = once a month / 12 times per year
	3	24 = once a fortnight / 24 times per year
	4	52 = once a week / 52 times per year
	5	>52 = more than once a week / >52 times per year
Number of anglers	1	1 angler per boat
	2	2 anglers per boat
	3	3 anglers per boat
	4	4 anglers per boat
Number of lines per angler	1	<1 line per angler (for boats with >1 angler)
	2	1 line per angler
	3	1.5 lines per angler (e.g. 2 lines for boat with 3 anglers)
	4	2 lines per angler
	5	2.5 lines per angler (e.g. 5 lines for 2 angler boat)
	6	3 or more lines per angler

ii) Differences between open and ROFA estuaries

1) Success rate comparisons

The binary success rate data (i.e. trips classified as successful ("1") or unsuccessful ("0") for catching at least one fish from the particular fish group) were examined via CARTs (see Section 3.3.1 for explanation) to determine whether fishing location (bay and management status) had a significant effect on success rate for each fish group. The models resulting from the 1-SE rule are shown here, while models resulting from the min-CV error rule are listed in Appendix A6.3.

2) CPUE comparison for successful trips

The standardised (for the effect of fishing factors other than fishing location) CPUE data did not conform to the assumptions of Analysis of Variance (ANOVA) (i.e. data were not normally distributed and variances were not homogeneous). Therefore CARTs were employed to investigate possible differences between open and ROFA estuaries within each bay of the study area for all fish groups. As for previous CARTs, the model resulting from the min-CV error rule is shown only in instances were a larger tree with results of interest (i.e. whether ROFAs provide a higher CPUE than open estuaries) was produced. All remaining models can be viewed in Appendix A6.4.

3) Size frequency of barramundi

A size frequency histogram allowed basic examination of the difference in relative size frequency of barramundi caught by logbook holders between ROFA and open estuaries within the study area. Size distributions were compared via Kolmogorov-Smirnov tests. Further exploration was carried out via correspondence analysis within Statistica to investigate the relationship between the frequency of each size class and fishing location (grouped to open and ROFA estuaries within each bay).

The research questions for the recreational catch logbook data are:

1. Does management status (i.e. open vs. ROFA) have a significant impact on success rate compared to other fishing factors?
2. Is recreational fisher success rate for catching fish in any of the fish groups higher in ROFA estuaries than open estuaries within the study area?
3. Is CPUE (number of fish per angler per hour) for successful fishing trips for any fish group higher in ROFA estuaries than open estuaries within the study area?
4. Is the size structure of barramundi caught in ROFAs different to that in open estuaries within the study area?

Results

a) <u>Description of anglers and fishing days</u>

Most (90%) of the logbook holders targeting barramundi were male, providing 87% of logged fishing trips; however, the gender ratio of all fishers is not available because the gender of any extra persons in addition to the contact person on any logged trip was not recorded.

Many (39%) of the logbook holders were fishing club members, who provided 56% of logged fishing trips targeting barramundi; however, club membership was unknown for many (33%) anglers. Most (92%) of the logged trips were spent fishing from a boat rather than the shore.

There was a strong bias (86%) toward anglers who reported fishing 24 or more days per year (Figure 3.2). These more avid anglers provided 94% of the logged fishing trips in the present study. Anglers from these avidity categories made up 20% of the 2001 recreational fishing population for the Townsville region (according to results from QDPI&F's recreational fisher, 'RFISH', surveys (Higgs, QDPI&F, unpublished data)). In accordance with the theory that more experienced fishers are more likely to benefit from improved fish stocks (Johnson and Carpenter 1994; Griffin 2003; McPhee and Hundloe 2004), such anglers should be more likely to experience any possible difference in fishing quality between open and ROFA estuaries. Further, Hilborn (1985) found the strongest correlation with catch in recreational fisheries is effort, with more avid anglers catching more fish.

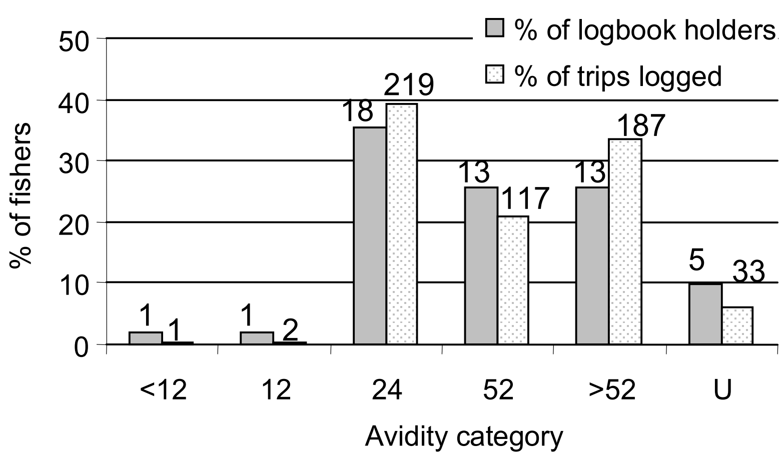


Figure 3.2 Percentage of recreational logbook holders (that targeted barramundi) in each avidity category, plus percentage of trips provided by anglers in each avidity category.

See Table 3.1 for list of avidity categories. n (number of logbook holders and number of trips logged) is indicated above each corresponding bar.

Most (63%) logged fishing trips were completed by fishing parties containing two anglers (Figure 3.3). Almost half of the fishing parties (49%) used one line per angler, while some fishing parties deployed additional lines (Figure 3.4). Most (86%) fishing trips were of 8 hours or less duration, with 35% within 4-5 hour duration (Figure 3.5). There were a few longer fishing trips where anglers combined their catches for weekend fishing trips. It was not possible to split these trips into specific fishing days because the time of each fish capture was not recorded. Each angler was asked to estimate actual time spent fishing in all instances – these time estimates were used to determine CPUE.

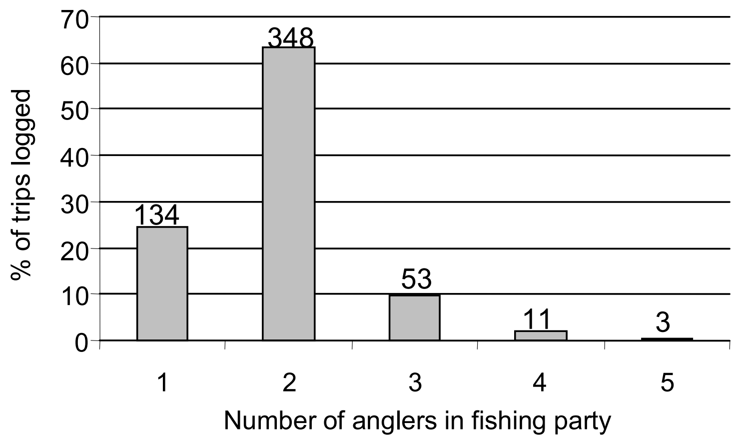


Figure 3.3 Percentage of trips logged by each fishing party size (i.e. number of anglers).
n (number of trips) is indicated above each corresponding bar.

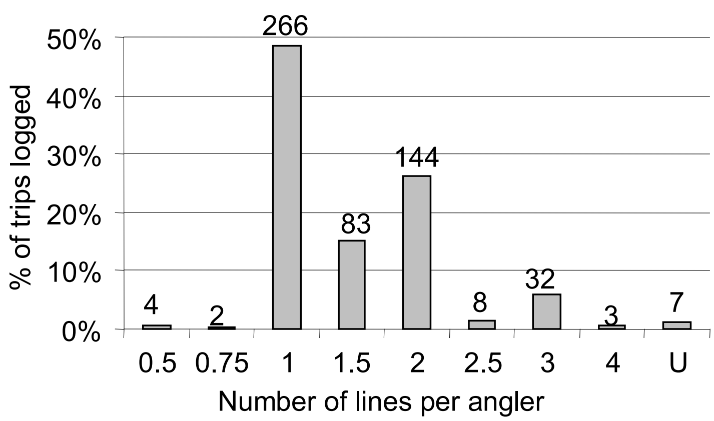


Figure 3.4 Percentage of logged trips by anglers using different line numbers per angler.
n (number of trips) is indicated above each corresponding bar.

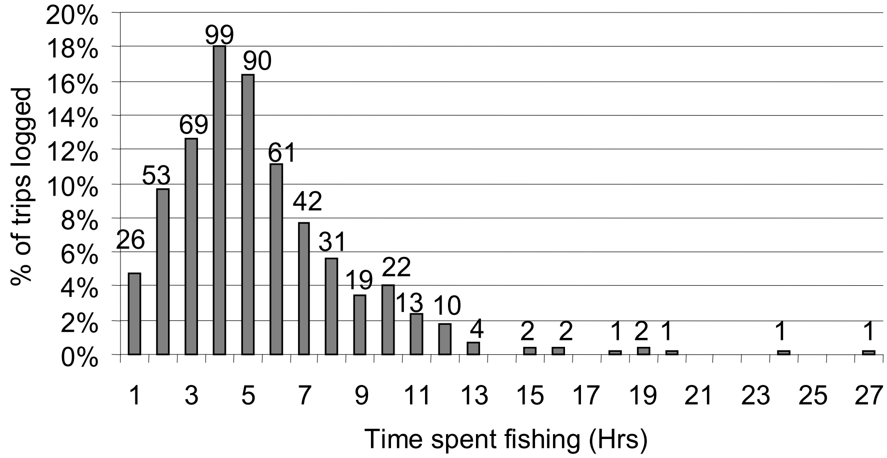


Figure 3.5 Duration of logged fishing trips within one-hour time categories (rounded up to the nearest hour)**.**
n (number of trips) is indicated above each corresponding bar.

Anglers targeting barramundi used various methods including live and dead bait (fish, prawns and yabbies), artificial lures and flies, and a combination of real and artificial baits. In many cases, anglers used both live and dead baits, or did not specify whether the bait used was live or dead on a given logged trip. Therefore, all live and dead baits were grouped as 'bait'. Overall, bait was used on 45% of logged fishing trips, while artificial baits (mostly lures) were used on 36% of trips. A mixture of bait and artificial baits ('mix') were used on 19% of trips (Figure 3.6).

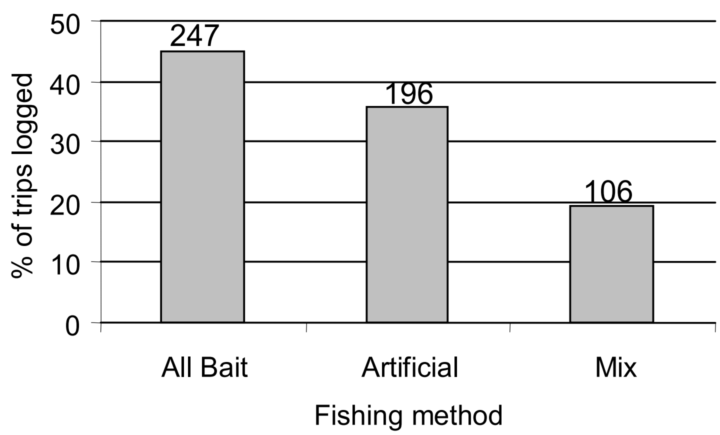


Figure 3.6 Percentage of logged fishing trips using each fishing method (i.e. bait type) to target barramundi**.**
n (number of trips) is indicated above each corresponding bar.

b) <u>Effect of fishing trip factors</u>

i) Effect on success rate

Before the general open vs. ROFA analysis, the effect of all fishing trip factors (time spent fishing, avidity, number of anglers, number of lines per angler, bay and management status) on success rate (% of trips where at least one fish in the particular fish group was caught) of any given trip was examined via CARTs to determine if management status (i.e. open or ROFA) had the highest effect on success.

For all of the fish groups, fishing trip factors other than management status has a greater effect on success rate than management status. For 'all fish', time spent fishing has the greatest influence on success rate (Figure 3.7 a), while fishing method followed by time spent fishing has the greatest influence on whether or not fishers caught an undersize barramundi (Figure 3.7 c) (which drives the result for 'all barramundi', Figure 3.7 b). For legal barramundi, bay fished has the greatest influence, however management status within each bay does not influence success rate (Figure 3.7 d). The models resulting from the min-CV error rule reveal further influences (such as avidity of logbook holders for all fish and undersize barramundi, and line number per angler for legal-sized barramundi), however the influence of ROFA vs. open estuaries is not evident (see Appendix A6.1for the min-CV error models).

The research question for this section is: *Does management status (i.e. open vs. ROFA) have a significant impact on success rate compared to other fishing factors?* Results show that fishing factors other than management status have a greater influence on success rate for all fish groups examined.

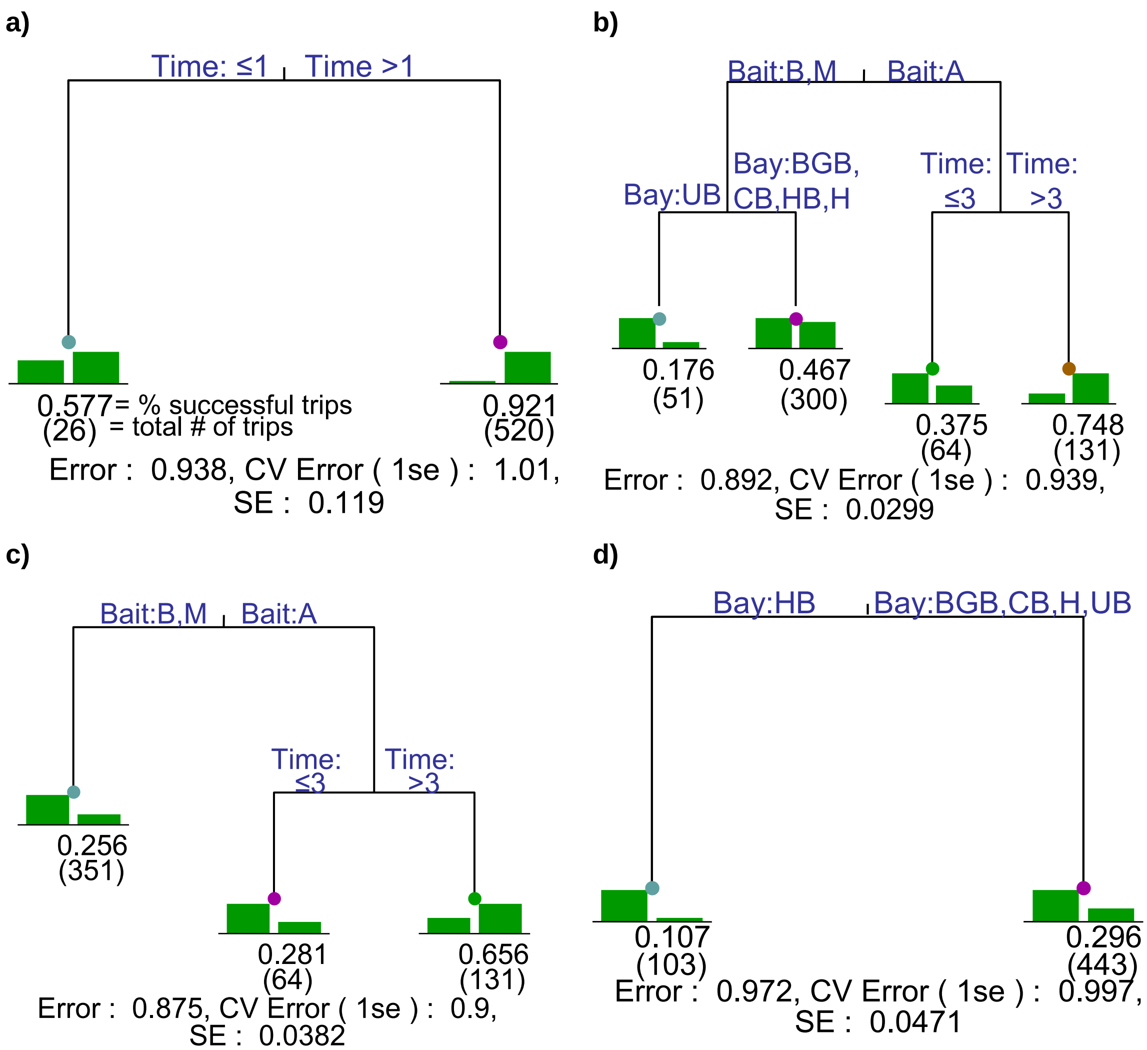


Figure 3.7 Classification and Regression Tree (CART) with the 1-SE rule for: a) all fish species; b) all barramundi; c) undersize barramundi; and d) legal-sized barramundi, examining the effect of various fishing factors on the percentage of successful (for catching at least one fish) trips.

"Error" refers to the amount of variability in the data unexplained by these models (87.5% - 97.2% in this case). Vertical length of each branch represents the relative amount of variation explained by each split. The graphs for each node show relative number of unsuccessful and successful trips, with % success (and number of trips) listed below. Percentage success increases from left to right on each tree.

Key: Time = time spent fishing (hrs) rounded up to nearest hour;

Bait – B = bait, A = artificial bait, M = mixed real and artificial bait;

Bay – BGB = Bowling Green Bay, CB = Cleveland Bay, HB = Halifax Bay, H = Hinchinbrook, UB = Upstart Bay.

ii) Effect on catch per unit effort

The effect of time spent fishing, avidity, number of anglers in each fishing party, and number of lines per angler, on CPUE of successful fishing trips was examined in order to reduce variation in CPUE outside of that provided by management status in each bay.

Time spent fishing per trip has a variable effect on CPUE for the barramundi fish groups. Parties fishing for 1 hour or less have a higher CPUE (partly due to the effect of multiplying catch to be equivalent to one hour of fishing); however, less than 3% of successful fishing trips are within this time category. The remaining time categories show no difference in CPUE when examined within a CART (see Appendix A6.2). As a consequence, the CPUE data are not standardised for duration of fishing trip.

CPUE does, however, differ between: 1) fishing parties with logbook holders of different avidity levels – fishers in the '52' (fish once a week/ 52 times per year) category provide trips with a higher CPUE for all fish groups; 2) fishing parties with various angler numbers – 1-angler parties provide a higher CPUE for all fish groups, decreasing with each additional angler in the fishing party; and 3) fishing parties employing different numbers of lines per angler – this effect varies depending on the fish group examined, however those fishing parties with 1- and 2-lines per angler show higher CPUEs for undersized and grouped barramundi when examined via CARTs. (See Appendix A6.2 for CARTs examining the effect of each fishing factor).

These three significant factors are assumed to interact with each other, and investigations via CARTs show some configurations (coded) of these fishing factors provide higher CPUEs than others (Figure 3.8 a-d). Where more than one code shows a higher CPUE (on the right-hand branch of the CART), line graphs reveal which code provides the highest CPUE (Figure 3.9 a-d). For example the highest CPUE for 'all fish' is provided by fishing parties with an avidity code of '52', with 1 angler and 2 lines per angler (i.e. code 414, see Figure 3.9 a); whereas the highest CPUE for 'all barramundi' and undersized barramundi is provided by fishing parties within the '52' avidity code, with 1 angler and 1 line per angler (code 412, see Figure 3.9 b & c). The distribution of trips provided by fishing parties within different categories of each of these factors varies across bays in the study area. As such, all CPUE data are standardised to the fishing factor code that provides the optimum (highest) average CPUE for the particular fish group.

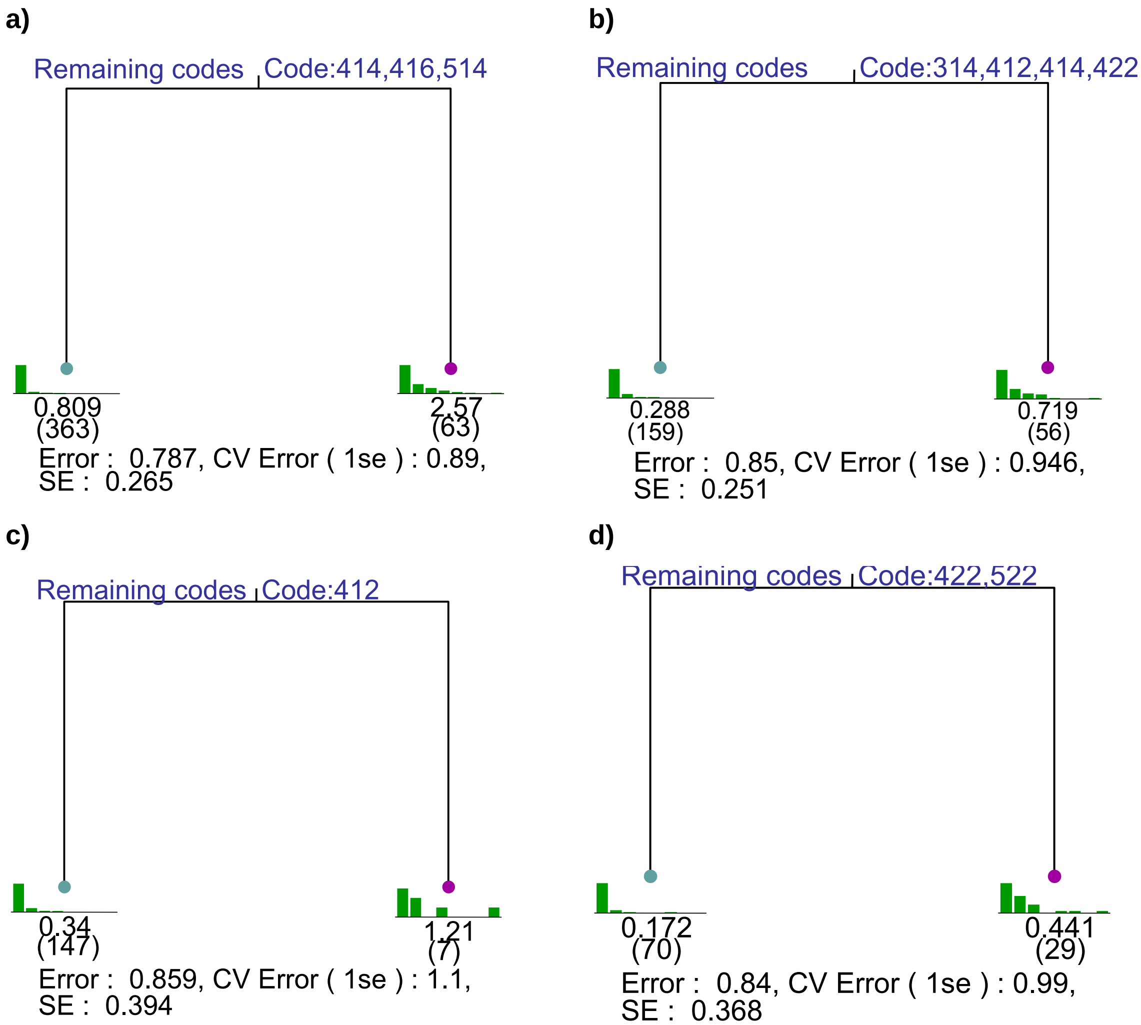


Figure 3.8 CART with the 1-SE rule for: a) all fish species; b) all barramundi; c) undersize barramundi; and d) legal-sized barramundi, examining the effect of combined fishing factors (avidity, number of anglers, and number of lines per angler) on catch per unit effort (CPUE, number of fish per angler per hour).

The graphs for each node show catch per unit effort with number of trips listed below in parentheses. CPUE increases from left to right on each tree. See earlier CARTs for further explanation of the models (Figure 3.7).

Fishing factors are coded ### as: #1 = avidity, #2 = number of anglers, and #3 = line number per angler. See Table 3.1 for the list of codes for each factor.

Codes of significance here are: 314 = avidity of 24 times per year, 1 angler boat, 2 lines per angler; 412 = avidity of 52 times per year, 1 angler, 1 line; 414 = avidity 52, 1 angler, 2 lines; 416 = avidity 52, 1 angler, 3 or more lines; 422 = avidity 52, 2 anglers, 1 line per angler; 514 = avidity >52, 1 angler, 2 lines; 522 = avidity >52, 2 anglers, 1 line per angler.

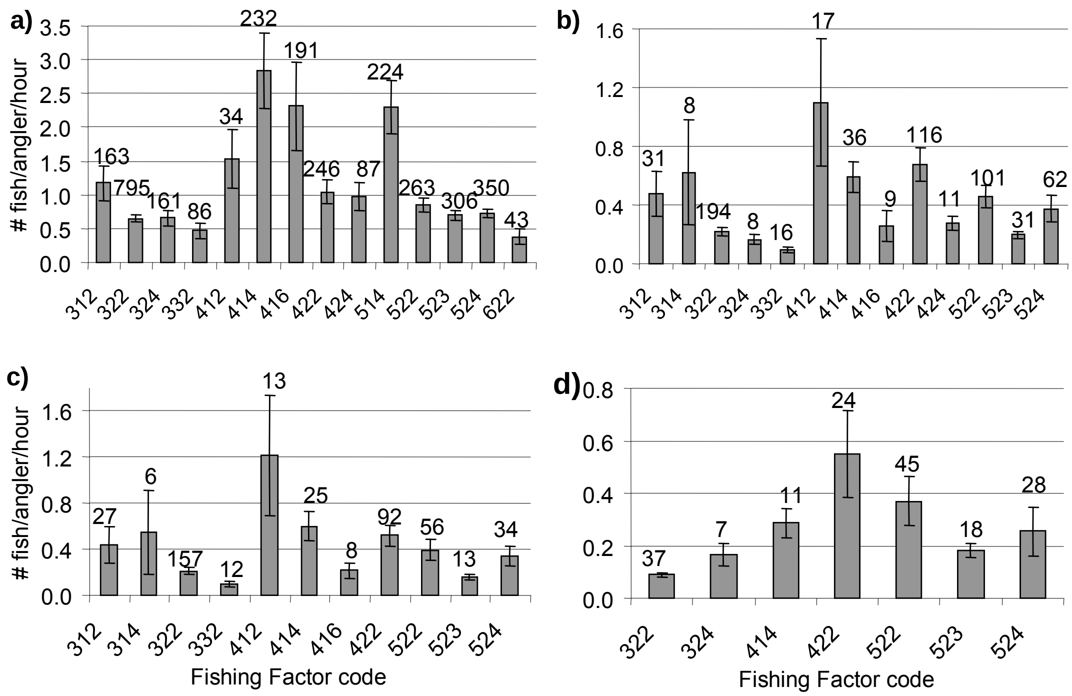


Figure 3.9 Interaction effect of avidity, number of anglers per fishing party and line number per angler on CPUE (number of fish per angler per hour) for successful trips for a) fish of any species; b) barramundi; c) undersize barramundi; and d) legal-sized barramundi**.**

Data provided are from those categories where 10 trips or more are available for 'all fish', and 5 trips or more for the barramundi fish groups. n (number of fish/barramundi) is indicated above each corresponding bar. Error bars are 95% CIs.

See Figure 3.8 for a description of the fishing factor codes

The effect of fishing method on CPUE was tested via CARTs (Figure 3.10). Trips using bait provide a higher CPUE for 'all fish', and undersize barramundi. However, there is no difference between CPUE for trips using real or artificial baits for 'all barramundi' (those trips using a mixture of these methods have lower CPUE for 'all barramundi'). Trips where artificial baits were used provide higher CPUEs for legal-sized barramundi. Given these differences in CPUE, and the finding that the proportion of trips provided by each method varies between bays, each fishing method was analysed separately following a grouped analysis to determine if CPUE differs between ROFA and open estuaries for each fishing method.

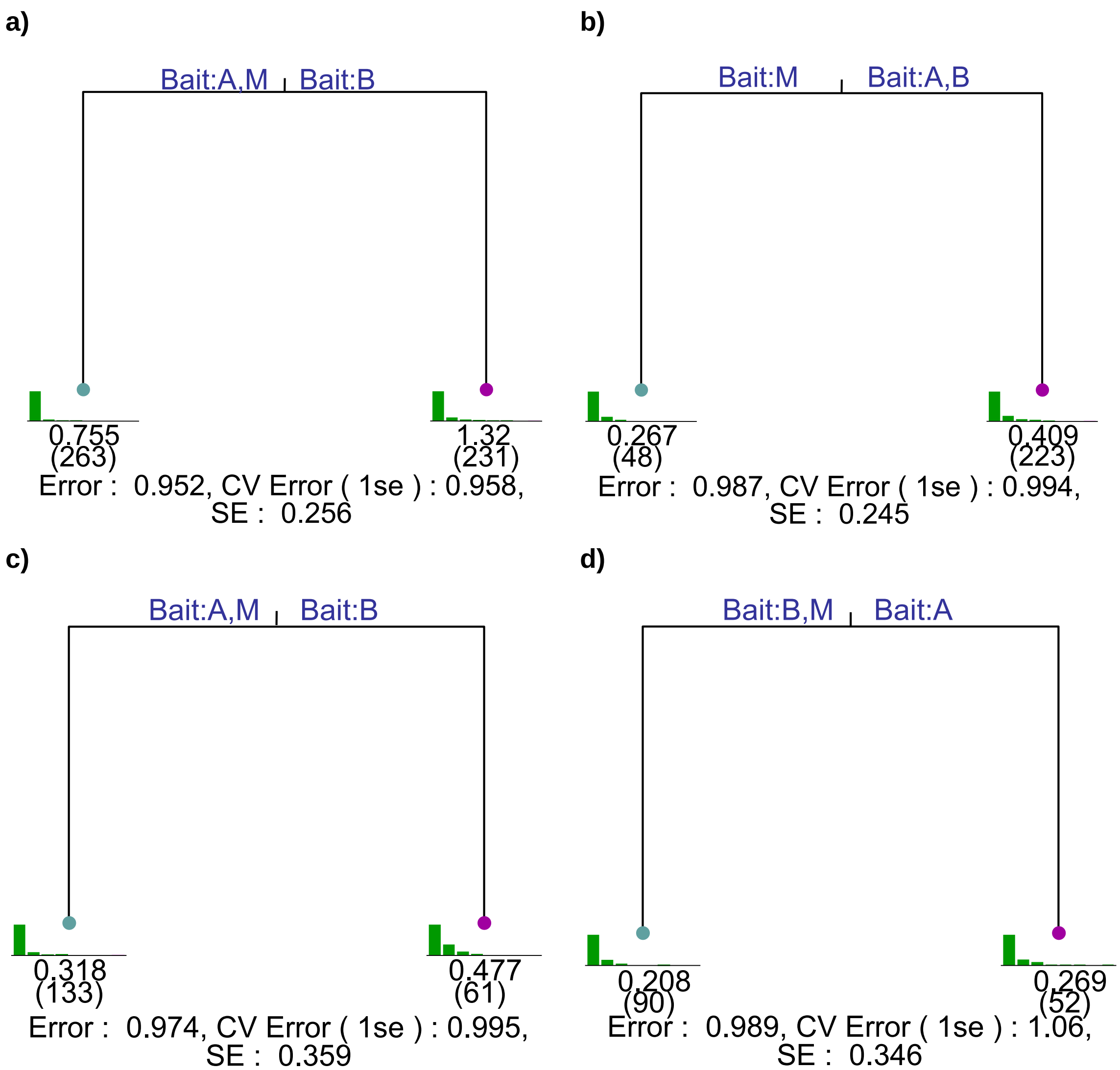


Figure 3.10 CART with the 1-SE rule for: a) all fish species; b) all barramundi; c) undersize barramundi; and d) legal-sized barramundi, examining the effect of fishing method on CPUE (number of fish per angler per hour).

See earlier CARTs for further explanation of the models (Figure 3.7 & Figure 3.8).

Key: Bait – B = bait, A = artificial bait, M = mixed real and artificial bait.

c) <u>Differences between open and ROFA estuaries</u>

i) Success rate

Unfortunately (given the findings above outlining the effect of fishing factors on success rate), the success rate data could not be standardised according to the influence of fishing factors because they are binary data (i.e. "1" = successful for catching at least one fish; "0" = unsuccessful). The influence of management status (potentially within each bay) was of most interest in the present study.

CARTs examining the difference in success rate for catching at least one fish of any species (i.e. 'all fish') reveal success rate for 'all fish' is lowest in Halifax Bay, but there is no difference between the other bays (Figure 3.11 a). In Halifax Bay open estuaries provided a higher success rate than ROFA estuaries. Further exploration with the min-CV error rule shows further splits between the remaining bays, but no instances where ROFAs produce a higher success rate than open estuaries (Appendix A6.3).

For all barramundi, success rate is highest in Bowling Green Bay and the Hinchinbrook Region (Figure 3.11 b). Open estuaries in the remaining bays have a higher success rate for barramundi than ROFA or part-ROFA estuaries. Further exploration via application of the min-CV error rule shows open estuaries in Bowling Green Bay (as there are no open estuaries in the Hinchinbrook region) produce higher success rates for all barramundi than ROFA or part-ROFA estuaries in either region (Appendix A6.3).

For undersize barramundi, success rate is highest in Bowling Green Bay, particularly in open estuaries. Likewise, open estuaries in the remaining bays produce higher success rates than ROFA or part-ROFA estuaries (Figure 3.11 c). Application of the min-CV error rule does not reveal any further splits of interest to the research question.

Halifax Bay produces the lowest success rates for legal-sized barramundi (Figure 3.11 d). The model resulting from application of the min-CV error rule reveals Bowling Green Bay and Hinchinbrook have the highest success rates for open and ROFA estuaries (Appendix A6.3).

Summary:

The research question for this section is: *Is recreational fisher success rate for catching fish in any of the fish groups higher in ROFA estuaries than open estuaries within the study area?* There is no evidence that ROFAs provide a higher chance of success for catching 'all fish' or undersized barramundi (which also affects 'all barramundi'). However, the Hinchinbrook region (which contains no open estuaries) provides relatively high success rates for all barramundi, which is driven by success rates for legal-sized barramundi. It is unclear whether the higher success rate for the Hinchinbrook region is due to regional differences or management status.

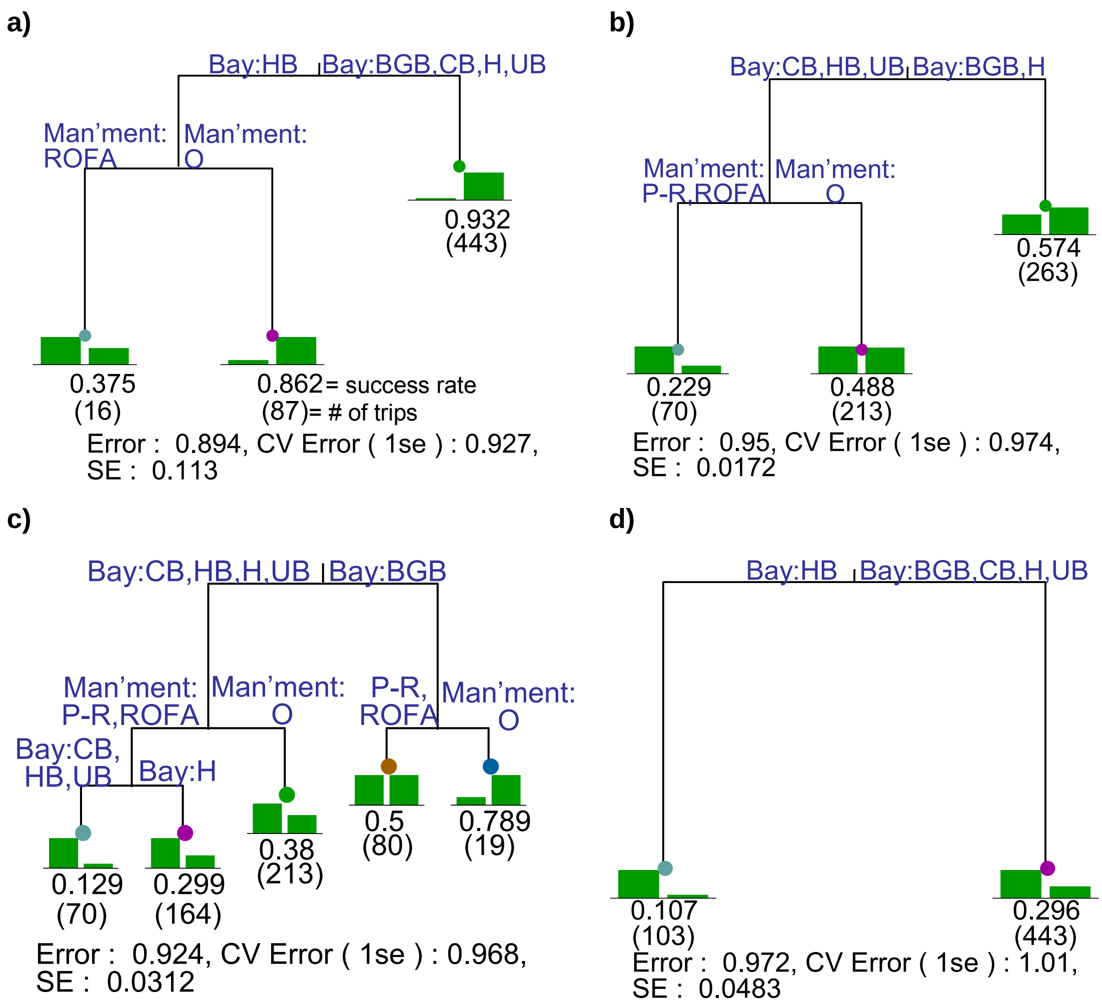


Figure 3.11 CART with the 1-SE rule for the success rate for catching at least one: a) fish of any species; b) barramundi; c) undersize barramundi; and d) legal-sized barramundi.

See earlier CARTs for further explanation of the models (Figure 3.7).

Key: Management: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

ii) CPUE for successful trips

Initial exploration reveals open estuaries yield a higher CPUE for all fish, and undersize barramundi (which drove the same result for all barramundi) than ROFA or part-ROFA estuaries within the study area (Figure 3.12 a-c). In contrast, initial exploration of average CPUE for legal-sized barramundi for successful trips reveals slightly higher CPUEs in ROFA rather than open estuaries (Figure 3.12 d). CPUE for legal-sized barramundi for part-ROFA estuaries overlap open and ROFA estuaries with large error bars due to low successful trip numbers within part-ROFAs.

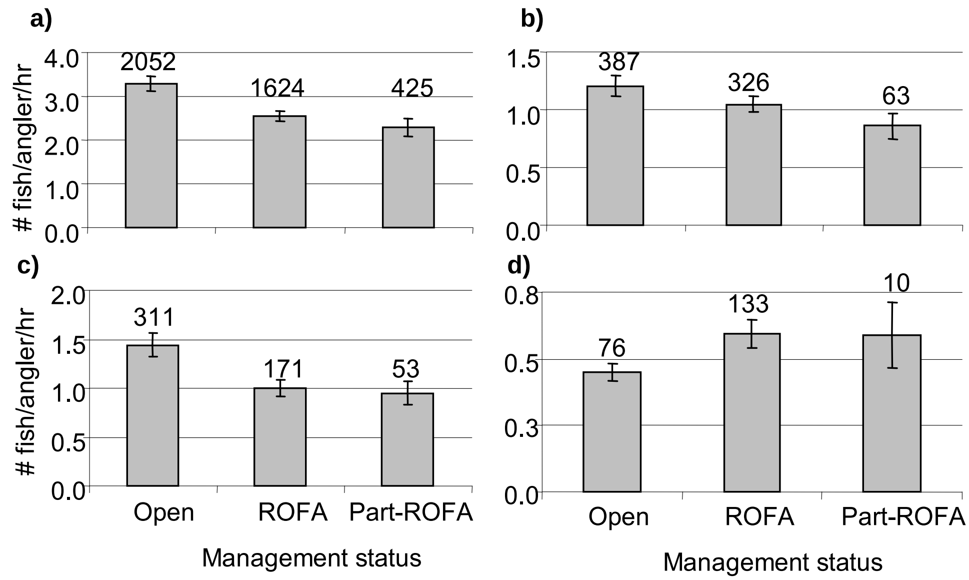


Figure 3.12 Average CPUE with 95% CI for successful fishing trips for: a) all fish; b) all barramundi; c) undersize barramundi; and d) legal-sized barramundi for open, ROFA and part-ROFA estuaries in the study area**.**

n (number of fish/barramundi) is indicated above each corresponding bar.

When the successful trip data are investigated by bay, the CART model resulting from the 1-SE rule shows open estuaries in all bays provided a higher CPUE for ‘all fish’ (Figure 3.13 a). For the barramundi groups, however, there is no split between open and ROFA estuaries in any of the bays (Figure 3.13 b-d). For legal-sized barramundi, as with the success rate data, the Hinchinbrook region produces a higher CPUE than the other bays (Figure 3.13 d) – there are no open estuaries in this region.

Application of the min-CV error rule reveals the initial finding of open estuaries having a higher CPUE for undersize barramundi than ROFA or part-ROFAs estuaries is due to a high CPUE in open estuaries in Bowling Green Bay. This result is the same for overall barramundi CPUE. For all fish, application of the min-CV error rule also shows open estuaries in Bowling Green Bay and Upstart Bay as having higher CPUE than any other configurations. These models can be found in Appendix A6.4. The model resulting from the min-CV error rule for legal-sized barramundi reveals no further splits.

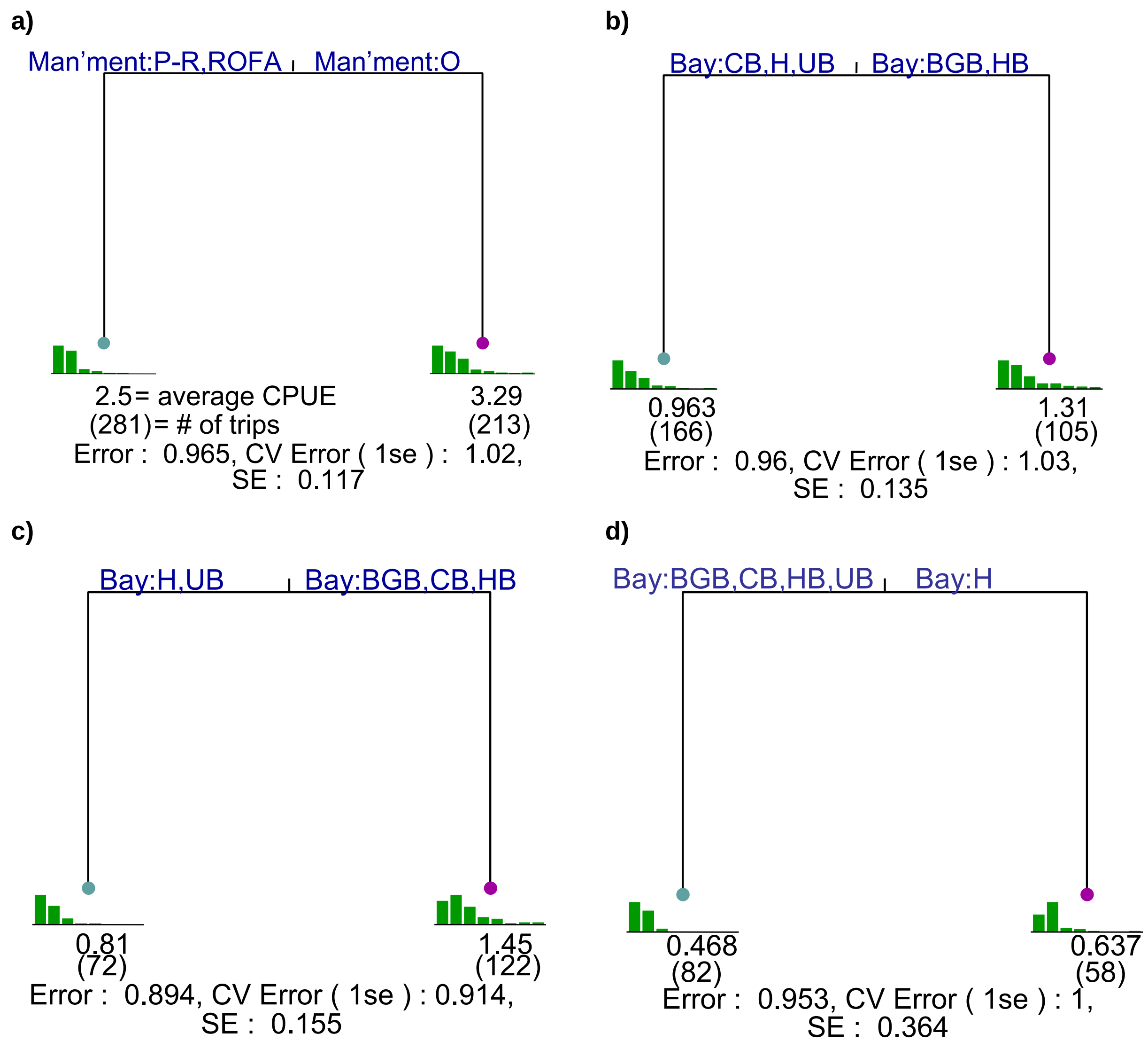


Figure 3.13 CART with the 1-SE rule for a) all fish, b) all barramundi, c) undersize barramundi; and d) legal-sized barramundi for CPUE for successful trips in each bay**.**

See earlier CARTs for further explanation of the models (Figure 3.7 & Figure 3.8).

Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

When data are divided into each fishing method (i.e. bait, artificial bait and a mixture of these two), results differ slightly from the grouped result for each fish group. However, these differences are only in terms of which bays showed higher CPUE and where the split between open and ROFAs is positioned within the model for each fish group – this is partially an artefact of reduced sample size for each method, particularly for the mixed fishing methods. The result of most interest to the research question was the same for all methods: i.e. there is no evidence that ROFAs provide a higher CPUE for all fish or undersize barramundi. Models for each fishing method can be found in Appendix A6.4.

For legal-sized barramundi, the overall finding that the Hinchinbrook region has a higher CPUE than all other bays is consistent for those trips using real bait. Cleveland Bay provides a similar CPUE to Hinchinbrook for those trips using artificial bait (Figure 3.14 a). For those trips using a mixture of real and artificial baits, Bowling Green Bay produces a lower CPUE than all other bays (Figure 3.14 b); however there are likely not enough successful trips using these methods to allow a meaningful comparison. Application of the min-CV error rule does not reveal any further splits for these models.

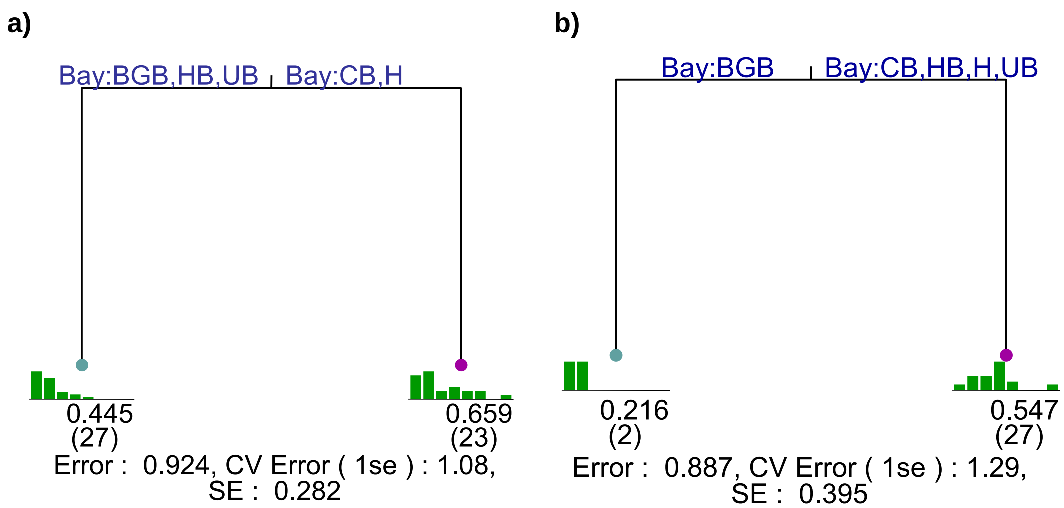


Figure 3.14 CART with the 1-SE rule for the legal-sized barramundi CPUE for successful trips in each bay using: a) only artificial bait; and b) a mixture of real and artificial bait**.**

See earlier CARTs for further explanation of the models (Figure 3.7 & Figure 3.8).

Key: Bay – BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

Summary:

The research question for this section is: *Is CPUE (number of fish per angler per hour) for successful fishing trips for any fish group higher in ROFA estuaries than open estuaries within the study area?* The results are mixed, but similar to that for the success rate data: i.e. there is no evidence that ROFAs provide a higher CPUE for all grouped fish species (i.e. 'all fish') or undersize barramundi (which drives the result for 'all barramundi').

Again like the success-rate data, the result for legal-sized barramundi contrasts to the other fish groups: while ROFAs do not show a significantly higher CPUE than open estuaries in any of the bays, the Hinchinbrook region (which contains no open estuaries) produces a higher CPUE for legal-sized barramundi for the combined fishing methods and those trips using real bait. Again, however, it is unclear whether the higher success rate for the Hinchinbrook region is due to regional differences or management status.

iii) Size frequency of barramundi

Initial exploration of size frequency data for barramundi caught within the recreational logbook program reveals a slightly higher relative occurrence of barramundi over the minimum legal size (MLS) in ROFA rather than open estuaries (Figure 3.15). However, a Kolmogorov-Smirnov test reveals this difference in shape is not significant ($p > 0.05$).

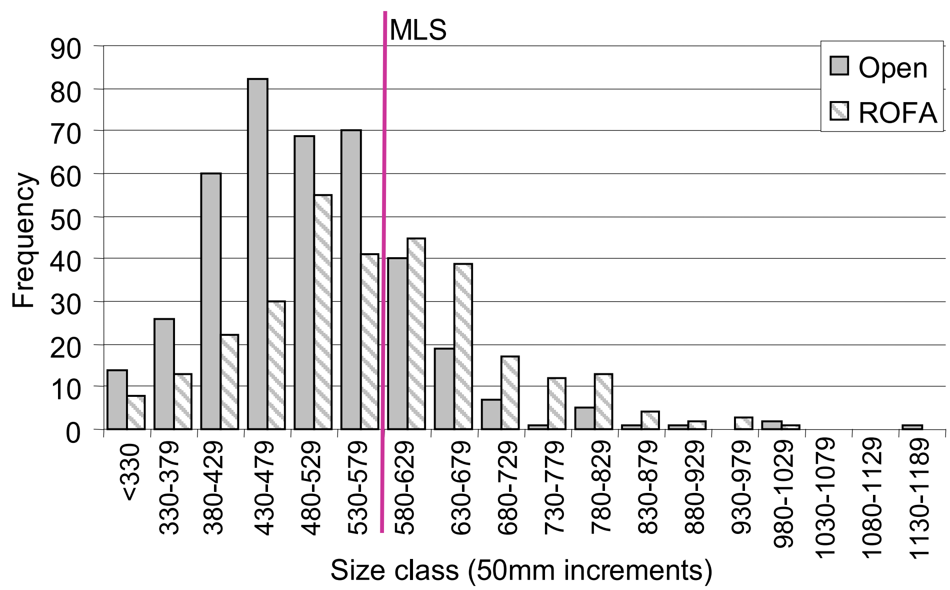


Figure 3.15 Frequency histogram of each size class of barramundi caught in open and ROFA estuaries throughout the study area.
Size classes are in 50mm increments centred around 580mm (minimum legal size, MLS – indicated on the figure).

When each bay and management status are investigated, correspondence analysis (Figure 3.16) shows a clear gradient in size classes from small size classes at the top left of the ordination space, through middle size classes at the bottom of the ordination, to large size classes at the top right. Size structures in Hinchinbrook and Upstart Bay ROFAs are biased towards large size classes, while Halifax Bay and Bowling Green Bay open estuaries are dominated by small individuals, with the remaining estuaries showing intermediate size distributions (see size frequency histograms, Figure 3.17).

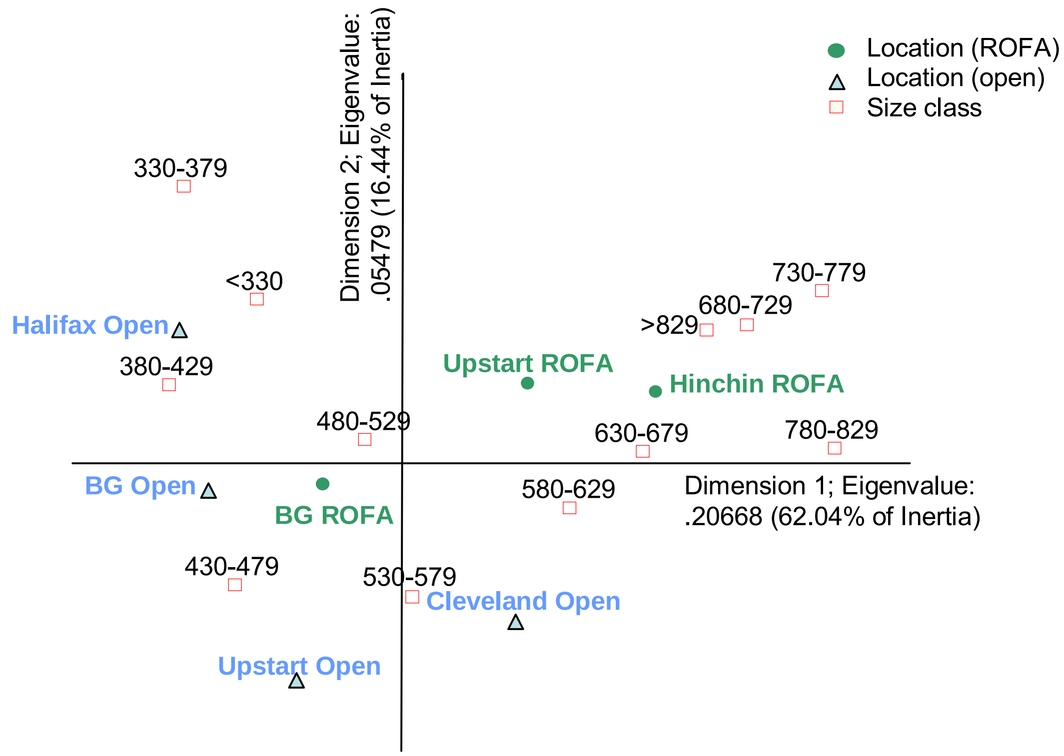


Figure 3.16 Correspondence analysis of size classes of barramundi caught in open and ROFA estuaries in each bay in the study area.

Key: BG = Bowling Green Bay; Cleveland = Cleveland Bay; Halifax = Halifax Bay; Hinchin = Hinchinbrook region; Upstart = Upstart Bay.

Summary:

The research question for this section is: *Is the size structure of barramundi caught in ROFAs different to that in open estuaries within the study area?* Results show that the size structure of barramundi caught by logbook holders is skewed towards larger fish in ROFAs compared to open estuaries when data are examined by each bay, particularly in the Hinchinbrook region. There are no open estuaries in the Hinchinbrook region to compare to ROFAs in that area, however, so it is unknown whether this is a regional or management effect.

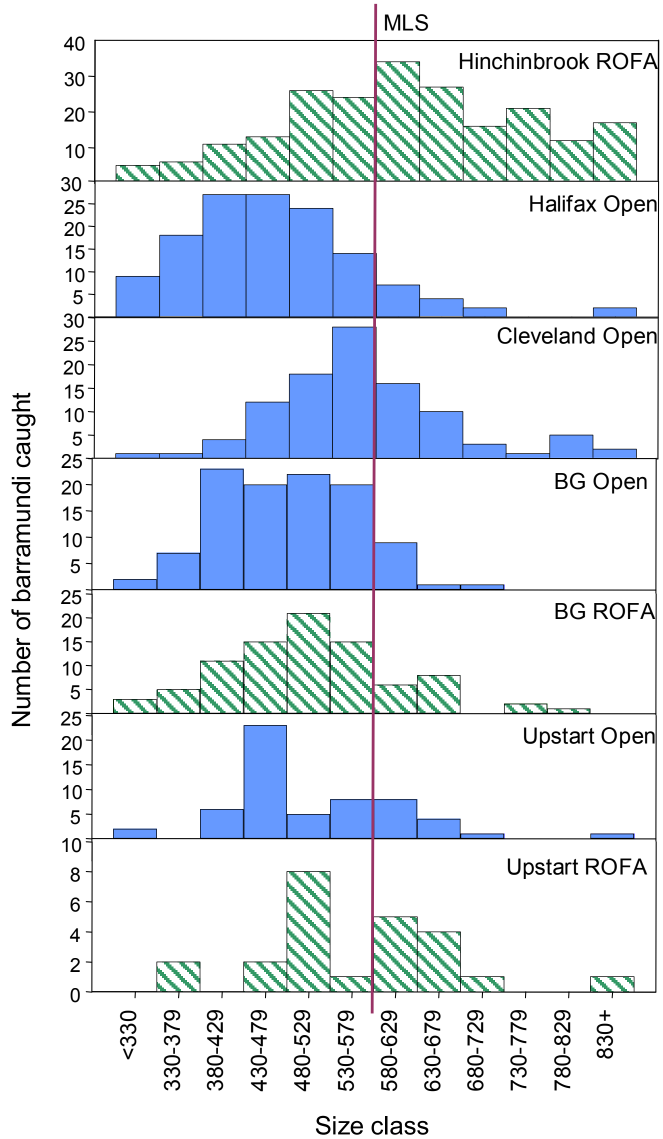


Figure 3.17 Size frequency histograms for barramundi caught in open and ROFA estuaries in each bay in the study area.

Size classes are in 50 mm increments centred on the 580 mm minimum legal size (MLS). All barramundi >829 mm are grouped together.

Key: BG = Bowling Green Bay; Cleveland = Cleveland Bay; Halifax = Halifax Bay; Hinchinbrook = Hinchinbrook region; Upstart = Upstart Bay.

3.3.3 ANSA time-series data for the Hinchinbrook region

Methods

Detailed catch and effort data for the Hinchinbrook region from October to December for 1987 to 2001 was provided by a small group of anglers (up to 8 anglers) within the Australian National Sportsfishing Association (ANSA). These fishers recorded fishing location, all catch information (species and length), time spent fishing each day, and number of anglers in each fishing party for each trip. The group provided a total of 281 trips (3-32 trips each year), totalling 1670 hours (22-192 hours each year). These detailed and consistently recorded data allowed the examination of catch per unit effort data (number of barramundi caught per angler per hour) and success rate (percentage of trips where at least one fish (barramundi and legal-sized barramundi) was caught) within the Hinchinbrook region from before and after-DPA implementation in January 1998. Some open estuaries adjacent to but just outside of the DPA (i.e. Victoria Creek, Gentle Annie Creek, Dallachy Creek and Wreck Creek) were included in the catch data, allowing a comparison of CPUE and success rate trends between the DPA area and adjacent open estuaries.

a) <u>CPUE for barramundi over time</u>

CPUE (number of fish per angler per hour) for barramundi (of any size) and legal-sized barramundi was compared between estuaries within the Hinchinbrook DPA and adjacent open estuaries over time (1987-2001). Following initial exploration the CPUE data were grouped into 3-year blocks, and the trend in the 3-year average over time was examined via CARTs. Note, however, data from 2001 were omitted given the lack of data for open estuaries. The CPUE trend over time (within 3-year blocks) was compared between open and DPA estuaries with cross-correlation analysis within Statistica.

b) <u>Success rate for barramundi over time</u>

Success rate (i.e. percentage of trips where at least one barramundi was caught) trends over time for barramundi and legal-sized barramundi were examined for estuaries within the Hinchinbrook DPA and adjacent open estuaries. Like the CPUE data, following initial exploration the success rate data were grouped into 3-year blocks. CARTs were used to confirm trends in the 3-year averages over time outlined in line graphs. Where an increase in success-rate was found post-DPA implementation, cross-correlation analysis examined whether the increase was consistent between estuaries within the DPA area and adjacent open estuaries.

c) Size frequency for barramundi pre- and post-DPA implementation

Size frequency histograms for barramundi were compared between pre- and post-DPA implementation years for the estuaries within the Hinchinbrook DPA area. Descriptive statistics (mean, skewness and kurtosis) of each time period were compared. Size distributions were compared via Kolmogorov-Smirnov tests.

The research questions for these data are:

1. Has CPUE for barramundi and legal-sized barramundi improved in the Hinchinbrook DPA area post-DPA implementation, and is the trend in CPUE over time different to that found for adjacent open estuaries?
2. Has success rate for barramundi and legal-sized barramundi improved post-DPA implementation, and is the trend different to that found for adjacent open estuaries?
3. Has average size and frequency of larger barramundi caught within the Hinchinbrook DPA area increased post-DPA implementation?

Results

a) CPUE for barramundi over time

Trends in catch per unit effort (number of barramundi per angler per hour) over time were examined in estuaries within the DPA area and adjacent open estuaries. Initial exploration reveals an increasing but variable trend in CPUE for both open and DPA estuaries over time (Figure 3.18). When data are grouped into 3-year blocks, the data show an increased CPUE for both open and DPA estuaries for the 3 years post-DPA implementation (Figure 3.19). Further exploration via CARTs confirm the trends indicated in the line graphs – i.e. the 3-year block post-DPA implementation provides a higher CPUE for barramundi for both open and DPA estuaries (Figure 3.20).

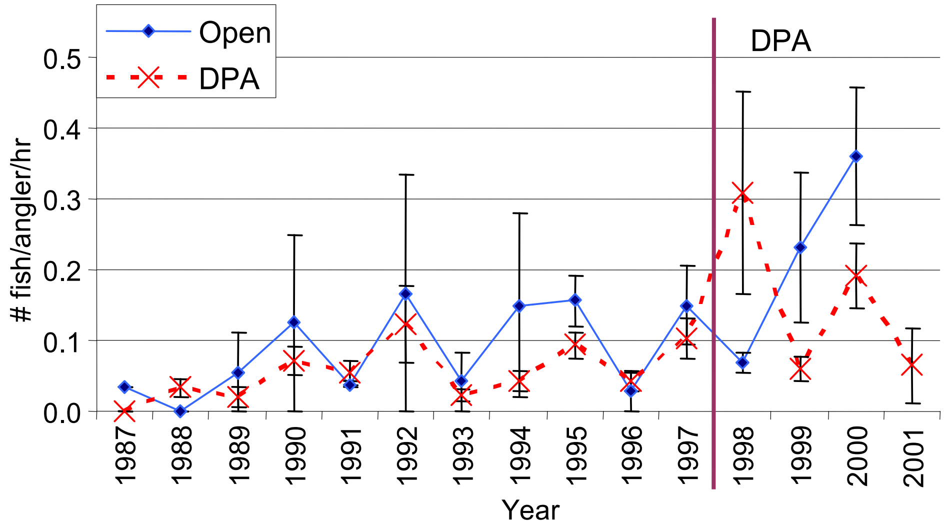


Figure 3.18 CPUE (number of fish per angler per hour) for all barramundi for estuaries within the Hinchinbrook DPA region and adjacent open estuaries over time**.** Error bars are 95% CIs. Date DPA was introduced is marked. n (number of barramundi) is omitted for presentation reasons.

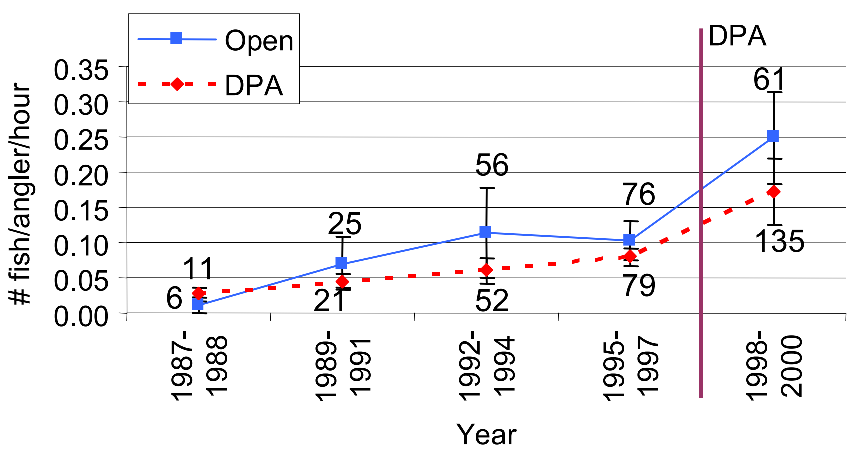


Figure 3.19 CPUE for all barramundi for estuaries within the Hinchinbrook DPA region and adjacent open estuaries over time (grouped within 3-year blocks)**.** n (number of barramundi) is indicated with each data point (open estuaries indicated above and DPA estuaries indicated below each data point). Error bars are 95% CIs. Date DPA was introduced is marked.

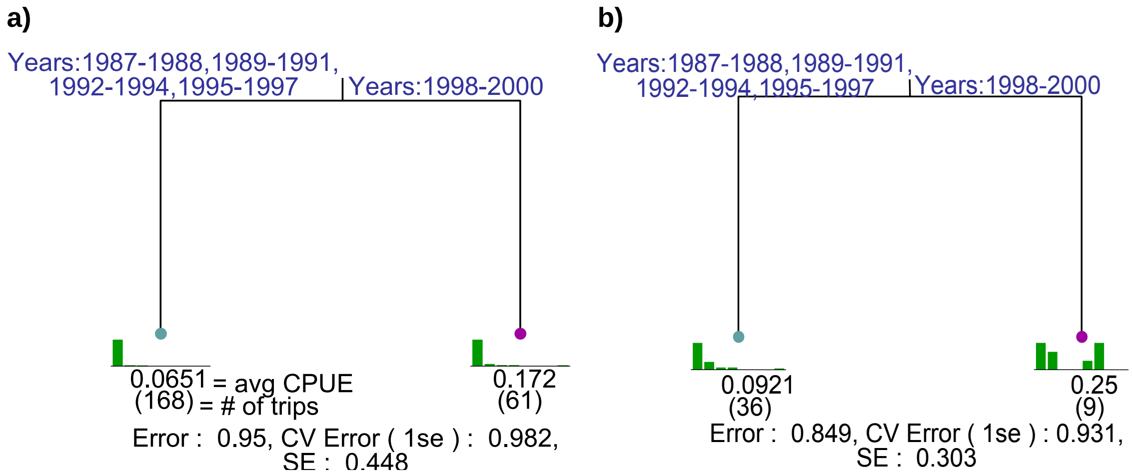


Figure 3.20 CART with the 1-SE rule for the number of barramundi caught per angler per hour in: a) estuaries within the Hinchinbrook DPA area; and b) adjacent open estuaries over time (within 3-year blocks)**.**
See earlier CARTs for further explanation of the models (Figure 3.7 & Figure 3.8).

Cross-correlation between CPUE trends over time (within 3-year blocks) for open and DPA estuaries reveal the trends for open and DPA estuaries are correlated (i.e. no significant difference between these two management areas – the only point where the bar reaches past the confidence limit is at zero lag (meaning zero-lag is significant), and there is no significant difference of any other time lag) (Figure 3.21).

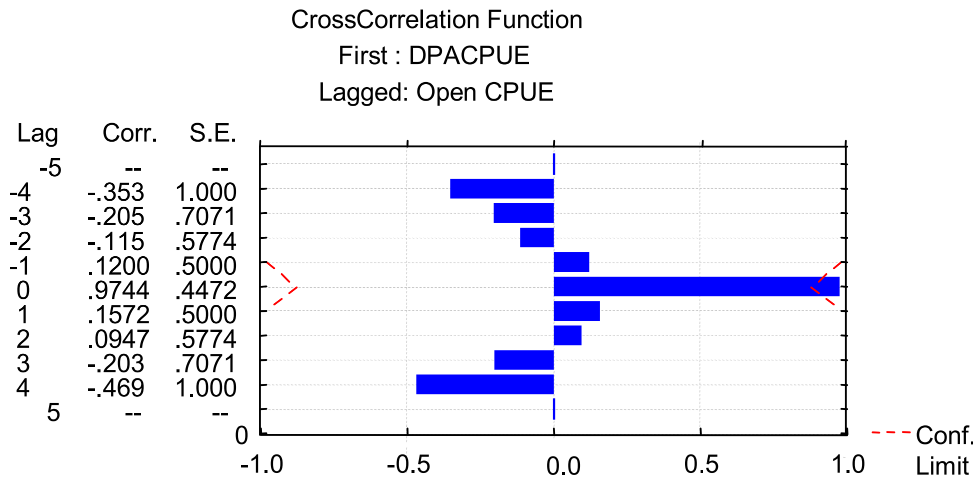


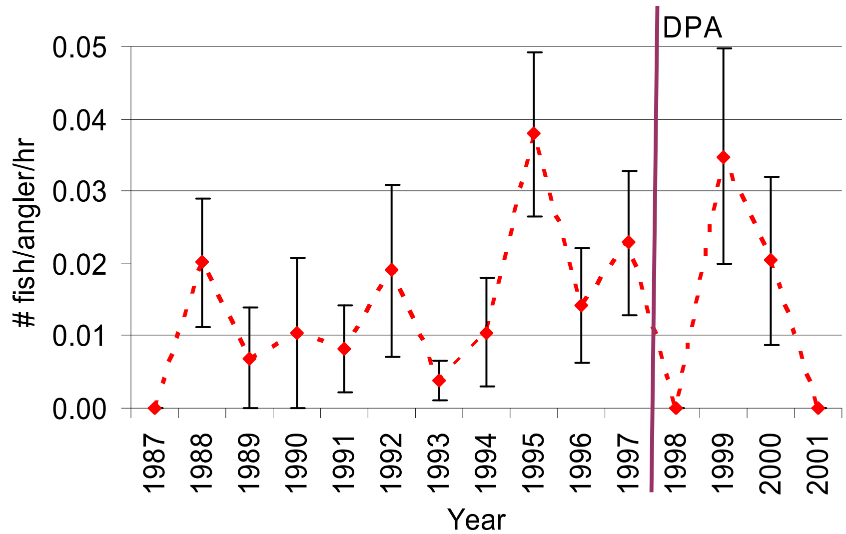
Figure 3.21 Cross-correlation of open versus DPA estuaries of average barramundi CPUE over time (within 3-year blocks)**.**

Confidence limit is marked by the hatched line. Overlap of zero lag with the confidence limit indicates significant correlation between the CPUE trend over time between open and DPA estuaries with zero lag.

CPUE for legal-sized barramundi over time does not show an increasing trend post-DPA implementation for either the DPA or open areas (Figure 3.22). Note the low CPUE for legal barramundi in the year 1998 (Figure 3.22 a) as compared to CPUE for all barramundi (Figure 3.18) for the same year.

Further investigation via CARTs for both open estuaries and estuaries within the DPA does not reveal higher CPUE for the 3 years post-DPA implementation compared to previous years (Figure 3.23). Application of the min-CV error rule does not result in further splits.

a)



b)

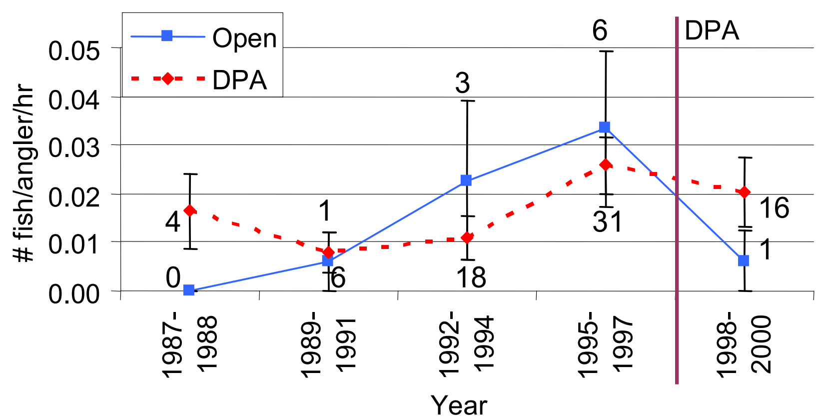


Figure 3.22 CPUE for legal-sized barramundi for: a) estuaries within the Hinchinbrook DPA region over time (open estuaries not included due to large error bars); and b) DPA and adjacent open estuaries within 3-year blocks.

n (number of barramundi) is indicated with each data point (open estuaries indicated above and DPA estuaries indicated below each data point). n is omitted from a) for presentation reasons. Error bars are 95% CIs. Date DPA was introduced is marked.

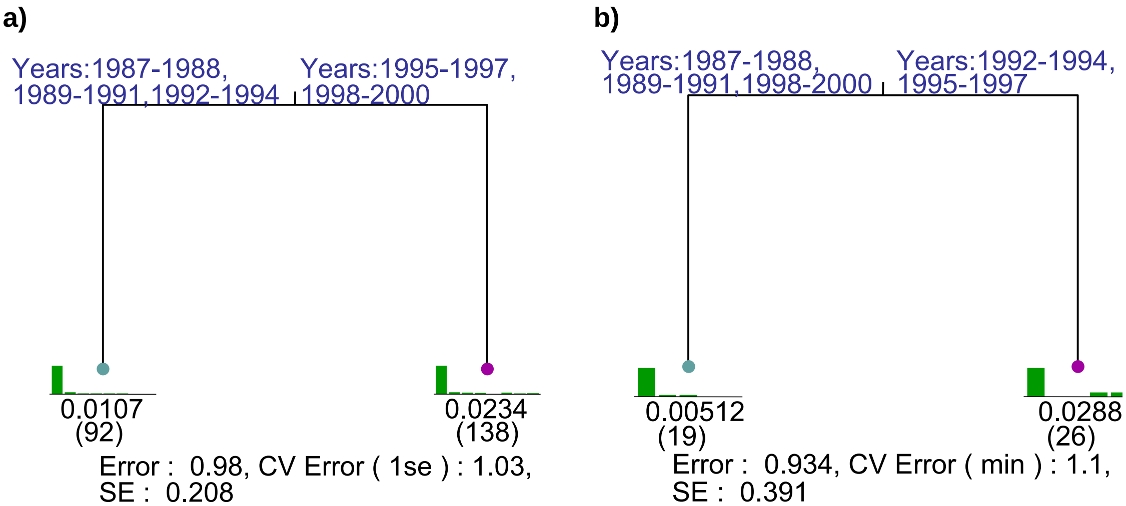


Figure 3.23 CART with the 1-SE rule for legal-sized barramundi CPUE in: a) estuaries within the Hinchinbrook DPA area; and b) adjacent open estuaries over time (within 3-year blocks).

See earlier CARTs for further explanation of the models (Figure 3.7 & Figure 3.8).

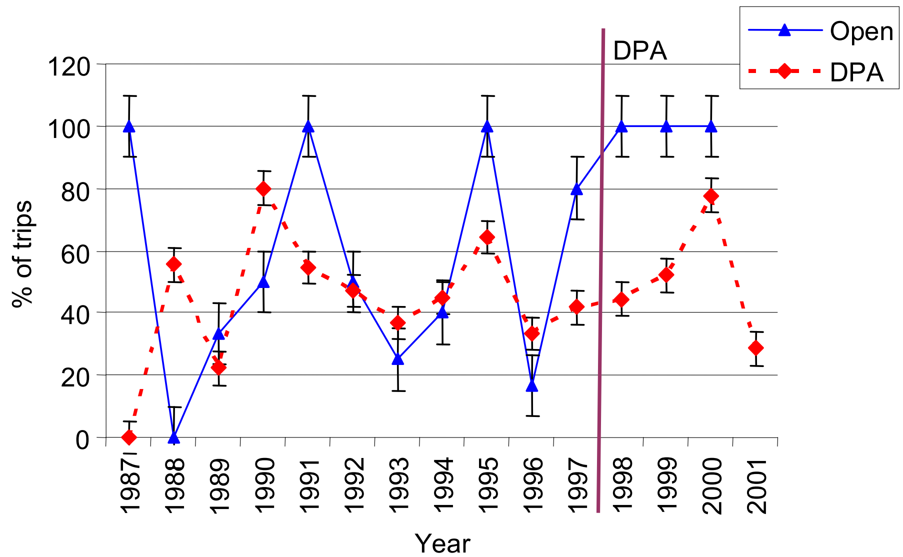
Summary:

The research question for this section is: *Has CPUE for barramundi and legal-sized barramundi improved in the Hinchinbrook DPA area post-DPA implementation, and is the trend in CPUE over time different to that found for adjacent open estuaries?* Results show that CPUE has improved in the Hinchinbrook DPA area post-DPA implementation, but for undersize barramundi only (not for legal-sized barramundi), and this increased CPUE is not different to that found in adjacent open estuaries.

b) Success rate for barramundi over time

Examination of success rate (% of successful trips) for catching at least one barramundi reveals no obvious improvement in success rate post-DPA implementation for estuaries within the DPA area when examined by individual years (Figure 3.24 a). Success rate does improve in estuaries within the DPA (slightly) and adjacent open estuaries post-DPA implementation when data are grouped into 3-year blocks (Figure 3.24 b).

a)



b)

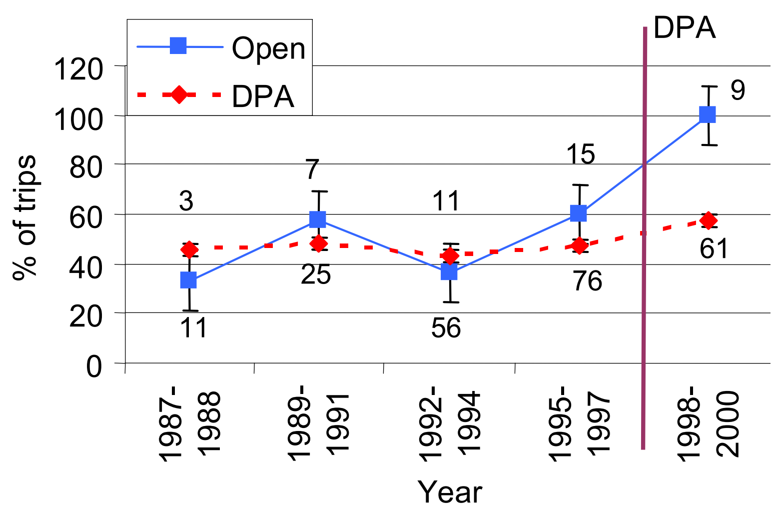


Figure 3.24 Success rate for all barramundi for estuaries within the Hinchinbrook DPA region and adjacent open estuaries for: a) individual years; and b) 3-year blocks**.**

n (number of trips) is given with each data point (open estuaries indicated above and DPA estuaries indicated below each data point) for grouped years (b). n (number of barramundi) is omitted from a) for presentation reasons. Error bars are 95% CIs based on pooled data (across years). Date DPA was introduced is marked.

CARTs confirm these results – i.e. no consistent improvement in success rate when data are analysed by individual years, but an improvement in success rate post-DPA implementation for both DPA and open estuaries when data are grouped into 3-year blocks (Figure 3.25 a & b). Application of the min-CV error rule reveals no further splits. However, cross-correlation analysis reveals that the trends for open and DPA estuaries are correlated (i.e. no significant difference between these two management areas), as shown by the significance of zero, which is overlapped by the confidence limit, while no other bars approach the confidence limit (Figure 3.26).

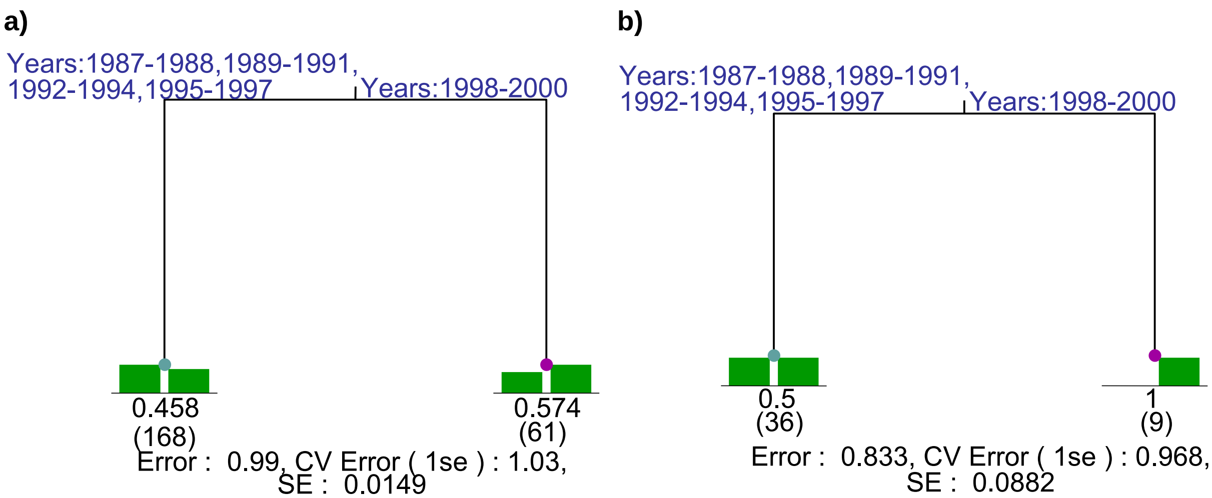


Figure 3.25 CART the 1-SE rule comparing average success rate for 3-year blocks for barramundi between: a) estuaries within the Hinchinbrook DPA area; and b) adjacent open estuaries**.**

See earlier CARTs for further explanation of the models (Figure 3.7).

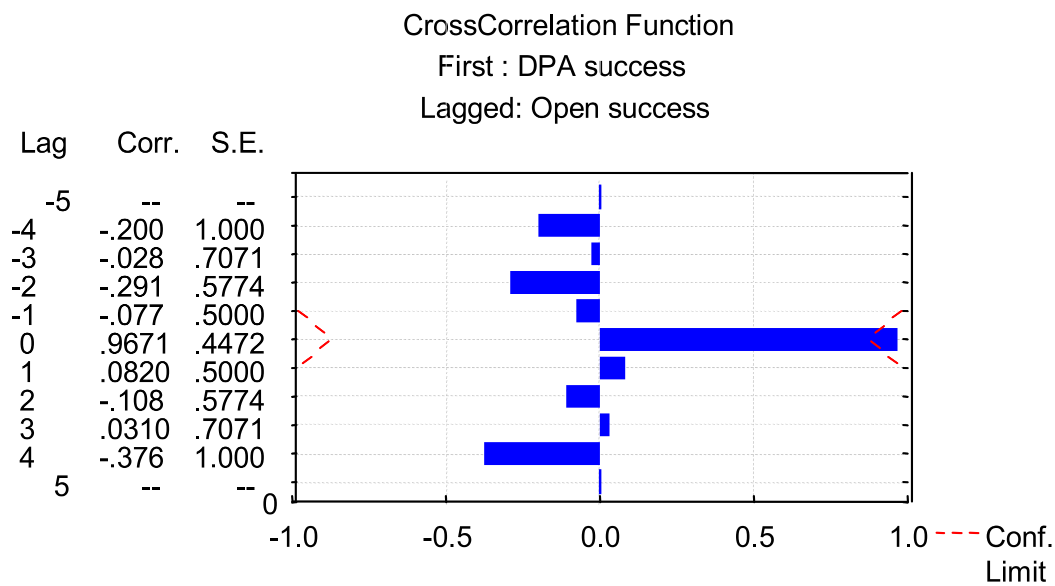
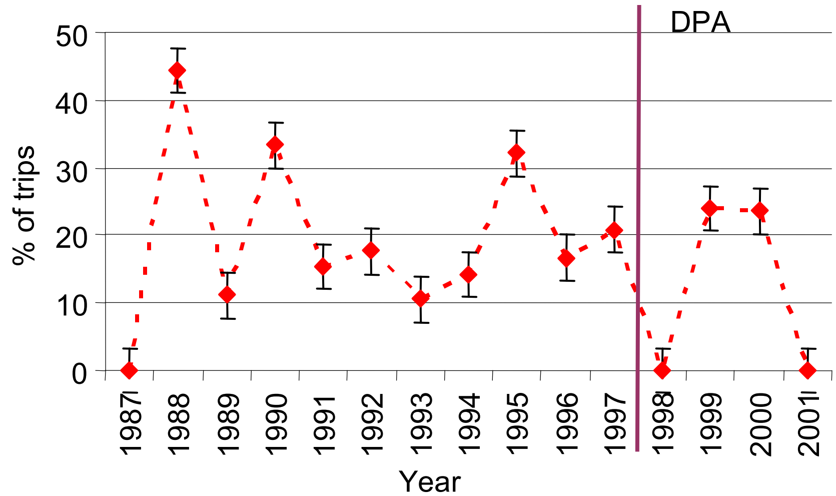


Figure 3.26 Cross-correlation of open versus DPA estuaries of success rate for catching barramundi (within 3-year blocks).

Confidence limit is marked by the hatched line. Overlap of zero lag with the confidence limit indicates significant correlation between the success rate trend over time between open and DPA estuaries with zero lag.

Success rate for legal-sized barramundi for DPA estuaries over time does not reveal an increasing trend post-DPA implementation, either for individual years or grouped years (in 3-year blocks) (Figure 3.27). CARTs confirm the years post-DPA implementation do not consistently provide a higher success rate for legal-sized barramundi catch in estuaries within the DPA and adjacent open estuaries, both for individual years and 3-year blocks (see Figure 3.28 for 3-year block success rate comparisons).

a)



b)

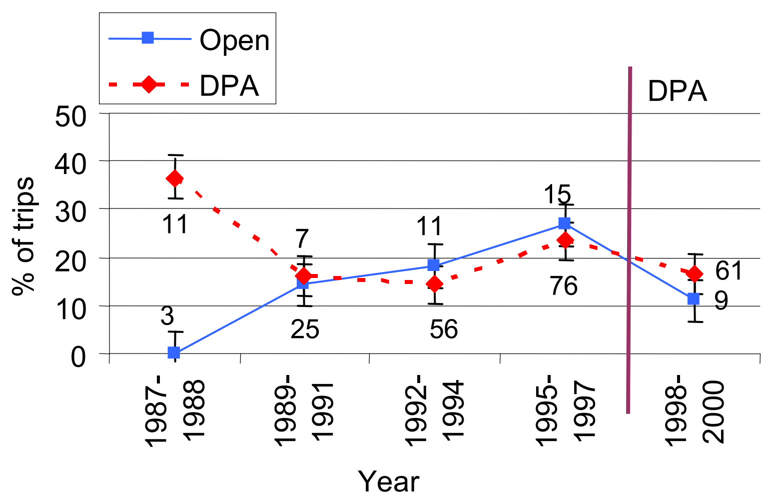


Figure 3.27 Success rate for legal-sized barramundi for: a) estuaries within the Hinchinbrook DPA region over time (open estuaries not included due to large error bars); and b) DPA and adjacent open estuaries within 3-year blocks**.** n (number of trips) is given with each data point (open estuaries indicated above and DPA estuaries indicated below each data point) for grouped years (b). n (number of barramundi) is omitted from a) for presentation reasons. Error bars are 95% CIs based on pooled data (across years). Date DPA was introduced is marked.

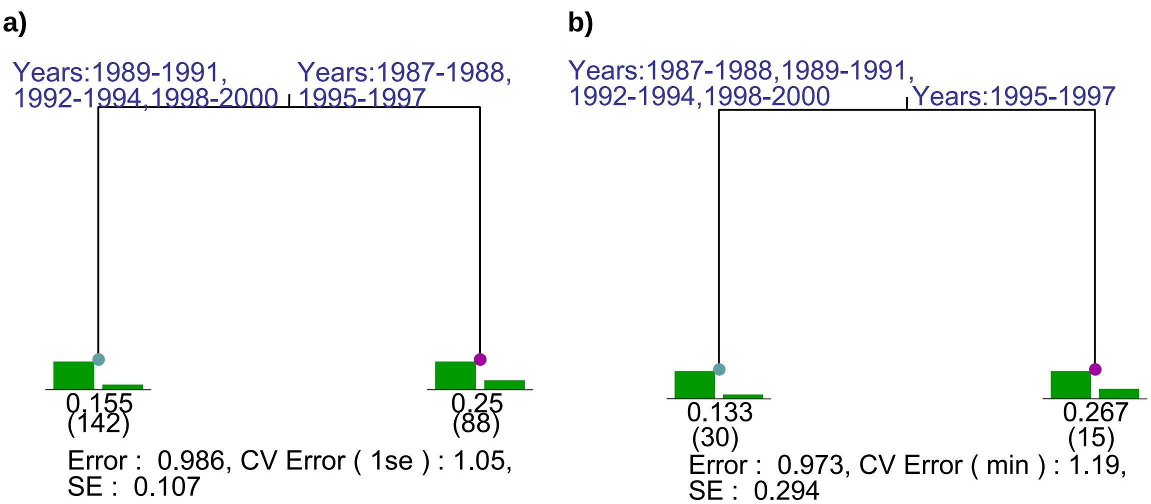


Figure 3.28 CART the 1-SE rule comparing success rate for legal-sized barramundi between 3-year blocks in: a) estuaries within the Hinchinbrook DPA area; and b) adjacent open estuaries**.**

See earlier CARTs for further explanation of the models (Figure 3.7).

Summary:

The research question for this section is: *Has success rate for barramundi and legal-sized barramundi improved post-DPA implementation, and is the trend different to that found for adjacent open estuaries?* Results show that as with the CPUE data, success rate improved for overall barramundi post-DPA implementation, but this trend is driven by undersize barramundi catch and is consistent between estuaries within the DPA area and adjacent open estuaries. Success rate for legal barramundi does not improve post-DPA implementation.

c) Size frequency of barramundi over time

Examination of the size frequency data for barramundi does not reveal an increase in mean/modal size post-DPA implementation (Figure 3.29). Investigation of basic descriptive statistics reveals the mean of barramundi size post-DPA implementation (447.9 mm ± 9.8) is lower than that found prior to DPA implementation (536.9 mm ± 7.2), although the mode is the same for each period (430 mm). The size frequency histogram for barramundi post-DPA implementation is more skewed and peaked (i.e. greater kurtosis) to the left of the minimum legal size than for the period prior to DPA implementation, showing a greater proportion of undersize barramundi for the post-DPA period. However, Kolmogorov-Smirnov test reveals no significant difference ($p > 0.05$) between the pre- and post-DPA size frequencies.

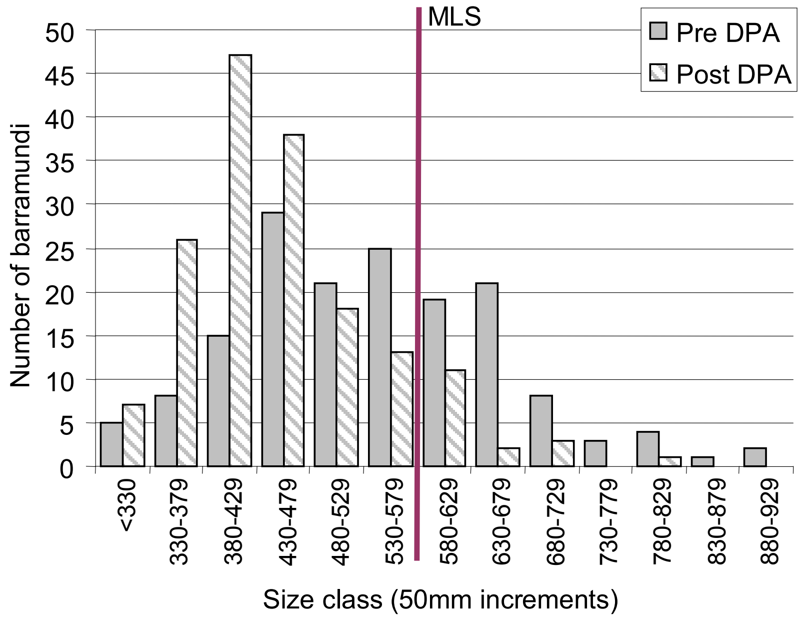


Figure 3.29 Size frequency histogram for all barramundi caught within the Hinchinbrook DPA region pre- and post-DPA implementation**.** Minimum legal size (MLS) is marked.

Summary:

The research question for this section is: *Has average size and frequency of larger barramundi caught within the Hinchinbrook DPA area increased post-DPA implementation?* Results show that average size and frequency of larger barramundi does not increased in the Hinchinbrook DPA area post-DPA implementation.

3.4 Discussion

3.4.1 Is recreational fishing quality better in ROFAs?

While each fishery-dependent data source (i.e. charter fisher logbooks, voluntary recreational catch logbooks, and ANSA time series data) has its own limitations, together these data show no evidence of significant improvement in CPUE or success rate for barramundi in ROFA compared with open estuaries within the north Queensland study area. Success rate was influenced more by other factors such as time spent fishing and the type of bait used rather than whether the fishing location was a ROFA or an open estuary. With any commercial or recreational fishery, there are factors that affect catch rates outside of the abundance of fish stocks, such as the composition of fishing fleet (including number and skill level of fishers), method of fishing, and where and when fishing occurs (Maunder and Punt 2004). Future studies may benefit from attempts to standardise fishing trips according to these influences (e.g. using personal diaries, and standardising trip length and fishing methods) to determine if there are differences in catch rates when standard methods are used. Importantly, however, the purpose of this study was to determine if ROFAs had a significant influence on recreational catch rates between common recreational fishing trips regardless of variable fishing factors.

While open and ROFA estuaries showed no differences in CPUE and success rates for barramundi in each bay in the study area, the recreational catch logbook data did reveal higher CPUE and success rates for legal-sized barramundi in the Hinchinbrook region (which has recently (1998) been closed to commercial gill net fishing) compared to other regions. This higher CPUE and success could be due to the absence of commercial fishing and may stand-out from ROFAs in other bays because the effective ROFA in the Hinchinbrook region is relatively large and encompasses all estuaries within the region (cf other ROFAs where generally one estuary is closed to commercial gill netting and is surrounded by open estuaries and commercially fished foreshores).

The size of the ROFA is potentially an important factor because barramundi are known to move in and out of, and between, estuaries (Russell and Garrett 1988; Halliday et al. 2001), and, for no-take areas at least, the success of protected areas can depend on the movement patterns of the species being protected relative to the size of the protected area (Edgar and Barrett 1999; Kramer and Chapman 1999; Chapman and Kramer 2000; Botsford et al. 2003; Stefansson and Rosenberg 2006). For no-take areas, differences between protected and non-protected areas in fish population density and mean body size will be greater for species with relatively small home ranges than for those with relatively large home ranges; for non-migratory species than for species with periodic migrations; and for strongly site attached species than for weakly site attached species (Kramer and Chapman 1999). Juvenile barramundi are known to move significant distances – For example, Russell and Garrett (1988) showed movement of 0+ and 1+ barramundi could be as large as 23 km. However, it appears most barramundi on Queensland's east coast remain resident in a single river system – During a three-year tagging study in north-east Queensland, Russell and Garrett (1988) found most barramundi were recaptured at the original tagging location, with only 2.5% of all tagged fish caught away from the tidal creeks they were released in. Further, recreational tagging data reveals minimal movement of adult barramundi away from their resident rivers – In the Fitzroy River there was up to 10% migration southwards from the river in wet years but virtually no migration out of the river in dry years (Bill Sawynok, SUNTAG, pers. comm., 2006). Similarly, of the 100 recaptured stocked barramundi in the Trinity Inlet near Cairns, only 1 was recaptured outside of the Inlet (Bill Sawynok, SUNTAG, pers. comm., 2006). Hence single estuary ROFAs may be sufficient to protect barramundi from commercial fishing, although further investigation would be beneficial.

The increased CPUE and success in the Hinchinbrook region may be due to this region's characteristics – e.g. the amount and type of estuarine and freshwater habitat, the amount of freshwater flow, level of disturbance from urban and rural development, etc – which may result in higher productivity (Dunstan 1959; Russell and Garrett 1983; Griffin 1984; Russell and Garrett 1988). Other studies have found that there can be considerable variation in growth and abundance of barramundi between rivers, dependent on the rivers' natural characteristics (Dunstan 1959; Davis and Kirkwood 1984; Griffin 1987a). Griffin (1988), for example found the Daly River likely had higher productivity than the Liverpool River in the Northern Territory, which he assigned to differences in flood plain area for which barramundi are dependent on during their juvenile stages. Such characteristics are unquantified for the bays in the study region.

Investigation of time-series data from the Hinchinbrook area revealed no improvement in CPUE or success rate for legal-sized barramundi following implementation of the DPA in January 1998. While overall barramundi CPUE did improve, this trend was driven mainly by high catches of undersized barramundi in late 1998. This increase in undersize barramundi may be due to a recruitment pulse resulting from high rainfall associated with Cyclone Justin in the 1996-97 wet season (Queensland State Disaster Management Group 2004), and higher than average rainfall in the 1997-98 wet season (Department of Primary Industries and Fisheries 2005). There is a close association between the level of breeding success and the amount of annual wet season rainfall (meaning barramundi recruitment is highly variable depending on wet seasons) (Dunstan 1959; Griffin 1984, 1987a, b; Williams 2002a), and the amount of freshwater flow affects the survival of juvenile fish (and thus year class strength) (Staunton-Smith et al. 2004). Most juvenile barramundi remain resident in small tidal creeks until the end of the first year (previously recorded at 290 - 355 mm in length (Davis and Kirkwood 1984; Davis 1987)), after which they disperse to nearby estuaries and coastal habitats (Russell 1987; Russell and Garrett 1988) and recruit to the fishery (at 580 mm) at 3 - 5 years of age when they are sexually mature (Davis 1987; Garrett 1987; Grey 1987; Welch et al. 2002). According to the size frequency histogram (Figure 3.29) for the years post-DPA implementation, these 1 - 2 year old barramundi resulting from previous high rainfall wet seasons are likely the fish in higher abundance in the 1998 catch.

It is unlikely that the increase in CPUE for undersize barramundi is due to the removal of commercial fishing via the DPA – Commercial gill nets for barramundi select for larger individuals and thus do not affect abundances of undersize barramundi (Halliday et al. 2001). Furthermore, an increase in CPUE for this group of anglers was also found in adjacent open estuaries for the years following DPA implementation. This increase in CPUE could be due to improved fishing quality throughout the region perhaps due to weather or other natural influences, improved skill of the anglers, or potentially unknown changes in data recording practices from anglers in the group. There is also potential for some barramundi to move from the DPA area to nearby open estuaries – Russell and Garrett (1988) provided movement information for tagged barramundi from Trinity Bay and Rockingham Bay (just north of the Hinchinbrook Channel) in north Queensland, and found some movement of juvenile barramundi from the original estuary to adjacent coastal habitats and other river and creek systems (in Trinity Inlet and Rockingham Bay the average distance was 7.6 km and 23 km respectively, and maximum distance was in 17 km and 76 km respectively). However, as stated previously, the percentage of juvenile and adult barramundi that move to other estuaries appears minimal (Russell and Garrett 1988; Bill Sawynok, SUNTAG, pers. comm., 2006).

There is potential that increased juvenile abundances in the Hinchinbrook ROFA may have resulted from reduced commercial fishing pressure on adult stock and increased subsequent recruitment (Milton et al. 1998), although rainfall is likely to have a more important impact on recruitment. On the other hand, reduced pressure on adult stock could also result in increased cannibalism, as adult barramundi are known to feed on juveniles of their own species (Moore 1982; Russell and Garrett 1985; Griffin 1988).

The result found from the ANSA time series data in the Hinchinbrook region highlights the importance of collecting good quality time series recreational catch and effort data from before and after ROFAs are implemented. Without such data it could be concluded that the large area closure within the Hinchinbrook area results in an improvement in legal-sized barramundi catches. The ANSA time series data revealed, however, that the higher CPUE and success rate for legal-sized barramundi is probably not related to the ROFA status.

Why improved CPUE of barramundi in ROFAs – particularly large barramundi which are shared in harvest by commercial gill net fishers in open estuaries – is not realised by anglers is not known. Some authors suggest that if ROFAs result in improved recreational fishing, recreational effort would increase until fishing quality is reduced to be no better than other areas with shared access (Cox and Walters 2002; Cox et al. 2002; Rogers and Curnow 2003; Walters 2003). The Effects of Net Fishing (EoNF) project did find higher abundances of barramundi over 800 mm total length (TL) in ROFAs when they compared experimental gill net catches between open and ROFA estuaries in north Queensland; however, the EoNF project did not find any difference in the number of barramundi up to 800 mm TL between ROFAs and open estuaries (Halliday et al. 2001). It is expected that barramundi over 800 mm make up a very small proportion of the recreational catch (the recreational catch logbook program within the present study revealed only 2% of barramundi caught were greater than 800 mm TL), which is probably also related to relative abundance of such large barramundi. Therefore, perhaps recreational effort has increased in the ROFAs but the effect of this increase has only been evident for barramundi smaller than 800 mm. While such an increase in recreational effort is possible (the EoNF study stated they observed higher recreational effort in ROFAs (Halliday et al. 2001)) results from the questionnaire program within the present study (Chapter 2) suggest most anglers are unaware of and do not deliberately choose ROFAs in preference to open estuaries in north Queensland. Furthermore, the counts of trailer numbers and estuary fisher interviews from the questionnaire program indicate no significant difference in effort between ROFA and open estuaries in the study area (Chapter 2). Further investigation of the effect of ROFA introduction on recreational effort is needed before the effect of recreational fishing on barramundi in ROFAs can be concluded. There is a lack of detailed information on relative recreational effort in open and ROFA estuaries, which could also take into consideration characteristics such as size of estuary, proximity to population centres, number of access points, etc. If the number of anglers visiting ROFAs increases, this may result in an increased total recreational catch in such areas (which may not be evident via individual fishers' CPUE); however this was not measured in the present study.

If the trend of more large barramundi in ROFAs found through the EoNF project is consistent throughout the study area, improved recreational CPUE and success rates for large barramundi are expected. Either the recreational catches of such large barramundi are too infrequent to allow examination of any catch trends, or the findings of this study support previous research which highlight that angling success is highly variable and not always directly related to the size of the fish population (Ruello and Henry 1977; Johnson and Carpenter 1994; Anderson 1999; Cowx 1999; Griffin and Walters 1999; Arlinghaus 2005). The most comparable example is for the Mary River in the Northern Territory, where an increase in barramundi abundance was found using fishery-independent techniques, but no increase in angler success was evident (Griffin and Walters 1999; Griffin 2003).

The skill level and avidity of anglers is often quoted as an important factor in determining whether improved recreational catches are realised, with the more avid anglers catching most fish and benefiting from any improved fish abundance (Hilborn 1985; Johnson and Carpenter 1994; McPhee and Hundloe 2004). In the present study, participants were highly avid (e.g. most logbook holders fished 24 times a year or more), and would therefore have been the anglers most likely to realise any catch benefits if they are available.

It is also possible that the trend of higher abundances of large barramundi found in selected estuaries through the EoNF is not consistent throughout the study area. One explanation may be that there is “leakage” of barramundi between open and ROFA estuaries. As stated above, barramundi are known to move between estuaries (Russell and Garrett 1988; Halliday et al. 2001), and fish removed from open estuaries might leave an excess of resources – therefore barramundi may move from ROFA estuaries to open estuaries to replace those taken by the commercial fishery. Further investigation via tagging studies would be required to determine the level of movement of barramundi from ROFA to open estuaries, although as stated, current tagging records indicate movement of barramundi between river systems is minimal (Russell and Garrett 1988; Bill Sawynok, SUNTAG, pers. comm., 2006).

Relative abundance of barramundi may also be highly influenced by differences in estuarine and freshwater habitat, estuary size, disturbance by rural and urban development, amount of freshwater flow, water quality, etc. (Dunstan 1959; Russell and Garrett 1983; Griffin 1984, 1987a; Russell and Garrett 1988; Halliday et al. 2001) – all of which are unquantified for bays within the study area, and are likely variable between estuaries within each bay. Some authors state that the destruction of fish habitat and water quality is more responsible for a decline in estuarine fish stocks than recreational or commercial fishing, but the former is often not recognised as it is poorly supported by scientific data (Henry 1984; Russell and Garrett 1985; Russell 1987; Brayford 1995; Healy 1995; Scialabba 1998). It is very difficult to determine if variations in fish abundance are due to changes to, or differences in, habitat, or to variation in levels of fishing (Scialabba 1998). A confounding factor is the fact that the open and ROFA estuaries examined are pseudo-replicates – each estuary is likely to have differences that may mask any management status effect on catch rates. Ideally comparable data from before and after ROFA implementation should be examined within each estuary.

The recreational catch logbook data did reveal higher relative frequencies of larger size classes of barramundi in catches from ROFAs compared to catches from open estuaries within each bay, particularly for the Hinchinbrook region. This may indicate an increased availability of larger barramundi in ROFAs and an increase in fishing quality in terms of size of fish caught. However neither CPUE nor success rate for legal-sized barramundi was higher in ROFAs rather than open estuaries, meaning anglers have as much chance of catching a large barramundi in open estuaries as they do in ROFAs. These findings may have a number of possible explanations:

- Firstly, the difference in relative frequency of sizes within catches in open and ROFA estuaries may be due to the variability in recreational fishing success (Maunder and Punt 2004).
- Alternatively, if the catches are a reflection of the actual stock structure and size, exactly why this occurs requires investigation. For instance, while ROFAs had a higher relative frequency of larger barramundi in the recreational catch, they had a lower frequency of undersize barramundi than open estuaries – Coupled with a similar CPUE for legal-sized barramundi, these findings suggest a smaller overall stock size in ROFAs. The effect of greater numbers of large barramundi may be exaggerated in anglers' catches, because larger fish would likely be more efficient at competing for anglers' bait. It may be that the relatively greater abundance of large barramundi in ROFAs has increased competition for food for smaller barramundi (Davis 1985) and/or possible predation on smaller barramundi from more abundant large, cannibalistic barramundi (Moore 1982; Russell and Garrett 1985; Griffin 1988; Halliday et al. 2001), meaning fewer small barramundi are able to survive. Why this may occur in ROFAs and not open estuaries is unclear.
- Another option is that the differences in relative abundance of different sizes may be due to the strength of particular year-classes in certain areas (Halliday et al. 2001; Staunton-Smith et al. 2004), or differences in growth rates in different rivers (which has been found in previous studies, see Davis and Kirkwood 1984; Griffin 1988)).

Griffin (1988) found similar relative size frequencies when he sampled barramundi populations using net fishing techniques in the Daly River (which was heavily exploited by recreational and commercial fishers) and Liverpool River (which had only minor exploitation) in the NT: In the Daly River pre-commercial ages of 2+ and 3+ barramundi were predominant while the Liverpool River catch included higher proportions of 4 and 5 year old barramundi which form the bulk of the catch in exploited areas. He suggested that if the size structure in each river was the same prior to exploitation, then the effect of fishing had not been to reduce the numerical abundance of barramundi but to convert their biomass to a greater number of younger, smaller fish. He further stated that the observed higher relative abundance of younger barramundi in the exploited population may be partly due to reduced mortality of juveniles because of the reduced abundance of larger barramundi which may prey upon them[5] (Davis 1985; Griffin 1988).

The Hinchinbrook region in particular provided higher catches of large barramundi within the logbook program relative to other regions in the study area. However, the time series data provided by the ANSA fishers did not show an increase in average size of barramundi caught in the Hinchinbrook DPA area post-DPA implementation. Therefore, the larger barramundi caught in this region appears to be a characteristic of this area for the years sampled via the logbook program rather than an consequence of commercial closure. Again, such differences may be due to unquantified habitat, flow or disturbance characteristics of the area, or may be a chance artefact showing strength of particular year classes due to the stochastic nature of recruitment over time.

3.4.2 Consequences for future ROFAs

Given the findings of these sources of fishery-dependent data, it is unlikely that the introduction of further estuarine ROFAs within north Queensland would result in improved recreational fishing quality. Further investigation into why recreational catch benefits are not realised is required. For instance, perhaps ROFAs encompassing single estuaries are not sufficient to protect barramundi from commercial harvest. Barramundi are known to move between estuaries (Russell and Garrett 1988; Halliday et al. 2001), although studies have shown most barramundi on Queensland's east coast remain resident in a single river system (Russell and Garrett 1988; Bill Sawynok, SUNTAG, pers. comm., 2006). More information on movement of adult barramundi as a result of ROFAs (e.g. from tagging studies) would be beneficial.

Alternatively, the lack of differences in recreational catches between open and ROFA estuaries within the present study may simply highlight the inability of recreational fishing catches to accurately reflect fish abundances (Cowx 1999;

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[5] Barramundi are voracious predators, sometimes taking prey greater than 50% of its body length and a relatively high incidence of cannibalism has been reported (Griffin 1984; Davis 1985; Griffin 1987b, 1988; Halliday et al. 2001).

Arlinghaus 2005). That is, there is a lack of sensitivity of CPUE to detect changes in biomass of the order that may have occurred. Further investigation into actual barramundi abundance within open and ROFA estuaries may be required.

While this study only examined the benefits of ROFAs, it is unlikely that the recreational catch benefits outweigh the potential costs of ROFAs. For example, the creation of 30 fishing havens in NSW required the purchase of 251 fishing businesses at cost in excess of $18.5 million (NSW Department of Primary Industries 2004). The exact costs will be fishery specific and will extend beyond the purchase of affected commercial fishing licences (e.g. social and economic costs to commercial fishers and related industries, and various to the community such as reduced local bait and seafood availability as the area fished and number of commercial fishers is reduced). Therefore, future studies should aim to examine the costs and benefits of specific ROFAs in order to determine whether ROFAs are worth-while.

3.4.3 Difficulties with fishery-dependent data

Being dependent on the fishery, there were some limitations to each data source. For instance the logbook data from the Charter Fishery provided only a very crude trip-based CPUE estimate, and catches for specific estuaries were unavailable. The voluntary recreational catch logbook data sought to improve the CPUE (with information on amount of time spent fishing, number of fishers, methods used, etc. each trip) and fishing location (to the estuary level) accuracy, however there are likely high levels of variability in skill level and knowledge of fishing locations between participants which may influence the CPUE and success rates found. The amount of variability in skill level and fisher knowledge is unquantifiable, however in the present study it has been assumed to be spread throughout the study area. An increase in the logbook sample may reduce variability between logbook holders, but a high variability is likely regardless of larger sample sizes. In future, personal diaries rather than group based diaries may reduce variability in skill level.

Participants in the logbook program likely differed significantly from non-respondents (most logbook holders were highly avid anglers), which is expected with voluntary logbook programs (Pollock et al. 1994). Such anglers, however, should be more likely to realise any improvements in fishing quality if any are available (Johnson and Carpenter 1994; Griffin 2003; McPhee and Hundloe 2004). Therefore, where catch comparisons between areas are required rather than overall catch for the fishery, this avidity bias is not considered a problem (Essig and Holliday 1991; Sztramko et al. 1991; Pollock et al. 1994).

One particular problem with a voluntary catch logbook program is keeping in contact with participants to ensure a high response rate and that data are of the highest quality possible (Pollock et al. 1994). Diary programs require significant financial support to enable continued contact with diarists. The NRIFS, for example, employed approximately 100 interviewers to maintain contact with fishers, resulting high retention rates of diarists (Henry and Lyle 2003). Continued contact within the present study was difficult due to commitments to other parts of the study. Future programs should endeavour to employ full-time staff solely responsible for this significant but essential task.

As with any recreational catch data, there are many trips with no catch recorded, meaning the resulting data are highly skewed and may not meet the assumptions required for many standard statistical techniques (O'Neill and Faddy 2003; Maunder and Punt 2004). This is unavoidable with fishery-dependent recreational catch data.

The ANSA time-series data was limited in terms of number of barramundi caught within each year. This meant that size data had to be grouped across years, meaning any difference in sizes may be confounded by recruitment variability. Future surveys should aim to collect larger numbers of barramundi each year to allow annual comparisons of size classes between open and ROFA estuaries.

Regardless of these limitations, the combination of the different methods revealed the same result – i.e. there is no evidence of ROFAs providing improved fishing quality for anglers in north Queensland. As such, together these data are significantly robust.

3.4.4 Future directions

The results of this study highlight the need for quality recreational catch data at a small regional scale to enable the investigation of whether expected benefits of ROFAs, in terms of improved recreational catches of previously shared species, are realised. Where data are lacking anecdotal claims take precedence. However, in the present study the available catch data do not support anecdotal evidence of improved recreational catches in estuarine ROFAs in north Queensland. Why expected recreational catch benefits are not being realised is unknown and requires further investigation.

The findings within the Hinchinbrook DPA in particular highlight the importance of quality time series data from before and after ROFA implementation. Without it, incorrect conclusions may be drawn where two incomparable areas are compared and any improvements in fishing quality may be incorrectly assigned to the absence of commercial fishing. Longer-term time series data with increased replication post-ROFA implementation would also be useful as it is unknown how long it may take for catch benefits, if there are any, to be realised. Future ROFAs should be preceded and followed by collection of recreational catch data to determine whether expected catch benefits are realised.

CHAPTER 4: FISHERY-INDEPENDENT STRUCTURED FISHING SURVEYS

4.1 Introduction

Anecdotal evidence suggests that Recreational Only Fishing Areas (ROFAs) result in improved recreational fishing quality (i.e. size and/or number of target species caught) (see Griffin 1995; Brown 2001; Anon 2002b; AFANT 2005). However, in most cases there are insufficient data available to support or refute such claims (Smith and Pollard 1995; Griffin and Walters 1999). Catch information on a small scale, including for specific ROFAs, is rarely available, with most data investigating trends in recreational catches being collected at the large-scale regional or State-wide level (see Higgs 1997, 2001; Henry and Lyle 2003).

Studies collecting information on recreational catches in specific ROFAs typically rely on fishery-dependent data such as creel surveys (e.g. O'Neill 2000), voluntary catch logbooks (e.g. Sztramko et al. 1991), or charter fishing records. The fishery-dependent data presented in Chapter 3 were sourced to allow comparisons of recreational barramundi catches between specific estuaries open ('open') and closed ('ROFA') to commercial gill net fishing in north Queensland. Fishery-dependent data, however, suffer from a number of biases, and their reliability is highly variable: i.e. fishers are of varying skill levels, use a number of different fishing methods (e.g. bait type, hook type and size, bait positioning in relation to fish habitat, etc), and fish different tides (direction and strength) and times of the day. Within the present study, for instance, fishing factors such as time spent fishing per trip and type of bait used had a greater effect on CPUE and success rate than management status (see Chapter 3).

To reduce the variability inherent with fishery-dependent data, fishery-independent structured fishing surveys were employed to investigate differences in angling catch rates in open and ROFA estuaries in the study area. Fishery-independent surveys using consistent fishing methods and fishing times may provide more accurate estimates of CPUE at a finer scale than fishery-dependent methods. This would allow the more direct investigation the effect of ROFA implementation on angler catches.

Fishery-independent surveys are often more costly than fishery-dependent methods (Maunder and Punt 2004), and consequently few such surveys for the recreational fishery are available. However, given the absence of regular small-scale fishery-dependent data collection for the recreational fishery (c.f. the commercial fishery which has compulsory catch logbooks), complete fishery-dependent data collection would need to be established, making costs comparable to independent surveys.

The most comparable research to the present study was completed in 2001 through the Effects of Net Fishing (EoNF) Project. The EoNF project found higher abundances of large barramundi (> 800 mm total length) in ROFAs rather than open estuaries in north Queensland (Halliday et al. 2001). The EoNF project, however, used commercial gill net fishing techniques, and it is unknown whether these abundance differences translate into improved recreational line fishing quality. Many studies state that recreational line fishing is highly variable and success is often not directly related to fish abundance (Ruello and Henry 1977; Anderson 1999; Griffin and Walters 1999). To test this question, the structured surveys in the present study were based on the sampling design used by the EoNF project, which compared experimental gill net catches between three open and three ROFA estuaries. The present study, however, used recreational line fishing techniques rather than commercial gill net fishing methods to compare catches between open and ROFA estuaries.

4.2 Objectives

This chapter further addresses the following objective:

3. To determine if there is a difference in recreational line fishing quality between estuaries that are open and closed (ROFAs) to commercial gill net fishing.

This fishery-independent survey program aims to provide a comparison of recreational line catches between open and ROFA estuaries within the study area. These surveys aim to reduce variability and biases inherent with fishery-dependent data, potentially validating trends found through such sources (Chapter 3), and to test whether higher abundances of large barramundi found in estuarine ROFAs via the EoNF project translate into improved recreational line fishing quality.

4.3 Methods

4.3.1 Site selection

To ensure sampling was spread throughout the study area, the study area was divided into three regions, each defined by proximity to major geographical features or towns (Figure 4.1). Within the Townsville region, the estuaries sampled during the EoNF project were chosen to allow a more accurate comparison with the results from that study. A list was then constructed listing estuaries accessible to both recreational and commercial fishers that were completely open or closed to commercial fishing (no partially closed estuaries were included). Estuarine ROFAs listed had been closed to commercial gill net fishing for a minimum of 4 years before sampling in 2002. From this list, two estuaries (1 open and 1 ROFA estuary) were randomly chosen from each of the remaining regions (i.e. 6 estuaries total). See Table 4.1 for the list of chosen estuaries.

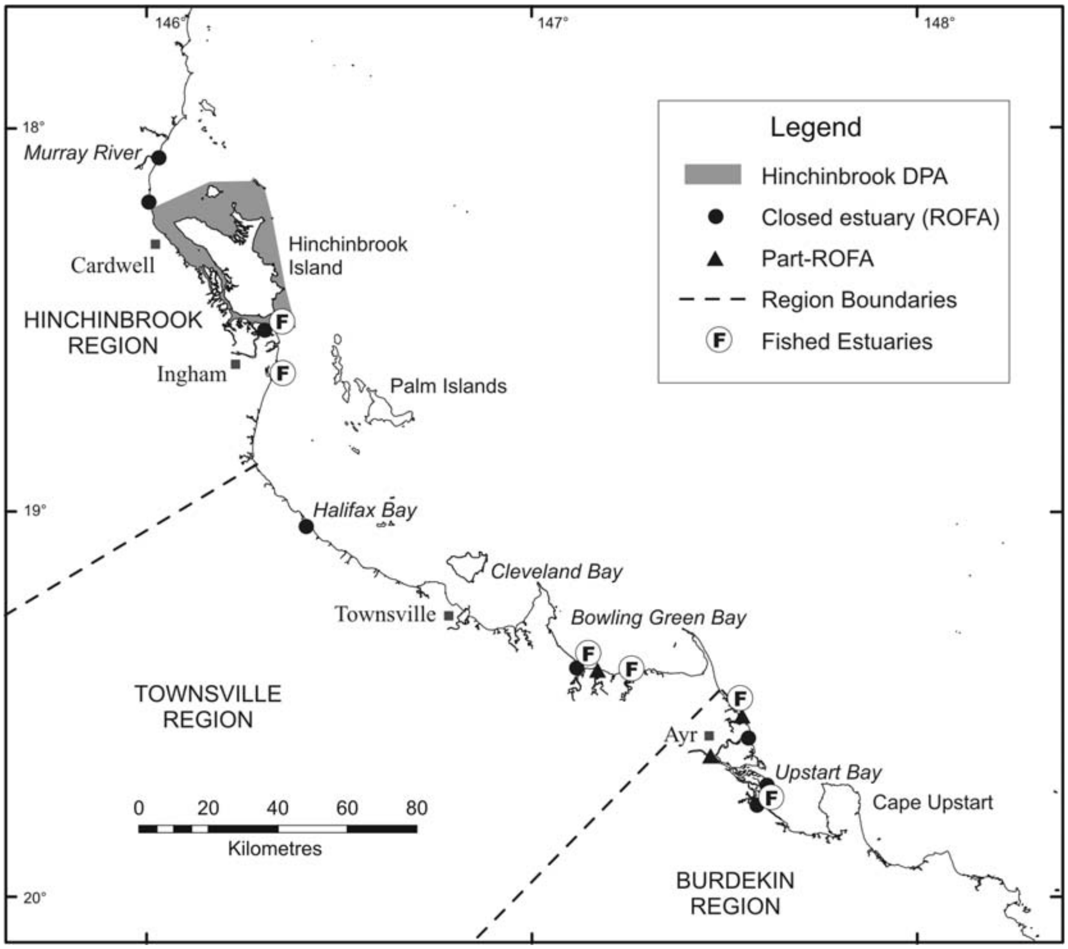

Figure 4.1 Map of estuaries sampled (fished) within the fishery-independent structured fishing surveys within each region in the study area**.**
Fished estuaries are indicated by an "F" symbol.

Table 4.1 Estuaries sampled within each region for the fishery-independent structured fishing surveys, including approximate estuary dimensions.

Region	Burdekin		Townsville		Hinchinbrook	
Estuary	Ocean Creek	Yellowgin Creek	Barrattas River	Haughton River	Victoria Creek	Herbert River
Management	Open	ROFA	Open	ROFA	Open	ROFA
Tidal delta (km2)*	0.36	Unlisted	10.93	9.73	6.4	6.38
Maximum length (km) *	4.48	Unlisted	Unlisted	Unlisted	12.8	31.38
Estimated fishable length (km)	3.5	6.5	13	9.8	6.8	4.5

*Source for tidal delta and length dimensions: (Geoscience Australia)

High variation was expected between estuaries, making it preferable to increase the number of estuaries sampled (Underwood 1981). Six estuaries was the maximum number that could be sampled over a single period of the lunar cycle (see *Sampling periods* below), with one estuary sampled each day for each 6-day trip. This sampling design is consistent with the EoNF project.

4.3.2 Sampling periods

Sampling occurred between May and November, 2002, after the recreational questionnaires were completed. This timing was prior to the closure of the barramundi season, and outside of the wet season (which may have increased the variability of flow between estuaries). Primary sources of temporal variation include tidal and lunar cycles (Halliday et al. 2001), thus sampling was structured to minimise such effects. Neap tides on each quarter moon were sampled, when flow was expected to be least variable between estuaries, and the optimum tide for the sampling methods used. During neap tides there was a period of 6 days during which tidal run was similar before the making tides of the new and full moons produced increasing tidal run. The 6 days within each neap tide-cycle were chosen according to predicted tidal strength: between 0.5 m and 2 m change from the previous tide level (i.e. 'tidal run') for 6 consecutive days (1 estuary per day). This tidal strength was chosen on advice from experienced fishers and charter operators who considered neap tides as the most appropriate for the methods chosen (see *Sampling methods* below).

Eleven 6-day trips were completed, including the pilot survey (see Appendix 7 for the timetable for these surveys). For the pilot survey, sampling was planned for 3-4 hours on the ebb tide each day on advice from experienced fishers. However, this limited the time available for sampling, and the actual time of change of tide was often unpredictable due to the presence of extensive sandbars at the mouths of most estuaries. Following further advice, it was concluded that the strength of the tidal run was more important than the direction. Therefore, subsequent surveys aimed to sample either both the ebb and flood tides (ideally) or the tidal direction of most optimum tidal strength (between 0.5 m and 2 m tidal run). Sampling was then continued for up to 6 hours per day. Actual time spent sampling was sometimes limited by bait availability. For example, on days when bait was scarce, more time was spent collecting bait prior to sampling, reducing the amount of time available for sampling within the specified tide.

4.3.3 Sampling within estuaries

To ensure the whole length of the estuary was sampled each trip, each estuary was divided into 3 sections - upper, mid, and mouth – each containing approximately equal areas of fishable habitat. Start point and direction travelled (up- or down-stream) from the start point was chosen randomly for the first trip, then sequentially from this first start point for the following trips. This was done to ensure different sections of the estuary were sampled at each tidal level and time of day.

Ideally both directions (up- and down-stream) were sampled each day, with optimal timing of change of direction coinciding with the turn of the tide, allowing each section to be sampled on both tides. However, this was not always possible due to: variability of the time of turn of the tide; unsuitability of one of the tide directions (e.g. where one tidal direction was of greater than 2 m tidal run); lack of bait (most common); lateness in the day; and for the larger estuaries, the length of the estuary given time constraints.

Within each section, a minimum of 3 “snags” (i.e. fallen and submerged or partially submerged trees) were sampled (i.e. fished), giving a minimum of 9 snags per estuary per day. A maximum of 15 snags per estuary per day were sampled to ensure consistency between estuaries. Each snag was sampled for a minimum of 5 minutes and maximum of 20 minutes (catches were corrected for the duration of sampling), giving fish a chance to bite at each snag, and preventing fishers from spending too much time on a productive snag. The length of time spent on each snag on some sampling days was further limited by the amount of bait available.

Snags in each estuary were mapped, with maps updated each trip as some snags disappeared and new ones were formed. These maps were broken into grids of 0.5 km^2 (0.25 km^2 for smaller estuaries) and snags were numbered within the grids.

This allowed a random choice of snags to be sampled each day – i.e. random choice of section (upper/mid/mouth), grid number, and snag number as encountered from the previously chosen travel direction. It was not possible to determine the complexity of the snags beneath the surface due to the turbid estuarine water. Snags chosen had enough structure above the water to tie the boat to, allowing fishing to occur amongst the snag rather than away from it. See Appendix 8 for a copy of 'mud-maps' outlining the sections, grids and snags for each sampled estuary.

4.3.4 Sampling methods

This chapter aimed to examine the effect of management status (open vs ROFA estuaries) on recreational line catches of barramundi, therefore consistent line fishing methods were essential. Experienced fishers and charter operators were consulted to determine the most appropriate method to target barramundi.

Live prawn baits presented among snags was considered the most effective line fishing method. This is a common method used by recreational anglers and charter operators, particularly in the cooler months, and charter operators considered it the best method to maximise barramundi catch (Andrew Mead, Charter Fisher, pers. comm., 2002).

Two anglers fished at all times during sampling (the project leader and one experienced volunteer). Fishers used 5'6" boat rods with spin reels. Mustad "All-rounder" size 3/0 hooks were deployed on "dropper" rigs (Figure 4.2), with 40 lb leader connected to 20 lb line. Size 4 sinkers were sufficient to keep the line steady in the relatively slow neap tidal flow. This common rig used by charter fishers for live prawn fishing in snags allows the prawn to swim/flick and attract fish without getting wrapped in the snag. The all-rounder hooks are efficient at hooking the fish in the mouth rather than the gut, allowing successful release of all fish.

4.3.5 Data recorded

All fish caught and boated were identified and both fork length (FL) (for appropriate species) and total length (TL) were measured and recorded along with the snag number and time of capture. All fish were released.

Other details recorded were the date, estuary section, time spent fishing, weather, tidal direction, tidal speed (fast/slow), and time of tide change (see Appendix 9 for data sheets).

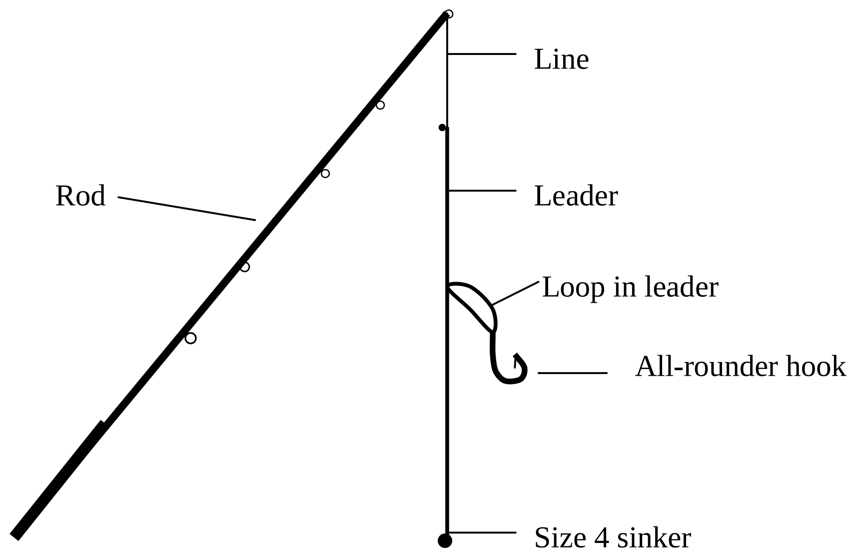

Figure 4.2 Common dropper rig used for targeting barramundi by fishing with live prawns in snags (exaggerated for clarity).

4.3.6 Data Analysis

The CPUE data obtained did not conform to the assumptions of Analysis of Variance (ANOVA): i.e. frequencies were not normally distributed and variances were not homogenous. Therefore, following initial graphical exploration, CARTs (as explained in Chapter 3, Section 3.3.1) were used to model differences in the number of fish and number of barramundi caught per angler per hour (i.e. CPUE) between open and ROFA estuaries. Initially the CART model selected was the most frequently occurring tree with cross-validation relative error within 1 standard error of the tree having the smallest cross-validation error (1-SE rule). This procedure is generally considered to produce the most parsimonious, valid model (Breiman et al. 1984). However the resulting tree for the barramundi CPUE data was extremely small and didn't reveal much information about the data. Subsequently the minimum cross validation error (min-CV) rule was also applied to allow further exploration of the data, although information from additional splits should be treated as indicative only (analogously to ambiguous p-levels in ANOVA).

A size frequency histogram was constructed to determine whether size distributions differed between the open and ROFA estuaries sampled. Size distributions were compared statistically via Kolmogorov-Smirnov test.

4.4 Results

4.4.1 Description of the catch data

Eleven trips were completed in each of the six estuaries, with average time spent fishing per trip ranging from 131 to 169 minutes. On average eleven snags were fished per trip, for an average of 11 and 14 minutes each snag depending on the estuary. Average fish number caught per trip ranged between estuaries from 9.5 and 12.8, while average barramundi number caught per trip was significantly lower, ranging from 0.4 barramundi in Ocean Creek to 4.1 in the Haughton River (Table 4.2).

Table 4.2 Description of fishery-independent structured survey fishing trips in each estuary.

Region	Burdekin		Townsville		Hinchinbrook	
Estuary	Ocean Creek	Yellowgin Creek	Barrattas River	Haughton River	Victoria Creek	Herbert River
Management	Open	ROFA	Open	ROFA	Open	ROFA
Total time spent fishing (mins)	1448	1680	1863	1670	1565	1473
Average time fishing per trip (mins)	131.6	152.7	169.4	151.8	142.3	133.9
Number of snags fished	125	125	139	120	123	118
Average number of snags per trip	11.4	11.4	12.6	11	11.2	10.7
Average mins per snag	11.6	13.4	13.4	13.9	12.7	12.5
Average number of fish caught per trip (±SD)	9.5 (±4.4)	10.5 (±4.6)	10 (±6.7)	11.3 (±5.3)	12.8 (±7.0)	11.4 (±3.7)
Average number of barramundi caught per trip (±SD)	0.4 (±0.5)	2.6 (±1.9)	3.7 (±2.5)	5.4 (±3.3)	4.5 (±3.4)	3.5 (±2.0)
Average number of legal-sized barramundi caught per trip (±SD)	0	0.5 (±0.7)	0.6 (±0.9)	0	1.1 (±0.3)	0.1 (±0.3)

4.4.2 CPUE comparisons

a) CPUE for all fish

In total 23 species groups (i.e. grouped in some instances to genus e.g. for all *Caranx* species) were captured, with captures dominated by barramundi, archer fish, cod (gold- and black-spot) and bream in most estuaries (Table 4.3).

Initial comparisons of CPUE (number of fish caught per angler per hour) for all species combined reveals no consistent difference between the open and ROFA estuaries in any of the regions (Figure 4.3).

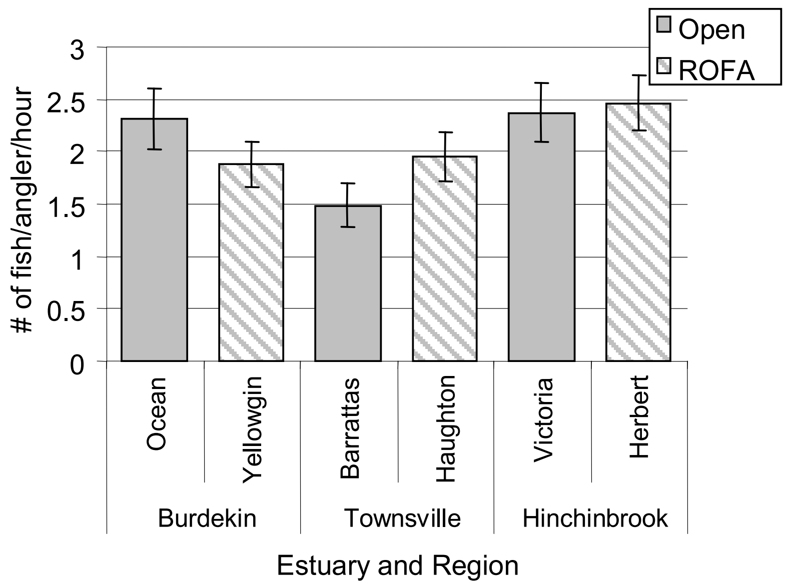

Figure 4.3 Average CPUE (number of fish per angler per hour) for all fish caught in each sampled estuary**.**

Error bars are 95% confidence limits (CIs).

Table 4.3 Total number (n) and catch per unit effort (CPUE, number of fish per angler per hour) of each species (grouped to genus in some instances) caught in each estuary with the fishery-independent structure fishing surveys**.**

	Region	Burdekin				Townsville				Hinchinbrook			
	Estuary	Ocean Creek		Yellowgin Creek		Barrattas River		Haughton River		Victoria Creek		Herbert River	
	Management	Open		ROFA		Open		ROFA		Open		ROFA	
Common name	**Species name**	**n**	**CPUE**	**n**	**CPUE**	**n**	**CPUE**	**n**	**CPUE**	**n**	**CPUE**	**n**	**CPUE**
Archer fish	*Toxotes* sp.	8	0.17	22	0.39	12	0.19	8	0.14	9	0.17	8	0.16
Barramundi	*Lates calcarifer*	4	0.08	29	0.52	41	0.66	59	1.06	49	0.94	38	0.77
Black bream	*Acanthopagrus berda*	46	0.95	13	0.23	14	0.23	18	0.32	18	0.35	26	0.53
Barred grunter	*Pomadasys kaakan*	0	0	0	0	0	0	0	0	2	0.04	2	0.04
Brown morwong	*Goniistius spectabilis*	0	0	0	0	2	0.03	1	0.02	1	0.02	5	0.10
Black spot cod	*Epinephelus malabaricus*	2	0.04	6	0.11	1	0.02	5	0.09	4	0.08	1	0.02
Barracuda	*Sphyraena barracuda*	0	0	1	0.02	0	0	0	0	0	0	0	0
Catfish	*Arius sp.*	1	0.02	1	0.02	2	0.03	0	0	0	0	0	0
Cod (unspec.)	*Epinephelus* sp.	1	0.02	0	0	0	0	0	0	1	0.02	0	0
Flathead	*Platycephalus* sp.	2	0.04	1	0.02	20	0.32	1	0.02	0	0	0	0
Fingermark	*Lutjanus johnii*	3	0.06	11	0.20	0	0	4	0.07	7	0.13	4	0.08
Gold spot cod	*Epinephelus coides*	6	0.12	19	0.34	10	0.16	15	0.27	12	0.23	7	0.14
Mangrove jack	*Lutjanus argentimaculatus*	2	0.04	0	0	3	0.05	1	0.02	4	0.08	1	0.02
Moses perch	*Lutjanus russelli*	16	0.33	5	0.09	2	0.03	7	0.13	12	0.23	9	0.18
Toadfish	*Chelonodon* sp.	1	0.02	2	0.04	2	0.03	0	0	0	0	3	0.06
Queenfish	*Scombermorus commersonnianus*	1	0.02	0	0	0	0	0	0	4	0.08	1	0.02
Sand bass	*Psammoperca waigiensis*	2	0.04	0	0	0	0	0	0	0	0	0	0
Small spotted grunter	*Pomadasys argenteus*	0	0	0	0	0	0	0	0	0	0	1	0.02

Further exploration was undertaken via CARTs. The CARTs resulting from the 1-SE and min-CV rules examining the difference in CPUE for all fish between each estuary sampled are identical; therefore only the 1-SE tree is shown here. Both models reveal no splits between open and ROFA estuaries. Those estuaries with the highest CPUE (on the right-hand branch) are a mixture of open and ROFA estuaries (Figure 4.4).

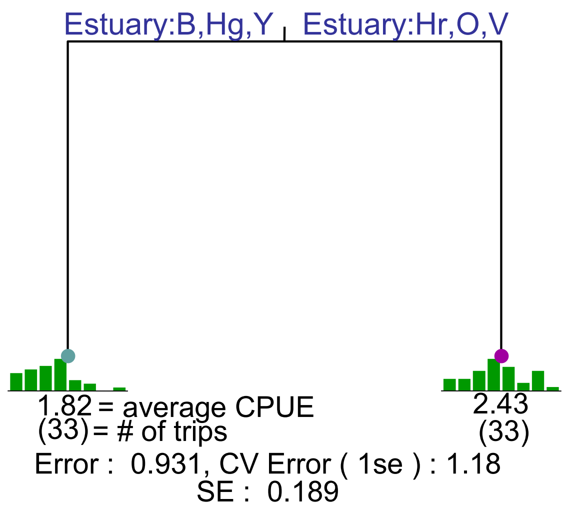

Figure 4.4 Classification and Regression Tree (CART) with the 1-SE rule for the CPUE (number of fish caught per angler per hour) of all fish in all sampled estuaries**.** The graphs for each node show the relative CPUE, with average CPUE (and number of trips) listed below. See Chapter 3, Figure 3.7 for more explanation of the CARTs.
Key: B = Barrattas Rv (open); Hg = Haughton Rv (ROFA); Hr = Herbert Rv (ROFA); O = Ocean Ck (open); V = Victoria Ck (open); Y = Yellowgin Ck (ROFA).

b) <u>CPUE for barramundi</u>

Initial exploration of CPUE for barramundi shows the ROFA estuary sampled provides a higher CPUE than the open estuary in the Burdekin region, but there is no difference between ROFA and open estuaries in the other regions, as shown by the overlap of error bars (Figure 4.5).

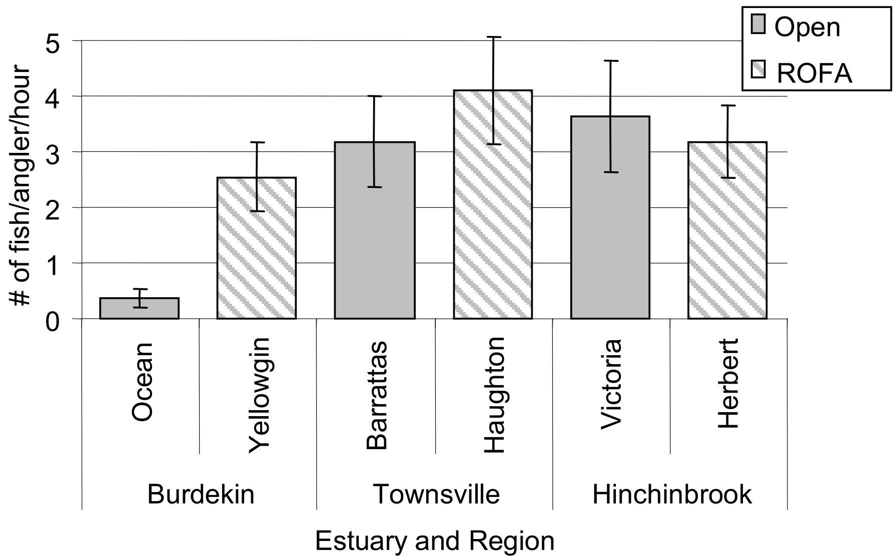

Figure 4.5 Average CPUE for all barramundi caught in each sampled estuary**.** Error bars are 95% confidence limits (CIs).

Further exploration via CARTs confirms the information shown in the bar graph: The CART model resulting from the 1-SE rule (Figure 4.6 a) shows the number of barramundi caught per angler per hour (CPUE) in Ocean Creek (open) is substantially lower than catches in all other estuaries sampled, but there is no significant difference between any of the other sampled estuaries. The data were further investigated selecting the final tree model on the basis of min-CV rule (Figure 4.6 b), which reveals the Haughton River (ROFA) provides a higher CPUE than the other estuaries, but the difference between the Haughton and Victoria (open) Rivers is very slight as indicated by the vertical length of the branch. Overall there is no consistent difference between open and ROFA estuaries.

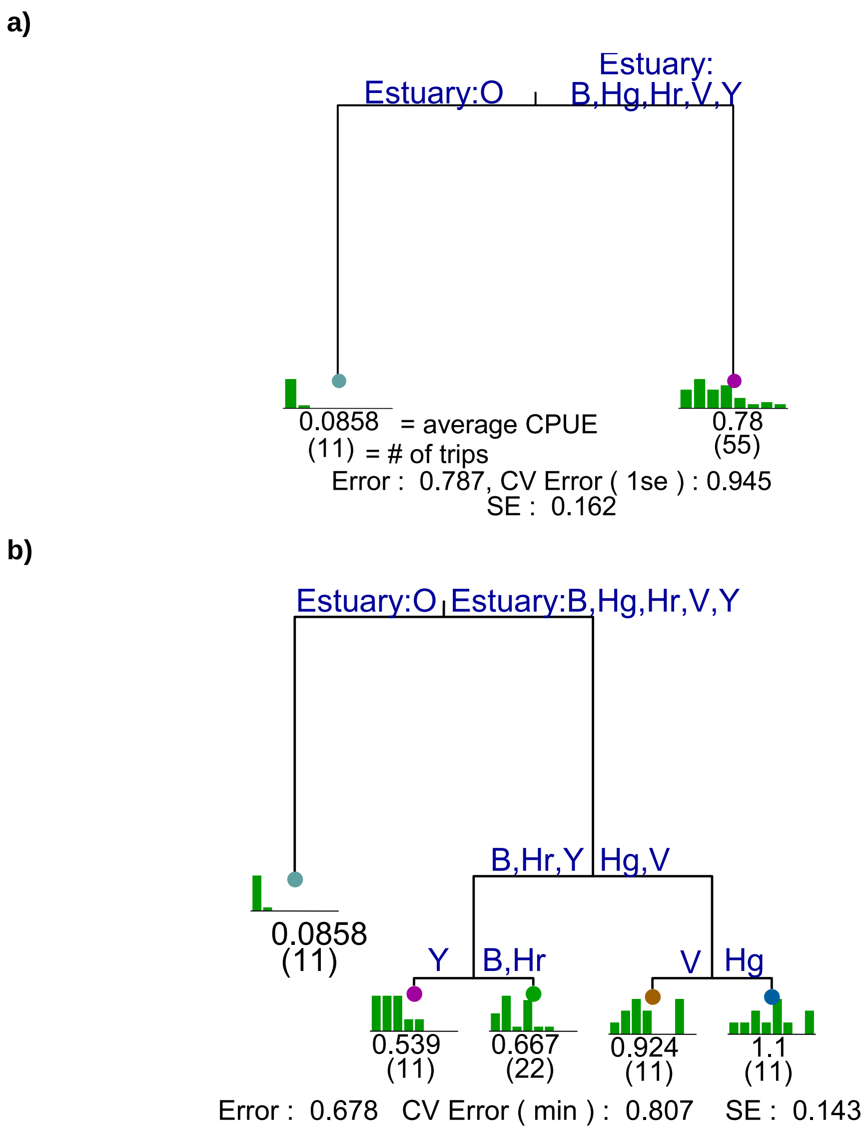

Figure 4.6 CART with the: a) 1-SE rule; and b) min-CV rule for barramundi CPUE in all sampled estuaries. The graphs for each node show the relative CPUE, with average CPUE (and number of trips) listed below. See Chapter 3, Figure 3.7 for more explanation of the CARTs**.**

Key: B = Barrattas Rv, Hg = Haughton Rv, Hr = Herbert Rv, O = Ocean Ck, V = Victoria Ck, Y = Yellowgin Ck.

4.4.3 Size frequency of barramundi

The size frequency histogram for barramundi caught in open and ROFA estuaries sampled shows no obvious difference between these two management types (Figure 4.7). Kolmogorov-Smirnov test confirms the distribution of size classes in open and ROFA estuaries is not significantly different ($p > 0.05$). Unfortunately the number of legal-sized barramundi caught in individual estuaries was too low to allow meaningful comparison, meaning estuaries, despite being pseudo-replicates, had to be grouped to management status.

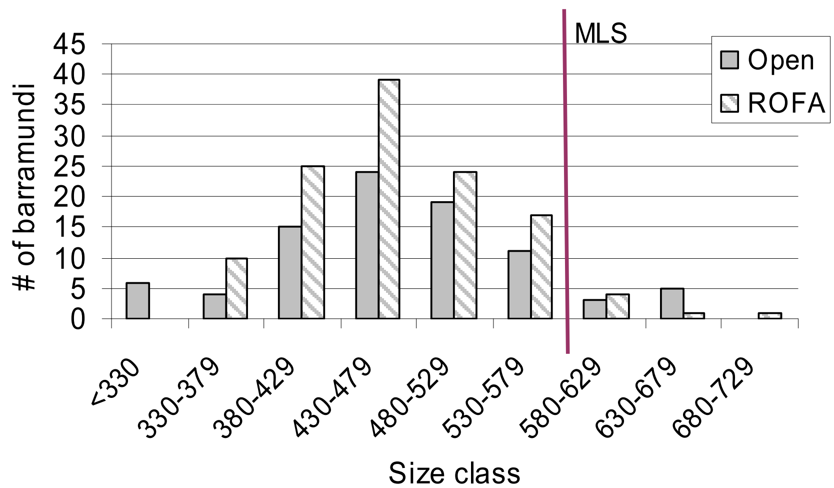

Figure 4.7 Size frequency histogram for barramundi caught in the sampled open and ROFA estuaries**.**

Sizes are in mm. Minimum legal size (MLS) is marked.

The average size of barramundi for both management types (with the 3 sampled estuaries for each management type combined) was 466 mm. T-test reveal p = 0.48 (i.e. >0.05), meaning there is no significant difference between mean sizes of barramundi caught in open and ROFA estuaries. When the average size of barramundi caught in each estuary is compared, Yellowgin Creek (ROFA) and the Barrattas River (open) have a higher average size than the other estuaries sampled, but there are no other differences, as depicted by the position of the error bars (Figure 4.8).

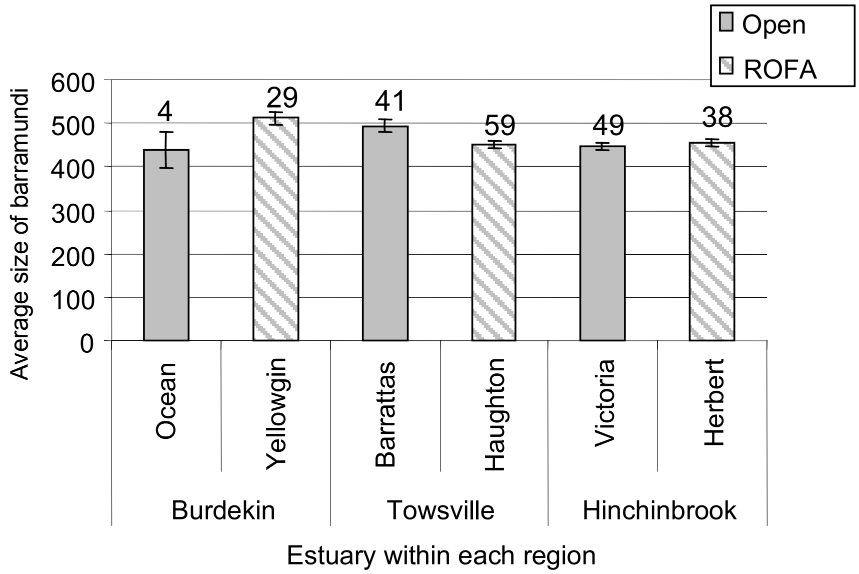

Figure 4.8 Average size of barramundi caught in the sampled open and ROFA estuaries**.**

n (number of barramundi caught) is listed above each corresponding bar.

Error bars are 95% confidence limits (CIs).

4.5 Discussion

The fishery-independent structured fishing surveys confirmed the results found through the fishery-dependent methods (Chapter 3) – i.e. there is no evidence that estuarine ROFAs produce higher line fishing CPUE of barramundi than open estuaries in north Queensland. There were some differences between the results from the fishery-dependent and -independent surveys: Unlike the recreational catch logbooks, the fishery-independent structured surveys did not produce a difference between the average size of barramundi between open and ROFA estuaries. However, the catch of legal-sized barramundi within the fishery-independent surveys was limited (only 7% of barramundi caught were of legal size) due to the fishing methods used (which selected for smaller barramundi due to where the bait was placed – i.e. in snags rather than deep holes), so a meaningful comparison between catches of legal sized barramundi was not possible. Further, the CPUE for barramundi and the average size of barramundi caught was higher for the fishery-dependent logbooks than for the fishery-independent surveys. Again, this was due to the various fishing methods employed for the recreational catch logbooks compared to the selective fishing method of the fishery-independent surveys.

The EoNF project suggested improvements in recreational line catches of barramundi were possible in ROFA estuaries, as they found significantly greater numbers of barramundi over 800 mm total length (TL) in ROFAs compared to open estuaries (Halliday et al. 2001). Unfortunately, this suggestion could not be tested through the fishery-independent surveys due to the catches of legal-sized barramundi being too low to allow meaningful comparison. The EoNF project did not find any significant difference in the number of barramundi of less than 800 mm TL between open and ROFA estuaries (Halliday et al. 2001), which is consistent with the results found in the present study.

One contrasting result was that Ocean Creek (open to commercial fishing), produced very low catch rates of barramundi compared to the other estuaries sampled. Being the only open estuary with significantly lower CPUE, this result is likely attributable to the characteristics of this small estuary. Ocean Creek's tidal delta, floodplain and water area are all substantially smaller than the other estuaries sampled (Geoscience Australia; Saenger 2004). Small estuaries may be more susceptible to net fishing pressure, or they may simply have naturally lower abundances of fish (Pease 1999). Pease (1999) found catch per taxa and richness of taxa were lower in smaller estuaries in NSW, which may be applicable here. Future surveys should endeavour to quantify estuary habitat features and size and to choose estuaries that are as similar to each other as possible in order to reduce variation outside of the effect of commercial fishing. Relative abundance of barramundi can be highly influenced by differences in estuarine and freshwater habitat, estuary size, disturbance by rural and urban development, amount of freshwater flow, water quality, etc (Dunstan 1959; Russell and Garrett 1983; Griffin 1984, 1987a; Russell and Garrett 1988; Halliday et al. 2001). This problem further highlights the importance of collecting time-series data from before and after ROFA implementation, rather than relying on comparisons of pseudo-replicate open and ROFA areas – these areas may not have had comparable fish production regardless of commercial exploitation, potentially due to different characteristics such as tidal delta size, river length, freshwater input, mangrove area, or recreational fishing effort.

Data from both the fishery-dependent and -independent surveys suggest that a high proportion of recreational catch consists of undersize barramundi: 93%, 72% and 78% of the barramundi catch from the structured surveys, the recreational catch logbooks, and the ANSA time-series data, respectively, was undersize. State-wide recreational catch surveys provide similar figures for the percentage of barramundi catch released – Both the National Recreational and Indigenous Fishing Survey (NRIFS) and the

Queensland state-wide RFISH surveys found a release rate of 72% for barramundi, (Higgs 2001; Henry and Lyle 2003; QDPI&F unpublished data). It is unknown exactly how many of the fish released within the RFISH surveys were undersize – RFISH data from the 2005 recreational catch diary round shows for those fishers who gave a reason for release, at least 47% released the barramundi specifically because it was undersize. Other more common reasons for release included "out of season" (13%) and "tagged" (16% - of which an unknown number may have been undersize) (QDPI&F unpublished data). Some studies suggest that high rates of releases and discards are primarily in response to mandatory regulations and to a lesser extent, voluntary releases (Bartholomew and Bohnsack 2005). The exact proportion of undersize barramundi caught within the recreational fishery requires further investigation.

There are two potential implications for such a high proportion of undersize barramundi in the catch:

1) Firstly, there are issues of post-release survival and stress. Fisheries managers have put more reliance on measures that require releasing fish, including minimum sizes; however the ultimate success of these measures requires sufficient survival of released fish (Bartholomew and Bohnsack 2005). Bartholomew and Bohnsack (2005) reviewed 53 release mortality studies, and found mean release mortality varied greatly between and within species. They listed various important factors that affected mortality, including anatomical hooking location (the most important mortality factor), type of bait, removing hooks from deeply hooked fish, hook type, depth of capture, warm water temperatures, and extended playing and handling times.

There is also growing debate regarding the ethics of catch-and-release angling in terms of pain and suffering experienced by released fish. Research suggests that all recreational fishing results in some level of injury and stress to an individual fish, however, the severity of the injury, magnitude of stress, and potential for mortality varies in response to a variety of factors such as fishing gear (e.g., type of hook, bait or net) and angling practices (e.g., duration of fight and air exposure, fishing during extreme environmental conditions, fishing during the reproductive period) (Cooke and Sneddon 2007). For barramundi, de Lestang et al. (2004) specifically examined the stress and survival of line-caught barramundi in the Northern Territory. They found barramundi showed significantly elevated physiological response to capture with concentrations of stress indicators (cortisol and lactate), which was greatest one hour after capture and decreased over 24 hours. The study found longer landing times significantly increased lactate levels, thus shorter landing times are preferred to reduce this stress response. Encouragingly, from 61 fish tagged with radio-transmitters, they found an overall post-release survival of 90.5%, with an 80% survival rate in summer and 100% survival rate in winter. The authors also examined the amount of damage (i.e. skin abrasions and fin damage) caused to barramundi by different types of landing nets typically used by anglers, and recommended the future use of knotless landing nets which caused less damage than knotted nets.

The high proportion of undersize barramundi, high release rate, and post-release survival rate and stress (which is a greater issue in warmer months) should be considered during fishery assessments for barramundi. Further investigation into selectivity of different line fishing techniques could provide insights into how to reduce the proportion of undersize barramundi caught and/or stress levels within released fish.

2) A second implication of the high percentage of undersize barramundi caught relates to the high sample size required to provide a meaningful comparison of catch of legal-sized barramundi between open and ROFA estuaries. Future surveys should aim to collect much larger sample sizes with the same methods used in the present study, or explore the applicability of different fishing methods to target legal-sized barramundi specifically. While fishery-independent surveys reduce variability inherent with fishery-dependent methods and provide a more accurate estimate of CPUE at a finer spatial and temporal scale, collection of large amounts of data is more difficult due the principal limitation of the number of surveys that can be carried out (Pecquerie et al. 2004). A possible alternative to the present surveys may be to employ experienced anglers to sample in a scientifically structured manner, which would take advantage of reduced variability such as from different fishing locations and fishing methods, but would increase sample sizes at a limited cost. It would be essential to provide scientific guidance to ensure fishing methodology is consistent spatially and temporally.

Previous studies have demonstrated the usefulness of employing recreational anglers within fisheries sampling. Attwood (2003) utilised volunteer recreational anglers for a controlled shore-angling program used to study galjoen (*Dichistius capensis*) in South Africa. A small number of anglers assisted the author and two other fishery scientists in the capture and tagging of fish. The composition of the angling team was kept as constant as possible. Although 86 anglers in total participated in the project, most effort was accounted for by only eight anglers. Initially, from 1984, the project involved fishing by a small group of anglers during monthly trips, each lasting 4 or 5 days. From 1995 trips were reduced to six per year, each lasting 5 days. The number of hours fished per angler was recorded. Prior to 1995, anglers kept to a single standard technique which targeted small epilithic feeders. From 1995 a second fishing technique was introduced to target larger piscivorous fish. Anglers were instructed to use one or the other technique, which was recorded against the angler’s catch.

In Queensland, an organisation known as ‘CapReef’ involves recreational anglers and the broader community in monitoring and collecting information on the local effects of management changes on the Great Barrier Reef (GBR) ecosystem. CapReef is owned and managed by the community with a Steering Committee comprising community and government interests to provide strategic guidance. CapReef links and works in partnership with other monitoring and research being undertaken in Queensland. It is a partnership involving the community and government with appropriate science support (Bill Sawynok, CapReef, pers. comm., 2007).

Together, these two examples show the willingness of anglers to participate in fisheries sampling. An organised group of anglers is able to collect scientifically rigorous data, which was also demonstrated within the current project via the ANSA time series data used in the fisheries-dependent data chapter. Data quality could be improved by scientific guidance, providing high quality data, consistently collected spatially and temporally. Collection of such data may otherwise not be possible without a reduction in the costs of sampling achieved via volunteer angler assistance (Attwood 2003). Future studies should investigate the applicability of including volunteer angler assistance to increase sampling at reduced costs.

CHAPTER 5: GENERAL DISCUSSION

5.1 Overview

This study examined the extent to which the expected benefits of Recreational Only Fishing Areas (ROFAs) in north Queensland estuaries are being realised. In particular, the study examined whether ROFAs are effective at resolving or reducing conflict between recreational and commercial fishers competing for shared barramundi (*Lates calcarifer*) stocks, and whether ROFAs improve recreational catches of barramundi. Examination of such benefits required the adoption of a multi-disciplinary approach, examining the social aspects of conflict, and the biological aspects of recreational catches.

Results from the social aspect of the project show that while conflict between recreational and commercial fishers in north Queensland estuaries is an issue for many stakeholders, ROFAs are not currently reducing the level of conflict, for two reasons. Firstly, current ROFAs do not segregate the recreational and commercial fishing sectors in estuarine waters in the study area. Secondly, it seems conflict is not due to contact between these competing sectors, but rather due to mutual misperceptions that fishers from each sector hold about the other. Consequently, as they stand at the moment, ROFAs are unlikely to resolve conflict in the long-term in this fishery.

Investigation of recreational catches from various fisheries-dependent and fisheries-independent sources did not reveal any improvement in recreational barramundi catches in current ROFAs compared to estuaries with shared access. Why such catch benefits are not being realised is unknown though a number of reasons were speculated in Chapter 3, such as the importance of natural variability in fish abundance, variability in recreational fishing success, etc.

If the expected benefits of current ROFAs are not being realised, it is questionable whether more ROFAs should be implemented without further examination of why expected benefits are not being achieved and thus how to improve outcomes in the future.

5.1.1 Segregation as a solution to conflict

Many studies suggest conflict between competing recreational and commercial sectors is increasing due to increasing contact between these sectors (Edwards 1991; Hannah and Smith 1993; Brayford 1995; Ramsay 1995; Scialabba 1998; O'Neill 2000; McPhee et al. 2002). Segregation of these competing sectors via ROFAs should reduce contact between them and thus reduce conflict (Samples 1989; Department of Primary

Industries and Fisheries 2003). Current ROFAs in north Queensland, however, are not increasing segregation of competing recreational and commercial sectors for a number of reasons. Firstly, contact is already limited through time segregation (no commercial gill netting is allowed in estuaries on weekends – a time when angling activity is highest (Queensland Department of Primary Industries 1995)), and commercial fishers tend to avoid areas where recreational fishing activity is high (Chapter 2). Secondly, results of this study show that anglers do not choose to fish in current ROFAs in preference to estuaries with shared access, and most anglers are unaware of where the current ROFAs are located (Chapter 2). Such a lack of knowledge of management changes, that have been made in favour of anglers, is common in other fisheries (Ruello and Henry 1977; The Recreational Fishing Consultative Committee 1994; Gwynne 1995). There is potential for anglers' choice of fishing location to alter if they are made aware of the presence and location of current ROFAs (Hunt 2005). Previous studies on fishing site choice by anglers suggest, however, that fishing site selection is complex and dependent on more than one variable (Schramm et al. 2003). In some cases, anglers have been found to be unwilling to change from their familiar fishing sites even when the attributes of these sites degrade (Mann et al. 2002; Pradervand et al. 2003; Hunt 2005). Consequently, further attempts to segregate these competing sectors in north Queensland via ROFAs are unlikely to resolve conflict because physical contact is not the cause of the conflict.

Jacob and Schreyer (1980) suggest that direct physical contact may not be needed for conflict to exist. Instead, conflict can occur based on the perceptions that members of one sector hold about the behaviours and operations of the competing sector. Jacob and Schreyer defined conflict as "goal interference attributed to another's behaviour". Under this definition, conflict will exist when an individual makes a link between goal interference (e.g. an angler's inability to catch the desired amount of fish) and another person's or group's behaviour (e.g. commercial fishing operations which are perceived by the angler to be unsustainable). When people are questioned about conflict, however, it is often not clear whether their perception of goal interference is based on knowledge gained from direct personal experience or contact, or on information obtained from the public media, gossip, or other sources (Jacob and Schreyer 1980). Based on this theory and the findings of this research, fishers' knowledge about the competing sector within the north Queensland barramundi fishery is more likely gained from other sources such as hearsay and the public media than direct experience or contact.

If fishers have minimal direct contact with the competing sector, there are two possible outcomes: 1) fishers don't see the competing sector as a threat or a problem because they don't notice the competing sector; or 2) fishers hear about their competitors, and with a low understanding of their competitor's operations, may see them as a 'scapegoat' for their own perceived low catches. Scapegoating is the process where feelings of personal frustration are projected onto another, thus displacing the locus of responsibility (Jacob and Schreyer 1980). The second outcome is the situation found in north Queensland estuaries, where despite minimal direct contact, anglers perceive commercial fishers as responsible for a perceived decline in barramundi catches (Chapter 2). This situation is common in many fisheries (Ruello and Henry 1977; Gartside 1986; Quinn 1988; Macreadie 1992; Staniford and Siggins 1992; Garrell 1994; Bartleet 1995; Gladwin 1995; Kearney 1995a; Griffiths and Lamberth 2002; Kearney 2002a, b, 2003b).

Consequently, physical segregation of these competing sectors via ROFAs is unlikely to resolve conflict in the long-term. Future research should aim to determine where fishers' misperceptions are coming from and thus how to counteract these perceptions. Aslin and Byron (2003) found most people within the general Australian public received information about the commercial fishing sector from the mass media, particularly television, while recreational fishers relied more on books, magazines and fishing clubs. Further investigation is needed to determine whether these findings are consistent within the particular fishery being examined.

5.1.2 Education and communication as a solution to conflict

Given the above discussion, education of fishers from each sector regarding their own and their competitor's operations and impacts should be more likely to reduce conflict than segregation via ROFAs. The likelihood of fishers blaming their competitors for goal interference depends on how fishers perceive their own impacts, and how they perceive the operations and impacts of their competitors (Gartside 1986; Holder 1992; Nakaya 1998). These perceptions are influenced by fishers' previous experience and by other sources including other people and the public media (Liska 1984; Schreyer et al. 1984; Taylor et al. 1997). Attitudes fishers hold towards themselves and their competitors are a function of their perceptions (Ajzen and Fishbein 1980), and thus if perceptions are altered, it is likely fishers' attitudes will consequently be altered.

Altering fishers' negative perceptions about their competitors via increased education and communication has been suggested as a possible solution to conflict by numerous other studies (see Ruello and Henry 1977; Henry 1984; Mitchell 1991; Loomis and Ditton 1993; Kearney 1995b; McLeod 1995; Aas and Skurdal 1996; Arlinghaus 2005). Unfortunately there are few published examples of situations where education of fishers has been implemented and tested to determine whether it is successful in reducing conflict. Kearney (2002a) outlined an example involving conflict in Victoria’s bays and inlets. In that situation, anglers were pushing for a ban of commercial gill netting because they believed that commercial gill netting killed undersize fish, damaged seagrass beds, over-exploited target species, reduced the availability of food for key angling species, and ultimately reduced the availability of fish to the recreational sector. On the other hand, commercial fishers were concerned that anglers sold fish illegally, ignored bag limits, and that their sheer numbers resulted in significant mortality of undersize fish. Kearney investigated each of these claims and found them to be incorrect or unlikely. The correcting of these primary misperceptions was seen as a major step forward in reducing conflict in the area. Unfortunately, whether this education and communication strategy has continued or has been successful in resolving conflict in the long-term remains unclear due to a lack of published studies.

In north Queensland, fishers from both the commercial and recreational sectors hold negative perceptions about their competitors. Education of fishers from both sectors is one way to counteract these negative perceptions. Anglers’ negative perceptions about commercial fishing in particular are most likely due to adverse publicity via the public media; although the exact source of fishers’ perceptions is unknown.

Much information about the operations and relative impacts of both the commercial and recreational sectors in Queensland estuaries is available to fisheries managers and researchers; however, such information is not currently readily available to fishers or the general public. Available information includes: high compliance levels with fisheries regulations by both sectors (QBFP unpublished data); high selectivity of commercial gill nets (Halliday et al. 2001); and relatively similar harvest levels by each sector (Williams 2002a). This information should be disseminated to the general public and both fishing sectors by both fisheries departments and fisheries organisations (such as Sunfish and QSIA). As outlined in Chapter 2, fisheries managers, researchers and stakeholder organisations should work together to develop an appropriate on-going education strategy to ensure fisheries information is distributed objectively. To do this, managers and researchers will need to develop a trusting relationship with stakeholder organisations (Ham 2001; Bruckmeier 2005; Kyllonen et al. 2006; Taylor et al. 2007). The public media appears to be the most successful medium to use (Aslin and Byron 2003), however useful participatory processes such as workshops and meetings (including MACs) to encourage communication and hence ‘social learning’, should also be included (Schusler et al. 2003; Taylor et al. 2007). Importantly though, participants of such workshops or meetings must objectively disseminate information to their constituencies. Any education campaign should be flexible regarding what methods are used. Determination of exact methods to use at any point in time should be determined by a detailed exploration costs and benefits, including evaluating whether particular methods are successful (e.g. by surveying focus groups before, during and after any education campaign).

By increasing fishers' understanding of each sector's operations and impacts through increased education and communication, misperceptions can be reduced, hopefully resulting in fishers holding a more positive view of the competing sector, reducing blame and hence reducing conflict. Further, some authors state that communication between competing sectors may lead to additional positive outcomes (Schusler et al. 2003). For instance, increased communication may lead to fishers finding common goals and a potential co-operative approach which may make it possible for commercial and recreational fishers to co-exist (Henry 1984; Baird 2001; Olsen 2002). Fishers from both sectors may find they each have the best interests of the resource in mind (Henry 1984; Kearney 2002a), and work together to mitigate seemingly greater threats to the barramundi resource than either recreational or commercial fishing, such as habitat destruction and loss of freshwater flow (Russell and Garrett 1985; Garrett 1987; Healy 1995; Halliday et al. 2001).

5.1.3 The use of ROFAs to improve recreational catches

Many north Queensland anglers did state that "fishing quality" was a high priority for site selection. If ROFAs do result in improved fishing quality (or even the perception of improved quality (Schramm et al. 2003)), then perhaps anglers will be more likely to utilise these areas if they are aware of them. Contrary to anecdotal claims (e.g. Brown 2001) and expectations (see Chapter 2), however, examination of recreational line catches of barramundi through numerous sources (charter fishing data, voluntary recreational catch logbooks, recreational time series catch data, and fishery-independent structured fishing surveys) did not reveal any evidence of improved recreational catches of barramundi in ROFAs compared to open estuaries in the north Queensland study area. Exactly why recreational catches have not improved in these areas is unknown, but a number of reasons are speculated in Chapter 3 and below.

If recreational catches are a true reflection of barramundi abundance, further research is needed to investigate why there are not greater numbers of barramundi in ROFAs compared to open estuaries. For instance, further consideration of the biology of barramundi is required to determine the appropriate scale of ROFAs. Barramundi are known to move between estuaries (Russell and Garrett 1988; Halliday et al. 2001), therefore current ROFAs (where single estuaries are closed to commercial fishing) may be insufficient to result in increased barramundi abundance. However, while juvenile barramundi have been shown to move distances along the coast as far as 23 km, studies have shown most adult barramundi on Queensland's east coast remain resident in a single river system (Russell and Garrett 1988; Bill Sawynok, SUNTAG, pers. comm., 2006).

It is highly probable that barramundi abundance is more greatly affected by natural variables than commercial harvest. Relative abundance of barramundi is influenced by differences in estuarine and freshwater habitat, estuary size, disturbance by rural and urban development, amount of freshwater flow, water quality, etc (Dunstan 1959; Russell and Garrett 1983; Griffin 1984, 1987a; Russell and Garrett 1988; Pease 1999; Halliday et al. 2001). Studies have highlighted the importance of protecting freshwater and estuarine habitats in order to maintain healthy barramundi populations. Many researchers consider the loss of habitat and freshwater flow due to agricultural and urban development a major threat to the barramundi resource, potentially greater than any threat from fishing by either sector (Moore 1982; Russell and Garrett 1983; Davis 1985; Russell and Garrett 1985; Garrett 1987; Russell 1987; Brayford 1995; Healy 1995; Scialabba 1998; Halliday et al. 2001; Martin 2001; Williams 2002a). Unfortunately comparative information on environmental factors is not available for the bays within the study area, and is likely to be variable between estuaries within each bay. This lack of information highlights the importance of collecting time-series data from before and after ROFA implementation, rather than relying on comparisons of open and ROFA areas which may not have had comparable fish production regardless of commercial exploitation.

It is also possible that the abundance of barramundi has improved in ROFAs compared to open estuaries, at least in some instances, but these improvements may not have been evident in recreational catches. The Effects of Net Fishing (EoNF) project surveyed 3 open and 3 ROFA estuaries in north Queensland (including two of the same estuaries sampled in the fisheries-independent surveys in the present study, Chapter 4) using commercial gill netting methods. The results did show higher abundances of large (> 800 mm) barramundi in ROFAs compared to open estuaries (Halliday et al. 2001). These higher abundances found with commercial gill net techniques, however, were not evident in any of the recreational line catch data examined within the present study. This may be due to naturally low recreational catches of large barramundi meaning a very large sample size would be required to detect any change. The present study would benefit from additional recreational catch data. For instance time series data were limited to a small group of anglers fishing in one area for only a few years post-ROFA implementation. Time series data collection could be expanded in other areas and for longer time frames. Anglers, particularly within fishing clubs, could prove useful in providing such data if they are given direction regarding the quality and detail of the data required (Attwood 2003; Bill Sawynok, CapReef, pers. comm., 2007). This option is explored in more detail in Chapter 4.

Alternatively, the lack of differences in recreational catches between open and ROFA estuaries within the present study may simply highlight the inability of recreational fishing catches to accurately reflect fish abundances (Cowx 1999; Arlinghaus 2005). Angling success is highly variable and not always directly related to the size of the fish population (Ruello and Henry 1977; Johnson and Carpenter 1994; Anderson 1999; Griffin and Walters 1999; Maunder and Punt 2004). Further investigation of the ecological consequences of ROFAs for barramundi populations is required, using a number of different sampling techniques rather than just line fishing, before this conclusion can be confirmed.

Investigation of recreational catch data in north Queensland estuaries revealed possible differences in population structure of barramundi in ROFAs compared to estuaries with shared access (Chapter 3) – i.e. there were higher relative (not absolute) abundances of small barramundi but lower abundances of large barramundi in open estuaries compared to ROFAs. Whether the trend found with the recreational catch data is representative of the actual situation requires further investigation. If these differences in population structure are confirmed, why this occurs and what this means for the barramundi populations should be examined. If larger, breeding females are not being captured in large numbers by anglers, ROFAs may prove beneficial to barramundi populations through increased spawning production from relatively high numbers of large females (Garrett 1987). Alternatively these larger barramundi may dominate the populations in ROFAs, resulting in fewer young barramundi surviving due to competition for food or increased cannibalism. Such a situation was speculated by Griffin (1988), who suggested the effect of commercial fishing in the Northern Territory may have been to convert barramundi biomass to a greater number of younger, smaller fish rather than to reduce the numerical abundance of barramundi – if recreational catches reflect the actual population structure, this finding is consistent in north Queensland. Further examination of the relative abundance of small and large barramundi would be beneficial to support this conclusion.

It is also possible that recreational fishing has a greater impact on smaller barramundi, which make up a far greater percentage of anglers' catch (Chapter 3 & 4; QDPI&F unpublished data; Henry and Lyle 2003), compared to commercial fishing which selectively targets larger fish (Russell and Garrett 1985; Halliday et al. 2001). Effects of catch-and-release on stress and survival of undersize barramundi requires further investigation. de Lestang et al. (2004) found barramundi showed significantly elevated stress responses to capture, however post-release survival was high (90.5%). There may be other effects of catch-and-release of large numbers of undersize barramundi, and these require exploration. For example there may be effects on behavior, physical condition, growth, and reproduction (Bartholomew and Bohnsack 2005). There is growing debate regarding the ethics of catch-and-release angling in terms of pain and suffering experienced by released fish. Research suggests that all recreational fishing results in some level of injury and stress to an individual fish, however, the severity of the injury, magnitude of stress, and potential for mortality varies in response to a variety of factors (Bartholomew and Bohnsack 2005). Importantly, investigation into the factors that cause injury, stress and mortality may help to minimise these effects. For example, changes in either gear (e.g., type of hook, bait or net) or angling practices (e.g., duration of fight and air exposure, fishing during extreme environmental conditions, fishing during the reproductive period) may help to improve the welfare of released fish (Cooke and Sneddon 2007). Investigations into selectivity of different line fishing techniques could also assist in reducing the proportion of undersize barramundi caught. Unfortunately, there are no estuaries in Queensland that are closed to all fishing (recreational and commercial) that would allow quantification of the relative impact of recreational line fishing on barramundi populations.

The ecological implications of ROFAs on Queensland's east coast are becoming of increasing importance, particularly since the recent (July 2004) introduction of inshore 'Conservation Park (yellow) zones' by the GBRMPA (Zeller and Snape 2005; Great Barrier Reef Marine Park Authority unknown-b). These areas ban gill netting, and hence are effectively ROFAs for barramundi and other finfish. These 'yellow' zones were implemented with the goal of protecting biodiversity; however, there are many conflicting views regarding the use of ROFAs for conservation purposes. While some proponents of ROFAs believe ROFAs will be able to fulfil sustainability or conservation goals by removing commercial effort, under the assumption that recreational fishers may not completely harvest the available catch that would have been caught by commercial fishers (MacDonald 2003; Rogers and Curnow 2003; Denny and Babcock 2004), others suggest resource allocation and conservation issues should be treated separately, as allocating a resource to one sector does not necessarily address conservation imperatives (Kearney 2003a; MacDonald 2003; O'Regan 2003; Denny and Babcock 2004). In situations where recreational harvest is significant (as a proportion of total harvest) or where effort and catches increase dramatically as a consequence of declaring ROFAs, ROFAs are unlikely to be effective in meeting conservation goals without management intervention to limit or reduce recreational effort (and harvest) (Anon 1995; Hancock 1995; Rogers and Gould 1995; Cox and Walters 2002; Mann et al. 2002; McPhee et al. 2002; Cox et al. 2003; Rogers and Curnow 2003; Sumner 2003; Walters 2003). The potential for ROFAs to fulfil conservation imperatives is explored in more detail in Chapter 1. Whether ROFAs will specifically be effective at achieving the goal of biodiversity conservation within the Great Barrier Reef Marine Park has yet to be determined.

5.2 Implications for future ROFAs

Reallocation of shared fisheries resources from the commercial to the recreational sector via such methods as ROFAs is becoming increasingly common in Australia and other developed countries (Owen 1981; Rogers and Gould 1995; Kearney 2002b; McPhee et al. 2002; Walters 2003). Calls for more ROFAs are likely to continue, particularly in inshore waters and close to population centres where recreational fishing is most popular (Edwards 1991; Ramsay 1995; Scialabba 1998; O'Neill 2000; McPhee et al. 2002). ROFAs are generally a permanent re-allocation of the resource to the recreational sector – there are no published cases of ROFAs being reverted to shared access where the same species are targeted by recreational and commercial fishers (McPhee and Hundloe 2004). Thus whether expected benefits are realised has important implications for the implementation of future ROFAs, particularly given the findings of this study.

Before further ROFAs are introduced, it is important that the goals of the ROFA(s) are specified at the outset. If ROFAs are suggested with the aim of reducing conflict, the nature and source of the conflict must first be determined (Jacob and Schreyer 1980; Aas and Skurdal 1996; Daigle et al. 1996; Scialabba 1998). If increasing contact is resulting in increased conflict, then segregation via ROFAs may be appropriate. Following implementation, anglers should be alerted to the presence of such areas, because in many situations anglers are unaware of changes made for their benefit (Ruello and Henry 1977; The Recreational Fishing Consultative Committee 1994). For example, in southern Queensland, part of the Pumicestone Passage was closed to commercial netting in 1965 to minimise conflict with anglers. Commercial licences were made non-renewable in 1981 meaning the Passage would become a ROFA when the 19 remaining commercial fishers retired. However, anglers appeared unaware of these regulations and pushed for a ROFA which was implemented in 1995

(Gwynne 1995). Such trends are likely to continue unless education campaigns to alert anglers to presence of ROFAs are implemented. Education campaigns for such topics may be made easier if a licensing system for recreational anglers was introduced in Queensland. Recreational fishing licences can be useful for collecting information on participation rates, catch and effort, general awareness of fisheries issues, and attitudes of licensed fishers (Lyle and Smith 1998). These benefits to managers may be reciprocated by allowing a pathway for return of information to fishers (e.g. regarding locations of ROFAs). However, Queensland's recreational fishing lobby group, Sunfish, appear unsupportive of the idea of recreational fishing licences (Sunfish 1998).

If ROFAs aim to segregate commercial and recreational sectors, their success may depend on whether the presence of ROFAs will influence anglers' choice of fishing location, which requires investigation prior to ROFA implementation. Fishing site choice is complex and often dependent on more than one factor (Schramm et al. 2003; Hunt 2005). In north Queensland, anglers are choosing their fishing location independent of the presence or absence of commercial fishing (Chapter 2), though this may vary in other fisheries.

Alternatively, if, as was found in this study, conflict is not caused by increasing contact, segregation via ROFAs may not be appropriate. In many cases conflict results from misperceptions, and thus many conflicts can be resolved through education of, and communication between, the parties involved rather than via ROFAs (Ruello and Henry 1977; Henry 1984; Kearney 1995b; McLeod 1995; Aas and Skurdal 1996; Griffiths and Lamberth 2002). Presence of misperceptions (and associated solutions to) should be investigated before ROFA implementation.

If the goal of ROFAs is to improve recreational catches, the effect of commercial fishing on recreational catches in areas with shared access should first be examined. In many fisheries the perceived effect of commercial fishing on recreational catches has been unfounded (e.g. Henry 1984; Sztramko et al. 1991), although in most cases there is an absence of adequate stock and catch data to determine whether claims of commercial fishing impacts are based on misperceptions or reality (Dovers 1994; Presser 1994; Department of Fisheries Western Australia 2000; Murray-Jones and Steffe 2000; Kearney 2002a). If ROFAs are introduced to improve recreational catches, researchers should aim to collect quality time series recreational catch data from before and after ROFA implementation, to ensure such expected benefits are being realised and to guide whether further ROFAs are appropriate in the future. Collection of data could be aided by allowing anglers to participate in structured research, increasing sample sizes at a reduced cost (Attwood 2003; Bill Sawynok, CapReef, pers. comm., 2007). Such monitoring of recreational catches may serve the additional purpose of determining the effect of recreational fishing effort on fish populations within ROFAs. This would be useful because recreational fishing catch and effort is generally unmonitored and unregulated and can have substantial impacts on fish stocks (Queensland Department of Primary Industries 1995; Rogers and Gould 1995; Sullivan 1997; Cowx 1999; Cox and Walters 2002; Cox et al. 2002; McPhee et al. 2002; Schroeder and Love 2002; Sumner 2003; Walters 2003; Westera et al. 2003; Coleman et al. 2004; Cooke and Cowx 2004; Denny and Babcock 2004).

Unfortunately the present study was not able to also examine the costs of ROFAs; however, given the lack of benefits found it is likely that the costs of implementing ROFAs outweigh the benefits. Costs associated with ROFAs (as outlined in Chapter 1) can include costs to: commercial fishers through loss of fishing grounds; recreational fishers through increased competition with displaced commercial fishers in adjacent areas and potentially within ROFAs from their own sector; the community through potential reduction of local seafood production; and potentially the fish stocks if unmonitored recreational effort increases in ROFAs. It is important that if ROFAs are planned, the potential costs are outlined and are measured post-ROFA implementation to ensure the costs do not outweigh the benefits.

Further, while this study examined the social and some ecological benefits of ROFAs, economic benefits and costs are also of importance. Potential economic benefits, such as increased spending by recreational fishers, are often promoted when ROFAs are requested (Hushak et al. 1986; Dominion 2002; Pereira and Hansen 2003), however few studies measure whether expected economic benefits are realised, and whether these benefits outweigh the costs.

5.3 Conclusion

ROFAs have been used extensively in north Queensland and elsewhere as a fisheries management tool with the primary aims of reducing conflict and enhancing recreational fishing opportunities. ROFAs are often implemented without adequate assessment of costs and benefits, and until now, very little effort has been devoted to measuring the effectiveness of ROFAs regarding whether expected benefits have been realised. This study found that in north Queensland, estuarine ROFAs are not segregating competing recreational and commercial sectors and are not likely to reduce conflict. Increased education and communication is more likely to resolve conflict in this fishery, because the conflict is caused by misperceptions held by fishers from each sector rather than high levels of contact between sectors. Furthermore, current ROFAs are not resulting in improved recreational catches of the shared target species, barramundi. While further investigation into why the expected catch benefits are not occurring is required, these findings have important implications for future ROFAs in north Queensland and elsewhere.

If fisheries managers wish to continue to use ROFAs as a management tool, they must become better prepared to set clear goals and objectives of the ROFA(s), and to examine whether these goals are likely to be achieved by ROFAs. Managers must also aim to monitor expected benefits and costs of ROFAs with quality time series data from before and after ROFA implementation.

The multi-disciplinary approach adopted by this study has proved useful for examining social and ecological effects of ROFAs. Such a multidisciplinary approach should be encouraged and expanded upon in future fisheries research. A more narrow approach may have found different conclusions: for example by examining only the ecological consequences for the fish stocks (e.g. via the Effects of Net Fishing Project), positive benefits of ROFAs could be inferred; however, inclusion of social aspects regarding the resolution of conflict reveals a different result. Future studies should aim to incorporate not just ecological and social aspects, but also economic aspects if possible.

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APPENDICES:

Appendix 1 QUEENSLAND ESTUARIES NORTH OF FRASER ISLAND CLOSED TO COMMERCIAL GILL NET FISHING (I.E. EFFECTIVELY ROFAS FOR FINFISH).

(Areas are listed from south to north, with nearby towns listed for interpretation. List is constructed from Queensland Fisheries Regulations 1995 (Queensland Department of Primary Industries 1995), not including those areas closed only on weekends and for annual spawning closure.)

Region	Estuary name	Part of estuary closed
Bundaberg	Theolodite Creek	Theodolite Creek and waterways joining it upstream of a line between Fish Boundary (F.B) signs near its banks.
	Coonar Creek	Coonar Creek and waterways joining it, upstream of a line between F.B signs near its banks.
	Burnett River	The Burnett River: (a) upstream of a line between F.B signs on opposite sides of the river near its junction with Bundaberg Creek; and (b) downstream of a line between F.B signs on opposite sides of the river near the western tip of Harriett Island.
	Round Hill Creek	Round Hill Creek and waterways joining it, upstream of a line between F.B signs at the creek's northern bank and the northern tip of the Miriam Vale Shire Council Caravan Park at the Town of Seventeen Seventy.
Gladstone	Eurimbula Creek	Eurimbula Creek and waterways joining it, upstream of a line between F.B signs near its banks.
	Rodds Harbour	Rodds Harbour and waterways joining it, within the following boundary: • from the eastern tip of Blackney Point to the eastern tip of Bird Island • to the western bank of Mort Creek, Rodds Peninsula • along the shore to Blackney Point.

	Wild Cattle Creek	(1) Wild Cattle Creek (also known as Red Cliff Creek) between the following lines: (a) a line from an F.B sign at the creek's northern bank to the F.B sign at the northern tip of Wild Cattle Island; (b) a line from an F.B sign about 1600m (measured along the bank) upstream from the F.B sign at the northern tip of Wild Cattle Island to an F.B sign on the opposite bank of Wild Cattle Creek. (2) The waters are closed from 1 September to 30 April.
	Boyne River and part of South Trees Inlet	(1) The Boyne River and waterways joining it, upstream from a line between F.B signs near its banks. (2) South Trees Inlet between the northern edge of the bridge over the inlet on Boyne Island Road and the inlet's junction with the Boyne River. (3) These waters are closed from 1 September to 30 April.
	Tannum Sands	(1) Foreshore waters between F.B signs near the southern bank of the Boyne River and the northern bank of Wild Cattle Creek (also known as Red Cliff Creek). (2) The waters are closed from 1 September to 30 April.
	Calliope River	The Calliope River and waterways joining it, upstream of a line passing through F.B signs on opposite sides of the river near the south-western tip of Farmers Island.
Rockhampton	Fitzroy River and waters near its mouth	The Fitzroy River and waterways joining it, upstream of a line: • from the intersection between longitude 150º40.14' east and the northern bank of the river; • to the intersection between longitude 150º40.34' east and the southern bank of the river.
	Cawarral Creek	Cawarral Creek and waterways joining it, upstream of the line between F.B signs near its banks.
	Causeway Lake, Shoal Bay	Causeway Lake and waterways joining it, upstream of the Shoal Bay Causeway on the Yeppoon–Emu Park Road.
	Water Park Creek	Water Park Creek (which flows into Corio Bay) and waterways joining it, upstream of the shortest line across the creek at the place commonly known as Kelly's Landing (about 2.6km from the creek's banks).

Mackay	Rocky Dam Creek	Rocky Dam Creek (which flows into Llewellyn Bay) and waterways joining it, upstream of a line between F.B signs on opposite sides of the creek about 100m upstream of the creek's junction with Cherry Tree Creek.
	Louisa Creek	Louisa Creek (which flows into Dalrymple Bay) and waterways joining it, upstream of a line between F.B signs near its banks.
	Pioneer River	The Pioneer River and waterways joining it, upstream of the Pioneer Bridge at Mackay.
	Reliance Creek, west of Eimio	Reliance Creek and waterways joining it, upstream of a line between F.B signs near its banks.
	Constant Creek	Constant Creek and waterways joining it, upstream of a line between F.B signs near its banks.
	Seaforth Creek	Seaforth Creek
	Victor Creek	Victor Creek.
Proserpine	Proserpine River	The Proserpine River and waterways joining it, upstream of a line between F.B signs near its banks.
	Pioneer Bay	Pioneer Bay south of the following line: • from an F.B sign at Mandalay Point to an F.B sign near the intersection of Broadwater Avenue and Ocean View Avenue, Airlie Beach • to an F.B sign at the eastern tip of Pigeon Island • to an F.B sign on the mainland shore about 2km south from Bluff Point.
Bowen	Merinda Creek	Merinda Creek (also known as Meatworks Creek) and waterways joining it, upstream of a line between F.B signs near its banks.
	Bowen Harbour and Magazine Island	Foreshore waters of Bowen Harbour, between the southern bank of Doughty Creek and the eastern tip of the harbour's entrance.

Ayr	Groper Creek, Yellow Gin Creek and the Burdekin River	The following waters: (a) Groper Creek and Yellow Gin Creek upstream of a line between an F.B sign on the shore north-easterly of Beach Hill and an F.B sign at the southern tip of Peters Island; (b) the Burdekin River upstream of a line between an F.B sign near the southern tip of Rita Island and an F.B sign at the eastern tip of Peter's Island; (c) waterways joining the waters described in paragraphs (a) and (b).
	Burdekin River	The Burdekin River Anabranch and waterways joining it, upstream of a line between an F.B sign near the anabranch's northern bank and an F.B sign at its opposite bank near the north-eastern tip of Rita Island.
	Plantation Creek and Seaforth Creek	Plantation Creek and waterways joining it, upstream of a line between F.B signs on opposite sides of the creek at the downstream side of its junction with Seaforth Creek.
Townsville	Haughton River and the Short Cut	The following waters: (a) the Haughton River and waterways joining it, upstream of a line between an F.B sign near the river's eastern bank (near Big Beach) and an F.B sign on the opposite side of the river near the north-western tip of Connors Island; (b) the channel commonly known as the Short Cut, between the Haughton River and Barramundi Creek.
	Barramundi Creek	Barramundi Creek and waterways joining it, upstream of a line between F.B signs on opposite sides of the creek near its junction with the channel commonly known as the Short Cut.

	Townsville Harbour and Cleveland Bay	(1) Townsville Harbour between the following lines: (a) a line between an F.B sign near the landward end of the oil tanker berth and an F.B sign at the landward end of the harbour's western breakwater; (b) a line between the seaward tip of the harbour's eastern breakwater and the northern tip of the rocks at the north-eastern end of the western breakwater. (2) Cleveland Bay, outside Townsville Harbour, within 400m of the mainland shore at low water and between the following lines: (a) a line running north-east from the point on the shore (near the landward end of the oil tanker berth) where the eastern breakwater of Townsville Harbour meets the rock seawall at the breakwater's landward end; (b) a line running north-east from Kissing Point. (3) For subsection (2), the mainland shore: (a) at the harbour entrance, is taken to be a line from the seaward tip of the eastern breakwater to the northern tip of the rocks at the north-eastern end of the western breakwater; and (b) is taken to extend to the seaward tip of any artificial structure on the shore.
	Rollingstone Creek	Waters within an 800m radius of the F.B sign near the southern bank of Rollingstone Creek (which flows into Halifax Bay).
Cardwell	Herbert River	The Herbert River and waterways joining it, upstream of the bridge across the river on the Ingham to Halifax-Bemerside Road.
	Meunga Creek	Meunga Creek (which flows into Rockingham Bay) and waterways joining it, upstream of a line between F.B signs near its banks.
	Murray River	The Murray River (which flows into Rockingham Bay) and waterways joining it, upstream of a line running west across the river through the northern tip of the island at the banks of Bedford Creek.

Innisfail	Johnstone River	The Johnstone River and waterways joining it, upstream of a line, across the river, passing through the western tip of Banana Island and the western tip of the island commonly known as Bergin Island.
	Russell River, Mulgrave River and Mutchero Inlet	The Russell River, the Mulgrave River, Mutchero Inlet, and waterways joining the rivers and inlet, upstream of a line between F.B signs at Flirt Point and Constantine Point.
Cairns	Trinity Inlet	Trinity Inlet and waterways joining it, upstream of a line between Stafford Point and the southern landward end of Marlin Jetty at the entrance to the inlet.
	Bloomfield River	The Bloomfield River and waterways joining it, upstream of a line between F.B signs near its banks.
Cooktown	Annan River	The Annan River and waterways joining it, upstream of a line between F.B signs on opposite sides of the river about 800m downstream from the bridge across the river on the Cooktown Developmental Road.
	Endeavour River	The Endeavour River and waterways joining it, upstream of a line between an F.B sign about 400m downstream of the No. 1 Public Wharf at Cooktown and an F.B sign on Sachs Spit about 400m north of Point Saunders commonly known as St. Patrick's Point).

Appendix 2 FISHER QUESTIONNAIRES

A2.1 Recreational fisher access point (boat ramp) survey questionnaire

Ramp:	**Date:** / / 2002	**Time:** : hrs

Note for Interviewer – options to circle are for <u>your</u> use. <u>Prompt only if necessary or for clarification</u>.
Note "ω" symbol for questions relevant to participants who fished <u>estuaries</u> today – not applicable to others.
Extra notes for you are in italics. Fill in dotted lines where possible/necessary.

"First, I'd like to learn to bit about yourself and how you fish."

Demographics:

1. a) Did you <u>estuary</u> fish today[ω]? *(circle)*	No *(go to b)* / Yes *(go to c)*
b) <u>If no</u>, do you fish in estuaries at other times? *(circle)*	<u>Y</u> - usually / sometimes *Continue questionnaire* <u>No</u> – *End & tally. Questionnaire is only applicable to estuary fishers*
c) <u>If yes</u>, which estuary did you fish in today? *(may differ from ramp)*	

2. Are you a boat owner?	Y / N	**3. Sex** *(you circle)*	M / F

4. What is your <u>age</u>[6] group? *(circle <u>one</u>)*	<20 / 20-29 / 30-39 / 40-49 / 50-59 / 60+
5. Are you a member of a <u>fishing club</u> or organisation? *(circle)*	N / Y - **Club**: ……………………………………………………… ANSA / SUNFISH / SUNTAG / AUSTAG

6. What is your <u>home</u> <u>postcode</u>?		**7. What suburb/town did you travel from <u>today</u>[7]?**	

8. On average, how often do you fish per year?[8] *(circle <u>one</u> only, prompt with bottom line)* →	<12 / 12 / 24 / 52 / >52 (<once/month, monthly, fortnightly, weekly, >once a week)
9. How long have you been fishing for (yrs)?	
10. a) What did you hope to catch	Barra / Bream / Fingermark / Flathead / Grunter / Salmon /

[ω] For some ramps, it may that they were reef fishing, or not fishing at all. They may still complete the survey if they estuary fish at other times. *<u>Look for this symbol</u> on other questions below that are applicable only to those who estuary fished <u>today</u>.*

<u>today</u> (target)?[9] *(circle)*	Mangrove jack / Anything / Other …………………………………….
b) What did you catch today?	…………………………………………………………………………………. ………………………………………………………………………………….
11. Which <u>estuary fish</u> do you <u>usually</u> target throughout the year? *(circle)*	Barra / Bream / Fingermark / Flathead / Grunter / Salmon / Mangrove jack / Anything / Other ………………………………………………..
12. ϖ a) What <u>methods</u> did you use to fish <u>today</u>? *(circle)*	Live bait ………………………… / Dead bait ..……………..……. / Lure / Troll / Fly / Other …………………………………………

"Now tell me a bit about <u>where</u> you choose to fish"

Choice of Fishing Location:

13. ϖ a) <u>Why</u> did you choose to fish in your chosen estuary[10] **today?** *(circle any #)*	Favourite / Familiarity[11] / Proximity[12] / Accessibility[13] / Beauty / Reputation[14] / # of recreational boats *(specify* many / few*)* / Other ……………………………………………………………….
b) Do you regularly come here? *(circle)*	First time / Once / Sometimes / Often
14. Are you aware of whether ………. (**the estuary you fished today) is open or closed to estuarine commercial gill net fishing?** (<u>If didn't estuary fish</u>, is <u>this</u> estuary (that ramp is on) open/closed?)	Open / Closed / Partly closed / Don't know
15. What usually <u>affects your choice</u> of fishing location the MOST? *(circle, <u>asterisk main</u> if >1)*	Proximity / Accessibility / Fishing quality / Beauty / Reputation / # of recreational boats *(specify* many / few*)* / Commercial fishing *(specify* presence / absence*)* / Other *(specify)*……………………… ……………………..……………………………………………………

"Now we'll talk about fishing quality"

Fishing quality:

16. a) How would you rate your fishing experience today (as a whole) on a scale of 1 to 5? *(explain and circle)*	1 2 3 4 5 *excellent - avg - terrible*
b) Why? *(circle and specify bracket choice)*	# of fish (high / low) / Size of fish (large / small) / Target (caught / not caught) / Diversity of catch / Take home fish / # of recreational boats (many / few) / Weather (good / bad) / Other …………………………………………………..
17. a) What qualities do you regard as essential for a good estuary fishing day? *(circle)*	Fish size / # caught / Target caught / Diversity of catch / Catch A fish / Take home fish / Beauty of location / Weather / Company[15] / Relax / # of other people *(specify* many / few*)* / Other *(specify)* ……….…………………………..
b) What is the MOST important? *(circle one only)*	Fish size / # caught / Target caught / Diversity of catch / Catch A fish / Take home fish / Beauty of location / Weather / Company[16] / Relax / # of other people *(specify* many / few*)* / Other *(specify)* ………………….……………………

"Now, if you don't mind, I'd like to know your opinion on a few more specific things"

Fishing Opinions

"For many of the following questions I'm trying to gauge the strength of people's opinions. So to make it easier to record your answers, could you please indicate the strength of your opinion in each instance. Please keep your answers simple. There will be room for further comment at the end."

Interviewer to judge strength of opinion and ask for clarification. You may need to prompt.

18. What do you see as biggest threat to estuarine fish stocks in the local area? *(circle one only)*	Habitat loss / Commercial gill-netting / Pollution / Recreational fishing / Over-fishing by all groups / Other (s*pecify)* ………………… ………………………………………………………………………..
19. a) Do you think the number of fish you catch has increased or decreased in recent years? *circle* **–** Don't know / Do know – scale →	1 2 3 4 5 increase - no change - decrease
b) Suspected reasons …………………………………………………………………………………. …….	
20. a) Do you think the number of legal fish you catch has increased or decreased in recent years? *circle* **–** Don't know / Do know – scale →	1 2 3 4 5 increase - no change - decrease
b) Suspected reasons ……………………………………………………………………………….	
21. a) Do you fish in the Dugong Protection Areas?	Yes / No / Don't Know
b) If yes, do you think your catch has changed since they were implemented?	Don't know / No / Yes – how? …………….. ……………………………………….………………

	…………………………………………………….
22.Do you ever buy seafood to eat?	No / Yes - Always / Often / Sometimes / Rarely
23.a) Can you list the fish species caught by the estuarine commercial gill net fishery that operates in this area? (circle)	Don't know / Barra / Bream / Fingermark / Flathead / Grunter / Salmon / Mangrove jack / Mullet / Whiting / Anything / Other ……………….
b) What is the main target?	
24.Do you actively choose not to fish estuaries that are open to estuarine commercial gill net fishing?	1 2 3 4 5 Always- sometimes - don't know - rarely - never
25.a) Do you think competition between recreational and commercial fishers in estuaries is a significant problem in the local area?	1 2 3 4 5 No-minor-don't know-medium-big problem
b) Is it an issue for you?	1 2 3 4 5 No-minor-don't know-medium-big problem
26.Do you think estuarine commercial gill net fishers take more or less fish than the stocks can handle overall (is unsustainable / sustainable)?	Don't know / Sustainable / Unsustainable
27.a) Are you familiar with the estuaries in the local area[17] that are closed to commercial gill net fishing?	All / most / some / none
b) Can you list the ones you know?	……………………………………………………………………………………….……… ………………………………………………………………………………………………. ……………………………………………………………………..
28.Would you expect to catch more fish on an average day in an estuary that is closed to commercial fishing? *circle* – Don't know / Do know – scale	1 2 3 4 5 More - same - less
29.Do you think recreational fishers as a group have an impact on estuarine fish stocks?	1 2 3 4 5 none - minor - don't know - medium - Big
30.Do you think it is necessary to close more estuaries in the local area to commercial gill net fishing?	Yes / No / Don't know
31.If an estuary was closed to commercial fishing, do you think recreational effort (# of people going there) in that estuary would increase as a result?	1 2 3 4 5 Increase - don't know - Decrease
32.Do you think estuarine commercial gill net fishing is important for the community in terms of providing fresh seafood?	Y / N / Don't Know

33. Do you think estuarine commercial gill net fishers take:	
a) a lot of under-size barramundi?	Y / N / Don't know
b) a lot of barramundi over 1m (large female)?	Y / N / Don't know
34. Would you consider closures to recreational fishing in some local estuaries to conserve stocks?	Y / N / Don't know
35. Do you think closing an area to one group for the benefit of the other (sector-specific closures)[18] is fair?	Y / N / Don't know
36. a) Overall, do you like or dislike estuarine commercial gill net fishing? *circle* – Don't know / Do know – scale →	1 2 3 4 5 strongly - Indifferent - strongly like dislike
b) Can you briefly explain why?	
37. If you think resource competition/conflict is a problem, what do you think should be done about it?	
38. Would you like to add anything else briefly?	

End.

A2.2 Commercial gill net fisher questionnaire

DATE: / / 2003	Self administered / Interviewed – Phone / Personal

Please complete the questions below. Your name is not taken, so all answers are ANONYMOUS. The questionnaire is voluntary, so if there are any sensitive questions you'd prefer not to answer, please leave them blank. The rest of the questionnaire will still be valid.

Please write as clearly as possible, and don't hesitate to ask questions. Dotted lines are for written answers. Options to circle are provided in most cases. Some options have footnotes to help at the bottom of the page.

First, I'd like to learn to bit about you and how you fish.

DEMOGRAPHICS:

1. Do you gill net fish for barramundi? *(circle)*	No *(STOP! Don't do survey)* / Yes *(continue below)*
2. Do you own or lease your net license? *(circle)*	Own / Lease
3. What is your <u>age</u> group? *(circle <u>one</u>)*	<20 / 20-29 / 30-39 / 40-49 / 50-59 / 60+
4. What is your <u>gender</u> *(circle)*	Male / Female
5. What is your <u>home</u> <u>postcode</u>?	48……
6. On average, how <u>often</u> do you gill net fish per season? *(circle <u>one</u> only)*	<12 / 12 / 24 / 52 / >52 (<once/month, monthly, fortnightly, weekly, >once a week)
7. How <u>long</u> have you been <u>fishing</u> for (including <u>personal</u> fishing)?	…………….yrs
8. How <u>long</u> have you been specifically <u>commercially</u> fishing for (yrs)?	…………….yrs
9. How long have you been <u>specifically</u> <u>gill net</u> fishing for (yrs)?	…………….yrs *(may be same as Q7.)*
10.a) Is commercial fishing in your <u>family</u> (eg. Your father/uncle fished commercially)? *(circle)*	Yes *(see b & c)* / No / Don't know
b) If yes, how many generations? (including you – eg. If you're the first in your family, generations = 1)	1 / 2 / 3 / >3 (you / parents / grandparents / more)
c) and if >1 generation, what <u>type</u> of fishing did they do? (eg. line, gill net, trawl, etc)	………………………………………

11. Why did you choose to go fishing	Lifestyle / Money / Family history / No other experience /

commercially? *(circle)*	Other ………………………………………………………………
12. Is gill net fishing your primary source of income? *(circle)*	Yes / No – what is? ………………………………………………. ………………………………………………………………………..
13. Which fish do you mostly target when gill net fishing? *(circle one only)*	Barra / Salmon / Mackerel / Mullet / Other……………………………………………………………….
14. What other species do you regularly keep when gill netting?	Barra / Salmon / Mackerel / Mullet / Fingermark / Mangrove Jack / Shark / Bream / Other……………………… ………………………………………………………………………..
15. What other species do you regularly catch but discard when gill netting?	Salmon / Mackerel / Mullet / Fingermark / Mangrove Jack / Shark / Bream / Other……………………………………… ……………………………………………………………………….
16. Do you also commercially crab? *(circle)*	No / Yes - rarely / sometimes / often
17. a) Do you fish recreationally? *(circle)*	No / Yes - rarely / sometimes / often
b) What species do you usually target when recreationally fishing? *(circle)*	ANYTHING / Barra / Bream / Fingermark / Flathead / Grunter (javelin) / Mangrove jack / Salmon / Whiting / Other …………………………………………………………

CHOICE OF FISHING LOCATION:

18. Please tell me which estuaries/areas you fish and the percentage of time you spend in each of them per year. (Eg. Barrattas 80% of the time)	**Estuary**	**% time**
	……………………………………………………	……………
	……………………………………………………	……………
	……………………………………………………	……………
	……………………………………………………	……………

19. a) For the estuary you fish in the <u>most</u> often, w<u>hy</u> do you choose to fish there? *(circle any # - please feel free to add others. See bottom of page for help with terms)*	Good catches / Favourite / Familiarity[19] / Proximity[20] / Accessibility[21] / Beauty / Reputation[22] / few recreational boats / few other commercial boats/ Other ……………………………………………………………………
b) If you circled more than one, what is <u>MOST</u> important?	…………………………………………………………………..

FISHING QUALITY:

20. What do you regard as essential for a <u>good</u> fishing trip/experience overall? *(circle any number)*	Lots of barramundi / Low bycatch / Size of barramundi / Company[23] / # of other boats *(specify* many / few*)*/ Beauty of location / Weather / Other *(specify)* ……………… …………………………………………………………………..
b) If you circled more than one, what is the MOST important?	……………………..………………………………………… ……………………………………………………………………….

	kg	**Number**
21. a) What do you regard as a <u>good</u> catch for a trip?		
b) What do you regard as <u>average</u> for a trip?		
c) What do you regard as a <u>bad</u> catch for a trip?		
d) Do you have many <u>zero</u> catch nights?	None / Some / Many	

22. Do you have an <u>optimal/preferred size</u> of barramundi to catch?	Yes / No / Don't know
b) If yes, what is your preferred size range?	………………………… kg / cm (*specify)*
c) Why? (eg. Market	……………………………………….. …………………………………………

[1]. Familiarity = come often, know how to fish it, etc. (Similar to favourite.)

[2]. Proximity = close to home

[3]. Accessibility = ease of access due to ramp / road access

[4]. Reputation = reputation for good fishing – from friends or media.

[5]. Company = people fishing with

demand for this size)	………………………………………………………………………………...

23. What mesh size do you usually use the most?	4" / 5" / 6" / 6.5" / 7" / 7.5" / 8" / ……………

Opinions

Now, if you don't mind, I'd like to know your opinion on a few more specific things. For many of the following questions I'm trying to gauge the strength of your opinions. So to make it easier to record your answers, could you please indicate the strength of your opinion where appropriate (on the 1-5 scale).

Please keep your answers simple. There is some room for brief comments on some questions, and there is also room for more detailed comment at the end.

24. What do you see as biggest threat to estuarine fish stocks in the local area?	……………………………………………………………………………….. ……………………………………………………………………………….
25. a) Do you think your total catch (all fish) has increased or decreased in recent years? *circle* – Don't know / Do know – scale →	1 2 3 4 5 increase - no change - decrease
b) Why do you think this has happened?……………………………………………………………………….. ………..	
26. a) Do you think the number of LEGAL barramundi you catch has increased or decreased in recent years? *circle* – Don't know / Do know →	1 2 3 4 5 increase - no change - decrease
b) Why do you think this has happened?……………………………………………………………………….. ………..	
27. a) Did you used to fish in what are now the Dugong Protection Areas (DPAs) before they were implemented in 1997? *(circle)*	Yes *(see b & c)* / No / Don't Know
b) If yes, where?	…………………………………………………………………………………………………..
c) If yes, did the implementation of the DPAs affect you?	Yes *(see i)* / No / Don't know
i) If yes, how? *(circle)*	reduced income / fish other areas / reduced catch / Other …………………………….. …………………………………………………………………………………………………
28. Do the current estuary closures (non-DPAs) for commercial gill netting affect you? *(circle)*	Don't know / No / Yes – How? ………….. ………………. …………………………………………………………………….
29. Do the current time restrictions for commercial gill netting affect you (eg. No gill netting in estuaries on weekends)**?** *(circle)*	Don't know / No / Yes – How? ………….. ……………… ……………………………………………………………….…… ……………………………………………………………….…....

30. Do you <u>actively</u> choose <u>not</u> to fish in estuaries that are heavily fished by <u>recreational anglers</u>? *(circle)*	1 2 3 4 5 Always / sometimes / don't know / rarely / never
31. a) Do you think <u>competition/conflict</u> between recreational and commercial fishers in <u>estuaries</u> is a <u>significant problem</u> in the local area? *(circle)*	1 2 3 4 5 No / minor / don't know / medium / big problem
b) Is it an <u>issue for you personally</u>? *(circle)*	1 2 3 4 5 No / minor / don't know / medium / big problem
c) How/why?	…………………………………………………………………………………………..
32. a) Do you think the East Coast commercial gill net fishery is <u>unsustainable</u> / <u>sustainable</u> at current levels? *(circle)*	Don't know / Unsustainable / Sustainable
b) Briefly, is there anything you would like to <u>change</u> to ensure its sustainability?	…………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………
33. Do you think the <u>recreational</u> estuarine fishery is <u>unsustainable</u> / <u>sustainable</u> at current effort levels? *(circle)*	Don't know / Unsustainable / Sustainable
34. Do you think the <u>Qld east coast commercial gill net</u> sector catches <u>more or less barramundi per year</u> than the <u>recreational</u> sector for the same area? *circle* – <u>Don't know / Do know</u> →	1 2 3 4 5 More → same → less
35. Do you think <u>closing</u> an estuary to <u>commercial</u> gill netting is <u>effective in conserving fish stocks</u>? *(circle)*	Yes / No / Don't know
b) Do you think these closures are beneficial to you?	Don't know / No / Yes – How? ……..………………………. ……………………..……………………..………………………
36. Let me give you 3 scenarios: **Would you expect to <u>catch more fish</u> in an estuary that was <u>re-opened</u> after it was:**	
a) Closed to <u>all</u> fishing? *circle* – <u>Don't know / Do know</u> →	1 2 3 4 5 More - same - less
b) Closed to <u>commercial</u> fishing only? *circle* – <u>Don't know / Do know</u> →	1 2 3 4 5 More - same - less
c) Closed to <u>recreational</u> fishing only? *circle* – <u>Don't know / Do know</u> →	1 2 3 4 5 More - same - less

37. a) Do you think that <u>recreational fishers</u> catch more fish on an <u>average day</u> in an estuary that is <u>closed</u> to commercial fishing? *circle* **–** Don't know / Do know →	1 2 3 4 5 More - same - less
b) Why?	…………………………………………………………………………………………..

38. Do you think <u>recreational</u> fishers as a <u>group</u> have an <u>impact</u> on estuarine fish stocks? *(circle)*	1 2 3 4 5 none / minor / don't know / medium / Big
39. Do you think it is <u>necessary</u> to <u>close</u> more estuaries in the local area to <u>commercial gill net</u> fishing? *(circle)*	Yes / No / Don't know
b) If more estuaries were closed to commercial fishing, <u>would it affect you</u>? *(circle)*	Don't know / No / Yes – How? ………….. ………………..… …………………………………………………………………… ……………………………………………………………..……..
40. If an estuary was <u>closed</u> to <u>commercial</u> fishing, do you think <u>recreational effort</u> in that estuary would <u>increase</u> as a result? *circle* **–** Don't know / Do know →	1 2 3 4 5 Increase - No change - Decrease
41.a) Do you think estuarine <u>commercial gill net</u> fishing is <u>important</u> for the <u>community</u> in terms of providing fresh seafood? *(circle)*	Yes / No / Don't Know

	Location	Percentage
42. a) To your knowledge what <u>percentage</u> of your fish product is <u>sold</u> locally (in Townsville), elsewhere in Qld, interstate or overseas?	Local	…………….
	Queensland	…………….
	Interstate	…………….
	Overseas	…………….

43. Do you ever <u>buy</u> seafood to eat? *(circle)*	No / Yes – always / often / sometimes / rarely

44. Do you think the <u>current net size/mesh restrictions</u> are effective in <u>minimising catch</u> of: *(circle)*

a) <u>under-size</u> barramundi?	Yes / No / Don't know
b) barramundi <u>over 1m</u> (large female)?	Yes / No / Don't know
c) <u>bycatch</u>/non-target species?	Yes / No / Don't know

45. **Do you think <u>recreational</u> fishers <u>regularly</u> take or keep:** *(circle)*	
a) <u>under-size</u> barramundi?	Yes / No / Don't know
b) barramundi <u>over 1.2m</u> (large female)?	Yes / No / Don't know
c) more than their allowed bag limit?	Yes / No / Don't know
d) fish to sell on the black market?	Yes / No / Don't know
46. Do you think we should <u>close</u> some local estuaries to <u>recreational</u> fishers, leaving those estuaries as '<u>commercial only</u>'? *(circle)*	Yes / No / Don't know
47. As a <u>trade-off</u>, would you consider <u>closures to commercial fishing</u> to make some areas 'recreational only' if there were <u>closures to recreational fishing</u> to make some areas 'commercial only'? *(circle)*	Yes / No / Don't know
48. a) Would you consider <u>closing</u> some estuaries to <u>all</u> fishing to conserve stocks? *(circle)*	Yes / No / Don't know
b) If yes, would you see this as <u>beneficial to you</u>? *(circle)*	Yes / No / Don't know
49. a) Do you think <u>closing an area to one group for the benefit of the other</u> is <u>fair</u> (either group)**?** *(circle)*	Yes / No / Don't know
b) Why?	…………………………………………………………………………………………………..
50. a) Overall, do you <u>like or dislike</u> <u>recreational</u> fishers? *circle* – <u>Don't know / Do know – scale</u> →	1 2 3 4 5 strongly like - Indifferent - strongly dislike
b) Can you briefly explain why?	……………………………………………………………………………………….. ………………………………………………………………………………………… ………………………………………………………………………………………..
51. If you think resource competition/conflict is a problem, <u>what do you think should be done about it</u>?	………………………………………………………………………………................. .... ……………………………………………………………………….……………… ………………………………………………………………………………………… ……………………………………………………………….……………………… …………………………………………………………………………………………

52. Would you like to add anything else briefly?	……………………………………………………………………………… ……………………………………………………………………………… ……………………………………………………………………………… ……………………………………………………………………………… ……………………………………………………………………………… ………………………………………………………………………………

END.

Appendix 3 TIMETABLES FOR THE RECREATIONAL FISHER ACCESS POINT (BOAT RAMP) BUS ROUTE SURVEYS.

A3.1 Bus route survey sampling days: routes and start points.

Date	Day-type	Route #	Start ramp
23/3/02	Weekend	3	Stoney Creek (Bohle Rv)
24/3/02	Weekend	1	Groper Creek Settlement
25/3/02	Week day	3	Balgal Beach (Rollingstone Ck)
26/3/02	Week day	1	Phillips Landing
27/3/02	Week day	4	Cardwell (Sheridan St)
29/3/02	Public holiday (weekend)	2	National Park Ramp (Ross Rv)
30/3/02	Weekend	4	Taylors Beach (Victoria Ck)
31/3/02	Weekend	3	Toomulla
1/4/02	Public holiday (weekend)	1	Wallace Landing (Yellowgin ck)
3/4/02	Week day	2	Barrattas River (Jerona huts)
5/4/02	Week day	1	Plantation Creek
7/4/02	Weekend	4	Port Hinchinbrook
9/4/02	Week day	2	Barramundi Creek
10/4/02	Week day	4	Dungeness (Lucinda)
11/4/02	Week day	3	Saunders Beach
12/4/02	Week day	4	Fishers Creek
13/4/02	Weekend	3	Saunders Beach
14/4/02	Weekend	1	Molongle Creek
16/4/02	Week day	3	Bluewater (Bluewater Rd)
17/4/02	Week day	2	National Park Ramp (Ross Rv)
20/4/02	Weekend	4	Taylors Beach (Victoria Ck)
21/4/02	Weekend	2	Cocoa Creek
24/4/02	Week day	1	Ocean Creek
25/4/02	Public holiday (weekend)	2	Cocoa Creek

Appendix 4 QDPI&F Charter Fishing Catch Logbook

A4.1 Example Charter fishing logbook page

Queensland Commercial Fishing Tour Logbook (CV03)

Log No: | Page No: | Vessel Name: Gin | MONTH: August | YEAR: 2003

Business Stamp

BOAT ACTIVITY CODE
0 ....Fishing/Searching
1 ....Not fishing - Weather
2 ....Not fishing - In Port
3 ....Not fishing - Broken down
4 ....Not fishing - Steaming
5 ....Not fishing - Other
10 ....Not fishing - Refit
12 ....Fishing in other fishery

PRM 00444E

Skipper's Name: Rolling Windman

Owner's Name: Rolling Windman

Day	Trip start	Daily Activity	Location: Grid/Reference Lat/Long River/Reef name	Effort: No dories fishing	Effort: No people fishing	Effort: Number guests	Effort: B=Bait L=Lure S=Speargun (Please list)
1		2					
2		2					
3		2					
4		2					
5		0	H15/23		7	8	B
6		0					
7		0					
8		2					
9		2					
10		2					
11		0	H15/23		9	9	BL
12		0	H15/23		9	9	BL
13		2					
14		2					
15		2					
16		2					
17		0	H14/22		10	10	BL
18		0	H14/22		10	10	BL
19		0	H14/22		10	10	BL
20		2					
21		2					
22		2					
23		2					
24		2					
25		2					
26		2					
27		2					
28		2					
29		2					
30		2					
31		2					

	CoralTrout			Red Emperor			BlackJew						Whiting			Cobia		
Day	Kg	No	R	Kg	No	R	Kg	No	R	Kg	No	R	Kg	No	R	Kg	No	R
1																		
2																		
3																		
4																		
5	30	20		5	1		6	1										
6																		
7																		
8																		
9																		
10																		
11	5	7		6	1		1	3					1	20				
12							4	1								6	1	
13																		
14																		
15																		
16																		
17	9	10											2	20				
18	12	10		4	1		7	1					4	30				
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26																		
27																		
28																		
29																		
30																		
31																		

	Spanish Mackerel			Bream			Flathead											
Day	Kg	No	R	Kg	No	R	Kg	No	R	Kg	No	R	Kg	No	R	Kg	No	R
1																		
2																		
3																		
4																		
5																		
6																		
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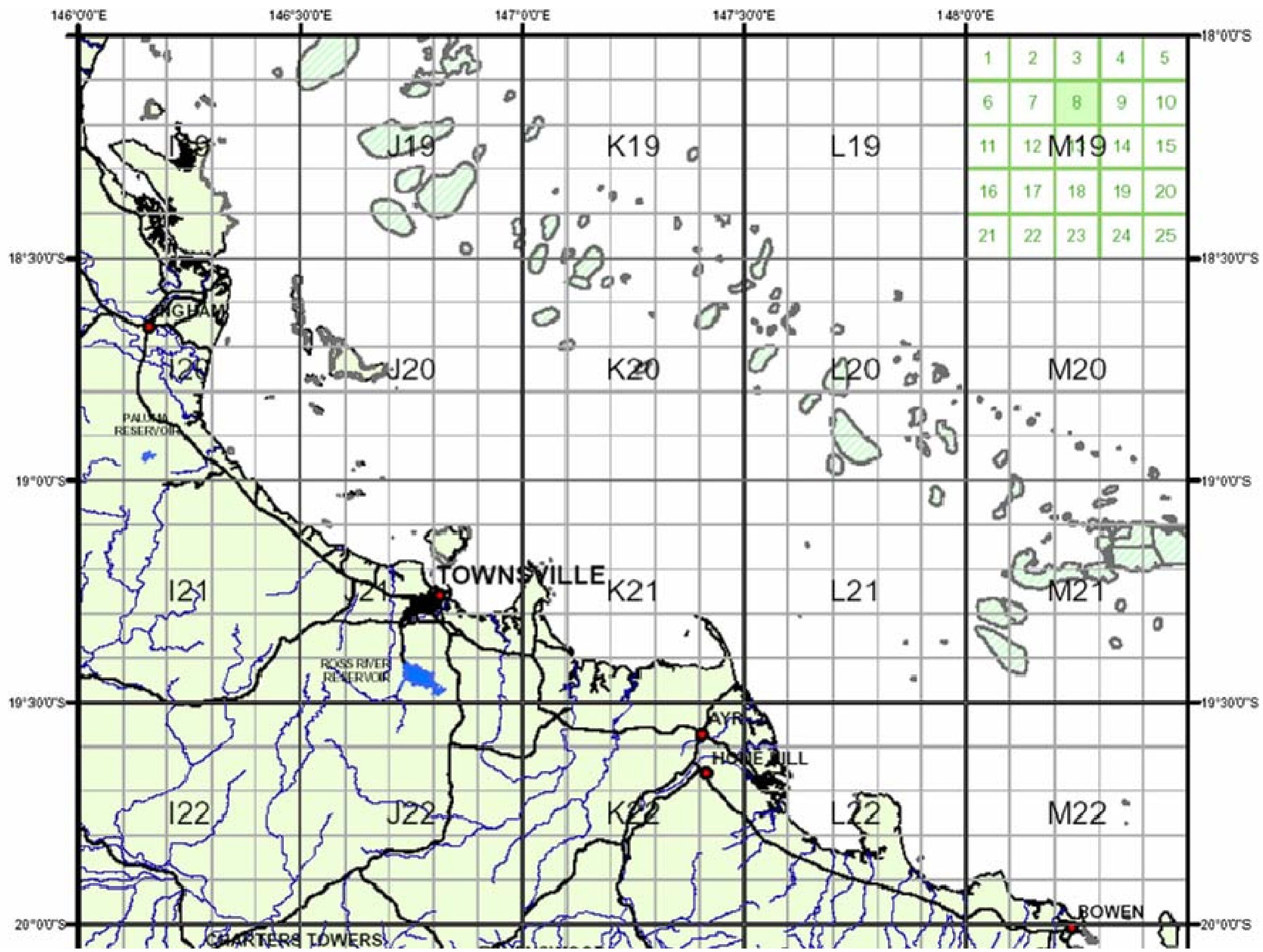
31																		

Provided by QDPI&F

A4.2 Map of study area showing grids used within Charter fishing logbooks



Provided by QDPI&F

Appendix 5 RECREATIONAL FISHER CATCH LOGBOOK

A5.1 Introduction page

Name: ____

Address: ____

____

Phone: ____________ **(H)** ______________ **(W)** ______________ **(M)**

Email: ____

Days usually spent fishing per year (circle one):

<12 / 12 / 24 / 52 / >52

Would you like a copy of your data returned? Yes / No

Explanatory notes:

Please fill out one page (fishing details and catch) for each day of fishing. Remember that no catch is still data, so please fill in the logbook even if you don't catch any fish! Please make it clear though – eg. write 'no catch' across the catch table.

To explain the categories above, 'time spent fishing per year' gives an indication of your effort level. '<12' = less than once a month, '12' = once a month, '24' = twice a month, and '52' = once a week, etc. Please indicate where you fit best in these categories.

To assist you, a worked example of the data sheets is given on the opposite page. Please take the short time needed to fill in your diary on each fishing trip.

'Launch site' is the place you launched your boat eg. 'National Park ramp' might be appropriate for the Ross River. However if you are not fishing from a boat, please enter the location you are fishing from, eg. 'beside National Park ramp', and note that you are not fishing from a boat.

'Actual time spent fishing' is the time you spent with your lines in the water, not including the time spent travelling from the boat ramp to the fishing site. This can be estimated, such as '2½ hrs'.

'Average number of lines used' means the average number of lines that were in the water over the actual time you spent fishing. Eg. If there were 2 anglers, but you had one extra line in the water as well as the one line you were each attending, the average number of lines would be 3.

For 'species targeted' and 'methods used' you may circle more than one choice if needed, however please list the main target and method in the spaces provided.

Rating of fishing – circle the category that best fits your day. Eg. if you caught heaps of fish and consider it an excellent fishing day, circle '1'. Please give a reason for your choice.

Method of fish measurement is total length, i.e. from the snout to the end of the tail.

Please give measurements as accurately as you can. Indicate clearly if the length was estimated. If you have forgotten to take a measure, please indicate if the fish was legal size or under-size. If you don't have a tape or a measuring sticker on board, contact Renae and she may be able to provide you with one.

If you have a great day and catch more fish than room allows, go on to the next page, making sure it's clear that it's for the same day.

A5.2 Logbook data page

Date:	Creek/River name:
Time boat launched:	Launch site:
Time boat retrieved:	**Actual time spent fishing:**
# of anglers:	Avg # of lines used per boat:

Reason for choice of creek/river (e.g. proximity/favourite, etc):

Location: River 'proper' River mouth Upper reaches

Tide (circle): ebb flood bottom of low top of high

Species targeted: Barramundi Mangrove Jack Fingermark Grunter
(circle) Salmon Anything Other (specify:)

Main target species:

Methods used: lure fly dead bait live prawn
(circle) live fish (species:)

Main method:

Comments:

How would you rate the fishing?: 1 2 3 4 5
(excellent → average → terrible)

Why?

Your Catch

Species	Length (mm TL)	Method of capture	Fate Kept/Rel	Tagged? (if yes, give tag #)

A5.3 Cover letter

Dear (name),

Thank you for your interest in participating in the estuarine fishing project. Your help is greatly appreciated!

Please find enclosed a catch logbook for you to fill in on your next fishing trips. At this stage of the project I am hoping that people will be able to let me know if the books are user friendly and easy to understand. They are relatively short in order to keep regular contact and also so books can be adjusted if the first one does not suit your needs. Explanatory notes are included in the front of the book. Suggestions for improvements are always welcome.

The data received from recreational anglers throughout the project will help to depict line catch trends in open and closed estuaries. In order for this data to be defensible and useful, your honesty in depicting your catch is crucial. This does of course include days when <u>no fish are caught</u>. When you do catch a few, all fish that were <u>released as well as kept</u> must be recorded. All data received are STRICTLY confidential.

The logbook is printed on waterproof paper, which makes it suitable for use while fishing. It is preferable that the logbook is filled out while fishing, rather than when fishers return from their trip and attempt to remember their catch. A pencil has been provided, as ink pens do not work well on this paper. There are explanatory notes in the front of the logbook. Please take the time to read through them. If you have any further questions, please don't hesitate to call. I'm available workdays on the number below.

Please return the logbook in the envelope provided when you have completed the book. I can send you more books when the first one is returned if you wish to continue collecting data. Please indicate on the back of the logbook…

Thanks again for your enthusiasm and participation. I look forward to hearing from you soon. Happy fishing!

Regards,

Renae Tobin.

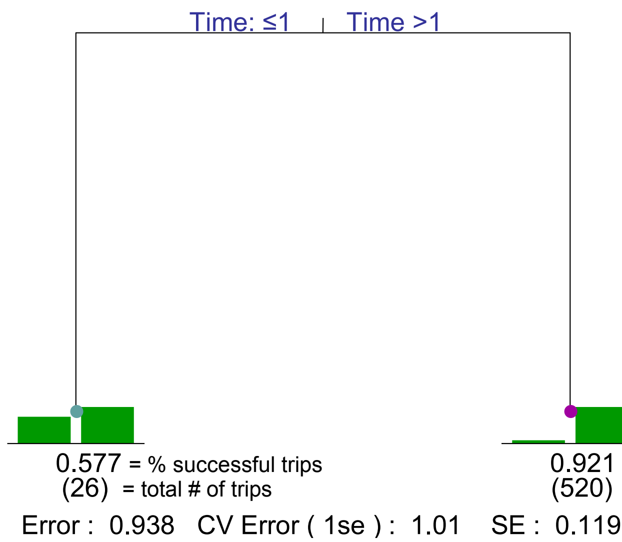
Appendix 6 CLASSIFICATION AND REGRESSION TREES FOR VOLUNTARY RECREATIONAL CATCH LOGBOOK DATA

This appendix contains all Classification and Regression Trees (including those resulting from the 1-SE and min-CV error rules) for the voluntary recreational catch logbook data. The 1-SE trees are shown within Chapter 3 but are repeated here for ease of interpretation.

A6.1 Effect of fishing factors on success rate

CARTs for ‘all fish’ revealed time spent fishing had the greatest effect on success rate, with those anglers fishing for more than 1 hour providing a greater percentage of successful trips (see 1-SE CART, Figure A6.1 a). The min-CV error CART (Figure A6.1 b) revealed those trips lasting for more than 4 hours tended to have the highest success rate, and that the logbook holders’ fishing more frequently (i.e. in higher avidity category) tended to be more successful.

a)



b)

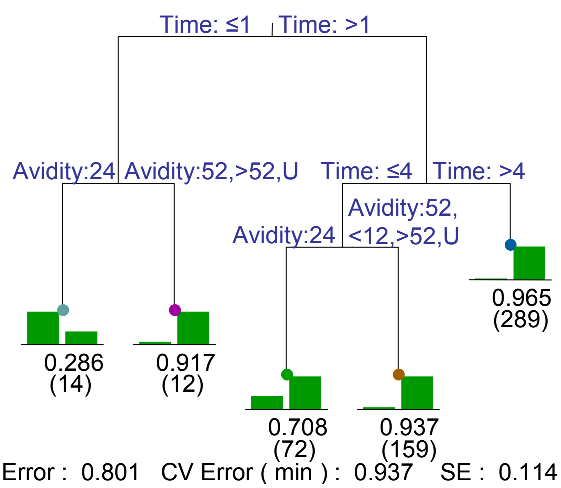


Figure A6.1: Classification and Regression Tree (CART) with the: a) 1-SE rule; and b) min-CV error rule examining the effect of various fishing factors on the percentage of successful (for catching at least one fish) trips for 'all fish'. "Error" refers to the amount of variability in the data unexplained by this model (80.1% in this case). Vertical length of each branch represents the relative amount of variation explained by each split. The graphs for each node show relative number of unsuccessful and successful trips, with % success (and number of trips) listed below.

Key: Time = time spent fishing (hrs) rounded up to nearest hour; Avidity = avidity category (see Chapter 3 for categories).

For ‘all barramundi’, fishing method was the most influential factor on success rate, with artificial baits providing a higher percentage of success days than the other fishing methods. Time spent fishing was also important for those fishers using artificial baits (trips of more than 3 hours duration provided higher success rates), and bay for those using bait or mixed methods (Upstart Bay had lower success rates than all other bays) (Figure A6.2).

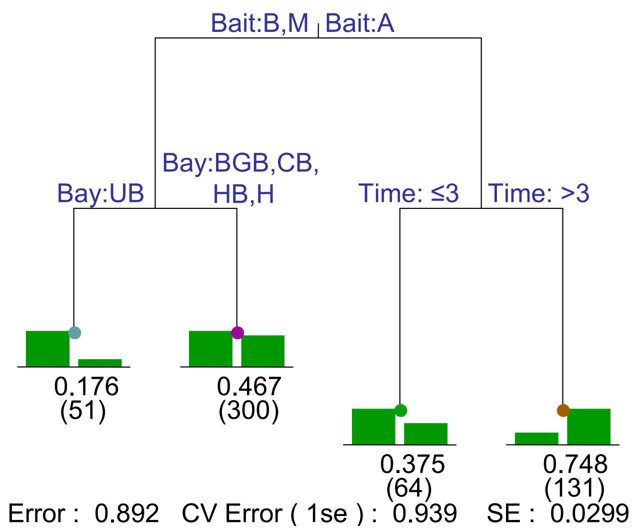
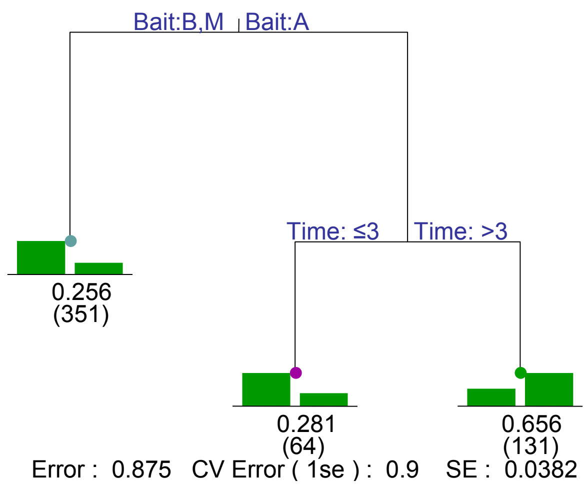


Figure A6.2: CART with the 1-SE rule examining the effect of various fishing factors on the percentage of successful (for catching at least one fish) trips for all barramundi. The min-CV error tree was identical to the 1-SE tree so only the 1-SE tree is shown here.

Key: Bait – B = bait, A = artificial bait, M = mixed real and artificial bait; Time = time spent fishing (hrs); Bay – BGB = Bowling Green Bay, CB = Cleveland Bay, HB = Halifax Bay, H = Hinchinbrook, UB = Upstart Bay.

Fishing method (again trips using artificial baits had higher success rates than trips using other methods) and time spent fishing (for those using artificial baits again trips of over 3 hours duration had higher success rates) were also the most important factors influencing success rate for undersize barramundi catch (Figure A6.3 a), however the min-CV error CART (Figure A6.3 b) also revealed the influence of other factors – of most interest is the influence of management status for those trips using artificial baits for 3 or less hours (“<3.5”), where those trips in the open estuaries showed a higher success rate than those in ROFA or part-ROFA estuaries.

a)



b)

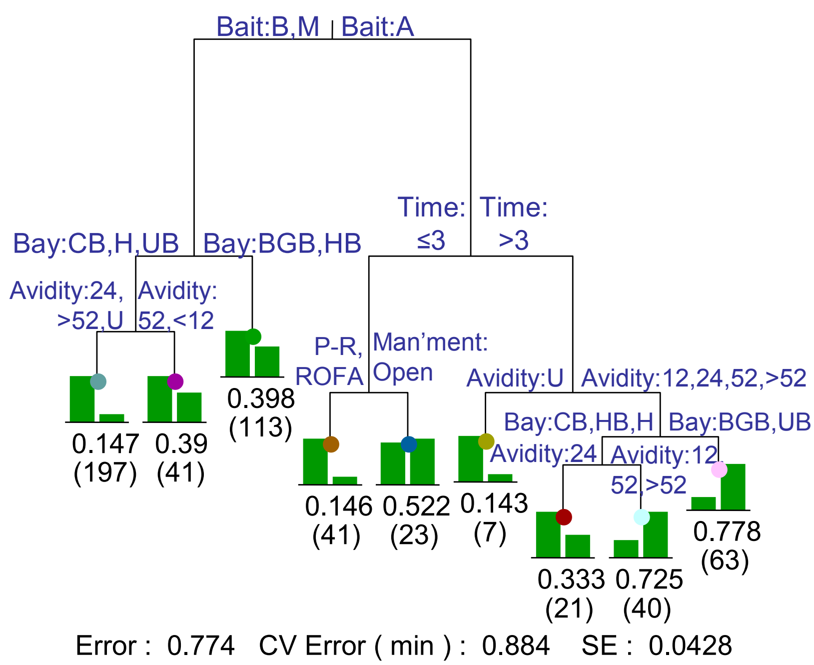
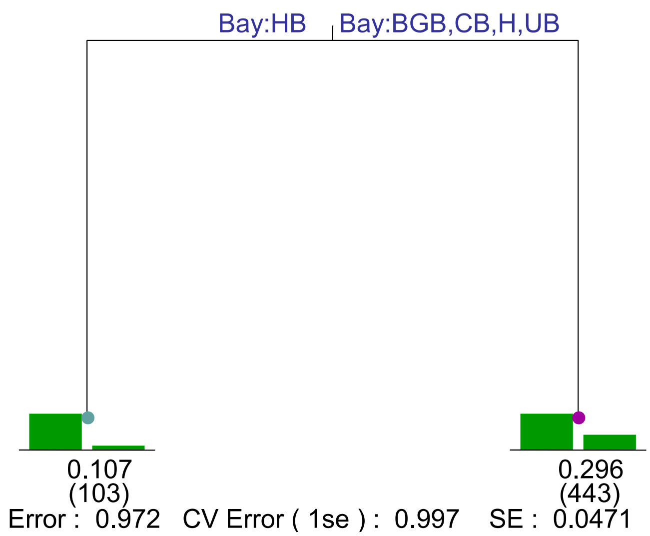


Figure A6.3: CART with the: a) 1-SE rule; and b) min-CV error rule examining the effect of various fishing factors on the percentage of successful (for catching at least one fish) trips for undersize barramundi.

Key: Bait – B = bait, A = artificial bait, M = mixed real and artificial bait; Time = time spent fishing (hrs); Bay – BGB = Bowling Green Bay, CB = Cleveland Bay, HB = Halifax Bay, H = Hinchinbrook, UB = Upstart Bay; Management – O = Open, P-R = Part-ROFA, ROFA = ROFA; Avidity = avidity category.

Bay fished had the most influence on success rate for catching legal-sized barramundi, with Halifax Bay providing a lower success rate than all other bays (Figure A6.4 a), however further examination via the min-CV error rule revealed open and ROFA estuaries had higher success rates than part-ROFA estuaries, and the number of lines used per angler was also important (those fishing parties using 2.5 lines per angler had the highest success rate) (Figure A6.4 b).

a)



b)

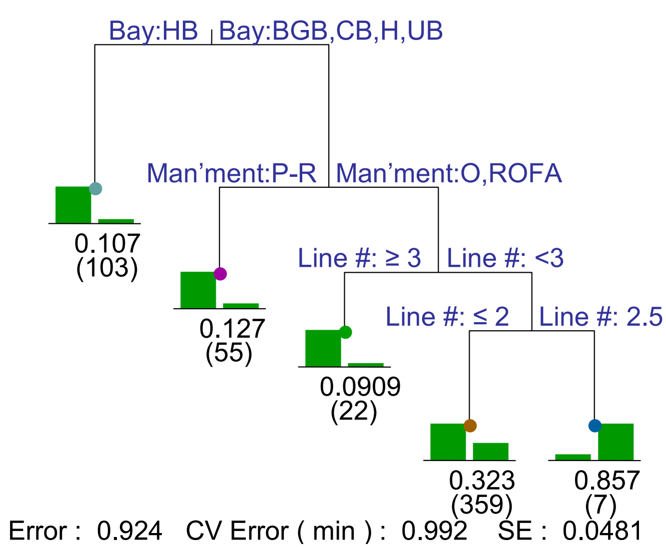


Figure A6.4: CART with the: a) 1-SE rule; and b) min-CV error rule examining the effect of various fishing factors on the percentage of successful (for catching at least one fish) trips for legal-sized barramundi.

Key: Bay – BGB = Bowling Green Bay, CB = Cleveland Bay, HB = Halifax Bay, H = Hinchinbrook, UB = Upstart Bay; Management – O = Open, P-R = Part-ROFA, ROFA = ROFA; Line # = line number per angler.

A6.2 Effect of fishing trip factors on CPUE for successful trips

A6.2.1 Effect of time spent fishing

Time spent fishing per trip had a variable effect on CPUE for the barramundi fish groups: those parties fishing for 1 hour or less provided a higher CPUE (partly due to the effect of multiplying catch to be equivalent to one hour of fishing), however less than 3% of successful fishing trips were within this time category. The remaining time categories showed no difference in CPUE when examined within CARTs (Figure A6.5).

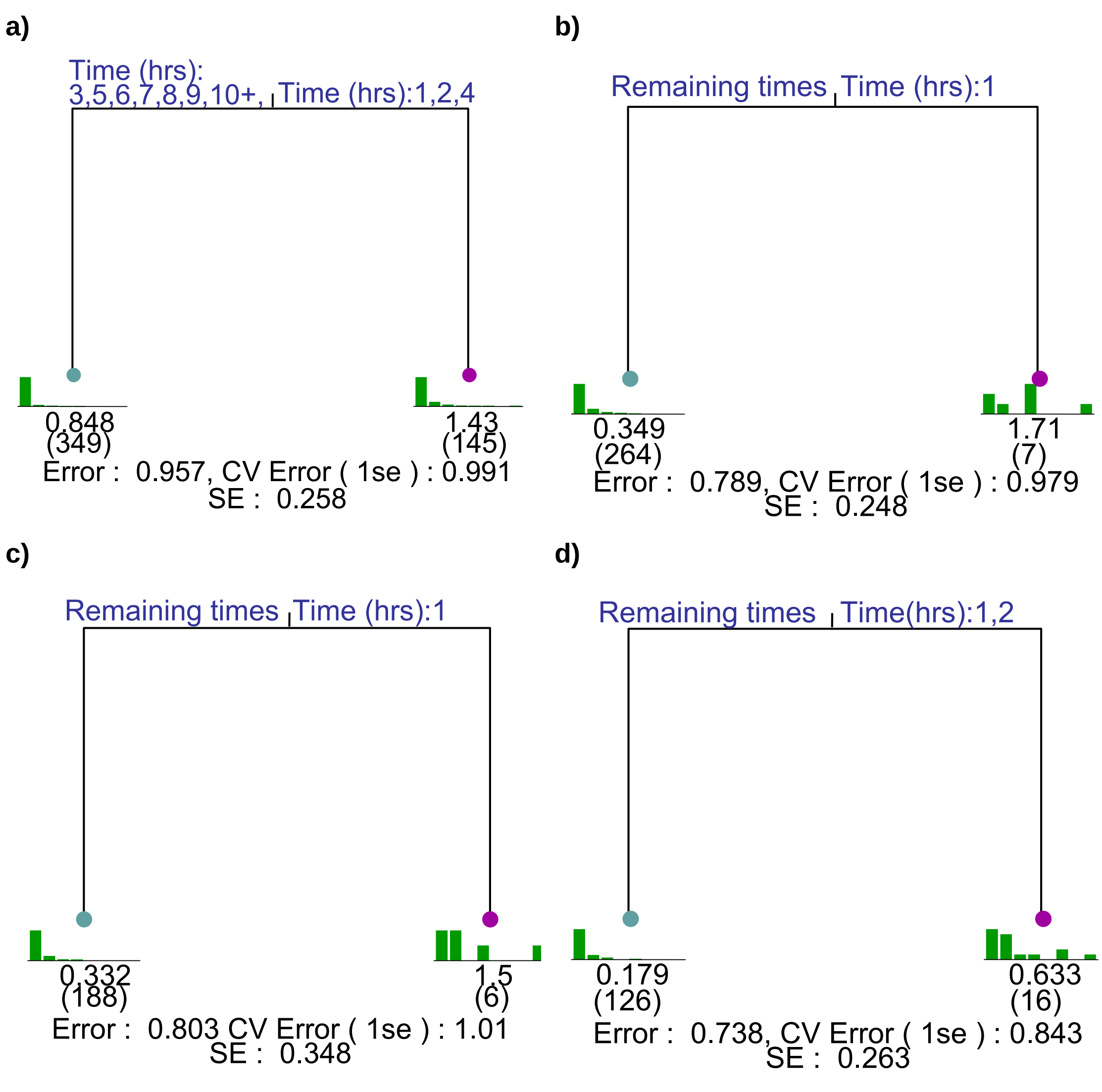


Figure A6.5: CARTs with the 1-SE rule for: a) all fish species; b) all barramundi; c) undersize barramundi; and d) legal-sized barramundi, examining the effect of time spent fishing on catch per unit effort for successful fishing trip.

Time spent fishing was rounded upwards to the nearest hour, and all trips of more than 10 hours duration were grouped.

A6.2.2 Effect of avidity category

Fishing parties with logbook holders within the '52' (fish once a week) category provided trips with a higher CPUE for all fish groups (although fishers within the '>52' category also provided higher CPUEs for legal-sized barramundi catch) (Figure A6.6).

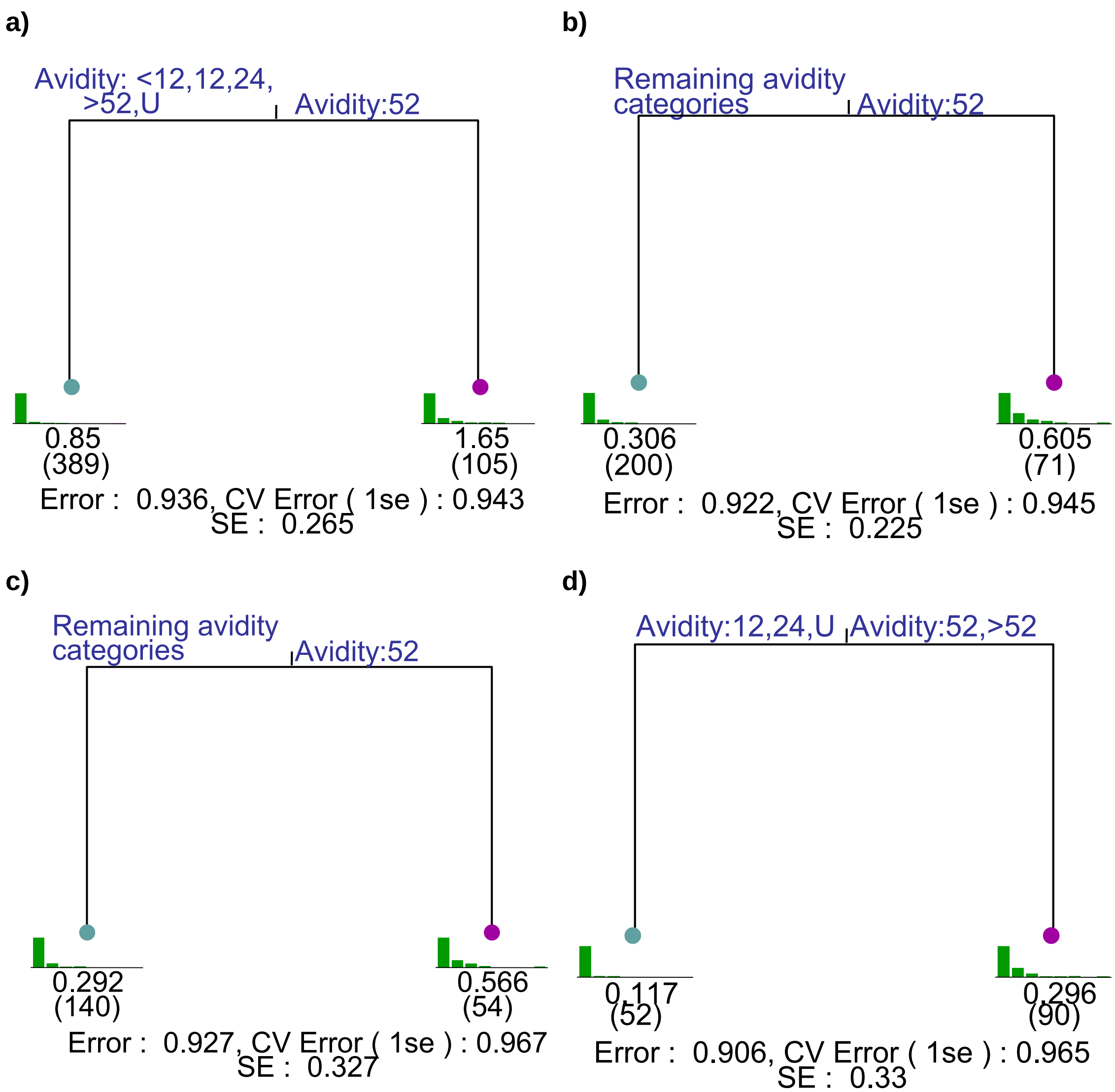


Figure A6.6: CARTs with the 1-SE rule for: a) all fish species; b) all barramundi; c) undersize barramundi; and d) legal-sized barramundi, examining the effect of avidity level on catch per unit effort for successful fishing trip.

Key: Avidity categories – <12 = fishes less than once a month; 12 = once a month; 24 = once a fortnight; 52 = once a week; >52 = more than once a week; U = unknown.

A6.2.3 Effect of number of anglers

Fishing parties containing only one angler provided the highest CPUE for all fish groups (although 2-angler parties also had higher CPUEs for legal-sized barramundi) (Figure A6.7).

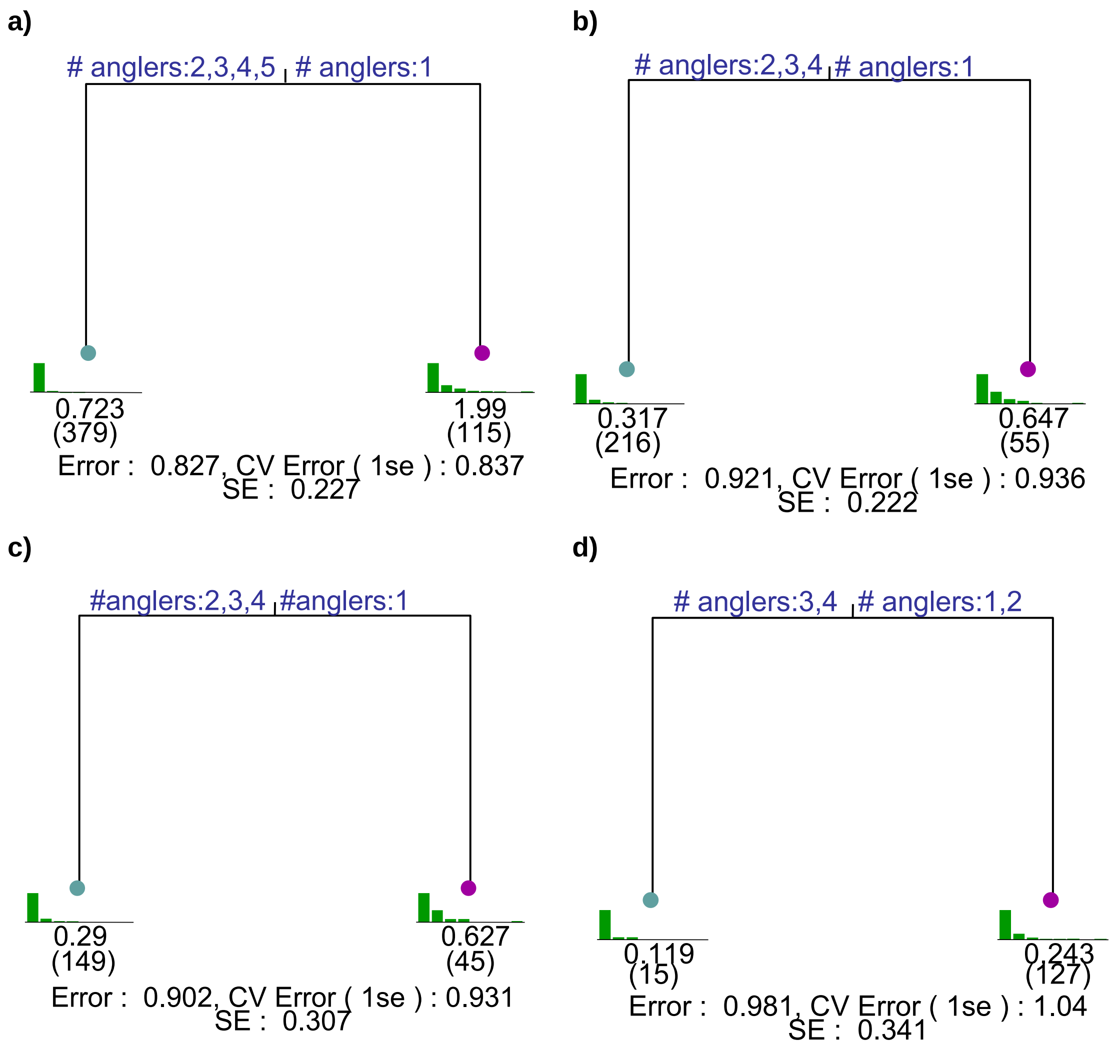


Figure A6.7: CARTs with the 1-SE rule for: a) all fish species; b) all barramundi; c) undersize barramundi; and d) legal-sized barramundi, examining the effect of the number of anglers in each fishing party on catch per unit effort for successful fishing trip.

A6.2.4 Effect of number of lines per angler

The effect of fishing parties employing different numbers of lines per angler varied depending on the fish group examined, however those fishing parties with 1- and 2-

lines per angler showed higher CPUEs for undersized and grouped barramundi when examined via CARTs (Figure A6.8).

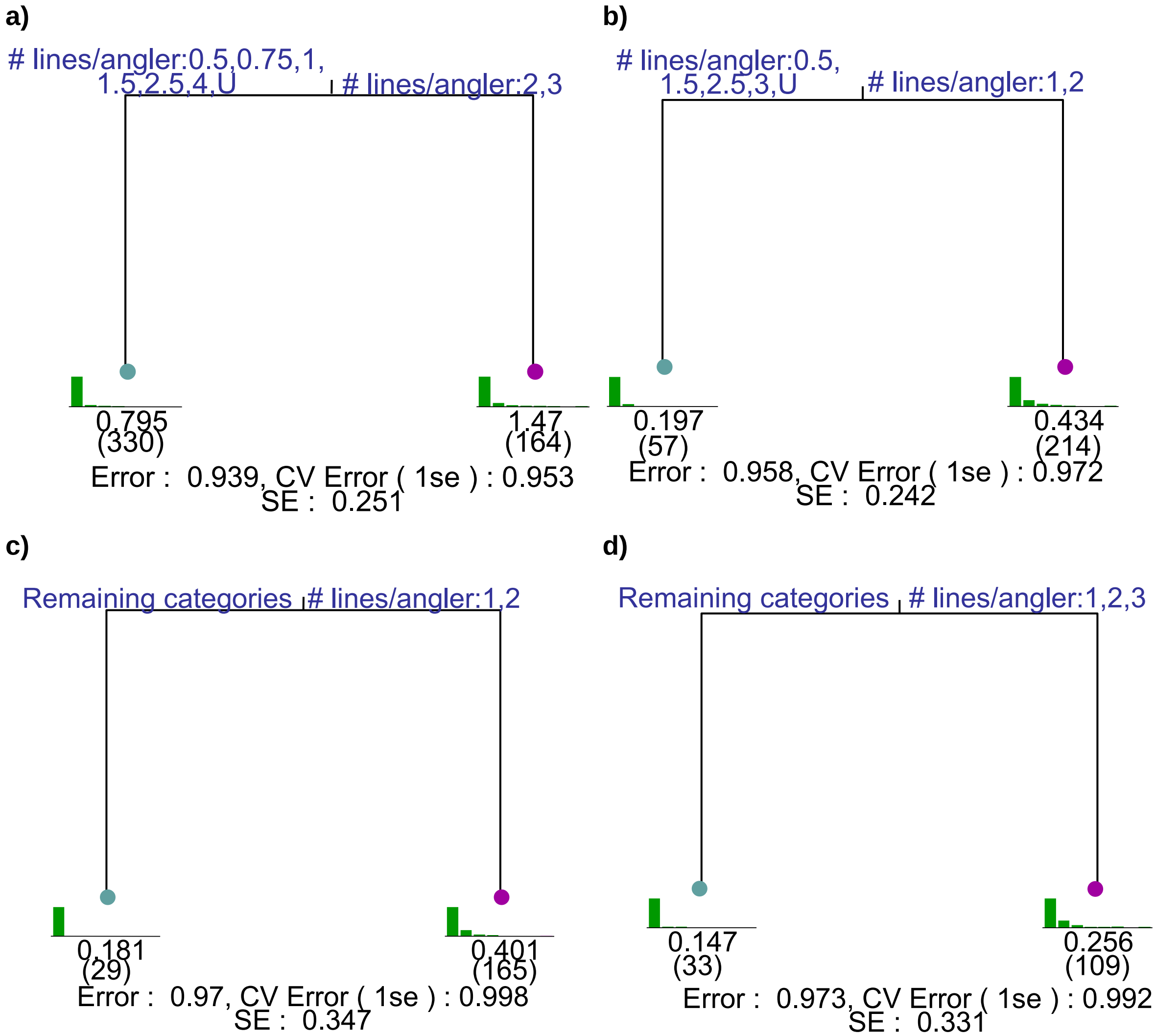


Figure A6.8: CARTs with the 1-SE rule for: a) all fish species; b) all barramundi; c) undersize barramundi; and d) legal-sized barramundi, examining the effect of the number of lines used per angler on catch per unit effort for successful fishing trip.

A6.3 Success rate comparisons between ROFA and open estuaries

A6.3.1 Success rate comparisons for all fish

CARTs comparing success rate (i.e. % of successful trips for catching at least one fish in the particular fish group) revealed success rate for ‘all fish’ is lowest in Halifax Bay, but there is no difference between the other bays (Figure A6.9 a). In Halifax Bay open estuaries provided a higher success rate than ROFA estuaries. Further exploration with the min-CV error rule showed further splits between the remaining bays, but no instances where ROFAs produced a higher success rate than open estuaries (Figure A6.9 b).

a)

b)

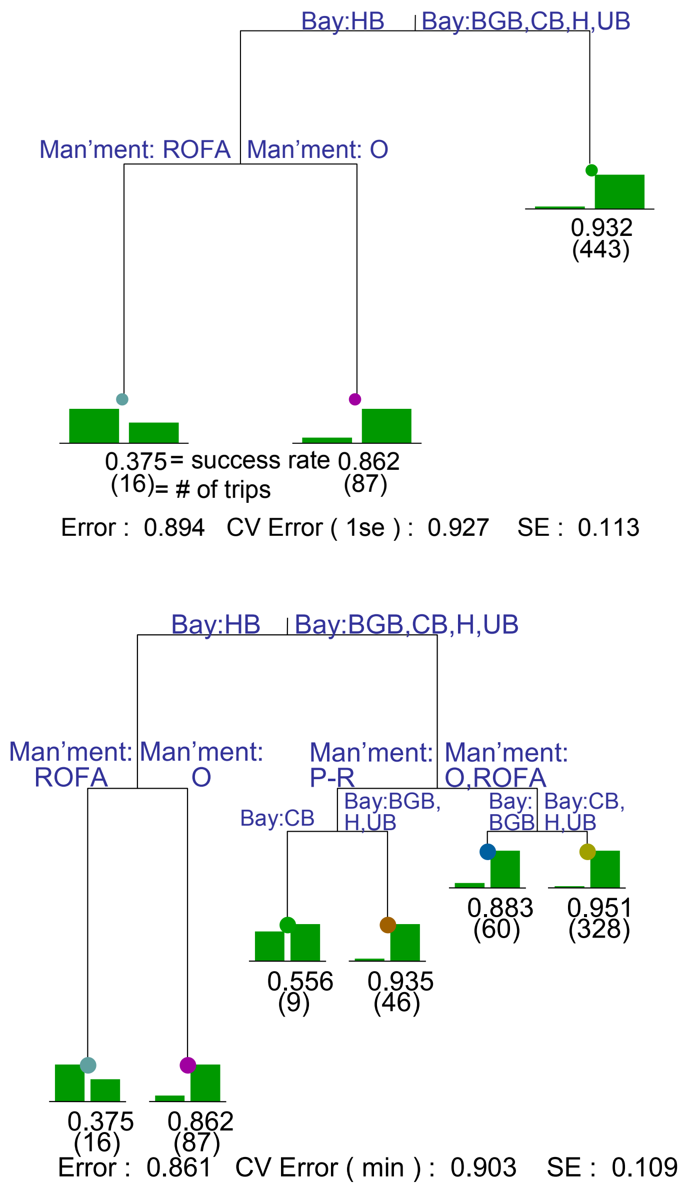
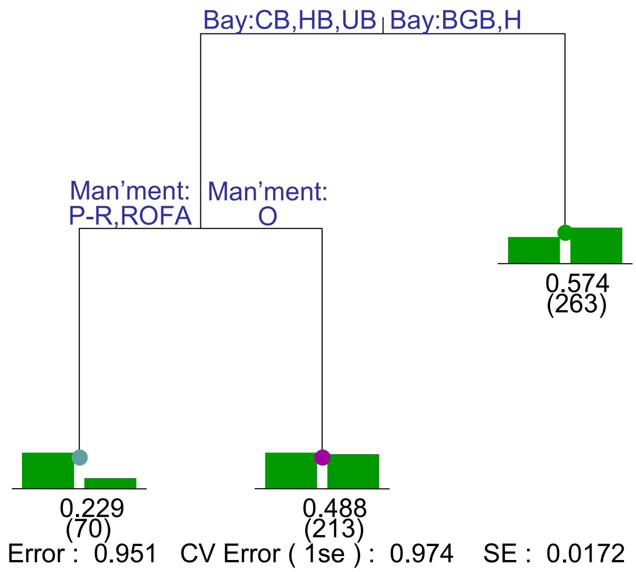


Figure A6.9: CART with the: a) 1-SE rule; and b) min-CV error rule for the success rate for catching at least one fish of any species. "Error" refers to the amount of variability in the data unexplained by this model (86.1% in this case). Vertical length of each branch represents the relative amount of variation explained by each split. The graphs for each node are frequency histograms of non-success and success, with the percentage of successful trips (and total number of trips) for each node given below. Success rate increases from left to right on the tree. Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

A6.3.2 Success rate comparisons for all barramundi

CARTs examining success rate for barramundi revealed Bowling Green Bay and Hinchinbrook Region have higher success rates than other bays (Figure A6.10 a), but further exploration via application of the min-CV error rule show open estuaries in Bowling Green Bay (as there are no open estuaries in the Hinchinbrook region) produce higher success rates for all barramundi than ROFA or part-ROFA estuaries in either region (Figure A6.10 b). Both models show open estuaries in the remaining bays have a higher success rate for barramundi than ROFA or part-ROFA estuaries.

a)



b)

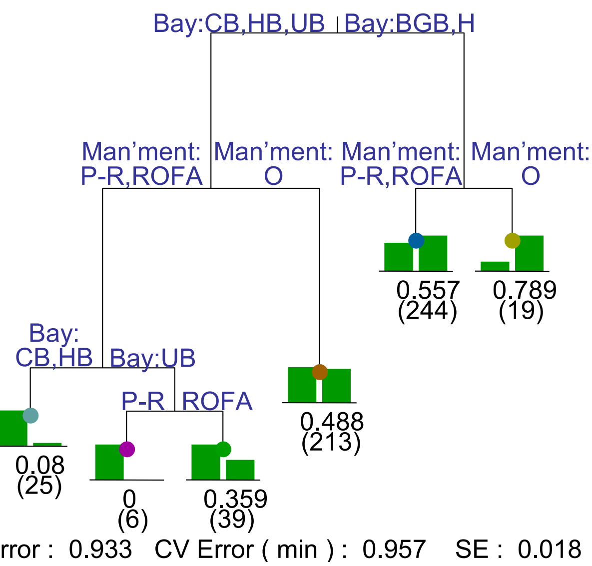


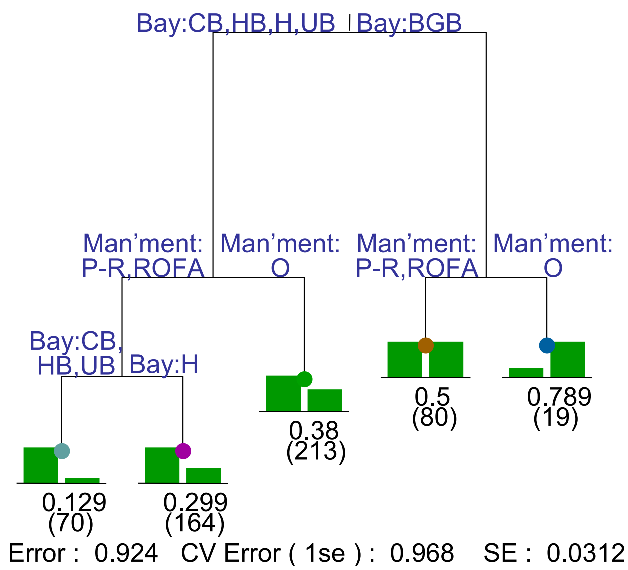
Figure A6.10: CART with the: a) 1-SE rule; and b) min-CV error rule for the success rate for catching at least one barramundi.

Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

A6.3.3 Success rate comparisons for undersize barramundi

For undersize barramundi, success rate is highest in Bowling Green Bay, particularly in open estuaries. Likewise, open estuaries in the remaining bays produced higher success rates than ROFA or part-ROFA estuaries (Figure A6.11 a). Further exploration via the min-CV error rule application reveals some further splits on the left-hand branches of the tree (Figure A6.11 b).

a)



b)

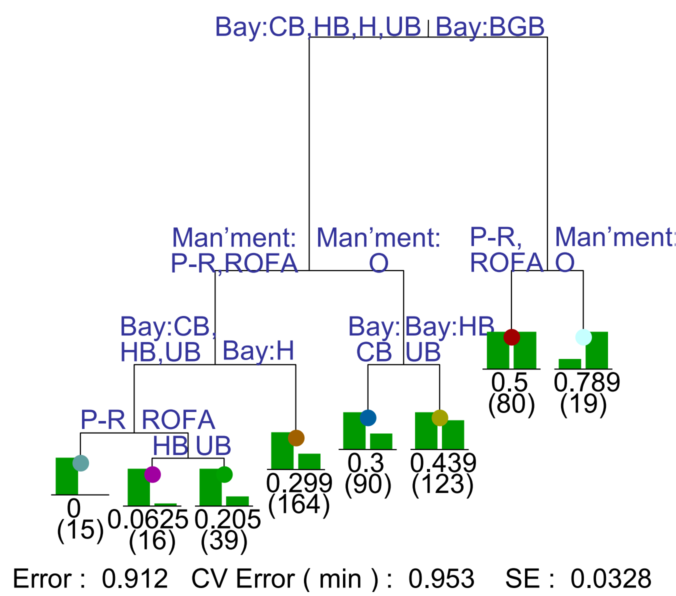


Figure A6.11: CART with the: a) 1-SE rule; and b) min-CV error rule for the success rate for catching at least one undersize barramundi.

Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

A6.3.4 Success rate comparisons for legal-sized barramundi

Halifax Bay produced the lowest success rates for legal-sized barramundi (Figure A6.12 a). The model resulting from application of the min-CV error rule revealed Bowling Green Bay and Hinchinbrook had the highest success rates for open and ROFA estuaries (Figure A6.12 b).

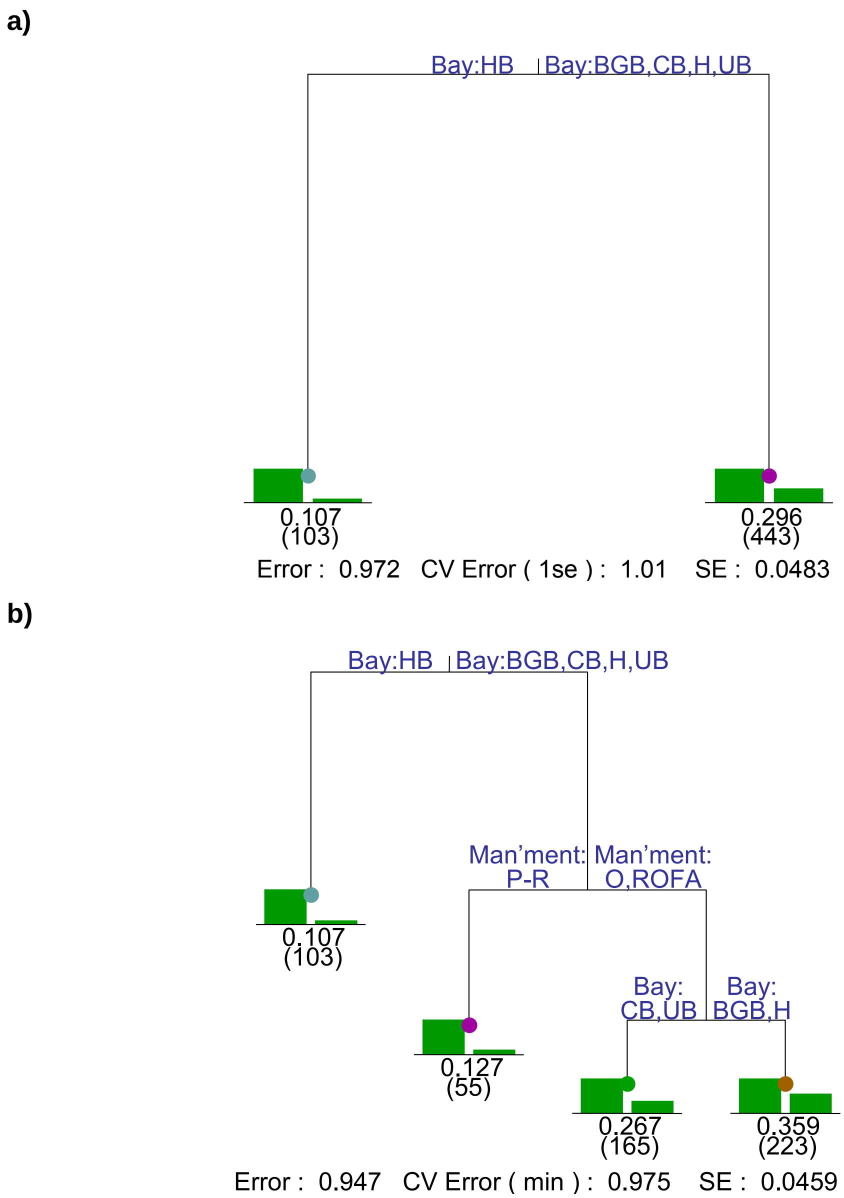


Figure A6.12: CART with the: a) 1-SE rule; and b) min-CV error rule for the success rate for catching at least one legal-sized barramundi.

Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

A6.4 CPUE comparisons between ROFA and open estuaries

A6.4.1 CPUE comparisons for all fish

Initial exploration revealed open estuaries yielded a higher CPUE for all fish than ROFA or part-ROFA estuaries within the study area (Figure A6.13).

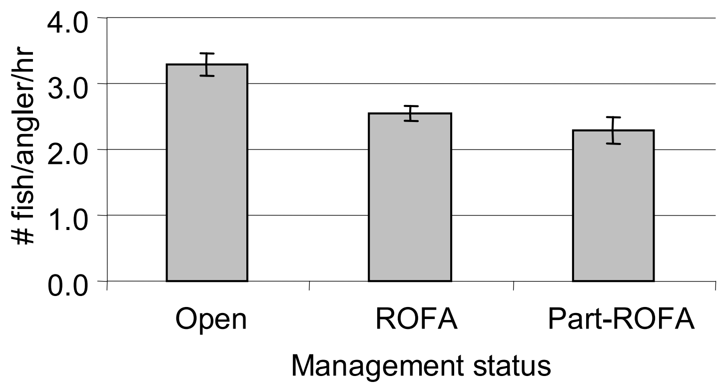


Figure A6.13: Average CPUE for successful fishing trips for all fish for open, ROFA and part-ROFA estuaries in the study area.

When the successful trip data were investigated by bay, the CART model resulting from the 1-SE rule showed open estuaries in all bays provided a higher CPUE (Figure A6.14 a). With the min-CV error rule the model revealed open estuaries in Bowling Green and Upstart Bays provided trips provided the highest CPUE (Figure A6.14 b).

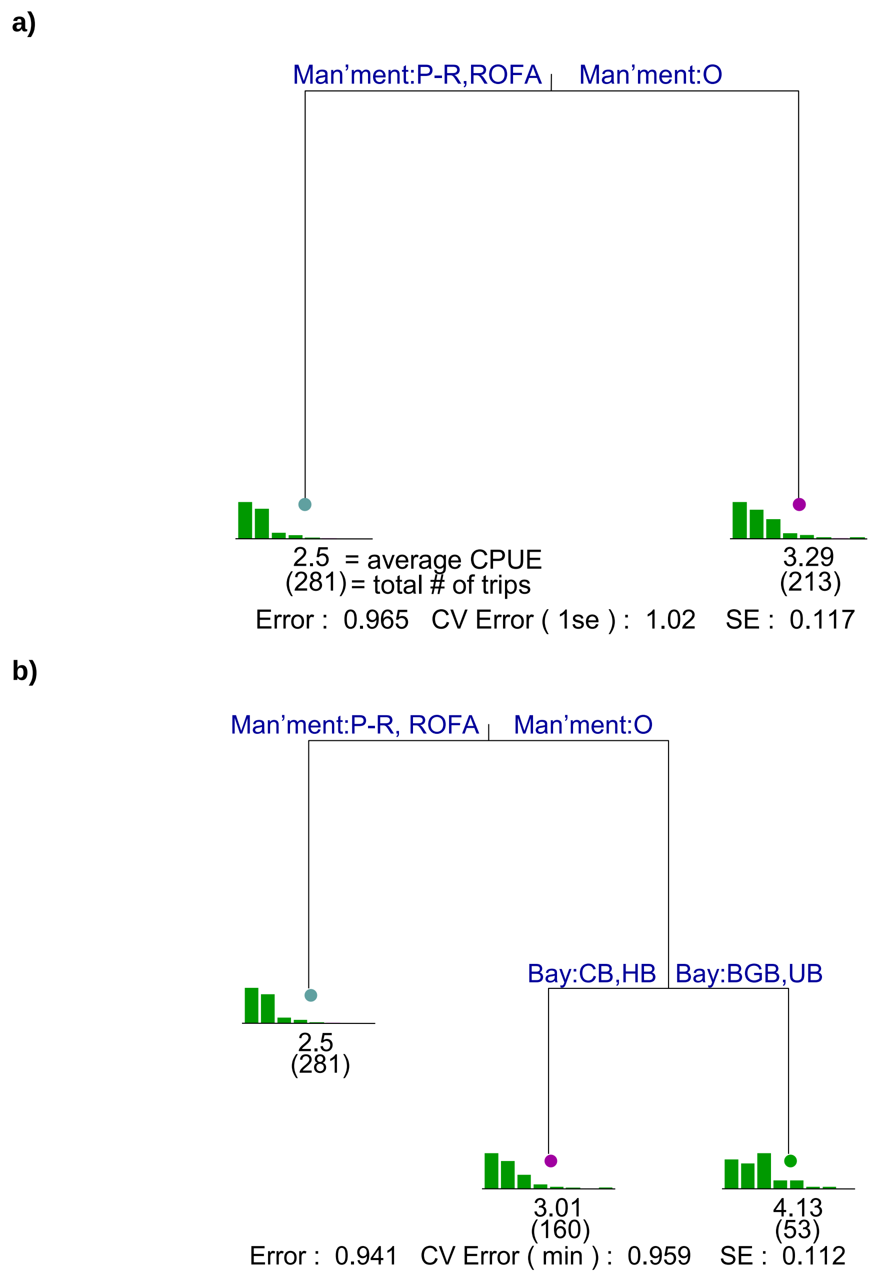


Figure A6.14: CART with the: a) 1-SE rule; and b) min-CV error rule for the number of fish caught per angler per hour in each bay for successful trips. "Error" refers to the amount of variability in the data unexplained by this model (94.1% in this case). Vertical length of each branch represents the relative amount of variation explained by each split. The graphs for each node are frequency histograms of CPUEs, with the average CPUE (and number of trips) for each node given below. Average CPUE increases from left to right on the tree.

Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

When data were divided into each fishing method (i.e. bait, artificial bait and a mixture of these two), results differed slightly from the grouped result. For those trips using only bait, only the estuaries in Upstart Bay showed significant difference in CPUE for open rather than ROFA or part-ROFA estuaries (see Figure A6.15). The 1-SE and min-CV error trees were identical so only the 1-SE tree is shown here.

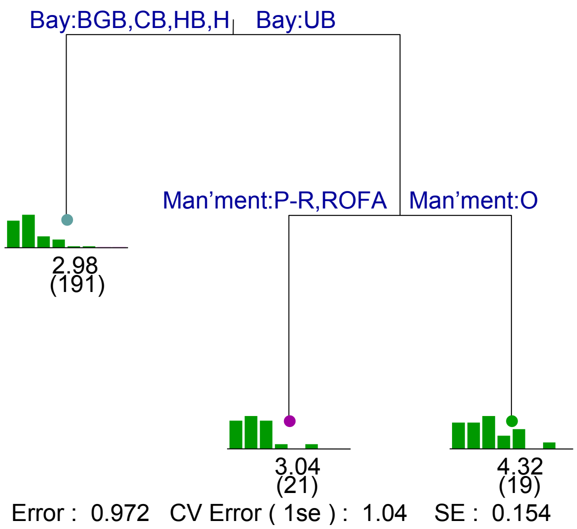


Figure A6.15: CART with the 1-SE rule for the number of fish caught per angler per hour in each bay for successful trips using only bait.
Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

For those trips using artificial baits, the resulting CART using both the 1-SE and min-CV error rule was identical to the min-CV error tree for the grouped fishing method data (see Figure A6.14 b) – i.e. open estuaries in all bays provide a higher CPUE, particularly in Bowling Green and Upstart Bays. As such these trees are not shown here.

Those trips where a mixture of real and artificial baits was used reveal a different result: possibly an artefact of fewer data points. Halifax Bay provided a relatively higher average CPUE than with the other fishing methods (Figure A6.16 a), though note there is only one ROFA within this bay. Open estuaries again revealed higher CPUEs for the remaining bays when then min-CV error rule was applied to the model, with higher CPUEs in Upstart Bay (Figure A6.16 b).

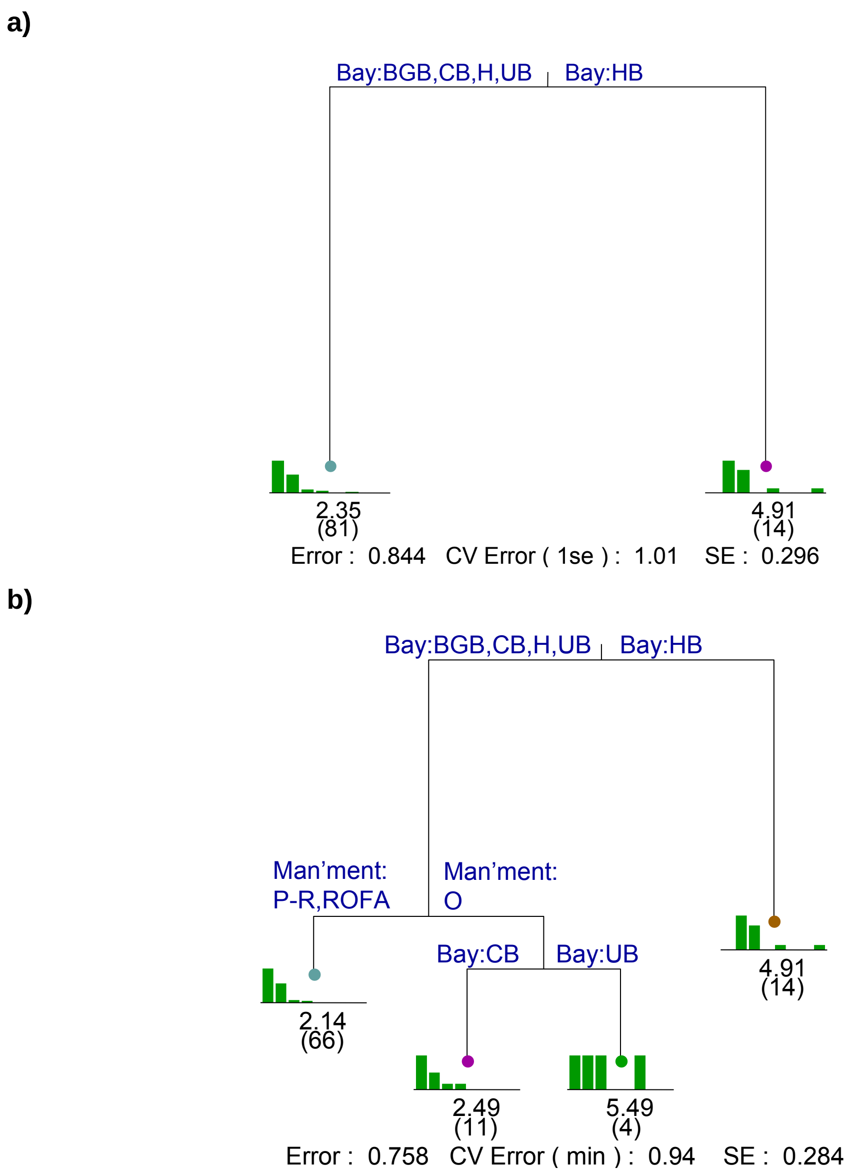


Figure A6.16: CART with the: a) 1-SE rule; and b) min-CV error rule for the number of fish caught per angler per hour in each bay for successful trips using a mixture or real and artificial baits.

Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

A6.4.2 CPUE comparisons for all barramundi

Initial exploration of the average CPUE of all barramundi for successful trips showed a slightly (though not significantly) higher CPUE for open estuaries than ROFA or part-

ROFA estuaries (Figure A6.17); a result probably driven by the undersize barramundi catch (outlined below).

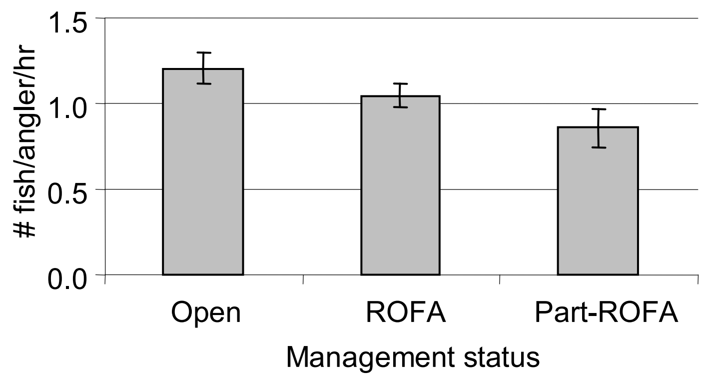
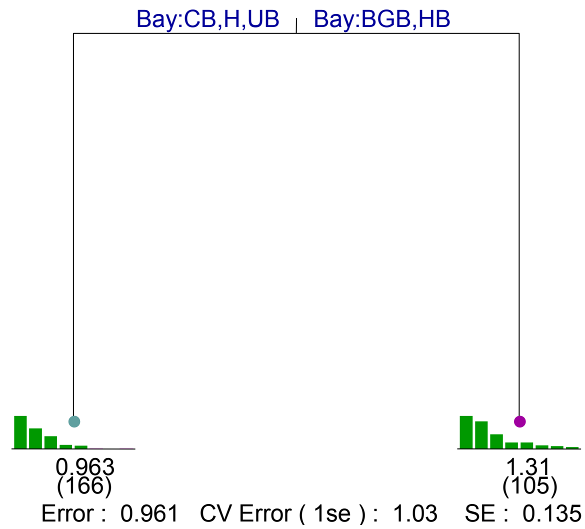


Figure A6.17: Average CPUE for successful fishing trips for all barramundi for open, ROFA and part-ROFA estuaries in the study area.

When the data were investigated by bay, the CART model resulting from the 1-SE rule indicated that the CPUE for 'all barramundi' was highest Bowling Green Bay (like the findings for the Charter Fishery records) and Halifax Bay, but there was no split between open, ROFA and part-ROFA estuaries (Figure A6.18 a). The CART with the min-CV error rule (Figure A6.18 b) revealed a split between ROFA and open estuaries for Upstart and Bowling Green Bays; however as with the result for 'all fish', in both bays the open estuaries provided a higher CPUE than ROFAs. Like the 'all fish' result, open estuaries in Bowling Green Bay provided a higher average CPUE for barramundi than any other node. In contrast to the CPUE for all fish, however, CPUE for barramundi in Upstart Bay was relatively low.

a)



b)

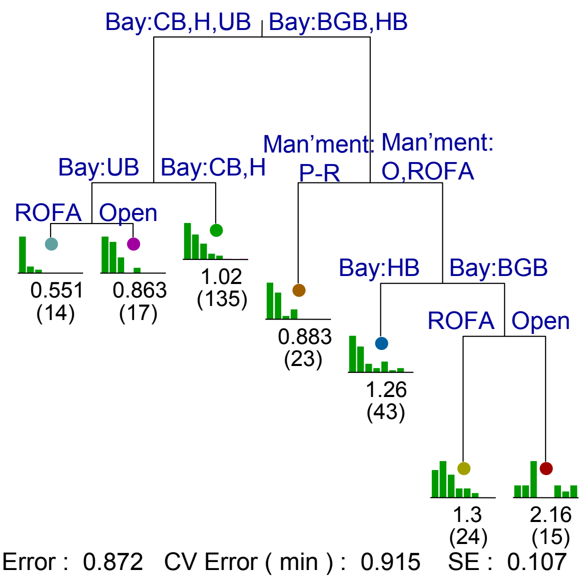
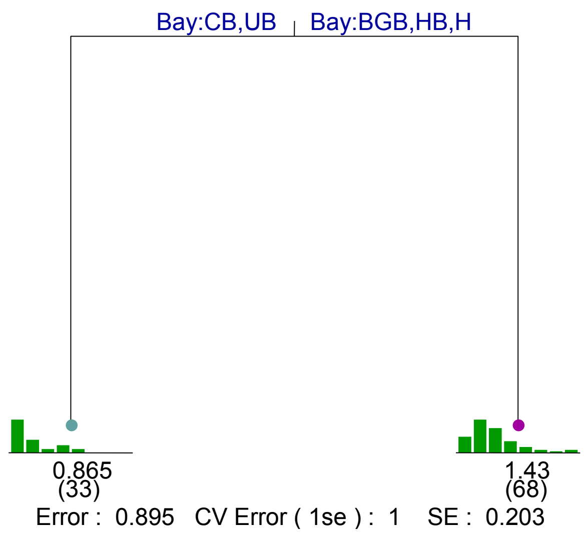


Figure A6.18: CART with the: a) 1-SE rule; and b) min-CV error rule for the number of barramundi caught per angler per hour in each bay for successful trips. Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

When the data were divided by fishing method, the resulting CARTs were slightly different to the trees resulting from grouped fishing method data. When trips using only bait were examined, the Hinchinbrook region appeared on the right-hand branch of the 1-SE tree, though like the grouped method data, the model did not provide a split between open, ROFA or part-ROFA estuaries (Figure A6.19 a). The min-CV error

CART for those trips using bait showed no split between open and ROFA estuaries in Bowling Green Bay (probably an artefact of sample size). Also, the ROFA estuaries of Halifax Bay and the Hinchinbrook region provided a higher average CPUE than the open estuaries of Halifax Bay (this branch could be read as a split between the Hinchinbrook region and Halifax Bay because there is only one ROFA in Halifax Bay and no open estuaries in the Hinchinbrook region), however note the length of the branch is relatively short, meaning this spit is not explaining much of the variation within the model (Figure A6.19 b).

a)



b)

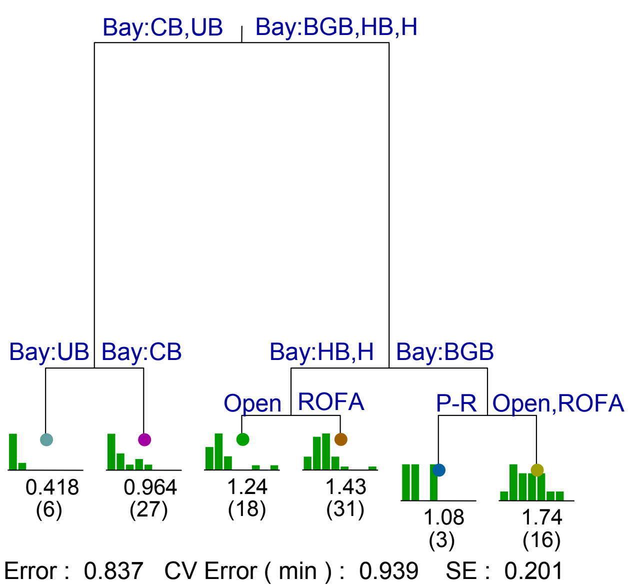


Figure A6.19: CART with the: a) 1-SE rule; and b) min-CV error rule for the number of barramundi caught per angler per hour in each bay for successful trips using only bait.

Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

For those trips using only artificial baits, similar to the model for artificial bait use for all fish, open estuaries provided a higher CPUE in all bays, particularly for Bowling Green

Bay (Figure A6.20). The model resulting from the 1-SE rule was the same as that resulting from the min-CV error rule; therefore only the 1-SE tree is shown here.

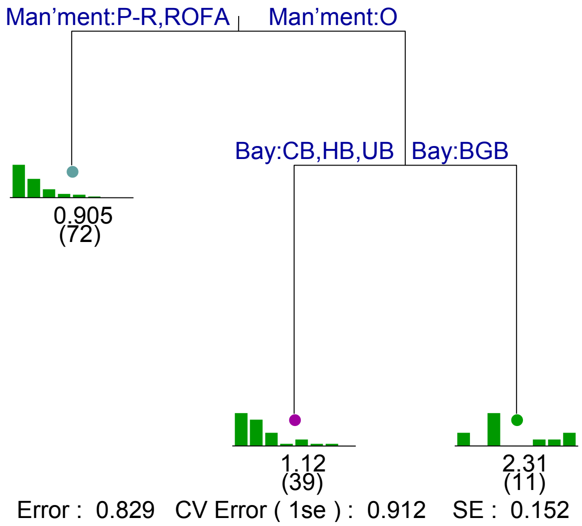


Figure A6.20: CART with the 1-SE rule for the number of barramundi caught per angler per hour in each bay for successful trips using only artificial bait. Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

For trips using a mixture of real and artificial baits, the resulting models (with both the 1-SE and min-CV error rules) were identical to the 1-SE tree for all fish (see Figure A6.16 a) and as such are not shown here – i.e. Halifax Bay provided a higher CPUE than the other bays, but there was no split between open, ROFA or part-ROFA estuaries in any of the bays (partly an artefact of sample size for this method).

A6.4.3 CPUE comparisons for undersize barramundi

Initial examination of average CPUE for undersize barramundi for successful trips revealed significantly higher CPUE in open estuaries rather than ROFA or part-ROFA estuaries (Figure A6.21).

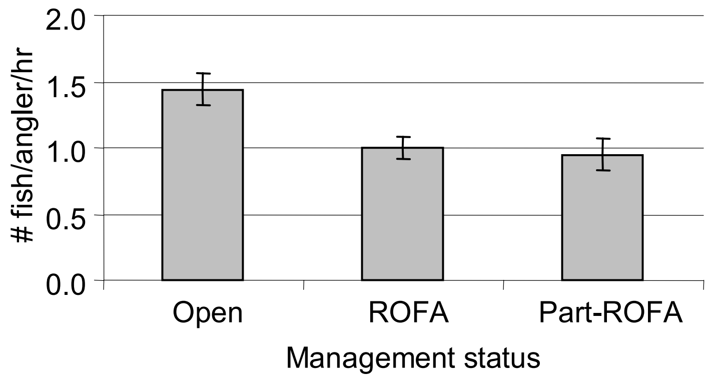
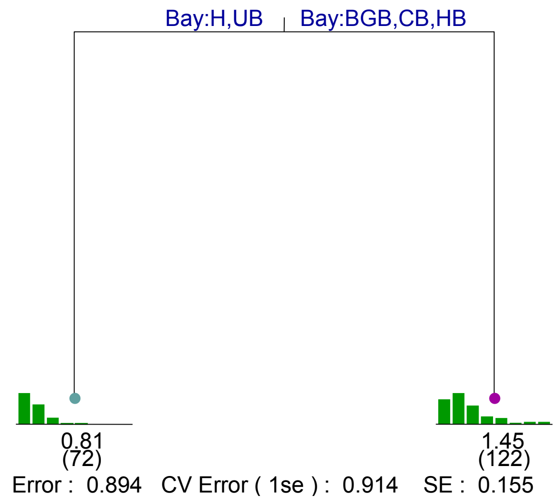


Figure A6.21: Average CPUE for successful fishing trips for undersize barramundi for open, ROFA and part-ROFA estuaries in the study area.

When data were examined by bay, the 1-SE CART did not reveal any split between open, ROFA or part-ROFA estuaries for any of the bays (Figure A6.22 a). The min-CV error CART, however, split part-ROFA estuaries for the bays on the first right hand branch, and split ROFA and open estuaries for Bowling Green Bay, with open estuaries in this bay showing the highest average CPUE than any other node (Figure A6.22 b), which is the same as the result for all barramundi.

a)



b)

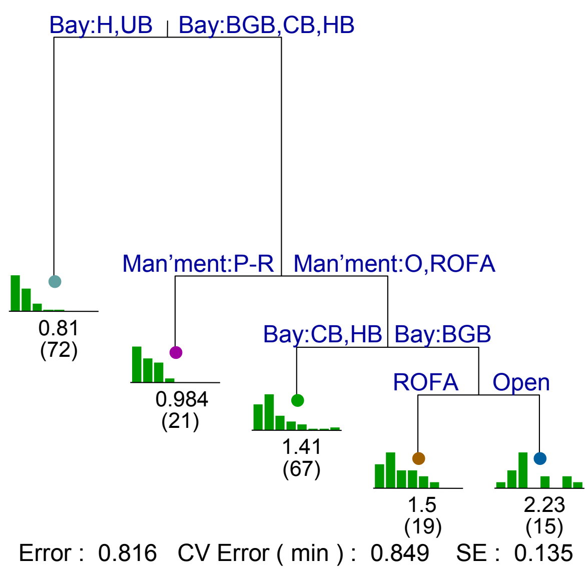


Figure A6.22: CART with the: a) 1-SE rule; and b) min-CV error rule for the number of undersize barramundi caught per angler per hour in each bay for successful trips.

Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

When data were divided into each fishing method, the results varied from the grouped data, partly due to the lower trip number for each method. For those trips employing only bait, there were no splits between estuaries of each management status in any bays, and Bowling Green Bay had the highest average CPUE (Figure A6.23). The 1-SE and min-CV error CARTs were identical so only the 1-SE tree is shown here.

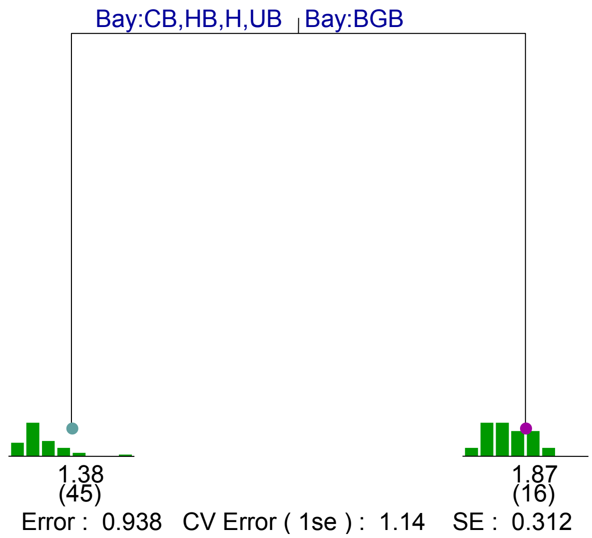
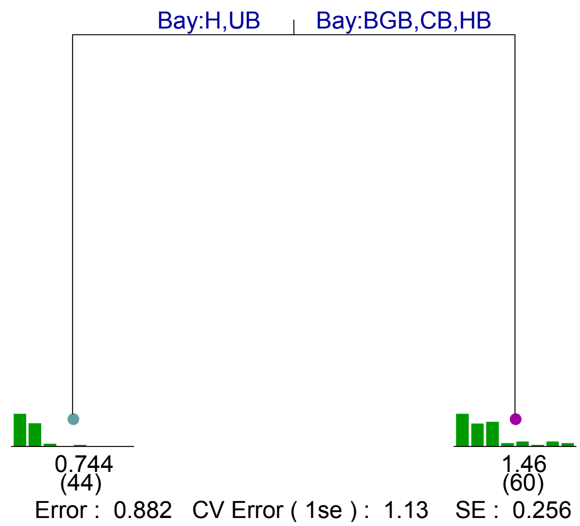


Figure A6.23: CART with the 1-SE rule for the number of undersize barramundi caught per angler per hour in each bay for successful trips using only bait.
Key: Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

For those trips using only artificial baits, the 1-SE model again did not split estuaries of each management status in any of the bays (Figure A6.24 a), however the min-CV error model revealed the CPUE for open estuaries in Bowling Green, Cleveland, and Halifax Bays had higher average CPUEs than the ROFA or part-ROFA estuaries in these bays (dominated by Bowling Green Bay due to the low numbers of ROFA in Cleveland and Halifax Bays (zero and one, respectively)). Like the grouped method data, open estuaries in Bowling Green Bay had the highest average CPUE (Figure A6.24 b).

a)



b)

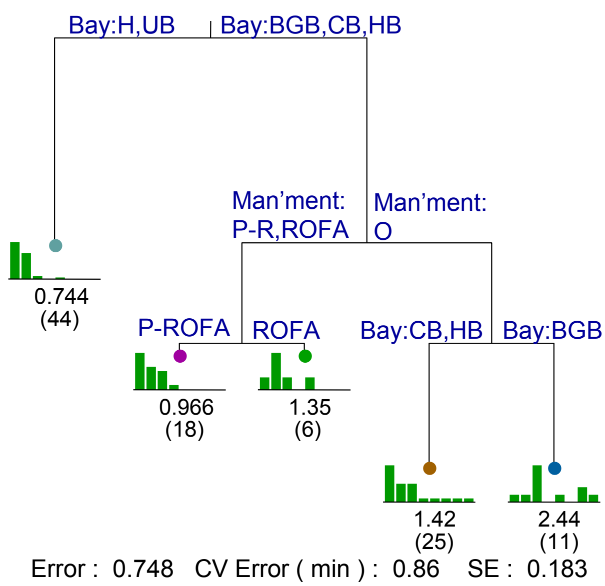


Figure A6.24: CART with the: a) 1-SE rule; and b) min-CV error rule for the number of undersize barramundi caught per angler per hour in each bay for successful trips using only artificial bait.

Key: Man'ment: O = Open, ROFA = ROFA, P-R = part-ROFA; Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

Trips using a mixture of real and artificial bait revealed no split between open, ROFA or part-ROFA estuaries in any of the bays, and, like the models for all fish and all barramundi, CPUE for successful trips for this fishing method was quite high in Halifax

Bay relative to other methods (Figure A6.25). The 1-SE CART is identical to the min-CV error CART so only the 1-SE tree is shown here.

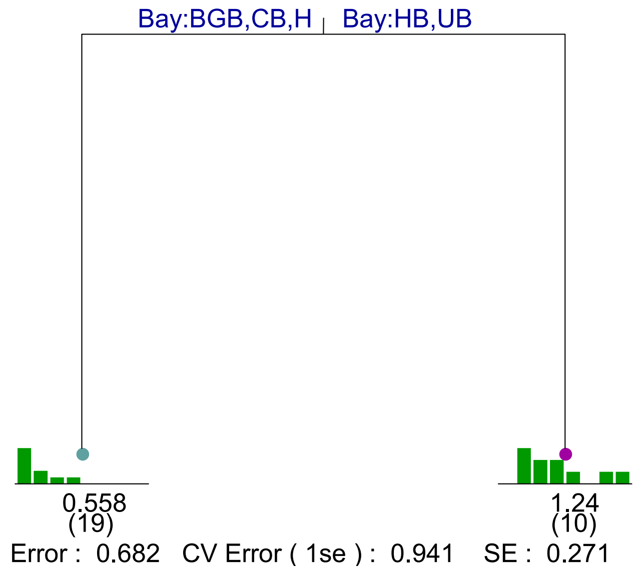


Figure A6.25: CART with the 1-SE rule for the number of undersize barramundi caught per angler per hour in each bay for successful trips using both real and artificial bait.

Key: Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

A6.4.4 CPUE comparisons for legal-sized barramundi

Initial exploration of average CPUE for legal-sized barramundi for successful trips revealed – in contrast to the result for undersize and 'all' barramundi – slightly higher CPUEs in ROFA rather than open estuaries (Figure A6.26). CPUE for part-ROFA estuaries overlapped open and ROFA estuaries with large error bars due to low successful trip numbers within part-ROFAs.

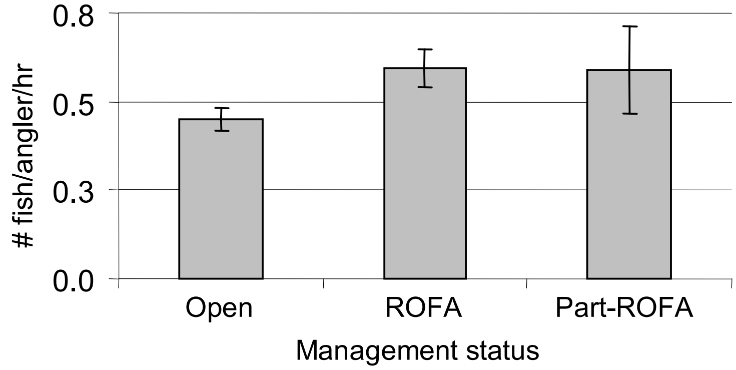


Figure A6.26: Average CPUE for successful fishing trips for legal-sized barramundi for open, ROFA and part-ROFA estuaries in the study area.

When these data were investigated by bay, the Hinchinbrook region showed a significantly higher CPUE than all other bays (Figure A6.27). Note there are no open estuaries in this region. The 1-SE CART and the min-CV error CART were identical; thus only the 1-SE tree for the grouped fishing method are shown here.

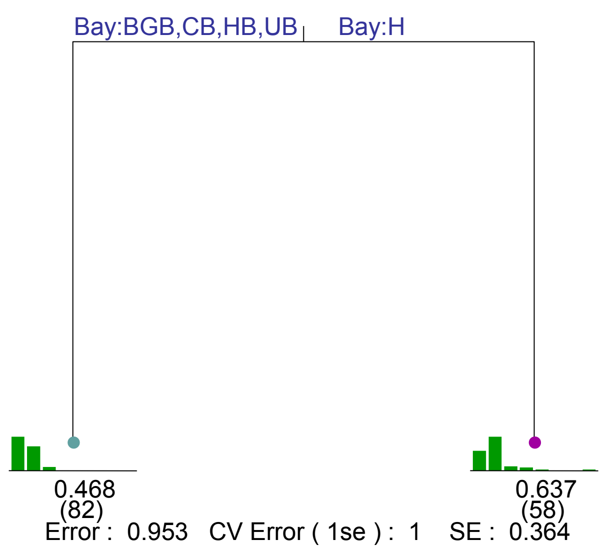


Figure A6.27: CART with the 1-SE rule for the number of legal-sized barramundi caught per angler per hour in each bay for successful trips.
Key: Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

For those trips using only bait, the 1-SE CART was identical to the tree resulting from the grouped fishing methods data (so it is not shown here). The min-CV error tree revealed a further split between bays on the left-hand branch, but no further split between estuaries of each management status (Figure A6.28).

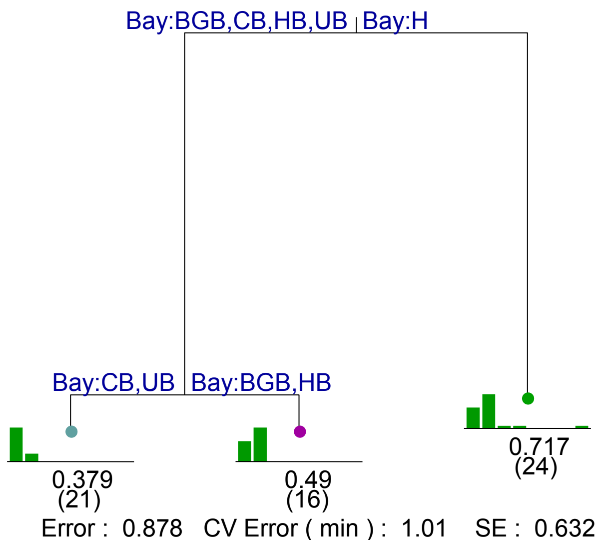


Figure A6.28: CART with the min-CV error rule for the number of legal-sized barramundi caught per angler per hour in each bay for successful trips using only bait.
Key: Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

Both the 1-SE and min-CV error CARTs (only 1-SE tree shown) resulting from trips using only artificial baits revealed both the Hinchinbrook region and Cleveland Bay had the highest average CPUE for legal-sized barramundi for successful trips. There were no splits between open, ROFA or part-ROFA estuaries for any of the bays (Figure A6.29).

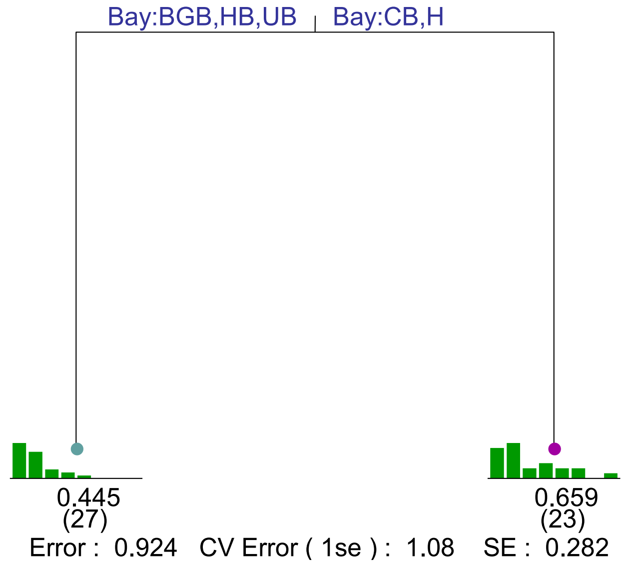


Figure A6.29: CART with the 1-SE rule for the number of legal-sized barramundi caught per angler per hour in each bay for successful trips using only artificial bait.

Key: Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

For those trips using both real and artificial baits, while there were no splits in the CARTs for management status, the bays on each branch differed to other fishing methods (Figure A6.30). There were very few trips for this method in Bowling Green Bay, however. The 1-SE and min-CV error CARTs were identical; therefore only the 1-SE tree is shown here.

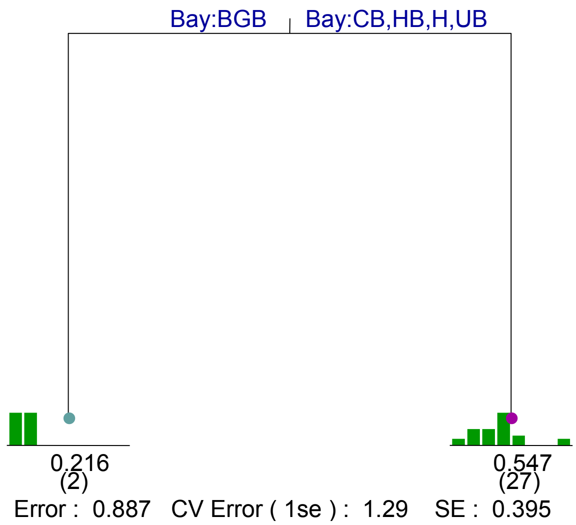


Figure A6.30: CART with the 1-SE rule for the number of legal-sized barramundi caught per angler per hour in each bay for successful trips using both real and artificial bait.

Key: Bay: BGB = Bowling Green Bay, CB = Cleveland Bay, H = Hinchinbrook, HB = Halifax Bay, UB = Upstart Bay.

Appendix 7 TIMETABLE FOR FISHERY-INDEPENDENT STRUCTURED FISHING SURVEYS.

Note these are actual fishing times. Start and finish times were often dependent on bait availability. Planned times were 6 hours of fishing, but this was subject to bait availability and strength of tidal flow.

Abbreviations are: Barrat (Barrattas Ck), Hau (Haughton Rv), Yellow (Yellowgin Ck), Vic (Victoria Ck), Herb (Herbert Rv), Burd (Burdekin region), Tsv (Townsville region), Hinch (Hinchinbrook region), O (open), and R (ROFA).

Date	Creek	Region	O/R	Start Point	Prev Tide (m)	Run (m)	Target Tide (m)	Run (m)	Next Tide (m)	Target tide time	Expected Delay	Actual Delay	Predicted target tide time	Start time	Finish time
4/5/02	Barrat	Tsv	O	Mouth	2.91	1.7	1.17	1	2.18	11:45	?	0:45		11:45	15:10
5/5/02	Hau	Tsv	R	Mouth	2.98	1.9	1.06	1.3	2.38	12:22	?	1:40		11:20	16:25
6/5/02	Ocean	Burd	O	Upper	3.02	2	0.99	1.6	2.55	12:53	?	0:50		11:50	15:10
7/5/02	Yellow	Burd	R	Mouth	3.03	2.1	0.96	1.7	2.69	13:18	?	1:40		12:10	16:20
8/5/02	Herb	Hinch	R	Mouth	2.92	2	0.96	1.8	2.71	13:30	?	2:20		12:00	16:30
9/5/02	Vic	Hinch	O	Upper	2.88	2	0.93	1.9	2.81	13:47	?	2:15		13:20	16:30
3/6/02	Yellow	Burd	R	Upper	2.72	1.6	1.13	1.1	2.22	11:41	1:40	2:00	13:00	11:00	15:50
4/6/02	Ocean	Burd	O	Mid-u	2.74	1.7	1.04	1.4	2.4	12:15	0:45	1:15	13:00	11:10	14:35
5/6/02	Hau	Tsv	R	Upper	2.73	1.8	0.97	1.6	2.57	12:42	1:40	1:20	14:00	12:10	15:50
6/6/02	Barrat	Tsv	O	Upper	2.7	1.8	0.92	1.8	2.72	13:05	0:45	1:00	13:40	11:00	15:25
7/6/02	Vic	Hinch	O	Mouth	2.59	1.7	0.87	1.9	2.75	13:17	2:00	2:20	15:00	11:00	15:25
8/6/02	Herb	Hinch	R	Mouth	2.54	1.7	0.81	2.1	2.88	13:36	2:20	2:25	15:30	12:50	16:15

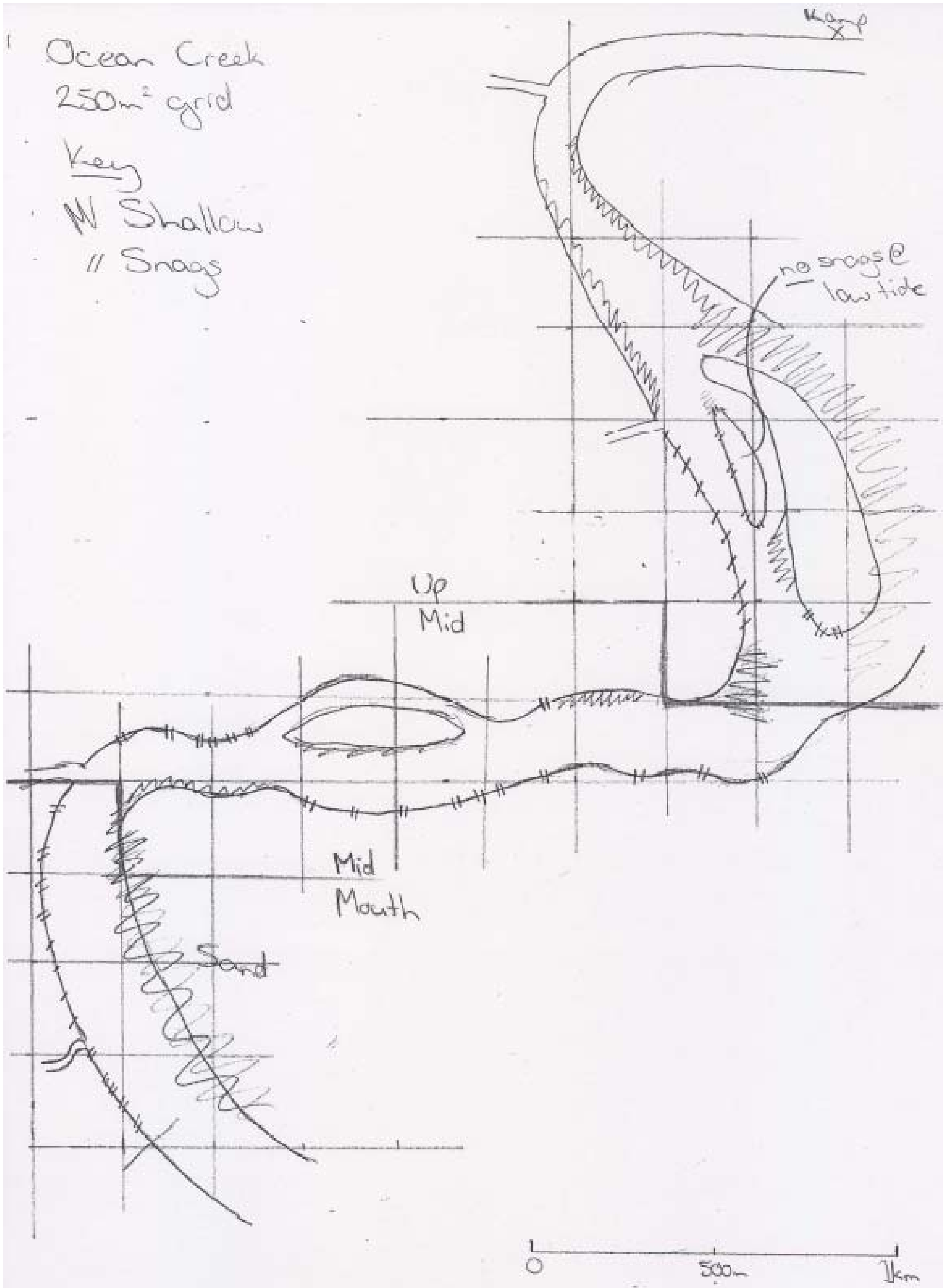
Date	Creek	Region	O/ R	Start Point	Prev Tide (m)	Run (m)	Target Tide (m)	Run (m)	Next Tide (m)	Target tide time	Expected Delay	Actual Delay	Predicted target tide time	Start time	Finish time
28/6	Herb	Hinch	R	Mid-d	1.42	0.6	2.01	1.1	0.96	11:12	?	0:50	11:10	09:40	14:35
29/6	Vic	Hinch	O	Mouth	1.46	0.4	1.89	0.7	1.18	12:09	?	0:50	12:10	10:25	15:45
30/6	Ocean	Burd	O	Mouth	1.42	0.5	1.9	0.5	1.45	13:32	1:00	0:10	10:00	10:40	15:10
1/7	Yellow	Burd	R	Mouth	2.57	1.2	1.35	0.6	1.93	10:01	1:40	1:10	11:40	09:15	14:20
2/7	Barrat	Tsv	O	Upper	2.47	1.2	1.24	0.8	2.07	10:54	0:45	0:50	11:40	09:15	14:30
3/7	Hau	Tsv	R	Mid-u	2.42	1.3	1.13	1.1	2.27	11:33	1:00	1:30	12:30	10:45	16:05
13/7	Hau	Tsv	R	Upper	1.21	1	2.23	1.5	0.72	10:53	?	0:05	11:00	11:10	14:15
14/7	Barrat	Tsv	O	Mid-u	1.21	1	2.24	1.3	0.94	11:58	?	0:10	12:00	10:15	14:40
15/7	Vic	Hinch	O	Upper	1.22	0.9	2.08	0.9	1.15	13:13	0:50	1:00	14:00	11:55	15:20
17/7	Herb	Hinch	R	Mid-d	2.67	1.7	0.99	1.3	2.31	3:50	2:20	2:45	12:30	10:40	14:06
18/7	Yellow	Burd	R	Mid-d	2.64	1.8	0.82	1.9	2.71	11:12	1:20	3:05	12:30	10:45	14:26
19/7	Ocean	Burd	O	Mid-d	2.58	1.9	0.69	2.3	2.97	12:01	?	1:20	12:30	10:20	14:05
29/7	Ocean	Burd	O	Mouth	1.48	0.5	1.99	0.6	1.41	12:19	0:00	0:35	12:20	11:00	13:15
30/7	Yellow	Burd	R	Mouth	1.48	0.4	1.92	0.2	1.68	13:44	?	0:50	13:44	11:20	15:25
31/7	Barrat	Tsv	O	Mouth	2.29	0.9	1.4	0.6	2	9:55	:45	0:30	10:45	08:25	13:35
01/8	Hau	Tsv	R	Mouth	2.12	0.8	1.28	0.9	2.22	10:49	1:30	0:00	12:15	09:50	14:05
02/8	Herb	Hinch	R	Upper	2.01	0.9	1.16	1.2	2.34	11:31	2:40	0:30	2:00	12:30	16:10
03/8	Vic	Hinch	O	Mid-u	2.02	1	1.04	1.5	2.55	12:00	2:00	1:10	2:00	11:45	16:00

Date	Creek	Region	O/ R	Start Point	Prev Tide (m)	Run (m)	Target Tide (m)	Run (m)	Next Tide (m)	Target tide time	Expected Delay	Actual Delay	Predicted target tide time	Start time	Finish time
12/8	Vic	Hinch	O	Mid-d	0.99	1.4	2.41	1.5	0.87	11:34	1:00	0:50	12:20	10:00	14:45
13/8	Herb	Hinch	R	Mouth	1.06	1.2	2.29	1.1	1.23	12:45	:45	01:00	13:15	11:00	14:10
14/8	Yellow	Burd	R	Upper	1.07	1.3	2.36	0.9	1.51	14:31	01:00	?	15:00	10:15	14:00
15/8	Ocean	Burd	O	Mid-u	2.43	1.4	1.01	1.5	2.55	09:43	:45	01:05	10:30	08:45	12:15
16/8	Hau	Tsv	R	Mid-d	2.28	1.4	0.9	1.9	2.84	10:57	01:20	0:50	12:15	09:30	14:05
17/8	Barrat	Tsv	O	Mid-d	2.28	1.5	0.76	2.3	3.09	11:56	01:00	01:20	12:50	10:45	15:45
29/8	Barrat	Tsv	O	Mid-u	1.53	0.5	2.01	0	1.99	14:52	0	0		10:25	15:05
30/8	Hau	Tsv	R	Mouth	1.93	0.5	1.44	0.7	2.15	10:06	0:45	0:35	10:50	09:30	13:20
31/8	Herb	Hinch	R	Upper	1.74	0.4	1.3	1.1	2.38	10:57	0:30	0	11:25	10:10	13:00
01/9	Vic	Hinch	O	Upper	1.84	0.7	1.13	1.5	2.61	11:35	01:00	02:00	12:30	12:30	15:30
02/9	Ocean	Burd	O	Upper	2.05	1.1	0.95	2	2.98	12:10	0:45	02:00	12:55	11:25	15:50
03/9	Yellow	Burd	R	Upper	2.23	1.5	0.74	2.5	3.23	12:43	02:00	?	14:45	10:45	14:45
11/9	Yellow	Burd	R	Mid-u	0.94	1.7	2.61	1.2	1.42	12:20	0	0:40	12:30	09:20	13:10
12/9	Ocean	Burd	O	Upper	1.09	1.4	2.51	1	1.56	14:18	0	?	14:20	10:20	12:40
13/9	Hau	Tsv	R	Upper	2.07	1	1.12	1.6	2.7	09:14	:45	01:15	10:00	08:00	12:30
14/9	Barrat	Tsv	O	Upper	2.02	1	1.01	2	2.97	10:43	:45	01:00	11:30	08:50	13:00
15/9	Vic	Hinch	O	Mid-u	2.07	1.2	0.86	2.2	3.03	11:40	02:00	02:10	13:40	10:15	13:55
16/9	Herb	Hinch	R	Mid-u	2.23	1.5	0.75	2.4	3.14	12:24	:45	01:15	13:10	11:00	13:35

Date	Creek	Region	O/R	Start Point	Prev Tide (m)	Run (m)	Target Tide (m)	Run (m)	Next Tide (m)	Target tide time	Expected Delay	Actual Delay	Predicted target tide time	Start time	Finish time
27/9	Herb	Hinch	R	Upper	1.36	0.7	2.04	0.6	1.46	12:50	0	0:15	12:50	11:00	14:10
					4:10	10h		13h	3:33						
28/9	Vic	Hinch	O	Upper	1.46	0.8	2.22	0.7	1.51	17:00	0	?	17:00	11:15	13:55
					3:33	16h		8h	1:49						
29/9	Ocean	Burd	O	Mouth	1.72	0.3	1.45	1.1	2.56	10:09	0:45	01:10	10:50	10:10	12:50
30/9	Yellow	Burd	R	Mouth	1.87	0.6	1.24	1.6	2.87	11:05	01:00	01:40	12:05	09:20	13:40
01/10	Barrat	Tsv	O	Mouth	2.08	1.1	1	2.1	3.07	11:45	01:00	01:45	12:45	09:30	13:30
02/10	Hau	Tsv	R	Mouth	2.33	1.6	0.76	2.6	3.33	12:19	01:00	>1:00	13:20	08:50	13:15
11/10	Hau	Tsv	R	Mid-u	1.1	1.6	2.69	1.2	1.46	13:57	0	?	14:00	08:30	12:50
12/10	Barrat	Tsv	O	Upper	1.82	0.6	1.22	1.6	2.81	08:39	:45	01:10	09:30	08:50	13:35
13/10	Vic	Hinch	O	Mouth	1.83	0.7	1.14	1.7	2.87	10:12	02:00	?	12:10	09:10	11:55
14/10	Herb	Hinch	R	Mouth	2.05	1	1.02	2	2.99	11:18	:30	>1	11:50	09:05	12:20
15/10	Yellow	Burd	R	Mid-d	2.36	1.4	0.92	2.3	3.17	12:13	01:20	?	13:30	09:40	12:35
16/10	Ocean	Burd	O	Mouth	2.52	1.6	0.88	2.3	3.17	12:48	01:30	?	14:10	08:55	12:00
09/11	Ocean	Burd	O	Mouth	1.05	1.8	2.87	1.5	1.38	13:15	0		13:15	08:40	10:40
10/11	Yellow	Burd	R	Upper	1.28	1.6	2.84	1.7	1.19	15:09	0		15:10	09:10	11:45
11/11	Barrat	Tsv	O	Mouth	1.87	0.6	1.31	1.7	2.97	09:34	01:00		10:35	09:45	13:15
12/11	Hau	Tsv	R	Upper	2.1	0.9	1.25	1.7	2.97	10:48	01:00		11:45	07:45	12:00
13/11	Herb	Hinch	R	Mouth	2.2	1	1.19	1.7	2.86	11:33	01:00		12:30	09:00	11:10
14/11	Vic	Hinch	O	Mid-d	2.37	1.2	1.16	1.7	2.85	12:14	02:00		14:15	09:15	13:05

Appendix 8 MUD-MAPS[24] OF EACH SAMPLED ESTUARY FOR THE FISHERY-INDEPENDENT STRUCTURED FISHING SURVEYS

A8.1 Ocean Creek mud-map



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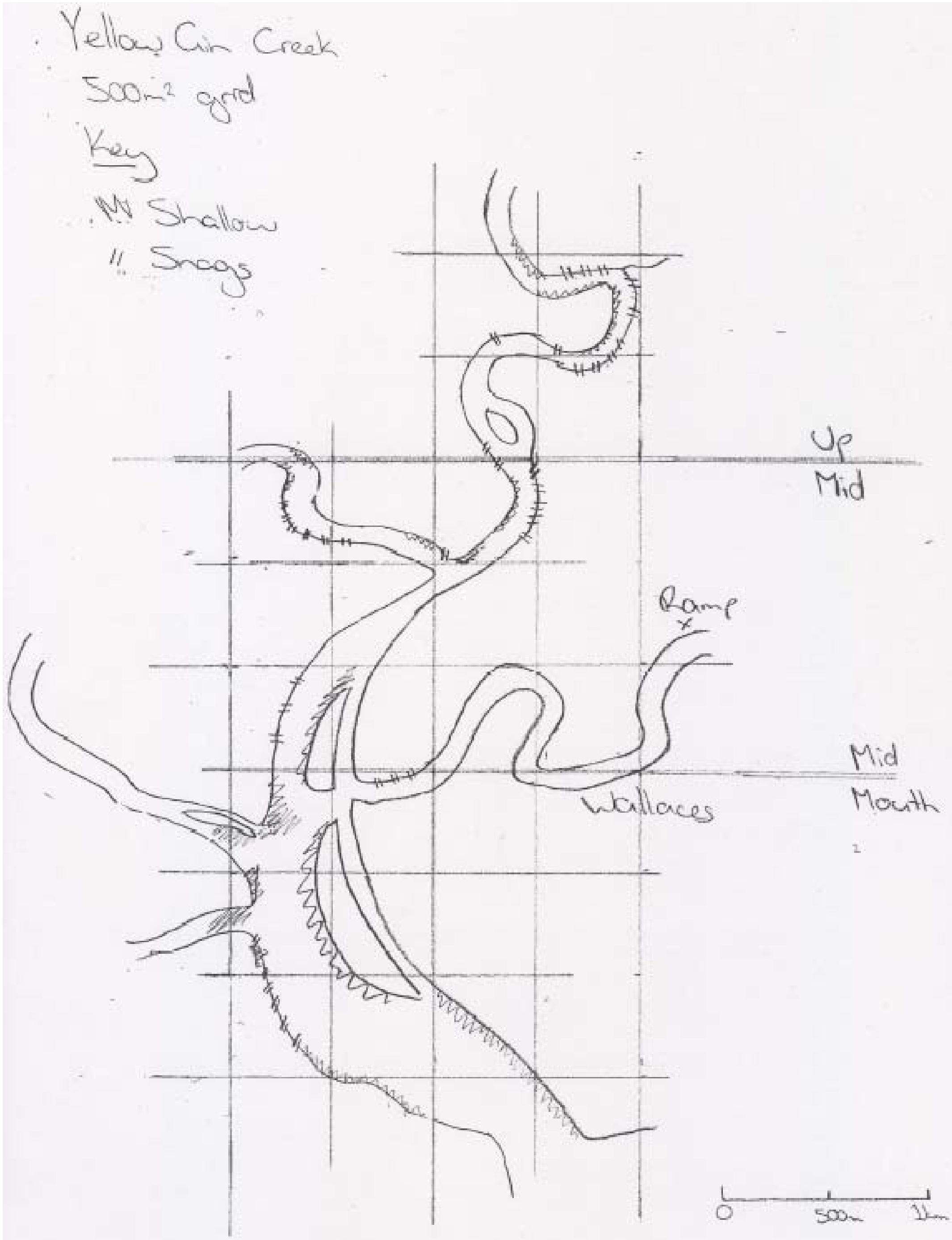
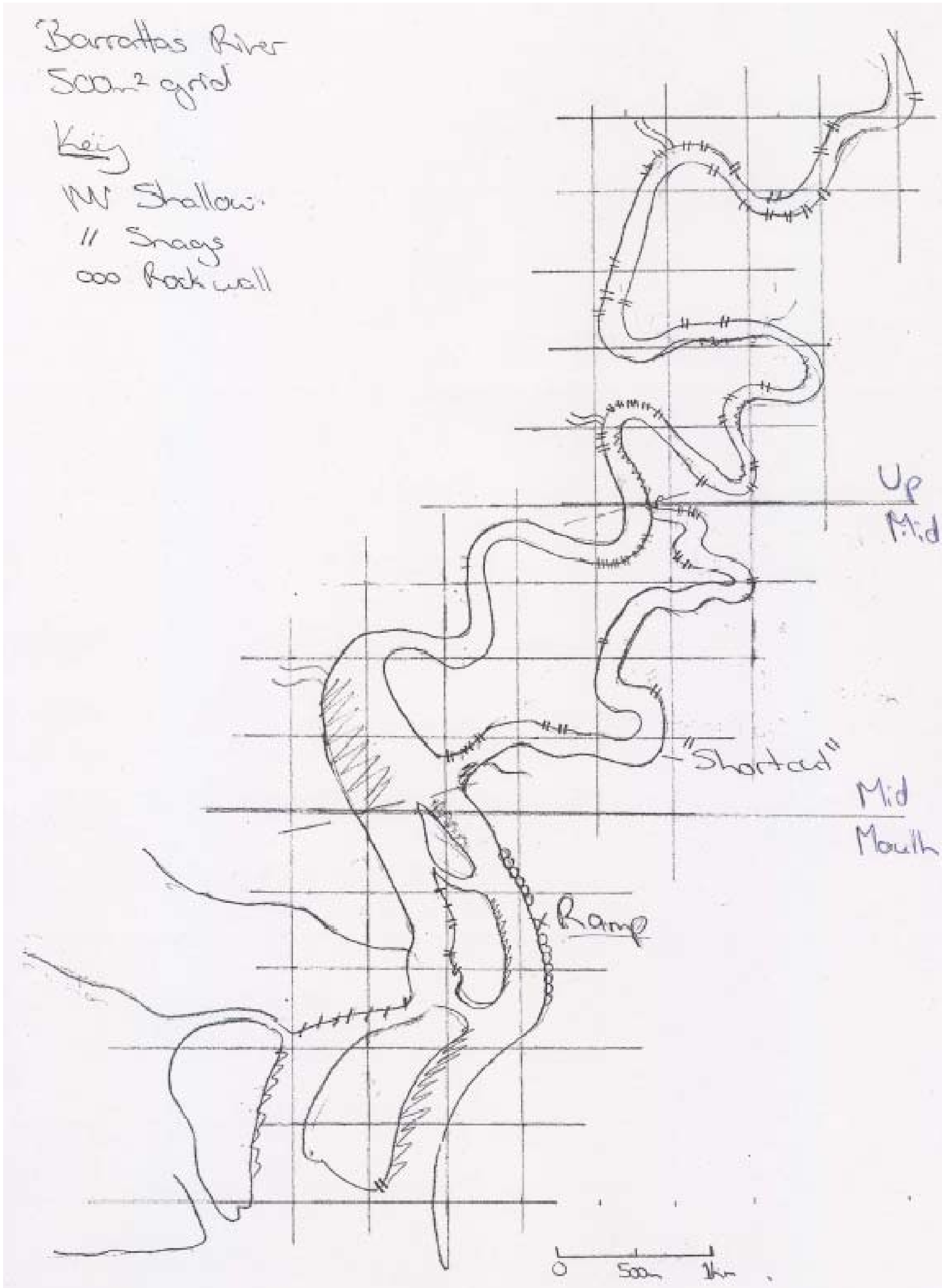
[24] Mud-maps shown were constructed from registered maps, aerial photos, and on-site exploration.

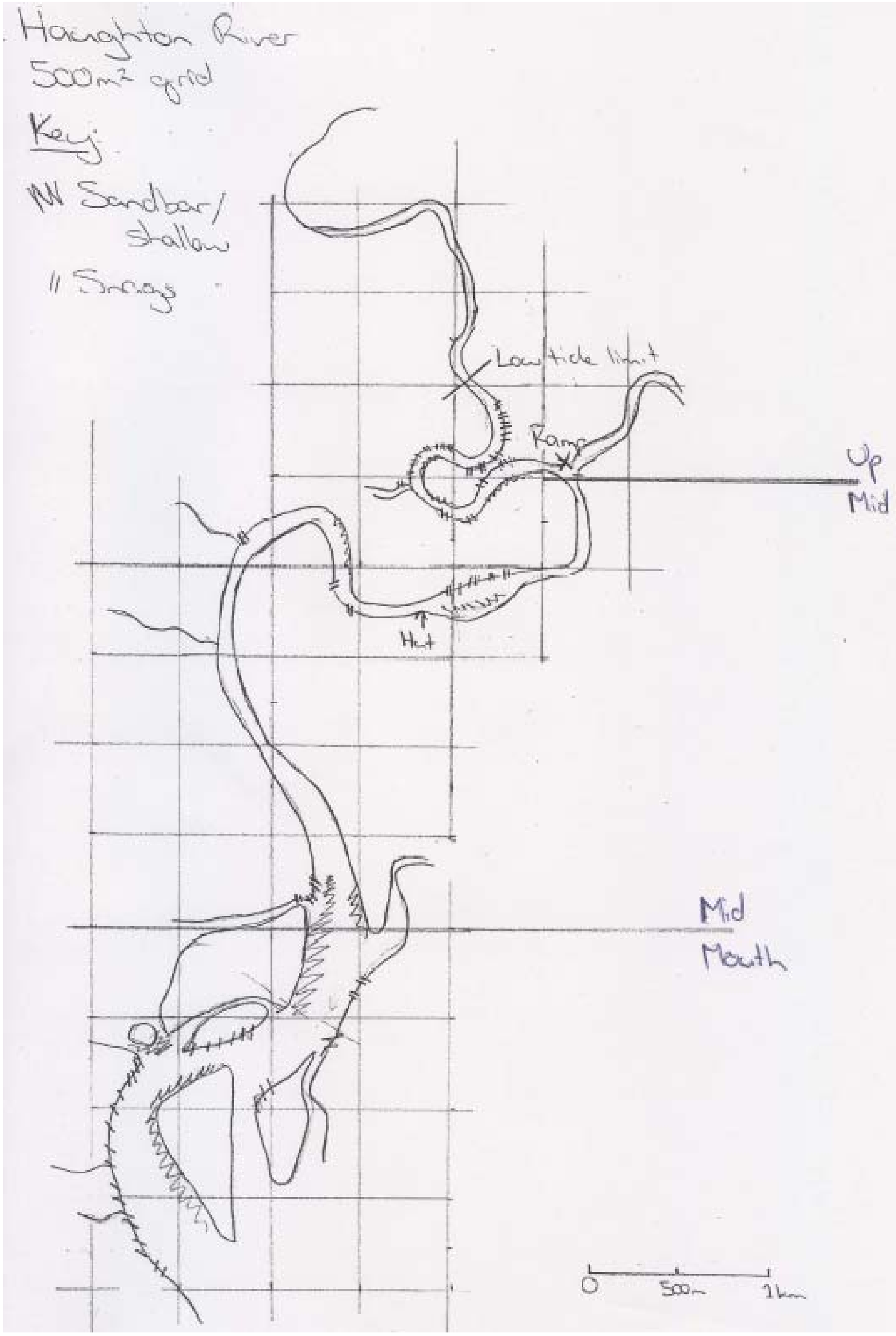
A8.2 Yellowgin Creek mud-map



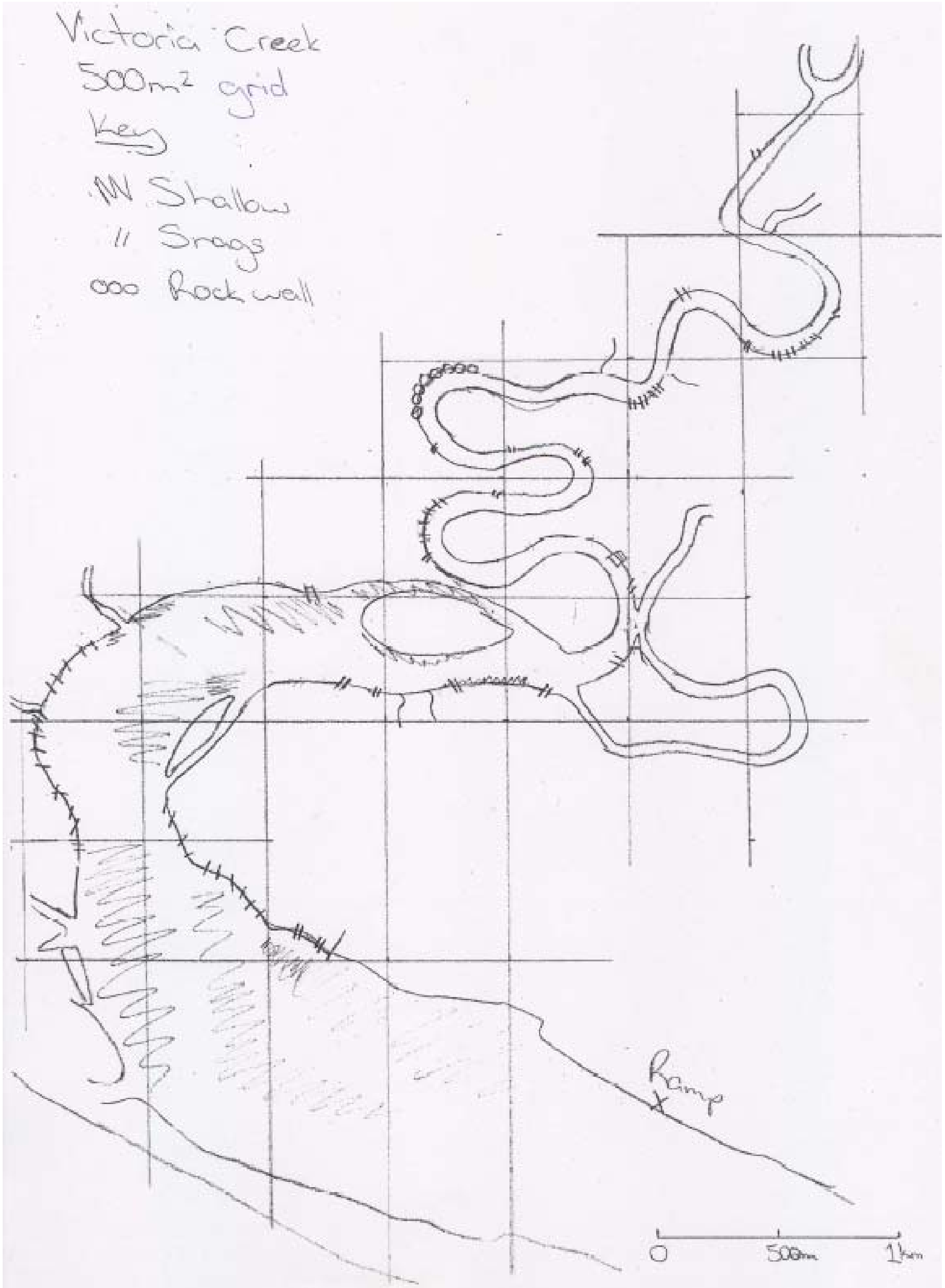
A8.3 Barrattas River mud-map



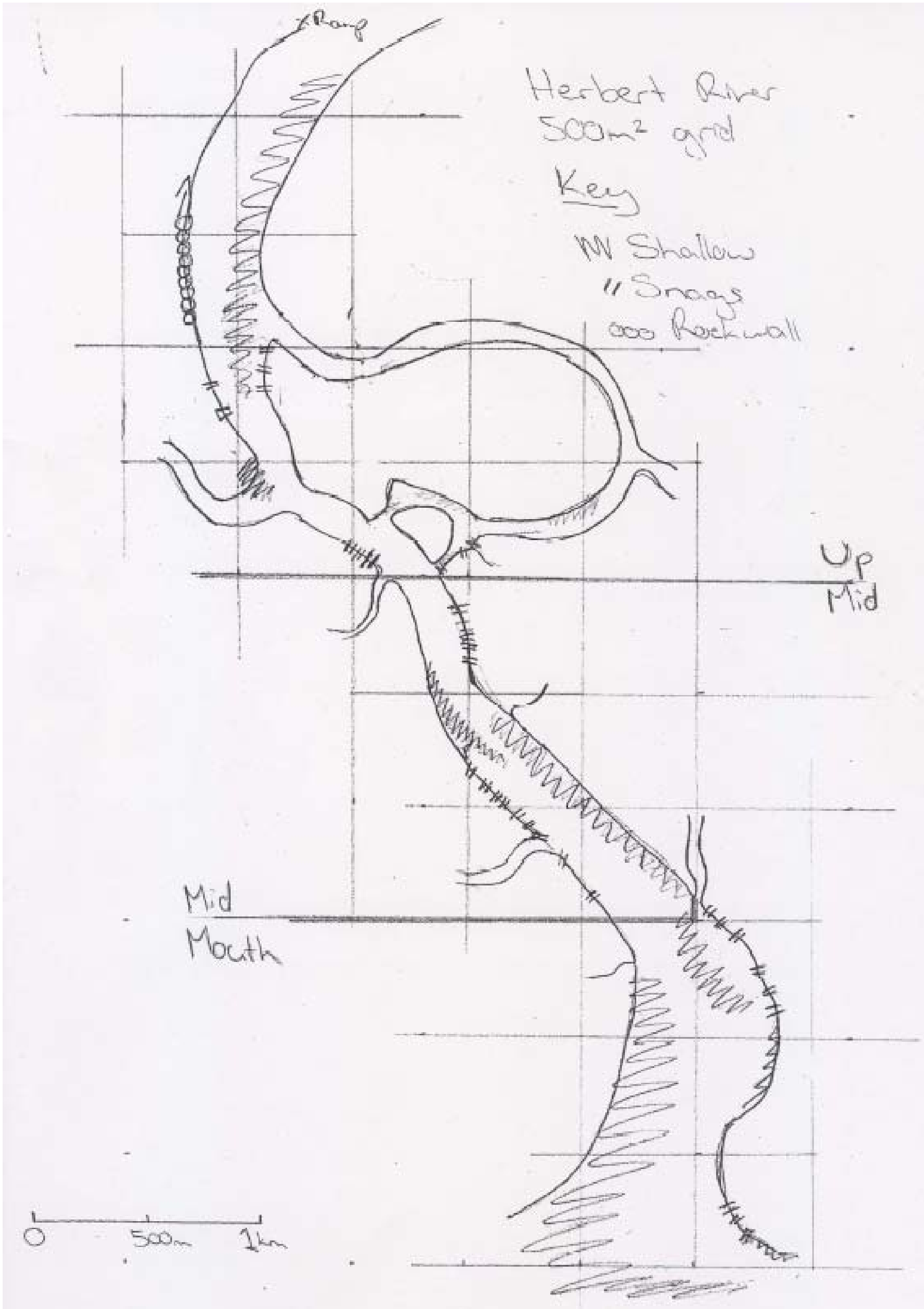
A8.4 Haughton River mud-map



A8.5 Victoria Creek mud-map



A8.6 Herbert River mud-map



Appendix 9 DATA SHEETS FOR FISHERY-INDEPENDENT STRUCTURED FISHING SURVEYS

Date: ___/___/ 02___ **Estuary:** **Start Point:**

Fishers: **1)** ______________ **2)** ______________

Weather: Fine / Sunny / Overcast / Windy / Raining / Drizzle

Time start: ______________ **Time stop:** ______________

***** *Mark all snags on map*

Snag #	Location (mo/mid/up)	Time start	Time end	Tide (ebb/st/flow)	Catch	# prawns	Notes
1		:	:				
2		:	:				
3		:	:				
4		:	:				
5		:	:				
6		:	:				
7		:	:				
8		:	:				
9		:	:				
10		:	:				
11		:	:				
12		:	:				
13		:	:				
14		:	:				
15		:	:				

Species Codes

Code	Common Name
BAR	Barramundi
ARC	Archer Fish
YBR	Bream - yellow fin
BBR	Bream - pikey
GRC	Gold spot cod
BSC	Black spot cod
QGC	Queensland grouper
MJK	Mangrove Jack
FMK	Fingermark
MPB	Moses Perch
BSB	Black Spot Sea Perch
BGR	Grunter - barred
SBR	Grunter - small spotted
QUF	Queenfish
BUD	Barracuda

Code	Common Name
CAT	Catfish
FLH	Flathead
SOJ	Soapy Jewfish
BSA	Salmon - Blue
KSA	Salmon - King
TAR	Tarpon
TRV	Trevally
MUL	Mullet - diamond scale
	Other mullets?
MIL	Milkfish
SIC	Sicklefish
MST	Milk-spot toad fish
WHI	Whiting
BMW	Brown Morwong
MUD	Mud crab

Page 2: Catch **Date:** **Estuary:**

Snag #	**Time Caught**	**Species Code**	**Length** FL/TL (mm)	**Fisher**	**Kept/Rel**
	:				
	:				
	:				
	:				
	:				
	:				
	:				
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